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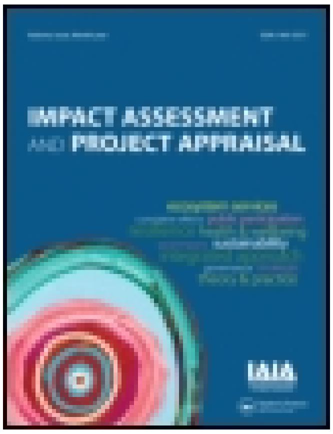

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Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tiap20

The significance spectrum and EIA significance determinations

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Published online: 23 Jan 2015.

To cite this article: Alan Ehrlich & William Ross (2015): The significance spectrum and EIA significance determinations, Impact Assessment and Project Appraisal, DOI: 10.1080/14615517.2014.981023

To link to this article: http://dx.doi.org/10.1080/14615517.2014.981023

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Impact Assessment and Project Appraisal, 2015
http://dx.doi.org/10.1080/14615517.2014.981023

The significance spectrum and EIA significance determinations

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(*Received 21 May 2014; accepted 8 October 2014*)

The concept of significance is fundamental to environmental impact assessment (EIA). Even though there are many guidelines describing technical characteristics of impacts (such as magnitude, geographic extent, extent and frequency) that should be considered, there has remained a long-standing need for increased clarity on how significance determinations are ultimately reached by significance determiners, those who, on behalf of governments, make a legal determination of significance in EIAs. This involves the application of societal values, in the form of subjective informed judgement, about the acceptability of the predicted impacts. This paper introduces the significance spectrum, a graphic model that illustrates a process for determining significance, using the following steps: (1) determining the threshold of significance for each valued component; (2) weighing the evidence and considering predicted impacts; (3) deciding which side of the threshold the predicted adverse impact falls on; and (4) for unacceptable impacts, deciding if mitigations can make the residual impact acceptable. Concepts such as ecological significance should not be confused with significance in EIAs, which may not only include ecological significance but also considers societal values. We provide specific steps for determining significance that help clarify this fundamental aspect that lies at the core of EIA decision-making.

Keywords: EIA decision-making; EIA significance determination; significance spectrum; societal values

Introduction

Determining the significance of predicted impacts is one of the most important decisions in the environmental impact assessment (EIA) process. Good EIA should focus on the impacts that matter most, and, as a result, EIA systems involve systematic steps to determine whether the likely adverse impacts of proposed projects are significant. This paper:

(1) briefly identifies the key academic literature regarding the importance of significance determinations in EIA and the need for improved understandings of how to determine significance;
(2) looks, from the perspective of the academic literature and practically, at why and how values are part of significance determinations;
(3) presents a simple visual model, called the significance spectrum, to clarify how significance determinations are made; and
(4) examines some of the implications of the role of values in significance determinations to contrast ecological significance with significance as it is used in EIA.

Significance is a fundamental question of EIA

The question of whether or not the impacts (in this paper, the terms 'impact' and 'effect' are used interchangeably) of a proposed project are likely to be significant is key in many, if not all, EIA systems (e.g. EC 2001; CEQ 2005; World Bank 2013). Sippe (1999) lists examples of the legislative bases of significance determinations from around the world, including the USA, New Zealand, the European Union and Australia. The United Nations Environment Programme states that '[p]articular attention is given in EIA practice to preventing, mitigating and offsetting the significant adverse effects of proposed undertakings' (Sadler et al. 2002, p. 103).

Despite this widespread centrality of the question of significance in EIA, straightforward methods for reaching significance determinations remain challenging and sometimes unclear. This is true even though there are many examples of EIA guidance that identify characteristics of a predicted impact that need to be considered in reaching significance determinations. These typically include impact characteristics such as magnitude, duration, frequency, likelihood and reversibility (e.g. EC 2001, p. 25; Mackenzie Valley Environmental Impact Review Board [MVEIRB] 2004, p. 18; Canadian Environmental Assessment Agency 2012, p. 3; Glasson et al. 2012, p. 126). The United Nations Environment Programme describes similar characteristics (Sadler et al. 2002, p. 264). In the USA, the Council on Environmental Quality regulation (CEQ 2005, s. 1508.27) describes the determination of a significant impact as a function of context and intensity. The five characteristics listed in Canadian guidance (magnitude, geographic extent, duration and frequency, reversibility and ecological context) are widely cited and, superficially, appear to suggest that determinations of significance are a scientific exercise. We think not.

Note: Many participants and parties make decisions about the significance of potential impacts throughout the EIA process, such as a developer deciding what mitigation to propose or interveners deciding whether they agree with a developer's impact predictions. Sippe (1999, p. 81–84) and Weston (2000, p. 186) list several others. In this paper,

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*Corresponding author. Email: aehrlich@reviewboard.ca we are primarily referring to the determination of significance made on behalf of government(s). Such decisions are made by governments, by regulators, by independent tribunals (environmental assessment panels) and the like. These are different from the views of significance by others because they stand as legal determinations of what constitutes significance.

Need for a clear process for determining significance

The need for greater clarity and understanding of the actual process of significance determination is recognized in the literature ranging from the 1980s to present, but there is little apparent progress evident. Beanlands and Duinker (1983) call significance determinations 'the very heart of EIA', and recognize the need for an operational framework regarding significance as a concept to guide EIA practitioners and participants (p. 43). Sippe (1999) observes the centrality of the concept of significance to decision-making in most EIA systems, but notes that 'despite the prominence of the concept around which decisions turn and the controversy which such decisions attract, the concept remains largely undefined, at least to the point of general consensus amongst decision makers' (p. 74). Wood and Becker (2004) recognize the need for improved understanding of significance evaluation in EIA. They attribute the complexity of significance determinations partly to the role of values in EIA decision-making. Wood and Becker state:

> Decisions that surround the evaluation of the significance of environmental impacts are a critical component of EIA, with implications for all stages in the process. Despite this, significance evaluation arguably remains one of the most complex and least understood of EIA activities, involving a combination of technical 'scientific' approaches to appraisal situated within a political decision making arena, characterised by value judgements and case-specific interpretations. (2004, p. 73)

Several others have recognized this need for increasing clarity of the significance determination process:

- Haug et al. (1984) observe of the US National Environmental Protection Act regulations that 'they provide no clear definition of significance that can be applied objectively and uniformly to environmental issues and the consequences of man's activities' (p. 16).
- Lawrence (2005) concludes that '(i)mpact significance determination is widely recognized as a vital and critical EIA activity, both in Canada and in other jurisdictions. Yet it remains one of the most complex and least understood of EIA activities' (p. 33). He lists several criticisms of significance determination requirements, and observes that this 'suggests a far from settled EIA sub-field. Clear and unequivocal good practice significance determination standards are unlikely to emerge in the foreseeable future' (p. 12).
- Lawrence (2007) lists numerous criticisms of prevailing practices of significance determination, and says that '[a] necessary first step toward addressing these needs (for an enhanced level of EIA practice) is greater clarity, specifically regarding the basic characteristics of significance determination activities' (p. 757).
- Wood (2008) states that '(t)he evaluation and communication of the significance of environmental effects remains a critical yet poorly understood component of EIA theory and practice' (p. 22).
- As recently as 2013, Lyhne and Kornov recognized that although there are many checklists, criteria and thresholds available to guide significance determination, non-technical subjective elements make the determination of significance more complex. They identify 'a need to notice and recognize significance determination, (to) have conversations in interactions about its nature and role . . . '.

This paper is intended to add clarity to the significance determination process. The paper and the model it presents are products of the authors' reflections on direct experiences in numerous deliberations in Canada. Federal Canadian legislation sets the determination of whether a project is likely to cause significant adverse impacts as the main question that decision-makers must answer (Canadian Environmental Assessment Agency 2012, s.52). In EIA under the Canadian Environmental Assessment Act (CEAA), the Mackenzie Valley Resource Management Act (MVRMA), and elsewhere (as described above), much depends on these determinations of significance. Under CEAA 2012 the question of impact significance is fundamental to whether the project may proceed to the regulatory stage or if it is referred to Governor in Council (Government of Canada 2012, s. 52). Under the MVRMA [s. 128], the question of impact significance is fundamental to determining whether a proposed project needs to undergo an environmental assessment, and whether, at the outcome of the environmental assessment, the project is required to proceed with or without with mitigation measures, or indeed if the project is to proceed at all [Government of Canada 1998]).

In our experience, we have observed that technical experts are usually engaged in analysing impact characteristics such as impact geographic extent, magnitude, etc. (typically described as the technical bases for significance determinations). For example, a biologist may predict that a valued component may be affected to a certain degree, over a certain area, over a certain time, with a certain probability. We suspect, however, that if you were to ask that biologist the crucial question of whether or not the predicted change is acceptable, the biologist should respond that the answer is not a strictly scientific judgement.

Subjective informed judgement

In the authors' experiences, determinations of significance depend on the *subjective informed judgement* of decision-makers concerning the valued component being considered. This does not replace considering the detailed characteristics of the predicted impact, but necessarily goes beyond that. Subjective does not mean arbitrary – those using subjective informed judgements to make significance determinations still must rely on the evidence that has been brought forth by the participants of the EIA, and must use cogent reasoning. Importantly, when an EIA significance determiner applies subjective informed judgement to make a significance determination, it reflects the significance determiner's (and, ideally, society's) values.[1]

Subjective judgement informed by a body of evidence compiled through a fair process and reflective of a set of societal values is not only credible, but it is in fact a mainstay of some of the most important decisions made in society – by the courts. The same principles lie at the heart of significance determinations in EIA. As in the courts, this approach is used to decide between two categories. Court judges must determine whether the accused is guilty or not; EIA decision-makers must determine whether potential impacts are significant or not.

Below, we examine why the role of values is and should be central to EIA significance determinations, and how, step by step, they can be practically applied to go from impact predictions to legitimate significance determinations.

The role of values in significance determinations

The EIA academic literature supports the idea that value judgements are, and should be, an important part of significance determinations.

- Beanlands and Duinker (1983) assert that 'ultimately, impacts would be measured on the yardstick of human values. Any comprehensive definition of a significant impact with respect to environmental assessment must reflect this value judgement' (p. 45).
- Lawrence (2005) notes, among other things, that the 'central role of values and subjectivity' is a factor that makes the emergence of good practice standards for significance determination unlikely (p. 12). In his conclusions, he describes significance determinations as 'subjective, normative and value-dependent' (p. 33).
- Haug et al. (1984, p. 18) conceptually separated the values associated with of a predicted impact (which they refer to as 'the meaning of the impact') from the characteristics of the impact ('the fact of the impact'), and stated:

  > The *fact* of an environmental impact is the change itself, its magnitude, direction, units, and the estimated probability that it will occur. The *meaning* of an environmental impact is the value placed on the change by different affected interests. It is the answer to the question: If this impact occurs, so what? *The 'so what?' determines how important or 'significant' an environmental issue is, and to whom.* (Italics in original)

- Sippe (1999) asserts that the adaptability of the concept of significance to sociopolitical contexts (presumably including values) has been an important part of the international success of EIA (p. 74). He includes a decision tree for determining environmental acceptability that considers both of the components identified by Haug et al. (1984) above.
- Glasson et al. (2012) frame significance in terms of impact acceptability (p. 126). The same paper notes (with respect to socio-economic impacts) that significance determinations involve weighing the importance of impacts, and that '[t]his involves interpretation and the application of judgement. Such judgement can be rationalized in various ways and a range of methods are available, but all involve values and all are subjective' (p. 128).

There are several other examples recognizing the importance of value judgements in EIA significance determinations.

- Weston (2000) notes that significance-based decisions in EIA are 'inherently based upon value judgements and are made within a political context' (p. 200), and that these value-based decisions 'will inevitably rely on professional, political and intuitive judgements' (p. 198). Weston further states that 'the (scoping) process is therefore at heart human centred and not ecocentred; it is anthropocentric rather than ecocentric' (p. 199), and describes this as a strength of EIA, not a weakness.
- Harding (1998, p. 79) emphasizes that inadequate consideration of values often underlies apparent disagreements over fact in the environmental decision-making process.
- Sadler et al. (2002, p. 274) describe two steps for evaluating significance that emphasize the consideration of 'impact importance' in the second step, using a subjective value.
- Gibson et al. (2005) state that 'the significance decision involves judgement in light of context' and argue that the unique context-specific nature of the interplay between a particular project and its setting requires 'context-specific choices that depend on fair process rather than regulatory type predetermined thresholds' (p. 166–167).
- Briggs and Hudson (2013) recognize that subjectivity is a part of determining significance, but observe that there exists concern that developers, or the consultants working for them, can use it to minimize the predicted impacts to increase odds of project approval (p. 17). This is discussed further below.
- Gibson et al.'s sustainability-based criteria and trade-off rules for evaluating the significance advocate for applying specific values (in these cases, based on sustainability principles) to significance determinations (2005, p. 173–178). In this context, Gibson et al. state that '... significance decisions are essentially matters of public choice. Assessment is more about valuing than calculating' (p. 175).
- Rowan (2012, p. 190) argues for applying specific human values to improve the credibility of the social impact assessment process.

It is noteworthy, with respect to the significance spectrum presented below, that some of these authors have described significance in terms of impact acceptability (e.g. Beanlands & Duinker 1983, p. 44; Haug et al. 1984, p. 19; Sippe 1999, p. 85; Sadler et al. 2002, p. 274; Gibson et al. 2005, p. 174; Lawrence 2007, p. 763; Glasson et al. 2012, p. 126). The International Association for Impact Assessment's *Principles of Environmental Impact Assessment Best Practice* also states that the evaluation of significance involves determining the importance and acceptability of impacts (Senecal et al. 1999).

To summarize, there are many published guidelines describing criteria for impact prediction, and there is a recognition that values play a role in significance determinations. However, there is little straightforward guidance available to EIA decision-makers on exactly how to apply values to impact predictions to reach significance determinations. Even though this is a vital part of the EIA process, we have observed that this remains problematic to practitioners. That is the purpose of this paper – to help clarify how significance determinations are actually made. The model below, which we call 'the significance spectrum', is intended to illustrate a clear and straightforward method of determining significance.

Why social values are central to significance determinations

There are two distinct reasons why we conclude that societal values (supraindividual values, according to Rokeach [1979]) need to play a central role in determining significance. The first is more theoretical, based on the proper role impact assessment plays in leading to better development decisions. The second is based on best professional practice in Canada and, we believe, elsewhere.

Theoretical reason for societal values in determining significance

The International Association for Impact Assessment defines impact assessment as 'the process of identifying the future consequences of a … proposed action'. Impact assessment is important because it leads to better decisions concerning proposed projects. The World Bank (2013) requires EIA '… to help ensure that [projects proposed] are environmentally sound and sustainable, and thus to improve decision making'. This purpose of EIA is made clear in Canada where the Canadian Environmental Assessment Agency indicates 'environmental assessment provides an effective means of integrating environmental factors into planning and decision-making processes in a manner that promotes sustainable development' (Canadian Environmental Assessment Agency 2012).

In short, EIA is used to determine the consequences of proposed actions (projects) to determine if they are environmentally acceptable. Indeed, one of the purposes of the CEAA is to 'to ensure that projects are considered in a careful and precautionary manner before federal authorities take action in connection with them, in order to ensure that such projects do not cause significant adverse environmental effects' (Government of Canada 1992). It is clear from these features that the use of EIA is to assist decision-makers to avoid significant adverse effects.

This provides the important link between the impact assessment process and the subsequent regulatory decision-making process into which impact assessment feeds. While these two processes (impact assessment and regulatory decision-making) are conceptually different, they are closely linked and it is very desirable to have the meaning of significance be the same, not different. It should be noted that regulatory decision-makers will consider more than what is included in the impact assessment. But what is in the impact assessment documents ought to be in the same 'language' as the decision-makers are using.

Decision-makers in Canada and in most of the world make project decisions based on some form of public interest test. A clear example of such a test is found in Alberta (the Energy Resources Conservation Act) where the test to approve energy projects (from producing wells to oil sands mines) is to determine the project is 'in the public interest having regard for environmental, social and economic matters'. The main point is that significance of effects is determined by the decision-maker. In making a public interest decision, legitimately determined public policies and societal values should properly influence that decision.

As noted above, a purpose of the CEAA is to ensure that 'projects do not cause significant adverse environmental effects'. It is clear that this determination of significance for each effect (and hence the determination of the project as a whole being in the public interest) is the responsibility of the significance determiners. It seems equally clear that significance relies heavily on the values of the society related to the valued component for which the decision is being made. Note that significance is attributed to each effect and thus is determined for the specific valued component affected. The public interest test is applied to the project as a whole. The level of significance for each effect would properly be determined based on ecological, social and financial considerations and would be based on the values of society. For example, in Alberta to determine significance, air quality is often compared to the Alberta Ambient Air Quality Objectives. These are, according to the Alberta Environment web page, determined based on scientific, social, technical and economic factors. Such regulators, for example, should not (barring exceptional circumstances) permit projects that would create effects in violation of laws and regulations. For this reason, the US EPA has provided the following example of a significant adverse effect: 'the activity will introduce pollutants to the air that will cause ambient air quality to exceed established levels' – violating levels established by society. The point being made here is that significance determiners should identify an impact as significant if it does not meet government determined objectives, regulations and standards. However, the corollary is not necessarily true – that is, an impact may meet government determined objectives, regulations and standards, and still be significant for other reasons.

As mentioned above, Briggs and Hudson (2013) cite the concern that subjectivity in significance determinations allows unscrupulous developers or their consultants to sugar-coat (i.e. minimize) the significance of potential impacts, in order to make them seem more acceptable. While this does sometimes occur, in this paper we are referring primarily to the EIA significance determiner (as described above). In the context in which we are writing, the EIA significance determiner in a procedurally fair EIA must be without apprehensions of bias. Significance determiners are in a good position to use their own subjective informed judgement, when weighing evidence, to consider possible misrepresentations and biases of EIA participants (including those with interests that oppose one another) to reach wise decisions that reflect societal values – which can ultimately help to *reduce* the problem described by Briggs and Hudson.

Our use of the term 'societal values' is not at all intended to mean values of individuals or groups that are arbitrary. We mean subjective informed judgements. Examples include compliance with legislation, regulations passed by responsible authorities, regional policies set by authorities following appropriate public consultation and the like.

Sadar (1996, p. 100) states that:

> in the first stage (of significance determination) one relies on scientific and/or specialized knowledge. In the second stage, one is concerned with the relative values of the society or segments of it. This latter stage involved value judgements and is not necessarily based on scientific knowledge.

Sadler (1996) mentions that 'During the more detailed phase of impact analysis, determination whether impacts are significant and acceptable involved both prediction and estimation of nature, magnitude, timing, and duration, as well as the attribution of importance or value to these findings' (p. 118).

Furthermore, the CEAA 2012 indicates: 'If the decision maker decides that the designated project is likely to cause significant adverse environmental effects … the decision maker must refer to the Governor in Council the matter of whether those effects are justified in the circumstances' (Government of Canada 2012, s. 52). The sequence is first a determination of the significance of (adverse) effects based on a societal threshold of significance (including environmental and ecological features as important factors) and then using this (and other) information to decide whether the project as a whole is in the public interest. In deciding whether the project is in the public interest, it may be necessary to decide if any significant adverse effects are justifiable under the circumstances.

Two features are worth noting. First, if the likely significant adverse effects are justifiable, the project may be allowed to proceed – the public interest may override significant adverse effects. Second, the determination that the likely significant adverse effects are justifiable can only be made by Cabinet, a high level of government.

The regulator uses the term 'significance' in such a manner that it includes a variety of social, economic and ecological aspects (public interest). There are two reasons for expecting the word to have the same meaning in impact assessment. The first is that the wise proponent will make decisions regarding mitigation measures based on the analysis presented in the EIS, more precisely, based on the possibility of significant adverse effects. The proponent will almost certainly be paying attention to the decision to be made by the regulator, who will base the decision on the public interest and hence (*inter alia*) on the significance of effects. If the term 'significance' has a different meaning in the EIS than it has for the regulator, that will be a disservice to the proponent or will require a complicated discussion between the proponent and its consultant.

The second reason is that, if the term has a different meaning, this will cause much confusion for all participants in the project review process. They will need to use the meaning the regulator will use in spite of the term having a different meaning in the EIS. This confusion may even create uncertainty in the mind of the significance determiner, a situation that could jeopardize the review process, or lead to judicial review. Anyone may make an argument regarding effect significance or regarding project public interest. But such arguments must only be treated as advice to the significance determiners.

Professional practice in implementing the CEAA

Independently of the above theoretical analysis, we took the following two steps to determine best practice in determining significance under the CEAA. We examined the significance guidance document (Canadian Environmental Assessment Agency 2012). In this document, it is stated:

> The most common method of determining whether the adverse environmental effects of a project are significant is to use environmental standards, guidelines, or objectives. If the level of an adverse environmental effect is less than the standard, guideline, or objective, it may be insignificant. If, on the other hand, it exceeds the standard, guideline, or objective, it may be significant.
>
> Environmental standards, guidelines and objectives have been established by federal, provincial, and in some cases municipal departments, ministries, and agencies. They often define either maximum levels of emissions or discharges of specific hazardous agents into the environment or maximum acceptable levels of specific hazardous agents in the environment. They are usually based on the results of studies in the field and with laboratory animals, available technology, and/or prevailing attitudes and values.

That is, the guidance document suggests using government determined standards, guidelines or objectives. Because the standards, guidelines and objectives are based on prevailing attitudes and values are used to determine significance, this also suggests that significance can properly be based on prevailing attitudes and values.

In addition, we consulted a very knowledgeable expert on the CEAA, Bob Connelly. Connelly (personal communication, 2012), conveyed the following message regarding the determination of significance under the Act:

> I would agree that societal values should, and I believe are meant, to be included in determining significance ... Public participation is a fundamental purpose of the Act and provision for it is reflected throughout. It is therefore implied and widely accepted that public values will be considered in the CEAA process including, in my view, in determining significance. After all, significance involves value judgements and consequently understanding public values is essential in making this judgement.

This idea of significance determinations being based on subjective informed judgement instead of a purely technical factoring of characteristics means that significance determinations are more than inevitable deterministic outcomes. Because this involves the application of values, it matters who decides. For example, the MVEIRB is a co-management court-like tribunal composed of members who are nominated by Aboriginal (Indigenous) organizations and non-Aboriginal governments in equal numbers. Different board members bring different world views and societal values to the decisions (Christensen et al. 2007).

In the case of co-management, and in other settings where the potentially affected public includes primarily Aboriginal communities, social values of the potentially affected community should be an important factor in determining significance. When these social values conflict with those of non-Indigenous society, reaching significance determinations can be much more difficult. Larcombe (2000) noted that '[t]he practice of determining significance is highly subjective and driven by non-Aboriginal society values' (s. 4.3.2). The MVEIRB's co-management approach to EIA decision-making makes it easier for it to recognize, consider and incorporate Aboriginal social values when making its significance determinations.

Significance simplified

The MVRMA EIA process (Government of Canada 1998) requires that any project that is determined likely to be a cause of significant adverse impacts must have its impacts prevented by measures or be rejected (unless ordered to a review panel for further assessment, which has occurred only twice since the Act was passed). The question of whether an impact is significant can therefore be reasonably interpreted operationally by the decision-makers to mean 'Does the impact matter enough so that it should be reduced or prevented?' If so, the impact is significant. Board members have found that this question has greatly simplified significance determinations. This wording clarifies the decision while emphasizing the subjective determination of acceptability based on social values and considering the public interest.

The following graphic model (Figure 1) further clarifies the significance test, helps show the role of mitigations and clarifies the separate roles of the EIA significance determiners and those of the regulators who will later decide on project approvals for most projects.

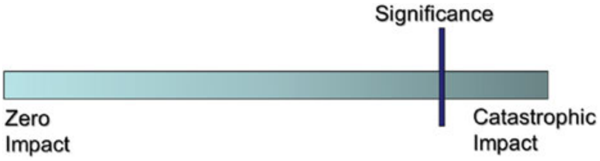

Figure 1. The significance spectrum and threshold of significance. The EIA significance determiner decides where the significance threshold should be drawn for each potentially significant impact.

We call it 'the significance spectrum'. Although drawn from our experiences, the significance spectrum model is not specific to any particular EIA regime. It is intended to illustrate how to go from impact predictions to significance determinations.

One of us (Alan Ehrlich) has used this model successfully to clarify the process of significance determination for EIA significance determiners from different cultures with varying degrees of technical background, prior to actually reaching significance determinations for several high-profile environmental assessments of proposed large-scale projects. In discussions with EIA practitioners at International Association for Impact Assessment conferences, we have determined that EIA decision-makers from other regimes in other countries confirm that it is an accurate representation of the process they too have implicitly undertaken when making significance determinations. This model has been accepted and adapted by regulatory boards in Canada's Northwest Territories as a conceptual basis for an entire adaptive management framework (Racher et al. 2011), and has recently been reflected in a management framework of a major multinational mining company (De Beers 2014).

This model is based on the principle that significance determinations involve the comparison of a predicted change to a limit of acceptable change, which is a case-by-case application of a value-based threshold (Ehrlich 2007). This idea is supported by Haug et al. (1984), which similarly identifies the concept of a threshold of concern, described as 'a maximum or minimum number, or other value, for an environmental impact of resource use which, if exceeded, causes that impact or use to take on new importance' (p. 18), and as 'the point at which an impact becomes acceptable or unacceptable ...' (p. 19).

The significance spectrum model represents the full continuum of possible adverse impacts arising from a proposed project, ranging from the theoretical extreme of no impact whatsoever to the opposite extreme of catastrophic impact (the horizontal bar in Figure 1). Because significance tests focus primarily on likely *adverse* impacts, the spectrum does not include the range of beneficial effects, although one could reasonably imagine a mirror-image extension of the scale to the left to include a full continuum of desirable impacts.

Note: Likelihood is a common element of significance determination in many jurisdictions (e.g. Government of Canada 1998; EC 2001; Sadler et al. 2002; CEQ 2005; Canadian Environmental Assessment Agency 2012; World

Bank 2013). With respect to the word 'likely', we interpret the term to mean more likely than not (i.e. greater than 50% probability of occurrence; MVEIRB 2006). Haug et al. (1984, p. 24) interpret the term similarly when applying it in significance determinations. We believe that this is a part of predicting the impact, and should be done separately from determining the acceptability of the impact. We further note that for worst-case-type scenarios (meaning low-probability high-consequence events), even an unlikely impact may be unacceptable if it is severe enough; likelihood should be understood in the context of risk when determining significance (see MVEIRB [2013 p. 18–19] for further discussion).

In determining whether a proposed impact is significant, the EIA decision-maker must decide where to establish the threshold of significance – where to draw the line (Ehrlich 2009). This threshold could occur anywhere along the significance spectrum, and how far along it is drawn depends on the informed subjective judgement of significance determiners.

This threshold separates the realm of the acceptable from the realm of the unacceptable (Figure 2). It considers any relevant evidence in the EIA and reflects the significance determiner's (and society's) values. For example, for a wildlife species, if the species is determined to be an endangered species, or is highly valued by society, it would be expected to have a more stringent significance threshold than a similar wildlife species in the same area without those characteristics. The arguments of the parties may play a role in this step.

In deciding where to set the threshold of significance, the idea is to separate the setting of a threshold for a valued component from the determination of justifiability. The former is the setting of a significance threshold for a particular valued component and is not dependent on the project. It depends only on the societal values for the valued component. The latter is a different societal value judgement that does deal with the merits of the proposed project, and should not be confused with the impact significance determinations made in EIA.

It is worth noting that, since the acceptability of adverse effects to a valued component reflects how society feels about the valued component, the significance threshold will be the same whether the impact is caused by a single human activity or by multiple human activities. That is, the significance threshold for given valued component will be the same for project assessment as it would be for cumulative effects assessment.

The decision-maker must weigh the evidence (the impact predictions) and consider the arguments of parties participating in the EIA. This may include carefully judging between the conflicting predictions of different participants, who may have (deliberately or otherwise) introduced their own values into predictions and who also may have competing views in where the threshold of significance should be for a given valued component. Public participation in the EIA provides a potentially valuable source of input on parties' views on the latter, for decision-maker's consideration in this step.

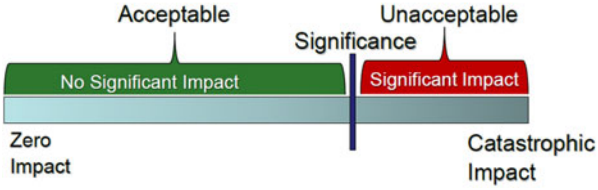

Figure 2. The realm of the acceptable and the realm of the unacceptable.

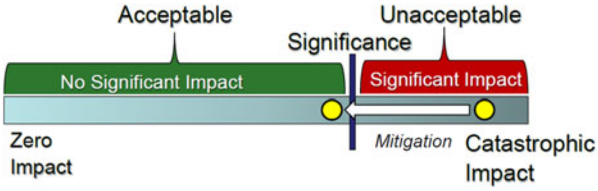

Figure 3. Impact significance and mitigation. The significance determiner decides where on the spectrum a predicted impact (shown as the yellow circle) falls, and weighs the effect of mitigation measures (shown as the arrow) on impact significance.

The significance determiner must then decide where any predicted adverse impact will fall on the spectrum, it falls whether on the side of the acceptable (and therefore is not a significant impact) or on the side of the unacceptable (and is therefore a significant impact) (Figure 3). If the impact falls on the unacceptable side, and is therefore significant, the significance determiner must consider whether mitigation measures are sufficient to shift it across the threshold of significance, so that the residual impact is not significant.

Even though this depends on the values of the significance determiner, the subjective element of significance determination does not make it arbitrary. The significance determiner's judgement should be informed by a reasonable weighing of the evidence, and by the values of society, and, for social and cultural impacts, should particularly consider the rights of, and impacts to, the affected public. For cultural impacts, the cultural context should be considered in significance determinations (Canadian Environmental Assessment Agency 1996). For transparency, the rationale should be reported in a manner that makes clear the reasoning and judgements that led to the significance determination, in language understandable to EIA participants.

In short, the four steps to significance determination using this model are:

(1) Decide where on the spectrum of potential impacts to place the threshold of significance for that particular valued component.
(2) Weigh the evidence (impact predictions).
(3) Decide which side of the threshold the predicted adverse impact falls on.
(4) If the impact falls on the unacceptable side, decide if additional mitigation measures will shift the predicted impact to the acceptable side.

The role of the EIA versus later regulation

The significance spectrum illustrates a particular relationship between EIA decision-making and the later regulatory authorization process that usually follows it. A question the authors have encountered is 'Why do people conducting EIAs bother to consider the significance of impacts that will eventually be regulated by conditions in licenses?' In most jurisdictions, there are regulators who set specific limits in authorizations. Regulators also have enforcement mechanisms. As well, national standards may apply to the specific valued components. Why, then, is it necessary for EIAs to examine significance of impacts on these? Why not simply leave these for the regulators to take care of during the later licensing stage?

As an analogy, consider the role of the driving examiner, whose job it is to decide whether the applicant who wants a driver's license is an acceptable driver. Note that the examiner does not need to decide if the applicant is a perfect driver, but only if the driver is good enough to be allowed on the road with others. Clearly, there are regulations, such as specific speed limits and defined traffic rules, that would apply to the driver. There is also a system of enforcement that penalizes drivers who exceed limits. Does this mean that examiners do not need to apply the test?

Obviously not, because despite regulation, an unacceptable driver may still hurt other people, or cause other unintended damage. The question of acceptability must be decided before relying on speed limits and traffic police. The same holds true in EIA. The significance (i.e. acceptability) of potential impacts needs to be established in EIAs before relying on regulation or enforcement.

One reason for this is because regulations are primarily designed to deal with impacts that are not significant. The regulators who issue authorizations such as water licenses are primarily legally able to do so for projects that do not have significant impacts. These authorizations typically define specific limits. The range of these, on the significance spectrum, would appear as an area within the 'no significant impact' range (shown as the green oval in Figure 4). Regulators are able to choose the final limits of their authorizations only if the EIA significance determiner *first* decides that the residual impacts are acceptable (i.e. not significant). As shown on the significance spectrum, the regulators select an appropriate range in the realm of the acceptable once the EIA has determined which side of the significance threshold the impact (with mitigations if necessary) falls on. For matters of potential significance, a responsible significance determiner will determine the significance of potential impacts rather than relying purely on eventual regulatory authorizations.

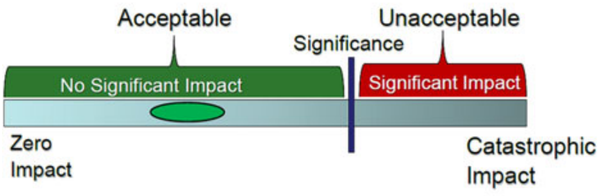

Figure 4. An example of a range of impacts that regulators can allow. Regulators can only authorize activities if the proposed projects are first determined to be acceptable (i.e. do not cause a significant adverse impact).

Ecological significance versus EIA significance

In different processes under the two regimes described here, each of us has encountered developers confusing ecological significance with significance as used in EIA determinations. In each case, the developers used regional population persistence as an assessment endpoint in their examinations of potential impacts of proposed mines on wildlife. They asserted that if the population persists, the impact on that valued component could not be ecologically significant, and therefore there should be a finding of no significance by the EIA significance determiner.

Our view is that this position is not reasonable because it excludes the societal values that a local human population may place on the species or biological community. In the significance spectrum model, these values would be applied to determine the threshold of significance. While ecological significance must play an important role in determining significance of an impact on wildlife, we believe it must not be the only determinant, as societal values should also play an important role in determining what is significant in the overall assessment of a project, for the reasons described above.

The same participants have explicitly rejected using compliance with legislation (the *Species at Risk Act* in particular) as being a relevant consideration in determining significance of effect on a listed species. This is not consistent with the best practice approach or the theoretical approach as determined above because it explicitly rejects the very kinds of societal values that others, including ourselves, insist should be used in determining significance.

So, does this mean that the determinant for a significant adverse effect for a specific population of wildlife should be that the regional population is not persistent? Certainly, if the regional population of a species is not persistent, this would (by most reasonable interpretations) be a significant adverse effect (i.e. population of that species would decline until extirpated). But whether a population that persists regionally would ensure the effect is insignificant is another matter entirely. It may be that the population has other targets set by responsible regulators. Failure to meet these requirements would, by any reasonable interpretation of the word 'significance', mean the effect was significant and adverse.

The example one of us (Bill Ross) has used in his capacity as a regulator (temporary appointment for the purpose of hearing the application for an oil sands mine by Alberta's Energy Resources Conservation Board in 2011) is the determination made that the effect on threatened or endangered species would be significant and adverse if it violated the federal *Species at Risk Act*. This Act has a prohibition against harming an individual of a threatened or endangered species, its residence or its critical habitat. Violating this prohibition, it was determined, would be a significant adverse effect even if the regional population persisted. Another example of 'other targets' is where regulators (e.g. fish and wildlife management agencies) set targets for sustainable harvest (e.g. elk, furbearers, grizzly bears). Is it a significant effect where a target for sustainable harvest (for example, as identified by surplus yield models) has to be reduced because of 'takings' by the mine? We would often say 'yes'.

Similar problems would arise if other regulators set policy or regulatory conditions on regional populations (or sub-regional populations). For example, Parks Canada establishes targets for ecological conditions within national parks. These may go beyond the achievement of persistence of regional populations of species primarily because the legislation governing the Parks Canada mandate expects 'ecological integrity' as its first priority. Similar limits may be set for other protected areas.

For species at risk in Canada, recovery strategies or action plans may be determined. These are based on science but reflect social values. Recovery strategies or action plans set goals for the species that are by no means limited to only the persistence of regional populations. Proponents that assert that the persistence of regional populations means no significant impact in EIA could still conduct activities that violate such plans or policies. Doing so would seem to be a clear indication of a significant adverse effect.

But there is a higher principle involved. Proponents are entitled to include (almost) any material they see fit in their applications. Because of this principle, they may choose to define significance as they see fit and use of the ecological significance criterion suggested is acceptable, even if ill advised. For example, one could define a 'significant adverse effect' as 'the presence of purple pigs with no tails'. Then, if one makes the (almost certainly correct) prediction that the project would not cause the presence of purple pigs with no tails, one must conclude that the project would not cause significant adverse effects, by definition. Significance determiners should surely reject this definition (and hence the conclusion), thus nullifying a good deal of significance-related analysis. The consequence of developers using a peculiar definition of significance is that other parties involved in the decision-making process must exercise great care to point out the flaws in the definition to the significance determiners. Significance determiners should use a broader and more correct determination of significance – one that takes into consideration other properly determined societal goals.

As an aside, if the above arguments were rejected and the use of an ecological (not societal) determination of significance was found to be acceptable, we cannot understand how the use of 'persistence' of a regional population could possibly be upheld as the sole determination of significance. The simplest counterexample would be for a threatened or endangered species for which a recovery strategy or an action plan is in place. These would have been developed by experts for the species and must surely take precedence over the indicator of regional population persistence. The same argument would equally apply to many such regulations or local policies provided they had been properly developed by knowledgeable experts. Of course, such strategies, plans, policies, etc., are almost always required to undergo suitable public consultation. Does this requirement place them outside the limit of ecological significance even if they are initially based on the best ecological expertise? We think not.

Conclusion

The steps described above for reaching significance determinations using the significance spectrum are systematic, clear and consistent with the goals of EIA. The significance spectrum appears to provide some of the additional clarity that Beanlands and Duinker (1983), Sippe (1999), Wood and Becker (2004), Lawrence (2005) and Lyhne and Kornov (2013) have found wanting. The steps provide a reasonable method to use subjective informed judgement to explicitly apply societal values to significance determinations, allowing for a systematic integration of values, as authors like Sippe (1999), Sadar (1996), Sadler (1996), Weston (2000), Gibson et al. (2005) and Rowan (2012) have recognized as essential. The order of the steps in the significance spectrum model conform to the two general steps described in Sadler et al. (2002), while providing a more specific and applicable method to the second step. The steps may help operationalize those described by Sippe (1999, p. 85) and provide a more clear process for how and when to apply values to impact predictions. Likewise, they further operationalize the concepts described by Haug et al. (1984). The steps we suggest are adaptable to a variety of world views and values (as they are not culture specific), and have broad applicability in virtually any EIA system, including international contexts, offering the sociopolitical flexibility that Sippe stated has allowed significance determinations to contribute to the 'wide international success EIA has achieved' (1999, p. 74).

In summary, there is a sound theoretical basis for applying societal values in significance determinations, and best practice includes doing so. The steps for applying the significance spectrum model to determine significance of impacts are as follows: (1) determine the threshold of significance for each valued component; (2) weigh the evidence and consider impact predictions; (3) decide which side of the threshold the predicted adverse impact falls on; and (4) for unacceptable impacts, decide if mitigation measures can make the residual impact acceptable. Hopefully, the specific steps prescribed help clarify this fundamental aspect that lies at the core of EIA decision-making.

Acknowledgements

Roger Creasey, before his untimely passing, made helpful contributions to this paper. We gratefully acknowledge his input. Reviewers for the Journal of Impact Assessment and Project Appraisal also made many very helpful suggestions.

Note

1. Noteworthy academic literature relating to values includes Rokeach (1973, 1979), Catton and Dunlap (1978), Dunlap

and Van Liere (1978) and Bengston (1994). We do not summarize these here, as this paper focuses primarily on the practical application of values in EIA, but suggest them to readers interested in further exploring the subject of values.

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Ms. Violet Camsell-Blondin
Chair
Wek'èezhíi Land and Water Board
Box 32
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10 December 2012

Re: Annual ICRP Progress Report

The Wek'èezhíi Land and Water Board (WLWB) approval of the Interim Closure and Reclamation Plan (ICRP) included a requirement for Diavik Diamond Mines Inc. (DDMI) to provide the Board with an Annual Progress Report (WLWB letter of September 26, 2011). DDMI is please to submit for your consideration the 2012 Interim Closure and Reclamation Plan Progress Report.

DDMI understands that this submission itself is "not for approval" however there are two items of note within the Progress Report where a Board decision is requested:

1. Regarding the on-site disposal of inert closure materials; and
2. On crediting closure and reclamation security required under the Environmental Agreement against the amount required under the Water License.

Please note that the distribution of Appendix I-2: EMAB TK/IQ Panel Report – *Renewing Our Landscape* has been limited at the Panel's request. Two electronic copies of the Progress Report have been included; one for the WLWB's use which includes the Panel Report and one for general distribution with the Panel Report removed.

Please advise the undersigned if there are any questions regarding this Progress Report.

Regards,

Gord Macdonald

cc Patty Ewaschuk (WLWB)
Ryan Fequet (WLWB)

Attachment: Annual Interim Closure and Reclamation Progress Report - 2012

Rio Tinto

Diavik Diamond Mines Inc.

Annual Interim Closure and Reclamation Progress Report - 2012

Document #: CLSR-001-1112R0

10 December 2012

Prepared for the Wek’èezhíi Land and Water Board under Water License W2007L2-0003

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Appendix VI – Blank

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Appendix VIII – Security Update

VIII-1 AANDC Table of Environmental Agreement Security

1. Report Summary

- Community Engagement Summary
    - Proceeded with efforts to establish community working groups with each of the 5 Participation Agreement community organizations;
    - Held discussions relating to preferred methods of communication and engagement to ensure that community governments/organizations, Traditional Knowledge holders and membership are informed of the process and content of Diavik's developing closure plan;
    - Sought input on waste disposal options and landscape-level considerations for the waste rock pile by having these as the focus of community working group and Traditional Knowledge (TK) Panel meetings;
    - Reviewed Traditional Knowledge programs relating to closure, wildlife movement and re-vegetation that have been conducted in other regions; and
    - Held a site visit with TK Panel members, and initiated clay and computer modelling, videography and photography development work to assist community members in understanding the scale of site infrastructure.

- Reclamation research programs are progressing substantially on plan. A new task has been added to the North Inlet research to conduct a Toxicity Identification and Evaluation (TIE) in an attempt to determine the cause of observed toxicological responses in treatment plant sludge and North Inlet Sediments. Results and conclusions relevant to all closure and reclamation research are summarized in Section 3.2 with detailed reports appended.

- Design concepts will likely change from those assumed in the Interim Reclamation and Closure Plan (V3.2) for the North Inlet and Processed Kimberlite Containment facility. Research and engineering studies are proceeding to provide the necessary information to support these changes.

- In 2012 DDMI decommissioned numerous small buildings for on-site disposal and removed 80 pieces of equipment from site as part of progressive reclamation.

- The overall closure schedule is on track with final design concepts planned for completion by 2015, ICRP V4.0 submission in December 2015 and the last year of mine production currently at 2023; a one year extension to the mine life.

- DDMI has provided opportunity for communities to comment and discuss any concerns with on-site disposal of closure waste material and now requests permission to proceed with landfilling in the North Country Rock Pile. Progressive reclamation waste materials are currently stored adjacent to the landfill location awaiting this approval.

- Aboriginal Affairs and Northern Development Canada have defined what closure and reclamation security is to be held under the Environmental Agreement. DDMI requests a reduction in the amount of security held under the Water License to account for the amount held under the Environmental Agreement.

2. Community Engagement

Following on the successful process that contributed to the development of the Colomac Remediation Plan, Diavik Diamond Mines Inc. (DDMI) sent a request to establish a community working group with each of the 5 Participation Agreement (PA) community organizations in January 2012. The 5 organizations are the Tlicho Government (TG), Yellowknives Dene First Nation (YKDFN), Kitikmeot Inuit Association (KIA), Lutsel K'e Dene First Nation (LKDFN) and the North Slave Metis Alliance (NSMA).

At this same time, significant efforts were being undertaken with each of these same 5 community organizations to develop and implement an Aquatic Effects Monitoring Program (AEMP) Traditional Ecological Knowledge (TEK) study for the 2012 monitoring year. Once this study was complete, DDMI renewed its efforts in establishing working groups with each of the community organizations in the fall of 2012. To date, meetings have been held with the North Slave Metis Alliance (15 November 2012) and the Tlicho Government's Kwe Beh Working Group (20 November 2012). A meetings with the Lutsel K'e Dene First Nation and has been scheduled for 11 December 2012 and a January 2013 meeting with the Kitikmeot Inuit Association is planned. The Yellowknives Dene First Nation has indicated that they are currently determining their preferred method for engagement relating to closure and will notify DDMI once this decision has been made.

A copy of the presentation and speaking notes that are being shared with the community working groups is included as Appendix I-1. The purpose of the meeting is to provide a high-level overview of the Diavik interim closure plan. To achieve this, DDMI has 'divided' the mine site into 5 areas and provided a summary of the plans and research to date (refer to slides 5 to 10). DDMI intention was also to have a focussed discussion on the preferred methods for engagement (refer to slides 11, 12 & 15). DDMI envisions a process for engagement that includes community working groups with consistent participation that will allow for the development of knowledge and provision of informed recommendations on specific topics or questions relating to Diavik's closure plans. To date, community organizations have expressed an interest in providing the summary of such meeting discussions to DDMI, rather than DDMI recording the meeting notes for verification by the community organization. At the time of submitting this update, community summaries had yet to be provided. DDMI would then plan to share the working group's recommendations with the greater community membership through our annual update meetings to confirm support and/or determine any other considerations relating to the closure plan. DDMI's vision for this process is being considered by each community organization to determine a mutually-agreeable process that meets the needs of both parties.

Another goal of the first round of meetings was to address the Wek'èezhìi Land and Water Board's direction to engage communities on the issue of on-site burial of buildings, machinery and equipment at closure (refer to slides 13, 14 & 15). DDMI explained the results of the Golder Associates Ltd. analysis relating to on-site versus off-site disposal, and clearly indicated our preference for material disposal.

Concurrently, DDMI has also worked to support the Environmental Monitoring Advisory Board's (EMAB) efforts to focus on reclamation considerations for the North Country Rock

Pile through the Traditional Knowledge (TK) Panel that has been established as provided for in the Environmental Agreement. The TK Panel has met three times to discuss closure during 2012, including one site visit and de-brief meeting with some of the Panel members. As noted in slide 12 of Appendix I-1, DDMI values a link between the TK Panel member and their community organization, as well as with that of the proposed closure working groups and community updates. Appendix I-2 includes a copy of the TK Panel interim report that highlights some of the main considerations and recommendations relating to closure.

Comments, ideas and recommendations relating to closure made through the above-noted venues and discussions with communities have been captured by DDMI in the table below. Please note that all parties generally consider these as guidance at this point in time. With the exception of the inert waste disposal information; this information has not been formally recommended, considered or incorporated into DDMI's closure plan.

Topic	Consideration	Venue
Landscape (including wildlife movement & re-vegetation)		
Caribou Access	Contour the waste rock pile with smooth gravel, most notably where caribou would come on and off the rock pile	2009 Post-closure Wildlife Movement Workshop
	Follow historical trails when planning access around or across areas such as the rock pile	2009 Post-closure Wildlife Movement Workshop
	Caribou crossing areas need to be smooth; remove large boulders	2009 Post-closure Wildlife Movement Workshop
	Restrict access to possibly harmful areas	2009 Post-closure Wildlife Movement Workshop
	Consider ramps similar to those at Misery for caribou crossing areas	2009 Post-closure Wildlife Movement Workshop
	Fence off the whole island to prevent wildlife access	TK Panel Report: Renewing our Landscape
	Caribou will use their old trails once the mine is gone	TK Panel Report: Renewing our Landscape
	Caribou will access the island from the west side during spring and fall migrations; access area needs to be wide	TK Panel Site Visit Recommendations
Roads/Airstrip	Turn up road and airstrip materials so they are not so linear and hard-packed	TK Panel Site Visit Recommendations
	Keep the airstrip in tact with a small shack or cabin for emergency use	TK Panel Site Visit Recommendations
	Leave the airstrip in place	NSMA Working Group Meeting, 15 Nov 2012
Re-vegetation	Plan for biodiversity and wildlife habitat with re-vegetation	TK Panel Report: Renewing our Landscape
	Grizzly bears tend to stay close to berry patches	TK Panel Report: Renewing our Landscape
	Monitor for invasive species & remove them if found	TK Panel Report: Renewing our Landscape
	Use native plants for re-vegetation	TK Panel Report: Renewing our Landscape

Topic	Consideration	Venue
	Include some re-vegetation plans for the rock pile	TK Panel Report: Renewing our Landscape
	Use good soil from eskers on the rock pile to help vegetation grow back	TK Panel Report: Renewing our Landscape
	Lichen is a vegetation that caribou eat	TK Panel Report: Renewing our Landscape
	Mix in a bit of soil with sand, crushed rock and till	TK Panel Site Visit Recommendations
	Look at eskers and old archaeological sites to see what grows in different areas (shade, sun, leeward, top, etc.)	TK Panel Site Visit Recommendations
	Black dirt from mossy areas of the tundra will help vegetation and mosses to grow	TK Panel Site Visit Recommendations
	There is no need to re-vegetate the top of the rock pile	NSMA Working Group Meeting, 15 Nov 2012
Water Flow	Collection ponds around the mine site should be drained and enhanced to promote clean drainage after closure	NSMA Working Group Meeting, 15 Nov 2012
	Consider the amount of tundra available in different areas for 'wetland treatment' of water flow after closure; encourage water to flow in directions where there is more tundra present before reaching Lac de Gras	NSMA Working Group Meeting, 15 Nov 2012
Open Pits		
Backfilling	Wash the walls of the pits before backfilling them with water	2009 Post-closure Wildlife Movement Workshop
	Do not fill the pits with boulders	2009 Post-closure Wildlife Movement Workshop
	Rock from the pile should be put back into the open pits	TK Panel Site Visit Recommendations
	Put some of the rock pile back into the pits; cover maybe less than half	TK Panel Report: Renewing our Landscape
	Conduct in 2 stages: stop at pit crest to allow settled material to stay in pit area and not on new fish habitat areas	Kwe Beh Working Group Meeting, 20 Nov 2012
Testing	Let the water in the pits stand for at least 2 years before determining if it is safe to re-connect to Lac de Gras	2009 Post-closure Wildlife Movement Workshop
Waste Rock Pile (including waste disposal)		
Rain/Seepage Water	Prevent this water from entering Lac de Gras	2009 Post-closure Wildlife Movement Workshop
	Find a way to contain the water coming from the rock pile	TK Panel Report: Renewing our Landscape
	There will be very cold spots inside the pile and cold water will flow from inside the pile, just like it does from an esker.	TK Panel Report: Renewing our Landscape
	Don't want to see a pool of water on top of the rock pile	TK Panel Report: Renewing our Landscape
	Use a geotextile material in drainage areas downstream of the rock pile & re-vegetate these areas	TK Panel Site Visit Recommendations

Topic	Consideration	Venue
	Consider snow deposition patterns based on prevalent winds; determine where to design the pile to be steep or rounded	TK Panel Site Visit Recommendations
	Snow pack will be near vertical on the leeward side of the pile	TK Panel Site Visit Recommendations
	Use undulating slopes to control water movement down the pile and direct it to different areas	TK Panel Site Visit Recommendations
	Have small collection ponds at the base of the pile for water collection; then 'strain' the water from there	TK Panel Site Visit Recommendations
	Ensure seepage water travels slowly over the land; not fast, and not directly to LDG	TK Panel Site Visit Recommendations
Animal Use	Animals will den on the side of a hill that faces the sun	TK Panel Report: Renewing our Landscape
	Caribou will travel on hills that are not rocky	TK Panel Report: Renewing our Landscape
	Animals will dig into eskers in the summertime to keep cool	TK Panel Report: Renewing our Landscape
	Flatten the pile a bit to allow easier access for animals to cross; no berms on top	TK Panel Report: Renewing our Landscape
	Remove or cover large boulders from the base of the rock pile to allow safe access for wildlife	TK Panel Site Visit Recommendations
	Smooth and flatten the sides, and round the top edges of the rock pile; this is better than a formal 'ramp'	TK Panel Site Visit Recommendations
	Leave the steep sides and large rocks on the rock pile and PKC to prevent caribou access	2009 Post-closure Wildlife Movement Workshop
Aesthetics	Level off the pile; make it look less high, even if it means filling in some other areas of the island	TK Panel Site Visit Recommendations
	Slope the pile down before putting any capping materials on it; keep it the height it is now, slope and material similar to sides of the test pile	TK Panel Site Visit Recommendations
	Make boulders smaller before placing them into the pile in the future	TK Panel Site Visit Recommendations
	Start trying to grow some plants on the rock pile now	TK Panel Report: Renewing our Landscape
	Allow re-vegetation to occur naturally	TK Panel Site Visit Recommendations
	Grass on the rock pile, especially near the base, would be nice to see	TK Panel Site Visit Recommendations
	Place soil near the bottom of the rock pile only and plant shrubs in this area	TK Panel Site Visit Recommendations
	Simulate an esker - shape, water flow, vegetation, cover material, wildlife access	TK Panel Site Visit Recommendations
	Study a natural rock/esker formation that is similar to the waste rock pile to obtain community input on closure considerations for the rock pile	Kwe Beh Working Group Meeting, 20 Nov 2012
Color	Try to match the color of the pile more closely to that of the natural landscape	TK Panel Report: Renewing our Landscape
	Use esker material from the tundra or pebble-sized crushed rock as cover if there isn't enough from A21	TK Panel Site Visit Recommendations

Topic	Consideration	Venue
	The covered and sloped test pile looks more natural	TK Panel Site Visit Recommendations
Waste Disposal	Recycle materials wherever possible	TK Panel Report: Renewing our Landscape
	Do not put the rock from the pile back into the pit; it could pollute the water	TK Panel Site Visit Recommendations
	Do not bury metals in the pile; ship it off site	TK Panel Site Visit Recommendations
	Any materials that go into the landfill need to be clean - no oil	TK Panel Site Visit Recommendations
	Do not leave buildings behind; do not bury them	TK Panel Site Visit Recommendations
	Use waste processed kimberlite to fill in the voids of the rock pile	TK Panel Site Visit Recommendations
	Reserve a spot to bury materials for disposal	NSMA Working Group Meeting, 15 Nov 2012
	Would like to consider special disposal considerations for the ammonia nitrate building	NSMA Working Group Meeting, 15 Nov 2012
	Prefer disposal of inert materials on site, rather than somewhere else in the territory; reduce amount of winter road traffic & keep it away from higher-use areas such as those around Yellowknife or the communities	NSMA Working Group Meeting, 15 Nov 2012
	Prefer inert waste to be disposed locally at the mine, rather than transporting the waste to the landfill remotely.	Kwe Beh Working Group Confirmation, 7 Dec 2012
North Inlet		
Reconnection to Lac de Gras	Presentation of the north inlet study results	Kwe Beh Working Group Meeting, 20 Nov 2012
	Keep the dams in place	NSMA Working Group Meeting, 15 Nov 2012
Water Quality	Consider treating & removing all water and backfilling area with rock	NSMA Working Group Meeting, 15 Nov 2012
	Plan for water quality that is acceptable for fish & wildlife, including birds	NSMA Working Group Meeting, 15 Nov 2012
Processed Kimberlite Containment (PKC) Area		
Fence	Set up a fence around the PKC	2009 Post-closure Wildlife Movement Workshop
Surface	Rock cover should be placed starting at the dam and working toward the center	NSMA Working Group Meeting, 15 Nov 2012
	Consider pumping the waste PK for disposal underground, or stabilizing it either in place or in the pit somehow; no harm in putting it back where it was	NSMA Working Group Meeting, 15 Nov 2012
	Consider keeping rock pile slopes steep near the PKC in order to deter caribou access	NSMA Working Group Meeting, 15 Nov 2012
	Consider using till on the PKC to prevent or minimize water coming in and going out	NSMA Working Group Meeting, 15 Nov 2012
Drainage	Use natural tundra filtration systems with staging ponds for water drainage after closure	2009 Post-closure Wildlife Movement Workshop

Topic	Consideration	Venue
	Ensure drainage from the PKC has a lot of tundra to travel over prior to draining to Lac de Gras	NSMA Working Group Meeting, 15 Nov 2012

3. Reclamation Research Update

3.1 Status of Immediate Research Tasks

The status of each immediate research task is summarized in the following table. Where documentation is available for a research task a reference is provided. If the documentation has not been previously submitted to the WLWB, a copy is included in Appendix II. The full research plans can be found in Appendix VIII of the Interim Reclamation and Closure Plan (ICRP) (Version 3.2).

Immediate Research Tasks		**Status**
1. Traditional Knowledge and Community Participation		
1.1 Wildlife Movement	1.1.1 Desktop study to review available TK for caribou and other wildlife in the Slave Geological Province	Complete. Documented in Appendix II-1 *Literature Review of Traditional Ecological Knowledge Related to the Resource Sector.* July 2011.
	1.1.2 More detailed discussions with members from each of the Aboriginal organizations to obtain more specific recommendations on preferred options and where/how to best incorporate these recommendations in the final closure design, while still taking into account technical considerations.	On-going. More detailed discussions have occurred with the TK/IQ Panel and community representatives specifically around caribou movement and the North Country Rock Pile (see Section 2).
1.2 Re-vegetation	1.2.1 Desktop study to review available TK for vegetation in the Slave Geological Province	Complete. Documented in Appendix II-1 *Literature Review of Traditional Ecological Knowledge Related to the Resource Sector.* July 2011.
	1.2.2 A summary of DDMI 5-year research on re-vegetation is to be provided to Aboriginal organizations and combined with TK views on which of those species are suited to re-vegetation or are beneficial for wildlife.	Initiated. Summaries of the Phase I and II studies have been provided in annual Wildlife Monitoring Program reports. A full summary of both phases, including plans to continue re-vegetation research, will be included in the 2012 Environmental Agreement report.
	1.2.3 DDMI hopes to discuss these topics in community-	Initiated. The TK Panel site visit of 20 August 2012 included a visit to the re-

Immediate Research Tasks		Status
	based workshops and with the TK/IQ Panel.	vegetation plots and a discussion of results to date. Community working group meetings also provided an overview of the results to date. Resulting recommendations relating to re-vegetation are included in Section 2.0.
1.3 Landforms	1.3.1 DDMI to work with Aboriginal organizations to begin developing more detailed images of what the mine will look like post-closure to assist community members in understanding what the mine site might look like. These images can incorporate different rock features, vegetation, or wildlife trails that community members may recommend.	Initiated – both computer and clay models have been started with the TK/IQ Panel. Intention is to develop these further with site employee & contractor input, as well as by sharing them with communities at the appropriate stages of development.
	1.3.2 DDMI will assess the technical feasibility and material availability to meet Aboriginal organizations recommendations for key landforms. A model that best represents the final look of the land will be constructed and shared with each of the Aboriginal organizations to obtain any further feedback.	Pending recommendations and more advanced models.
	1.3.3 DDMI hopes to discuss the models in community-based workshops and with the TK/IQ Panel.	Pending final landforms and model.
1.4 Community Engagement	1.4.1 Development of a TK/IQ Panel under the Environmental Agreement	Panel is established and has met on several occasions in 2012 (see Section 2).
2. Open Pit, Underground and Dike Area Research		

Immediate Research Tasks		**Status**
2.1 Geochemical loadings from the walls of the pit and underground workings are expected to be greater from areas with exposed biotite schist than areas with granite. The walls of the open pit represent the largest surface area of rock that will be washed by the flooding of the pit. The relative areas of granite versus biotite schist will be measured using photo imagery techniques and the results will be available for future updates to flooded pit water quality predictions.		Complete – documentation included in Appendix II-2 *Total Surface Area of Exposed Metasedimentary Rock for the A154 Pit* December 2011 and Appendix II-3 *Total Surface Area of Exposed Metasedimentary Rock for the A418 Pit* December 2011
2.2 Actual geochemical loading rates from pit or underground walls during flooding will be measured by spraying water over small sections of exposed granite and biotite schist and collecting and analysing the wash water. These results will be compared with estimates from waste rock geochemical testing. The results will be available for future updates to flooded pit water quality predictions.		Field work complete – documentation included in Appendix II-4 *Pit wall washing methods description* August 2012. Analytical results, analysis and documentation are pending.
2.3 DDMI is working with Fisheries and Oceans Canada on a survey method for verifying fish use of the exterior slopes of the A418 and A154 dikes. This work may also be an opportunity to combine TK approaches. The information will be used to verify expected post-closure fish habitat use.		Field work with DFO is complete. Documentation is pending as is TK opportunity.
3. Waste Rock Research		
3.1 Thermal	3.1.1 Based on the monitoring results from the test piles and waste rock as well as possible mathematical modelling, provide an estimate of the depth of annual thaw for the waste rock pile.	Complete – Documented in Appendix II-5 *Heat Transport and the Effects of Climate Change in a Large-scale Waste Rock Pile Located in a Continuous Permafrost Region at Diavik Diamond Mine.* ICARD May 2012.
	3.1.2 Provide this estimate for scenarios assuming both a cover and no cover.	Complete – Documented in Appendix II-5 *Heat Transport and the Effects of Climate Change in a Large-scale Waste Rock Pile Located in a Continuous Permafrost Region at Diavik Diamond Mine.* ICARD May 2012.
	3.1.3 Determine the effect of a climate change scenario on	Complete – Documented in Appendix II-5 *Heat Transport and the Effects of*

Immediate Research Tasks		Status
	these initial estimates.	*Climate Change in a Large-scale Waste Rock Pile Located in a Continuous Permafrost Region at Diavik Diamond Mine.* ICARD May 2012.
	3.1.4 Revise estimates with any changes in monitoring information, mathematical modelling or cover design parameters.	Not started.
3.2 Hydrological	3.2.1 Based on the monitoring results from the test piles and thermal analysis provide an interim estimate of the fraction of rainfall and snow melt expected to travel within the annual thaw zone and exit the rock pile as seepage.	Underway. Estimates are to be prepared by research team.
	3.2.2 Provide this estimate for scenarios assuming both a cover and no cover.	Underway. Estimates are to be prepared by research team.
	3.2.3 Determine the effect of a climate change scenario on these initial estimates.	Underway. Estimates are to be prepared by research team.
	3.2.4 Revise estimates with any changes in monitoring information or cover design parameters.	Not started.
3.3 Geochemical	3.3.1 Based on the monitoring results from the test pile, thermal analysis and hydrological analysis provide an interim estimate of the geochemical loading rates in seepage from the waste rock.	Initiated but awaiting results from hydrology tasks 3.2
	3.3.2 Provide this estimate for scenarios assuming both a	Initiated but awaiting results from

Immediate Research Tasks		**Status**
	cover and no cover.	hydrology tasks 3.2
	3.3.3 Determine the effect of a climate change scenario on these initial estimates.	Initiated but awaiting results from hydrology tasks 3.2
	3.3.4 Revise estimates with any changes in monitoring information or cover design parameters.	Not started.
4. Processed Kimberlite Containment Area Reclamation Research		
4.1 Geotechnical	4.1.1 Interpretation and analysis of piezocone testing of the PKC slimes to determine consolidation rates and magnitudes. An estimation of consolidation rates and magnitudes can provide an indication of final landscape topography, and the volume of pore water that may be expelled during consolidated.	Complete. Documentation is included in Appendix II-6 *2010 Geotechnical Site Investigation Factual Report*. AMEC December 2011.
	4.1.2 Laboratory tests for additional slimes characterization, could contribute to estimates of consolidation rates and magnitudes.	Complete. Documentation is included in Appendix II-6 *2010 Geotechnical Site Investigation Factual Report*. AMEC December 2011.
	4.1.3 Installation of thermistors in the beaches and/or slimes and collection of thermal data can provide an indication of permafrost development and the propensity for thermokarst topography.	Installation complete. Three horizontal strings of thermistor have been installed in the main cell of the PKC and one vertical string is in the north cell that gets raised as the beach rises. Data collection and interpretation is on-going.
	4.1.4 Contract a qualified engineer to review the 2001 cover design for the PKC.	Underway. Review is being completed as part of PKC closure design options review (see also Section 4). Some findings are

Immediate Research Tasks		Status
	Specifically to provide expert opinion on the expected performance of the till layer as an impermeable layer over an unconsolidated PK material and provide a written report.	included in the documentation of Task 4.1.1 and 4.1.2 in Appendix II-6 *2010 Geotechnical Site Investigation Factual Report*. AMEC December 2011.
4.2 Geochemical	4.2.1 Annual or semi-annual sample collection from surviving/accessible piezometers (as accessible) to monitor changes to pore water chemistry and identify any potential elements of concern.	On-going. See Appendix II-7 *Hydrogeochemical Investigation of the Processed Kimberlite Facility at Diavik Diamond Mines Inc*. July 2011.
	4.2.2 Pore water chemistry trend analysis and interpretation; to identify any changes in pore water chemistry over time and identify any potential elements of concern.	On-going. See Appendix II-7 *Hydrogeochemical Investigation of the Processed Kimberlite Facility at Diavik Diamond Mines Inc*. July 2011.
	4.2.3 Laboratory and/or small scale field leaching experiments to monitor accelerated and in situ weathering of FPK and the resultant water quality.	Field leaching experiments initiated in 2012 with a series of barrel test. Processed kimberlite placed in a number of barrels that are exposed to climate while collecting and analysing seepage water quality. Testing will run for several years.
	4.2.4 Pore water chemistry modelling based on pore water chemistry trends, and laboratory experiments and/or small-scale field experiments that may include predictive/reactive transport modelling.	Not started.
	4.2.5 A screening level risk assessment using available PKC pond monitoring (SNP 1645-16) information, pore	DDMI is evaluating using direct monitoring program using PKC seepage water as a precursor to this task. Characteristics and behaviour of existing

Immediate Research Tasks		Status
	water chemistry information, and laboratory and/or field experiment preliminary results to estimate possible outlet seepage water quality. This risk assessment will identify parameters of potential concern and may help focus characterization of sources (e.g. pore water, beach runoff) or processes (e.g. freezing, oxidation) governing the concentrations in the outlet and seepage water.	PKC seepage could provide an immediate representation of post-closure outlet water characteristics and potential effects. This research would include the scope of task 4.3.1 below.
4.3 Water quality criteria	4.3.1 A screening level risk assessment will be completed based on initial estimates of probable ranges of outlet water quality and quantity. Water quality criteria from Appendix V, Table V7 will be used as the basis for screening. Areas where exposure concentrations will be estimated include streams and or inland lakes along any seepage pathway and areas of Lac de Gras.	See 4.2.5 above
	4.3.2 Update water quality criteria, if required	To be initiated following 4.2.1
	4.3.3 Other scopes of work may be identified based on the results of the analysis described above.	See 4.2.5 above
5. North Inlet Reclamation Research		
5.1 Follow-up studies and testing from 2010 characterization program to isolate the source of	5.1.1 Estimate leaching potential of contaminants from NI sediment	Laboratory testing complete – documentation underway with submission anticipated Q1 2013

Immediate Research Tasks		Status
measured biological responses	5.1.2Confirm sediment chemistry and toxicity in NI sediment	Complete - Documented in: *North Inlet Supplemental Environmental Investigations – Task 2, Further Investigations of North Inlet Sediments.* Submitted January 5, 2012
	5.1.3 Conduct additional chemical and toxicological testing on NIWTP sludge	Complete – Documented in: *North Inlet Supplemental Investigations -Task 3, Further investigation of North Inlet Water Treatment Plant Sludge.* Submitted April 2, 2012
	5.1.4 Conduct zooplankton sampling in NI	Complete – Documented in: *North Inlet Supplemental Environmental Investigations – Task 4, Zooplankton Sampling in North Inlet.* Submitted July 10, 2012
	5.1.5 Conduct preliminary Toxicity Identification Evaluation (TIE)	New task initiated October 2012 with results expected in Q1 2013
	5.1.6 Model acceptable NI water quality conditions for a partial breach to Lac de Gras as a closure alternative	On hold pending outcome of characterization studies
5.2 Conduct and document screening level risk assessment for NI water and sediment quality		On hold pending outcome of characterization studies
5.3 Conduct and document detailed level risk assessment, if required		Not started
5.4 Develop risk management strategy, if required		Not started
5.5 Update water and sediment closure criteria		Not started
6. Infrastructure Area Reclamation Research		
6.1 Re-vegetation	6.1.1 Continue monitoring of re-vegetation research plots	Comprehensive three year work plan being developed with University of Alberta for field implementation starting 2013.

Immediate Research Tasks		Status
	6.1.2 Interpretation and documentation of field and laboratory monitoring results	See 6.1.1 above
	6.1.3 Assess information availability and applicability from Ekati	See 6.1.1 above
	6.1.4 Assess confidence in developing re-vegetation procedures	See 6.1.1 above
	6.1.5 Identify any additional research that may be required and long-term monitoring scope for existing re-vegetation plots.	See 6.1.1 above
6.2 Contaminated soils	6.2.1 Conduct and document risk assessment for options for management and disposal of petroleum hydrocarbon contaminated materials.	Complete – Report attached as Appendix II-8 *Preliminary Assessment of Management Options for Hydrocarbon Contaminated Soils*. January 2011
6.3 Closure Reference Concentrations	6.3.1 Develop site-specific, risk-based closure reference concentrations; document and distribute for review	Not started
	6.3.2 Update closure criteria	Not started
6.4 Post Closure Vegetation Metals Level Risk	6.4.1 Literature review to determine potential metals levels in plant that may be used for re-vegetation and that are expected to colonize naturally.	Not started
	6.4.2 Compare these literature values with risk-based reference concentrations.	Not started
	6.4.3 Determine if there is a need to further research this	Field measurements included in scope for

Immediate Research Tasks		Status
	potential contaminant pathway.	6.1 above.

3.2 Results Summary and Conclusions

The following sections summarize key results and conclusions, relevant to closure, derived from the reclamation research recently completed.

3.2.1 Traditional Knowledge and Community Participation

Results summaries related to community engagement and Traditional Knowledge are provided in Section 2.0.

3.2.2 Open Pit, Underground and Dike Area Research

- Total exposed surface area of A154 pit is 896,143m^2 and of this 51,965m^2 (5.8%) is exposed biotite schist.

- Total exposed surface area of A418 pit is 609,835m^2 and of this 26,070m^2 (4.3%) is exposed biotite schist.

- The percentage of exposed pit wall that is biotite schist (4.3%-5.8%) is about half of what was assumed (10%) for initial closure estimates of pit water quality.

3.2.3 Waste Rock Reclamation Research

- The depth of the annual thaw zone in the waste rock pile is estimated to equilibrate at 3.7m by 2020 assuming no till/rock cover. With an assumed climate change and no till/rock cover this depth is estimated to increase to 7.0 m by 2110.

- With a till/rock cover the depth of the annual thaw zone is estimated to equilibrate at a depth of 3.0m by 2020, 0.7m less than without a cover. The till/rock cover is estimated to help mitigate effects of climate change as thaw zone depths increase to 3.9m by 2110 in this scenario as compared with 7m without a cover.

3.2.4 Processes Kimberlite Containment Area Reclamation Research

- Undrained shear strength of fine processed kimberlite is very low (less than 2 kPa) in the upper 10-12 m and then increase appreciable to 19-20 kPa at depths of 25m. These higher values still represent only a ‘very soft’ soil.

- These results indicate that implementation of the original 2001 closure design would be highly problematic in terms of the ability of the fine processed kimberlite in the central portion of the PKC to geotechnically support the originally proposed cover design and in terms of the anticipated magnitude and rate of consolidation of such a cover, should it be feasible to physically construct.

- Annual thaw zone in the PKC beach was measured at 1.23 to 1.70m from the beach surface and the water table was measured at 1.14 to 1.25m depth from the beach surface.

- There are distinct differences in average concentrations of pH, Eh and dissolved ions from the unsaturated zone, saturated zone and frost zone. Oxidation conditions in the unsaturated zone result in higher concentrations of sulphate, most major cations and most metals compared with the saturated zone. The concentration of dissolved ions are significantly lower in the frost zone than the in the saturated zone.

- Porewater in the fine PK under the pond showed no frost to a depth of 27m and concentrations of dissolved ions and Eh are generally higher in the pond water and decrease with depth through the fine PK material.

- The subaqueous disposal and freezing of the processed kimberlite material limits the release of dissolved concentrations of metals and SO_4 to the adjacent porewater. Closure designs that result in larger extents of frozen saturated processed kimberlite will likely result in better surface water quality.

3.2.5 North Inlet Reclamation Research

- The results to date support a hydraulic connection between the North Inlet and Lac de Gras and possibly a full connection. The later has not yet been determined definitively.

- The results to date do not indicate a significant risk with continuing sludge disposal in the North Inlet.

3.2.6 Infrastructure Area Reclamation Research

- Results of the risk-based analysis indicated that unrestricted disposal of petroleum hydrocarbon contaminated soil may not be safe for people and ecological receptors following mine closure.

- Preliminary management options analysis indicated that disposal within a cover of sufficient depth to ensure material remains beneath the active thaw zone minimized exposure for potential human health and ecological risk.

3.3 Research Timelines

Research timelines have been adjusted based on results and progress to date and will continue to change as the research progresses. The following chart shows our current view of the research schedule for the immediate research tasks. Task descriptions for each of the task numbers are included in the research status table in Section 3.1.

Immediate Research Task		2013				2014				2015			
1. TK and Community Participation													
1.1 Wildlife Movement	1.1.1 Desktop study	Complete											
	1.1.2 Discussions	▨	▨	▨	▨								
1.2 Re-Vegetation	1.2.1 Desktop study	Complete											
	1.2.2 Discussions	▨	▨	▨	▨								
1.3 Landforms	1.3.1 Development	▨	▨	▨	▨	▨							
	1.3.2 Assessment				▨	▨	▨						
	1.3.3 Discussion							▨	▨	▨			
1.4 Community Engagement	1.4.1 TK/IQ Panel	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
2. Open Pit, Underground and Dike Area													
2.1 Wall mapping		complete											
2.2 Geochemical loading		▨	▨										
2.3 Fish use - exterior		▨	▨										
3. Waste Rock													
3.1 Thermal	3.1.1 Initial estimate	complete											
	3.1.2 Scenarios	complete											
	3.1.3 Climate change	complete											
	3.1.4 Update estimates					▨	▨						
3.2 Hydrological	3.2.1 Initial estimate			▨	▨								
	3.2.2 Scenarios			▨	▨								
	3.2.3 Climate change			▨	▨								
	3.2.4 Update estimates						▨	▨					
3.3 Geochemical	3.3.1 Initial estimate				▨	▨							
	3.3.2 Scenarios				▨	▨							
	3.3.3 Climate change				▨	▨							
	3.3.4 Update estimates							▨	▨				
4. Processed Kimberlite Containment Area													
4.1 Geotechnical	4.1.1 Slimes analysis	complete											
	4.1.2 Slimes testing	complete											
	4.1.3 Instrumentation	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	4.1.4 Design review	▨	▨										
4.2 Geochemical	4.2.1 Sampling		▨	▨			▨	▨					
	4.2.2 Trend				▨	▨			▨	▨			
	4.2.3 Leaching tests	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	4.2.4 Modelling							▨	▨				
	4.2.5 Risk assessment									▨	▨		
4.3 Water quality criteria	4.3.1 Risk assessment										▨	▨	
	4.3.2 Update criteria											▨	
	4.3.3 Gaps												▨
5. North Inlet Area													
5.1 Follow-up Studies	5.1.1 Leaching potential	▨											
	5.1.2 Sediment chemistry	complete											
	5.1.3 Sludge analysis	complete											
	5.1.4 Zoolpankton	complete											
	5.1.5 TIE	▨	▨										
	5.1.6 Modelling			▨									
5.2 Screening level risk assessment					▨								
5.3 Detailed risk assessment						▨							
5.4 Risk management strategy							▨						
5.5 Update criteria								▨					
6. Infrastructure Area													
6.1 Re-vegetation	6.1.1 Monitoring	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	6.1.2 Interpretation	▨	▨								▨	▨	
	6.1.3 Ekati data		▨	▨									
	6.1.4 Procedures											▨	
	6.1.5 Gaps												▨
6.2 Contaminated soils	6.2.1 Management options	complete											
6.3 Reference Concentrations	6.3.1 Development								▨	▨	▨	▨	
	6.3.2 Update criteria												▨
6.4 Vegetation metals	6.4.1 Literture review					▨	▨						
	6.4.2 Compare								▨	▨			
	6.4.3 Gaps												▨

4. Proposed Changes to Design Concepts

4.1 Pit, Underground and Dike Area

In the WLWB approval of ICRP V3.2, the approval letter dated September 26, 2011 includes a list of aspects of the closure plan that are “well developed and would require evidence to support a change” and aspects that are “preliminary and will evolve as DDMI collects more information and directs more resources towards developing them”. The WLWB lists “k. Dike breach locations and sizes” in the latter category.

Dike breach location and size has been approved by Transport Canada (Appendix IV-1). The objective for the dike breaches was to minimize the amount of wind driven water circulation that would occur within the flooded pit area. Transport Canada defined for DDMI what the minimum breach locations and sizes would be from a navigation perspective and these are what have been included in the ICRP V3.2. DDMI has no plans to revisit the number, size or location of these breaches and suggests that this closure activity would be more correctly included in the “well developed and would require evidence to support a change” category.

4.2 Waste Rock Area

The preferred closure activities currently remain as described in ICRP V3.2. Key closure activities including re-sloping and placement of cover material are awaiting verification with communities and are also contingent upon development of an A21 open-pit.

4.3 Processed Kimberlite Containment

The preferred closure activities associated with the Processed Kimberlite Containment (PKC) facility are not the same as the activities approved in the ICRP V3.2. The differences are described in Section 5.2.6.3 of ICRP V3.2. Research results described in Section 3.2.4 above provide additional information in support of alternative closure activities for the PKC. DDMI is working towards compiling the necessary information to support an application for approval of alternative closure activities.

Engineering options analysis is being conducted to screen possible closure concepts and then systematically evaluate a short list of options to select the preferred concept. Once complete, the preferred concept will be submitted along with supporting rationale.

4.4 North Inlet

Results of research on the quality of the lakebed sediment in the North Inlet indicates that it may be more appropriate to have a closure design concept that allows a hydrological connection between Lac de Gras and the North Inlet but limits fish passage. This design change has not been confirmed as the research work is not complete.

5. Closure Objectives and Criteria

At this time there are no proposed changes to the closure objectives documented in ICRP V3.2. If it is determined that a change to the North Inlet design concept is appropriate (see Section 4.4) DDMI will submit a request for approval to revise the North Inlet closure objectives NI1 – Reconnect the North Inlet with Lac de Gras; and, NI-3 - Suitable fish habitat in the North Inlet.

With regard to closure criteria, DDMI presented at, and participated in, the December 2011 Risk Assessment Workshop hosted by the WLWB. A copy of DDMI's presentation is included in Appendix V-1. DDMI looks forward to participating, as appropriate, in the *Regulator's Role Workshop* as proposed by WLWB for determining the role of regulators in developing closure criteria.

6. Progressive Reclamation

The following Tables list the progressive reclamation activities completed in 2012 and planned for 2013. Items listed below as disposed on-site in 2012 are actually stored beside the landfill location awaiting WLWB permission to dispose.

Progressive Closure - On-site Disposal	
2012 Actual	**2013 Planned**
CS Harnois Mega Dome skeleton	50 % of South Camp - 90 Rooms
South Camp N Dorm (consists of 8 trailers)	
South Camp P Dorm (consists of 8 trailers)	
Crusher/Paste - DNX building	
Environment field lab (4 trailers)	
North construction offices (20 trailers)	
NIWTP - trailers used for Thermosyphon installation	
North side Maintenance - old LDG muster station	

Progressive Closure - Removed from Site			
2012 Actual		**2013 Planned**	
Light Vehicles	40	Dozer	3
830 Haul Truck	7	Zoom Boom	1
Drill	1	Drill	1
C-Cans	9	Le Tourneau	1
Generator	1	Loader	1
Compressor	1	Cement Truck	3
Water Truck	2	Excavator	3
Gravel Truck	2	75000 L Fuel Tanks	4
Emulsion Truck	1	Manlift	3
Reimer Truck	1	Lube Truck	1
Skid Steer	1	80 ton trailer	1
Bolter	1	50000 L Fuel Tank	7
MUT's	4	785 Haul Truck	1
18' Lund Boat	3	Light Vehicles	20
Zodiac	1		
16' Lund Boat	1		
Outboard Motors	4		

7. Schedule

The overall closure schedule remains largely as described in ICRP 3.2. Some updates and key milestones are listed below.

- The current Life-of-Mine schedule has extended the last year of mine production by 1 year from 2022 (ICRP V3.2) to 2023.

- While research studies continue for aspects of the North Country Rock Pile, the engineering design has been placed on hold pending further input from communities on the landform and wildlife aspects and decisions from DDMI regarding the development of A21. Both research and engineering work are sufficiently advanced that the anticipated delays will not impact the overall closure schedule for this area.

- DDMI currently does not have WLWB permission for on-site dispose of closure waste material. As noted in Section 6, DDMI has proceeded with decommissioning of numerous buildings as a part of progressive closure. These buildings have been prepared for on-site disposal and relocated to the operational landfill in the North Country Rock Pile. Permission to dispose of this closure waste material has become a schedule issue.

- Research and engineering studies remain on track to complete final closure design concepts for all of the five closure areas by 2015.

- DDMI is also currently on track to submit ICRP V4.0 in December 2015.

8. Security Update

DDMI suggests that the WLWB RECLAIM estimate (January 2012) remains valid. DDMI has not updated the RECLAIM closure cost estimate to reflect the progressive reclamation work completed in 2012. The only new site development work completed in 2012 that might increase the closure cost estimate was the installation of the wind turbines.

The WLWB determined that the total estimated liability for land and water reclamation was $131,360,000 (January 25, 2012). WLWB also determined that the $11,090,000 held by AANDC under the Land Leases can be subtracted from the total to derive a Water License amount of $120,270,000 (February 9, 2012).

The WLWB Reasons for Decision – Security Review dated April 24, 2012 explains the decision to subtract, from the total estimated liability, the security held by AANDC under the Land Lease.

> *"The NWB adopted a "holistic but practical" approach to assessing total security indicating as follows at page 47 of its reasons:*
>
> > *"…. the Board's focus in assessing security is that the Applicant must have posted sufficient security, through all means, when taken together, to ensure that the overall reclamation of the site (land and water) has been adequately addressed. Consequently, the Board's starting point to assess security remains considering any security requirements holistically and then deducting from the aggregate land and water reclamation totals any security held under other instruments, with the remainder being secured under the water licence."*
>
> *The Board sees merit in this approach in appropriate cases. Here, the additional security is held by AANDC under the land leases for the Diavik mine site. The lease security can be applied to closure and reclamation if required. There is no doubt that DDMI has the capacity to pay the costs of closure and reclamation for the site. In fact, as indicated elsewhere in these reasons, the Crown currently holds more security than is required for closure and reclamation of the mine. Finally, DDMI has a good track record of compliance with the requirements of their water licence. Thus, in the Board's view, the company satisfies the criteria necessary for the Board to apply its discretion to the setting of security under section 12 of the Regulations."*

Subsequent to the WLWB decision described above, AANDC has determined that $28,100,000 in security is to be held under the Environmental Agreement (November 20, 2012). Appendix VIII-1 details the basis for AANDC's $28,100,000.

DDMI requests that the WLWB revise the amount of security to be held under the Water License taking into consideration $25,100,000 of the $28,100,000 in security held by AANDC under the Environmental Agreement. Our rationale is that this request satisfied the criteria necessary for the Board to set security under Section 12 of the Regulations. Specifically:

- Similar to the Land Leases $25,100,000 security under the Environmental Agreement can be applied to closure and reclamation obligations if required (see Articles 15 of the Environmental Agreement). Under Article 15.1(iv) $3,000,000 of the security under the Environmental Agreement cannot be used for closure and reclamation;

- The $25,100,000 security under the Environmental Agreement is held by AANDC in the same form as the Land Leases (see Article 15.1 of the Environmental Agreement);

- DDMI has the capacity to pay the cost of closure and reclamation of the mine site;

- The Crown currently holds more security ($159,460,000) than is required for closure of the mine ($131,360,000); and

- DDMI has a good track record of compliance with the requirements of the Water License.

Additionally, DDMI has concluded that $24,381,000 of the $28,100,000 in security was specifically estimated as land and water reclamation costs. Item #5 of Appendix VIII-1, “Serious and Imminent Threat to the Environment” Article 15.1(b) and the line item “Security for EMAB Article 15.1(k)” total $3,719,000 and are not considered by DDMI to be land and water reclamation costs.

This $24,381,000 held by AANDC under the Environmental Agreement is, we believe, included in one or more of the following January 2012 WLWB RECLAIM line items:

MONITORING AND MAINTENANCE		$16,845,117
PROJECT MANAGEMENT		$4,007,039
ENGINEERING		$4,007,039
CONTINGENCY		$16,028,155
	Total	$40,887,349

DDMI engaged the WLWB in discussions around this issue of duplication in closure cost estimating with an AANDC-WLWB-DDMI meeting July 24, 2012 and a subsequent letter of July 25, 2012. Our letter of July 25, 2012 provides additional information related to this issue and requested clarification from the Board.

9. Other Important Information

At this time there is no additional information to provide beyond what has already been included in the document.

10. Record of Revisions to be made in Version 4.0 of the ICRP

Following is a list of revisions to be made in Version 4.0 of the Interim Closure and Reclamation Plan. This list was taken from the WLWB Letter of September 26, 2011 and will be added to as new items are identified.

1. Develop a monitoring plan, including estimated time periods.

2. Include a detailed explanation of how the mine would passively treat seepage in situ.

3. Provide a more detailed description of risks associated with each selected closure activity. For each reclamation activity, identify the preferred contingency and significantly increase the level of detail for this contingency. Ensure all uncertainties associated with the preferred contingency are addressed. For example, if using Lac de Gras water to dilute water in the pit area is DDMI's preferred contingency, describe how this would be achieved, clearly define the environmental costs and benefits (compared to water treatment or other contingencies), and address any associated uncertainties.

4. Estimate the quantities of contaminated soils/materials expected at the end of operations, in order to facilitate the remediation of potentially contaminated material (landfarming).

5. Provide a general description of the types and quantities of materials that the company plans to leave underground, based on available information. Also, discuss the risk that this disposal may contaminate groundwater or surface water and identify any uncertainties.

6. Identify potential benefactors of salvaged infrastructure (e.g. buildings, tanks, equipment, supplies, crushers, generators, etc.) earlier rather than later and provide more detail about current plans and options.

7. Include updated predictions of water quality at closure and the duration and magnitude of residual effects using the most current information. This must include an analysis, using the most current data available, to update the 1998 runoff water quality predictions. Identify ways to reduce water quality problems associated with runoff.

8. Include detailed performance and post-closure monitoring plans and updated predictions of effects using the most current information. (Consider hosting a workshop or information session on post-closure monitoring prior to submission of Version 4.0 of the ICRP).

9. Address the issue of air contaminants released to land and water during operations, in the context of closure.

10. Provide the proposed revegetation procedure.

11. Include final design of the waste rock pile slopes and a resloping plan.

12. Provide a more detailed description of how metal uptake in revegetated plant communities will be monitored (per Water Licence condition Part L, Item 3f).

13. Provide "a description of the Plan to assess and monitor any ground water contamination during post-closure" (Water Licence condition Part L, Item 1g).

14. Develop "a field-testing program and an implementation timetable to verify the effectiveness of the proposed impermeable closure cap for the Process Kimberlite

Containment Facility and the Waste Rock Storage Facilities" (Water Licence condition Part L, Item 3g).

15. Clarify how wetlands will be used for the closure of the collection ponds and the PKC Facility. Discuss whether it is imperative that wetlands develop in order to achieve the closure objectives? Discuss procedure and timetable for development of the wetland.

16. Add "identify opportunities to enhance/diversify fish habitat in the North Inlet" to the reclamation research plan (RRP) outlined in appendix VIII-5 (assuming ongoing investigations support full reconnection of the North Inlet to Lac de Gras) ;

17. Include a closure plan for the A21 causeway (including closure objectives, preferred activities, etc.);

18. Ensure that all information in section 3 of the ICRP (Project Environment) is correct and up to date (e.g., geological info, climate data, traditional use information, etc.). Refer to a number of INAC comments for specific revisions.

19. Include a statement that, during temporary shutdown, the stationary surface and underground mobile equipment stored within the common parking areas would have drip/spill trays placed in appropriate locations to absorb fluids which could leak.

20. Define closure vs. post-closure.

21. Include improved diagrams of the waste rock pile, as described above in the outline for the Annual ICRP Progress Report.

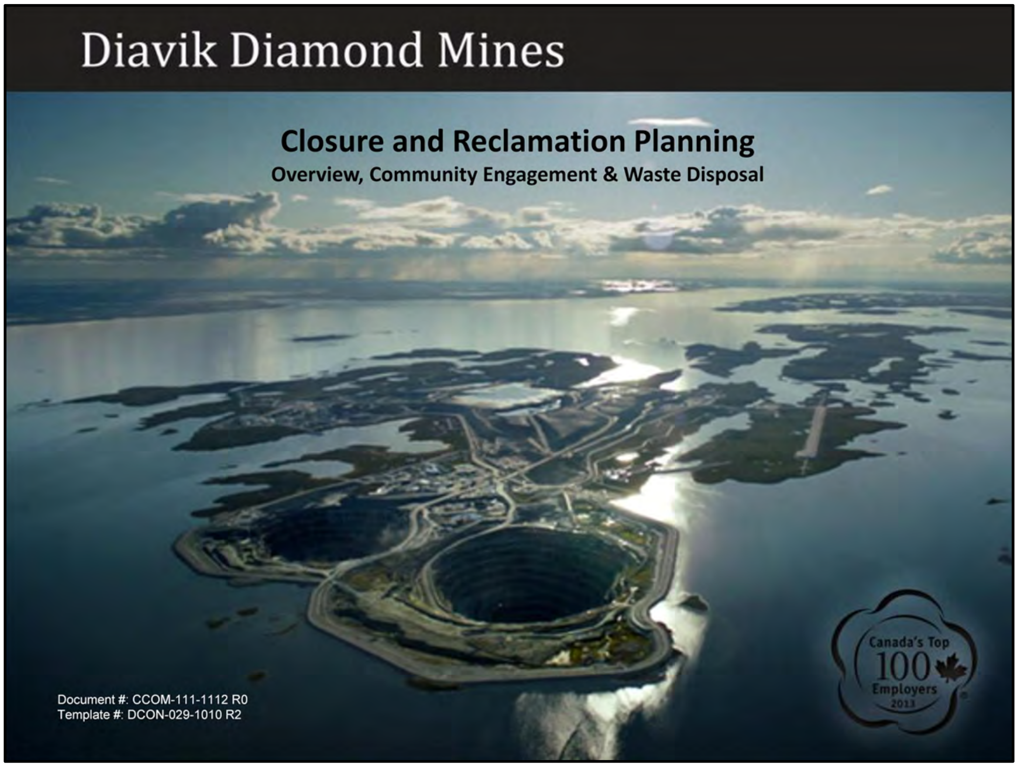
22. Provide detailed and informative figures illustrating the final closure design of each mine component.

23. Provide additional detail about long-term water treatment, including: any required changes to the existing treatment plant; implications on the post-closure requirement for fuel, chemicals, and personnel; maintenance requirements; proposed disposal location for treatment sludge; etc.

24. List all sub-appendices in the table of contents, and include cover pages for all appendices and sub-appendices. Ensure all subsections and appendices are bookmarked correctly in pdf version of the ICRP.

Appendix I-1

Community ICRP Presentation Material

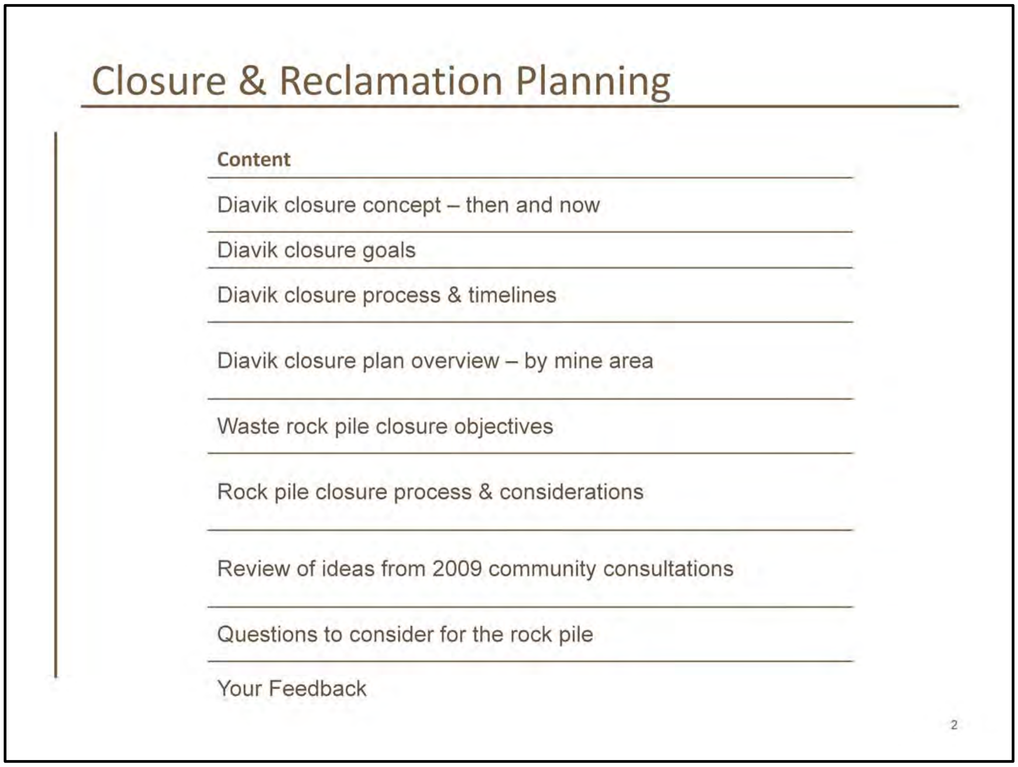


Diavik Diamond Mines

Closure and Reclamation Planning

Overview, Community Engagement & Waste Disposal

Document #: CCOM-111-1112 R0
Template #: DCON-029-1010 R2

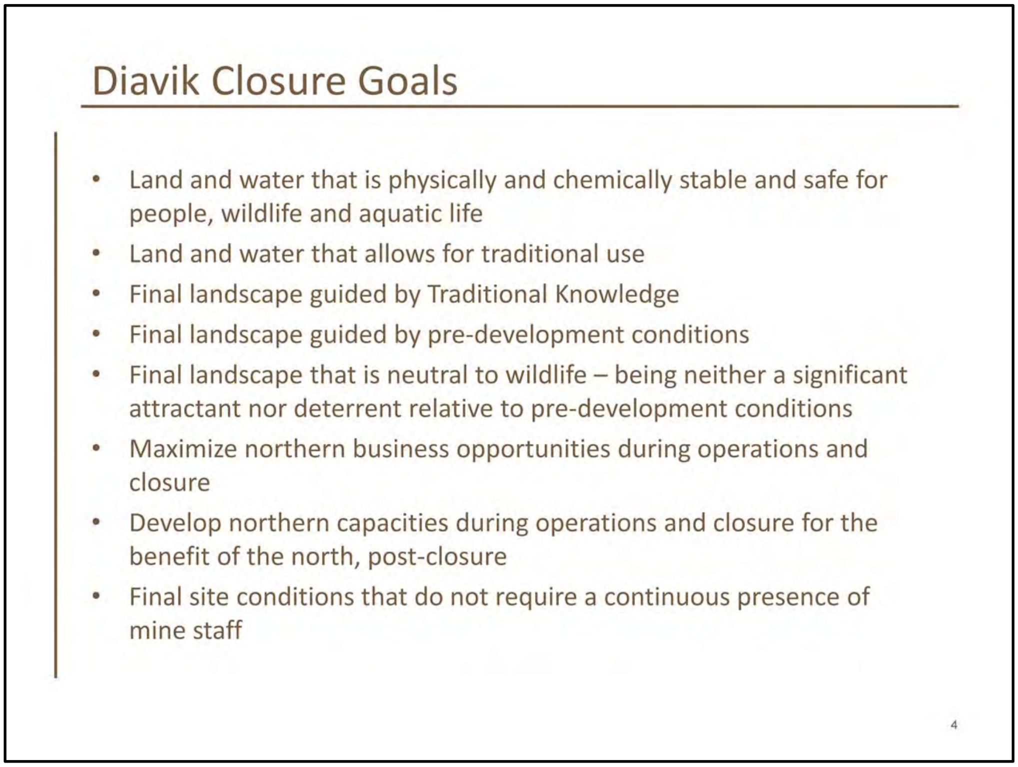


Closure & Reclamation Planning

Content

- Diavik closure concept – then and now
- Diavik closure goals
- Diavik closure process & timelines
- Diavik closure plan overview – by mine area
- Waste rock pile closure objectives
- Rock pile closure process & considerations
- Review of ideas from 2009 community consultations
- Questions to consider for the rock pile
- Your Feedback

1998 Pre-feasibility



Diavik Closure Goals

- Land and water that is physically and chemically stable and safe for people, wildlife and aquatic life
- Land and water that allows for traditional use
- Final landscape guided by Traditional Knowledge
- Final landscape guided by pre-development conditions
- Final landscape that is neutral to wildlife – being neither a significant attractant nor deterrent relative to pre-development conditions
- Maximize northern business opportunities during operations and closure
- Develop northern capacities during operations and closure for the benefit of the north, post-closure
- Final site conditions that do not require a continuous presence of mine staff

Overview of Closure Plans, by area

We have ‘broken’ the site into 5 key areas to consider for closure – click through slide/photo sequence

1. Open pits – need to consider: process for developing fish habitat inside the dike prior to flooding, process & timeline for flooding, process & timeline for re-connecting the pits with the lake
2. North Inlet – do we connect the NI area back with LDG completely, partially or keep separate
3. PKC – method & materials to cap the pond, completely dry vs small pond of water, timing, landscape
4. Rock Pile – waste disposal options, cover material, water drainage, landscape
5. Infrastructure – disposal, salvage, re-vegetation, roads, airstrip, etc

Open pits

Open pits – need to consider: process for developing fish habitat inside the dike prior to flooding, process & timeline for flooding, process & timeline for re-connecting the pits with the lake

North inlet

North Inlet – do we connect the NI area back with LDG completely, partially or keep separate

PKC

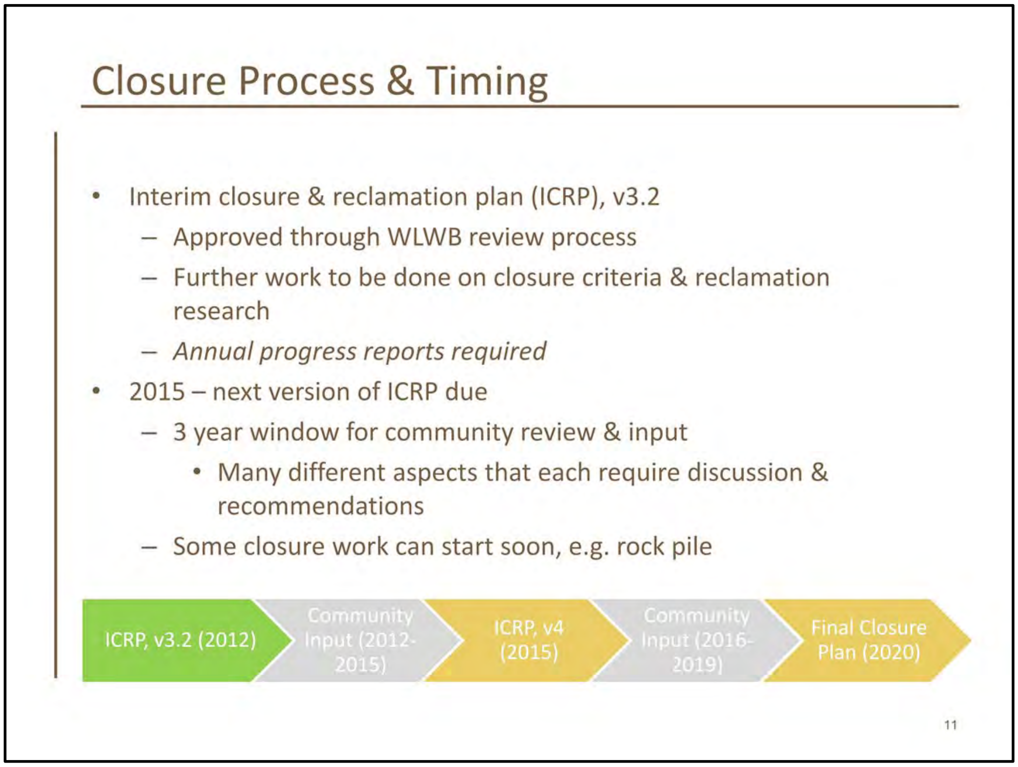
PKC – method & materials to cap the pond, completely dry vs small pond of water, timing, landscape

Rock Pile

Rock Pile – waste disposal options, cover material, water drainage, landscape

Infrastructure

Infrastructure – disposal, salvage, re-vegetation, roads, airstrip, etc

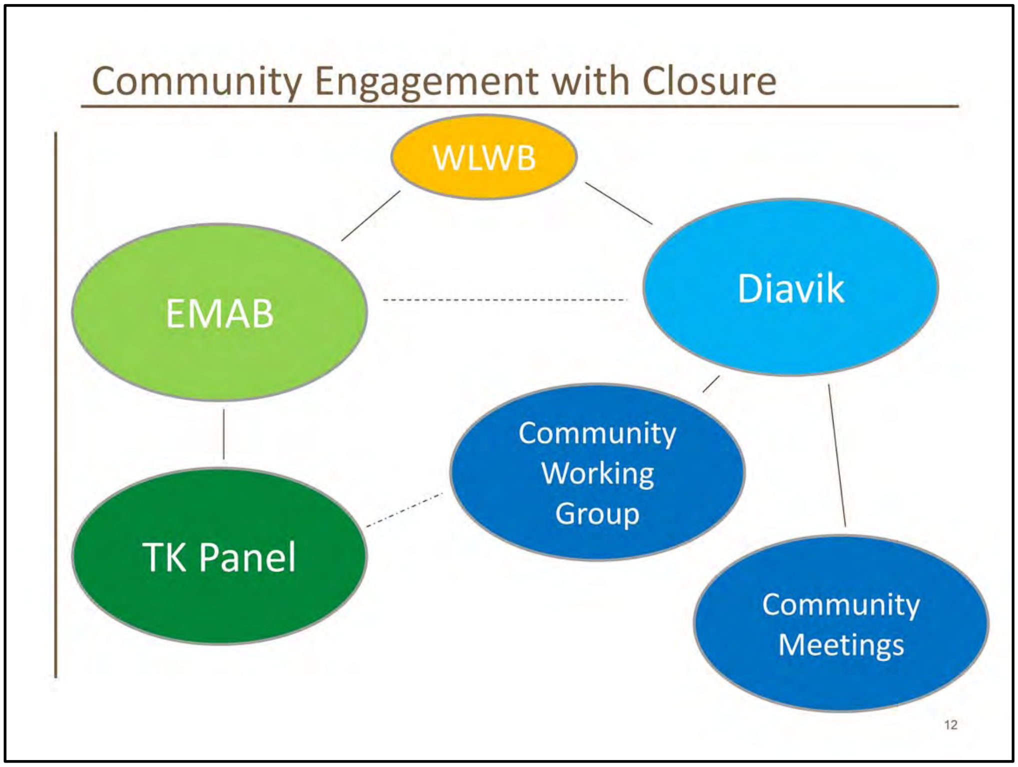


Closure Process & Timing

- Interim closure & reclamation plan (ICRP), v3.2
  - Approved through WLWB review process
  - Further work to be done on closure criteria & reclamation research
  - *Annual progress reports required*
- 2015 – next version of ICRP due
  - 3 year window for community review & input
    - Many different aspects that each require discussion & recommendations
  - Some closure work can start soon, e.g. rock pile

ICRP, v3.2 (2012) → Community Input (2012-2015) → ICRP, v4 (2015) → Community Input (2016-2019) → Final Closure Plan (2020)

Note that annual progress report for 2012 is to be provided in late November/early December. Would like to include results from this meeting.



Community Engagement with Closure

WLWB

EMAB

Diavik

Community Working Group

TK Panel

Community Meetings

WLWB oversees ICRP and is interested in work that is being done with communities by Diavik, as well as work that EMAB is undertaking.

We'd like your input on how best to engage with communities in relation to closure planning, especially over the next few years.

Diavik has considered the following option:

1. Establishment of community working groups – participants selected by the community (or is an existing organization within the community), consulted on various topics of interest (e.g. as identified by WLWB or others), ideally includes their community member from the EMAB TK Panel & someone from the community's Enviro department; **focus of this group is not to conduct TK** – it is for general input on various topics that may be more technical in nature
2. Community Update Meetings - results from working group meetings shared for discussion and input with the greater community.

EMAB has a TK Panel that has identified closure as a key area of focus. For example, they are currently discussing landscape level closure considerations for the rock pile based on TK – wildlife movement, water flow/drainage, slope angle, materials, re-vegetation, etc. The information and recommendations generated by this Panel will be shared with EMAB, Diavik, communities & the WLWB.

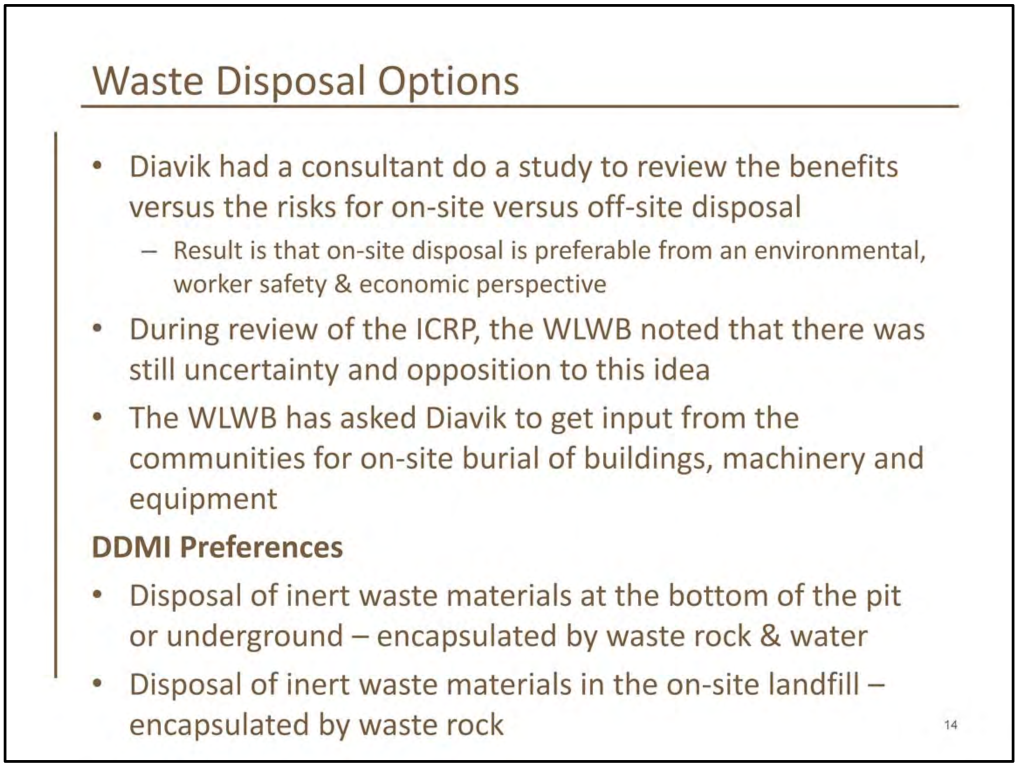
So far, the areas that Diavik has identified for TK input in closure are: fish habitat, re-vegetation areas and methods, wildlife movement, landscape/landform considerations

DISCUSSION – are our proposed engagement ideas appropriate? If so, how would the working group prefer to capture their ideas & recommendations – will they summarize and report back to Diavik? If so, how long need to turn around notes (1 week?) Or prefer Diavik to do and provide back to group for review? If so, how long need for review? Other ideas on how it should work??

Other ideas on areas where TK can best inform the closure plan?

Diavik waste rock pile closure objectives

- Physically stable slopes to limit risk of failure that would impact the safety of people or wildlife
- Rock and till pile features (shape and appearance) that match the look of the surrounding natural area, as much as possible
- Waste disposal areas that cannot contaminate land and water



Waste Disposal Options

- Diavik had a consultant do a study to review the benefits versus the risks for on-site versus off-site disposal
  - Result is that on-site disposal is preferable from an environmental, worker safety & economic perspective
- During review of the ICRP, the WLWB noted that there was still uncertainty and opposition to this idea
- The WLWB has asked Diavik to get input from the communities for on-site burial of buildings, machinery and equipment

DDMI Preferences

- Disposal of inert waste materials at the bottom of the pit or underground – encapsulated by waste rock & water
- Disposal of inert waste materials in the on-site landfill – encapsulated by waste rock

14

Diavik's view is that off-site disposal is not the preferred method from an environmental perspective (below).
Inert materials would include non-salvageable buildings/materials, pipe, equipment (e.g. pumps).
Would not include hazardous materials, wood, paper or food waste
Removal of large, inert items is very costly and can cause further environmental impacts – increased winter road hauls, transferring the problem somewhere else ("not in my backyard"), many will not be re-usable (this is currently being assessed by a demolition expert)
Materials would not be visible, e.g. already one closed landfill from construction within the pile

Closure Plan, v3.2 (excerpt)

On-site versus off-site disposal of unwanted materials and debris from the demolition of mine infrastructure was discussed. Some viewed off-site disposal as preferable because it would remove all materials from site and would result in conditions most similar to pre-development conditions. It is DDMI's view that on-site disposal of materials in most, but not all, cases is the better environmental option.

The Comprehensive Study Report (pg. 111) includes a statement that:

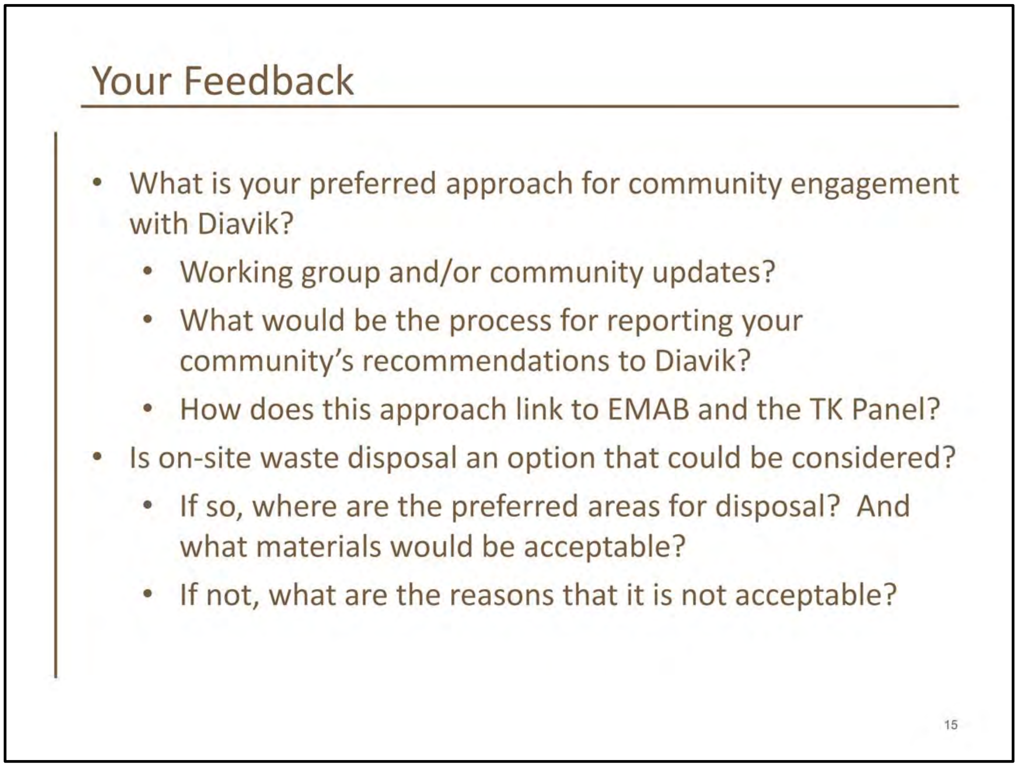
"The approved A&R Plan will not allow burial of buildings, machinery and equipment on the mine site. It will include an estimate of implementation costs at various stages in the life of the mine."

DDMI notes that this statement is not referenced and is not supported by an environmental, technical or legal basis for not allowing burial of buildings, machinery or equipment. In fact, DDMI currently has an approved, active, on-site landfill for disposal of inert materials.

DDMI requested an expert opinion regarding environmental trade-offs between on-site and off-site burial, as suggested by WLWB in their letter of May 19, 2010. This expert opinion is included in Appendix X-4, which includes a preliminary estimate of closure landfill waster volumes, and supports DDMI's view that on-site disposal is generally the better option.

Options that were considered for on-site disposal locations included the PKC, waste rock pile, pit bottom and underground workings. The PKC would be the most limiting location for a post-closure landfill because it would be challenging to cover suitably. Opposition to an in-pit landfill was expressed, and is discussed in Section 5.2.1.3. This opposition seemed to be based on what were expressed as: a) DDMI commitments made in the Comprehensive Study Report; and b) conditions of the DDMI Land Leases. Environmental rationale for why an open-pit landfill location was inferior to a land-based location was not provided. DDMI has decided to not advance an in-pit option at this time. Underground tunnels and an area of the waste rock pile are DDMI preferred options for land fills for closure.

Post-closure reuse of mine site infrastructure both on-site and off-site in communities was discussed in general terms. There was a preference by all participants to maximize the reuse of the infrastructure and materials, with reuse in the North identified as a priority. Plans for on-site and/or off-site reuse will need to be promoted in the years before closure.



Your Feedback

- What is your preferred approach for community engagement with Diavik?
  - Working group and/or community updates?
  - What would be the process for reporting your community's recommendations to Diavik?
  - How does this approach link to EMAB and the TK Panel?
- Is on-site waste disposal an option that could be considered?
  - If so, where are the preferred areas for disposal? And what materials would be acceptable?
  - If not, what are the reasons that it is not acceptable?

Are our proposed engagement ideas appropriate? If so, how would the working group prefer to capture their ideas & recommendations – will they summarize and report back to Diavik? If so, how long need to turn around notes (1 week?) Or prefer Diavik to do and provide back to group for review? If so, how long need for review?
Other ideas on how it should work??
Are there other areas of the closure plan where you think TK could effectively be incorporated?

Overview of Closure Plans, by area

We have 'broken' the site into 5 key areas to consider for closure – click through slide/photo sequence

1. Open pits – need to consider: process for developing fish habitat inside the dike prior to flooding, process & timeline for flooding, process & timeline for re-connecting the pits with the lake
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4. Rock Pile – waste disposal options, cover material, water drainage, landscape
5. Infrastructure – disposal, salvage, re-vegetation, roads, airstrip, etc

Appendix I-2

EMAB TK/IQ Panel Report - Renewing Our Landscape

(note: Distribution of this reports is limited to the WLWB, DDMI and EMAB at the Panel's request)

Appendix II-1

Literature Review of Traditional Ecological Knowledge Related to the Resource Sector

July 19, 2011

LITERATURE REVIEW OF TRADITIONAL ECOLOGICAL KNOWLEDGE RELATED TO THE RESOURCE SECTOR

RECOMMENDATIONS

Submitted to:

Colleen English
Diavik Diamond Mines Inc.
#205, 5007 - 50th Avenue
Yellowknife, NT.
X1A 2P8

REPORT

Report Number: 1013280028-001-R-Rev1

Distribution:

2 Copies - Diavik Diamond Mines Inc.

2 Copies - Golder Associates Ltd.

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TABLES

APPENDICES

1.0 BACKGROUND

Diavik Diamond Mines Inc. (DDMI) requested a desktop study / literature review of Traditional Ecological Knowledge (TEK) / Inuit Qaujimajatuqangit (IQ) sources pertaining to the resource sector / industry, in general and to baseline data, monitoring, and closure planning, in particular. Golder Associates Ltd. (Golder) and Natasha Thorpe Consulting are pleased to provide the following report in response to this request.

2.0 OBJECTIVES

This review set out to demonstrate examples where TEK / IQ has been meaningfully incorporated into the resource sector / industry, with a focus on mineral development and with the overarching goal of assisting DDMI in considering TEK / IQ in current and future operations.

Specifically, the objectives of the review are to explore the following key areas:

- Review of baseline data for the Lac De Gras region (*e.g.*, WKSS studies) or other relevant TEK monitoring results for the region.
- Examples of TEK / IQ monitoring within Canada and the circumpolar Arctic that have successfully been carried out to monitor potential effects from the resource sectors / industry (*e.g.*, monitoring of water, wildlife, fish, etc.).
- Examples of TEK / IQ within Canada and the circumpolar Arctic informing or being incorporated into closure planning initiatives from the resource sector / industry, and any details on what the process was to obtain this input.

3.0 TRADITIONAL ECOLOGICAL KNOWLEDGE EXPLAINED

Throughout the literature, numerous terms are used and misused to describe studies that include or focus on the local knowledge of a population who has lived for multiple generations in a given region. These include TEK, traditional knowledge, indigenous knowledge, indigenous ecological knowledge, local knowledge or knowledge specific to a particular people (*e.g., Inuit Qaujimajatuqangit*). There remains debate and confusion about the most appropriate term to use, even within communities (GNWT 2002). Within the resource development context, most of the focus has been on the environmental elements of the local knowledge. Practitioners and community members need to do a better job at making sure that these less tangible elements of the knowledge system are integrated into resource development (Stevenson 1996; Tester and Irniq 2008). Only when this is achieved should the more inclusive term ‘traditional knowledge’ be used (Usher 2000).

While a nomenclature debate (Johnson 1992; Berkes 1999; Wenzel 1999; Usher 2000) is beyond the scope of this report, it is generally understood that traditional ecological knowledge is “cumulative over generations, empirical in that it must continuously face the test of experience, and dynamic in that it changes in response to socioeconomic, technological, physical or other changes” (Neis and Felt 2000: 3). Berkes puts forth a comparable working definition for TEK as “a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission about the relationship of living beings (including humans) with one another and with their environment” (Berkes 1999: 8). Others provide similar definitions that suggest that this knowledge embodies adaptive and self-management practices through a relationship of respectful reciprocity with the environment (Nakashima 1986; Feit 1988; Gunn et al. 1988; Nakashima 1993; Pinkerton 1994 and 2007; Ferguson et al. 1998; Thorpe 2000; Fox 2002; Thorpe et al. 2002; Tester and Irniq 2008; Gombay 2010).

The Inuit Qaujimajatuqangit Working Group (IQWG) members, for example, have adopted a definition that distinguishes that IQ “refers to the wisdom of Inuit (Elders) rather than what they (Inuit or Elders) know” (Joe Tigalluraq pers. comm. email 2000). In this they have identified that they want to establish that they view IQ equating wisdom as a higher level of knowledge or a special form of expertise. Whereas IQ is understood as ‘traditional knowledge’ the term ‘Inuit Qaujimaningit’ refers to Inuit knowledge without reference to temporality. This latter term encompasses Inuit TK as well as Inuit societal values, Inuit knowledge and more (QIA 2009 in NIRB 2010). Even within IQ, there is debate on the most appropriate term although ‘Inuit Qaujimajatuqangit’ has generally become the standard. In all definitions, there is a clear identification that living on the land and depending on ecological resources for survival, and an iterative approach to “managing” within a group or community local environment is a component of both TEK and IQ.

Building upon the ideas put forth by others, TEK can be understood as an accumulated and evolving body of knowledge that comprises the intergenerational survival skills, beliefs, practices, wisdom and experiences of people who demonstrate an acute awareness of dynamic interactions between people, lands and resources (Thorpe 2000; Thorpe et al. 2001). TEK includes an understanding of ecosystems and relationships between ecological as well as social, cultural, and spiritual values (Thorpe 2000; Thorpe et al. 2001).

3.1 Defining TEK in this Report

For the purpose of this review, the term "traditional ecological knowledge" or "TEK" will be used as the majority of the knowledge contributed by First Nations, Inuit and Métis peoples in the context of resource developments such as mining has to do with the environment, ecosystem or land use rather than the socio-cultural or spiritual elements.

3.2 Defining "Meaningful" Inclusion of TEK into Resource Development

Criteria to evaluate the effectiveness of how TEK has been incorporated into resource development should be established such that an assessment could be carried out. The goal of this review was to identify where TEK has been incorporated into resource development rather than to assess whether this was done in a *meaningful* way; however, to make recommendations useful to DDMI requires some level of assessment of 'meaningful' in this context.

In order for TEK to be incorporated in a meaningful way, it is assumed in this report that there are clear causative links made between TEK and specific operations, procedures, practices or other mining activities, for example, as documented in an EIS. This might be when an Elder discusses the importance of a particular caribou migration route and so the siting of a proposed road is altered or the knowledge of traditional indicators of 'safe ice' is communicated to mining employees such that this factors into corporate health and safety policy and guides employee decision-making as to whether travel on sea ice is safe. While it is clear that TEK has been included in the EIS process, it is not always clear exactly how this information influenced operations. In order to be included in a meaningful way, these links need to be communicated.

The best way to evaluate whether inclusion of TEK was 'meaningful' would be to ask communities involved in the EIS process whether they felt that their contributions influenced a particular aspect of a proposed or operating resource development. This level of assessment is beyond the scope of this review, but it would get at the root of the matter and provide insight into how TEK / IQ may be incorporated into future EIS processes.

To be fair, it is not always clear to proponents how exactly to incorporate TEK / IQ. For example, NIRB (2009: 7) instructs proponents to:

> incorporate into the EIS the TK to which it has access or that it may reasonably be expected to acquire through appropriate due diligence, in keeping with appropriate ethical standards and without breaching obligations of confidentiality.

NIRB elaborates on the nature of the information that should be collected and/or reviewed in their EIS Guidelines for the Mary River Project (NIRB 2009: 55):

> Presentation of available published information and/or information resulting from community IQ studies regarding identified VECs, including: the relative seasonal and annual trends in abundance and distributions; the estimated productive capacity; migratory patterns and associated corridors/routes; critical habitat on or in proximity of shipping routes; and sensitive periods.

Proponents, agencies, governments, communities and community organizations alike continue to struggle with exactly how TEK / IQ can and should be incorporated into the environmental assessment process and how this can be done in a meaningful way while at the same time great strides have been made, particularly in the last decade.

In the absence of a truly replicable method of determining “meaningful” inclusion of TEK into a development based operation we have continued to use a qualitative and subjective approach. A TEK study was deemed to have had a meaningful contribution if it was readily apparent in the report / manuscript where TEK had a causative link to a decision and was not just listed as supporting information. This could include instances where the TEK was seen to influence an operational procedure or had been given equal weight as western scientific data in the decision making process of an EIS or similar study.

4.0 METHODS

The project was carried out in two phases: literature review; and database, recommendations and reporting.

4.1 Phase One: Literature Review

A review was carried out of online and readily available literature with a focus on baseline, monitoring and closure in the resource sector / industry. The general geographic focus of the review was Canada and the circumpolar Arctic. The review was not intended to be global; however, as few examples were available in the circumpolar region, a cursory search of other regions where TEK studies are routinely completed (*e.g.,* Australia) was carried out.

The review focus was on readily available and published literature available through internet searches and phone / email contact for less available and unpublished (grey) literature. Most efforts centred on published literature, but as many TEK reports remain unpublished, in part due to confidentiality and intellectual property rights concerns, multiple phone and email contacts with industry officials and TEK practitioners were made. Further, reviewing hundreds of pages of consultant reports prepared for environmental impact assessments was onerous so receiving direction from industry officials on where to focus was valuable.

This literature review centred on readily available online publication databases and resources (*e.g.*, Mackenzie Valley Review Board (MVRB) website, Arctic Institute of North America, Government of the Northwest Territories, Government of Nunavut, Canadian Environmental Assessment Agency registry, ArcticNet, Aurora Research Institute, Nunavut Research Institute, Inuit Heritage Trust, Prince of Wales Northern Heritage Centre, Gwich'in Social and Cultural Institute, Dene Research Institute, Alaska Native Knowledge Network, Canadian Arctic Resources Committee, World Wildlife Federation, Canadian Polar Commission, Agreements, Treaties and Negotiated Settlements Project, and Indigenous Studies Portal), academic holdings (*e.g.*, Canadian Periodicals, Ecology and Society Journal, Environment Journal, Arctic Journal, Canadian Mining Journal) library holdings (*e.g.*, Inuvialuit Cultural Resource Centre) and academic search engines (*e.g.*, JSTOR, Canadian periodicals, Epscohost, Springerlink). Frequently the bibliographies of relevant documents served as key resources to locate additional sources using a version of the 'snowball technique' (Neis and Felt 2000). In addition, a series of keywords and keyword combinations were entered into an online search engine (Google®) to try to uncover relevant references.

Keywords and combinations used in this search included the following:

- Traditional ecological knowledge;
- Traditional ecological knowledge and mining;
- Traditional ecological knowledge and development;
- Traditional Knowledge Incorporate;
- Aboriginal Knowledge Mining;
- Lac de Gras Traditional Ecological Knowledge;

- Traditional Knowledge;
- Traditional knowledge resource sector;
- Traditional knowledge industry;
- Traditional knowledge monitoring;
- Traditional knowledge mine closure;
- Traditional knowledge plan;
- Traditional knowledge recommendations incorporate;
- Inuit Qaujimajatuqangit;
- IQ;
- Aboriginal knowledge mining Australia;
- Traditional knowledge mining Australia;
- Arctic traditional knowledge;
- Northern knowledge;
- Yukon traditional knowledge;
- Northwest Territories traditional knowledge;
- Nunavut traditional knowledge;
- Alaska traditional knowledge;
- West Kitikmeot Slave Study; and,
- Northwest Territories Traditional Knowledge Publications.

Table 1 contains a list of websites used in the online reference search.

Table 1: List of Online Website Search

Websites
ASRC Western Arctic Coal Turning Challenges Into Opportunities (http://www.bhpbilliton.com/bbContentRepository/wacNewsletterDec06.pdf)
Aboriginal Enterprises in Mining, Exploration and Energy Ltd. (www.aemee.com)
Agreements, Treaties, and Negotiated Settlements Project (www.atns.net.au)
Alaska Native Knowledge Network (www.ankn.uaf.edu)
Alaska Native Science Commission (www.nativescience.org))
Arctic Institute of North America (www.arctic.ucalgary.ca)
Arctic Research Consortium of the US (www.arcus.org)
Aurora Research Institute (www.nwtresearch.com)
Association for Mineral Exploration British Columbia (www.amebc.com)
Akaitcho Treaty 8 Tribal Corporation (www.akaitcho.info/the_akaitcho_treaty_8_tribal_corporation_006.htm)
British Columbia Technical and Research Committee on Reclamation (www.trcr.bc.ca/index.htm)
Canadian Arctic Resources Committee (www.carc.org)
Canadian Environmental Assessment Agency (www.ceaa-acee.gc.ca)
Canadian Mining Journal (www.canadianminingjournal.com)
Canadian Periodicals Quarterly (find.galegroup.com.ezproxy.library.uvic.ca/gtx/start.do?prodId=CPI&userGroupName=uvictoriacpi)
Canadian Research Knowledge Network (www.crkn.ca/)
The Changing Arctic: Indigenous Perspectives (http://www.acia.uaf.edu/PDFs/ACIA_Science_Chapters_Final/ACIA_Ch03_Final.pdf)
The CircumArctic Rangifer Monitoring and Assessment Network (www.carmanetwork.com/display/public/home)
Collaborative Integrated Management in Canada's North: The Role of Local and Traditional Knowledge and Community-Based Monitoring (http://www.ingentaconnect.com/content/tandf/ucmg/2007/00000035/00000001/art00008)
Cumulative Environmental Management Association (www.cemaonline.ca)
Dene Cultural Institute (www.deneculture.org/)
Diavik Mine (www.diavik.ca)
Ecology and Society (http://www.ecologyandsociety.org/)
Ecological Society of America (www.esajournals.org.ezproxy.library.uvic.ca/)

Websites

Environmental Studies Research Funds Publications (www.esrfunds.org/)

Exchange for Local Observations and Change of the Arctic (www.inuitknowledge.ca) (http://www.eloka-arctic.org)

Ebscohost Academic Search complete (www.ebscohost.com/)

First Nations Land Rights and Environmentalism in British Columbia - Mining (www.firstnations.de/mining.htm)

Gwich'in Social & Cultural Institute (www.gwichin.ca)

Government of Northwest Territories (www.gov.nt.ca)

Google (www.google.ca)

Google Books (books.google.ca/)

Google Scholar (scholar.google.ca/)

Government of Yukon Libraries (virtua.gov.yk.ca:8080/)

Government of Northwest Territories, Environment and Natural Resources (www.enr.gov.nt.ca/_live/pages/wpPages/Our_wildlife_Publications.aspx)

Hearing the Elders (www.trailheadconsulting.ca/pubs/J.%20Prno%20(2009)%20-20'Hearing%20the%20Elders'.pdf)

Incorporating traditional knowledge in the Arctic (http://www.eoearth.org/article/Incorporating_traditional_knowledge_in_the_Arctic?topic=49527)

Indian and Northern Affairs Canada (www.ainc-inac.gc.ca)

Indigenous Knowledge and Development Monitor (www.iss.nl/ikdm/ikdm/ikdm/index.html)

International Institute for Sustainable Development (www.iisd.org/)

JSTOR (www.jstor.org)

Lore: Capturing traditional environmental Knowledge (http://books.google.ca/books?hl=en&lr=&id=Oeuiv0DyFQcC&oi=fnd&pg=PA1&dq=traditional+knowledge+arctic+mining&ots=O0TFUdz-Z4&sig=UBuXxX8Wja2CHWYBUU7ODT8qdrA#v=onepage&q&f=false)

Mackenzie Valley Environmental Review Board (www.reviewboard.ca)

Native Americans and the Environment (www.cnie.orgl)

Native Journal (www.nativejournal.com)

Northwest Territories Cumulative Impact Monitoring Program (www.nwtcimp.ca/index.asp)

Nunavut Impact Review Board (www.nirb.ca)

Nunavut Mining Symposium (http://www.nunavutminingsymposium.ca/category/presentations/)

Nunavut Research Institute (www.nri.ca)

Natural Resources Canada (www.nrcan.gc.ca)

Websites
Northern Gas Project Secretariat (www.ngps.nt.ca/)
Parkland Institute (parklandinstitute.ca/)
Park Science: Integrating Research and Resource Management in the National Parks (www.nature.nps.gov/parkscience/)
The Politics of TEK: Power and the "Integration" of Knowledge (http://www.jstor.org/pss/40316502)
Proquest (http://www.proquest.com)
Red Dog Mine (www.reddogalaska.com)
The Scott Polar Research Institute (www.spri.cam.ac.uk)
Springerlink (www.springerlink.com)
Taiga Net Data Server (yukon.taiga.net/)
Tłîchô Government (www.Tłîchô.ca/)
Traditional Ecological Knowledge: Concepts and Cases (http://books.google.ca/books?id=J2CNS64AFvsC&pg=PA50&lpg=PA50&dq=traditional+knowledge+resource+development+inuvialuit&source=bl&ots=KzefFltoFn&sig=MnuhTHJjl-861N5TgeY_-A0Z6kg&hl=en#v=onepage&q=traditional%20knowledge%20resource%20development%20inuvialuit&f=false)
Traditional Ecological Knowledge in the Kache Tue Study Region (http://www.assembly.gov.nt.ca/Library/ArchiveEdocs/2001/WKSS/a261929.pdf)
Traditional Knowledge Annual Report (http://www.gov.nt.ca/research/publications/pdfs/TK_Annual_Report.pdf)
University of Victoria Library Electronic Journals Master Search (uvic.summon.serialssolutions.com.ezproxy.library.uvic.ca)
University of Manitoba (http://umanitoba.ca/institutes/)
West Kitikmeot Slave Study Society Projects and Reports (www.enr.gov.nt.ca/_live/pages/wpPages/West_Kitikmeot_Slave_Study.aspx)
Wiley Online Library (onlinelibrary.wiley.com)
World Bank (siteresources.worldbank.org)
World Wildlife Fund (www.worldwildlife.org/what/wherewework/arctic/index.html)

Phone / email contact was made with northern TEK / IQ experts as well as representatives from mining companies, government agencies, organizations, First Nation, Inuit and Métis organizations, as presented in Table 2. In addition, efforts were made to contact researchers as well as several individuals who had participated in the West Kitikmeot Slave Study (WKSS). Most contacts were made with key Canadian experts although individuals in Australia, Finland and the USA were also reached.

Table 2: List of Contacts

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Through the online search and follow-up work from conversations with experts, the review can be considered comprehensive, although not exhaustive given the very nature of carrying out a literature review and the sheer number of sources available on a global scale. Instead, the review intended to capture the key TEK references pertaining to the resource sector / industry with the goal of providing examples of where TEK had been incorporated into baseline data, monitoring, and closure planning.

4.2 Phase Two: Database, Recommendations and Reporting

As references were identified through either the online search or key experts, they were added to bibliographic information system software called EndNote®. While the ProCite® software was first identified as the 'software of choice', it soon became clear that EndNote® was superior particularly given the compatibility with MS Word and several other tools including the search tool, export function and ease of use. After consult with DDMI, EndNote® was then selected for the database.

Each reference was entered into the database with relevant information cited (*e.g.*, author, date, title, source, page, weblink (URL), volume, issue, abstract) depending on the type of document (*e.g.,* government report, journal article, book, thesis). Where provided and due to constraints in time, abstracts were copied directly from references into the annotation field of the database. Annotations and comments were also included where relevant. Hotlinks were generated so that the actual reference can be pulled up directly from the database: where available, a digital copy of each reference was saved along with a hotlink so that DDMI will have ready access to the references in the future. Further, DDMI will have the ability to continue to add to this database.

Depending on the subject of the reference, the following keyword(s) were assigned:

- **Science** – Reference provides examples of where TEK and western science have been integrated or discusses the inherent benefits and/or challenges existing in combining these two knowledge systems.
- **Baseline** – Reference is relevant to baseline information collected in and around the Diavik Diamond Mine.
- **Monitoring** – Reference pertains to a type of environmental monitoring practice where TEK was incorporated.
- **Closure** – Reference discusses closure or reclamation events or planning which integrated TEK.
- **Recommendations** – Reference informs the recommendations provided in the review or itself is a list of recommendations that pertain to TEK and/or the resource sector.
- **Other** – Reference is a valuable resource or key document in the body of literature pertaining to TEK, cross-cultural relations and/or mining. TEK guidelines and protocols are also included in this category.

Once the database was complete, this report was prepared which included carrying out a literature review, evaluating the process of integrating TEK into mining operations and providing recommendations applicable to current and future TEK programs at the DDMI mine.

5.0 RESULTS

The literature review and resulting database contain 157 references that discuss TEK in the context of mining, operations, baseline and closure as well as the interplay between TEK and western scientific approaches. Guidelines, protocols and procedures for carrying out TEK work are also included.

A discussion of key literature follows in Section 6.0 and recommendations for how DDMI may consider TEK in future operations are presented in Section 7.0.

5.1 Phase One: Literature Review

An internet search of online academic libraries, key northern institutes as well as government sites yielded over 130 references. A total of 26 search words were used in 59 sites that were visited.

Key TEK practitioners, agencies and governments were contacted to ask whether individuals were aware of examples where TEK had been integrated into resource development projects. Attempts were made to contact a total of 28 individuals, with 20 successful contacts made via phone and/or email (Table 2). Discussions with key individuals helped narrow the focus of the search to specific examples, mines, websites, and/or processes. In general, these discussions were fruitful and yielded more than 30 applicable references.

No unpublished sources were identified either through the online search or through contacts. A total of 14 TEK practitioners and 8 individuals who are employed in mining / resource sector positions that interact with components relating to TEK were engaged in telephone interviews relating to the incorporation of TEK into project planning and operations. The TEK practitioners and/or resource experts contacted unanimously agreed that there were few examples of TEK being truly integrated into a mining or resource sector.

As described in the methods section, a semi-directive interview technique (Huntington 2000) was employed during phone conversations that supplement the literature review component of this project. A formal questionnaire was not employed during these phone interviews. To encourage an open dialogue, the promise was made not to attach a specific statement to a particular individual. Some key comments provided by individuals were as follows:

- TEK does not easily ‘fit’ into the western scientific format of a typical EIS or EIA. I would argue that it is not appropriate to even try.
- There is just so little information out there: this is a new field.
- That [TEK integrated into mining operations] is just such a big gap in the literature.
- In all of Alaska, I can think of just one company doing this [integrating TEK] well.
- Too often - almost always - TEK is a sub-chapter or separate appendix in an EIS: we hope this changes with our new guidelines.
- I haven’t seen any examples [of mining companies integrating TEK] myself; I am not surprised you can’t find much.

- One challenge that we are facing is how to incorporate IQ into our own organization. How can we expect companies to integrate IQ if we are not doing it well ourselves.
- It is like pulling teeth to find out how it [TEK] is applied [in mining operations].
- [My company] has been funding capacity building and TEK initiatives that are more meaningful to people as they are led by communities.
- Funding TEK studies is part of the social licence to operate.
- The socio-cultural dimension of TEK must be dealt with. If mining companies do incorporate TEK, it is only the environmental information and not the less tangible elements. People need help in a “re-relationship with place” as places and spaces become more fractional.
- There is the mechanical reclamation, but what about the social-spiritual reclamation as part of integrating TEK into mining operations?
- Communities want more meaningful processes. If a company wants to “do TEK”, what does it look like for them? Likewise, what does it look like for the communities?
- How can TEK inform just one element or one question of resource development? Of bigger importance is the underlying process of [community] engagement.
- We found that a TEK Advisory Group with representation from each group was very useful in providing continuous pressure on the process and on technical consultants.
- How to integrate TEK into reclamation has to be thought of early, even during baseline.
- There must be a regulatory and community push [to meaningfully incorporate TEK].
- The best idea is to put mining and industry people into the bush or out on the land on community terms: make them as uncomfortable as we are in boardrooms to help them understand.
- When [the company] listened to elders about the required depth of soil and where the best soil was found, they saw better success [in reclamation].
- It is interesting that the mines [in Canada] are struggling [to integrate TEK] as there were very innovative elements to the agreement making and environmental side of things in the early days. When I was last there, however, it did seem that elements of 'the relationship' between the communities and the companies were fading and becoming confused in many ways.

The above sampling of insights provided by those working in the fields where TEK and the resource sector overlap illuminates some of the challenges, issues and recommendations surrounding the integration of TEK into mining operations as discussed in Sections 6.0 and 7.0.

5.1 Phase Two: Database, Recommendations and Reporting

A first draft of the database was provided to DDMI which was followed by a phone meeting to discuss the overall format. As a result of this meeting, it was decided that the review would present the references by keyword and include these as appendices even though some references had more than one keyword ascribed and so would present in more than one appendix.

The final version of the database and references and a first draft of the annotated bibliography (as appendices to the current report) were provided to DDMI on a USB flash drive (memory stick). Large, unavailable or copyright protected materials (*e.g.,* books) were not delivered in digital format although links to where to purchase such sources were presented where possible. A draft version of this report was submitted shortly thereafter.

Database Results

A total of 160 references were reviewed and entered into the EndNote® database. As each reference was identified through either the online search or contact with experts, the source was assigned one or more keyword: baseline, monitoring, closure, recommendations, science or other. Overlap between keywords was common.

Once the database was finalized, six separate exports to MS Word from the database were made according to each of these keywords. (Note that in future exports, one can command the software to export in almost any referencing format.) These exported documents form the Appendices of this report (Appendix A-F). The number of sources for each keyword (and thus contained in each Appendix) is as follows: science (50), baseline (34), monitoring (34), closure (19), recommendations (60), and other (80).

While all references fell into a minimum of one category, some documents could have spanned all keyword categories and should be considered critical references for consideration by DDMI. Although some of these references did not focus on mining directly, they contain important lessons applicable to the broader mining context. These sources include:

- **Rescan (2007)** outlines various ways in which TEK was applied to the Caribou and Roads Project carried out by BHP Billiton as well as the *Wildlife Effects Monitoring Program* **(Rescan 2011)** at the EKATI Diamond mine in the Northwest Territories.
- **Briggs (2005)** in his paper *The Use of Indigenous Knowledge in Development: Problems and Challenges* provides a broad basis for understanding some of the key issues surrounding the integration of TEK.
- **Deleon and Ventriss (2010)** evaluate a mine development in Botswana and the Diavik Diamond Mine in terms of the challenges to participatory strategies in addressing power differentials, decision-making and information sharing in *Diamonds, Land Use and Indigenous Peoples: The Dilemmas of Public Participation and Multi-National Diamond Corporations.* Issues raised in this paper are applicable to all areas of community engagement and, by extension, incorporating TEK into operations.
- **Doohan (2008)** in her book *Making Things Come Good* provides a detailed account of Aboriginal participation in the Argyle Diamond Mine operated by RioTinto in Australia. This mine provides a key example on how to integrate TEK into mining operations, build social capital and integrate local perspective into mining practices and procedures.

- **Ellis (2005)** covers both top-down and bottom up ways of considering TEK in resource development in the NWT in his paper *Meaningful Consideration? A Review of Traditional Knowledge in Environmental Decision Making*.
- **Emery (2000)** has developed an impressive report containing important guidelines and best practices on how to involve indigenous peoples and their knowledge in projects entitled *Integrating Indigenous Knowledge in Project Planning and Implementation*. The guidelines were reviewed by hundreds of individuals from around the world and so contain a diversity of knowledge and prescriptions. Although this is written primarily for international development projects (*e.g.,* operated by CIDA), the guidelines are large applicable to the mineral industry.
- **Eisner et al. (2009)** articulate clear examples of how local observations of landscape change are being integrated with western science, particularly through satellite imagery and GIS in their paper *Advancing Landscape Change Research through the Incorporation of Iñupiaq Knowledge.*
- **Fedirchuk et al. (2008)** provide a comprehensive guide to integrating TK into impact assessments in their publication entitled *Traditional Knowledge Guide for the Inuvialuit Settlement Region Volume II: Using Traditional Knowledge in Impact Assessments*. This document includes guiding principles of TEK research and protocols around collecting, applying and reporting TEK. Particularly relevant for DDMI at this point may be the section on applying TEK (Chapter 4).
- **GNWT (2005)** *Summary of Best Practices for Applying Traditional Knowledge in Government of the Northwest Territories Programming and Services; Guidelines for Incorporating Traditional Knowledge in Environmental Impact Assessment* prepared by MVRB (2005); and *Living Proof: The Essential Guidebook for Indigenous Use-And-Occupancy Map Surveys* by Tobias (2010) all provide how-to advice from data collection to the application of TEK in various state, research and resource contexts particularly in the North.
- **GNWT and INAC (2010)** in the publication entitled *Northern Voices, Northern Waters, NWT Water Stewardship Strategy* list keys to success in partnerships and community engagement and articulate a commitment to a more holistic understanding, particularly in the context of monitoring and research programs.
- **Johnson (1992)** in her book called *LORE: Capturing Traditional Environmental Knowledge* and Berkes (1999) in his publication *Sacred Ecology* (reprint and expanded edition published in 2008) are good general references for understanding the many complexities and dimensions of TEK.
- **Kavik-AXYS and FMA Heritage Resources (2005)** carried out a literature review of TEK sources in *Traditional Knowledge Manual Volume I: Literature Review and Evaluation* which provides an excellent overview of TEK literature. The current report attempted to build upon this reference rather than repeat the information contained therein.
- *The Mary River Project EIS* proposed in Nunavut by Baffinland Iron Mines Corporation **(Knight Piésold 2010)** discusses the *Mary River Inuit Knowledge Study* and how it was integrated into the EIS.
- **Stevenson (1996)** in his paper *Indigenous Knowledge in Environmental Assessment* outlines the factors that have limited the incorporation of TEK into resource development in the Lac De Gras area.

- The *Final EIS for the Red Dog Mine* **(Tetra Teck 2010)** in Alaska, operated by Teck Resources, provides an excellent account of subsistence use over time related to the development of the mine. In addition, there are a few examples that directly link how local knowledge relates to a particular mine practice.

Science

The keyword ‘science’ was applied broadly to 50 references that discussed the interplay between TEK and western science as this is an area of key interest articulated by DDMI (Appendix A). The Appendix is presented first as it provides context to the consideration of all other categories, namely, baseline, monitoring, closure, recommendations and other.

References in the science category spoke to TEK and western science in general (Agrawal 1995; Abele 1997; Johnson 1992; Berkes 1993 and 1999; Nadasdy 1999; Huntington 2000; Mazzocchi 2008; Briggs 2005) as well as in management, capacity-building, training, formal education and language (Walters and Holling 1990; Battiste 1998; Berkes 1999; Tobias 2000; Kimmerer 2002); the politics, colonization, appropriation and power-struggle surrounding TEK (Abele 1997; Battiste and Henderson 2000; Deleon and Ventriss 2010); environmental processes, resource development and management (Johnson 1988; Stevenson 1996; Berkes 1999; Usher 2000; Thorpe et al. 2001 and 2002; Casimirri 2003; Ellis 2005; Parlee 2006); wildlife (Gunn et al. 1988; Cluff 2005; Thorpe 2000; Thorpe et al. 2001a and 2001b) and fish (Knopp 2010) management as well as co-management (Moller et al. 2004; White 2009; Pinkerton 2007); hydrology and (Tamuno 2009); GIS and remote sensing (Eisner et al. 2009; Kumpula et al. 2010) and community-based monitoring (Armitage et al. 2007; Berkes 2007) settings.

Innovative and appropriate ways to communicate projects integrating TEK and western science are also explored (Bonny and Berkes 2008). Finally, Emery (2000), Fedirchuk et al. (2008), NIRB (2002; 2004 and 2009) offers guidelines on how to integrate TEK and western science. As mentioned, the list of references above cannot be considered exhaustive as the body of literature surrounding TEK is both deep and broad.

Baseline

References in the baseline category are those 34 sources directly associated with TEK as it relates to the baseline data collection process for resource development projects (Appendix B). These ranged from projects and reports carried out as part of the West Kitikmeot Slave Study (Thorpe 1997; Cluff 2005; Dogrib Treaty 11 Council 2002; Łutsel K’e Dene First Nation 2001; Legat et al. 2001; Thorpe et al. 2001; Saxon et al. 2002; SENES 2008) to traditional knowledge reports submitted as part of or related to the environmental assessment process (Berger 1977; BHP 1996; Dene Cultural Institute 1995 and 1996; CEAA 1999; Tetra Teck 2009; Golder Associates 2010; Knight Piésold 2010) to academic prescriptions for how to include TEK to carry out baseline work (Johnson 1992; Berkes 1993 and 2007; Golder Associates 2002 and 2003; Kendrick et al. 2003; Fedirchuk et al. 2008; McIntosh 2008; GNWT 2010). Efforts to review documents directly linked to the Diavik Diamond Mine were minimal given the assumption that DDMI is already familiar with this work.

Monitoring

The category of monitoring contained 34 references covering the development of indicators for community wellness monitoring and community-based monitoring, as outlined in Appendix C (Łutsel K'e Dene First Nation and Parlee 1997; Parlee et al. 1998; Lutsel Ke Dene First Nation et al. 2001; Łutsel K'e Dene First Nation 1999; Łutsel K'e Dene First Nation and Wildlife, Lands and Environmental Department 2003 and 2005; Noble and Birk 2011);

Other references were relevant to wildlife monitoring (Łutsel K'e Dene First Nation 1999; Łutsel K'e Dene First Nation and Wildlife, Lands and Environmental Department 2002; Kendrick et al. 2003; Parlee et al. 2005) and environmental change (Huntington 2000; Łutsel K'e Dene First Nation and Wildlife Lands and Environment Department 2002; Berkes 2007; Eisner et al. 2009; Kumpala 2010). TEK is also valuable as a ground-truthing tool in the context of monitoring (Reid et al. 1998; Huntington 2000; Riedlinger and Berkes 2001; Kendrick et al. 2003; Eisner et al. 2009; Kumpala et al. 2010).

The application of TEK in identifying valued ecosystem components (VECs) and valued social-ecosystem components (VSECs) were included (Golder Associates 2003; Devon Canada Corporation 2004). Fedirchuk et al. (2008) discuss a project in the oil sands where scientific analysis did not identify caribou as a VEC whereas through TEK interviews, caribou were identified as the 'most important' wildlife species.

Finally, several more general references on TEK contain information applicable to the design and implementation of monitoring programs (Berkes 1993; Parlee 1998; Johnson 1992; Ross 2004; Kavik-AXYS and FMA Heritage Resources 2005; MVRB 2005; Terra Firma and Gartner Lee 2005; Fedirchuk et al. 2008; NIRB 2009; Kumpala et al. 2010; Pearse 2010).

Closure

There were 19 references as listed in Appendix D that fell into the closure category, most of which focus on three key examples of applying TEK: using cultural keystone species in reclamation (Garibaldi et al. 2006; Garibaldi and Straker 2009); collaborative planning and decision-making (Pearse 2010); and turning mining pits into an aquaculture project (Wilson-Clark and Tran 2010). One source, written by Chief Nolan of the Missanabee Cree First Nation, discusses the role of Aboriginal communities in risk assessment related to mine closure (Nolan 2009). Another source provides observations and recommendations from a workshop on mine reclamation and closure (Terra Firma and Gartner Lee 2005) while how to integrate TEK into reclamation and closure is discussed in INAC (2007) and Fedirchuk et al. (2008) and with particular attention to wildlife in CEMA (2006).

Several reports from an environmental assessment process also contain information applicable to including TEK into closure planning (ABR 2000; NIRB 2009; Tetra Teck 2009; Knight Piésold 2010; Access Consulting Group 2011). The role of TEK in regulatory regimes is elaborated in SENES (2005). Three sources discussed the use of TEK in risk analysis, particularly as it relates to the precautionary principle and Bayesian statistics (Tacher and Golicher 2004; Liedloff et al. 2009; Drew and Perera 2011).

Recommendations

The majority of the sources (60) fell under the recommendations category (Appendix E). TEK projects, as a whole, often make recommendations within their reports. These often include recommendations for further work, how to incorporate the TEK into a broader study or how the TEK may be used by community members on future projects. It may be worth consideration to have sections of recommendations or different appendices of recommendation types if the database grows much larger.

Several references that contribute to recommendations speak to the overall value and utility of TEK as well as ways to integrate TEK and western science (Abele 1997; Battiste 1998; Battiste and Henderson 2000; Thorpe 2000; Thorpe et al. 2001; Riedlinger and Berkes 2001; Kimmerer 2002; Briggs 2005; SENES 2005) and the importance of validating TEK and TEK holders (Abele 1997; Davis and Wagner 2003; MVRB 2005; GNWT 2007).

Some recommendations relate to the challenges of power-sharing (Wismer 1996; Nadasdy 1999; Crawley and Sinclair 2003; Briggs 2005; Gibson 2008; Tester and Irniq 2008; Deleon and Ventriss 2010) and the link between TEK, Aboriginal engagement and participation in mining (INAC and Sub-committee of the Intergovernmental Working Group on the Mineral Industry 1997; INAC 2007; GNWT n.d.).

Recommendations related to community-based monitoring were largely drawn from the work of the Łutsel K’e Dene First Nation as part of the WKSS (Parlee and Łutsel K’e Dene First Nation 1998; Berkes 2007). Recommendations on how to integrate TEK in monitoring in general are provided in two sources (Ross 2004; Noble and Birk 2011) and the challenges encountered in monitoring programs are also noted (Ross 2004; Rescan 2007). One source illustrates the combined use of TEK and western science (Knopp 2010), while a few relate to VECs, VSECs or ‘significance’ of effects (Larcombe 2000; NSMA 2001; NIRB 2010).

Other sources describe or were part of environmental assessments (Berger 1977; Legat et al. 1995; BHP 1996; NSMA 2001; NIRB 2004; Inuvik Community Corporation et al. 2006; Doohan 2008) or recommend changes to current approaches and regulatory systems (Wismer 1996; McCrank 2008). Others speak to TEK in the resource development industry (Evans and Goodjohn 2008).

Several resources provide recommendations of how to integrate TEK into reclamation through example (Golder Associates 2003 and 2010; Garibaldi and Straker 2009; Knight Piésold 2010; Rescan 2011) or discuss the vulnerability and adaptive capacity to environmental change (Wesche and Armitage 2010).

Many references provide recommendations as part of TEK guidelines or protocols related to data collection through to reporting (GNWT n.d.; Royal Commission on Aboriginal Peoples 1993; Huntington 2000; NIRB 2002; Tobias 2000 and 2010; GNWT 2005a, 2005b, 2007, 2010a and 2010b; Kavik-AXYS and FMA Heritage Resources Consultants Inc. 2005; MVRB 2005; SENES 2005; Fedirchuk et al. 2008; Department of Environmental and Natural Resources Interdepartmental Traditional Knowledge Working Group 2010). Recommendations about the suggested ways to communicate TEK in the context of the diverse knowledge, audiences and media types available today were drawn from the authors’ professional experience as well as from a key reference (Bonny and Berkes 2008). One key source provided recommendations aimed at Aboriginal communities facing mining (Natural Resources Canada 2010) and developments (Emery 2000) in their traditional territories.

Other

As most sources are already described in the above five sections, they won't be repeated under this category. However, 80 sources were identified.

Most of the sources allocated to the 'other' category contain protocols, guidelines, or procedures for carrying out TEK work (Appendix F) provide a good general background which may be useful to DDMI in evaluating possible TEK processes or projects (Emery 2000; GNWT 2002; Manseau et al. 2005; MVRB 2005; GWNT 2007; Lines 2009).

Some sources are specific to DDMI and the challenges surrounding the environmental assessment process and/or diamond mining (Bielawski 2004; O'Reilly 2006; Gibson 2008) as well as the role of Aboriginal peoples in risk assessment related to orphaned/abandoned mines (Nolan 2009). An overview of community-based monitoring is included (Fletcher 2003) as well as a review of cultural impact assessment sources (McDonald et al. 2008).

There are examples of TEK projects related to northern riparian areas (Tamuno et al. 2009; Candler et al. 2010), fisheries (Rompkey and Patterson 2010); and mining (NIRB 2002 for the Doris Hinge Project; NIRB 2004 for the Meadowbank Project; De Beers for the Snap Lake Project 2004; Rescan 2006 for the EKATI Mine; MVRB 2009 for the NICO Project; Tetra Teck 2009 for the Red Dog Mine Extension; Knight Piésold 2010 for the Baffinland Mary River Project; Rescan 2011 for the EKATI Mine).

Finally, several references pertain to land claims in the north (South Slave Métis Tribal Council et al. 2002; INAC 2003 and 2007b).

6.0 DISCUSSION

The literature review yielded few examples of where it was articulated that TEK directed, influenced or altered a particular mining and/or resource operations. This is not so much a reflection of the utility or value of TEK, but rather, illustrative of the fact that there are challenges inherent in integrating TEK into such operations.

6.1 Challenges to Integrating TEK into Resource Operations

The literature review illuminated some of the reasons why TEK is not systematically and frequently integrated into mining and resource operations in a meaningful way. While it is commonplace today for TEK to be included in environmental assessment, monitoring and reclamation, this is not done systematically from one mine to another. There are at least eight key challenges to the integration of TEK into northern resource developments discussed in the literature and experienced as practitioners:

1) TEK does not always apply well to systems grounded in the western scientific approach such as the environmental assessment and monitoring processes or mining engineering.

2) The belief system underpinning TEK can be challenging to apply in a resource context and for some non-Aboriginal peoples to appreciate or understand.

3) Cultural rules in Aboriginal communities may not be well understood or respected.

4) Mistrust between Aboriginal and non-Aboriginal parties is part of history as well as today.

5) Due to the nature of TEK, there is some information that simply cannot be shared.

6) Industry typically funds communities to carry out TEK projects and then communities decide what, when and how much TEK to share while the timelines, priorities, approaches, formats and scope of these TEK projects may not always align between industry and communities.

7) Legal requirements and attempts to integrate TEK into resource development continue to evolve.

8) While cases of where TEK has influenced mineral development are ongoing, there is a lack of well documented working examples, due in part to the relatively recent emergence of TEK as a structured discipline.

Challenge 1: Integrating TEK and Western Science

TEK does not always ‘fit’ into a predominantly western or scientific framework or timeline typical of an environmental impact assessment or monitoring program (Agrawal 1995; Abele 1997; Johnson 1988; Berkes 1993 and 1999; Nadasdy 1999; Huntington 2000; Arnakak 2002; Moller et al. 2004; Mazzocchi 2008; Briggs 2005). The complexity, interconnectedness and wealth of information that characterize TEK / IQ can be lost when it is translated and written down rather than explained, demonstrated or acquired through experience. As Berkes (1999: 28) asserts, writing a definition down “will never be an adequate format for the teaching of indigenous knowledge.” In other words, a young boy will learn more from watching and listening to his grandfather hunt a caribou and then experiencing the hunt himself, rather than by reading a book about hunting. This was the case for Alootook Ipellie, an Inuk who speaks to IQ as a unique way of knowing:

> *I was often in awe of the extraordinary abilities of my elders to understand the season, in knowing the behaviour of all Arctic animals species and to co-exist with their fellow Inuit in a common goal to survive as a collective. In the Arctic's harsh environment, one mistake or a lapse in judgement could spell certain disaster. By observing, listening and practising what my elders did, I was instilled with the will to survive for the moment and go on for another day. (Ipellie 1997: 98)*

This challenge is illustrated in the way that the NIRB - more than twelve years after self-government in Nunavut – is still trying to develop a review process grounded in IQ within the constraints of the current environmental assessment regime. Similarly, the MVEIRB and NWMB, although making "sincere, sustained efforts to bring TK and IQ into their operation… the frameworks within which these boards operate limits the influence of TK and IQ," (White 2009: 412).

Industry is also faced with trying to appreciate the fact that each Aboriginal group is culturally, environmentally, socially and economically different. There are inequities in relationships and capacity levels as well as disparate TEK protocols, goals, objectives and methods between groups and even between communities within one group. It can be difficult for industry to understand the many frameworks and structures (some stated and others not) underlying indigenous groups and to develop an equitable and appropriate path forward for each. Further, community concerns about intellectual property rights may lead to a lack of transparency in the ways in which TEK projects are carried out which can frustrate industry. Ultimately, these factors can influence the understanding and willingness of businesses to invest in TEK studies.

Critics also caution that ecological knowledge held by indigenous peoples should not be romanticized to be more than it really is or taken out of context (Howard and Widdowson 1997; Cruikshank 1998; Krech 1999; Briggs 2005). Just as not all data collected by western scientific methods are pertinent to answering the questions necessary to understand the development of a resource project, so too are some data collected through TEK methods. The inclusion of data simply because it is TEK can be as problematic as not recognizing the scope of a western scientific study (Davis and Wagner 2003; Ellis 2005; Eisner et al. 2009).

Another caveat suggests that the use of the word 'traditional' in traditional knowledge or traditional ecological knowledge is limiting in that it purports that customs and beliefs are "frozen at a particular point in time" (Nadasdy 2003: 120). Battiste and Henderson (2000: 46) explain that "what is traditional about traditional ecological knowledge is not in its antiquity, but the way it is acquired and used." Regardless of the terms used, TEK is understood to encompass both historical and contemporary knowledge acquired through story-telling and passed down through generations as well as through first-hand experience.

Although there are challenges in combining western scientific knowledge and TEK, the process can build partnerships, community consensus and ultimately enable indigenous wildlife users to consider scientific predictions on their own (Gunn et al. 1998; Berkes 1999; Thorpe 2000; Riedlinger and Berkes 2001; Golder Associates Ltd. 2003; Moller et al. 2004; Kavik-AXYS and FMA Heritage Resources 2005; Kendrick et al. 2005; Garibaldi 2006; Eisner et al. 2009).

To address community concerns regarding caribou potentially getting caught in the mine's Processed Kimberlite Containment (PKC) area during their annual migration, the Environmental Monitoring Advisory Board (EMAB) facilitated consultations between Diavik and local community leaders to come up with a suitable fencing solution. The outcome from various workshops run by EMAB was a caribou fencing plan, designed and managed according to local traditional knowledge of caribou and predator activity, implemented by the operation. It consisted of a snow fence with permanent metal posts fixed in to the ground. The fence was left on the ground to prevent predators and other animals from predation along the fence, or getting caught in the fence, but was able to be erected in a very short period of time if caribou were observed in the area.

Some struggles to integrate two world views are overwhelming, suggesting that a whole new framework for carrying out resource management should be implemented, one that is grounded in TEK rather than western science (Nadasdy 1993 and 1999; Stevenson 1996; Wismer 1996; Abele 1997; Berkes 1999; Battiste and Henderson 2000; Usher 2000; Crawley and Sinclair 2003; Briggs 2005; White 2009; Gibson 2008; Deleon and Ventriss 2010). Should this approach be considered, there would be a need to develop such a framework, with input from a diversity of community and corporate representatives.

Despite recent progress in settling land claims, formal apologies for the residential school experiences, and other measures to ameliorate a long legacy of colonization of non-First Nations in Canada, the fact remains that power differentials still exist. When this unequal power relationship between Aboriginal people and the state, resource managers, mining companies, etc. is not articulated or taken into consideration, the process of integrating TEK and western science serves to further concentrate power in the hands of the state rather than First Nations, Inuit or Métis particularly where the information is appropriated. For example, Elders may share critical TEK without being given due recognition or worse, later punished by sharing this information which then leads to a loss of use associated with a particular part of the land (*i.e*., you said you hunted caribou here and not there so thus this must not be an important part of traditional territory). Given a power imbalance, it is fair to say that the elements of the power struggle between Aboriginal peoples and non-Aboriginal peoples are echoed in the attempts to integrate their two knowledge systems. However, this is not to say that there are not similarities between TEK and western science (Aboriginal peoples and non-Aboriginal peoples) and that there are not as many elements of rigour that are part of TEK as there are science. It is important to introduce these power relationships here although an in depth discussion is beyond the scope of this report.

To summarize, while TEK should be understood as valuable in resource development, one should not unconditionally accept any form of knowledge without placing it within a context and recognizing both its strengths and limitations.

Challenge 2: Appreciating TEK Cosmology

The belief systems at the core of TEK can be difficult to integrate with a western scientific method - let alone resource development – which does not allow for a spiritual cosmology. For example, the Dogrib Treaty 11 Council (2001: 93) reports that:

> Only a few people have a spirit connection with the caribou, and therefore the knowledge and intelligence that comes from this. These people know where the caribou are at any given time, but cannot predict where the caribou will migrate to in the boreal forest.

Jaypeetee Palluq of Igloolik provides another example (Knight Piésold 2010: 38) in his description of earth eggs as well as giving a recommendation to scientists:

> Often, they will appear translucent as well, like you can see the yolk from the outside. These eggs will hatch animals like albino caribou, albino seals, etc. The earth is their mother, and these eggs and animals should never be disturbed. If a person disturbs an earth egg, the weather will turn bad, often for months…Scientists or people working on the Baffinland Project should be told about these earth eggs, how to identify them and why not to disturb them.

For many scientists working in the mining field, the spiritual elements of TEK can be outside of their ‘comfort zone’, belief system or research framework. It is one of the more important components of TEK to recognize however, as the cosmology and culture of the people will influence the type and method of information recorded and the means through which it is presented. If only certain individuals are believed to have the spiritual connection to a segment of a peoples’ ecological knowledge, then the selection of individuals to participate in a TEK study must be based on this information to allow for a complete representation. This is particularly relevant in the north where the relationship between people and their environments remains so strong.

A good example of where a mining company has embraced the spiritual elements of TEK is Rio Tinto’s support of a traditional Australian welcome ceremony (*manthe*) and offerings to Barramundi, the sacred Dreaming being whose fossilized organs are said to be the diamonds given up by the Argyle Diamond Mine in West Kimberley, Australia (Doohan 2008). The manthe helps to guarantee safe passage to the miners as well as honour the sacred Barramundi. Rio Tinto insists that all new employees attend a manthe as well as a scientific operational health and safety meeting. Not only is this an impressive example of a company incorporating the spiritual aspects of TEK, but also it demonstrates the integration of TEK and western science in a resource context.

Challenge 3: Making Sense of Cultural Rules

The cultural ‘rules’ (*pitquhiit* in Inuinnaqtun) integral to TEK are not always easily applied in a western scientific framework (Emery 2000; Thorpe 2000; Thorpe et al. 2001). For example, respect for animals is a central tenet in the cultural rules of Aboriginal culture. In the case of monitoring, Kendrick et al. (2003) discuss how Dene elders warn that a lack of respect for caribou can cause the animals to change migration routes, a similar assertion made by the Tłîchô (Dogrib Treaty 11 Council 2001). David Irnqaut of Igloolik as part of the Mary River Inuit Knowledge Study (Knight Piésold 2010: 27) explains that “Traditional knowledge teaches us not to speak negatively of the animals. I believe that today.” While wildlife biologists certainly share in recognizing the importance of respecting caribou, it is not clear how a western scientific framework can ‘accommodate’ an Aboriginal definition of respect nor is it likely that an indigenous concept of respect is the same that held by western science.

Challenge 4: Overcoming Mistrust

Issues of mistrust have been expressed between scientists and traditional knowledge holders and between Aboriginal peoples towards ‘outsiders’. The validity and usefulness of TEK has been questioned. For example, some people suggest that Elders are biased because of the belief that Elders are anti-development when, in fact, many Elders are pro-development as long as it is ‘done right’ and provides opportunities for communities. Some scientists are wary of TEK owing to the assimilation of Aboriginal peoples and the reduction in time ‘spent on the land’ (Johnson 1999). In contrast, others argue that TEK is on a path of evolution and not extinction and that “what is traditional about TEK is not its antiquity but the way it is acquired and used,” (Battiste and Henderson 2000: 46).

It is important to identify ‘experts’ within TEK just as it is within a western scientific context (Neis and Felt 2000; Davis and Wagner 2003; Eisner et al. 2009). Members of a TEK working group need to emphasize that understanding which aspects of the TEK are of value to the project development is key to making the program a success: not all traditional knowledge is valuable simply because it exists.

The commercialization of TEK and other misappropriation of use is part of recent memory for most First Nations, Inuit and Métis (Nadasdy 2003; Battiste 1998; Battiste et al. 2000) that contributes to a hesitation to share TEK. There are cases where information has been misappropriated, disrespect was shown towards intellectual property rights, credits forgotten, or the validity of TEK ignored (Nadasdy 1999; Ellis 2005). This is on top of a collective memory about the ways in which Aboriginal peoples have been treated throughout Canadian history, such as the removal of northern children to residential schools. Given this past, Aboriginal peoples and scientists are not always well positioned for an open exchange, as discussed above in the context of power differentials.

Challenge 5: Understanding Intellectual Property Rights

Even where mistrust is overcome, it is not always appropriate for communities to share TEK owing to issues of intellectual property rights, data ownership and sensitivities surrounding sacred or cultural sites. Multiple guidelines and protocols exist around the collection and use of TEK which have helped to ameliorate many challenges associated with sharing information. However, people may not want to share information that reveals community secrets; for example, berry patches, hunting grounds or fishing holes. People are also hesitant to make lines on map overlays which might suggest a reduction in the use of the land or that a particular use, activity or site is geographically limited (Thorpe 2000; Tobias 2010).

Industry representatives may not fully appreciate the sensitivities surrounding TEK and thus may be leary of funding studies without full transparency in their methods or results. Without this understanding, some people may worry that bias can enter into a particular TEK study such that results are manipulated to the detriment of a proposed project. For example, a TEK study may cite an important hunting ground that would lead to a change in the siting of a road that would make a project prohibitively expensive. Further, some corporate officials lament that industry is subjected to rigorous reporting and transparency requirements when communities can with-hold key information, thus suggesting that a double standard exists.

In the same way that communities can be misunderstood, so too can industry. Community members may not fully appreciate industry needs for transparency in process, budgets, research priorities and timelines associated with a particular development project. Communication and a willingness to build relationships are key to bridging gaps in understanding between both parties.

The Naonayaotit Traditional Knowledge Study (NTKS) provides an example of an IQ project where participants have overcome their concerns and trusted in the process. The NTKS is managed by the Kitikmeot Inuit

Association (KIA) and accessed by industry according to what KIA determines is appropriate to share. A development plan for a road, for example, may be reviewed by the KIA and a proponent given direction based on what KIA suggests rather than KIA actually providing the supporting information (Rescan 2007 and 2011; Gerry Atatahak pers. comm. 2010).

Challenge 6: Controlling Their Own Community Research

Communities are moving in the direction of controlling and carrying out their own TEK projects with funding assistance from industry such that communities determine exactly what and how much information is shared. However, what communities prioritize, agree to share as well as what their timelines may be, do not often match those of industry.

The WKSS, NTKS and TEK work being carried out for the EKATI Diamond Mine, Diavik Diamond Mine, Red Dog Mine, Mary River Project and Gahcho Kué Diamond Mine provide just some examples of industry funded TEK projects carried out by communities and where communities, in turn, shared results of the projects with industry for inclusion in their environmental assessments. Due to the sensitive and proprietary nature of the TEK, not all information was shared. In some cases, communities refused to share anything but a brief summary as witnessed by the report author. This can be frustrating for industry caught between reporting requirements, timelines, ‘wanting to do the right thing’ and genuinely valuing TEK and wanting to incorporate TEK into mining practices. Still, the number of good examples outweigh the bad in terms of industry-funded TEK work being carried out today for development projects.

Challenge 7: Legislating the Consideration of TEK

Attempts to integrate and document TEK into mining and resource operations have been on the rise, particularly in the last ten to twenty years and largely resulting from changes to legislation that have required industry to incorporate TEK (Manseau et al. 2005). Section 16.1 of the Canadian Environmental Assessment Act (CEAA), gives responsible authorities conducting an EA the discretion to consider Aboriginal traditional knowledge in any EA: "Community knowledge and Aboriginal traditional knowledge may be considered in conducting an environmental assessment." While this is ‘voluntary’, companies know that integration of TEK is part of a social licence to operate. Further, government guidelines such as those issued by the GWNT, NIRB and MVEIRB are increasingly more detailed in the ways they direct consultation and inclusion of TEK (Kavik-AXYS and FMA Heritage Resources Consultants Inc. 2005; White 2009; Fedirchuk et al. 2008; NIRB 2009). Court cases have similarly advanced the requirement to engage Aboriginal communities and integrate their knowledge in resource development (Sparrow 1990; Delgamuukw 1997; Haida 2004; Mikisew Cree First Nation 2005).

To assess the health of fish in the mine affected area, Diavik undertakes regular monitoring of fish in Lac de Gras, as required by a Fisheries Authorization. Elders and youth from the communities are encouraged to participate together in a study to monitor the continued palatability and texture of lake trout. Community representatives designed the study which rates the fish on appearance before cleaning, and on look and taste once cooked. Ratings are compared to several benchmarks, including the previous year’s survey, the quality of fish in the person’s home area and perceptions of the health of fish prior to mining operations. Tissue and organ samples of the same fish are submitted for laboratory analysis to determine metal levels. The palatability study has dual outcomes: contributing to environmental management and cultural heritage management on site while upholding fishing as a traditional way of life through monitoring the operation's impact on favoured fish species.

Some companies have been leaders in bridging the divide between TEK and western science outside of any legal requirements (Doohan 2008). Rio Tinto, again in the case of the Argyle Diamond Mine, negotiated the *Good Neighbour Agreement* in 1980 before Australian legislation required more intensive community consultation and incorporation of knowledge held by traditional owners (www.atns.net.au). This Agreement spelled out the rules of engagement between the mining company and Aborigines. Teck Alaska's Red Dog Mine similarly provides a good example where results from over fifty meetings with local communities over a five year period contributed to a closure plan.

BHP Billiton has responded to input from an Elders Advisory Group as part of the Caribou and Roads Project and wildlife monitoring programs (Rescan 2007 and 2011). For example, a roped fence was installed around the airport as well as along a mining pit. Inuksuit were also constructed along the airstrip to divert wildlife. In these cases, mining officials applied the elders' understanding of wildlife (*i.e.,* caribou migration routes can be altered by inuksuit and/or human activity) to make a change to their operations.

Challenge 8: Documenting Working Examples of Where TEK Has Been Incorporated

Cases where TEK has been incorporated into resource operations have been poorly documented even though the process has been ongoing ever since 'outsiders' have been working in traditional territories: miners have been interacting and dialoguing with Indigenous peoples and using results from these interactions to guide research, development and the generation of hypotheses since well before the delineation of TEK guidelines and practices. A confounding factor is that TEK is an oral and not written tradition (Huntington 2000) and so many contributions from Aboriginal peoples are delivered by word of mouth.

Personal experience as well as discussions with an expert northern hydrologist and wildlife biologist confirmed that the first step of any research or field plan is to talk with those most familiar with the land, not only in the context of consultation, but also to determine, for example, the location of the 'best' research sites, key landscape features, or migration routes (Steve Kokelj pers. comm. 2010; Damian Panayi pers. comm. 2011). In addition to these valuable contributions, TEK is used commonly to 'ground-truth' satellite images, map features and other scientific elements of research, for example, in the context of environmental change (Reid et al. 1998; Eisner et al. 2009). Recent examples show the strength of working together (Doohan 2008; Eisner et al. 2009; Tetra Teck 2010).

The EIS for the Mary River Project proposed by the Baffinland Iron Mine was prepared under guidelines from NIRB that called for specific measures to include IQ (Knight Piésold 2010). The company responded by highlighting where IQ was integrated into the report (primarily in Volume 4, Human Entitlement) and specifying where IQ influenced the EIS:

> As most harvesting activities, according to harvest data and IQ, occur close to the community and to the west of … the ships zone of disturbance is distant from these areas. (Volume 4, page 162).

In evaluating the potential of the proposed project to influence cultural well-being, Baffinland reviewed the project in relation to the IQ guiding principles articulated by the Inuit Qaujimajatuqanginnut Task Force (2002) thereby using an Inuit frame of reference to evaluate the impacts (see Volume 4, page 177). This was well received by NIRB.

Baffinland also supported an Inuit knowledge study (Mary River Inuit Knowledge Study) which factored largely into the EIS; however, it is presented as 'information' about wildlife, sea ice, customs, etc. and it can be difficult to see exactly how this information factored into planning for these environmental elements.

BHP Billiton has also incorporated TEK into their operations as part of the Caribou and Roads Project and the wildlife monitoring program, reports on which seem to highlight the direct links between TEK and action better than in the EIS. Inuksuit were constructed along the airstrip and other areas requiring caribou to be diverted from danger. A roped fence was also constructed by community members in response to their recommendations. An Elders Advisory Group operates independently from the mine and provides ongoing guidance on operations and plans for closure and monitoring.

Teck Alaska has responded to community direction by building protective berms along the edges of pits as well as integrating TEK into the EIS for the Red Dog Mine Expansion. For example, accounts of bowhead whales being sensitive to noise have influenced proposed operations at the port and local observations of changes in caribou populations have guided wildlife biologists.

Diavik Diamond Mine relied upon TEK to identify the VEC's, locations for water quality samples and habitat types to monitor. Additionally, streams with sufficient fish supply and passage, as well as locations for fish shoals inside the dikes, were fisheries habitat compensation requirements that were best identified using TEK. The initial wolverine track survey design was also based on TEK, as was the layout and location of various buildings and site infrastructure to take into account prevailing winds and minimize snow accumulation in various areas around the mine site.

As these recent examples highlight, the ways in which Baffinland Iron Mine Corporation, BHP Billiton, Diavik Diamond Mines Inc., Teck Alaska and Rio Tinto have integrated TEK into their environmental assessments and operations has been meaningful in that they have highlighted the causal link between knowledge (TEK) and action. There is still room to improve, but these contemporary examples show a move in the right direction.

7.0 RECOMMENDATIONS

The following recommendations are provided to assist in linking some of the best practices in TEK programs to resource development projects. It is important, as in all projects, to have clear scope and a defined objective before initiating into a program that involves TEK. The challenges of inter-cultural differences, historic mistrust, unclear regulatory requirements and established procedures and protocols can make a TEK program daunting to initiate.

7.1 General

Where companies have been successful in meaningfully incorporating TEK into their developments, they have been able to communicate, customize, "check it out" and co-ordinate, as discussed in the following recommendations.

Communicate

Frequent, respectful and ongoing communication between proponents and holders of TEK is key to the integration of both people and their knowledge into a proposed project.

Involve and consult communities early and often as the basis for relationship building. Discuss what your objectives are for the program from the outset and work together to identify meaningful ways to achieve those goals. A community member commented that "a key to success of the Colomac remediation was that it involved people: it was a human process that resulted in the sharing of knowledge and respecting each other's inputs" and that "it is harder to come back after the mine is built to fix the site, than addressing [remediation issues] up front before the mine is built" (Terra Firma and Gartner Lee 2005: 10).

People are eager to contribute and their contributions lead to their empowerment:

> Involvement of the communities is very important because we also have an opportunity to help you in your reclamation plans and would like to be included in the design and assessment of the methods to be used and the monitoring (Terra Firma and Gartner Lee 2005: 11).

Document and report back how TEK informed, altered or influenced a process, procedure, operation or program. Demonstrate causative linkages that information X led to action Y. It is critical that assessment scientists describe how TEK is used in their analysis and write up (Fedirchuk et al. 2008) so that communities can see how their information was used and so that other scientists can see the utility of TEK. Examples where TEK and western science have informed one another are opportunities for celebration.

While most references cite the importance of including TEK, there is rarely any discussion of methods or protocols on how to actually achieve this goal. It is interesting to note that TEK is not mentioned in the four key objectives of the Mine Site Reclamation Policy for the Northwest Territories (2002), as discussed in INAC (2007a). The reference itself mentions that TEK should be considered, but does not provide guidance on how. Industry needs guidance on moving forward in this regard, not only from communities but also from agencies.

Be forthright with intentions around TEK studies and Aboriginal engagement. Companies want to develop resources and in order to gain the social licence to operate, they must carry out consultation and engagement and incorporate TEK in the environmental assessment process: at the end of the day, including TEK is a business decision first. Further, power imbalances at the core of participatory processes should be highlighted up front (Nadasdy 1999; Deleon and Ventriss 2010). Communicate how TEK will be collected and where in the development process it will and will not be utilized so that community members can have clear expectations. Disclose areas, operations or processes where 'full and equal consideration of TEK" is simply not possible or appropriate. Seek to be forthcoming with priorities, timelines, formats and deliverables so any discrepancies in expectations can be addressed early.

Be respectful, clear and appropriate in language and translation. Providing materials in the appropriate languages and employing highly skilled translators, despite the accompanying costs of translation, is critical to communication (Ellis 2005). This can be a challenge when 'scientific' words don't have an Aboriginal analogue (Cruikshank 1998). Ellis (2005: 70) discusses the hearings for the proposed expansion at EKATI in 1994, when translators simply used the English word 'ammonia' as there is no equivalent word in aboriginal languages. Later, the Elders wondered why the mine water effluent was going to be "infected with pneumonia".

During a Mine Reclamation and Closure Workshop (Terra Firma Consultants and Gartner Lee 2005: 8), one participant commented that:

> There is concern about the language used and a desire to see more Aboriginal involvement explaining the terms used in mine reclamation and closure. There is a general desire to see Aboriginal peoples involved throughout a mine reclamation and closure process.

Elders have also suggested that larger print be made available on some communications materials and that traditional place names are used. When these requests are accommodated, the path towards a relationship of respect is followed: sometimes it is these 'little things that count'.

Customize

Our world is a patchwork of cultures, none exactly the same. Thus, different approaches to considering TEK must be considered.

Honour that not all First Nations are homogenous and that heterogeneity calls for customized approaches. As Deleon and Ventriss (2010) discuss, each community has different capacities, cultural rules and protocols and more when it comes to TEK. Thus, communication with key leaders as to how TEK projects can be carried out and how TEK can be included in a resource development must not be assumed to be the same.

Recognize that for every 'type' of TEK documented, different management and media systems are required. The ways in which TEK systems must be managed and preserved differ greatly than the ways in which western scientific knowledge is documented (Stevens 2008). As media tools advance, so too do the ways in which TEK can be integrated into mining operations. Matching TEK as an oral tradition with audio or video tools can be a much more creative, meaningful and effective format (Bonny and Berkes 2008). There are incredible tools available online (often at no cost) that speak to the 'iGeneration' today.

“Check It Out”

Verification is a critical component of everything from evaluating knowledge contributed by an individual through to whether the information was documented and then communicated correctly.

Spend time getting to know your TEK holders and on what topics they are considered by their peers to be knowledgeable enough to represent the community. Do not assume that Aboriginal participation in processes always translates as the submission of TEK (Ellis 2005) given that the source may be more important than the knowledge. In the same way there are scientific experts, there are also TEK experts (Abele 1997). It is important to carry out a “transparent and defensible” process in how TEK holders are selected to participate (Huntington 2000; Davis and Wagner 2003).

Be open-minded when considering a belief system. While it can be challenging for scientists to treat Aboriginal observations and beliefs as inherently valid, particularly those in the spiritual realm, it is important that this is the starting place (Eisner et al. 2009). From there, observations and beliefs can be placed within a broader context of from who they were provided and whether they form part of independent or collective knowledge or first-hand or second-hand observations. Verification in this context may be exploring how many people share the same beliefs.

Verify or vilify: check the information before it is put ‘in print’ lest you be the target of disrespect or have a TEK holder refuse to work with you again. It is important that you give individuals the opportunity to review their TEK contributions (*e.g.,* in meetings, workshops, reports) prior to final release of information. This small measure of respect can be large in terms of relationship building.

Co-ordinate

An organized and co-ordinated approach to working with scientists and holders of TEK can minimize frustrations and set the stage for a well-respected process of engagement.

Recognize, accept and celebrate convergences and divergences between TEK and western science. Figure out when one knowledge system would contribute more in what setting. For example, maybe science can contribute a measure of pH while TEK can contribute a qualitative measure of smell and taste. Further, look for ways that TEK can generate objectives for future scientific programs related to environmental assessments, monitoring, operations and closure - and vice-versa (Gunn et al. 2008; Thorpe 2000; Moller et al. 2004; Kendrick et al. 2005; Eisner et al. 2009).

7.2 Mining Operations

The following section provides recommendations specific to the various stages of mining operations: baseline, monitoring, and closure. In all phases, the engagement of an arms-length Elders Advisory Group is highly recommended. Frequent and ongoing meetings of this group as well as regular meetings and interviews with TEK holders throughout all phases of a mining project will facilitate the integration of TEK and the building of meaningful and constructive working relationships.

Incorporating community members and TEK holders in baseline data collection, monitoring and reclamation can be through various settings such as an Elder-youth camp, TEK-science camp, workshops, interviews and on-the-job training sessions. A combination of these settings will provide a more balanced, complete and diverse data set, program and outcome as well as learning experience for both community members and industry leadership.

The following sections that highlight baseline, monitoring and closure come from a combination of the literature fifteen years of the author's personal experience working with TEK holders and mining companies in the north.

Baseline

When TEK is included in baseline studies and a co-ordinated approach undertaken by scientists and holders of TEK, the outcomes can include a more accurate description of the environmental and socioeconomic conditions, a more cost-effective approach owing to higher social capital and better information, and ultimately a better project design. For example, Fedirchuk et al., (2008) report on an Elder advising a northern mining operation that the direction of their proposed airstrip was problematic due to prevailing wind conditions which led to the redesign of the airstrip well before construction began. In the case of the Red Dog Mine in Alaska, an interviewee commented that Teck invested heavily in including TEK in baseline work and thus ended up with a much better project overall, both in terms of design and community engagement.

Companies should be funding and empowering communities to carry out their TEK studies and both learning from and applying the information which is documented and shared. The earlier this process starts, the better for the project as well as the parties involved. There is a shared onus upon both companies and communities to be forthcoming about what each party needs in terms of a TEK study in order to try to reconcile differences in priorities, timelines, formats and deliverables early. Still, it is likely that concessions will have to be made by both parties, although it is better to be aware of what these are from the outset so that each party can plan accordingly. This transparency of process and high level of open communication will lead to stronger working relationships and more satisfied parties to any agreement.

The following examples outline ways in which TEK can be particularly relevant to baseline work:

Sampling and infrastructure planning. As TEK embodies long-term environmental knowledge, Elders may contribute critical information specific to a location across time to assist in planning and carrying out baseline work. For example, Elders may provide observations of freeze-thaw cycles, typical snow depths, or whether an area is located within a calving ground well in advance of scientists carrying out research at the site that may direct industry to site an exploration camp. Elders may even discuss unique geological features, perhaps contributing information as to where future core sampling may take place.

Spatial and temporal considerations. TEK holders can provide key information in planning for the types and levels of efforts required for baseline work. People can be familiar with a large region owing to their frequent excursions on the land to carry out subsistence or traditional practices such as hunting. They may also contribute long term observations of this large expanse. For example, Elders might point out key areas on eskers where dens are located (either presently or in the past) thereby reducing helicopter time as wildlife biologists carry out searches. In other cases, maybe Elders can contribute information about berry patches indicative of particular habitat type or hydrological regime. During the early days of the EKATI mine, Elders told fisheries biologists there were land-locked char in some nearby lakes when scientific research had not shown as much. Subsequent scientific work carried out as a result of these observations shared by Elders corroborated this TEK.

Focus and/or critical areas. Working within constraints of limited budgets and time, industry must make well informed decisions as to what baseline work is carried out where. Input from TEK holders with respect to VECs and VSECs early in project planning can assist mining personnel, consultants and others on where to focus their baseline data collection efforts to best suit the interests and needs of communities as well as industry committed to sustainable development. Further, in responding to community input, companies have an opportunity to demonstrate their willingness to accommodate.

Integrating and identifying areas of TEK and western science. In reporting baseline results, it is important to identify where TEK versus western science contributed to the development of particular findings and where areas of convergence and divergence in these two knowledge systems exist. For example, one successful format is to have an introductory section (*e.g*., caribou), followed by a discussion of where TEK and western science share the same observations (*e.g*., migration routes, calving grounds, physiology) and then an account of where western science and TEK differ or where anomalies occur (*e.g.,* according to TEK, there are more events of massive drownings due to thinner ice, or a caribou was once seen to cross into an area previously unknown as caribou habitat; or according to western science, parturition rates are changing or measures of energy expended avoiding insect harassment are fluctuating). Within baseline reports, it should be clear which information came from scientists and which came from TEK holders and how this baseline knowledge can or will then inform a future practice or operation. Particularly in the case of a TEK holder, making the origins known and articulating the linkages from 'knowledge to practice' will contribute to building working relationships grounded in trust, communication and respect.

Training and capacity building. Baseline work provides an early and ideal opportunity for training and capacity building within local communities to carry out both TEK and western scientific work. In an ideal setting, community members would be trained in TEK and western scientific methods either concurrently or consecutively such that they build skills in both approaches and so that the message delivered is that "both ways of knowing are important." Investment in such initiatives will equip community members with the necessary skills to assist not only with baseline work, but also with operations, monitoring and reclamation.

Monitoring

As with baseline work, the incorporation of TEK will contribute to better monitoring programs, particularly when coupled with a high level of community input. The design of a monitoring program should be collaborative and start as early as possible (*i.e*., several years) such that any differences in monitoring priorities, timelines, formats and deliverables can be discussed and accommodated.

Working in collaboration with scientists, community members can provide ongoing support and information to enhance the monitoring program. Noble and Birk (2011) warn that comfort monitoring -- monitoring that improves relationships and enhances corporate image but does little to support effects-based management – must be avoided. Thus, it is important that monitoring results are valuable to and integrated with regulatory-based monitoring and project impact management practices.

Community members have a considerable stake in making sure that monitoring programs are a success. Multiple examples show that the higher the level of community participation through an Elders advisory committee, trained and employed monitors, or participation in a monitoring board (*e.g.*, Environmental Monitoring Agency Board or EMAB), the stronger the programs are in function as well as community acceptance. Another positive aspect of involving community members in monitoring programs is that participants will report back to communities in both formal and informal settings thereby communicating information about the development.

Finally, there are lessons to be learned from the community-based monitoring work of the Łutsel K'e Dene First Nation and Brenda Parlee for the WKSS. Specifically, a high level of community input and control were key factors to success in their programs.

The following examples outline ways in which TEK can be particularly relevant to monitoring:

Training leads to capacity. When people are trained during the baseline phases of the project, these skills can be furthered in a monitoring context. Training should be ongoing throughout all phases of the project, but continuous training will build stronger skill sets and lead to better monitoring processes and programs.

Developing traditional indicators. Prior to any monitoring program, it is useful to consult with TEK holders to develop indicators or measures of a healthy ecosystem from a TEK perspective. Once these indicators are established, regular monitoring through specific measurements as well as through interviews with TEK holders (either as a group of individually) can provide monitoring results. For example, a common measure of caribou fitness using TEK is to measure the thickness of back fat. A caribou with a 'short tail' owing to the high amount of back fat is known to be healthy (Thorpe et al. 2000). Note that these indicators may differ between groups and that they should be incorporated with scientific measures as part of a combined monitoring program. TEK can provide information on how monitoring should occur based on cultural, environmental, social and economic knowledge combined.

Focus on key areas. As with baseline, TEK can assist in focusing monitoring programs on VECs, VSECs and cultural keystone species which are more of a priority to communities in addition to those elements that are priorities to industry.

Evaluating environmental linkages versus components. Given the holistic nature of TEK and the challenge of reducing it to components as common in western science, TEK can be particularly useful in monitoring linkages between environmental components (*e.g.*, the relationship between dust cover on vegetation and caribou) versus components (*e.g.*, caribou fitness) alone. While science can often provide data on species and habitats, TEK may provide insight into the multi-layered relationships between these two, particularly across a large spatial and temporal scale. Working with TEK holders to better understand the linkages inherent within ecological systems – both those well-known and those that are expressed as anomalies – is one key way in which TEK can contribute to monitoring. Perhaps it is the linkages that should be measured rather than the components themselves.

Applying adaptive management. Once in place, a monitoring program should have an active evaluative feedback process contributed to by TEK holders as well as scientists. Since adaptive management is a critical element of TEK and monitoring, it is only natural that holders of TEK have a significant role in this aspect of monitoring. For example, northerners have long applied adaptive management such that during years when wildlife was less plentiful, food staples would become fish or marine life. On a micro scale, when evaluating snow conditions during travel and facing unpredictable or more variability in weather conditions, people have always used their environmental knowledge to select safer, faster or smoother travel routes. A monitoring program that encourages constant analysis and revision using input from both TEK holders and scientists will lead to stronger results.

Closure

Several references speak to best practices for Aboriginal engagement as well as considering TEK in closure planning. Wilson-Clark and Tran (2010) advocate early and ongoing negotiations around closure, suggesting that they should commence at least five years before closure. Communities support ongoing and progressive reclamation and would like to see things ‘fixed along the way’ such that reclamation starts the day the environmental assessment begins (Terra Firma and Gartner Lee 2005). For companies, this approach reduces liability and, for communities, it lessens ongoing concerns for wildlife and the environment as well as worries about companies running out of funds for reclamation at the end of the project. Just as it is important to start early in planning for baseline as well as monitoring, the same is true for reclamation. In fact, planning for reclamation can assist in planning for baseline and monitoring too.

Language is important in communicating the differences between restoration, reclamation, remediation and rehabilitation, as many of these words are commonly misunderstood within communities. The subtle and not-so-subtle differences in these terms must be communicated in Aboriginal languages, even when an analogous term doesn’t exist (Terra Firma and Gartner Lee 2005). BHP Billiton has done some work in this regard, particularly with the community of Łutsel K’e.

As with baseline and monitoring, planning for closure will be most successful with a high level of community input and ownership. Such was the case with the closure of the Colomac Mine where DIAND and the Tłîchô embarked on a joint relationship to evaluate options for closure and to find a process where each partner could use its values and priorities to consider risks and ultimately determine the best closure option (Pearse 2010).

In addition to applying the importance of early planning, ongoing engagement, continued training and integrating TEK to give focus, as detailed in the above sections on baseline and monitoring, the following examples outline ways in which TEK can be particularly relevant to closure:

Identifying cultural keystone species. A successful method of integrating TEK into reclamation has been in identifying cultural keystone species, a technique that links social and ecological issues through identifying which plant or animal species hold a defining influence on a particular culture and offers a culturally meaningful point of reference in the landscape (Garibaldi and Straker 2009). Communities are engaged in the selection of species and subsequent monitoring, a process through which empowerment and engagement are constructed. Garibaldi and Straker (2009) report on the participation of Elders in designing a monitoring and reclamation program using cultural keystone species that was viewed by both industry and communities operating in the Alberta oil sands as a winning example. The key factors of success were having Elders engaged “early and often” and ultimately responding to their suggestions. For example, when a vegetative species was not thriving on a reclaimed area, the Elders explained that it was due to not enough of a particular nutrient rich soil horizon. When the company followed his advice and added more soil, the vegetation thrived: a win-win solution.

Identifying traditional measures of reclamation. As in monitoring, it is important to work with community members to identify measures which may be indicative of a 'reclaimed site' according to a TEK perspective. For example, TEK may provide indicators of what makes a lake reclaimed in terms of number or diversity of fish or perhaps the way the fish use the water body or the way in which they swim. Perhaps it is that the berries have a particular taste or the caribou have returned to the area to feed. Whatever the measures, there is the assumption that the concept of reclamation has been communicated.

Identifying traditional means of reclamation. Disturbance at various scales ranging from snowmobile tracks in the tundra to the construction of communities has always been a factor in the lives of northerners. Elders describe areas where caribou have grazed like lawn mowers on the tundra and the vegetation has come back extra green the years following. Caribou have been known to carve 'highways' into the tundra as they migrate on mass, one after another, leaving a well-trodden dusty trail where vegetation used to grow. Throughout the world, for example, Indigenous peoples have applied TEK in practicing controlled burning to facilitate growth of particular species dependent on fire as part of their life cycle. Knowledge of disturbances and how people have either observed re-growth or facilitated reclamation can assist in reclamation planning as part of closure initiatives.

Integrating TEK into risk assessment. A central component of closure planning is the ability to quantify and qualify risks and to explore both the magnitude and probability of those risks, a practice central to the way in which TEK is acquired. For example, a Dene hunter watches the slow freezing of the lake before her house. She evaluates weather patterns, with particular attention to freeze-thaw cycles, and monitors carefully any openings that are late to freeze. When all of the indicators point towards safety, she undergoes an ecological risk assessment: she quantifies and qualifies the ice, evaluates the likelihood of it being safe for travel and then calculates whether it is safe to travel by snow machine to go fishing. Although this example is presented in scientific terms, the process of risk assessment undertaken between western scientists and indigenous peoples who spend much time out 'on the land' is very similar.

There is great opportunity to integrate TEK into ecological risk assessment, particularly using a Bayesian paradigm which incorporates uncertainty and qualitative measures versus more traditional statistical analysis (Liedloff et al. 2009). A Bayesian paradigm also allows for a broader application of the precautionary principle, keeping in mind that there is controversy that ecological risk assessment itself can actually divert attention away from this principle. Although a controversial practice, when elements of TEK are broken down into categories (*i.e.,* objective versus subjective, primary versus secondary data, qualitative versus quantitative), there is a strong argument for the predictive capacity of TEK which can have application to both ecological risk assessment and closure planning (Tacher and Golicher 2004; Drew and Perera 2011).

An important caveat to note in using TEK as part of closure planning is that environmental changes are making it increasingly more difficult for TEK holders to use traditional measures to predict weather, environmental conditions and ecological relationships (Krupnik and Jolly 2003; Fox 2003). For example, weather is becoming more difficult to predict and extreme weather events more common. As these environmental changes continue, the uncertainty levels entered into an ecological risk assessment will increase.

8.0 CLOSING REMARKS

Finding literature that clearly and overtly links TEK to mining and the resource industry and demonstrates inclusion of TEK in operations proved challenging owing to many of the reasons outlined in Section 6.0. Efforts invested in communicating with TEK practitioners and industry officials were highly informative. Repeatedly, individuals cited examples where TEK had been considered, for example, in an environmental impact assessment process but not necessarily reported. It is strongly recommended that DDMI document, communicate and celebrate how and where TEK factors into closure planning.

This review was limited and would benefit from having additional time to critically review additional EIS reports. The sheer volume of consultant reports available for each proposed development was astounding. There are also lessons to be learned from other sectors such as forestry. A good starting point for key references related to the incorporation of TEK into forestry can be found on the website for *The Resource Centre for Aboriginal Forestry Issues in Canada* (http://www.nafaforestry.org/forest_home/knowledge_research.html). Other good references related to the fisheries sector can be accessed a through the UBC Fisheries Centre (www2.fisheries.com/archive/publications/reports/11-1/11-1b.pdf) and the NOAA Fisheries Local Knowledge Project (http://www.st.nmfs.noaa.gov/lfkproject/02_c.TEKRef.htm).

We trust the above meets your present requirements. Please do not hesitate to contact either Natasha at (250) 814.8876 or Grant (867) 873-6319 should you have any questions about this report. In advance, we thank you for the opportunity to prepare this report for DDMI.

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APPENDIX A

Science

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Golder Associates

Rio Tinto

Appendix II-2

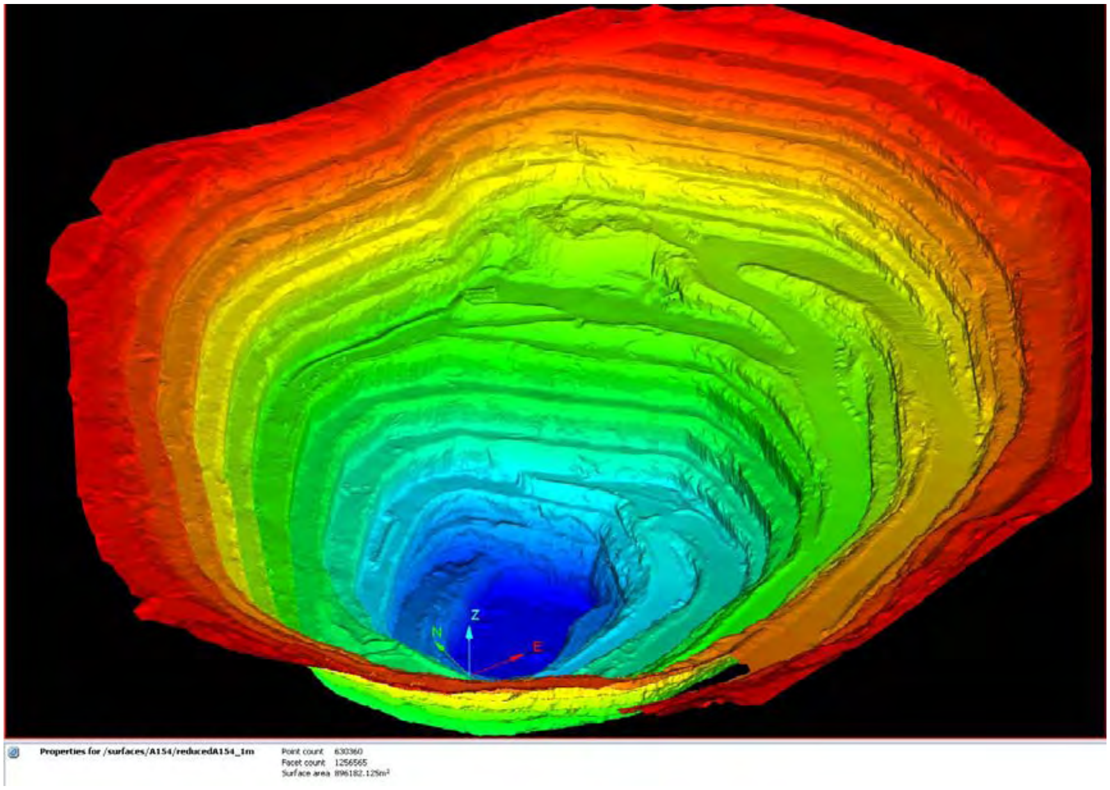
Total Surface Area of Exposed Metasedimentary Rock for A154 Pit

Rio Tinto

I-Site 3D Laser Scanner Pit Wall Mapping of Exposed Metasedemintary (Type 3) Rock in A154

Total Surface Area of Exposed Metasedemintary Rock for the A154 Pit

01 December 2011



Properties for /surfaces/A154/reducedA154_1m

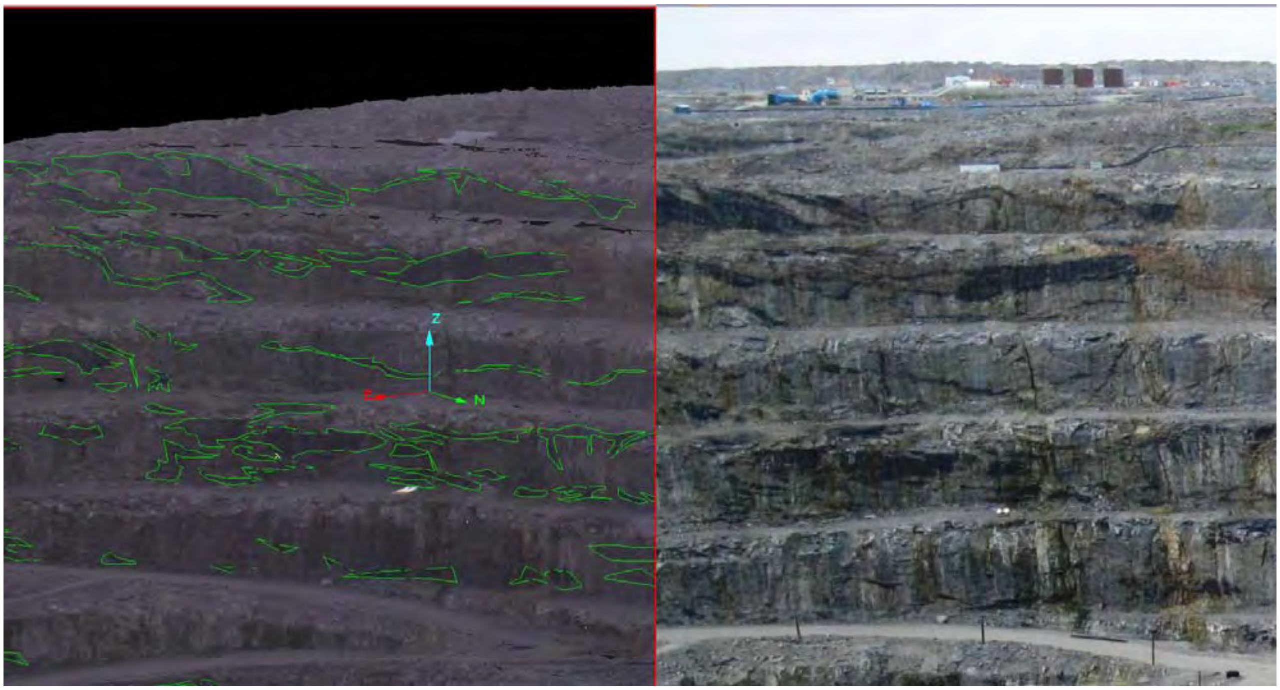
Point count 630360
Facet count 1256565
Surface area 896182.125m²

Digital Scans of the A154 pit was taken with the I-SiTE 8800 Scanner that is an advanced laser scanner hybrid, comprising a compact laser scanner system, digitalpanoramic camera, digital tilt compensator and survey alignment telescope. The laser scanner creates a 3D point cloud of the surface it is scanning, and then the high resolution image is automatically rendered within the I-SiTE Studio software. The image and point cloud are set to local coordinates by importing the location of the I-SiTE station from the surveyors GPS unit. This provided an added advantage of visualising the A154 pit walls in 3D photographic detail.

Once the photo draped scans of the pit were rendered they were quartered in to North, East, South and West quadrants and exposed metasedimentary surfaces were isolated for total surface area per quadrant. A total surface area of all exposed metasedimentary rock for the entire pit was calculated.

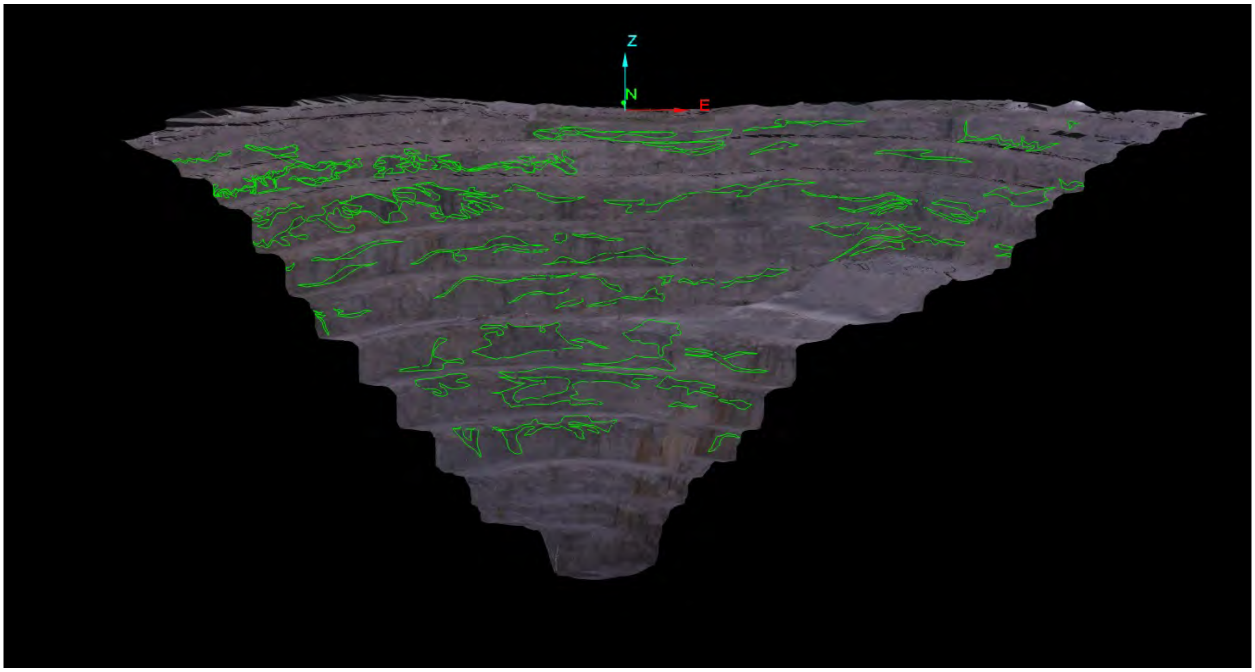
Total exposed metasedimentary rock in A154 Pit: 51 965m2

Total surface area of A154 Pit: 896 143m2



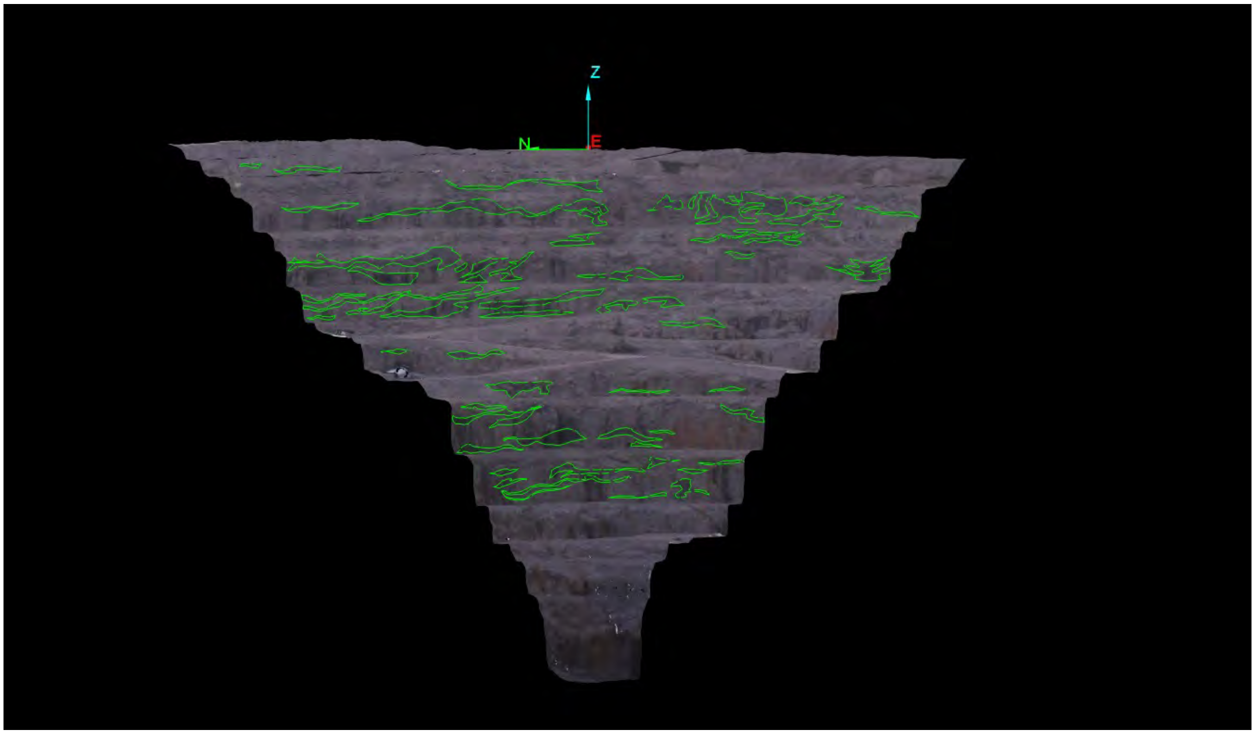
I-Site Pit wall mapping compared to hi-resolution photo of same area

A154 North Quarter of Pit: Total surface area 243097.830m2



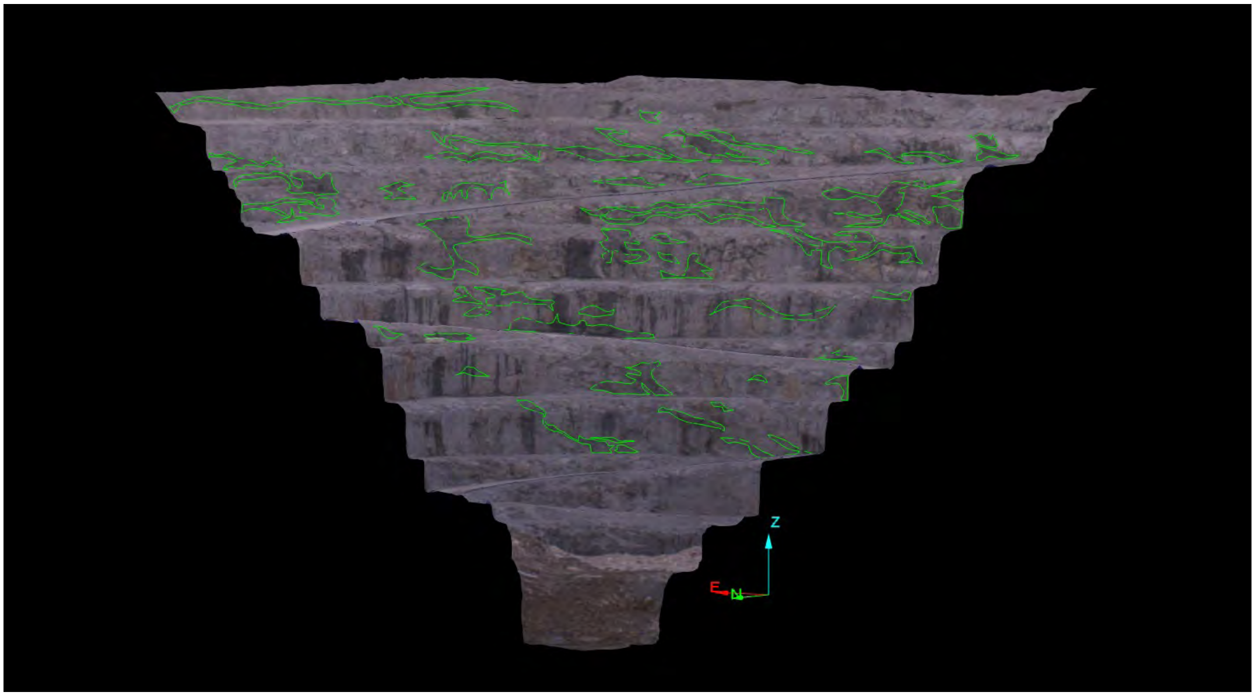
Total enclosed area (best-fit plane) 18431.434m2

A154 East Quarter of Pit Total surface area 171306.768m2



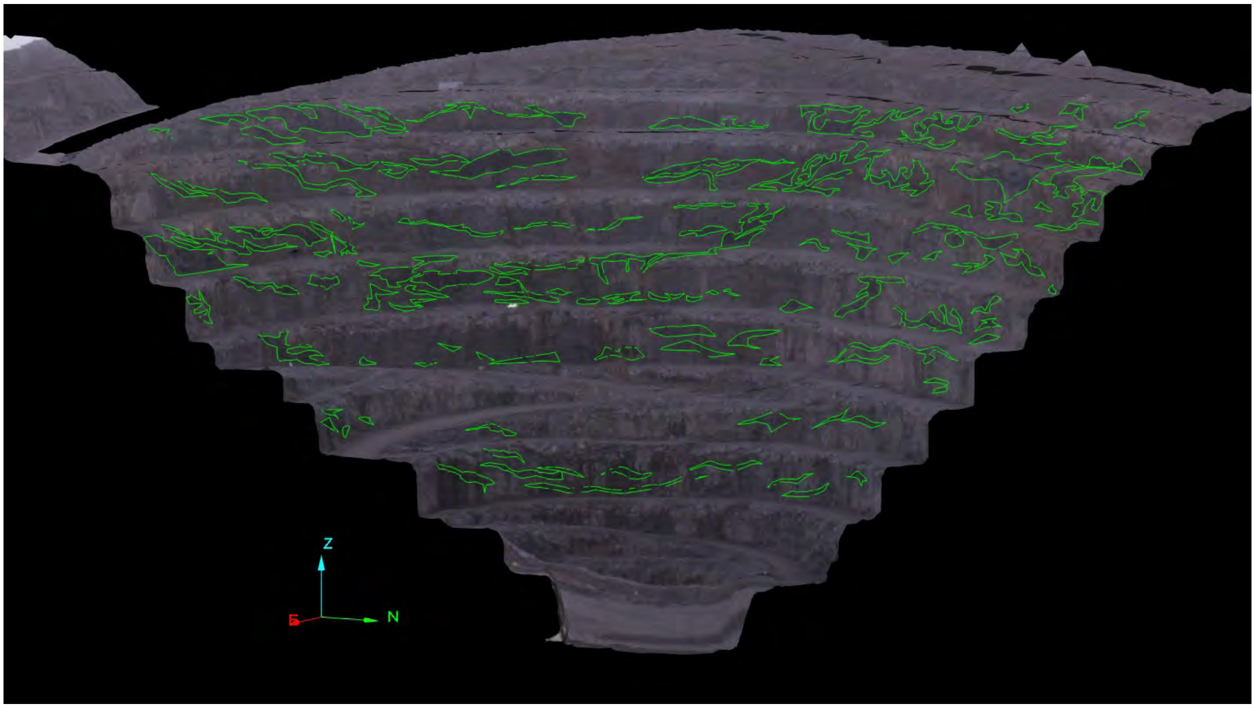
Total enclosed area (best-fit plane) 6679.642m2

A154 South Quarter of Pit Total surface area 179538.204m2



Total enclosed area (best-fit plane) **9045.391m2**

A154 West Quarter of Pit Total surface area 481738.696m2



Total enclosed area (best-fit plane) **17809.474m2**

A154 PIT Total surface area 896143.294m2

A154 NORTH LOOPS
Total enclosed area metasedimentary rock 18431.434m2

A154 EAST LOOPS
Total enclosed area metasedimentary rock 6679.642m2

A154 SOUTH LOOPS
Total enclosed area metasedimentary rock 9045.391m2

A154 WEST LOOPS
Total enclosed area metasedimentary rock 17809.474m2

Total enclosed area ALL A154 LOOPS metasedimentary rock 51965.941m2

896143.294m2 Total A154 surface area

51965.941m2 Total A154 metasediment exposed surface area

844177.353ms Total non-metasediment exposed area

Appendix II-3

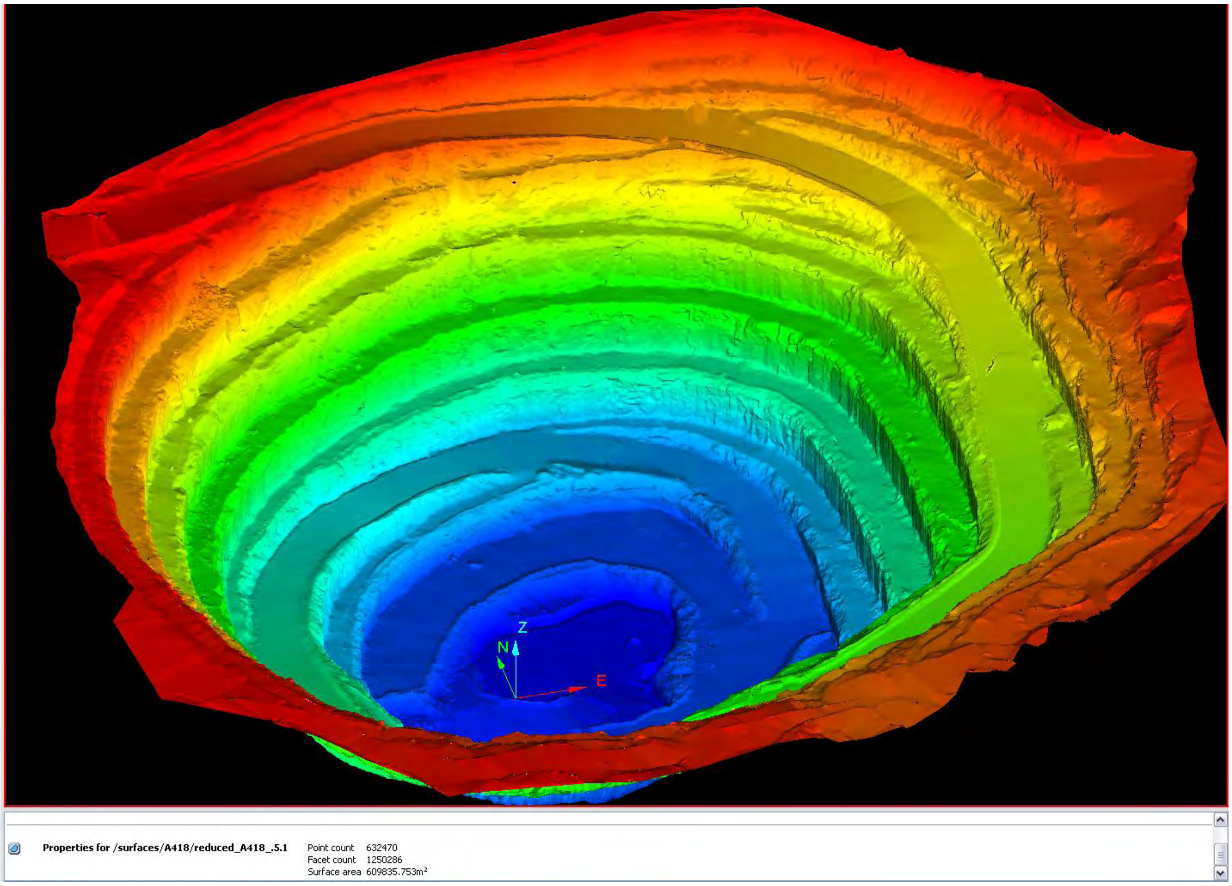
Total Surface Area of Exposed Metasedimentary Rock for A418 Pit

Rio Tinto

I-Site 3D Laser Scanner Pit Wall Mapping of Exposed Metasedemintary (Type 3) Rock in A418

Total Surface Area of Exposed Metasedemintary Rock for the A418 Pit

01 December 2011



Properties for /surfaces/A418/reduced_A418_.5.1

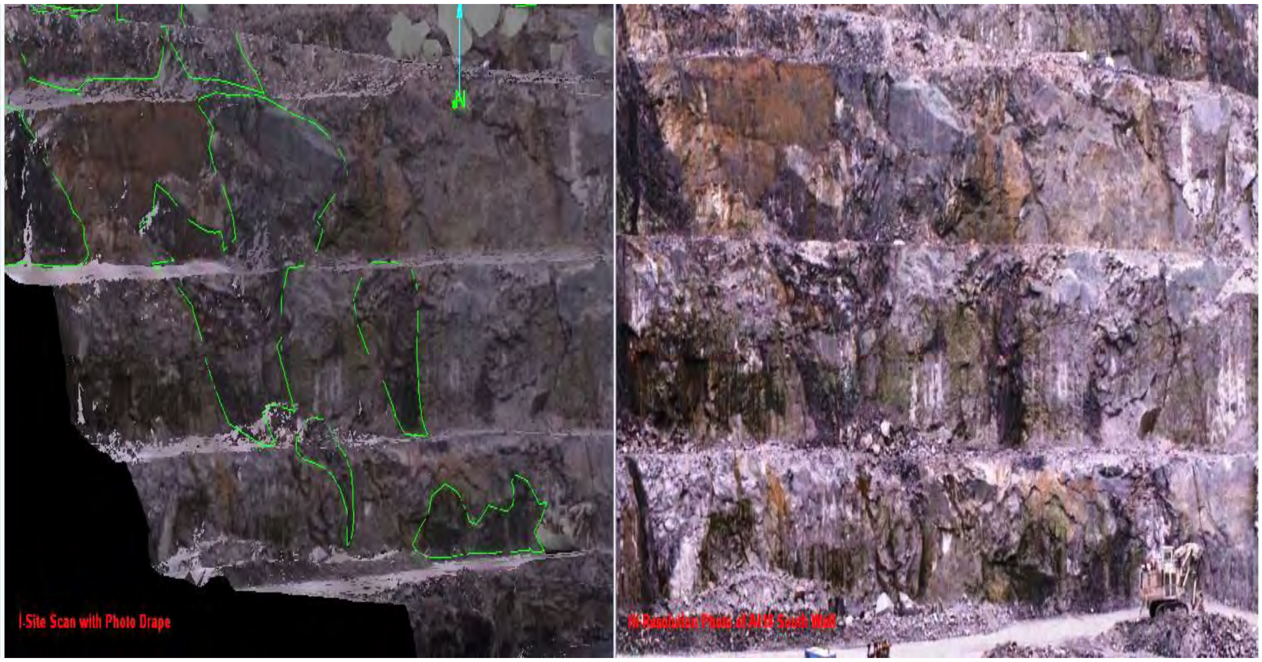
Point count	632470
Facet count	1250286
Surface area	609835.753m²

Digital Scans of the A418 pit was taken with the I-SiTE 8800 Scanner that is an advanced laser scanner hybrid, comprising a compact laser scanner system, digitalpanoramic camera, digital tilt compensator and survey alignment telescope. The laser scanner creates a 3D point cloud of the surface it is scanning, and then the high resolution image is automatically rendered within the I-SiTE Studio software. The image and point cloud are set to local coordinates by importing the location of the I-SiTE station from the surveyors GPS unit. This provided an added advantage of visualising the A418 pit walls in 3D photographic detail.

Once the photo draped scans of the pit were rendered they were quartered in to North, East, South and West quadrants and exposed metasedimentary surfaces were isolated for total surface area per quadrant. A total surface area of all exposed metasedimentary rock for the entire pit was calculated.

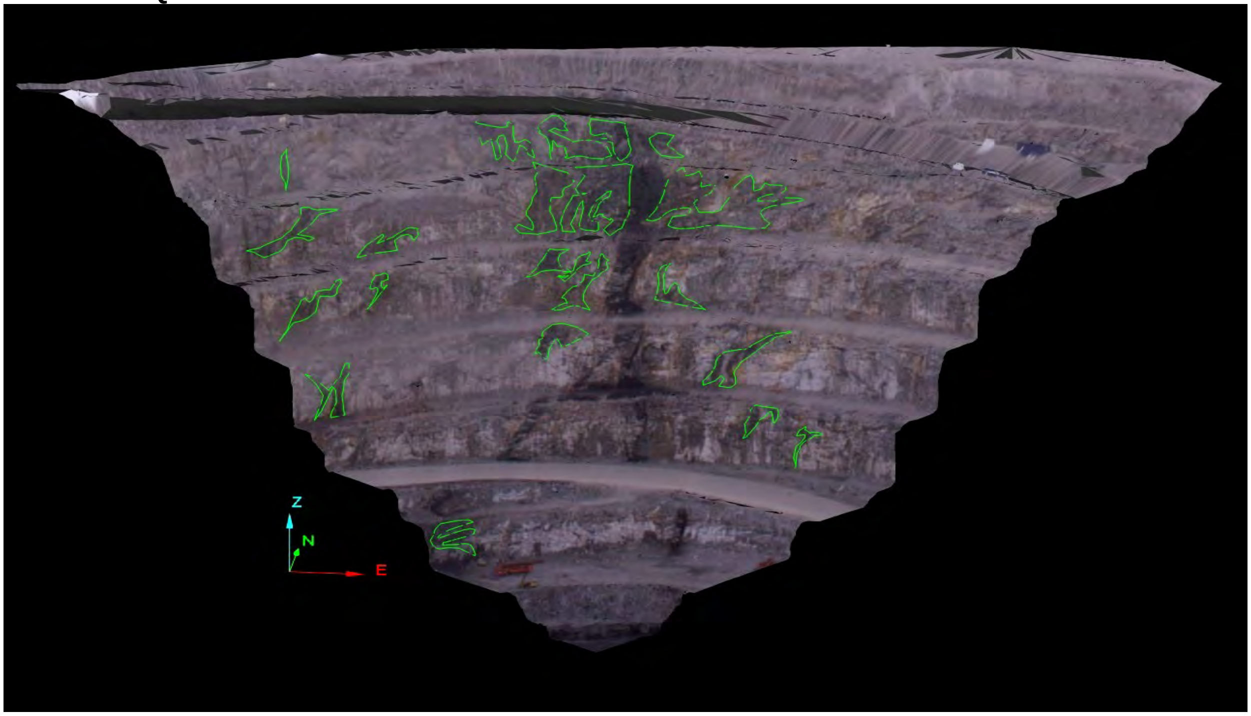
Total exposed metasedimentary rock in A418 Pit: 26 070m2

Total surface area of A418 Pit: 609 835m2



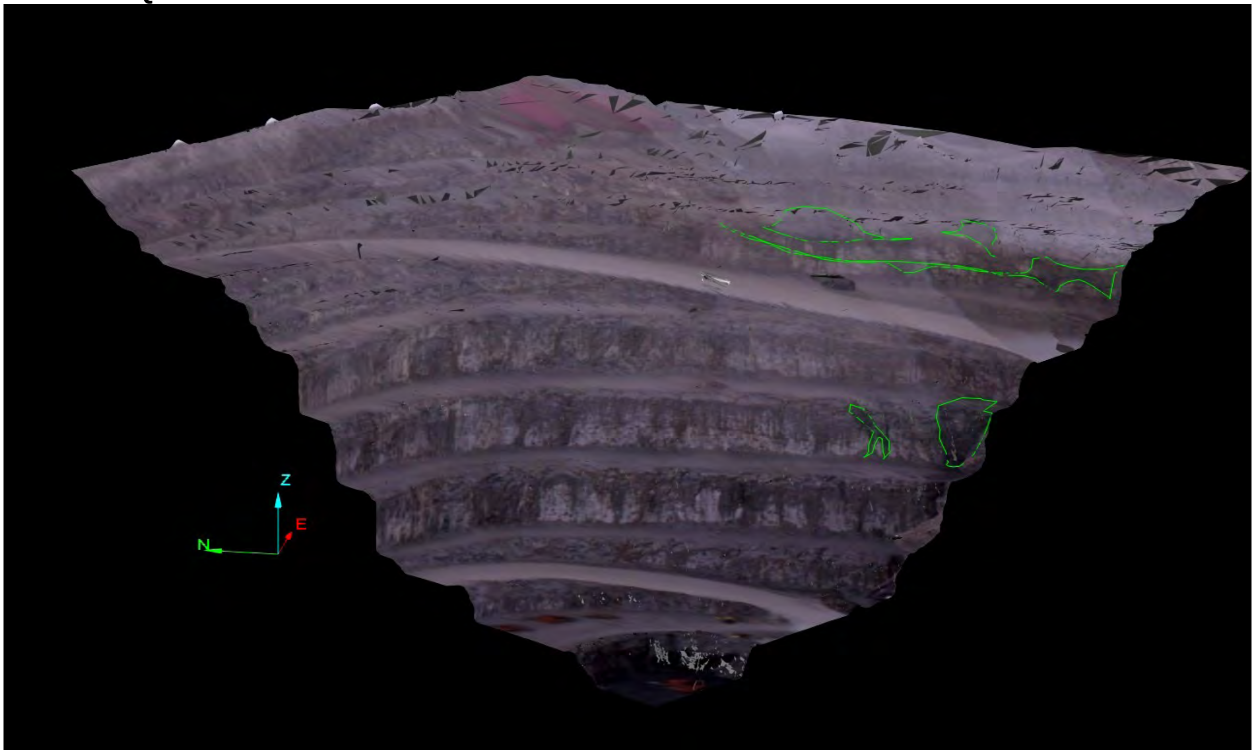
I-Site Pit wall mapping compared to hi-resolution photo of same area

A418 North Quarterof Pit Total surface area 126043.854m2



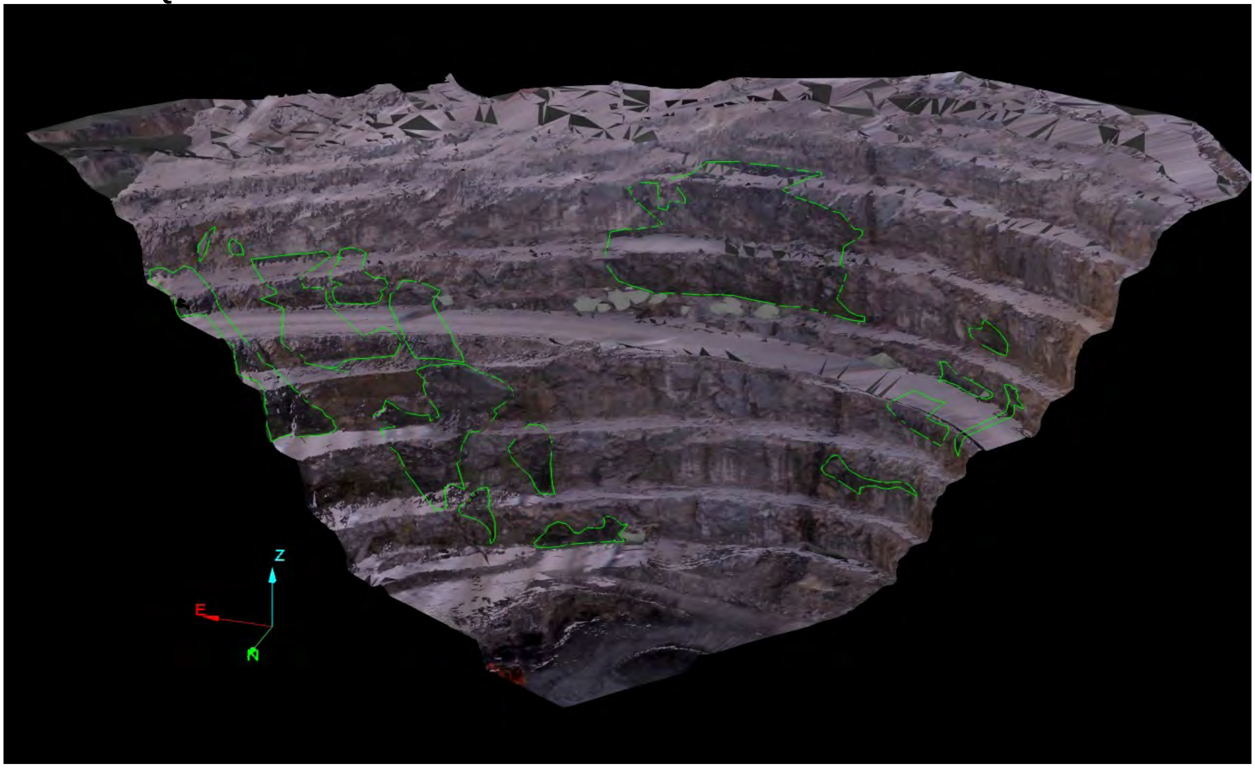
Total enclosed area (best-fit plane) **4302.484m2**

A418 East Quarter of Pit   Total surface area 153337.806m2



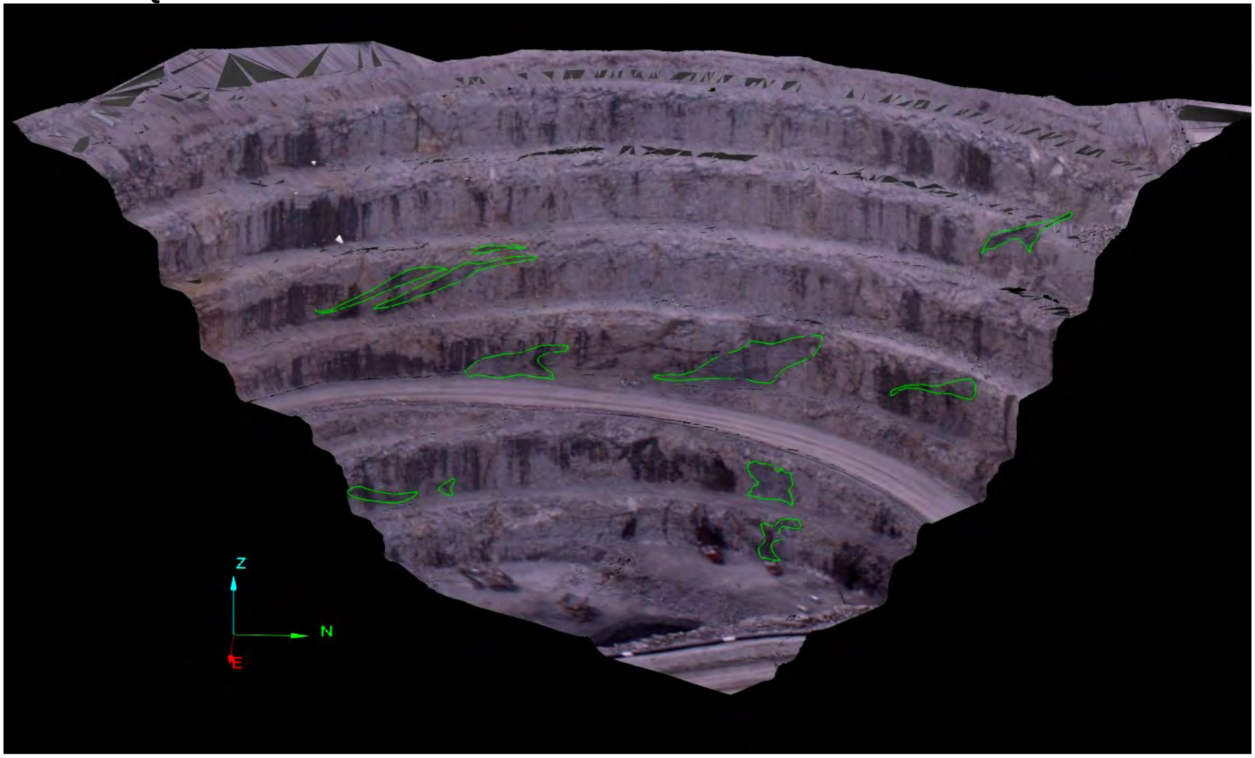
Total enclosed area (best-fit plane) **1958.893m2**

A418 South Quarter of Pit Total surface area   176762.277m2



Total enclosed area (best-fit plane)   16968.858m2

A418 West Quarter of Pit   Total surface area 153355.750m2



Total enclosed area (best-fit plane)   2840.152m2

A418 PIT Total surface area 609835.753m2

A418 NORTH LOOPS
Total enclosed area metasedimentary rock 4302.484m2

A418 EAST LOOPS
Total enclosed area metasedimentary rock 1958.893m2

A418 SOUTH LOOPS
Total enclosed area metasedimentary rock 16968.858m2

A418 WEST LOOPS
Total enclosed area metasedimentary rock 2840.152m2

Total enclosed area ALL A154 LOOPS metasedimentary rock 26070.388m2

609835.753m2 Total A154 surface area

26070.388m2 Total A154 metasediment exposed surface area =

583765.365m2 Total non-metasediment exposed area.

Appendix II-4

Pit Wall Washing Methods Description

Diavik Diamond Mines Inc.
P.O. Box 2498
5007 – 50th Avenue
Yellowknife, NT X1A 2P8
Canada
T (867) 669 6500
F (867) 669 9058

Internal memo

From	Lianna Smith
Department	Strategic Development
To	Gord Macdonald
CC	
Reference	**Pit wall washing—methods**
Date	14 Aug 2012

As requested, I completed a pit wall washing program Monday Aug 6, 2012 to contribute to solute loading estimates for pit flooding.

Site selection

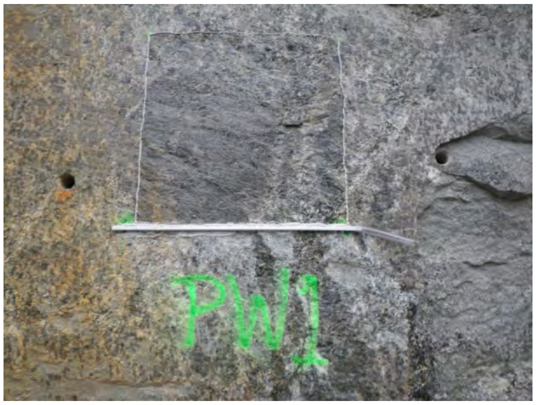
At this time, only walls in the A154 pit were safe to access. Accessing the pit walls in A418 was determined jointly with the Geotechnical Engineering group to be unsafe at this time. The A418 pit walls are more fractured and have more loose rock.

Three locations were selected in the A154 pit based on safety, accessibility and practicality. The site locations were in areas with no unstable, loose rock overhead; within walking distance from the main ramp; and at heights reachable without ladders or other support. The locations were selected such that the semi-flexible plastic trough could be attached to the pit wall to collect the rinse water.

Two granite locations and one metasediment (biotite schist) location were selected on the 190 catchment bench. PW1 and PW2 were the granite locations and PW3 was the metasediment location.

PW1
Granite with fine to coarse/pegmatitic zones. No fractures. Iron staining limited to bottom left corner (estimated at 2% of surface area). Good rinse water recovery (approximately 95%)
Full sample ID for analysis by Maxxam and import into MP5: A154-190-PW1

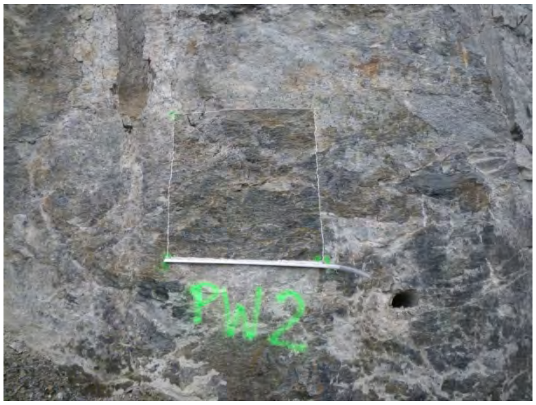
Dry – before rinse



Wet – after rinse

PW2
Granite, with fine to coarse zones. One in-filled, linear fracture running diagonally in upper part of sample site (not visible in photo). Some patchy iron staining estimated at 10% of surface area. Good rinse water recovery (approximately 95%).
Full sample ID for analysis by Maxxam and import into MP5: A154-190-PW2
Field blank ID for analysis by Maxxam and import into MP5: A154-190-PW2-2

Dry – before rinse



Wet – after rinse

PW3
Metasediment, fine grained, with some chlorite visible on surface. Likely slip surface. Some fracturing, but much less than typical metasediment occurrences observed in the pit wall. Iron staining estimated at 25% with pervasive staining in bottom third of sample area. Fairly good rinse water recovery (approximately 85%), with some rinse water loss to bottom left (observable in “wet” photo) due to overhanging fracture.
Full sample ID for analysis by Maxxam and import into MP5: A154-190-PW3

Dry – before rinse

Wet – after rinse

Methods

At each site location a 1 m x 1 m area was delineated using silicone sealant. A semi-flexible plastic trough was attached to the wall at the bottom of the 1 m x 1 m area to permit the rinse water to flow to the sample collection bottle. A 1 ¼-inch flexible PVC tube was attached to the trough to direct the rinse water into the sample collection bottle.

The sample location was rinsed with 1 L of in-house deionized (DI) water using a standard 500 mL lab squirt bottle. The test site was rinsed in a zig-zag pattern, ensuing the entire sample area was rinsed, and repeated until 1 L DI water was used. Rinse water was collected in 1 L HDPE bottles provided by the Environment group (“routine” sample bottles). A field blank was collected at PW2.

The collected rinse water was split into aliquots for the field parameter measurements pH, alkalinity, Eh, and EC, ammonia, phosphate, ferrous iron, turbidity and TSS, and for dissolved metals, total metals and nutrients.

Alkalinity was measured using the Hach digital titrator; pH, Eh and EC were measured using the probes and methods at the Test Piles field lab. Turbidity and TSS were measured by the Environment group. Ammonia, phosphate and ferrous iron were analyzed using Hach reagents and spectrophotometer. The aliquots for dissolved metals, total metals and nutrients were sent to Maxxam commercial lab as part of a regular Environment group shipment. Field parameter results are presented below.

Each location was 1 m by 1 m and each location was washed with 1 L of distilled water to permit straight-forward solute loading calculations, i.e.:

$$x\ \frac{mg}{L} \times 1\ L\ per\ 1\ m^2 wall\ = \frac{x\ mg}{m^2\ wall}$$

Locations with minimal fractures and a single lithology were selected so that scaling calculations would be more straightforward, i.e. assuming an overall pit shell surface area will be estimated for pit flooding calculations/modeling, and assuming the metasediment/granite distribution calculated using photogrammetry would be used.

This memo will be updated when metals and nutrient results are provided by Maxxam.

Appendix II-5

Heat Transport and the Effects of Climate Change in a Large-scale Waste Rock Pile Located in a Continuous Permafrost Region at Diavik Diamond Mine

Heat Transport and the Effects of Climate Change in a Large-scale Waste Rock Pile Located in a Continuous Permafrost Region at Diavik Diamond Mine

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Abstract

An on-going field study at the Diavik Diamond Mine, NT, Canada, is examining the hydrology, geochemistry, microbiology, gas transport, and heat transport mechanisms controlling acid rock drainage (ARD) in low sulphide waste rock the Canadian Arctic. The mine is located in the zone of continuous permafrost. This paper is focused on the thermal behaviour within a large-scale waste rock pile. Three drill holes to 40 m depth were used to monitor temperature inside the waste rock pile, beginning in July 2010. Temperatures measured at 5 m spacing indicate that the 0 °C isotherm is currently at 11 m below the top of the pile, reflecting thermal conditions following pile construction. Temperature variations in these drill holes are controlled by conductive heat transfer. Conduction modeling predicts that, with climate change, the 0 °C isotherm will be located at 7 m depth in 2110. Placement of a near-saturated till layer over the waste rock is predicted to cause the 0 °C isotherm only penetrate to 3.9 m in 2110.

Key Words: acidic drainage, permafrost, active layer, thermal modeling

Introduction

An on-going field study at the Diavik Diamond Mine, NT, Canada, is examining the hydrology, geochemistry, microbiology, gas transport, and heat transport mechanisms controlling acid rock drainage (ARD) in low sulphide waste rock located in the Canadian Arctic. At the end of the mine life, up to 120 Million tonnes (Mt) of waste rock will be stockpiled in a 60 to 80 m high permanent pile covering 3.5 km^2. The waste rock excavated during operations is analyzed for sulfur content and segregated into Type I (<0.04 wt % S), Type II (0.04 to 0.08 wt % S) or Type III (>0.08 wt % S) and stored in separate areas within the waste dump. Dry Engineered covers are a closure concept for the Type II and Type III waste rock dumps, including re-sloping the Type III areas to 18.4° (3H:1V) and covering with a 1.5 m lower permeability layer of till, and a 3 m layer Type I waste rock to act as an active freeze-thaw layer (Smith, 2009).

To monitor the evolution of thermal, geochemical and hydrogeological processes within the waste rock dump, three 8-inch holes spaced at 5 m, FD1 (32.2 m depth), FD2 (30.7 m depth) and FD3 (40.2 m depth), were drilled in May 2010 to install instruments. The instruments include thermistor cables, gas lines, soil water suction samplings (SWSS), ECH$_2$O moisture content sensors and permeability balls (Figure1). The drill holes were back filled with 3/4 inch crush and silica filter sand. Thermistors were installed at 5 m vertical spacing and ground temperatures are recorded at a 12-h interval. Hourly air temperature is measured at the Diavik meteorological station, which is about 1 km from the waste rock dumps.

This paper presents measured temperatures from installed thermistor cables in the waste rock dump. In 2011, additional boreholes were instrumented in other locations within the waste dump, but these data are currently being processed. Numerical simulations were carried out for a cover system based on the closure concept of the waste dump and for an uncovered waste rock pile to examine the thermal evolution into the future and the role of long-term climate change. The results of the simulations show the significant of the predicted future climate on the depth of the 0 °C isotherm in the waste dump and permafrost ground temperatures.

Figure1: Diavik Diamond Mine site map with location of the drill holes

Experimental Results and climate change

Air temperatures

Monthly averaged air temperatures vary significantly throughout the year, with the warmest temperatures in July and coldest in January. Indeed, over a ten-year period (from 2000 to 2010), monthly averaged air temperature in January and July was -29.3 °C and 11.5 °C, respectively (Figure 2A). Daily averaged air temperatures also varied significantly, however they showed greater fluctuation in winter (peak in January) than in summer (peak in July). It can be noted that the daily average air temperatures were -43 °C on January 21, 2002 and -5.2°C on January 19, 2009, and varied between 22.3 °C on July 27, 2003 and 4.8 °C on July 2, 2003 (Figure 2A).

The ground surface temperature variations are controlled by the local variation in air temperatures, precipitation, wind speed, solar radiation, among other factors (Frauenfeld et al., 2007). Air freezing and thawing indices, I_{af} (°C-days) and I_{at} (°C-days), which are used in describing the intensity of air-temperature variations, were calculated using Equation 1 and 2 in which t is time and T is air temperature in °C. Over the measured period, the averaged value of I_{af} was -4426.3 °C-days and the averaged value of I_{at} was 1082.7 °C-days. A linear trend line shows both I_{af} and I_{at} have increased over this 10-year period (Figure 2B). In fact, the thawing-index trend line indicates that I_{at} has increased 36 °C-days/decade (between 2000 and 2010) whereas the freezing-index trend line shows I_{af} has increased about 120 °C-days/decade. Frauenfeld et al. (2007), who analyzed air temperature data for various Northern Hemisphere land regions at latitudes north of 50 °N for recent decades, found the freezing index has increased on average by 85.6 °C-days/decade while thawing index has increased by 44.4 °C-days/decade. The differences in the rates (both I_{af} and I_{at}) between this study and Frauenfeld et al. (2007) could reflect the shorter length of the period of available data to determine the rates (a decade versus three decades) and/or local variations.

$$I_{atf} = \int_{t_o}^{t_1} T\mathrm{d}t \qquad T < 0°C \qquad \text{(Equation 1)}$$

$$I_{at} = \int_{t_o}^{t_1} T\mathrm{d}t \qquad T > 0°C \qquad \text{(Equation 2)}$$

Average mean annual air temperature (MAAT) was -9.1 °C over the decade and the trend line indicates an increasing rate of 0.73 °C/decade (Figure 2C). Figure 2C also shows that in 2004 air temperature was significantly colder than MAAT at -12.1 °C, whereas in the years 2006 and 2010 MAATs were much warmer at -6.4 °C and -6.7 °C, respectively. Chylek et al. (2009) determined long term air temperature trends (between 1880 and 2008) for the low Arctic (64 °N - 70 °N). They found three distinct periods: strong warming periods between 1880 - 1940 and 1970 - 2008 with warming rate of 0.59 °C/decade and 0.38 °C/decade, respectively, separated by a cooling period between 1940 and 1970 with a cooling rate of -0.36 °C/decade. Again, the difference in warming between this study and Chylek et al. (2009) reflects the length of the analysis and local fluctuations. The warming of air temperatures can also be associated with an increase in thawing days and a decrease in freezing days. Averaged thawing and freezing days were 122.4 days and 242.9 days. The number of thawing days has increased 5.7 days/decade and the number of freezing days has decreased 6.0 days/decade over the period based on available data (Figure 3).

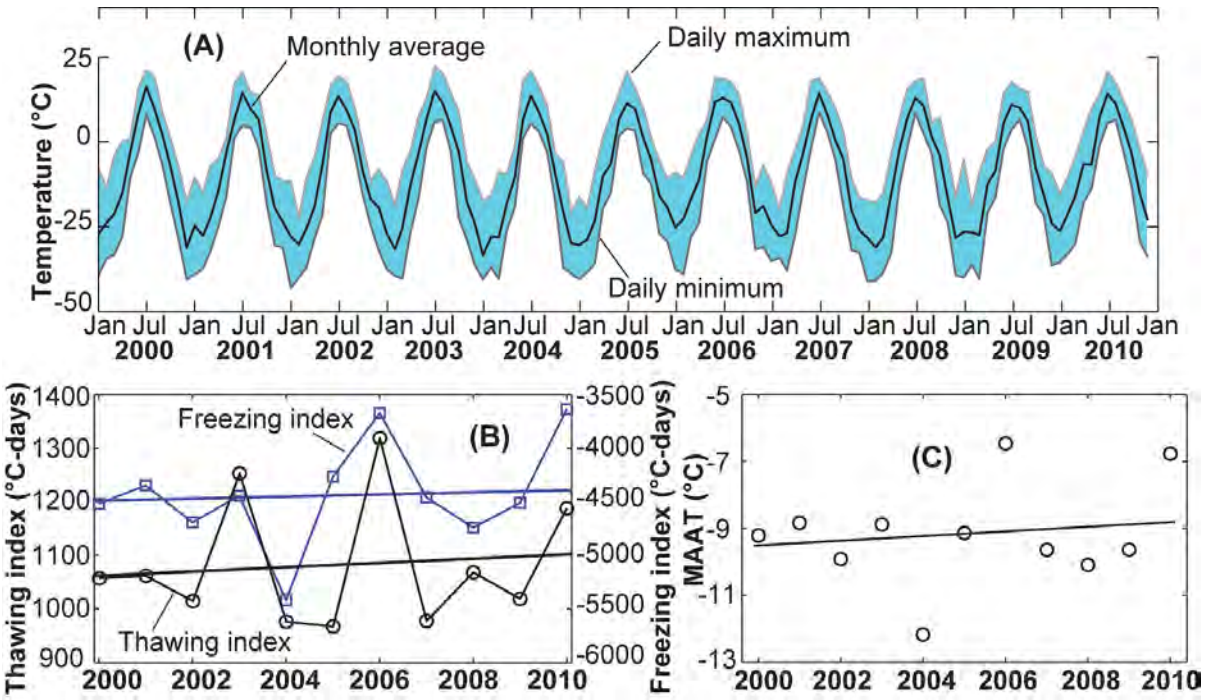

Figure 2. Monthly averaged air temperatures plotted with daily maximum and minimum air temperatures(A), calculated air thawing and freezing indices based on daily averages (B) and calculated mean annual air temperate (MAAT) (C). Data from Diavik Mine weather station.

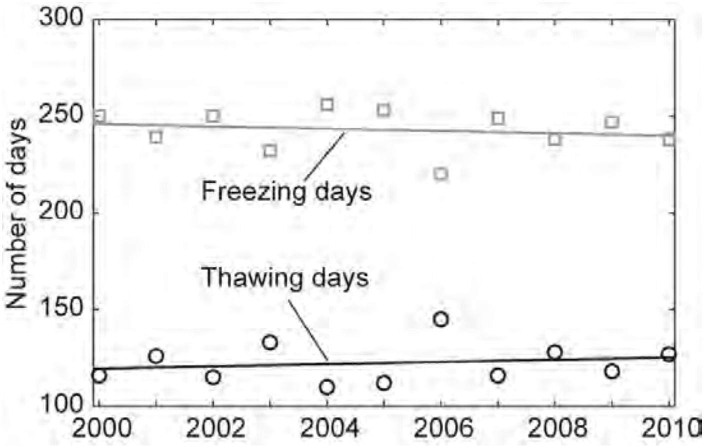

Figure 3. A variation of thawing and freezing days of air temperatures

Ground Temperatures

Ground temperatures below the surface of the waste rock pile can be represented using periodic functions obtained using Fourier analysis. The following is such an expression used to describe temperature as a function of time:

$$T(y,t) = a_0 + \sum_1^n \left(a_i \cos(i\omega t) + b_i \sin(i\omega t) \right) \qquad \text{(Equation 3)}$$

Where a_0 represents the mean annual ground temperature (MAGT) at a specific depth y, ω is the fundamental angular frequency. $A_i = (a_i^2 + b_i^2)^{1/2}$ and $\phi_i = \arctan(a_i/b_i)$ are amplitude and phase of ground temperatures corresponding to angular frequency iω. For representing ground temperatures, the value n =2 is sufficient (Tan and Ritchie, 1997).

Under assumptions of a periodically varying ground surface temperature and one-dimensional conductive heat transfer, the apparent (effective) thermal diffusivity (κ) can be calculated using phase or amplitude equations:

- Phase equation

$$\kappa = \frac{1}{2\omega}\left(\frac{y_2 - y_1}{\delta t}\right)^2 \qquad \text{(Equation 4)}$$

- Amplitude equation

$$\kappa = \frac{\omega}{2}\left(\frac{y_2 - y_1}{\ln\left(\frac{|T_2|}{|T_1|}\right)}\right)^2 \qquad \text{(Equation 5)}$$

Where: δt is phase difference,T_1 and T_2 are temperature amplitude at two depths y_1 and y_2. The values of Fourier's coefficients are shown in Table 1 at selected depths and the periodic functions described by Equation 3 with the calculated coefficients are plotted in Figure 4. The Fourier-series curves fit the monthly averaged ground temperatures very well. Furthermore, the ground surface temperatures were measured within 1 cm of the waste pile surface, which show the mean annual surface temperature (MAST) of -6.3 °C and amplitude of 20.5 °C. The amplitudes of ground temperature variations reduced rapidly with depth from 20.36 °C at the surface to 0.14 °C at 14.50 m depth (Table 1).

Table 1. Calculated Fourier's coefficients with ω=2π/365

Depths (m)	a_0	a_1	b_1	a_2	b_2	A_1
Borehole FD1						
Surface	-6.30	18.89	7.60	1.03	-0.14	20.36
1.86	-2.19	-4.60	-9.02	0.43	1.03	10.13
6.86	-0.97	0.75	-2.9	-0.10	0.63	3.00
11.86	-0.56	0.72	-0.20	-0.33	0.21	0.75
16.86	-0.05	0.01	0.01	-0.04	-0.02	0.01
Borehole FD2						
Surface	-6.36	-18.90	-8.20	1.76	-0.51	20.60
0.66	-4.80	-11.18	-10.16	1.50	-0.15	15.11
5.66	-1.08	0.73	-4.18	-0.16	0.56	4.24

10.66	-1.01	0.92	-0.54	-0.19	0.38	1.07
Borehole FD3						
4.50	-0.22	0.16	-3.33	-0.58	1.14	3.33
9.50	-0.67	0.71	-1.02	-0.33	0.67	1.24
14.50	-0.13	0.14	0.03	-0.08	-0.04	0.14
19.50	-0.32	0.00	-0.07	0.02	-0.03	0.07

Based on monthly averages, temperature profiles at FD1, FD2 and FD3 show the depth of the 0 °C isotherm at 11.5, 10.0 and 12.5 m, respectively (Figure 5). The depth of the 0 °C isotherm is expected to change over time as it evolves toward an equilibrium profile following pile construction, and the superimposed effect of global climate change. From December to April, and from the surface to the borehole depth of 40 m, ground temperatures were below 0 °C. The other months the upper zone of the waste dump was above 0 °C. The measured ground temperatures have not shown significant increase in temperature associated with oxidation of sulphide minerals at any depth when the overall temperature trend is examined.

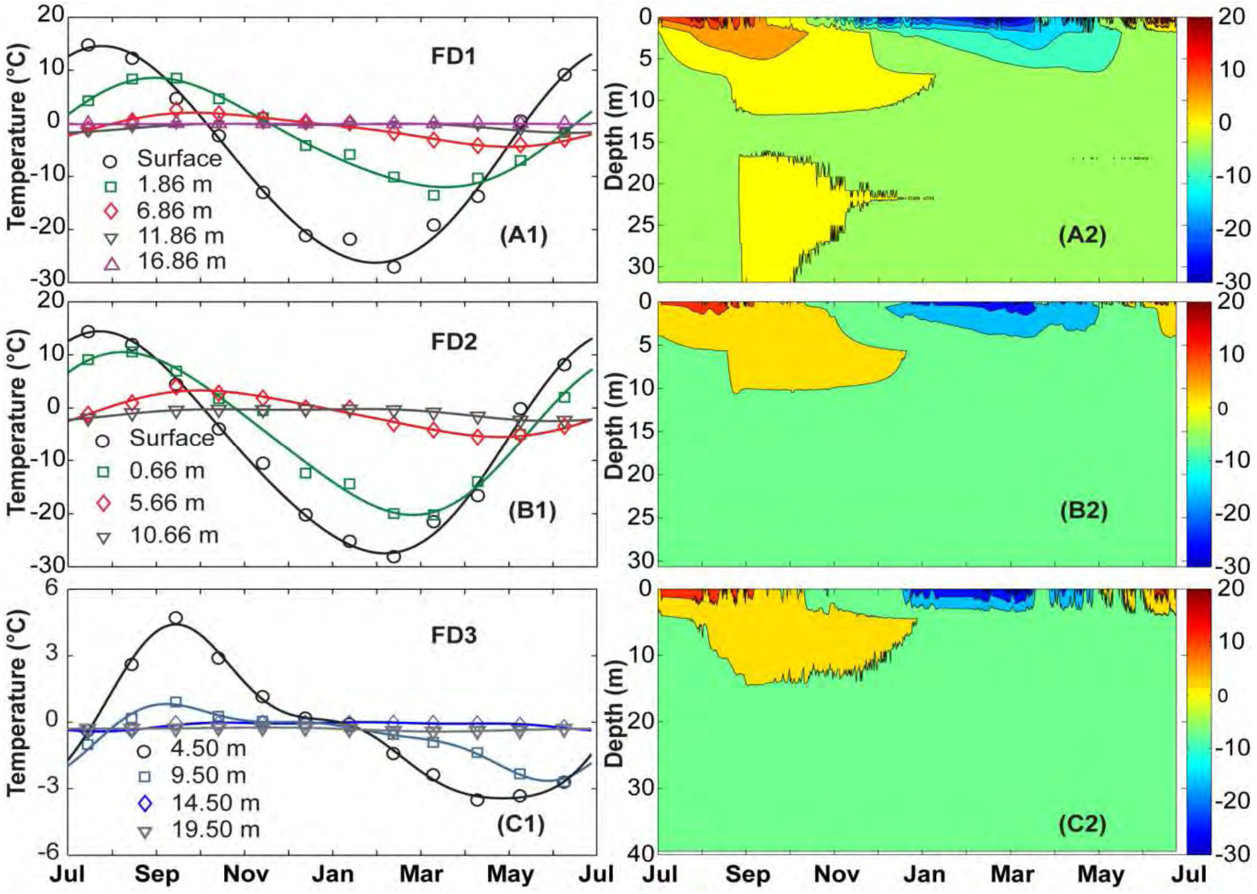

Figure 4. Monthly averaged ground temperatures from July 2010 to July 2011 at selected depths of FD1 (A1), FD2 (B1) and FD3 (C1); time-temperature-depth plot of FD1 (A2), FD2 (B2) and FD3 (C2).

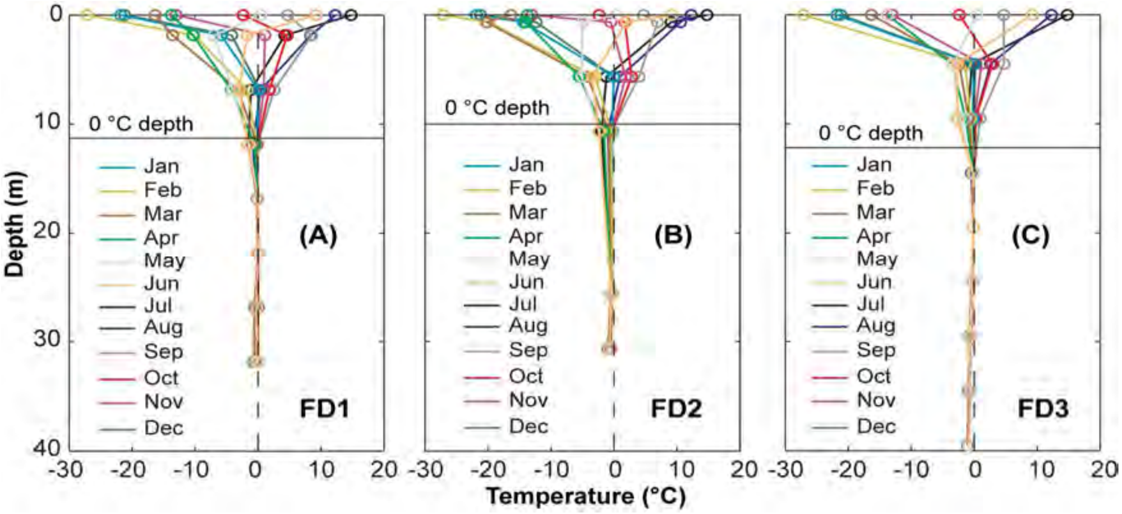

Figure 5. Temperature profiles of FD1 (A), FD2 (B) and FD3 (C)

The relation of the amplitude ratios between surface temperature and ground temperatures at depths were fitted well using an exponential curve with $R^2 = 0.96$ (Figure 6A). A linear regression was used to fit the relation between phase delay with depths to 14.50 m (Figure 6B) $R^2 = 0.97$ and below 14.5 m ground temperatures were strongly attenuated, as indicated by points that did not follow the linear regression line. An exponential curve was used to fit the relation between amplitude ratios and phase delays with $R^2 = 0.95$ (Figure 6C) for those ground temperatures to 14.5 m depth. The curves shown in Figure 6 indicate that heat transfer by conduction dominates in the waste dump and bulk thermal diffusivities were determined to be 5.39×10^{-7} m²/s (Equation 5) and 8.49×10^{-7} m²/s (Equation 4) and with an average of 6.94×10^{-7} m²/s. The average bulk thermal diffusivity is comparable to the value of 7.96×10^{-7} m²/s of a 15-m high experimental waste rock pile at the Diavik site (the Type I test pile; Pham et al., 2011).

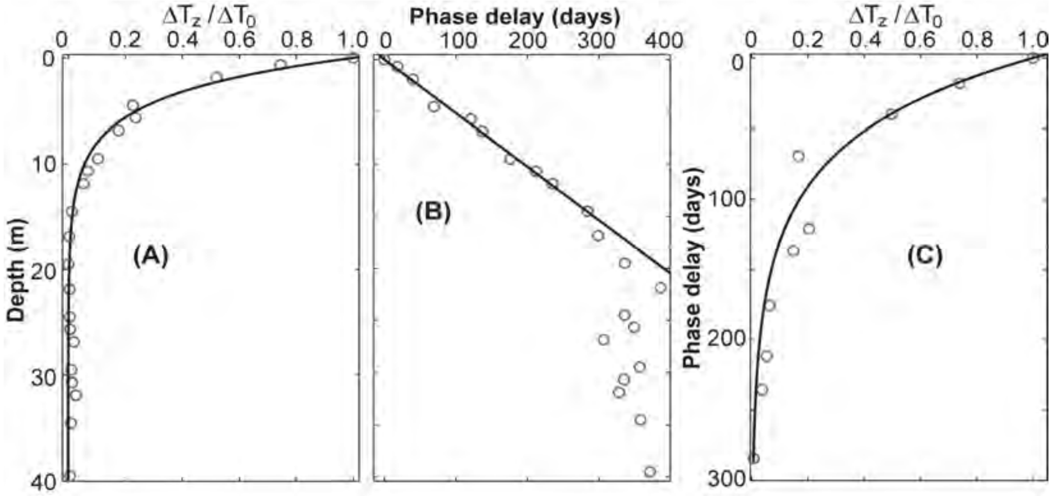

Figure 6. Relation between depth and amplitude ratio (A); depth and phase delay (C); phase delay and amplitude ratio (C)

Modeling Climate change

The climate models were run in two sets of six model members, one set to simulate the historical climate of the earth, and the other set was to simulate the future climate using up-to-date data adjustment (available up to early 2007) corresponding to the IPCC's A2 scenario (Nakicenovic and Swart, 2000). This makes the prediction closely resemble the A1B greenhouse gas/aerosol forcing scenario. The predictions of minimum, mean, and maximum temperatures from the assembled mean climate model were compared to those observed at Environment Canada's weather stations at Lupin A and Ekati and the limited data from the Diavik mine site for the period through to 2007. The predictions of annual temperature rise from 1970 to 2060 and are shown in detail in Figure 7:

- Maxima: from -8.3 °C to -2.8 °C, a rise of 5.5 °C over the 90 year period or 0.061 °C/year.
- Mean: from -11.0 °C to -6.0 °C, a rise of 5.0 °C over the 90-year period or 0.056 °C/year.
- Minima: from -14.7 °C to -9.3 °C, a rise of 5.4 °C over the 90-year period or 0.060 °C/year.

The predicted annual temperatures show a relatively constant rate of temperature increase over the period. The predicted-mean annual temperatures match closely to the measured MAATs although there were some years when the measured MAATs was closer to the predicted minimum or maximum, as expected (Figure 7A). Warming rates for months in the transitions between the four seasons are shown in Table 2. In January, the warming trends are quite significant for both the minima and maxima, which are the largest warming rates, and the warming rate of minima temperatures are slightly higher (Table 2 and Figure 7B). The warming rates in April and October are similar and quite comparable to the mean-annual warming rates, whereas the warming rates in July are the smallest (Table 2). In Figure 7A, the predicted minimum and maximum annual temperatures are the predictions of coldest and warmest climate models. The predicted mean annual temperatures are the mean of the predicted minimum and maximum annual temperatures.

Table 2. Predicted future air temperatures for selected months at Diavik.

	Maxima		Mean		Minima	
	1970 2060 (°C)	Rate (°C year^{-1})	1970 2060 (°C)	Rate (°C year^{-1})	1970 2060 (°C)	Rate (°C year^{-1})
January	-27.4 -19.8	0.084	-30.3 -22.6	0.086	-33.6 -25.4	0.091
April	-11.5 -7.9	0.040	-15.7 -11.0	0.052	-19.3 -13.7	0.062
July	15.7 17.5	0.020	11.6 13.7	0.023	7.5 9.4	0.021
October	-4.8 -0.6	0.047	-7.4 -2.5	0.054	-9.9 -4.4	0.061

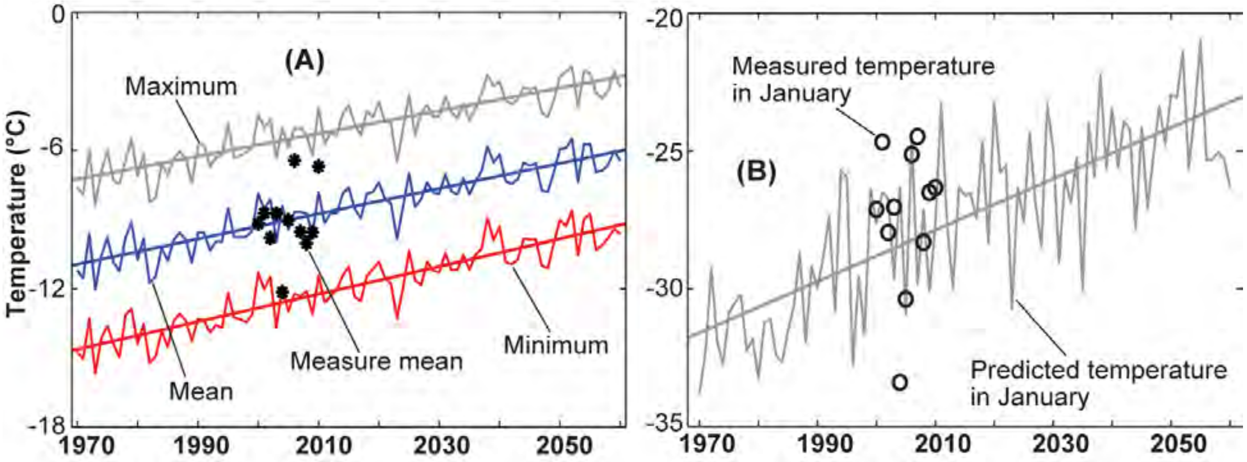

Figure 7. Predicted minimum, mean and maximum annual temperatures (A) and predicted mean January temperatures (B) for Diavik

Numerical simulation of heat transfer of the waste dump with climate change

Simulation cases

Predictions of future temperatures within the waste dump are derived from a one-dimensional conduction model. Case 1 is the baseline case, in which no cover layer is placed on top of the Type III waste rock. The pile is assigned a thickness of 80m. The case is used to investigate the change in depth of the 0 °C isotherm and ground temperatures under the future climate. Case 2 is a closure concept, where the Type III waste rock is capped using a 1.5 m till overlain with 3 m of Type I waste rock. Boundary conditions for Cases 1 and 2 are no heat flux at bottom of Type III waste dump. No heat flux at the bottom is used for preliminary investigations due to lack of measurements. This can be justified due to the boundary being at a great depth to the surface (80 m) and/or a low thermal conductivity liner at the base. The surface temperature is

$$T_s = -6.3 + 20.3\sin\left(\frac{2\pi t}{365}\right) + \frac{0.056t}{365} \qquad \text{(Equation 6)}$$

With climate change of 0.056 °C/year at the surface, and initial temperatures resembling measured temperatures on July 2010 using the instrumented boreholes.

Material properties

Thermal properties of the Type I, Type III waste rock and till were determined using *in situ* measurements from three experimental waste rock piles at the Diavik mine site, and calculated from measured ground temperatures within each same materials (Table 3) (Pham et al., 2011). Volumetric moisture contents of the Type I and Type III waste rock are assumed to remain at field capacity, about 5.7%, which was measured in the field due to the low precipitation and high evaporation at Diavik (Neuner, 2009).

Table 3. Material properties for materials used in simulation

Property	Value
Type I waste rock	
Porosity	0.25
Thermal conductivity	1.65 W/m/K
Frozen bulk heat capacity	2.38×10^6 J/m^3/K
Thawed bulk heat capacity	2.40×10^6 J/m^3/K
Volumetric water content	0.057
Type III waste rock	
Porosity	0.25
Thermal conductivity	1.69 W/m/K
Frozen bulk heat capacity	2.13×10^6 J/m^3/K
Thawed bulk heat capacity	2.15×10^6 J/m^3/K
Volumetric water content	0.057
Till	
Porosity	0.2
Frozen thermal conductivity	3.20 W/m/K
Thawed thermal conductivity	2.90 W/m/K
Frozen bulk heat capacity	2.13×10^6 J/m^3/K
Thawed bulk heat capacity	2.51×10^6 J/m^3/K
Volumetric water content	0.18

Results

The simulation cases were run for 100 years from July 2010. The assigned mean surface temperature T_s, after 100 years, at the top of the 80 m waste rock dump, will be -0.7 °C, which is similar to the current MAST at Yellowknife, Northwest Territories, Canada which is in the zone of discontinuous permafrost (Heginbottom et al., 1995).

Case 1

From measured data between July 2010 and July 2011, the 0 °C isotherm is initially about 11 m below the top surface and it rapidly rises to 3.9 m in 2014. From 2014 to 2020, the 0 °C isotherm slowly rises to a depth of 3.7 m, which is the minimum depth to reach 0 °C. After 2020, the 0 °C isotherm gradually moves downward with an average rate of 3.6×10^{-2} m/year (or 3.6 cm/year) to 7.0 m in 2110 (Figure 8A). At 4 m depth, ground temperature varies significantly with an amplitude of around 10 °C. Initially it decreases until 2020 similarly to the 0 °C isotherm and then increases. Its maximum value reaches 0 °C and 3.5 °C in 2040 and 2110, respectively. Meanwhile its minimum value is -10 °C in 2020 and increases to -6 °C in 2110. The temperature amplitude at 7 m is smaller (about 3 °C) and its maximum temperature does not reach 0 °C until 2110 (Figure 8B).

Below 20 m, the amplitude of the annual ground temperature variations are small and can be negligible. At 20 m, waste rock temperatures reach a minimum value of -3.4 °C in 2040 and then gradually increases to a value of -1.6 °C in 2110. The initial decrease is due to the initial temperature at 20 m, which is lower than the MAST and the later increases are due to the warming of MAST. The greater the depth below the surface, the later temperatures reach their minimum before gradually increasing (Figure 8C). This reflects the influence of warming and conduction behavior of the waste dump. Moreover, the waste rock acts as a low-pass filter of the temperature signal by removing short-term fluctuations (high frequencies) and leaving long term trends (long-term climate change). Figure 8D shows by 2110, the surface temperatures fluctuate between -21.0 and 19.6 °C and the 0 °C isotherm is at 7 m depth.

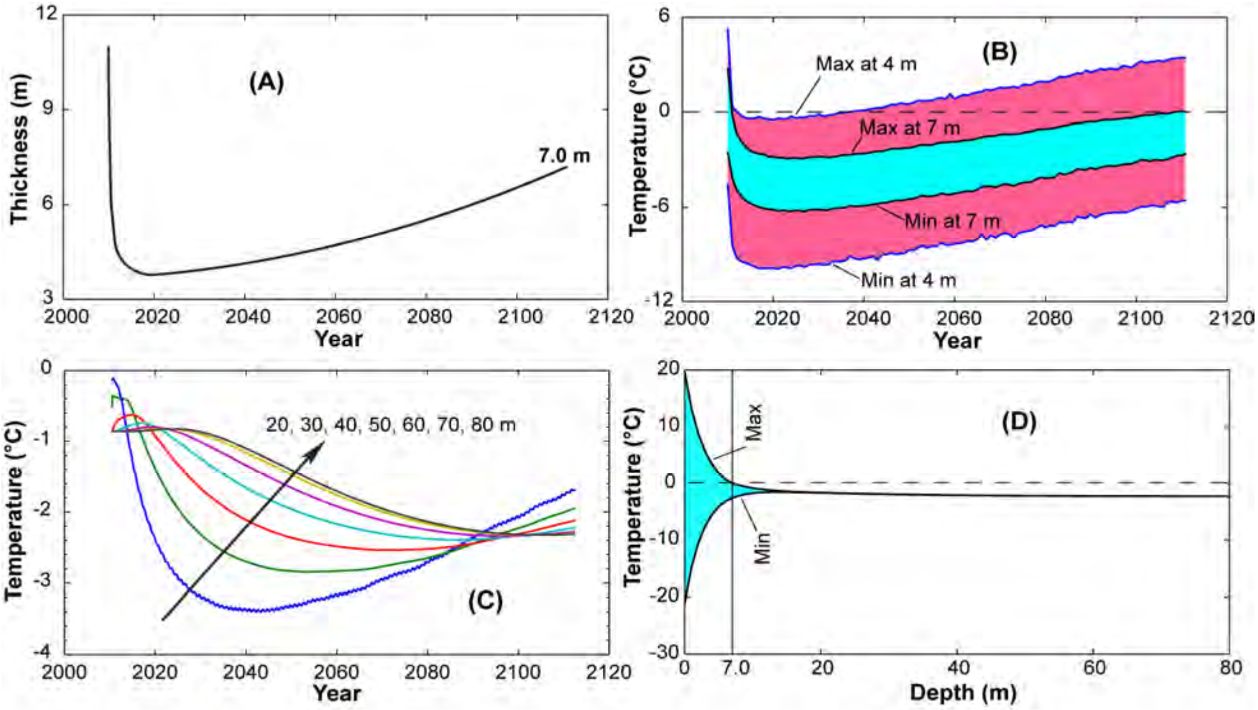

Figure 8.Case 1 scenario simulation results: 0 °C isotherm variation (A), temperature amplitudes at 4 and 7 m (B), temperature variations between 20 and 80 depths (C), minimum and maximum temperatures in the year 2110 (D).

Case 2

In Case 2, where a cover is placed on the Type III waste rock, the 0 °C isotherm rises in the first three years to 3.0 m, which is the top of the till, and remains there until 2040 due to latent heat effects in the till. Then, it gradually rises to a depth of 3.9 m (0.9 m into the till) by 2110 (Figure 9A). Similarly, the maximum temperature at the top of the till rapidly declines to a temperature just below 0 °C and stays constant until 2040. Then it increases slowly to 1.9 °C by 2110 (Figure 9B). The minimum temperature reaches -10.1 °C in the year 2020 and increases to -5.1 °C in the year 2110 (Figure 9B). At the base of the till, the temperatures remain colder than 0 °C. However, the maximum temperature ranges from -1.1 to -0.3 °C between 2020 and 2110 respectively. The minimum temperature is colder, varying from -9.2 to -3.6 °C between 2020 and 2110 (Figure 9B).

Temperatures below 20 m depth show similar results as discussed in case 1 but with significantly smaller deviations due to latent heat stored in the till (Figure 8C and Figure 9C). Figure 9D shows the 0 °C isotherm penetrates 0.9 m into the till (or 3.9 m from the surface) by 2110 and the figure also shows the depth of zero annual amplitude is at about 20 m.

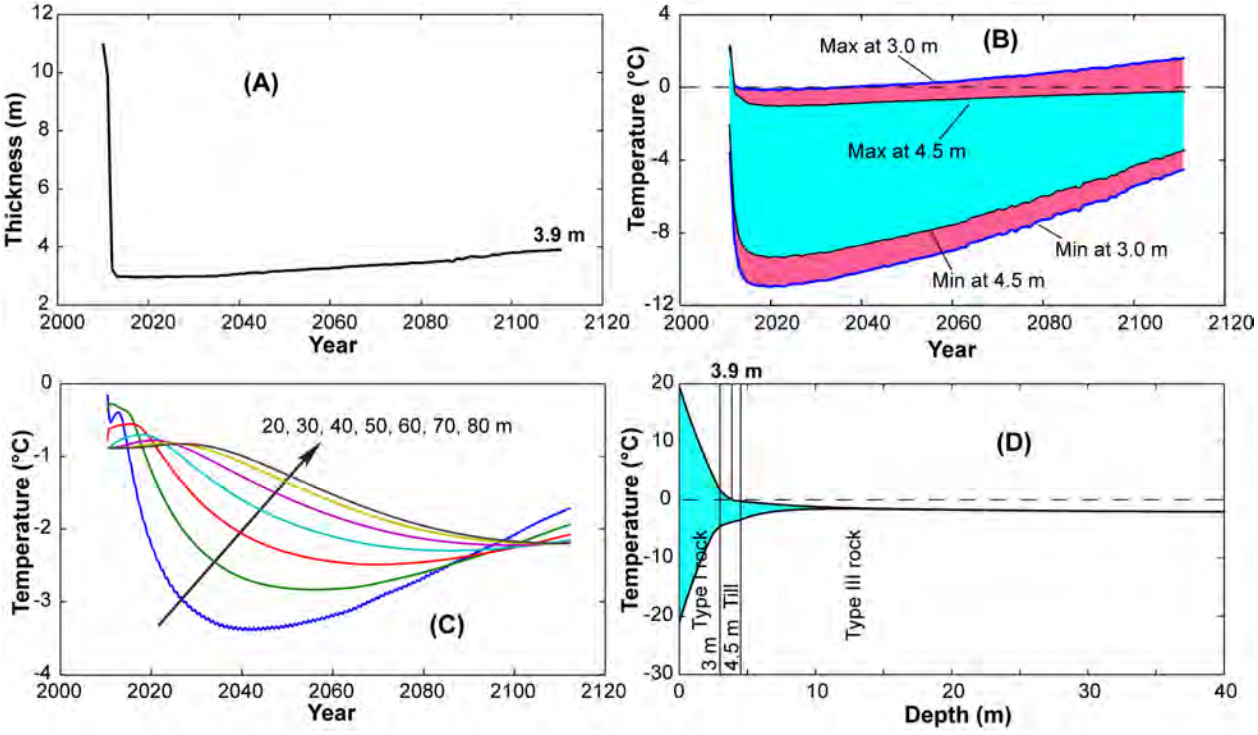

Figure 9. Case 2 scenario simulation results: 0 °C isotherm variation (A), temperature amplitudes at 3.0 m (top of the till) and 4.5 m (bottom of the till) (B), temperature variations between 20 and 80 depths (C), minimum and maximum temperatures in 2110 (D).

Conclusions

Measured air temperatures over the 10-year period (2000 - 2010) at the Diavik site has a MAAT of -9.1 °C and trend lines indicate warming of the air temperature expressed through the changes of freezing, thawing indices and numbers of freezing and thawing days. Based on air temperatures measured at the site, and other long-term air temperatures recorded at nearby locations, future climate modeling predicts the highest and lowest rates of temperature change occur in January and July respectively; while predictions for October and April indicate slight mean annual increases.

Ground temperature measurements in the Type I waste dump indicate the 0 °C isotherm is currently at 11 m below the surface and conductive heat transfer in the pile controls the temperature variations. No observations of increased temperatures due to oxidation of sulphide minerals have been recorded and the calculated thermal diffusivity from ground temperatures is comparable to measured values found in the test piles at the Diavik site. 1D conduction numerical modeling (case 1 without a cover) predicts the 0 °C isotherm will be at 7 m with climate change by 2110. In case 2, with the aid of a saturated till layer, the 0 °C isotherm rises to 3.9 m below ground surface. Ground temperatures below 20 m of case 1 and case 2 are similar.

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Appendix II-6

2010 Geotechnical Site Investigation Factual Report

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DIAVIK DIAMOND MINE PKC FACILITY
2010 Geotechnical Site Investigation Factual Report

Submitted to:

Diavik Diamond Mines Inc.
Yellowknife, NWT

Submitted by:

AMEC Environment and Infrastructure,
a Division of AMEC Americas Limited
Burnaby, BC

05 December 2011

AMEC File: VM00503.PKC

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IMPORTANT NOTICE

This report was prepared exclusively for Diavik Diamond Mines Inc. by AMEC Environment and Infrastructure, a wholly owned subsidiary of AMEC Americas Limited. The quality of information, conclusions and estimates contained herein is consistent with the level of effort involved in AMEC services and based on: i) information available at the time of preparation, ii) data supplied by outside sources, and iii) the assumptions, conditions and qualifications set forth in this report. This report is intended to be used by Diavik Diamond Mines Inc. only, subject to the terms and conditions of its contract with AMEC. Any other use of, or reliance on, this report by any third party is at that party's sole risk.

1.0 INTRODUCTION

This report provides factual results of geotechnical site investigations and the associated laboratory testing program carried out by AMEC Earth and Environmental (AMEC) within the Processed Kimberlite Containment (PKC) facility at the Diavik mine site located at Lac de Gras in the NWT. Site investigations were completed between 7 September 2010 and 16 September 2010; laboratory testing commenced shortly thereafter.

These investigations were undertaken in support of DDMI's planning for ongoing operations, and eventual reclamation and closure, of the PKC facility. The PKC facility has been a subject of ongoing study, undergoing various phases of site investigation, laboratory testing, design review, and inspection between 1998 and 2010. The objective of the 2010 site investigation and laboratory testing program was to fill historical data gaps in the characterization of the fine (minus 1 mm size) PK geotechnical properties, specifically, within the central portion of the PKC facility where the reclaim water pond has generally been maintained, and PK deposition has occurred sub-aqueously.

Section 2 of this report provides an overview of the PKC facility.

Section 3 summarizes previous characterization work undertaken primarily by Golder Associates for the PKC facility that, along with Section 2, provides context for the 2010 investigation program.

Section 4 discusses the scope of the field investigation program, and presents the results of the 2010 piezocone penetration testing, the ball penetration testing, and the vane shear testing, along with a summary of the sampling that was undertaken.

Section 5 presents the methodology and results of the laboratory test work undertaken on selected samples retrieved from the 2010 field program.

Section 6 provides a summary interpretation of the field and laboratory data, with emphasis on differentiation of zones displaying sedimentation, transition, and consolidation behaviour.

Section 7 provides a brief discussion pertaining to the implications of these data for DDMI's closure planning deliberations for the PKC facility.

2.0 BACKGROUND

The PKC facility at the Diavik Diamond Mine provides storage for all fine and coarse processed kimberlite (PK) produced as part of the diamond recovery process. The PKC facility was originally impounded by dams to the east and west, but with increasing height is now also contained by dams along its north and south perimeters. The upstream faces of these dams are lined with a geomembrane. For the starter East and West Dams, the face liner extends partially below the actual embankment in order to achieve a cutoff to frozen ground. For the South and North Dams, the liner is tied into a key trench at the upstream toes of these dams. The design of the PKC facility is intended to minimize seepage. Figure 2.1 provides an aerial view of the facility.

Figure 2.1: PKC Facility General Arrangement

Figures 2.2 through 2.4 provide aerial views (from 2008) of the PKC facility. PK is delivered to the PKC facility in two streams:

- Fine PK (minus 1 mm size material), discharged into the impoundment in slurry form. The fine PK slurry is discharged from the East and West Dams, and periodically from the waste rock divider/spigot berms that separate the central portion of the PKC facility (which includes the process water reclaim pond area) from the north and south cells, which are to store the coarse PK.
- Coarse PK (1 mm to 6 mm size material), hauled to the facility via trucks in a largely dewatered state. Under the original design for the PKC facility, which envisioned the PK split (by dry weight) to be 2 parts fine PK to 1 part coarse PK, the coarse PK was to be stored within the north and south cells. However, it appears that the actual split is closer 7 parts fine PK to 1 part coarse PK.

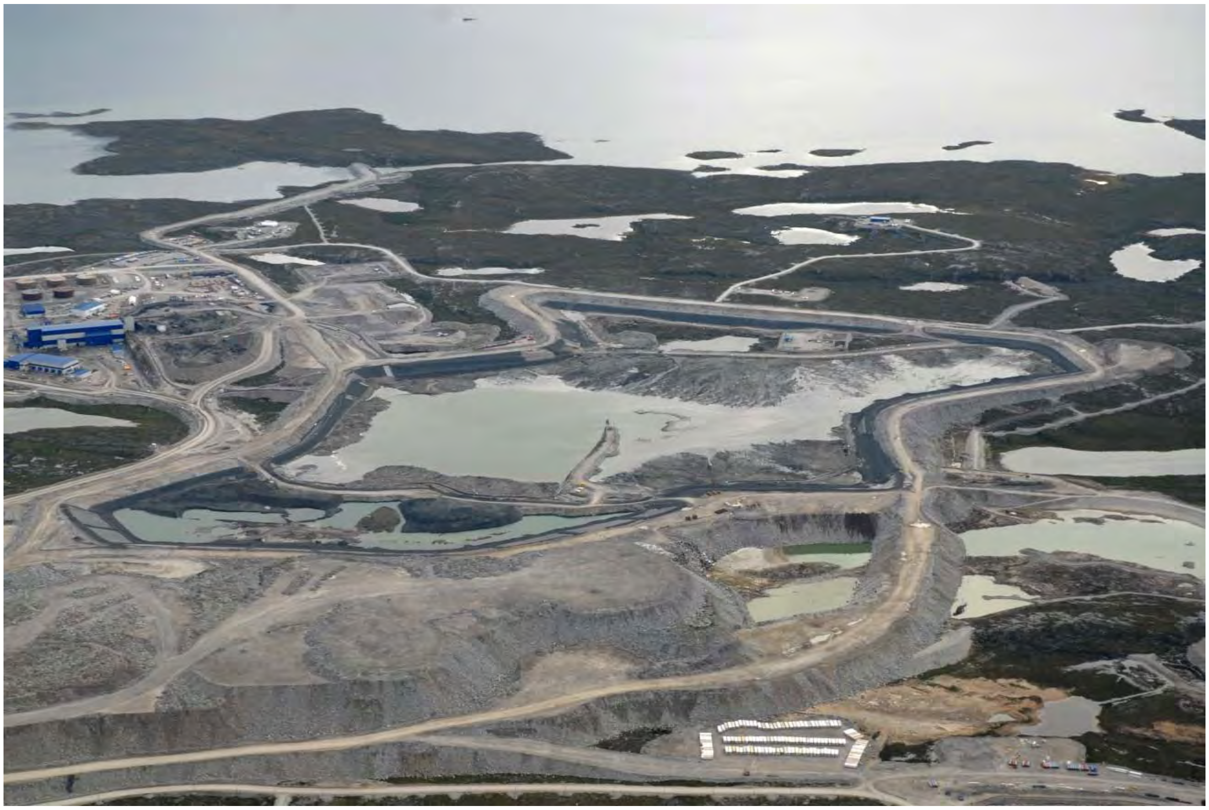


Figure 2.2: Aerial View of PKC Facility (2008), Looking South

Given the relative lack of coarse PK to fine PK, it appears that fine PK may be discharged into one or both of the North and South Cells.

Figure 2.3: Aerial View of PKC Facility (2008), Looking East

The fine PK slurry undergoes a significant degree of hydraulic segregation when discharged, with the coarser sizes being deposited relatively close to the discharge location (which is shifted regularly in order to achieve uniform beach development to the degree practical), and the finer sizes being deposited near and within the reclaim water pond. The material deposited near and within the pond contains considerable clay content, and as a result is much more compressible, and much less hydraulically conductive, than the coarser material deposited nearer the discharge locations. Further, given the challenges of operating the PKC facility in the long winter season, particularly with respect to the reclaim water pond, ice has become entrained within the fine PK deposit (as well as frozen PK), more so below the subaerial beaches, with likely decreasing ice and frozen PK closer to the water pond (a source of heat). Owing to the challenges of maintaining uniform spigotting and beach widths in front of the dams, the relative position of the reclaim pond within the facility tends to shift on a regular basis. As a result, certain areas of the deposit likely comprise interfingered and layered sequences of the coarser (sand, silt sizes) fraction of the fine PK and finer (silt/clay) fraction, along with layers of entrained ice.

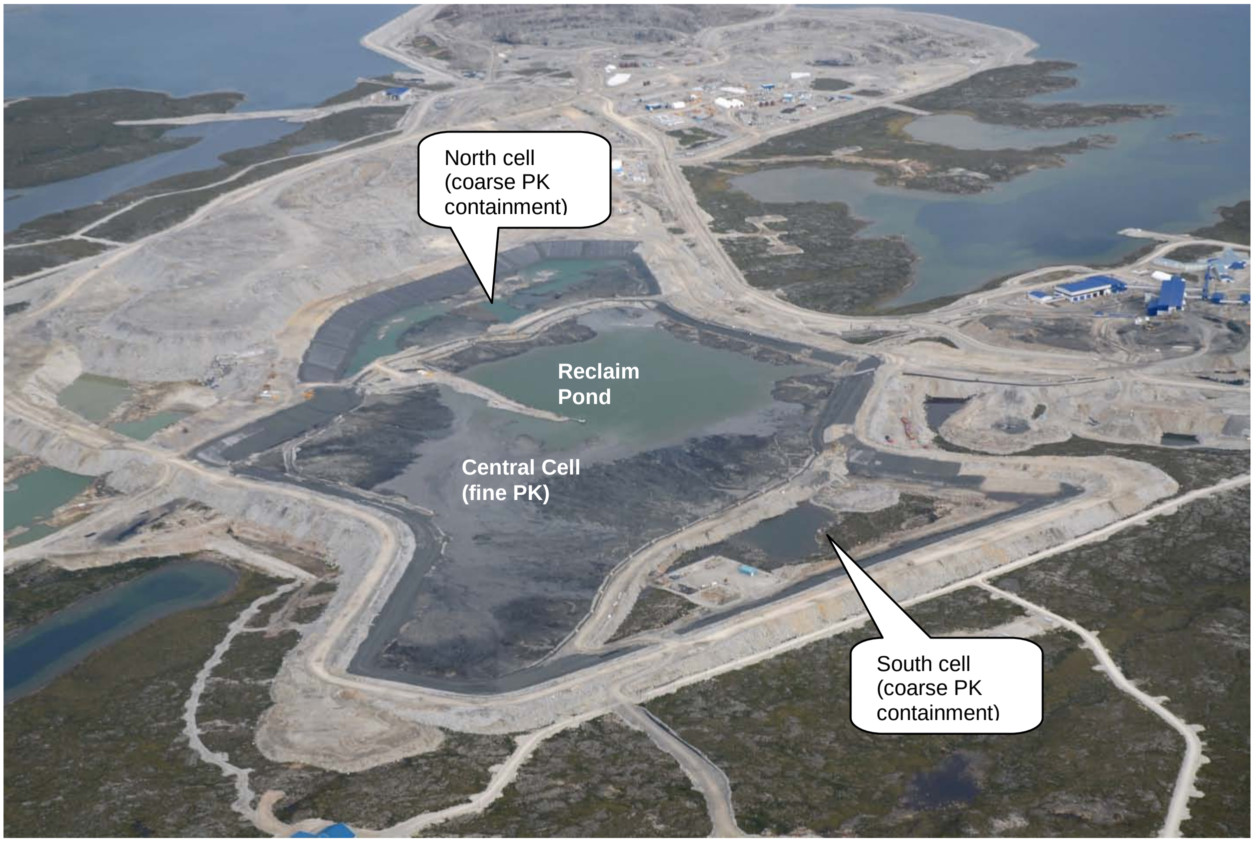


Figure 2.4: Aerial View of PKC Facility (2008), Looking Southeast

The degree of hydraulic segregation exhibited by the fine PK slurry (discharged at a low solids content which, along with the range of sand to clay sizes within the fine PK, is highly conducive to segregation) is in many respects similar to conditions in the oil sands tailings deposits, where the coarser sand around the perimeter of these impoundments contains a very soft, slow-to-consolidate material referred to as “mature fine tailings”, or MFT. This very soft material, which is largely fluid-like in behaviour, has been the subject of much research in terms of closure and reclamation. From a geotechnical perspective, the situation within the PKC facility likely represents in many respects an analogue to the oil sands, and as such closure and reclamation of the PKC facility will face many challenges similar to those in the oil sands tailings deposits.

3.0 PREVIOUS PKC FACILITY CHARACTERIZATION WORK

AMEC undertook a review of relevant data and studies available to date pertaining to the geotechnical aspects of the fine PK and the PK slimes. Pertinent data and studies are briefly summarized in the sections following, along with commentary as to the usefulness of the data.

3.1 Laboratory Testing in Support of PKC Facility Design Report

Appendix C of the 2001 NKSL design report for the PKC facility included laboratory testing conducted on PK samples, by Golder Associates. This testing was documented in the following Golder reports:

- Report by Golder Associates Re: Laboratory Tests on Processed Kimberlite Material, Diavik Diamond Project, Sept. 23, 1998
- Report by Golder Associates Re: Laboratory Tests on Processed Kimberlite Material, Diavik Diamond Project, July 28, 1999

These reports included gradation testing on fine and coarse PK samples, index property tests, column settling tests, conventional oedometer consolidation tests, and large strain consolidation tests. For the 1998 tests, it is not clear whether or not it was the slimes fraction of the fine PK that was subjected to the large strain consolidation tests, or the entire fine PK size fraction. Tests on only the slimes fraction (the material deposited within the limits of the reclaim water pond) would be of the most relevance. It does appear that the single large strain consolidation test conducted as part of the 1999 program did comprise only the fine fraction of the fine PK.

The column settling and large strain consolidation characteristics of the slimes PK are of the most significance in terms of assessing the consolidation of the PK slimes within the center of the PKC facility. The appropriate methodology for such tests is to take a direct measurement of hydraulic conductivity for each stage of loading, thus developing a relationship between hydraulic conductivity and void ratio. It appears that this was done for the 1998 and 1999 tests. Additional such tests were undertaken on samples retrieved during the 2010 program.

3.2 2008 Piezocone Program

A piezocone investigation was undertaken in the subaerial fine PK beach, near the East Dam, and near the South Spit Road, in 2008 by Conetec, under the technical direction of Golder Associates. The piezocone soundings were undertaken in close proximity to these structures, and as such, being relatively close to previous fine PK discharge locations, encountered the coarser fraction of the fine PK. A total of 16 piezocone soundings were undertaken. Test pits were also excavated in these areas, with disturbed samples retrieved. The primary focus of this program was to evaluate the geotechnical conditions of the fine PK, near the dams, as part of evaluating the feasibility of upstream raising of the perimeter dams (which requires much less fill to achieve than the downstream raises that have been constructed to date). The data from this program is useful in quantifying the degree of hydraulic segregation of the fine PK, and in differentiating the behaviour of the near-dam fine PK from that of the slimes PK deposited within and nearby the limits of the reclaim water pond.

3.3 Fine PK Characterization

Appendix I of the Golder (2007) design report for the Phase 5 raise of the PKC facility dams presents the results of a fine PK characterization program undertaken starting in 2005. This provides a very useful compilation of fine PK geotechnical properties, with 84 samples obtained from the subaerial fine PK beaches, and 15 Eckman grab samples of the fine PK slimes within the reclaim water pond area. Fifteen bulk density measurements were undertaken for the beached fine PK using push-in tubes, and ground penetrating radar (GPR) surveys and resistivity profiling were carried out to determine the presence of buried ice. Thermistors and piezometers were installed.

Key results from this program are summarized as follows:

- The extent of hydraulic segregation of the fine PK is significant, with sand sizes, and heavier specific gravity (SG) particles being deposited relatively close to the discharge points, and the finer materials (and those of lower SG) being deposited within the reclaim water pond. The fines contents in the PK slimes, sampled with the Eckman grab sampler, ranged from 90% to 100%.
- The hydraulic conductivity of the beach fine PK (10^{-4} to 10^{-3} cm/sec) is relatively high, reflecting the coarser particle sizes, while the hydraulic conductivity of the fine PK slimes (as derived from a single large strain consolidation test) is in the range of 10^{-6} to 10^{-5} cm/sec, reflective of the silt and clay sizes of that material.
- Tube samples from the fine PK beach yielded a dry density ranging from 1.5 to 1.8 t/m^3, with an average of about 1.7 t/m^3, much higher than the average assumed dry density of 1 t/m^3 for the overall fine PK deposit (per Table 3 of the June 2007 Golder Phase 5 design report). This clearly suggests that the average dry density of the PK slimes in the area of the reclaim water pond is considerably lower than 1 t/m3, although some of the difference is undoubtedly explained by ice entrainment, which is not possible to accurately quantify.
- The fine PK slimes are susceptible to frost heave and could develop significant ice lenses under appropriate conditions.
- The fine PK slimes have clay contents (% by dry weight finer than 2 microns) in the range of about 20-30%. Clay mineralogy indicates that vermiculite (a clay mineral of the montmorillonite/smectite group) comprises 18-25% by mass of the fine PK slimes, meaning that, from a geotechnical perspective, the fine PK slimes can be treated essentially as a high plasticity clay.
- The minerals predominant within the beached fine PK (forsterite and lizardite) possess relative high thermal conductivities, whereas vermiculite (dominant within the fine PK slimes) possesses a very low thermal conductivity. This means in effect that the different zones within the fine PK deposit will freeze at very different rates.

- A single large strain consolidation test was carried out on a sample of the fine PK slimes, but it appears that, rather than the hydraulic conductivity being measured for each individual loading stage, it was inferred from the rate of consolidation. As such, this was not a rigorous large strain consolidation test.
- No Atterberg limits testing was carried out on the fine PK slimes. Given the vermiculite content, such tests would likely have yielded a high degree of plasticity. Such tests, though yielding only index property data, are useful nonetheless as Atterberg limits data empirically correlate to other soil properties (in particular, the ratio of undrained shear strength to effective consolidation pressure).

3.4 Geophysical Surveys

Geophysical surveys were undertaken over the subaerial beach by Aurora Geosciences, work documented in Aurora’s report "*A report on a ground penetrating radar survey, of the processed kimberlite containment facility*", dated June 2007. These surveys confirmed the presence of ice layers within the subaerial beach.

3.5 Fine PK Porewater Sampling

In the fall of 2009, DDMI undertook a program wherein porewater samples were extracted from the fine PK. During the course of this program, it is understood that the probe and sampler could be hand-pushed to depths of about 15 m within the fine PK slimes underlying the reclaim water pond, and with some mechanical assist pushed to a total depth of nearly 25 m (deeper penetration was possible), confirming the very soft, and under-consolidated, nature of this material.

3.6 Data Gaps

The aforementioned investigations provided a significant database in terms of characterization of the fine PK, but with two principal data gaps:

- Within the limits of the reclaim water pond, where fine PK deposition has occurred sub-aqueously; and
- In the transition zone between the coarser (due to hydraulic segregation), more competent PK near the dams, and the edge of the reclaim water pond, that were not accessed during the 2008 piezocone program.

The following sections of this report describe the field and laboratory investigations undertaken to address the former of these two data gaps.

4.0 2010 GEOTECHNICAL SITE INVESTIGATION PROGRAM

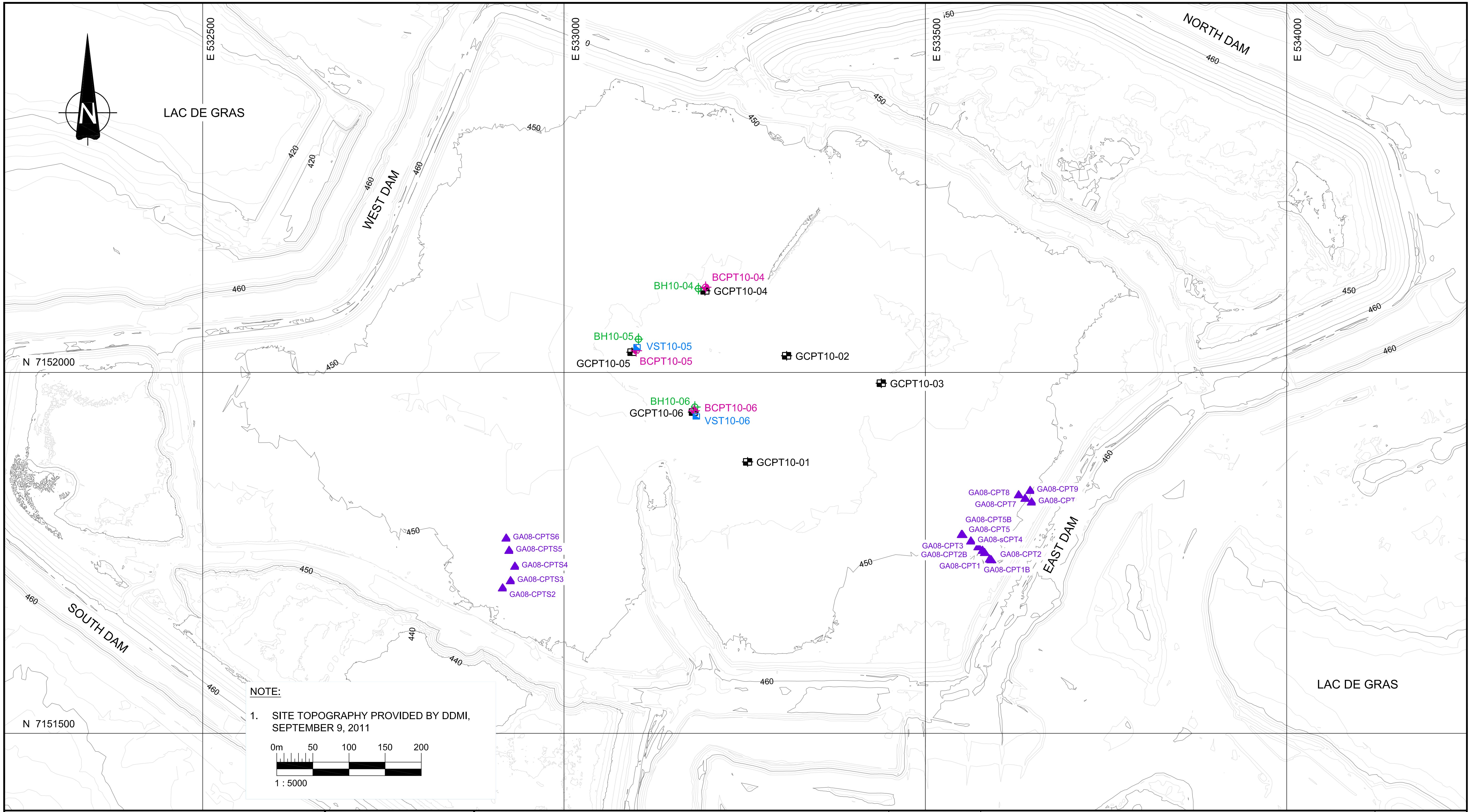
The 2010 site investigation and laboratory testing program concentrated on the deep, open water portions of the PKC pond. On-site work comprised a combination of in-situ testing and sample collection, completed by ConeTec Investigations Ltd. with continuous supervision and direction from AMEC personnel.

ConeTec used a 33 ft. (10 m) boat with stabilizing 'spuds' (Figure 4.1) as the platform from which to conduct testing. A total of 11 in-situ test holes were completed for gamma cone penetration testing (CPT) (six holes), ball penetration testing (three holes), or vane shear testing (two holes). Additionally, 17 fluid tailings samples were collected at three distinct locations. Figure 4.2 shows the PKC pond and the location of all completed 2010 in-situ testing and sampling holes. Table 4.1 summarizes the completed 2010 program. Selected photographs from the site investigation program are included in Appendix A. In-situ test results are summarised in the following sections and detailed in ConeTec's Field Data Report, provided in Appendix B.

Figure 4.1: ConeTec Workboat

Table 4.1: Summary of 2010 Site Investigation Program

Test Type	Hole ID	Date	Final Depth (m)	Northing (m)	Easting (m)	Elevation (masl)
Gamma CPT	CPT10-01	09-Sep-10	11.85	7,151,876	533,254	448.8
	CPT10-02	09-Sep-10	8.55	7,152,023	533,308	448.8
	CPT10-03	09-Sep-10	4.8	7,151,985	533,439	448.8
	CPT10-04	10-Sep-10	21.75	7,152,113	533,195	448.8
	CPT10-05	10-Sep-10	30.45	7,152,028	533,094	448.7
	CPT10-06	12-Sep-10	28.5	7,151,945	533,179	448.8
Ball Penetration	BCPT10-04	12-Sep-10	19.1	7,152,118	533,196	448.7
	BCPT10-05	11-Sep-10	27.85	7,152,030	533,100	448.7
	BCPT10-06	12-Sep-10	23.1	7,151,947	533,180	448.7
Vane Shear	VST 10-05	13-Sep-10	26	7,152,035	533,101	-
	VST 10-06	13-Sep-10	22	7,151,939	533,183	-
Sampling	BH10-04	14-Sep-10	16	7,152,116	533,186	-
	BH10-05	14-Sep-10	23	7,152,046	533,103	-
	BH10-06	14-Sep-10	17	7,151,952	533,181	-



NOTE:

1. SITE TOPOGRAPHY PROVIDED BY DDMI, SEPTEMBER 9, 2011

LEGEND

▲ GA08-CPTS6	GOLDER CONE PENETRATION TEST (2008)
■ GCPT10-04	GAMMA CONE PENETRATION TEST (2010)
⊕ BCPT10-04	BALL PENETROMETER TEST (2010)
◪ VST10-05	VANE SHEAR TEST (2010)
⊕ BH10-05	PK SAMPLING LOCATION (2010)

CLIENT LOGO

CLIENT:
DIAVIK DIAMOND MINES INC.

AMEC Earth & Environmental
4445 Lougheed Highway, Suite 600,
Burnaby, BC, V5C 0E4
Tel. 604-294-3811 Fax 604-294-4664

DWN BY: YC
CHK'D BY: JB
DATUM: NAD 83
PROJECTION: UTM ZONE 12
SCALE: AS SHOWN

PROJECT
DIAVIK PKC FACILITY STUDY

TITLE
2010 SITE INVESTIGATIONS

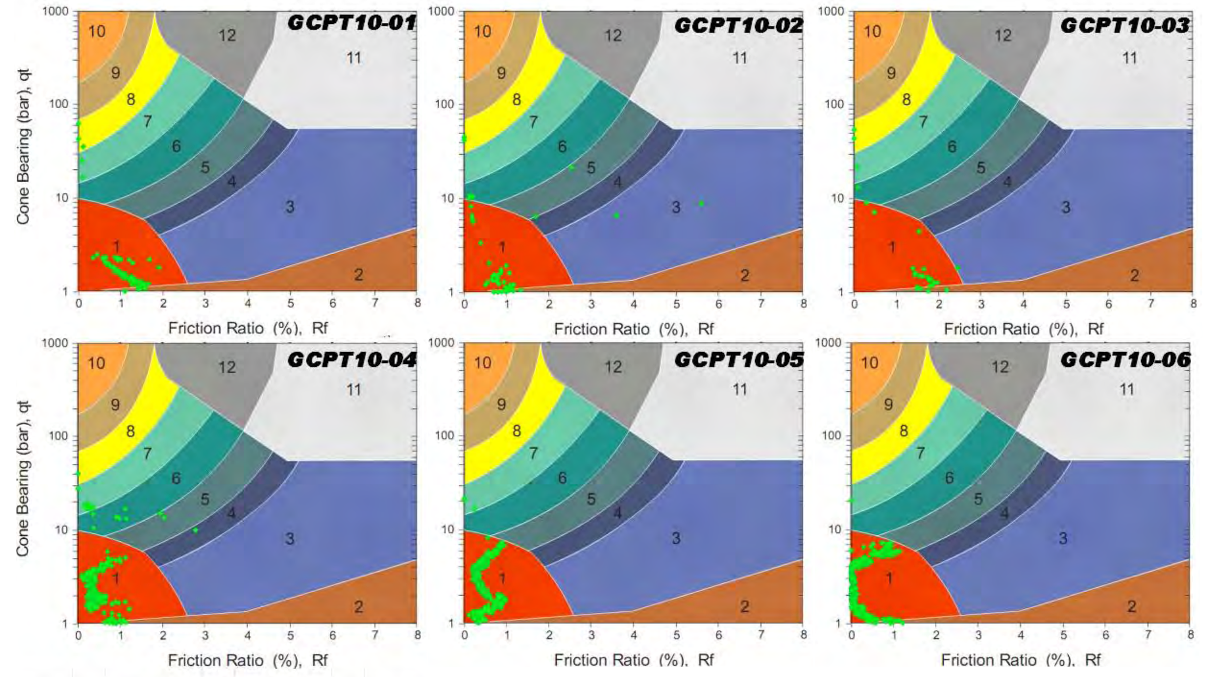
DATE: SEPT. 2011
PROJECT NO: VM00503.PKC
REV. NO.: A
FIGURE No. 4.2

S:\PROJECTS\VM00503 – A154 Dike DSR\Drawings\2010 site investigation\Figure 1.dwg – Layout1 – Dec. 05, 2011 12:55pm – yuan.chen

4.1 Cone Penetration Testing (CPT)

Cone penetration testing was carried out in general accordance with ASTM D5778-07 using a boat-mounted integrated electronic cone penetration testing and data acquisition system. Passive gamma testing was utilized in conjunction with all CPT testing to measure the presence of naturally occurring components within the soil that emit gamma radiation. Full equipment and test details, logs, and interpretation information are provided in Appendix B.

In general, CPT testing indicated low cone bearing stress (qt) and friction ratio (Rf) values. This indicates the predominant soil behaviour type is 'sensitive fine grained', according to the Robertson and Campanella soil behaviour charts (Figure 4.3). Exceptions to this classification typically occur at depth, when the cone reached near refusal on native soil.



Zone		qt / N	Soil Behavior Type	Zone		qt / N	Soil Behavior Type	Zone		qt / N	Soil Behavior Type
1	🟥	2	sensitive fine grained	5	■	2	clayey silt to silty clay	9	🟫	5	sand
2	🟫	1	organic material	6	🟩	2.5	sandy silt to clayey silt	10	🟧	6	gravelly sand to sand
3	🟦	1	clay	7	🟩	3	silty sand to sandy silt	11	⬜	1	very stiff fine grained *
4	🟦	1.5	silty clay to clay	8	🟨	4	sand to silty sand	12	■	2	sand to clayey sand *

Figure 4.3: PK Tailings Soil Behaviour Type
(After ConeTec and Robertson and Campanella)

Throughout penetration the CPT measured pore pressures in the u2 position (behind the tip). Pore pressure profiles for all holes are shown on Figure 4.4. Generally, hydrostatic pressure is detected for approximately the upper 5 m of the CPT profiles. This agrees with expectation while working on a pond. Below this depth, the measured dynamic pore pressure increases with depth at a greater rate than hydrostatic, indicating increased fluid pressure due to the presence of solids within the fluid tailings.

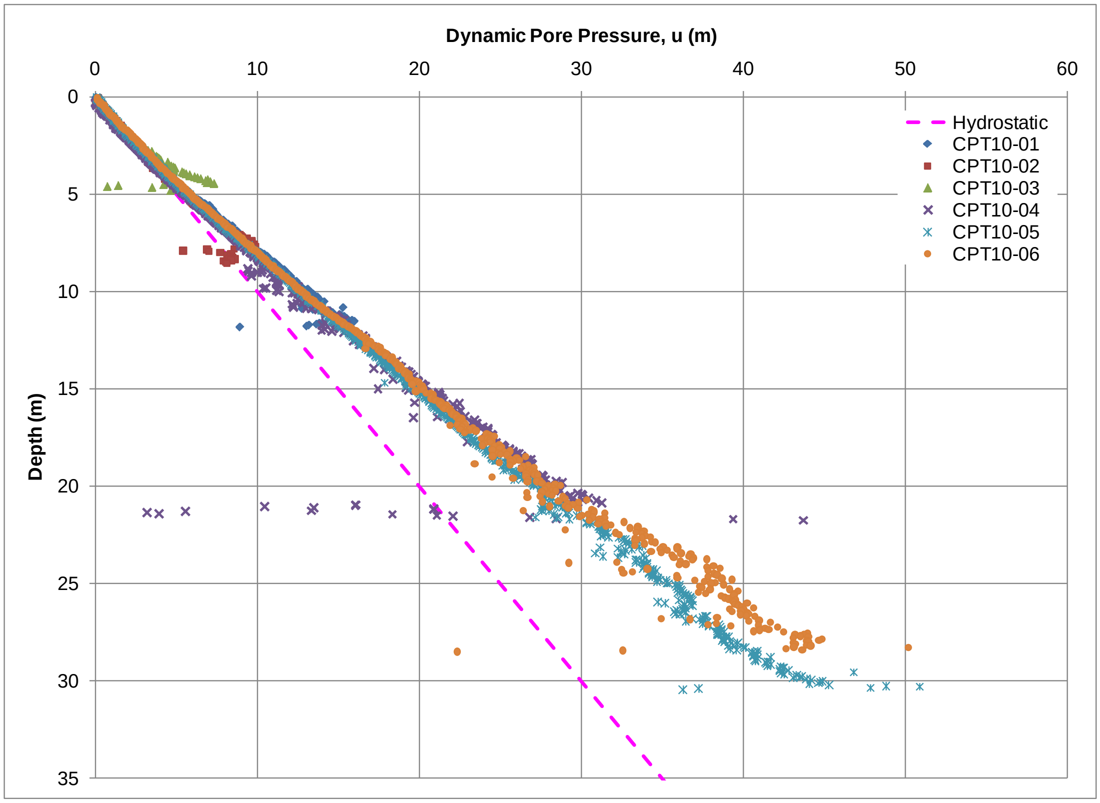


Figure 4.4: PK Tailings Pore Pressure

Based on the soil behaviour type assigned during CPT data interpretation, unit weights of encountered soil units are estimated. This, combined with measured pore pressure (u) data, allows approximations of the total vertical stress (σ_v) and vertical effective stress (σ_v'= σ_v-u) profiles to be developed for each CPT location (Figure 4.5). Due to the fluid nature of the tailings, measured pore pressure values are roughly equivalent to the total stress throughout much of the CPT profiles. This results in a very low level of effective stress within the PK tailings, indicative of an under-consolidated condition. Effective stress does not increase to non-zero levels until depths of 15 m or greater below pond level. The lack of effective stress within the upper 10 m of the PK tailings deposit will preclude many traditional tailings capping methodologies from consideration at this site unless a means of accelerating the consolidation of the material is implemented, as is being implemented on a trial basis in the oil sands via wick drains[1]. Another alternative under consideration in the oil sands is the construction of floating covers[2].

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[1] See, for example:
Wells, P.S. and J. Caldwell (2009). "*Vertical Wick Drains and Accelerated Dewatering of Fine Tailings in Oil Sands*", Proceedings, Tailings & Mine Waste '09, Banff, Alberta.

[2] Abusaid, A.H., Pollock, G.W., Fear, C.E., McRoberts, E.C. and P.S. Wells (2011). "*An Update to the Construction of the Suncor Oil Sands Tailings Pond 5 Cover*", Proceedings, Tailings & Mine Waste '11, Vancouver, B.C..

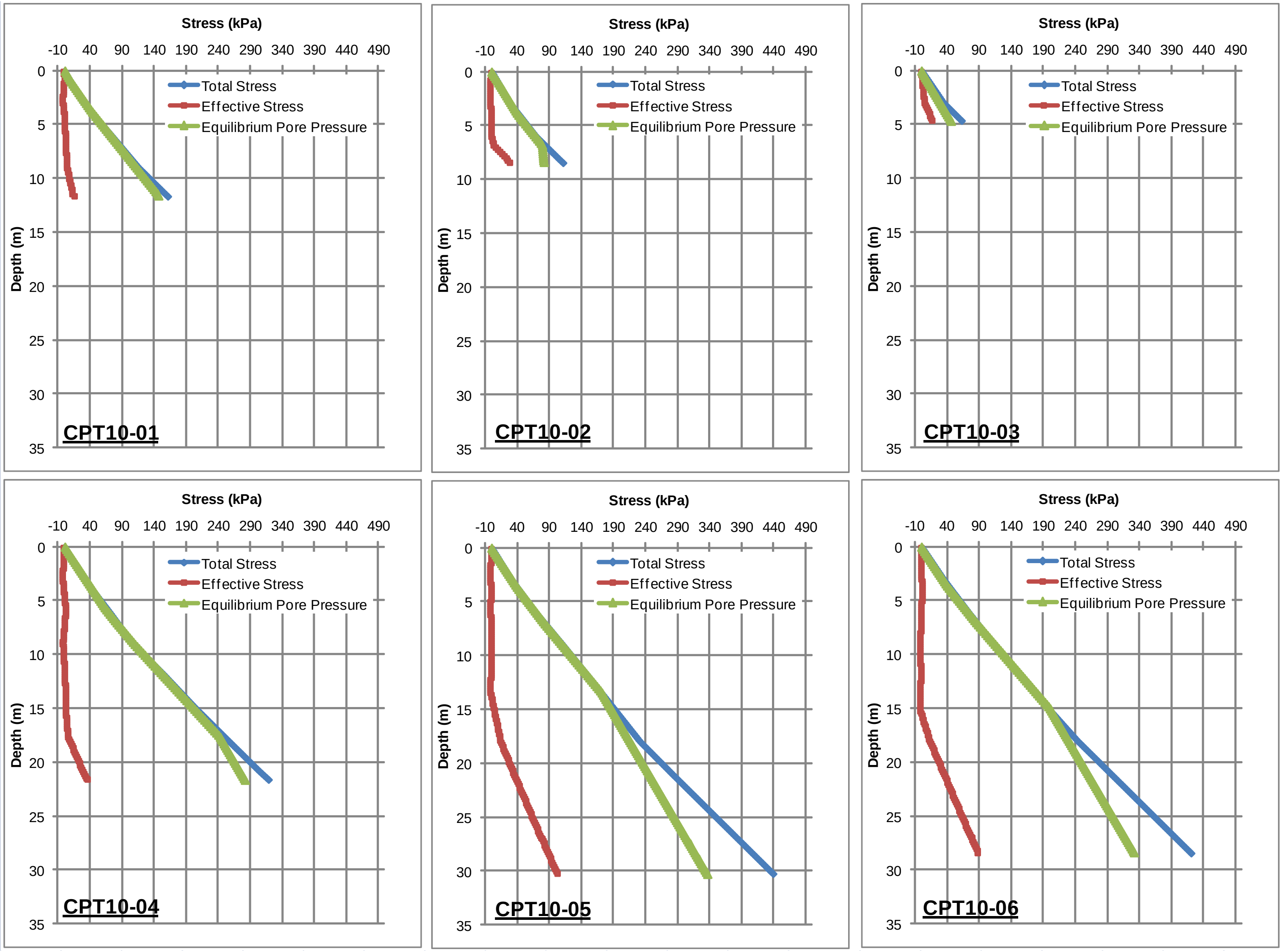

Figure 4.5: Estimated In-Situ Stresses in the Fine PK

4.2 Ball Penetration Testing

Ball Penetration Tests (also referred to as full flow penetration tests) were carried out in accordance with ConeTec's standard procedures using the same boat mounted cone penetration system described above. The ball penetrometer consists of a spherical attachment that replaces the ordinary cone tip. During penetration soil is able to flow around the penetrometer, significantly reducing the influence of overburden stress as compared to the cone penetration test (CPT). Data is recorded continuously and the test is performed in the same manner as the CPT. Full equipment and test details, logs, and interpretation information are provided in Appendix B.

Ball penetration tests provide a continuous profile of the undrained shear strength (Su) of low to medium strength soils. Because of the subdued sleeve and pore pressure response, ball penetration test results are not used for the interpretation of other geotechnical parameters or for soil classification. The test may be interrupted at selected depths to cycle the probe up and down to in order to achieve a completely remoulded soil state and provide an indication of sensitivity (loss of undrained shear strength in response to straining) in soft soils. Both continuous and cycled ball penetrometer tests were conducted at three locations. Results of the ball penetrometer testing are shown on Figure 4.6 below. Superimposed on the profiles for BCPT10-05 and BCPT10-06 are vane shear test derived undrained shear strength values for comparison. The vane shear soundings were undertaken at essentially the same location as the respective ball penetrometer soundings. In general, the ball penetrometer and the vane shear results, for both peak and remoulded conditions, are in reasonable agreement.

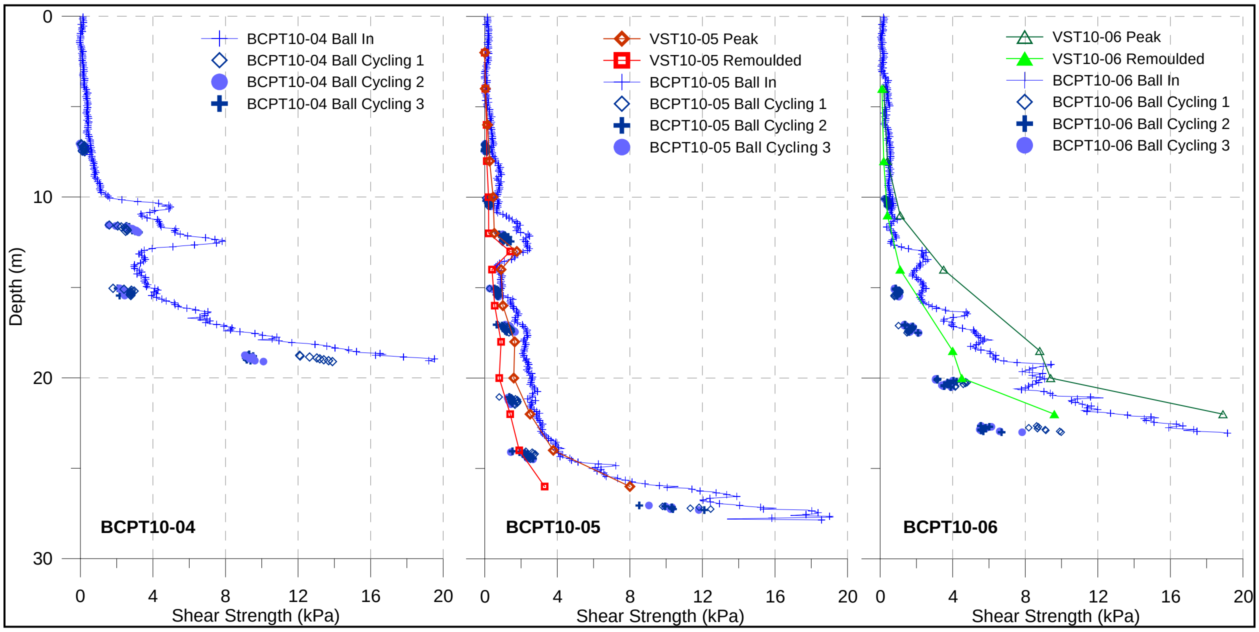

Figure 4.6: Undrained Shear Strength of PK Tailings

Overall, the undrained shear strength of the upper fine PK is very low, consistent with the fluid-like behaviour and under-consolidated nature of the deposit. In all three holes, undrained shear strength begins to increase appreciably at depths of 10 m to 12 m, eventually reaching peak strengths of 19 to 20 kPa at depths of near 25 m. Although higher, these values still represent only a ‘very soft’ soil. The remoulded shear strength (i.e. after ball cycling, and post-peak rotation of the vane shear apparatus) also increases with depth, with the maximum sensitivity of approximately 3 occurring at the greatest measured depths. This agrees with the expectation that fine PK behaviour transitions from fluid-like to soil-like with increased depth, therefore allowing shear strength to be developed at depth in contrast to the minimal shear strength of the upper fine PK, where, in the absence of grain-to-grain contact, peak undrained strength is the same as remoulded undrained strength.

4.3 Vane Shear Test Investigations

Vane Shear Tests were carried out at two locations using boat-mounted electric down-hole vane system tied into the electronic data acquisition system. The vane system uses a torque gauge to measure the torque required to shear the soil. An appropriately sized vane was selected based on the anticipated peak undrained shear strength of the PK. Upon advancing the vane to the correct depth, an electrical motor rotates the vane at a constant rate, allowing peak and post yielding shear resistance of the soil to be recorded. The vane is then rotated clockwise approximately ten times to completely remould the soil and a second (remoulded) measurement of soil shear strength is taken. This process is repeated at specified depths. Full equipment and test details, logs, and interpretation information are provided in Appendix B.

The soil shear strength values interpreted from vane shear testing are plotted on Figure 4.6 above to allow comparison with ball penetrometer results, as discussed above.

4.4 Pore Pressure Dissipation Testing

Periodically throughout cone and ball testing, penetration was stopped and pore pressure dissipation was monitored to determine the subsurface equilibrium pore pressure. Figure 4.7 shows equilibrium pore pressures above hydrostatic below about 4 m relative to the water pond surface. Pore pressure dissipation tests attempted below 17 m failed to achieve an equilibrium condition. The indicated trend is essentially the same as that shown on Figure 4.4. This is also reflected in Figure 4.8, which plots equilibrium pore pressures (obtained from dissipation testing) along with the dynamic pore pressure measurements obtained during penetration. There is little difference between the two measurements, indicating that little to no excess pore pressure is being developed during penetration. Thus, the PK tailings exhibit pore pressures equal to total stresses, with effective stresses essentially zero to significant depth.

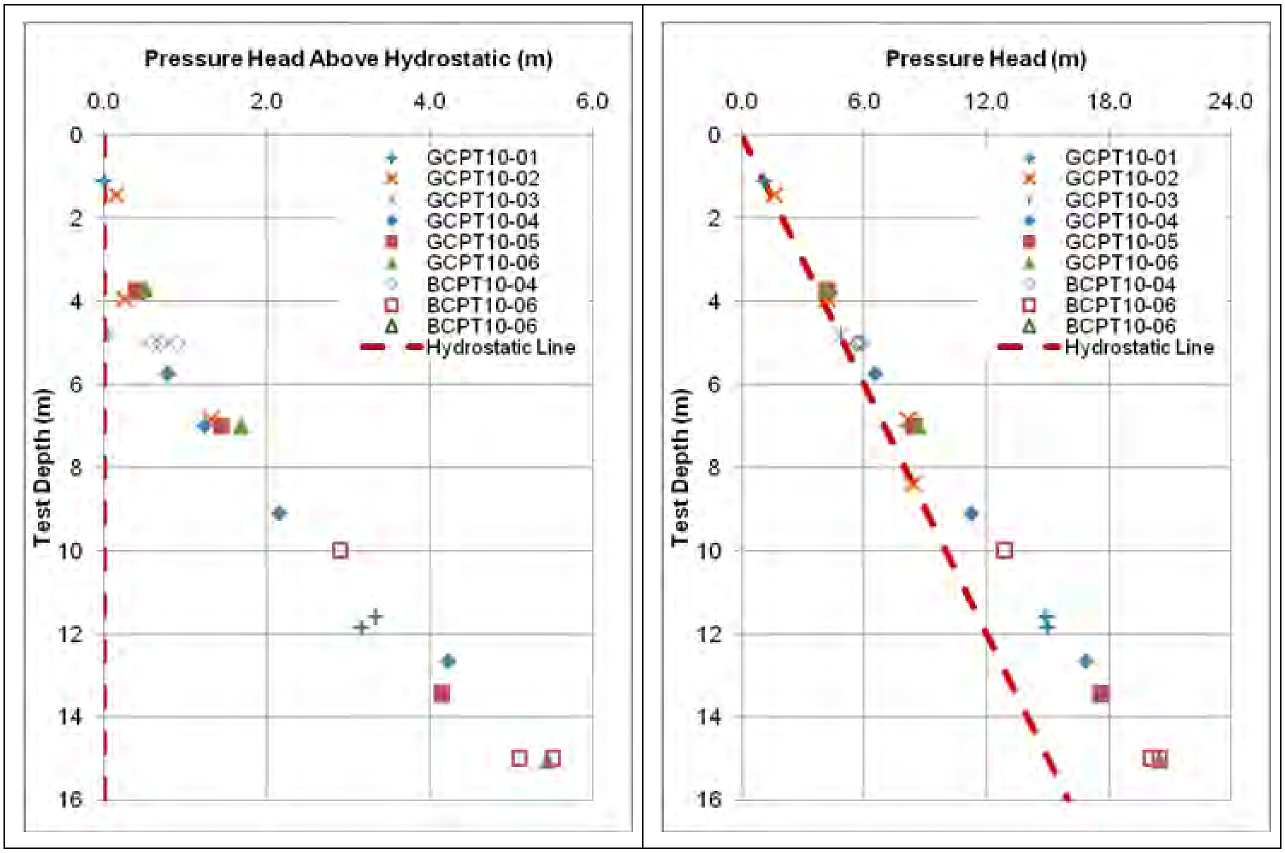

Figure 4.7: Pore Pressure Dissipation Data: Equilibrium Pore Pressures

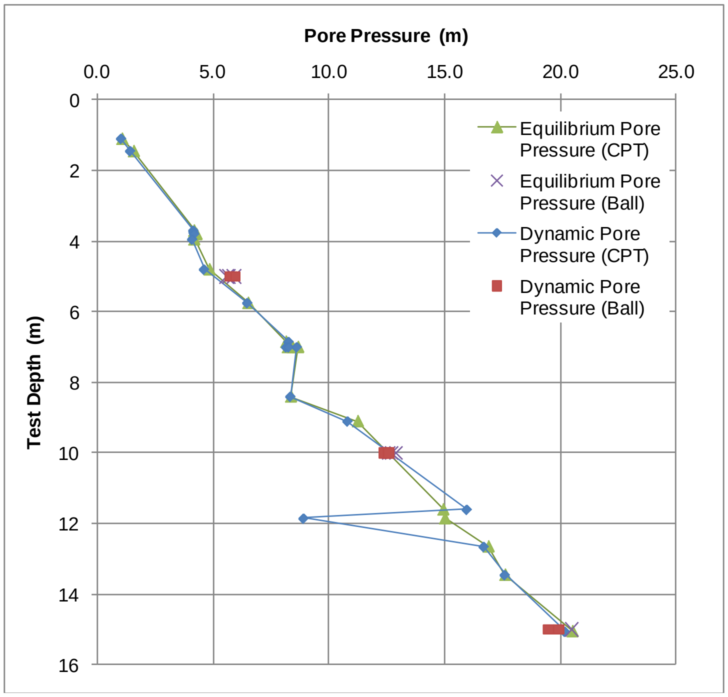

Figure 4.8: Comparison of Equilibrium and Dynamic Pore Pressure Measurements

4.5 Fluid Sampling

Samples of fluid to semi-fluid PK were obtained using a fluid sampler device lowered from the boat to target depths. The fluid sampler uses a compressed gas source to keep the sample chamber closed until the desired sample depth is reached, thus allowing a representative, but highly disturbed sample to be obtained. At surface, the sample is extruded into a permanent storage container.

A total of 17 samples of tailings were obtained, along with one sample of reclaim pond water for use in laboratory testing. Photographs of select samples are shown in Figure 4.9 for reference. All sample photos are provided within Appendix A. Full equipment and procedure details and sample logs are provided in Appendix B.

Figure 4.9: PK Tailings Samples

(Note: Pails are paint can size)

5.0 2010 LABORATORY TESTING PROGRAM

Upon completion of the on-site program described above, retrieved tailings samples were submitted to three different laboratories for a variety of testing. AGAT Laboratories Ltd. In Calgary Alberta completed X-Ray Diffraction (XRD) analysis of four samples. AMEC's Edmonton laboratory completed index testing of all samples and column settling testing of seven select samples. Finally, the Golder Associates laboratory in Calgary, Alberta completed large-strain consolidation testing on three select samples.

It should be noted samples were collected at only three locations within the PKC pond and were not collected to the full depth of the CPT soundings. Thus, the laboratory test results discussed herein are not representative of the lower, denser tailings units and native soils identified using the CPT. The laboratory testing program is summarized in Table 5.1 and is discussed in the following sections. Full test results are provided in Appendices C through G.

Table 5.1: Summary of 2010 Laboratory Testing Program

Hole ID	**Test Depth (m)**	**Test Type**						
		Moisture Content	**Specific Gravity**	**Atterberg Limits**	**Grain Size**	**XRD**	**Column Settling**	**Large Strain Consolidation**
BH10-04	6	✓	✓	✓	✓	-	✓	-
	8	✓	✓	✓	✓	-	-	-
	10	✓	✓	✓	✓	✓	-	-
	13	✓	✓	✓	✓	-	-	✓
	15	✓	✓	✓	✓	-	✓	-
	16	✓	✓	✓	✓	-	-	-
BH10-05	6	✓	✓	✓	✓	-	✓	-
	8	-	✓	-	✓	✓	-	✓
	12	✓	✓	✓	✓	✓	✓	-
	18	✓	✓	✓	✓	-	✓	-
	23	✓	✓	✓	✓	-	-	-
BH10-06	4	✓	✓	✓	✓	-	✓	-
	8	✓	✓	✓	✓	-	-	-
	12	✓	✓	✓	✓	✓	-	-
	13	✓	✓	✓	✓	-	✓	-
	15	✓	✓	✓	✓	-	-	-
	17	✓	✓	✓	✓	-	-	✓

5.1 Mineralogy (X-Ray Diffraction)

X-ray diffraction (XRD) testing was completed on four samples of PK solids. Testing revealed that the PK samples (clay to sand-sized fractions) are primarily composed of serpentine (clinochrysotile, 13%-29%) with sand/silt/clay size formation mineral particles of quartz (16%-20%), calcite (11%-22%), smectite (7%-11%), dolomite (6%-11%), plagioclase feldspar (20%, noted in one sample only), microcline, potassium feldspar (6%, noted in one sample only), pyrite (5%-9%), siderite (4%-10%), illite (1%-7%), and muscovite (3%-4%).

The laboratory segregated the minus 3 micron size from the larger sizes. The minus 3 micron portion of the samples ranged from 13.4% to 22.2% by weight. Mineralogy for the minus 3 micron fraction was dominated by smectite (40% to 78%), with lesser amounts of clinochrysotile (9% to 40%), calcite (2% to 10%), and illite (1% to 7%).

Full test results are provided in Appendix C.

5.2 Grain Size Testing

A total of 39 grain size tests (comprising both sieves and hydrometers) were completed on 17 fine PK samples. Duplicate testing was undertaken to ensure accuracy of the results. PK samples typically have a composition of clayey silt with some sand (Figure 5.1). Fines content (Figure 5.2) typically ranged between 80% and 100%, with local decreases occurring at depth. Clay contents ranged from 10% to 40% by weight. Given the significant clay content, and the predominant clay mineralogy (smectite), the slow consolidation and largely fluid-like of the fine PK for considerable depth is unsurprising.

Full laboratory test records are provided in Appendix D.

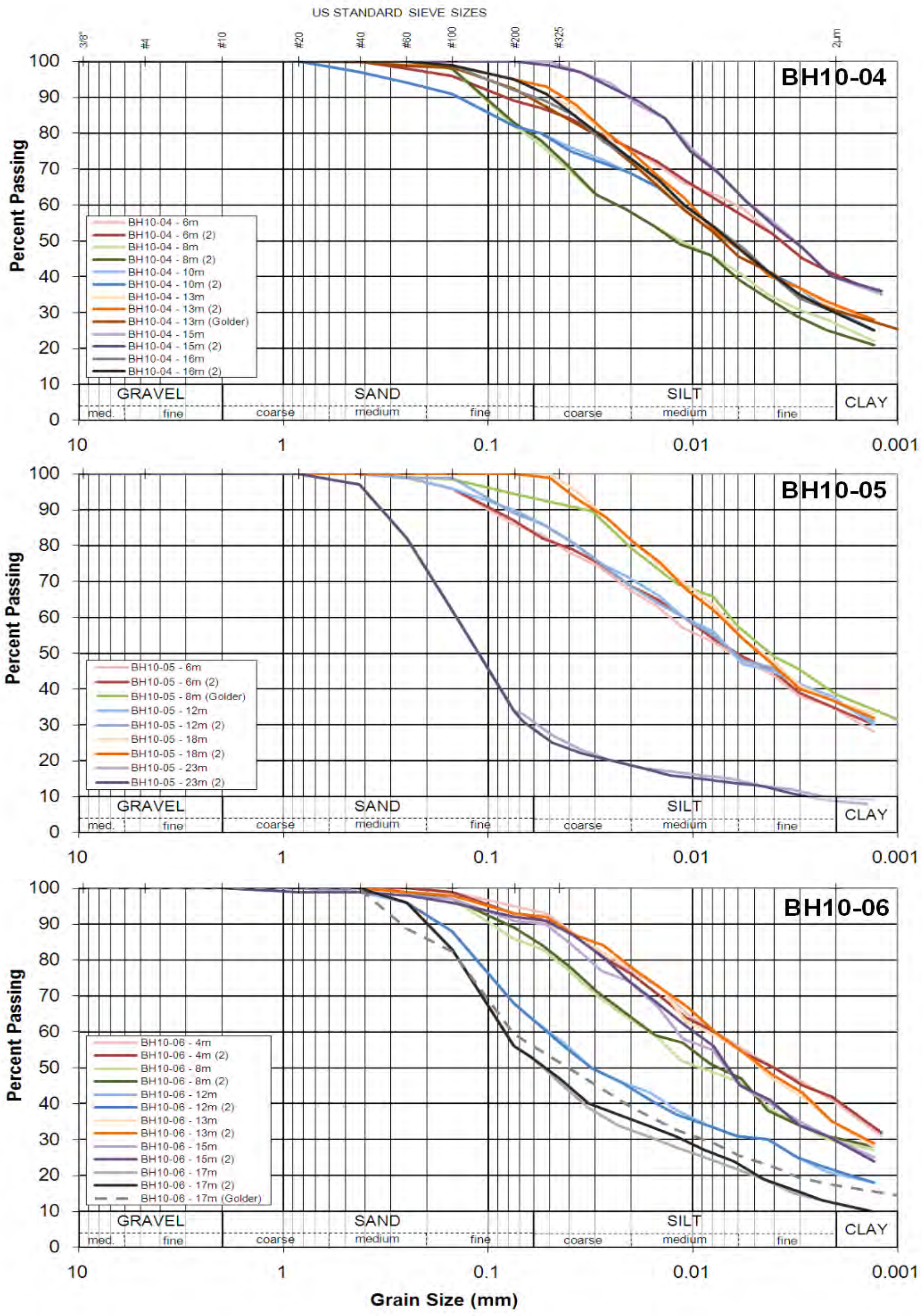

Figure 5.1: Grain Size of PK Samples

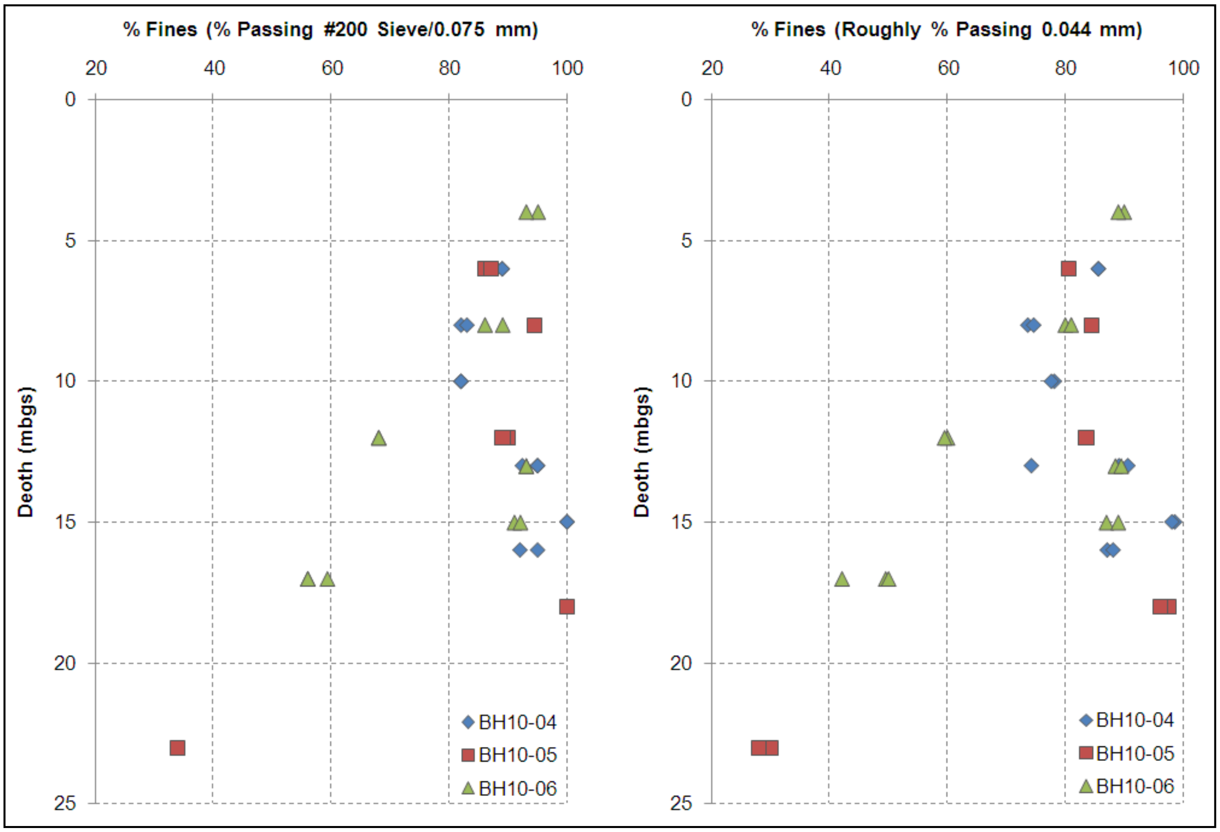

Figure 5.2: Fines Content of PK Samples

(Note: Pairs of points are a result of duplicate testing completed.)

5.3 Moisture Content and Specific Gravity

A total of 32 moisture content tests were completed on 16 PK samples. Duplicate testing was undertaken to ensure accuracy of the results. As shown on Figure 5.3, the moisture content (defined as weight of water to weight of solids) of the PK samples is high, reaching 200% (33% solids) near surface. This decreases with depth to moisture contents of 40% to 60% (63% to 71% solids). Sixteen specific gravity tests were completed (no duplicate testing), as shown on Figure 5.4. Specific gravity of the PK solids ranges from 2.7 to 2.8, increasing to 2.85 for the one test completed below 20 m. Bulk unit weights of samples were calculated based on measured solids content and specific gravity and ranged from 12.4 kN/m^3 to 17.4 kN/m^3, generally increasing with depth (Figure 5.5). Full laboratory test records are provided in Appendix E.

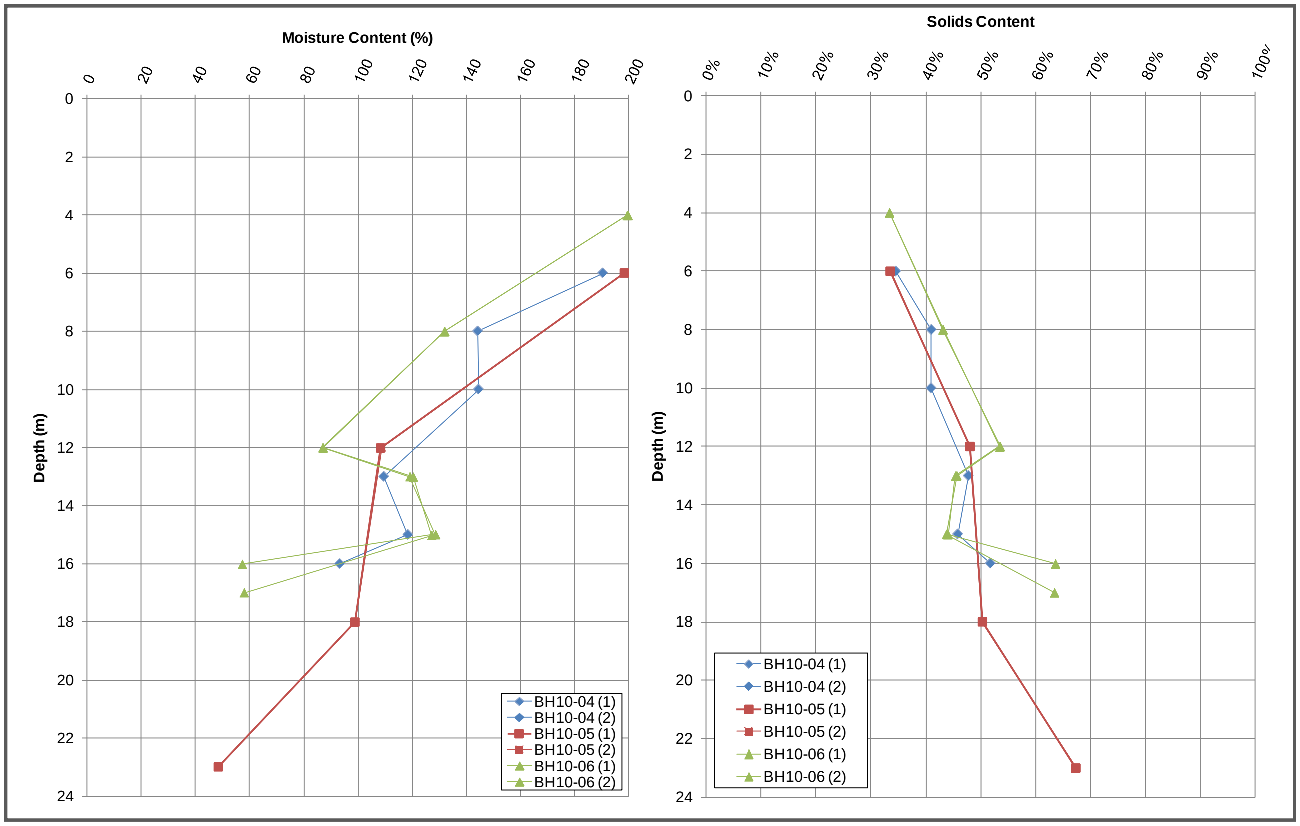

Figure 5.3: Moisture Content and Solids Content of PK Samples

(Note: Pairs of points are a result of duplicate testing completed.)

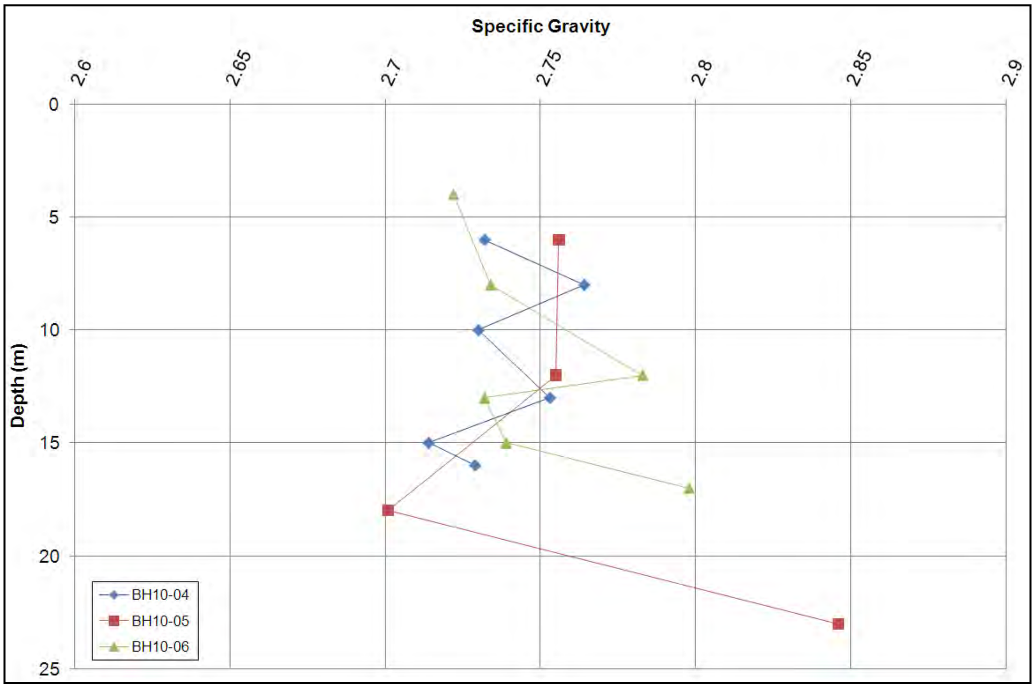

Figure 5.4: Specific Gravity of PK Samples

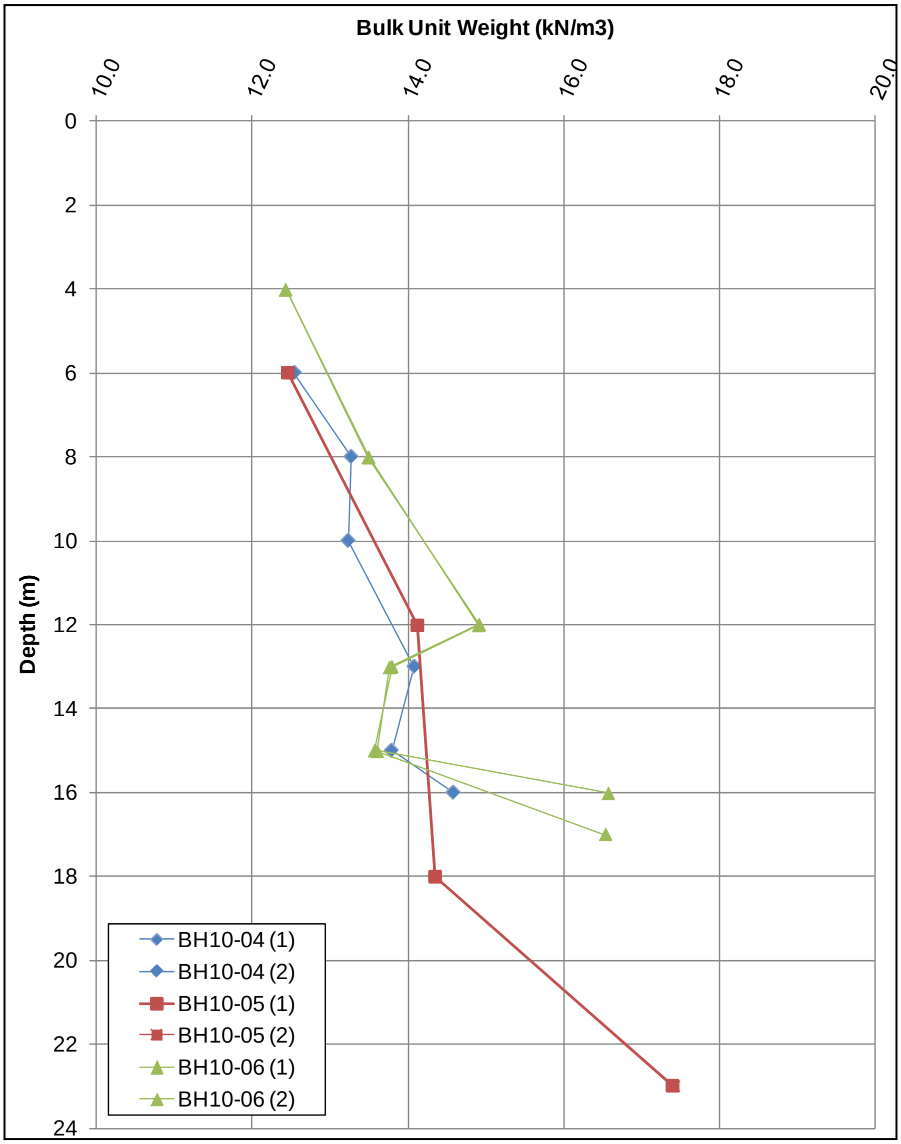

Figure 5.5: Bulk Unit Weight of PK Samples

5.4 Atterberg Limit Testing

A total of 32 Atterberg limit tests were completed on 16 PK samples. Duplicate testing was undertaken to ensure accuracy of the results. As shown on Figure 5.6, the PK primarily has the characteristics of high-plasticity clay, consistent with the dominance of smectite in the clay mineralogy. The two exceptions to this trend plot as low-plasticity silt and intermediate plasticity clay and are associated with greater depths (17 m and 23 m in BH10-06 and BH10-05 respectively). Figure 5.7 shows the distribution of Atterberg limits with depth for each hole. In general, limits remain relatively constant; the liquid limit varies between 60% and 80% while the plastic limit varies between 20% and 30%. Notable deviations from this trend occur at depth in

BH10-05&06 and near surface in BH10-06. Superimposed on these plots are the field water content profiles. In comparing these two the liquid limit values, it can be seen that the field water contents exceed the liquid limit values.

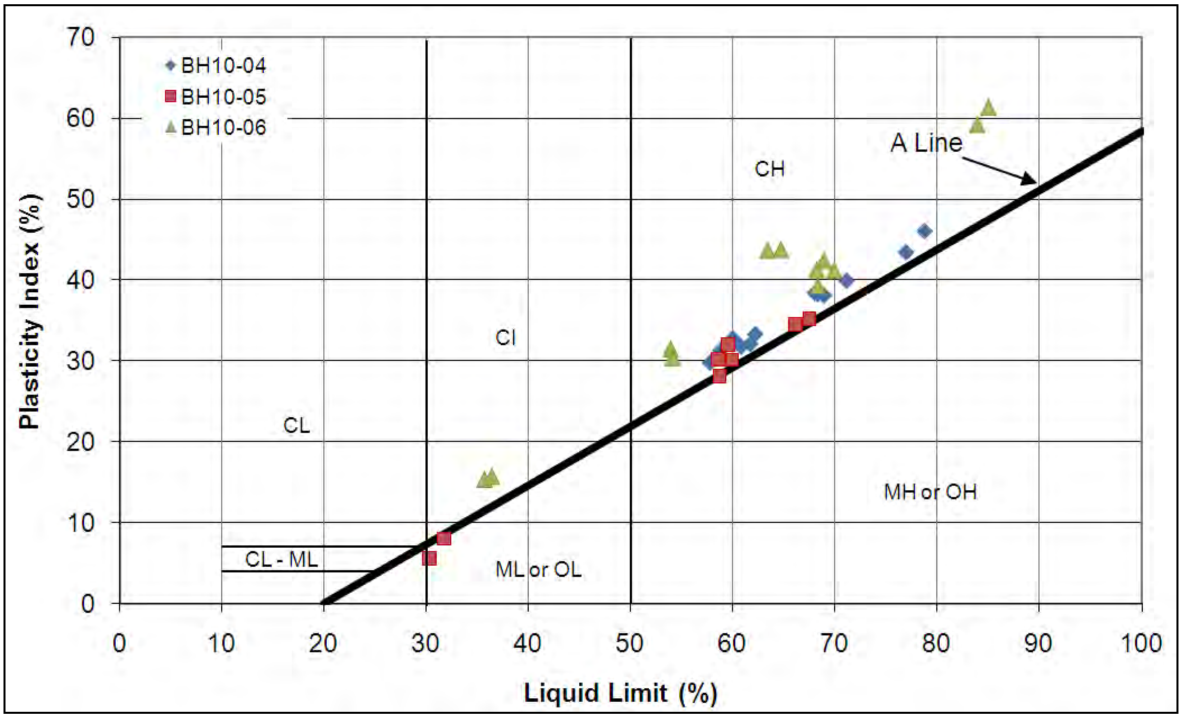

Figure 5.6: Plasticity of PK Samples

(Note: Pairs of points are a result of duplicate testing completed.)

Sobkowicz and Morgenstern (2009)[3] observed, in a study of the geotechnical aspects of oil sands tailings, that the liquid limit provides a useful means of empirically assessing low undrained shear strength. Figure 5.8 (Terzaghi et al., 1996)[4] provides a relationship between liquidity index (LI) and remoulded undrained shear strength of clays.

---

[3] Sobkowicz, J.C. and N.R. Morgenstern (2009). "*A geotechnical perspective on oil sands tailings*", Keynote address, Proceedings, Tailings & Mine Waste '09.

[4] Terzaghi, K., Peck, R.B. and G. Mesri (1996). "*Soil mechanics in engineering practice*", 3rd edition, John Wiley & Sons Inc.

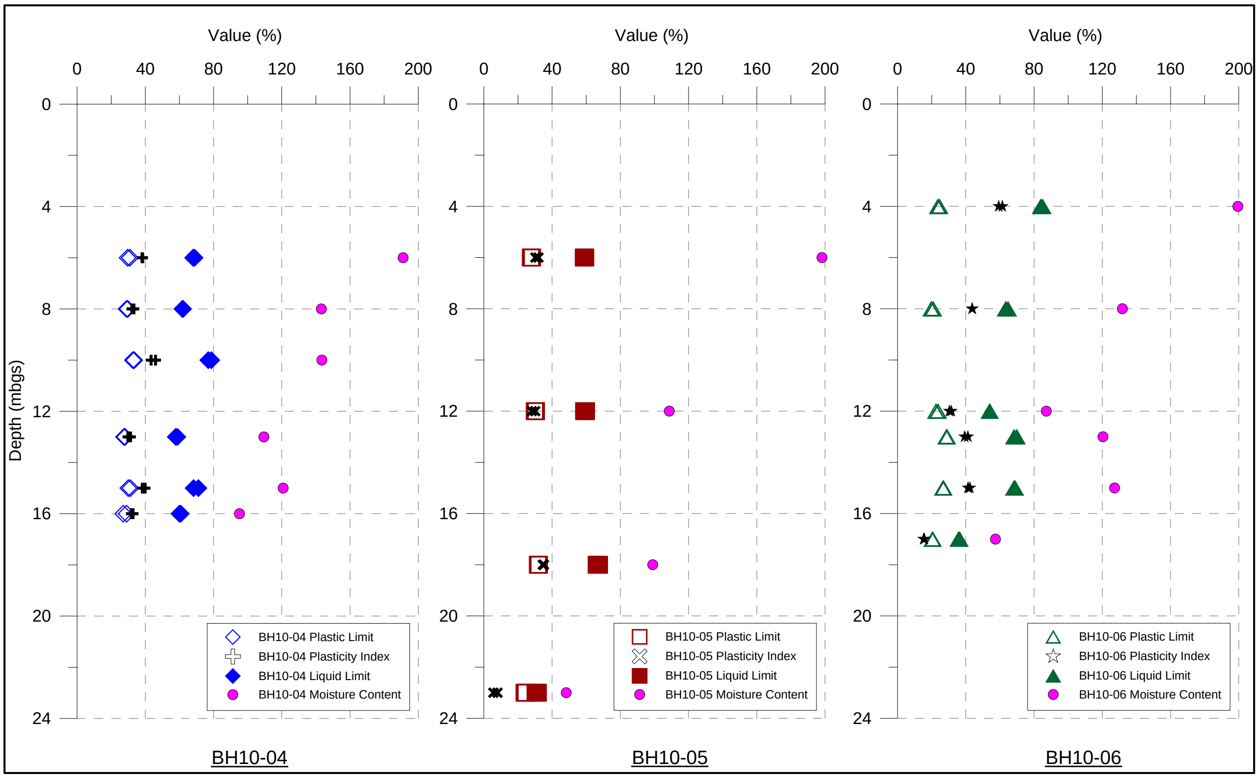

Figure 5.7: Atterberg Limits of PK Samples
(Note: Pairs of points are a result of duplicate testing completed.)

The LI is defined as follows:

$$LI = (w - PL)/(LL - PL)$$

Where:

w = water content
PL = plastic limit
LL = liquid limit

The data in Figure 5.7 indicate LI values generally in excess of 2. When points for which measured liquidity index and remoulded shear strength data exist are plotted on Figure 5.8, it becomes apparent that the Terzaghi et al. (1996) liquidity index – remoulded shear strength line forms at best a lower bound to the Diavik PK data. This lower bound would correlate to remoulded undrained shear strengths of about 0.2 kPa. Terzaghi et al. (1996) observe that this also corresponds to the remoulded shear strength of quick clays, which in the remoulded state display the consistency of a heavy fluid. The remoulded undrained strengths obtained directly from field testing (see Figure 4.6) are reasonably consistent with this interpretation to depths of between 10 m to 15 m, below which the remoulded strengths are significantly higher.

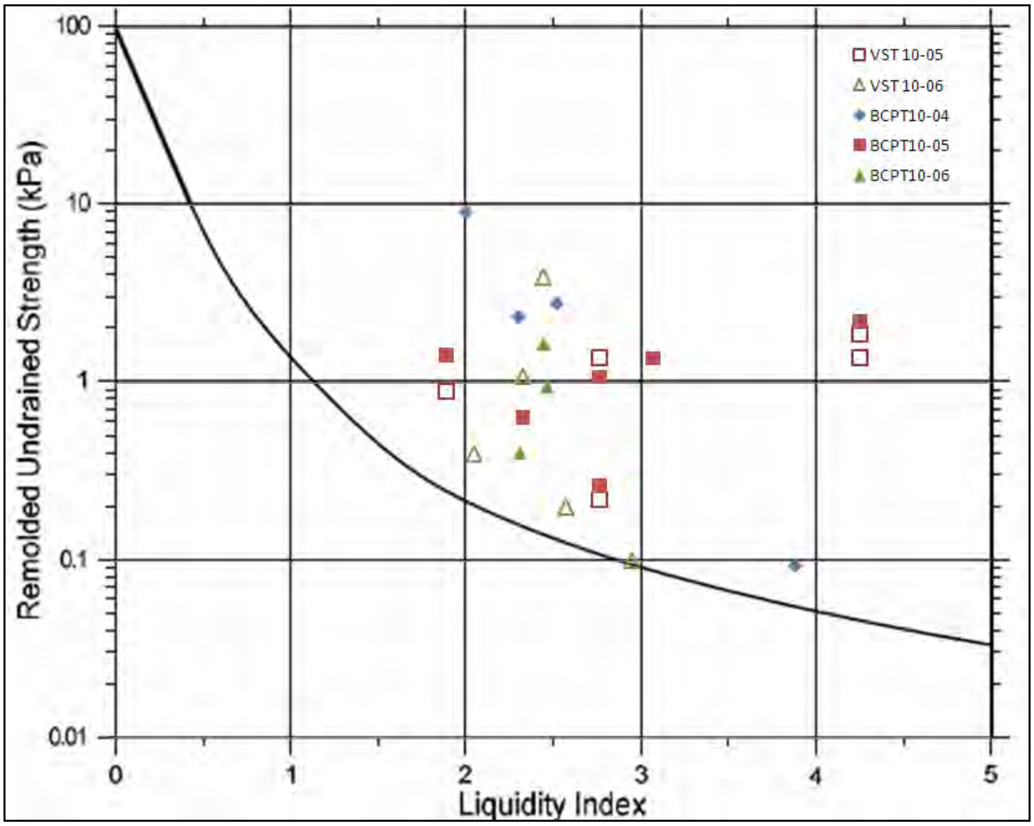

Figure 5.8: Remoulded Undrained Strength of Clays vs. Liquidity Index

Full laboratory test records are provided in Appendix F.

5.5 Column Settling Tests

Column settling tests were completed on seven samples of PK. In this test, the PK sample is remixed to a specified solids content and allowed to settle under self-weight. The test procedure was as follows:

1. The sample was placed into a 1 L graduated cylinder. The weight of the sample placed into the graduated cylinder was recorded.
2. Reclaim pond water (from the PKC pond) was added until the mixture in the graduated cylinder reached about a 20% solids content.
3. The sample was thoroughly stirred to mix it up and create suspended sediment.
4. The cylinder top was covered with plastic wrap to reduce the amount of moisture lost.
5. The starting time was recorded, along with the water level, and the level of any interface visually observed between sediment and water.
6. At regular time intervals, the time/date was recorded, with the corresponding water level, and the level of any interface(s) visually observed between the sediment and water.

7. The sample was topped up as required using reclaim pond water, and a record kept of when and how much water was needed to top the sample up.

Test results are illustrated in Figure 5.9, which shows that, given the constant initial solids content, all samples achieved full settlement within 15 to 20 days after deposition. Once settled, the resulting fine PK column had a dry density of 0.34 t/m^3 to 0.49 t/m^3 (28% to 37% solids content by weight). This represented a solids content increase ranging from 40% to 85% of the original solids content of the mixed samples. Attempts were made to correlate the ultimate settled dry density to various parameters (e.g. specific gravity of solids, fines content, depth), but no distinct trends are apparent. Assuming a solids specific gravity of 2.73, the final dry density values indicated a void ratio in the range of 6.4 to 8.8.

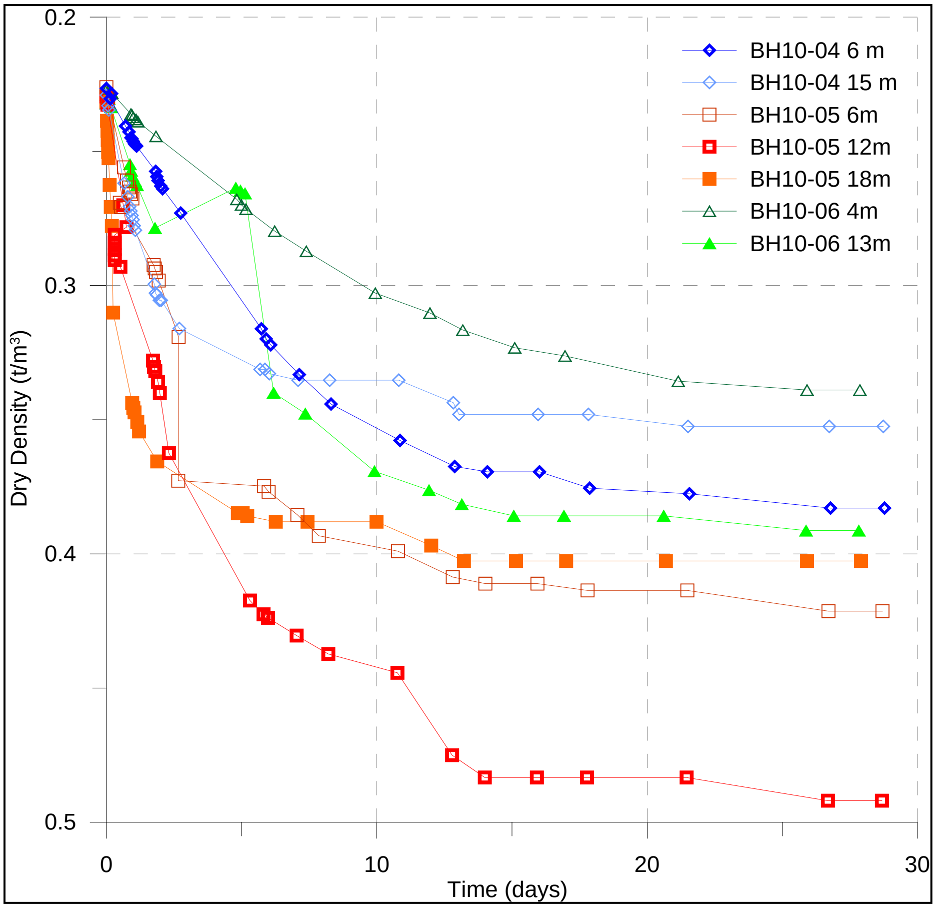

Figure 5.9: Column Settling Test Results

Each of the seven column settling tests resulted in a distinct interface between silty solids and clear water. In four of the tests, a thin transition unit of clayey PK was noted between the water and underlying silty solids at latter phases of the test. By calculating the rate at which the primary solids-water interface was observed to move down the water column in the early phases of the test, it is possible to infer a hydraulic conductivity of the fine PK. Using this process, the fine PK was found to have conductivities between 5.2 x 10^{-7} m/s and 6.6 x 10^{-6} m/s.

Figure 5.10 shows inferred fine PK hydraulic conductivities and provides the measured hydraulic conductivity obtained from low-stress load steps during large-strain consolidation testing for comparison. The two methods of determining hydraulic conductivity compare well and show a trend of increasing hydraulic conductivity with depth. This trend seems anomalous as, given the lack of trend in fines contents with depth, a decreasing hydraulic conductivity with depth would be expected.

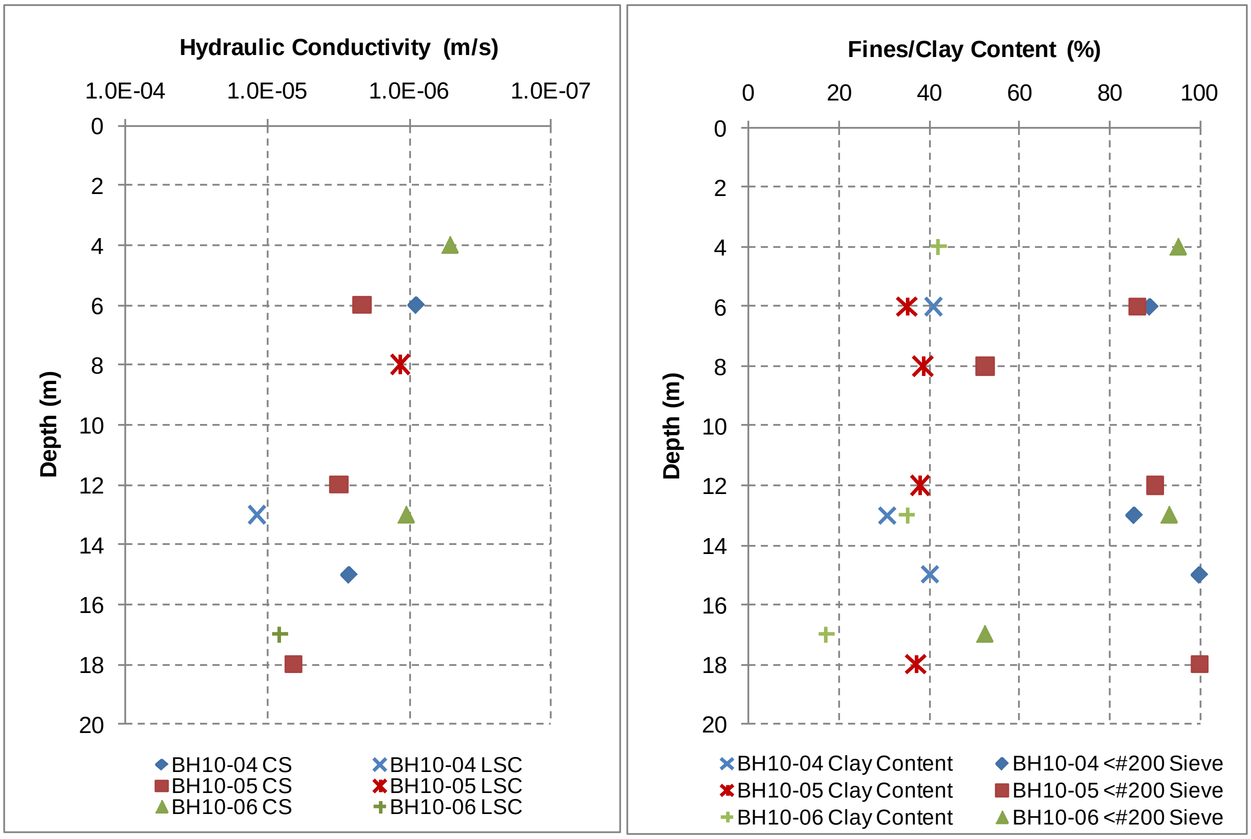

Figure 5.10: PK Hydraulic Conductivity – Inferred from Column Settling Test Results

Also plotted on Figure 5.10 are the clay and fines (percent finer than #200 sieve) contents for the tested samples. In general, clay and fines contents remain relatively constant across sample locations and depths. Two samples (BH10-05, 8 m and BH10-06, 17 m) vary from the general trend, exhibiting fines contents approximately 30% lower. However, these low fines contents do not seem to correlate to higher hydraulic conductivity, as would generally be expected of coarser soils.

5.6 Large-Strain Consolidation Testing

Three PK samples (one from each of boreholes BH10-04, 05 & 06) were submitted to large strain consolidation (LSC) testing with periodic hydraulic conductivity measurements. This test is conducted by subjecting the PK sample to increasing stress levels and monitoring the change in sample volume. The initial dry density of the PK samples (between 0.5 t/m3 and 0.9 t/m3, or solids contents between 41% to 60%) was higher than the ultimate density achieved under self-weight settling (section 5.5 above). Approximate stress levels were applied in (roughly) the following sequence: 1.5 kPa, 3 kPa, 5 kPa, 11 kPa, 21 kPa, 38 kPa, 89 kPa, 191 kPa, and 396 kPa. Under the ultimate load level, the sample dry density increased to between 1.2 t/m^3 and 1.4 t/m^3, or solids contents between 70% to 83%. The variation of PK density (represented by void ratio) under various stress levels is shown in Figure 5.10.

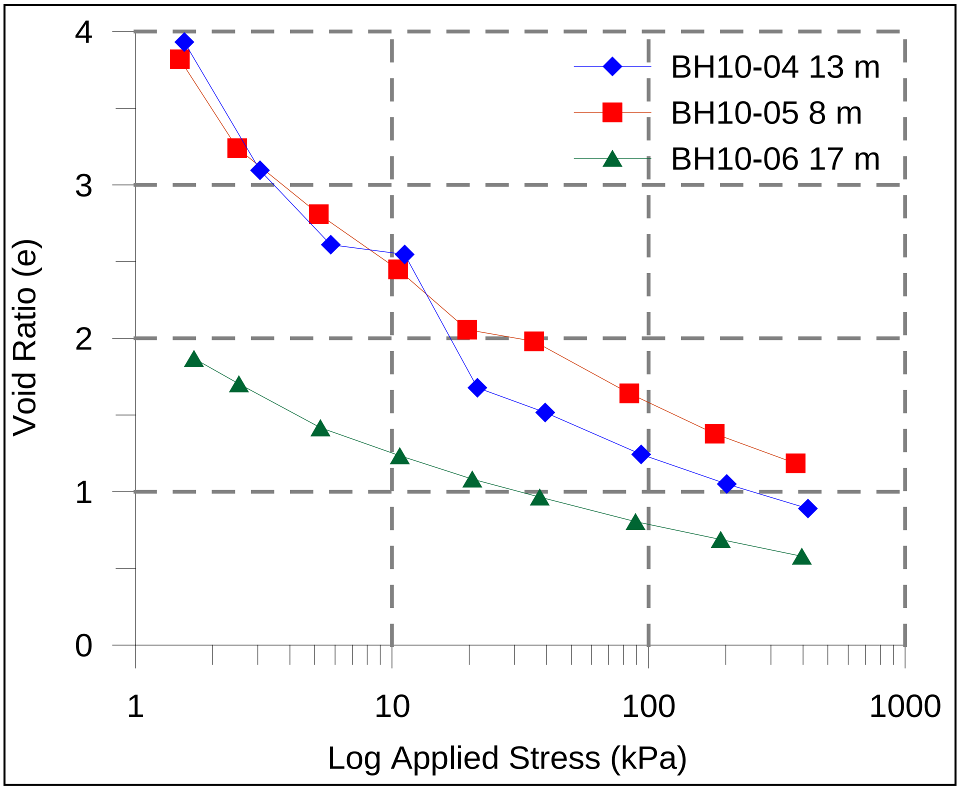

Figure 5.11: Relationship Between Void Ratio and Applied Stress from LSC Testing

At select stress levels, the large-strain consolidation test was paused to allow direct measurement of soil hydraulic conductivity. As anticipated, the fine PK hydraulic conductivity decreases with increasing applied stress (i.e. decreasing void ratio or increasing density), as shown on Figure 5.12. The samples from BH10-04 and 06 (red and blue on tFigure 5.12) have very similar particle size distributions with over 90% fines whereas sample BH10-05 has a much lower fines content (60%). This is reflected in the measured hydraulic conductivity values below. The coarser nature of BH10-05 allows high hydraulic conductivity to persist at a low (relative to the other samples) void ratio (i.e. higher density). Overall, the PK hydraulic conductivity decreases by over three orders of magnitude over the prescribed range of stress loading.

Pollock (1988)[5] observed that, for oil sands tailings, the variation of hydraulic conductivity with both void ratio and grain size distribution converges to a single relationship when plotted against fines void ratio. This methodology was applied to the PK tailings large strain consolidation test results under the assumption that the fines and coarse soil fractions have equal specific

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[5] Pollock, G.W., 1988. "*Large Strain Consolidation of Oil Sand Tailings Sludge*", M.Sc. Thesis, University of Alberta

gravities (Figure 5.11), but a unique relationship did not result. This may be due to a difference in specific gravity between the fine and coarse soil fractions, possibly related to the amount of low specific gravity bitumen within the oil sands tailings, a substance not present within the fine PK.

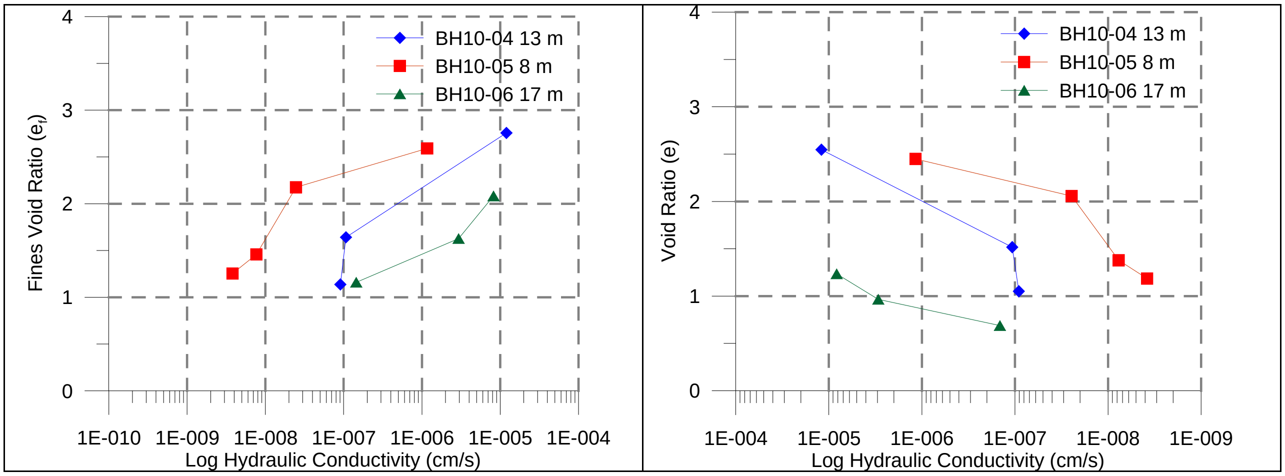

Figure 5.12: Relationship Between Void Ratio and Hydraulic Conductivity from LSC Testing

6.0 INTERPRETED PK COMPOSITION

Based on site observations, historical data, and the 2010 CPT and laboratory testing discussed above, it is evident that characterization of the fine PK within the portion of the impoundment tested (i.e. where deposition has been pre-dominantly sub-aqueous) can be undertaken using frameworks developed for characterization of oil sands mature fine tailings (MFT) in terms of geotechnical behaviour. Oil sands tailings and the fine PK at Diavik display the following similarities:

- a high degree of hydraulic segregation,
- a range from sand to clay particle sizes, and
- slow consolidation rates in the portions of the deposits dominated by fines and sub-aqueous deposition, resulting in largely fluid-like behaviour remaining to significant impoundment depths.

Recent research[6] has developed empirical charts relating various properties measured in CPT testing to the PK deposit behaviour type and composition. In light of the observed similarities between MFT and PK, this methodology was applied to the results of 2010 CPT testing to characterize the fine PK within the portion of the PKC facility tested.

6.1 Overview of the Styler et al Method

The methodology proposed in Styler et al (2010) relies on a large dataset of gamma piezocone (CPT) testing and associated laboratory test results completed on nearby samples to relate properties measured in CPT testing to actual tailings composition (solids content and fines[7] content as a percent of total solids). As the tailings slurry is deposited in water, it will exhibit fluid-like behaviour and settle via self-weight sedimentation (i.e. the soil particles do not interact). As this process continues, the soil particles will begin to interact and eventually form a soil skeleton, at which point the soil begins a self-weight consolidation type of behaviour. Various criteria have been proposed to define points of transition from settlement to consolidation behaviours. Relevant parameters obtainable from CPT testing were selected and used to breakdown the database of CPT profiles into three ‘behaviour types’ (sedimentation – settlement behaviour, transition, and soil skeleton – consolidation behaviour). This breakdown is illustrated in Figure 6.1, and summarized in Table 6.1 (Styler et al., 2010).

Table 6.1: Tailings Behaviour Types Definitions

Phase	Defining Characteristic	Tailings Behaviour Type (TBT)
Sedimentation	No particle interaction	Sedimentation
	Particle interaction	Transition
Consolidation	Measurable effective stress	
	Behaviour is a function of effective stress	Soil skeleton

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[6] Styler et al. (2010). “*Determination of Oil Sands Tailings Composition through In-Situ Testing*”, ConeTec In-Situ Testing Seminar, November 29, 2010.

[7] It should be noted that in the oil sands, ‘fines’ refers to particles smaller than 44 microns (this differs from regular geotechnical practice), and this convention has been retained in the following discussion.

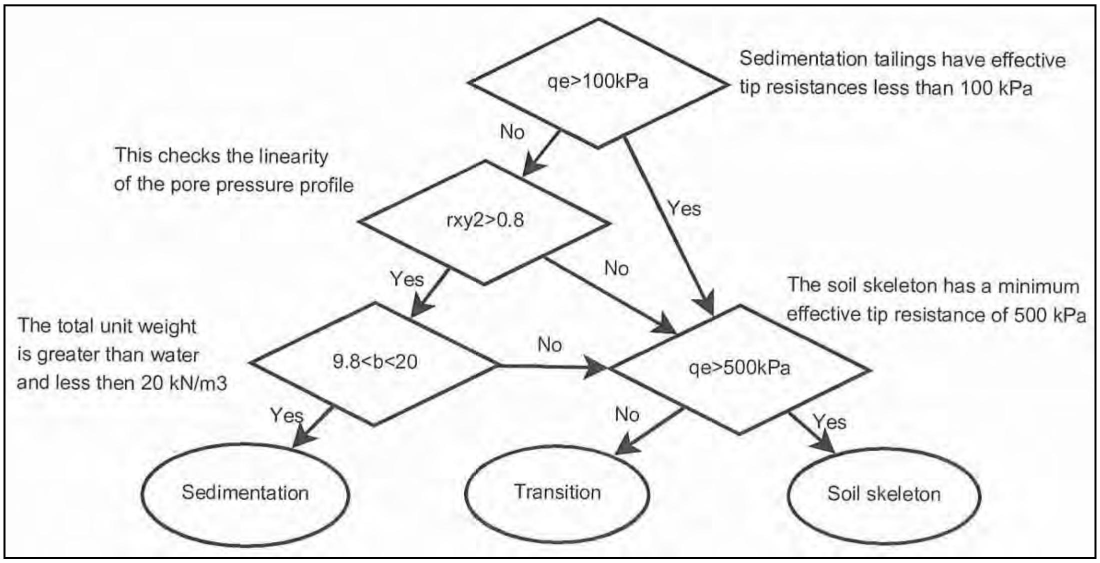

Figure 6.1: Flow Chart for Tailings Behaviour Type Characterization (Styler et al, 2010)

For each of the three above tailings behaviour types, the corresponding database of measured tailings compositions (as obtained from oil sands work) was analysed to define empirical correlations with measurable CPT parameters. The result is a series of graphs showing contours of fines or solids content for each tailings behaviour type (TBT). To use these graphs, the CPT data must be filtered using the criteria outlined in Figure 6.1, and plotted on these graphs before selecting the corresponding solids and fines contents from the empirical contours.

6.2 Applicability of Analysing 2010 PKC CPT Data using Styler et al Method

To use the methodology described above, the 2010 CPT data was analysed to yield a breakdown of Sedimentation, Transition, and Soil Skeleton phase TBT's. Differing calculation methods were necessary to determine the various required input parameters for each behaviour type:

- Sedimentation: The unit weight of tailings was estimated at each data point by assessing the slope of the CPT-measured pore pressure profile. Solids content was then derived from the estimated unit weight and the measured specific gravity. Fines content was obtained by plotting the unit weight and gamma count on the corresponding Styler et al (2010) graph.
- Transition: The unit weight of tailings was estimated at each data point by correlation with other CPT parameters and identified soil behaviour type (provided by ConeTec). Both solids and fines content were obtained by plotting the effective cone tip resistance and gamma count on the corresponding Styler et al (2010) graphs.
- Soil Skelton: As CPT investigations were terminated upon reaching contrasting, dense strata, no significant thicknesses of the soil skeleton behaviour type were encountered. Further analysis was not possible.

Where determining fines or solids content required picking contour values off a graph, analysis points were selected at roughly 2 m intervals, with additional concentration in areas of interest.

For BH10-04, 05, and 06, the various laboratory testing data was used to assess the accuracy of the Styler methodology (as illustrated for the example of CPT/BH10-04 in Figure 6.2). The following conclusions regarding the applicability of the methodology were obtained from analysis of similar graphs for CPT/BH10-04, 05, and 06:

- Solids Content:
  - Within the Sedimentation behaviour type, the calculated solids content (green triangles) agrees reasonably well with the measured solids contents (purple dots).
  - Within the Transition behaviour type, agreement is poor, with solids contents determined from the Styler graphs differing by up to 30% from measured values.

- Fines Content:
  - Within the Sedimentation behaviour type, the fines content obtained from the Styler graphs (blue stars) agrees moderately well with the measured (i.e. laboratory analyses) fines contents (orange crosses), keeping in mind that the measured values vary significantly.
  - Data is lacking, but within the Transition behaviour type, agreement appears to be poor, with fines contents determined from the Styler graphs differing by up to 40% from measured values.

- Unit Weight:
  - Within the Sedimentation behaviour type, the unit weight calculated from the slope of the pore pressure measurements agrees well with that calculated using measured specific gravity and moisture contents.
  - Within the Transition behaviour type, unit weights calculated from measured specific gravity and moisture contents agree moderately well with those assigned according to CPT data soil behavior type.

- Overall: The application of the Styler methodology to the Diavik PK tailings deposits appears to be reasonable within the Sedimentation TBT zones, but less reliable within the Transition TBT zones. Overall, this methodology should be viewed as a preliminary tool to assess tailings behaviour and large-scale trends.

6.3 2010 PK Tailings Composition Summary

Data collected from all six gamma CPT soundings completed in 2010 was analysed using the methodology and empirical relationships described above. The resultant zonation of TBT and composition are illustrated in Figures 6.3 and 6.4.

CPT soundings 01, 02, and 03 were located towards the eastern limit of the reclaim water pond, and encountered dense material (likely till, or potentially ice lenses) at relatively shallow depths of 5 m to 12 m (Figure 6.3). All three soundings showed a thin (1.5 m maximum) layer of transition behaviour type PK overlying the inferred native till and underlying sedimentation phase PK. Sedimentation phase PK solids contents increased with depth and ranged from 0% (i.e. pond water) to 80%. Fines contents (as a percent of total solids) decreased with depth and varied between 50% and 100%.

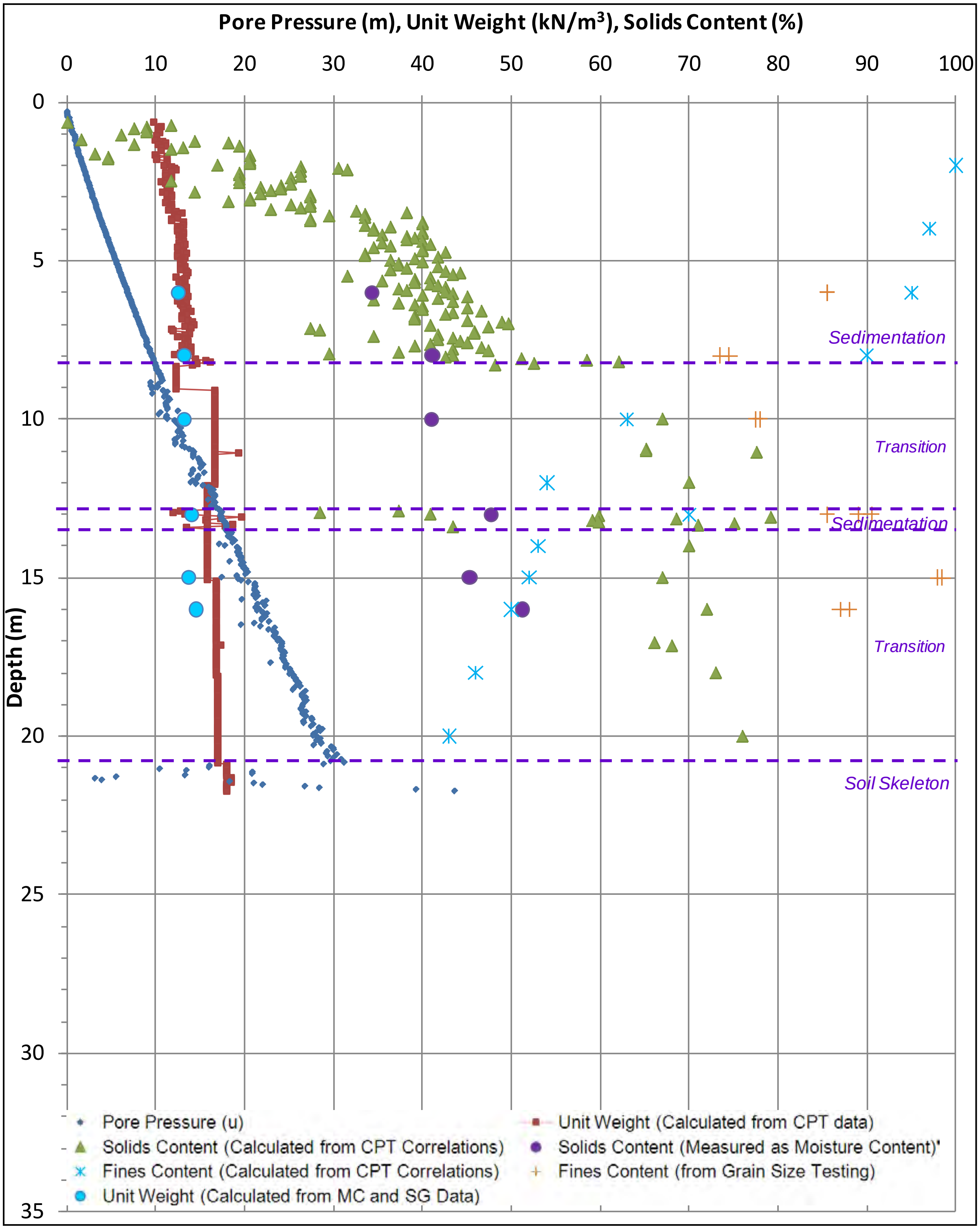

Figure 6.2: Profile of Tailings Composition – CPT/BH10-04

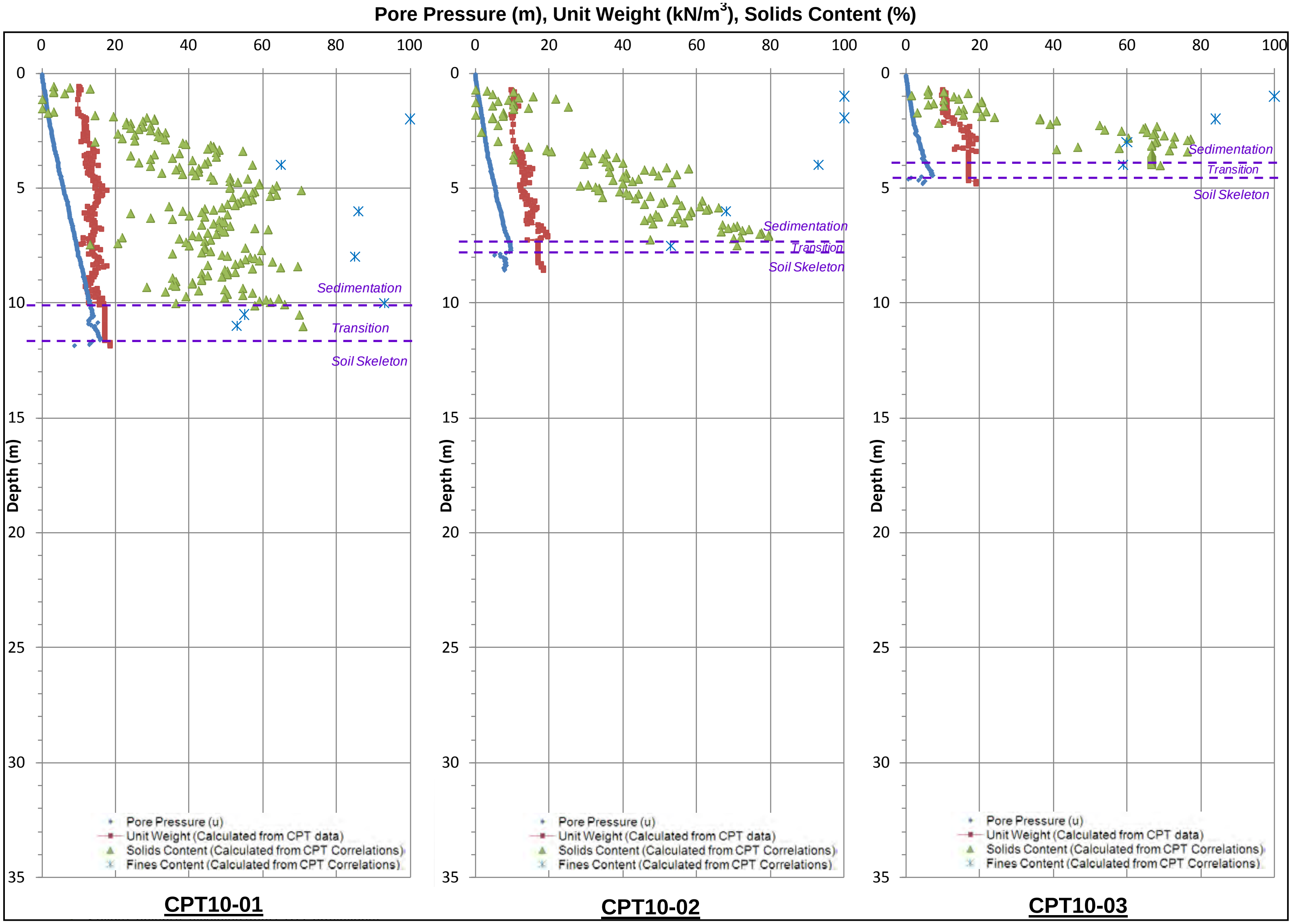

Figure 6.3: Profile of PK Composition – CPT10-01, 02, and 03

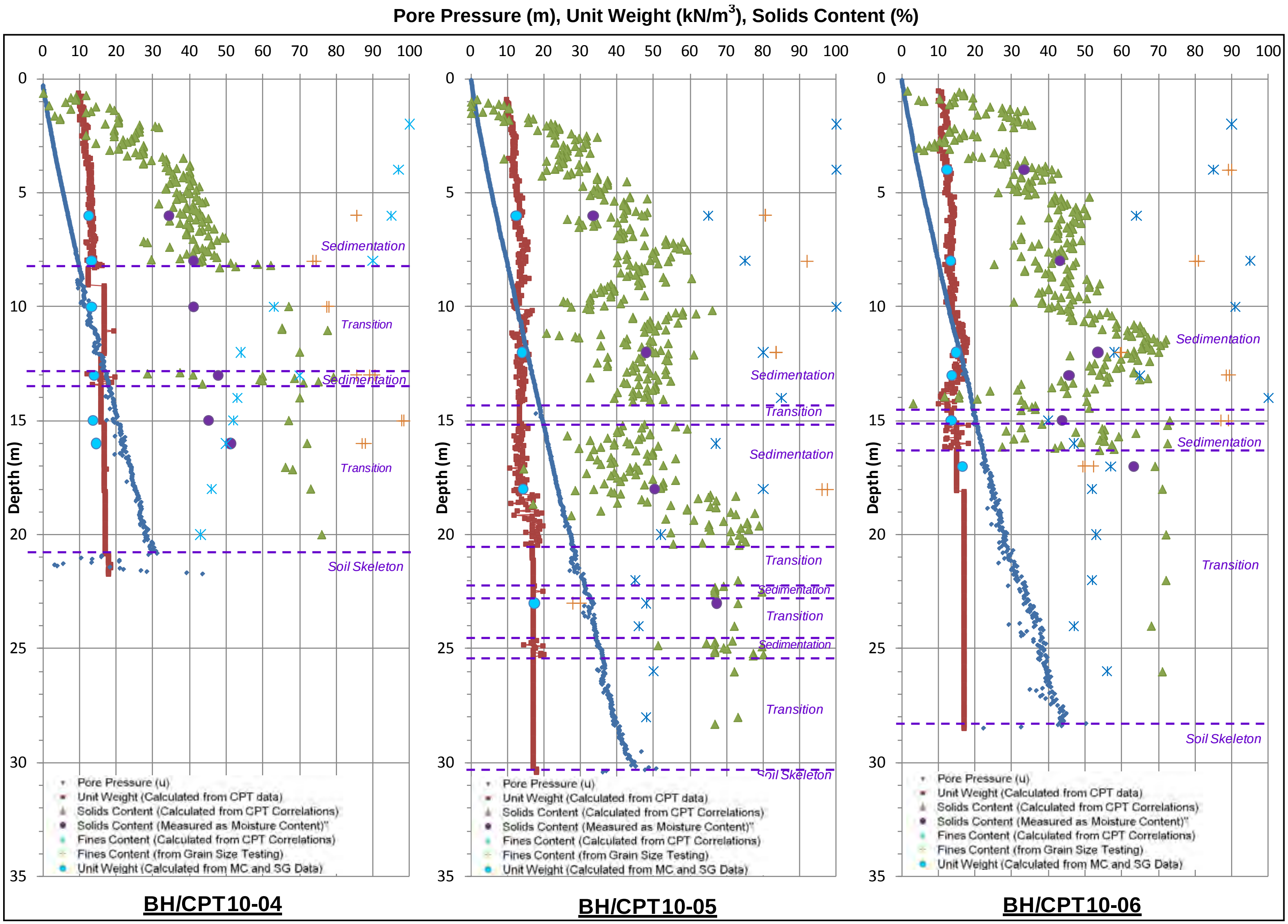

Figure 6.4: Profile of PK Composition – CPT10-04, 05, and 06

CPT soundings 04, 05, and 06 were located in the deeper portion of the water pond, and encountered dense material (likely till) at depths of 21 m to 30 m (Figure 6.4). All three soundings showed significant and distinct zones of the sedimentation and transition behaviour types, with local thin layering. The contact between the overlying sedimentation phase PK and underlying transition phase PK occurred at depths of 8 m to 14.5 m. Sedimentation phase PK solids contents increased with depth and ranged from 0% (i.e. pond water) to 80%. Fines contents (as a percent of total solids) decreased with depth and varied between 50% and 100%. Within the transition phase PK, both the solids content and fines contents remain roughly constant with increasing depth, varying between 65% to 75%, and 40% to 65%, respectively.

7.0 IMPLICATIONS FOR CLOSURE PLANNING

The results documented herein exhibit significant implications for DDMI's ongoing operational procedures and closure planning for the PKC facility. The original closure plan (NKSL, 2001) for the PKC facility involved covering the entire deposit as follows:

- The water pond would be drained at the end of active fine PK discharge.
- The low area within the impoundment would be backfilled with up to 5 m of coarse PK, and then covered with a 5 m thick "rock spacer" comprised of Type I (non potentially acid generating) waste rock.
- The 5 m "rock spacer" in turn would be covered by 1 m of sandy silt till, overlain in turn by 3 m of Type I waste rock.
- Outside of the former pond area, the fine PK beaches would be covered by 0.5 m of sandy silt till, overlain in turn by 3 m of Type I waste rock.
- The finished surface will be graded to shed runoff to the perimeter of the facility.

Figure 7.1 shows a conceptual plan of the closed PKC facility.

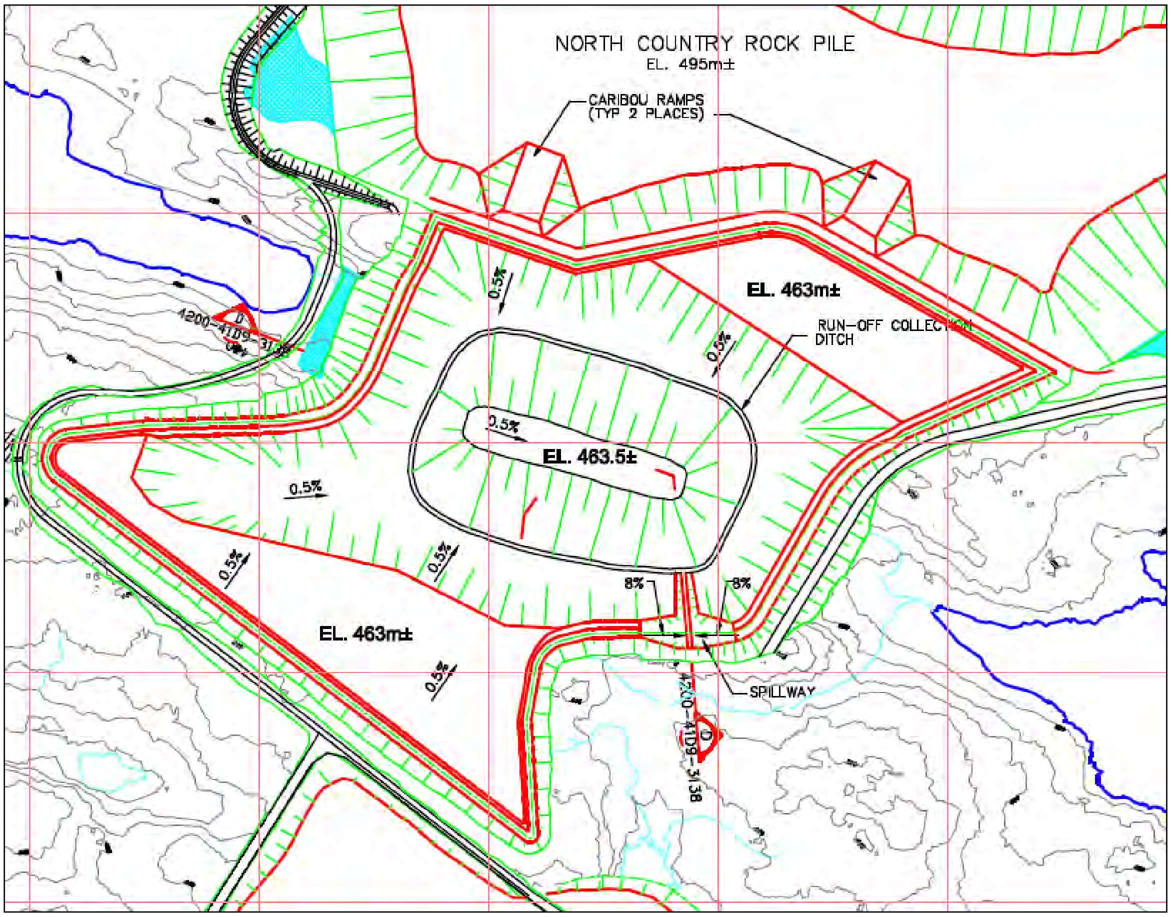

Figure 7.1: Original Closure Concept for the PKC Facility (NKSL, 2001)

Given the conditions revealed by the investigations documented herein (i.e. zero effective stress within the PK deposit to depths of up to 15 m), implementation of such a scheme would be highly problematic in terms of the ability of the fine PK in the central portion of the PKC facility to geotechnically support such a cover, and in terms of the magnitude and rate of consolidation of such a cover, should it be feasible to physically construct it.

It is understood that DDMI has already prepared a revised closure plan that does not call for the emplacement of such a substantial cover.

To place the low undrained shear strength values apparent in Figure 4.6 in some perspective, it is noted that the Alberta Energy Resources Conservation Board (ERCB) recently released Directive 074, *Tailings Performance Criteria and Requirements for Oil Sands Mining Schemes*[8], which requires the following in terms of oil sands fine tailings:

- Undrained shear strengths of > 5 kPa must be achieved within one year of deposition, and
- Undrained shear strengths of > 10 kPa must be achieved within 5 years upon completion of deposition to a given storage impoundment.

These criteria have been imposed in part to achieve "*a trafficable landscape at the earliest opportunity to facilitate progressive reclamation*". The undrained shear strength profiles shown in Figure 4.6 indicate that a significant portion of the fine PK deposit investigated in this study would not satisfy the requirements recently imposed on oil sands operations to facilitate closure cover construction and reclamation.

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[8] See http://www.ercb.ca/docs/documents/directives/directive074.pdf.

8.0 LIMITATIONS AND CLOSURE

The information presented herein is based on a factual geotechnical evaluation of the findings of the site investigation noted. As such, values and trends discussed herein do not comprise recommendations for use in design or a definitive description of the PKC facility.

This report has been prepared for the exclusive use of Diavik Diamond Mines Inc. for specific application to the area within this report. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. AMEC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report. It has been prepared in accordance with generally accepted soil and foundation engineering practices. No other warranty, expressed or implied, is made.

Respectfully submitted,

AMEC Environment & Infrastructure,
a division of AMEC Americas Limited

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Project Geotechnical Engineer

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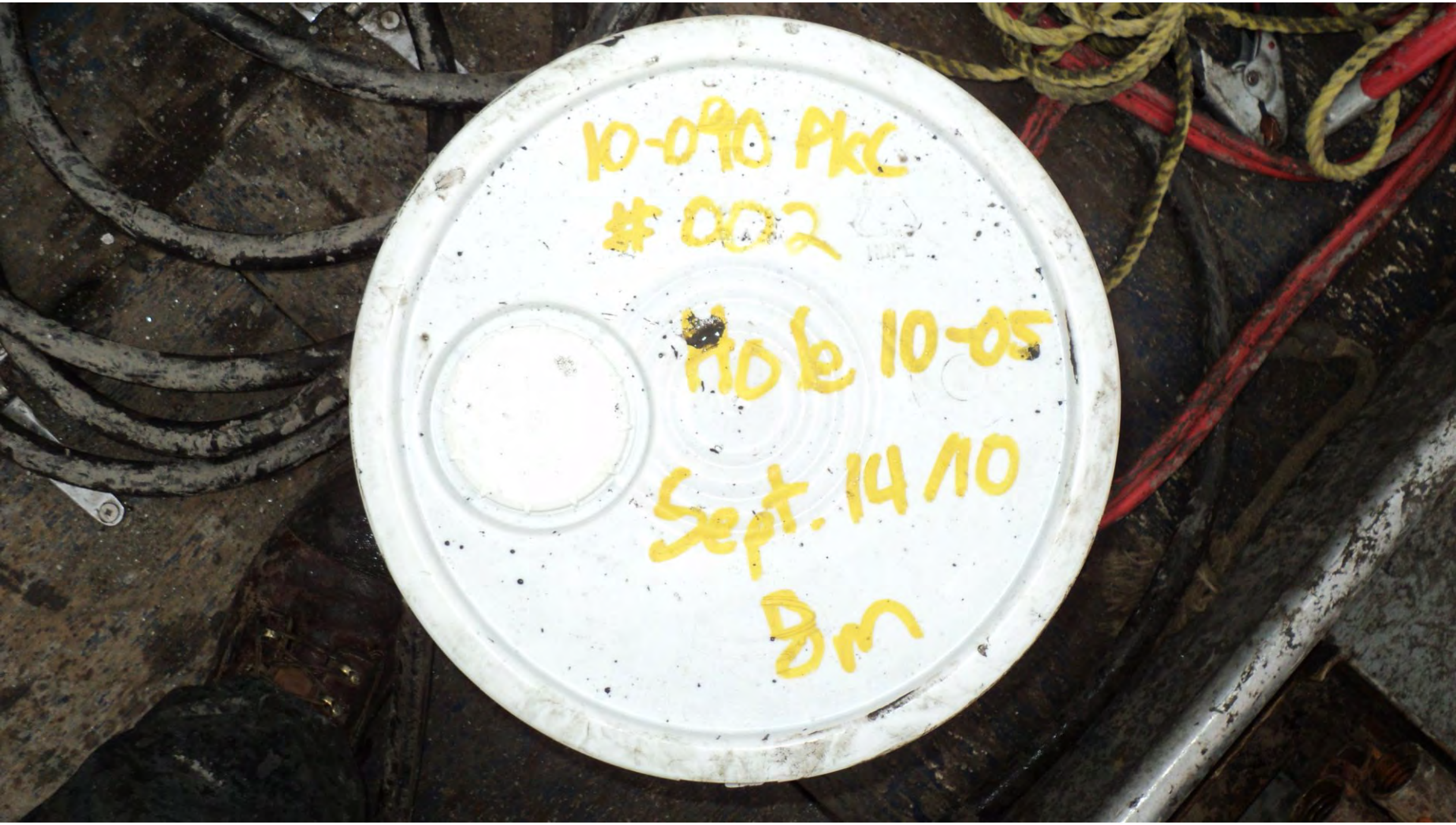
Project Manager

Ed C. McRoberts. Ph.D., P.Eng., FEIC
Senior Vice President

APPENDIX A

Photographs


10-090
#001
Hole 10-05
Sept. 14/10
6m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12m


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Sept.14.10
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18m


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Sept. 14/10
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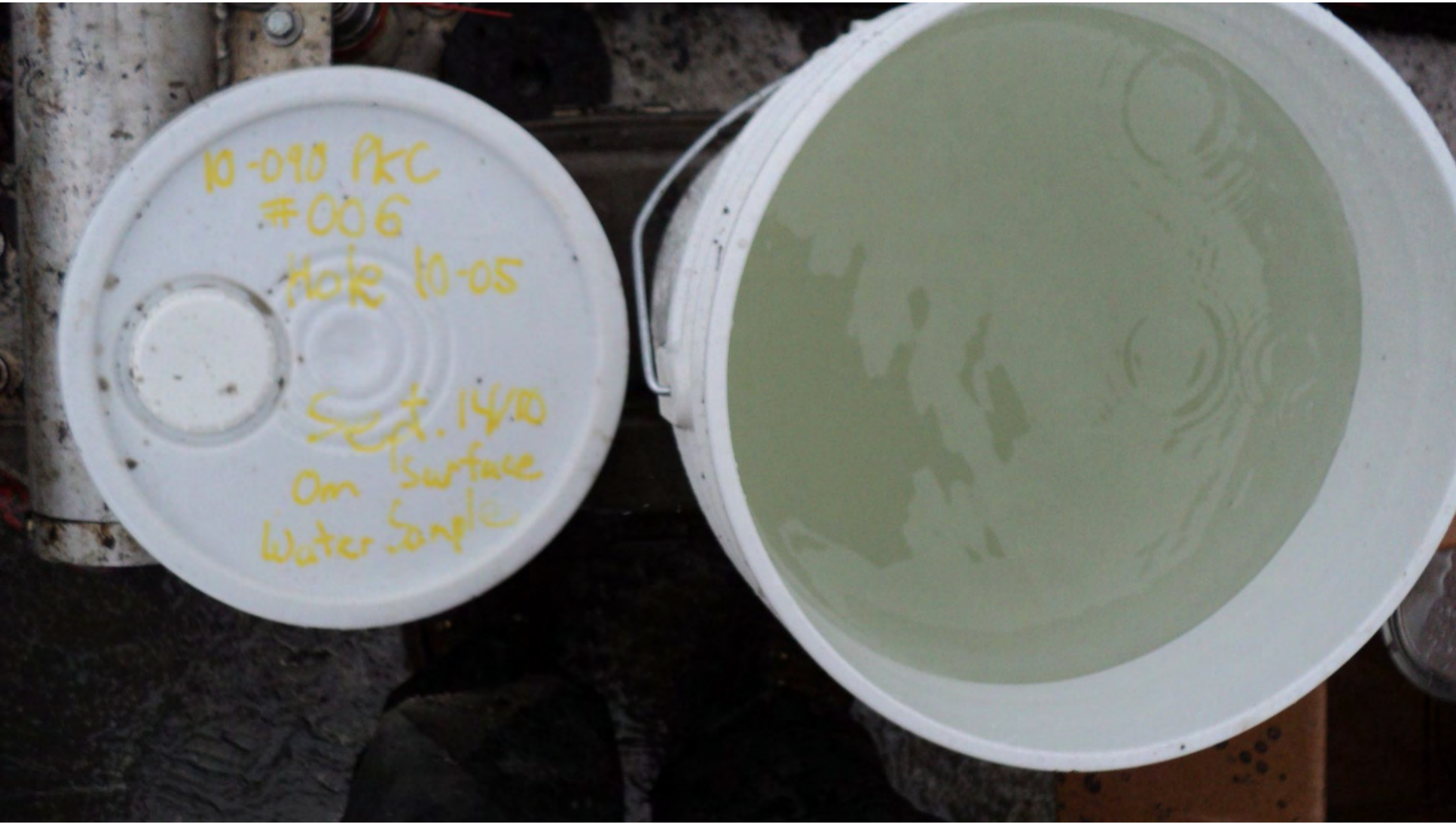
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Water Sample


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Sept. 14 10
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10-MO PKC
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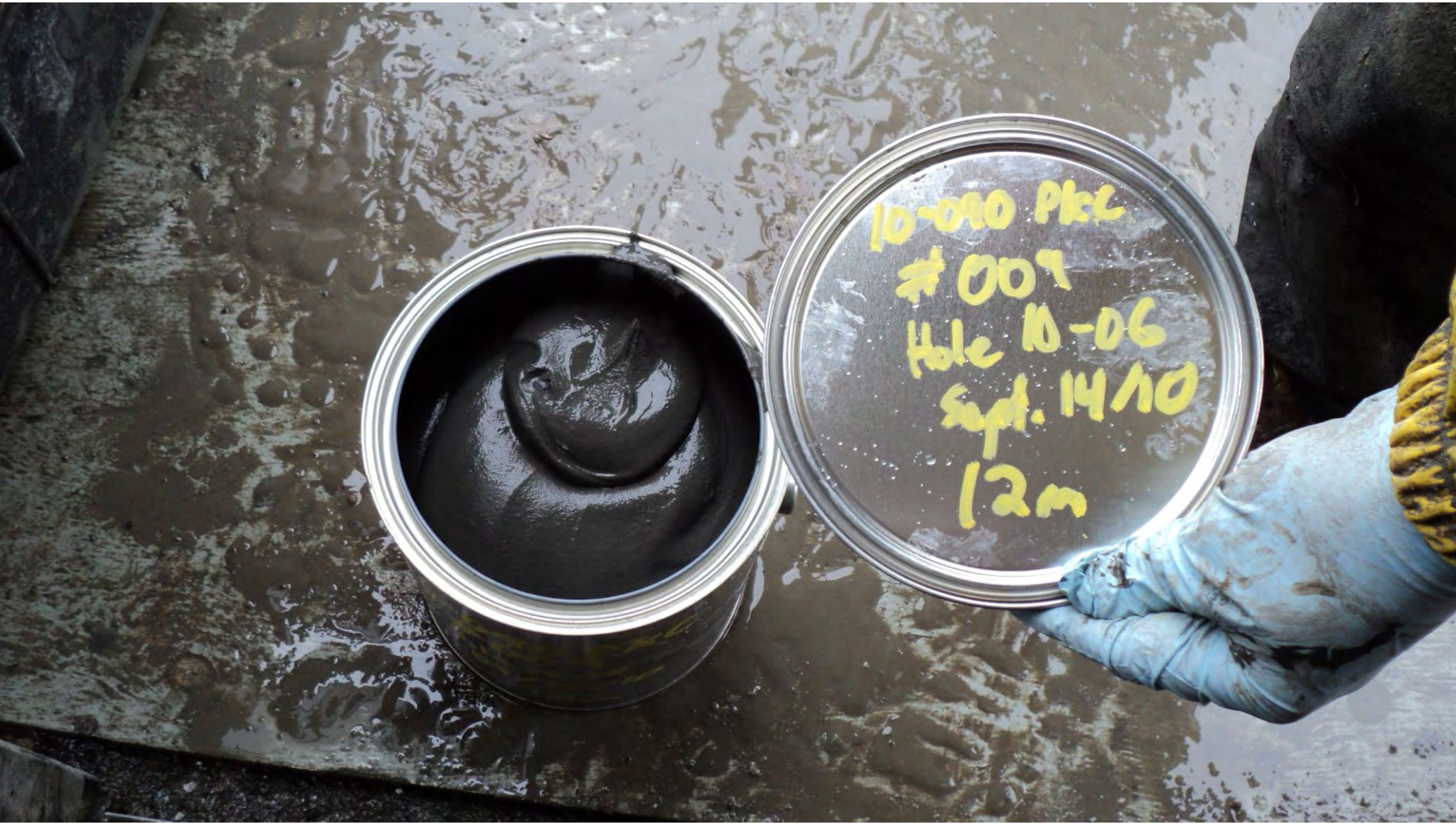
Sept. 14/10
8m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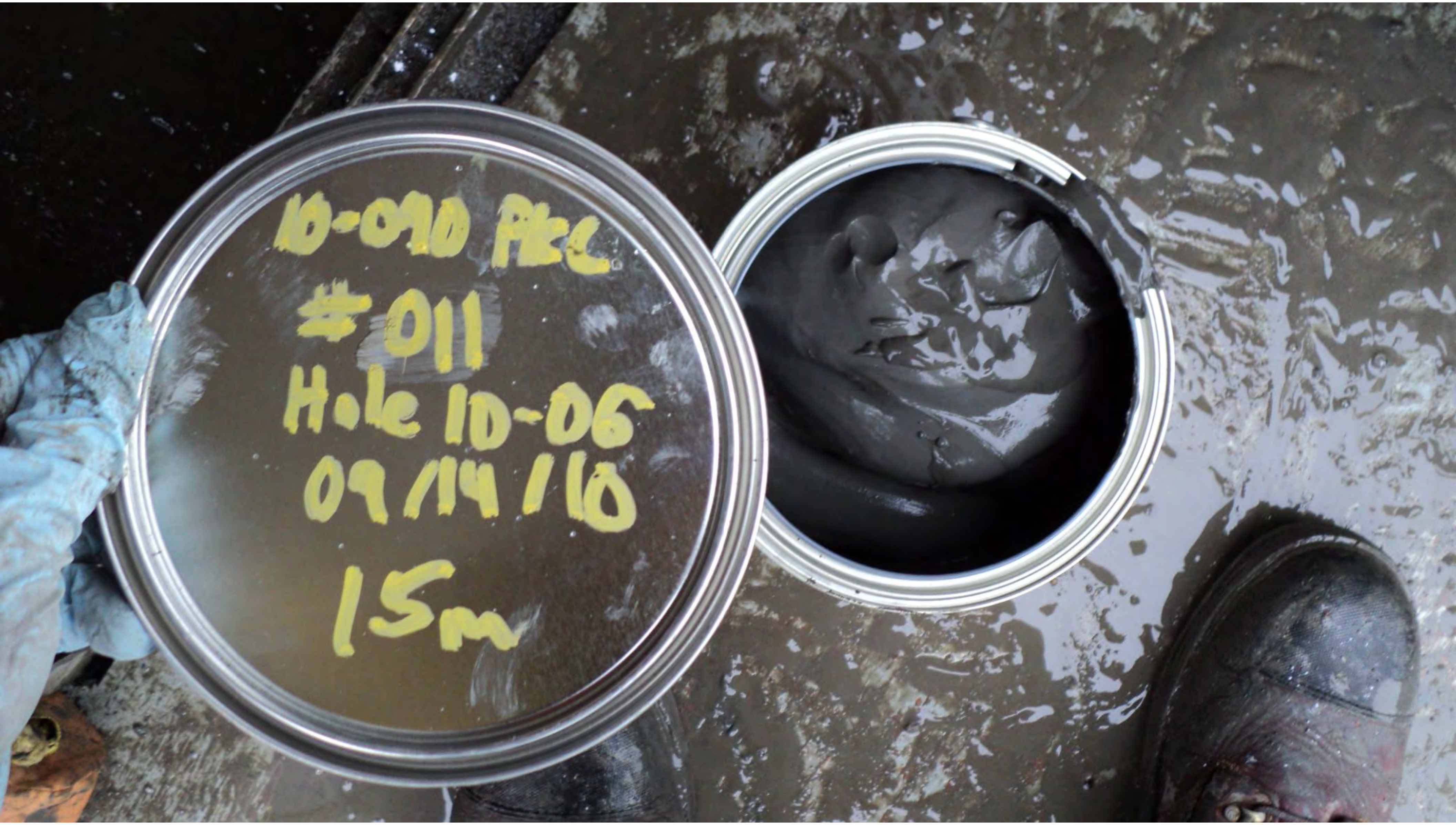
Hole 10-06
09/14/10
13m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15m


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17r


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Hole 10-04
09/14/10
6m


10-090PKL
#015
Hole 10-04
09/14/10
8m


10-090 PKC
#016
Hole 10-04
09/14/10
10m


10-090 PKC
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09/14/10
10m


10-010PKC
#017
Hole 10-04
09/14/10
13m


10-090 PKC
#018
Hole 10-04
09/14/10
15m


10-090PKC
#019
Hole 10-04
09/14/10
16m

APPENDIX B

Conetec Report (Contains CPT Logs and In-Situ Testing Results)

Field Data Report

Diavik PKC

Prepared for:

AMEC Earth and Environmental
Burnaby, BC

Job No: 10-090

- September 7th to 16th, 2010 -

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TABLE OF CONTENTS

1.0 INTRODUCTION

The enclosed report presents the results of a Cone Penetration Testing (CPT) program conducted by ConeTec Investigations Ltd. for AMEC Earth and Environmental. This program took place between from September 7th to September 16th, 2010 at the Diavik Mine Site in the North West Territories. Testing consisted of 6 Gamma CPT soundings, 3 Ball Penetration Tests, 2 Vane Soundings and 3 soil sample locations. The work was completed using ConeTec's workboat.

2.0 FIELD EQUIPMENT AND PROCEDURES

2.1 Cone Penetration Test Procedures

The cone penetration tests (CPTs) were conducted by ConeTec Investigations Ltd. of Vancouver, BC using an integrated electronic cone penetration testing and data acquisition system. The CPT soundings were completed in general accordance with ASTM D5778-07. The cone was deployed using ConeTec's ramset by pushing the cone rods into the fluid and soft tailings with the hydraulic cylinders at a steady rate (2 cm/s). This was located on the deck of the workboat. A medium capacity (MC-375) compression-type cone, as shown in Figure 1, was used for all GCPT soundings.

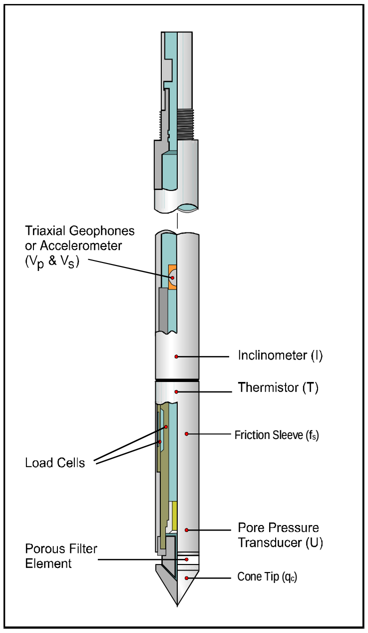


Figure 1: Cone Penetrometer

The MC-375 cone has a maximum tip capacity of 375 bar, a tip area (A_c) of 15 cm^2, a friction sleeve area (A_s) of 225 cm^2 and a pore pressure transducer with a capacity of 200 psi. A pore pressure filter is located directly behind the cone tip in the "u_2" position. The 5.0 mm thick pore pressure filter, which is composed of porous plastic, enables the cone to measure dynamic pore pressures during penetration, and record pore pressure dissipations at selected depths. The function of the filter is to allow rapid movements of the extremely small volumes of water needed to activate the pressure transducer while preventing soil ingress or blockage. Each pore pressure filter was saturated in glycerine under vacuum pressure prior to testing and the pore pressure cavity within the cone was filled with glycerine to maintain a compliant pore pressure measuring system. A viscous fluid is used to try to maintain saturation of the system. The data acquisition system automatically records and displays the pore pressure dissipation traces in real time (at five second interval) during pauses in penetration. ConeTec compression cones are designed with an equal end area friction sleeve; hence no corrections are required for friction sleeve data. ConeTec compression cones experience unequal area effects on the tip resistance due to the tip and load cell geometry. The unequal area is represented by the cone net area ratio (a) of 0.80. The net area ratio of ConeTec's compression cone has been verified through laboratory testing by subjecting the cone to a known pressure then measuring the load recorded on the tip. Refer to section 3.1 CPT Results for a detailed explanation of the use of the net end area ratio in correcting CPT data.

The cone system used during the program recorded the following parameters at 5.0 cm depth increments:

- Tip resistance (q_c) in kPa
- Sleeve friction (f_s) in kPa
- Dynamic pore pressure (u) in m of water
- Passive gamma (separate data acquisition system) in counts per second
- Temperature (deg C)

The gamma data was collected on 10 cm increments in order to allow enough time to collect a representative number of counts. However, the data is presented in 5.0 cm increments with the other CPT parameters by duplicating each 10 cm Gamma reading at the relevant 5.0 cm intervals.

A complete set of baseline readings were taken before and after each sounding to determine if a zero load offset had occurred due to a temperature change in the probe. Establishing the presence of temperature shifts and load offsets enables the operator to make corrections to the cone data as necessary. Since the probes are temperature compensated, load shifts due to changes in probe temperature are only a problem when extreme temperature changes occur.

2.2 Gamma CPT Procedures

Passive gamma testing was utilized in conjunction with all CPT testing. A continuous gamma ray profile was logged using the gamma module attached to CPT probe (Figure 2). The gamma module measures the presence of naturally occurring components within the soil that emit gamma radiation. Generally, clayey soils emit greater amounts of natural gamma radiation due to the presence of small amounts of Potassium-40. Therefore the natural gamma output (measured in counts per second) can be used to indicate variation in clay content. The gamma modules are calibrated against a number of standard materials such that their output remains consistent for different modules and over time. Due to the offset between the cone tip and the sensor location Gamma data is not available in the last 75 cm of each profile.

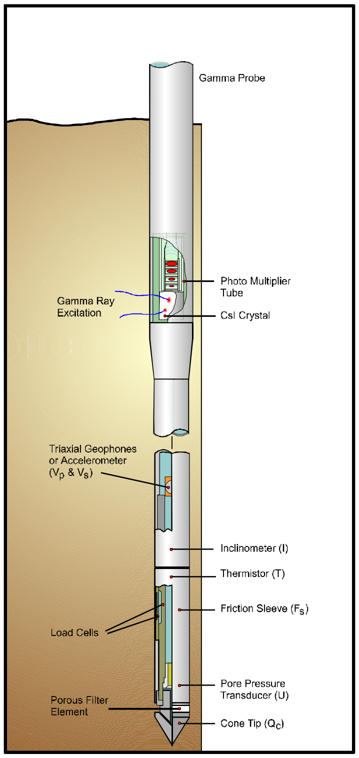


Figure 2: Gamma Cone Penetrometer

2.3 Ball Penetrometer Testing Procedures

Ball penetrometer testing (also referred to as full flow penetration testing) is used for assessing the undrained shear strength (S_u) of low to medium strength soils. The test incorporates a standard cone penetrometer body (typically 10 cm^2 plan area) and a spherical attachment that replaces the standard 60 degree conical tip, as shown in Figure 3.

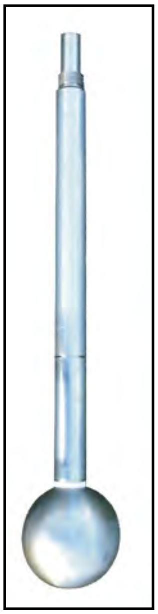


Figure 3: Flow Penetrometer

During penetration soil is able to flow around the penetrometer, significantly reducing the influence of overburden stress as compared to the cone penetration test (CPT). The undrained shear strength derived from the full flow penetration test is related to the net penetration resistance using the following relationship:

$S_u = q_{net} / N$ where N is typically 11

Although the N factor is generally considered to be unique across soil deposits, experience has shown that some minor variation does exist. However this variation is generally less compared to the N_{kt} factor for the standard CPT. Data is recorded continuously and the test is performed in the same manner as the CPT. Because of the subdued sleeve and pore pressure response full flow penetration test results are not used for the interpretation of other geotechnical parameters or for soil classification. The test may be interrupted at selected depths to cycle the probe up and down to in order to achieve a completely remolded soil state to provide an indication of sensitivity in soft soils. For the calculations to be valid, full flow of soil around the probe must be assumed, which is generally true in soils where $S_u < 20$kPa.

A 5 ton tip capacity, 10cm^2 cone penetrometer body was used with spherical attachments resulting in projected area (A_b) of 100 cm^2. Both continuous and cycled ball penetrometer tests were conducted.

2.4 Vane Shear Test Procedures

The shear vane testing was conducted using an electronic down-hole vane system which has a torque gauge located immediately above the vane. An appropriately sized vane was selected based on the anticipated peak undrained shear strength for the soils encountered at the site. A small vane is typically used for stiff soils, whereas a larger vane is required in softer soils.

The vane is advanced to the test depth by pushing the cone rods into the ground. Once the vane has reached the correct depth an electrical motor is used to rotate the vane and rods at a constant rate. The rods and vane are both rotated until the surrounding soil has yielded. Once yielding occurs, the vane continues to be rotated in order to characterize the soil's post yielding shear resistance. The vane is then released from the motor and is rotated clockwise approximately ten times with a pipe wrench to completely remold the soil. Once the soil is remolded, the motor is used to rotate the vane and rods to record the remolded strength of the soil.

2.5 Fluid Sampling Procedures

The Fluid sampler is comprised of two parts; a lower portion consisting of a cylindrical chamber, which collects the sample, and an upper weight which keeps the sampler in an upright position as it is lowered to sample depth. The Fluid sampler uses a compressed gas source to keep the sample chamber closed until the desired sample depth is reached. The gas source is connected to the sampler by use of an air line. An in-line valve is also used so that the gas can be turned on and released easily.

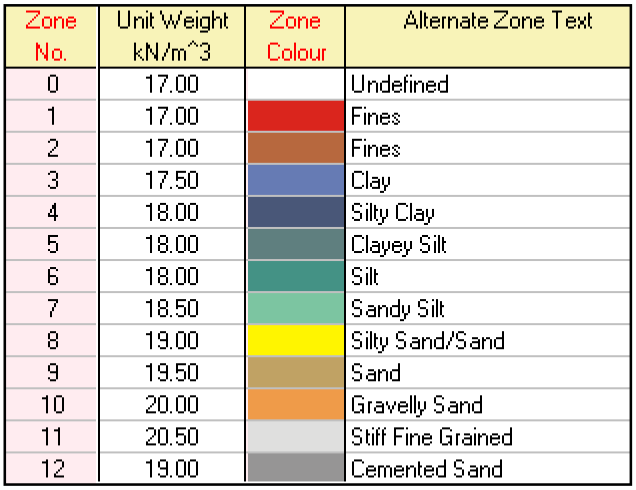
To start the procedure the Fluid Sampler is attached to the winch line, and nitrogen is turned on which forces the piston inside the sample chamber to the bottom. The sampler is lowered to the desired sampling depth, typically every meter from surface. Once the sampler is at the desired depth the nitrogen gas is turned off. Fluid pressure displaces the gas inside the sampler and the gas is replaced by fluid tailings. As the tailings fill the sample chamber the piston inside rises which expels the nitrogen gas, the sampler is not advanced while the sample is being taken. Once the operator deems that all the gas has been expelled, the sampler is winched back up for extrusion. The sample is extruded by turning the nitrogen back on, which pushes the piston in the sampler to the bottom while at the same time extruding the sample. The sampler is then lowered to the next depth and the procedures above are repeated.

3.0 TESTING RESULTS

3.1 Cone Penetration Test Results

A summary of the cone tests, with location and test details is provided in Appendix A. Each sounding was taken until refusal occurred. The penetration depths are referenced to the existing pond surface at the time of the investigation. All of the CPT data is presented in graphical form in the attached appendices and stored in ASCII and Excel format on the accompanying CD. The contents of the CD and file formats are detailed in Appendix J.

The CPT plots presented in Appendix A consist of corrected tip resistance (q_t) in kPa, sleeve friction (f_s) in kPa, friction ratio (R_f) as a percentage, dynamic pore pressure (u_2) in metres of water, and soil behaviour type (SBT) are plotted versus depth with measurements taken every 5.0 cm. Appendix C comprises plots of CPT corrected tip resistance, assumed unit weight (kN/m^3), undrained strength (kPa) derived from the tip resistance, using an N_{kt} factor of 15.0, dynamic pore pressure, and temperature (deg C). For soft fluid like deposits, unit weight profiles were generated using the dynamic pore pressure data put through regression in 3 meter intervals. The resulting unit weight summary is provided in Appendix C. For all other deposits the unit weights are based on the SBT zone classifications shown in Figure 3.



Zone No.	Unit Weight kN/m^3	Zone Colour	Alternate Zone Text
0	17.00		Undefined
1	17.00	🟥	Fines
2	17.00	🟫	Fines
3	17.50	🟦	Clay
4	18.00	🟦	Silty Clay
5	18.00	🟩	Clayey Silt
6	18.00	🟩	Silt
7	18.50	🟩	Sandy Silt
8	19.00	🟨	Silty Sand/Sand
9	19.50	🟫	Sand
10	20.00	🟧	Gravelly Sand
11	20.50	⬜	Stiff Fine Grained
12	19.00	⬛	Cemented Sand

Figure 3: Soil behaviour type zones and assigned unit weights

The plots in Appendices A, C, and D have dynamic pore pressure superimposed over the tip resistance and the hydrostatic line with equilibrium pore pressure dissipation values superimposed over the dynamic pore pressure. The results of the Gamma CPT testing are shown in Appendix D.

The cone tip (q_t) reading is the total force acting on the cone tip divided by the projected plan area of the tip. It indicates the relative density, or stiffness, of the soil. The sleeve friction (f_s) is the frictional force the soil is imposing on the friction sleeve divided by the surface area of the friction sleeve. The friction ratio (R_f), expressed as a percentage, is a ratio of the sleeve friction readings divided by the cone tip readings. The friction ratio gives an indication of the grain size characteristics of the material. Generally, fine-grained soils have a higher friction ratio than coarse-grained soils. The dynamic pore pressure readings record the pore pressures generated behind the cone tip during cone penetration. In freely draining soils the dynamic pore pressure will often be similar to the equilibrium pore pressure, while in fine grained soils penetration is undrained and the dynamic pore pressure will deviate from the equilibrium pore pressure profile. To record equilibrium or static water pressures, the penetration must be stopped to allow the dynamic pore pressures to stabilize. The rate at which this will occur is a function of the permeability of the soil.

Due to the inner geometry of the cone penetrometer, the ambient pore water pressure will act on the shoulder area behind the cone tip and on the ends of the friction sleeve. This results in an imbalance of stresses and is known as the “unequal area effect”. This effect influences the total stress determined from the cone and friction sleeve. For the cone resistance, the unequal area is represented by the cone net area ratio ‘a’, which is approximately equal to the ratio of the cross-sectional area of the load cell or shaft divided by the projected area of the cone. The corrected total cone resistance, q_t, is given by the equation:

$$q_t = q_c + u_2\ (1-a)$$

As stated earlier in the report, the net area ratio for ConeTec’s compression cone penetrometers is 0.80. All of the calculations and plots are in terms of q_t.

The stratigraphic interpretations included on the plots are based on a soil behaviour chart described in Robertson et al. (1990) as illustrated in Figure 4. The chart relates cone tip resistance to friction ratio in order to determine soil behaviour type (SBT). It should be noted that it is not always possible to clearly identify a soil type based on these parameters. In these situations, experience, judgment, the use of auxiliary modules and an assessment of pore pressure dissipation data should be used to infer soil behaviour type.

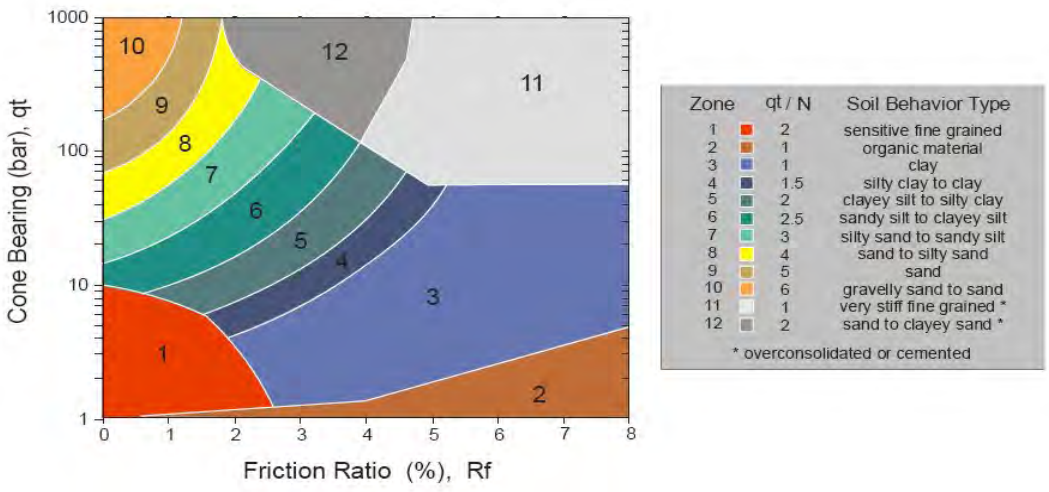


Figure 4: Soil Behaviour Type Chart, Robertson (1990)

3.2 Pore Pressure Dissipation Test Results

The penetration of the piezocone was halted at specific depths to carry out pore pressure dissipation tests. The variation of the pore pressure (u) with time was measured and recorded. All pore pressure data was recorded immediately behind the cone tip at the u_2 location. For this project, pore pressure equilibrium was achieved at a number of locations. A tabular summary of these results is provided along with the individual pore pressure dissipation plots in Appendix B. All of the dissipation data is provided on the CD along with a summary of the results in both Excel and PDF format.

3.3 Ball Penetrometer Test Results

Continuous profiles of undrained shear strength (S_u) from the ball penetrometer for the 3 locations are presented in Appendix E. In calculating undrained shear strength, an assumed unit weight profile based on the adjacent CPT was used. Cycling was completed at different depths throughout each profile. From 5 to 10 cycles were made at these locations until a stable resistance value was measured.

The plots presented Appendix E show the initial ball penetration, second cycle in, second to last and final cycle results, along with the undrained shear strength results from the vane tests. Cycling data allows for an easy comparison of the initial strength of the tailings to the residual or post peak strength, and finally to the completely remolded strength of the tailings. Recorded Ball Penetration pore pressure dissipation data can be found in Appendix F.

3.4 Vane Shear Test Results

A summary of the vane shear test results and individual rotational records at each depth are presented in Appendix G. Vane tests were completed using vanes with dimensions of either 65mm x 130mm or 150mm x 300mm. The peak and remolded undrained strength results at varying depths are superimposed on the corresponding ball penetrometer test undrained shear strength profiles in Appendix E.

3.5 Sampling Results

Samples were collected for at three locations using a fluid sampler with the exception of one piston sample at location 10-05 at 23m. The sample summary and samples sheets for each test are provided in Appendix H. A total of 18 samples were taken and pictures of each sample are provided on the accompanying CD.

4.0 CPT INTERPRETATION METHODS

A detailed set of CPT interpretations were generated and are provided in Excel format files on the CD. The CPT interpretations are based on values of corrected tip (q_t), sleeve friction (fs) and pore pressure averaged over a user specified interval of 20 cm. The total stress calculations generated are based on soil unit weights that have been assigned to the Soil Behaviour Type zones shown in Figure 3, with the exception of the intervals noted in the assumed unit weight summary which can be found in Appendix C. Pore pressure dissipation test results, as summarized in Appendix B, were used to define the pore pressure profile. Further details on the description of parameters and methods used for the interpretations are provided in Appendix I.

5.0 CLOSING

We trust that the information presented in this report is sufficient for your purposes. If you have any questions regarding the contents of this report, please do not hesitate to contact our office.

Sincerely,

Ilmar Weemees
ConeTec Investigations Ltd.

6.0 BIBLIOGRAPHY

ASTM D-5778-07 2007. "Standard Test Method for Performing Electronic Friction Cone. and Piezocone Penetration Testing of Soils". ASTM, West Conshohocken, US.

Lunne, T., Robertson, P.K. and Powell, J. J. M., 1997, " Cone Penetration Testing in Geotechnical Practice," Blackie Academic and Professional.

Robertson, P.K., "Soil Classification using the Cone Penetration Test", Canadian Geotechnical Journal, Vol 27, 1990 pp 151-158.

Greig, J.W., R.G. Campanella and P.K. Robertson, "Comparison of Field Vane Results With Other In-Situ Test Results", InternatIonal Symposium, on Laboratory and Field Vane Shear Strength Testing, ASTM, Tampa, FL, Proceedings, 1987.

Cargill, E., Greig, J., Howie, J., Sharp, J.T., Weemees, I., Woeller, D.J., "Improved Techniques For The In-Situ Determination Of Undrained Shear Strength In Soft Clays."

APPENDIX A

CPT Summary and Standard Plots

Job No: 10-090
Client: AMEC Earth & Environmental
Project: Diavik
Date: 09/09/10 to 09/12/10

CPT SUMMARY

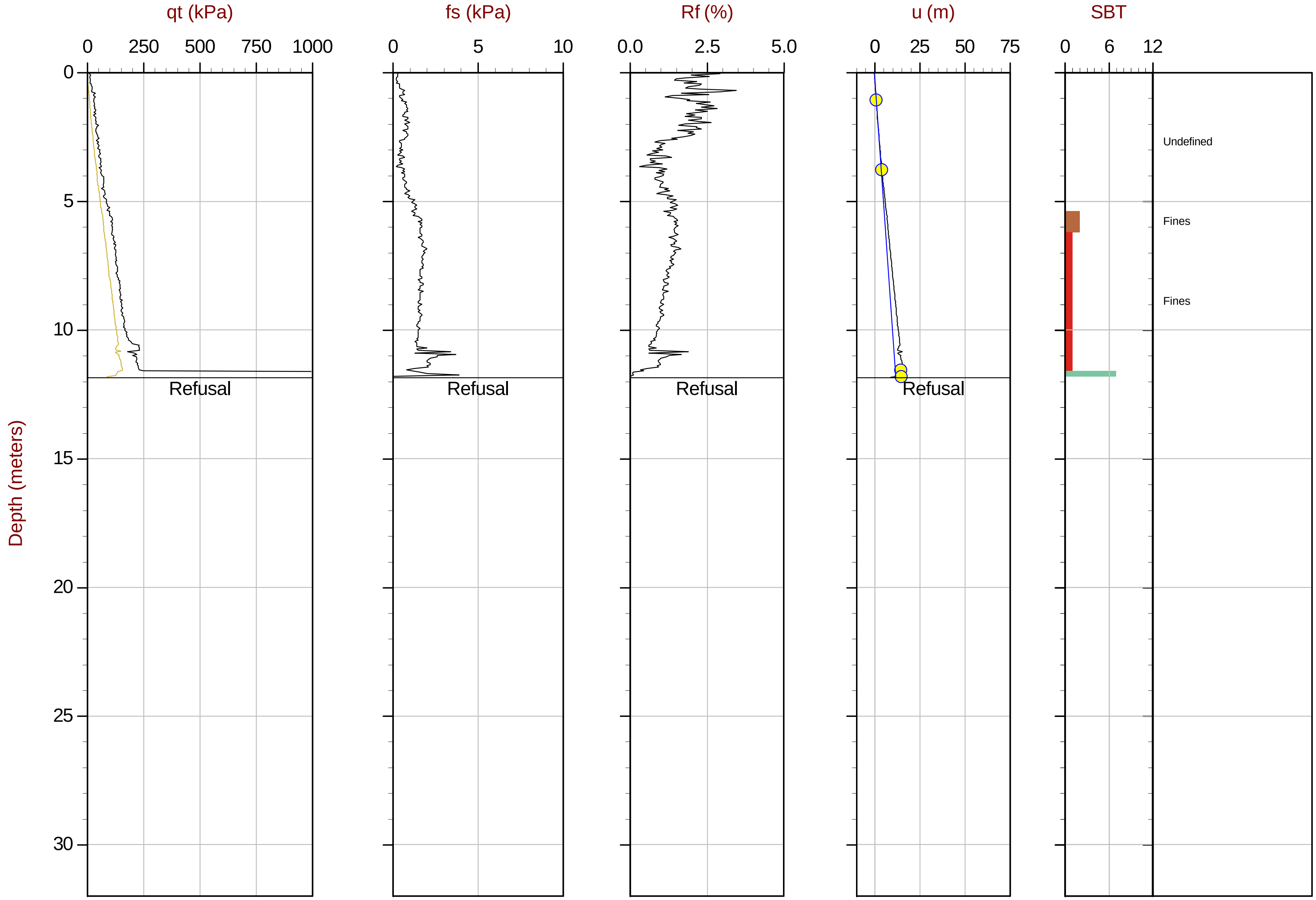
CPT Sounding	File Name	Date	Cone	Assumed Phreatic Surface (m)	Final Depth (m)	Coordinates - UTM 12W		
						Northing (m)	Easting (m)	Elevation (m)
GCPT10-01	090G01	09/09/10	272:T375F10U200	0.0	11.85	7151876	533254	448.8
GCPT10-02	090G02	09/09/10	272:T375F10U200	0.0	8.55	7152023	533308	448.8
GCPT10-03	090G03	09/09/10	272:T375F10U200	0.0	4.80	7151985	533439	448.8
GCPT10-04	090G04	09/10/10	272:T375F10U200	0.0	21.75	7152113	533195	448.8
GCPT10-05	090G05	09/10/10	272:T375F10U200	0.0	30.45	7152028	533094	448.7
GCPT10-06	090G06	09/12/10	272:T375F10U200	0.0	28.50	7151945	533179	448.8

ConeTec

AMEC

Job No: 10-090
Date: 09:09:10 11:30
Site: Diavik PKC

Sounding: GCPT10-01
Cone: 272:T375F10U200



Max Depth: 11.850 m / 38.88 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.200 m

File: 090G01.COR
Unit Wt: User Defined Layers and SBT Zones

SBT: Lunne, Robertson and Powell, 1997
Coords: N: 7151876 E: 533254 Elev: 448.8

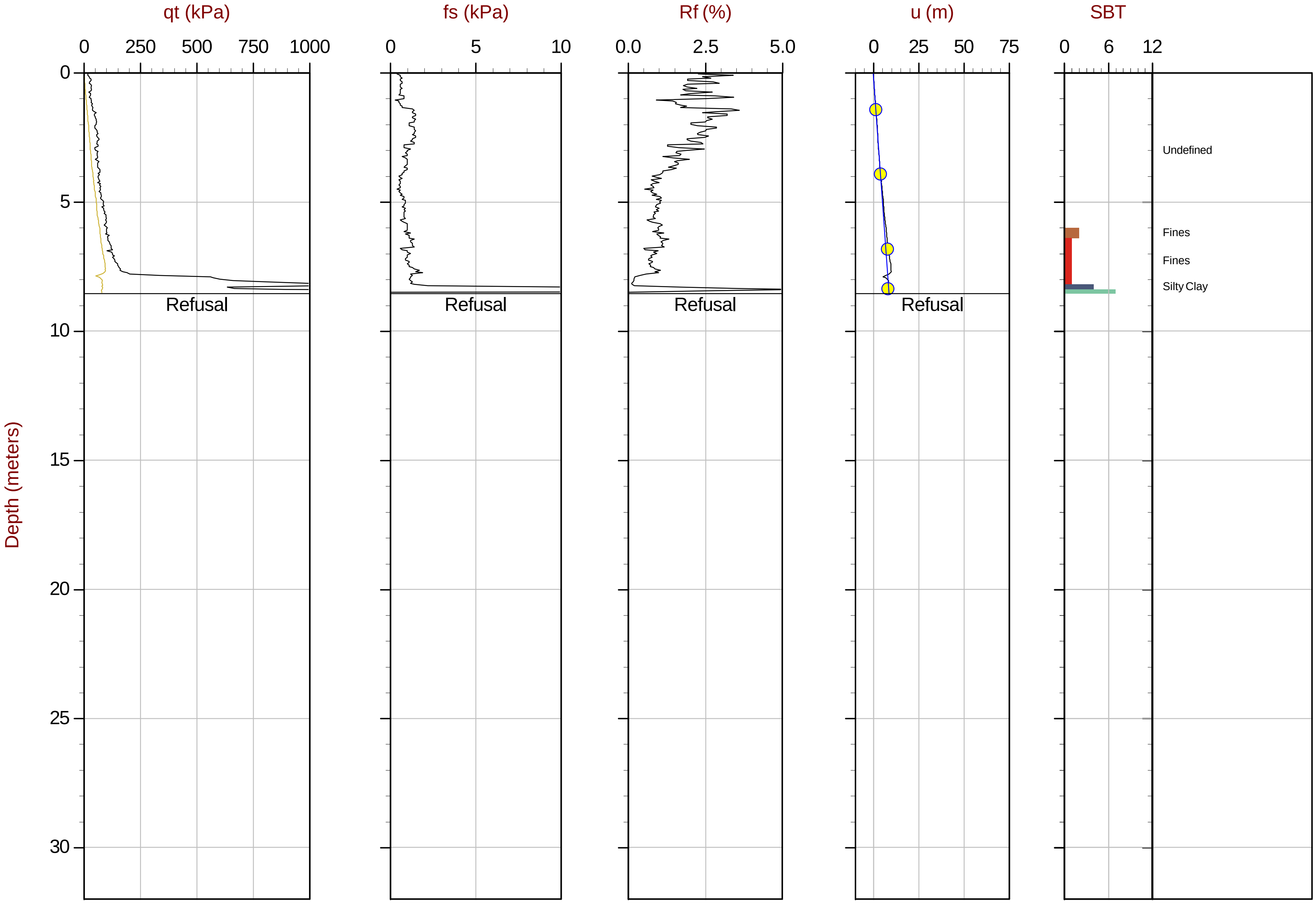
● U Equilibrium —— Dynamic U —— Hydrostatic Line

ConeTec

AMEC

Job No: 10-090
Date: 09:09:10 14:03
Site: Diavik PKC

Sounding: GCPT10-02
Cone: 272:T375F10U200



Max Depth: 8.550 m / 28.05 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.200 m

File: 090G02.COR
Unit Wt: User Defined Layers and SBT Zones

SBT: Lunne, Robertson and Powell, 1997
Coords: N: 7152023 E: 533308 Elev: 448.8

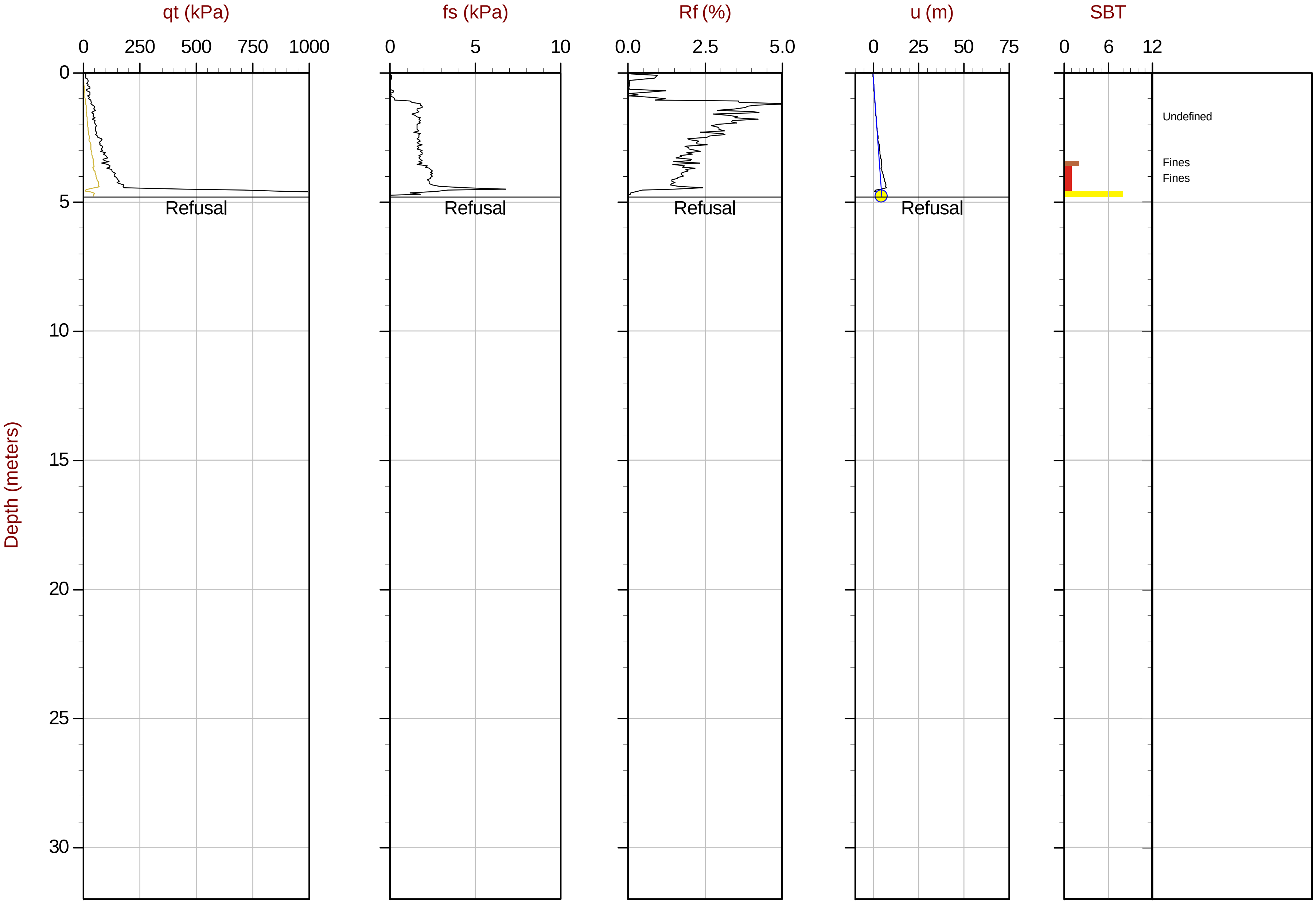
● U Equilibrium —— Dynamic U —— Hydrostatic Line

ConeTec

AMEC

Job No: 10-090
Date: 09:09:10 16:00
Site: Diavik PKC

Sounding: GCPT10-03
Cone: 272:T375F10U200



Max Depth: 4.800 m / 15.75 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.200 m

File: 090G03.COR
Unit Wt: User Defined Layers and SBT Zones

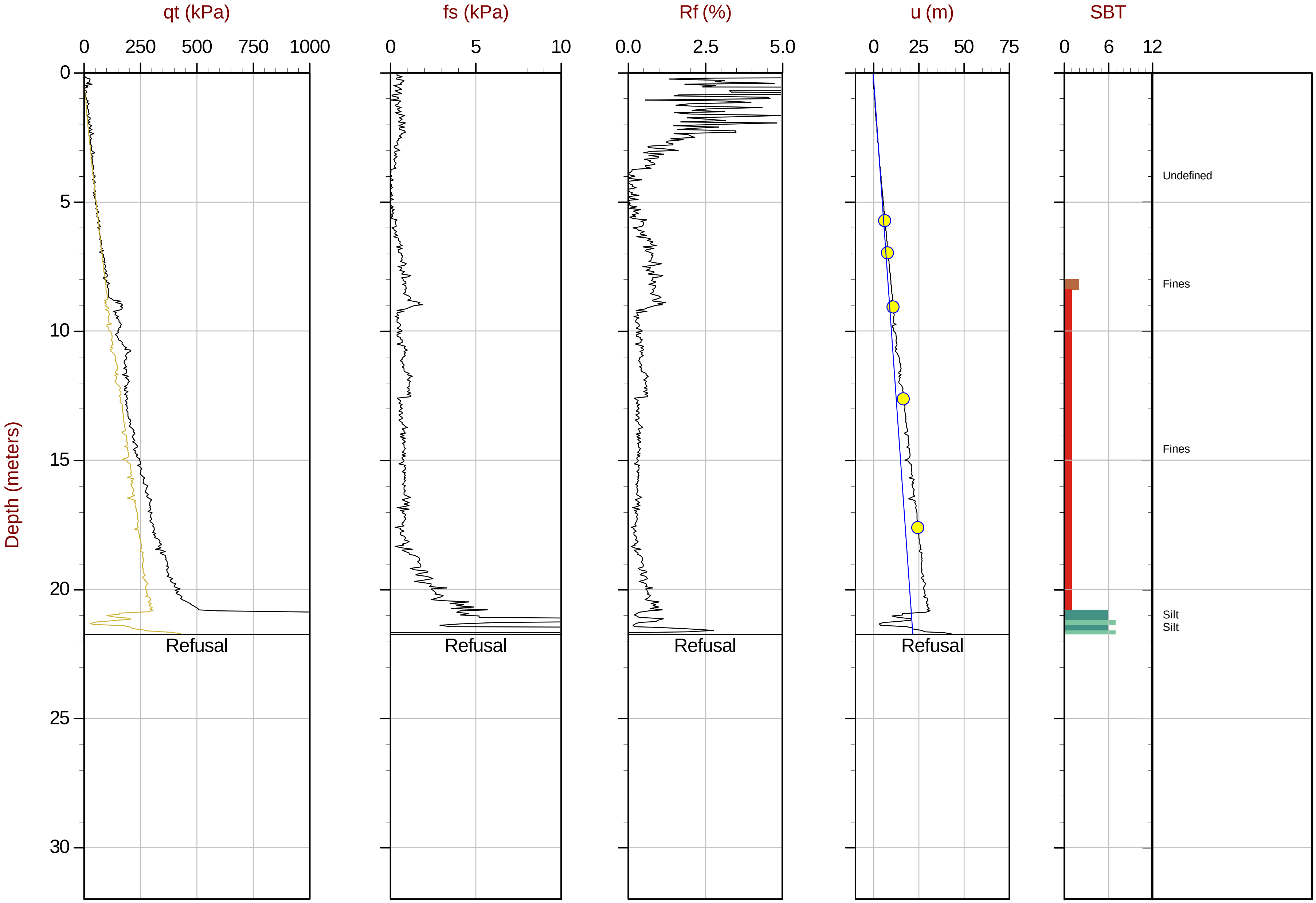
SBT: Lunne, Robertson and Powell, 1997
Coords: N: 7151985 E: 533439 Elev: 448.8

● U Equilibrium — Dynamic U — Hydrostatic Line

AMEC

Job No: 10-090
Date: 09:10:10 09:10
Site: Diavik PKC

Sounding: GCPT10-04
Cone: 272:T375F10U200



Max Depth: 21.750 m / 71.36 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.200 m

File: 090G04.COR
Unit Wt: User Defined Layers and SBT Zones

SBT: Lunne, Robertson and Powell, 1997
Coords: N: 7152113 E: 533195 Elev: 448.8

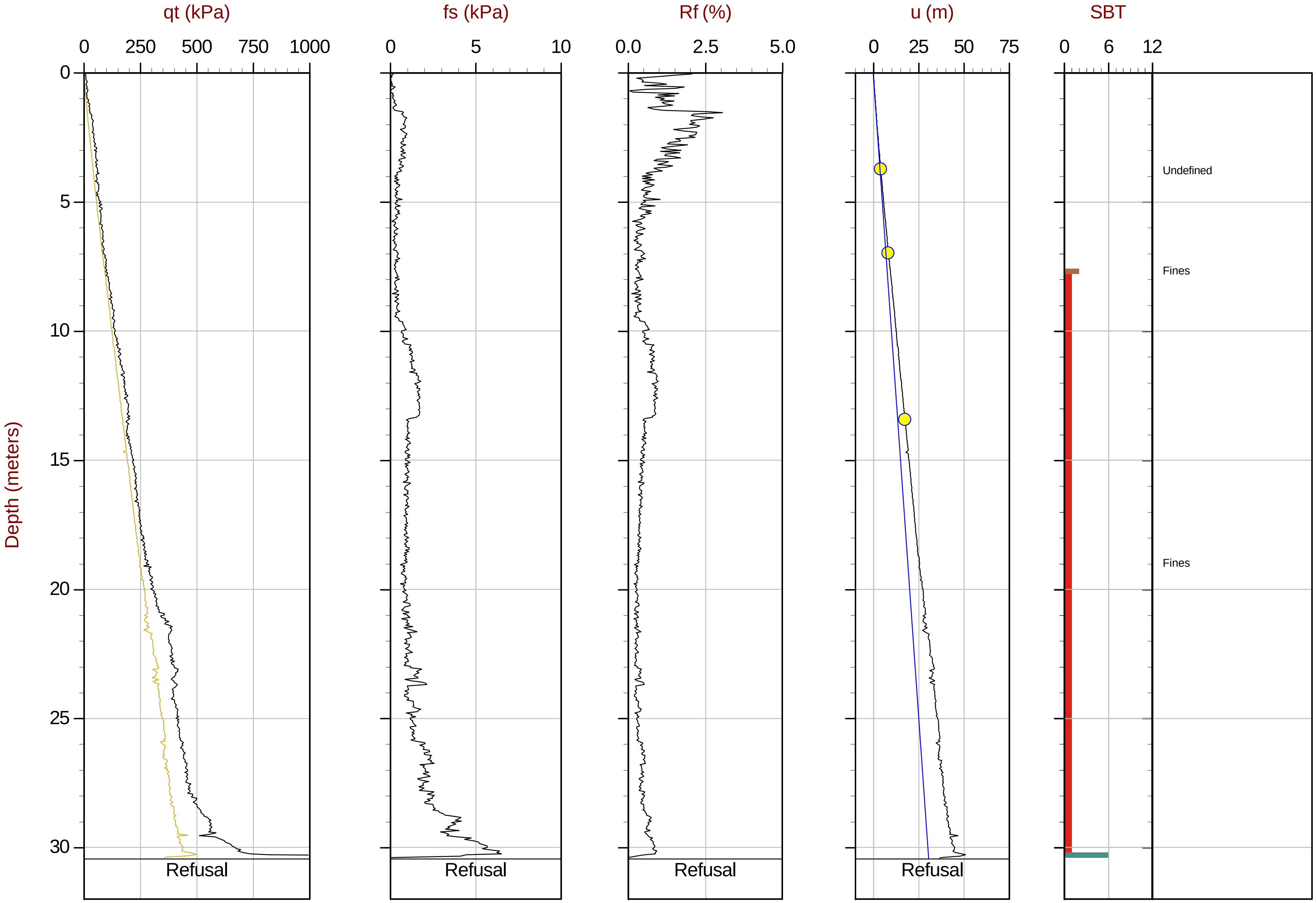
● U Equilibrium —— Dynamic U —— Hydrostatic Line

CONETEC

AMEC

Job No: 10-090
Date: 09:10:10 13:00
Site: Diavik PKC

Sounding: GCPT10-05
Cone: 272:T375F10U200



Max Depth: 30.450 m / 99.90 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.200 m

File: 090G05.COR
Unit Wt: User Defined Layers and SBT Zones

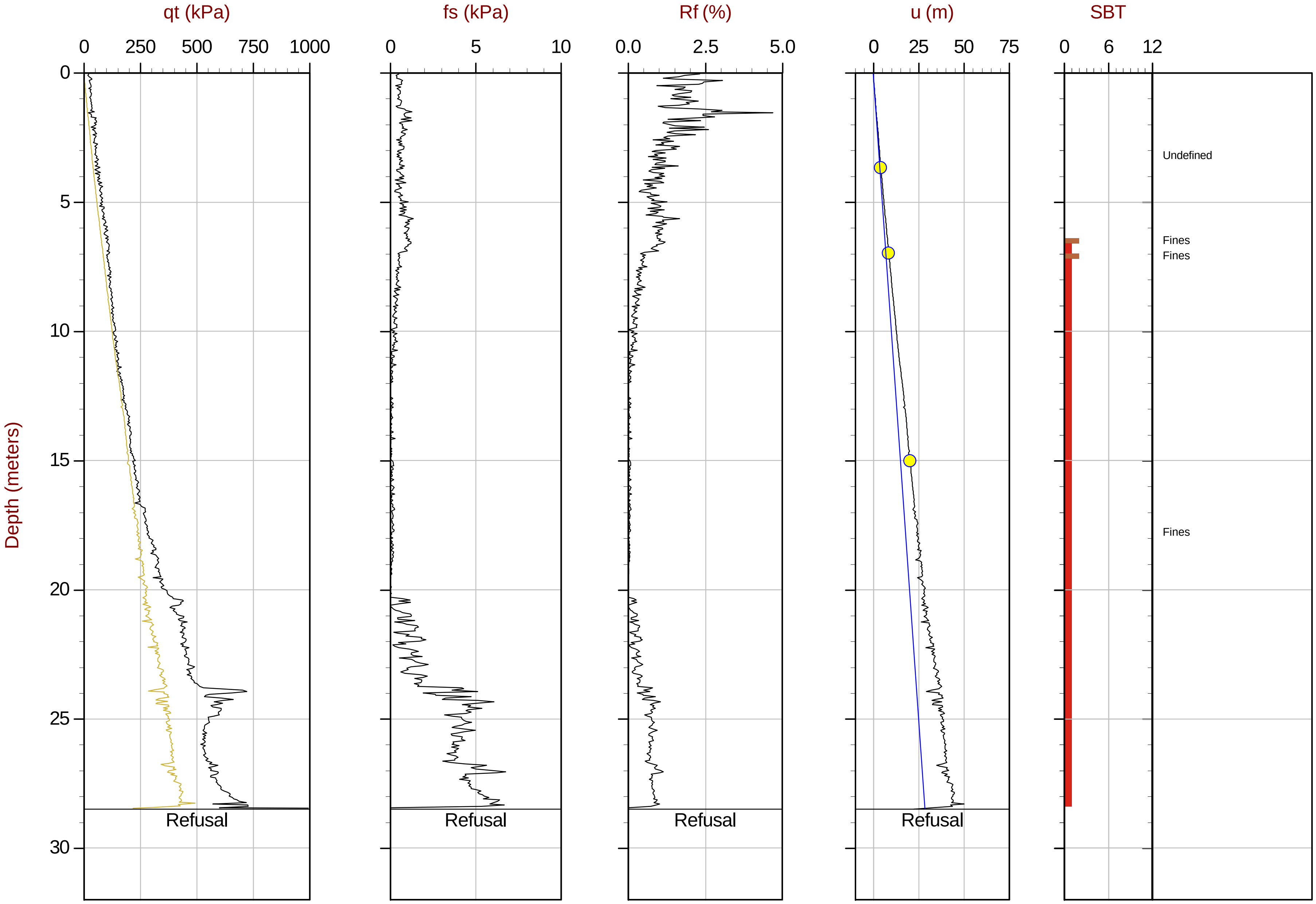
SBT: Lunne, Robertson and Powell, 1997
Coords: N: 7152028 E: 533094 Elev: 448.7

● U Equilibrium —— Dynamic U —— Hydrostatic Line

AMEC

Job No: 10-090
Date: 09:12:10 15:56
Site: Diavik PKC

Sounding: GCPT10-06
Cone: 272:T375F10U200



Max Depth: 28.500 m / 93.50 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.200 m

File: 090G06.COR
Unit Wt: User Defined Layers and SBT Zones

SBT: Lunne, Robertson and Powell, 1997
Coords: N: 7151945 E: 533179 Elev: 448.8

● U Equilibrium ── Dynamic U ── Hydrostatic Line

APPENDIX B

Pore Pressure Dissipation Summary and Plots

CONETEC

Job No: 10-090
Client: AMEC Earth & Environmental
Project: Diavik
Date: 09/09/10 to 09/12/10

PPD SUMMARY

CPT Sounding	Duration (s)	Test Depth (m)	Equilibrium Pore Pressure U_{eq} (m)*	Calculated Phreatic Surface (m)
GCPT10-01	375	1.10	1.1	0.0
GCPT10-01	75	3.80	4.3	-0.5
GCPT10-01	800	11.60	14.9	-3.3
GCPT10-01	180	11.85	15.0	-3.2
GCPT10-02	125	1.45	1.6	-0.2
GCPT10-02	150	3.95	4.2	-0.3
GCPT10-02	600	6.85	8.2	-1.3
GCPT10-02	410	8.40	8.4	0.0
GCPT10-03	450	4.80	4.9	-0.1
GCPT10-04	125	5.75	6.5	-0.8
GCPT10-04	400	7.00	8.2	-1.2
GCPT10-04	400	9.10	11.3	-2.2
GCPT10-04	700	12.65	16.9	-4.2
GCPT10-04	1200	17.65	not achieved	-
GCPT10-05	80	3.75	4.2	-0.4
GCPT10-05	300	7.00	8.4	-1.4
GCPT10-05	400	13.45	17.6	-4.2
GCPT10-05	400	19.05	not achieved	-
GCPT10-05	800	23.55	not achieved	-
GCPT10-05	900	30.45	not achieved	-
GCPT10-06	65	3.70	4.2	-0.5
GCPT10-06	300	7.00	8.7	-1.7
GCPT10-06	300	15.05	20.5	-5.5
GCPT10-06	1200	19.50	not achieved	-
GCPT10-06	1200	28.50	not achieved	-

* Equilibrium pore pressure estimated from dissipation tests.

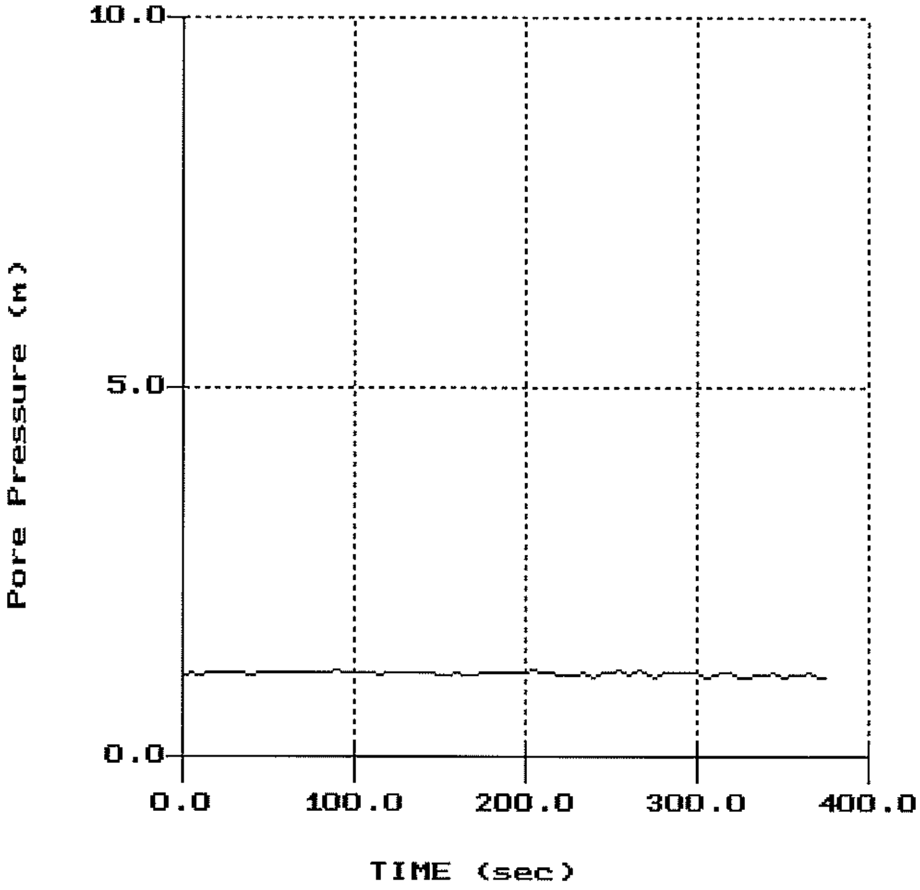
AMEC

Hole:GCPT 10-01
Location:PKC

Cone:272:T375F10U200
Date:09:09:10 11:30

File: 090G01.PPF
Depth (m): 1.10
(ft): 3.61
Duration : 375.0s
U-min: 1.06 330.0s
U-max: 1.18 255.0s

PORE PRESSURE DISSIPATION RECORD

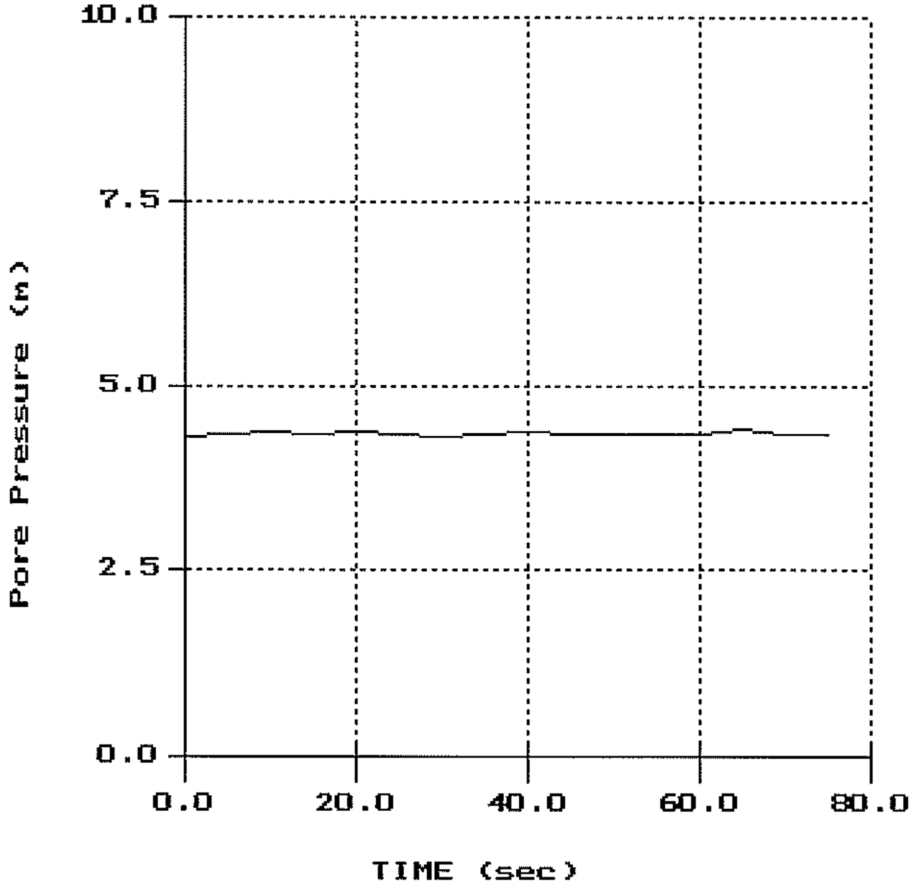


AMEC

Hole:GCPT10-01
Location:PKC

Cone:272:T375F10U200
Date:09:09:10   11:30

PORE PRESSURE DISSIPATION RECORD



File: 090G01.PPF
Depth (m): 3.80
(ft): 12.47
Duration : 75.0s
U-min: 4.31 30.0s
U-max: 4.40 65.0s

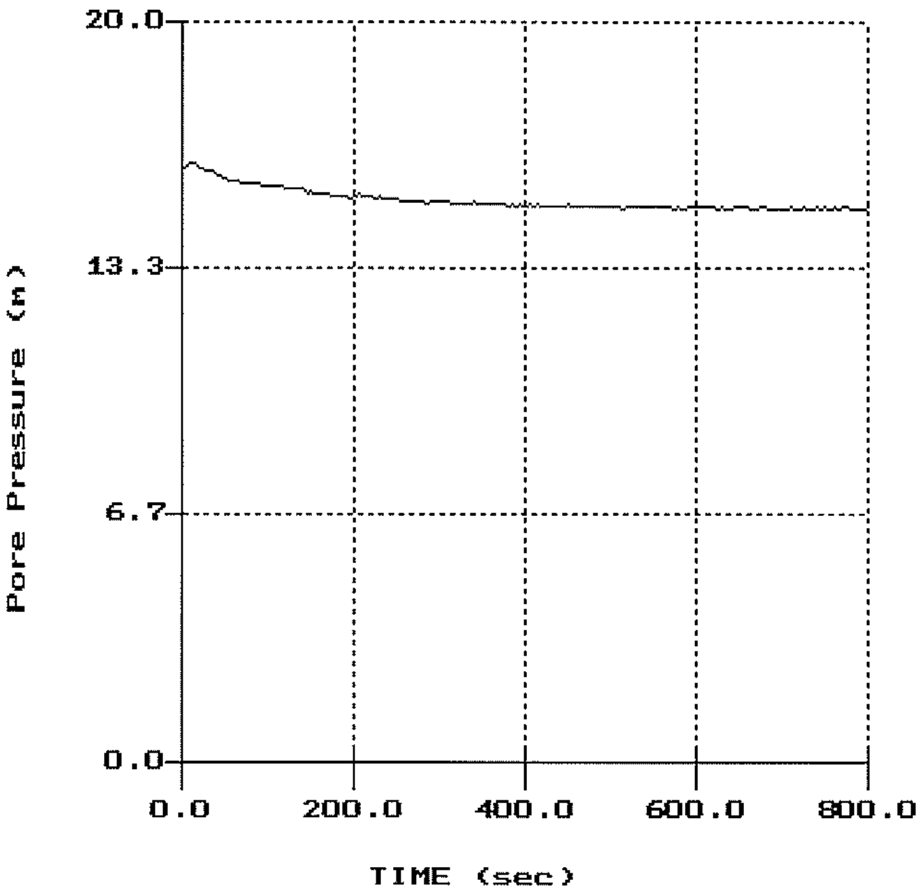
AMEC

Hole:GCPT10-01
Location:PKC

Cone:272:T375F10U200
Date:09:09:10 11:30

File: 090G01.PPF
Depth (m): 11.60
(ft): 38.06
Duration : 800.0s
U-min: 14.94 665.0s
U-max: 16.20 10.0s

PORE PRESSURE DISSIPATION RECORD



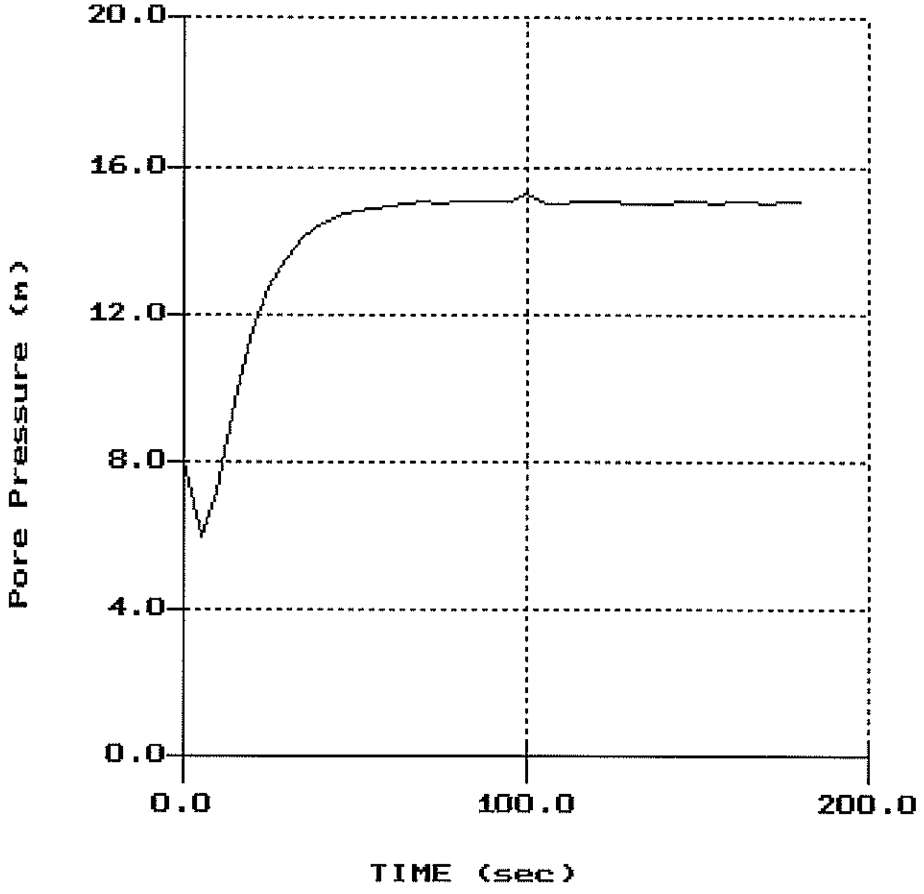
AMEC

Hole:GCPT10-01
Location:PKC

Cone:272:T375F10U200
Date:09:09:10 11:30

File: 090G01.PPF
Depth (m): 11.85
(ft): 38.88
Duration : 180.0s
U-min: 5.94 5.0s
U-max: 15.30 100.0s

PORE PRESSURE DISSIPATION RECORD



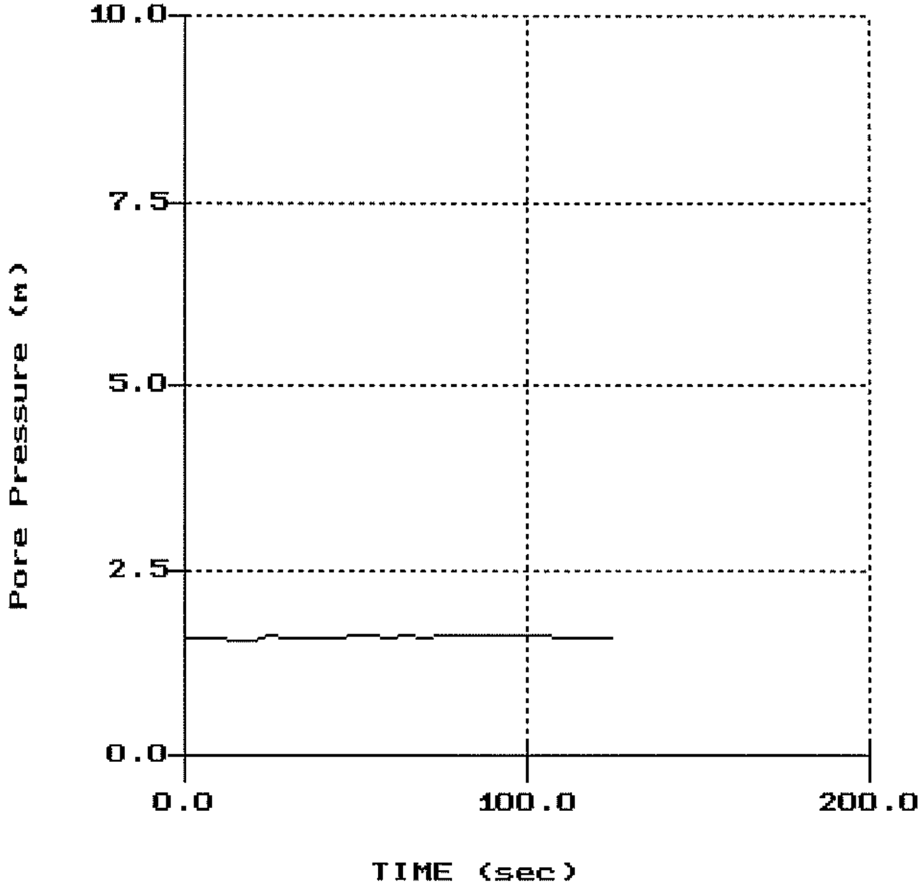
AMEC

Hole:GCPT10-02
Location:PKC

Cone:272:T375F10U200
Date:09:09:10 14:03

File: 090G02.PPF
Depth (m): 1.45
(ft): 4.76
Duration : 125.0s
U-min: 1.57 20.0s
U-max: 1.64 85.0s

PORE PRESSURE DISSIPATION RECORD



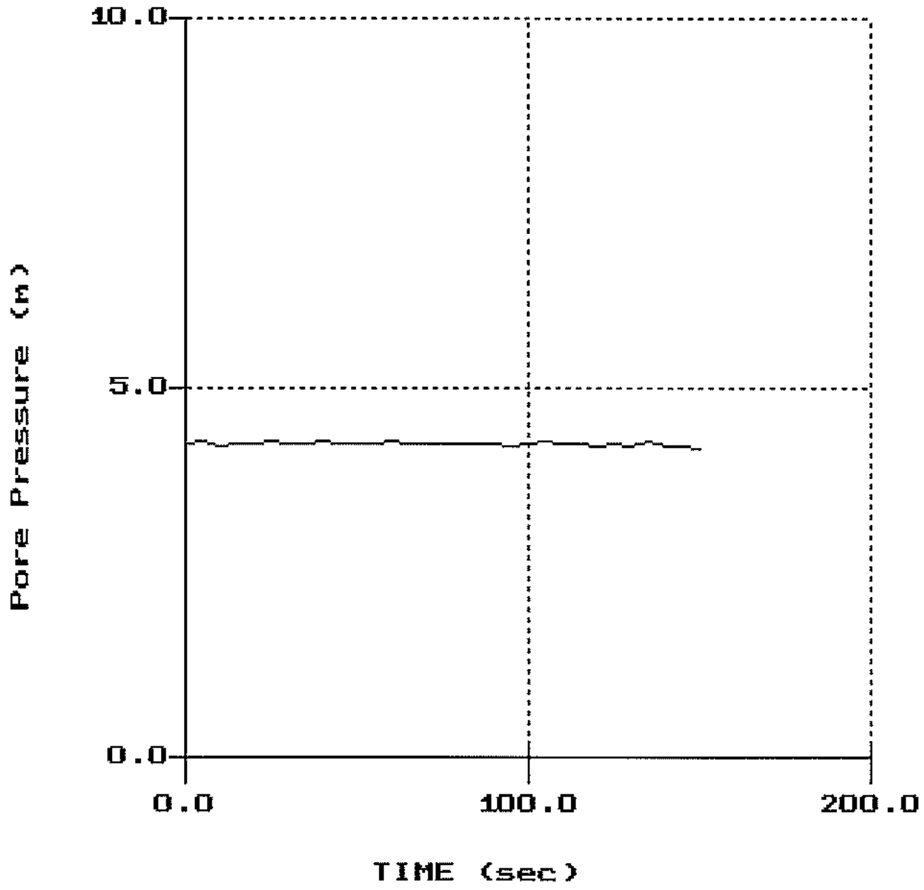
AMEC

Hole:GCPT10-02
Location:PKC

Cone:272:T375F10U200
Date:09:09:10 14:03

File: 090G02.PPF
Depth (m): 3.95
(ft): 12.96
Duration : 150.0s
U-min: 4.18 150.0s
U-max: 4.28 105.0s

PORE PRESSURE DISSIPATION RECORD



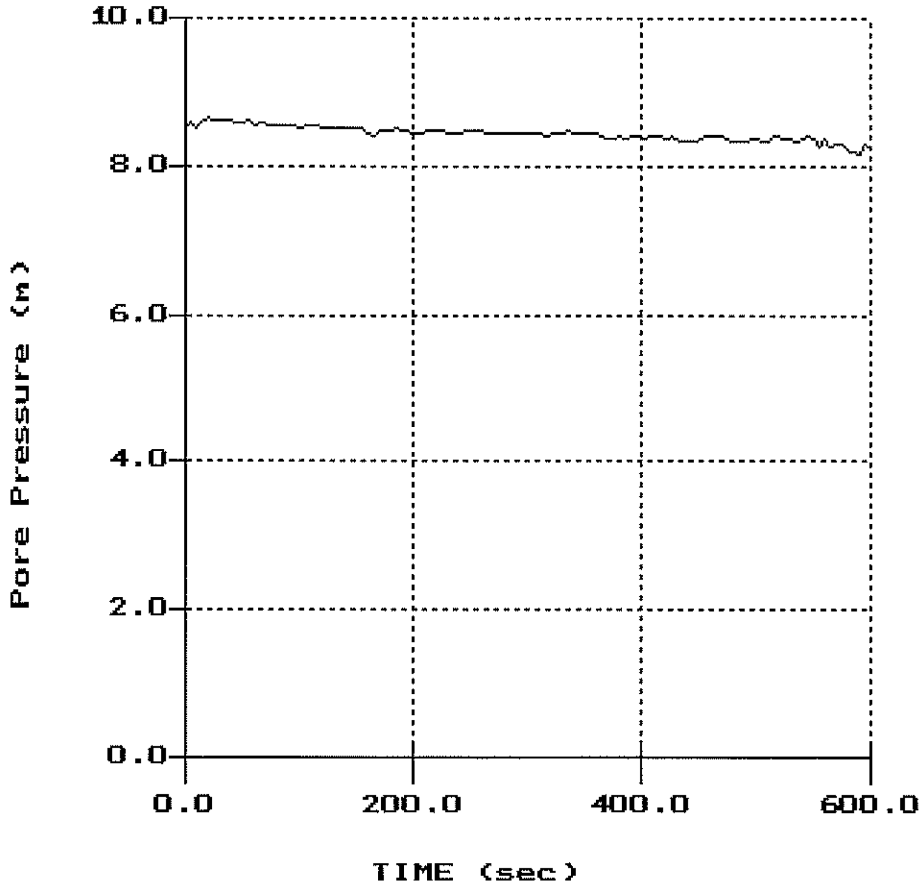
AMEC

Hole:GCPT10-02
Location:PKC

Cone:272:T375F10U200
Date:09:09:10 14:03

File: 090G02.PPF
Depth (m): 6.85
(ft): 22.47
Duration : 600.0s
U-min: 8.17 590.0s
U-max: 8.64 20.0s

PORE PRESSURE DISSIPATION RECORD

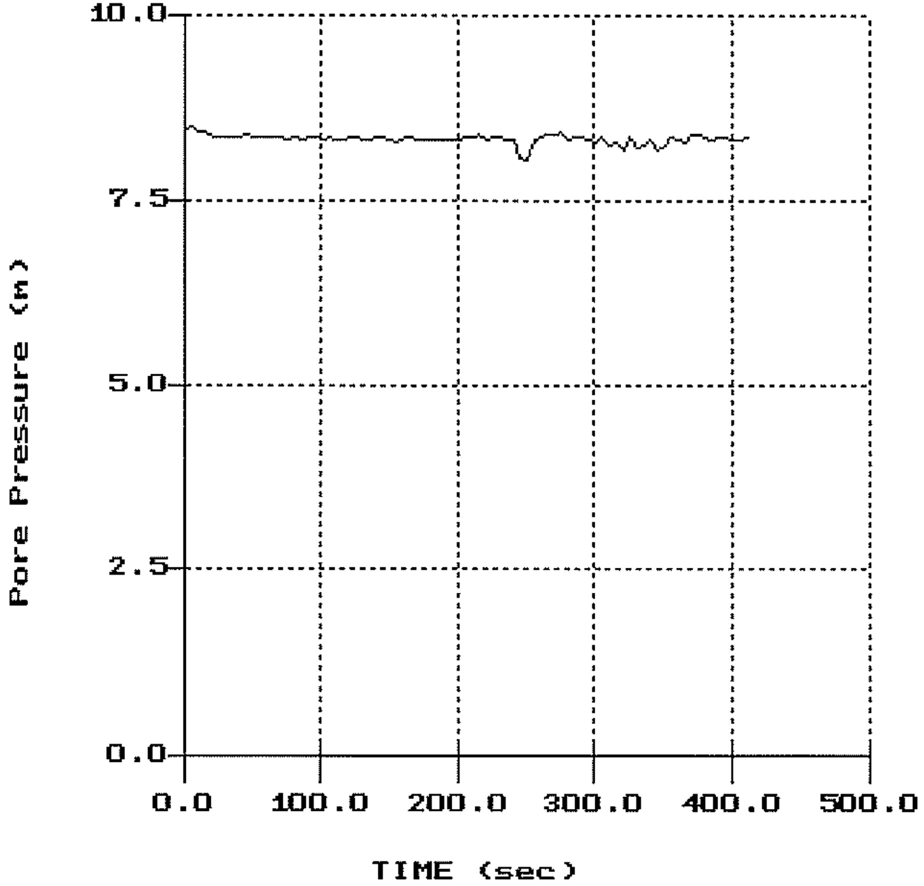


AMEC

Hole:GCPT10-02
Location:PKC

Cone:272:T375F10U200
Date:09:09:10 14:03

PORE PRESSURE DISSIPATION RECORD



```
File: 090G02.PPF
Depth (m):   8.40
     (ft):  27.56
Duration : 410.0s
U-min:   8.06 250.0s
U-max:   8.52   5.0s
```

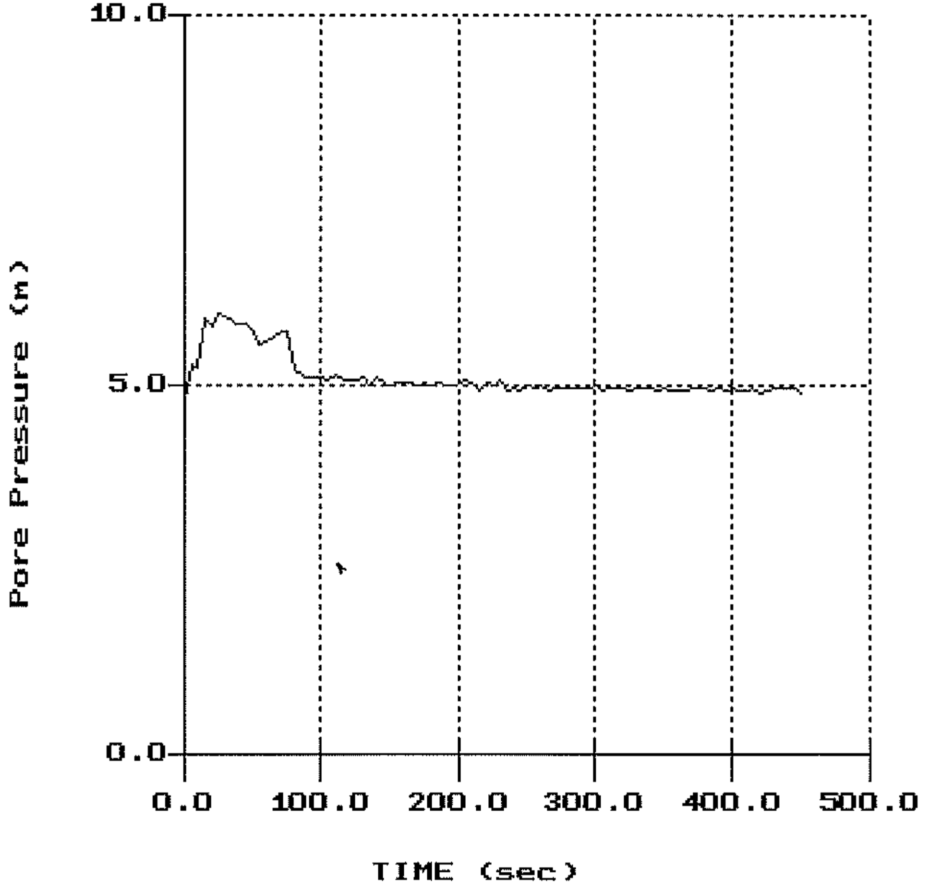
AMEC

Hole:GCPT10-03
Location:PKC

Cone:272:T375F10U200
Date:09:09:10 16:00

File: 090G03.PPF
Depth (m): 4.80
(ft): 15.75
Duration : 450.0s
U-min: 4.80 0.0s
U-max: 5.96 25.0s

PORE PRESSURE DISSIPATION RECORD

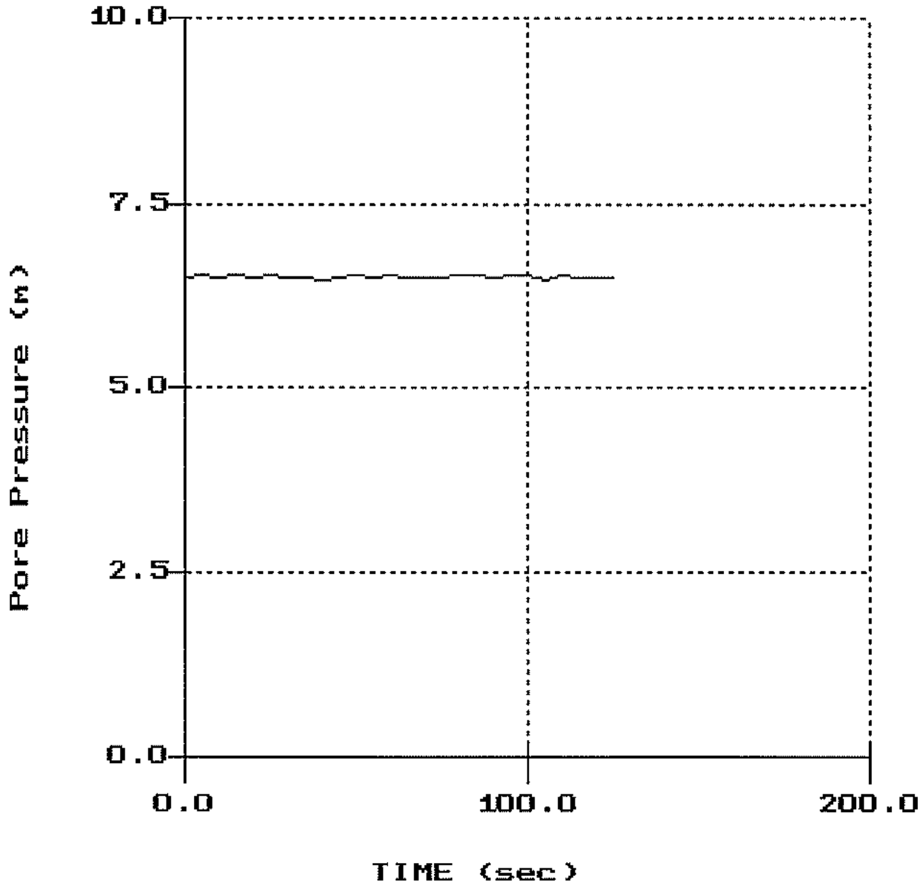


AMEC

Hole:GCPT10-04
Location:PKC

Cone:272:T375F10U200
Date:09:10:10 09:10

PORE PRESSURE DISSIPATION RECORD



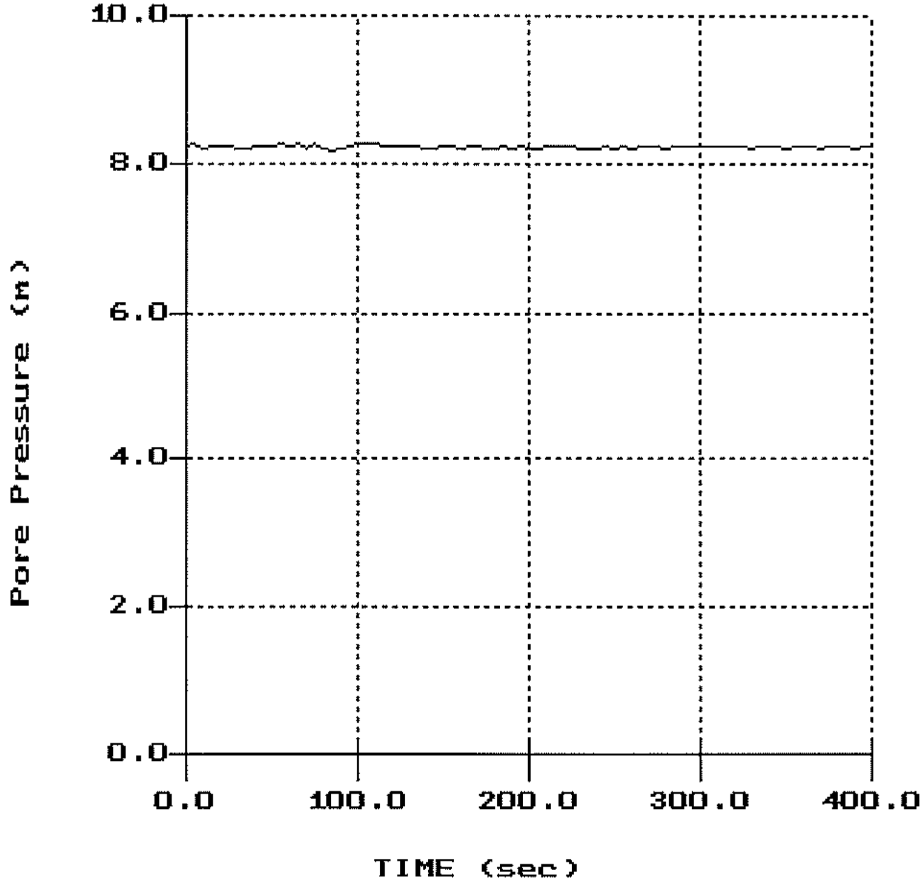
File: 090G04.PPF
Depth (m): 5.75
(ft): 18.86
Duration : 125.0s
U-min: 6.50 105.0s
U-max: 6.57 85.0s

AMEC

Hole:GCPT10-04
Location:PKC

Cone:272:T375F10U200
Date:09:10:10 09:10

PORE PRESSURE DISSIPATION RECORD



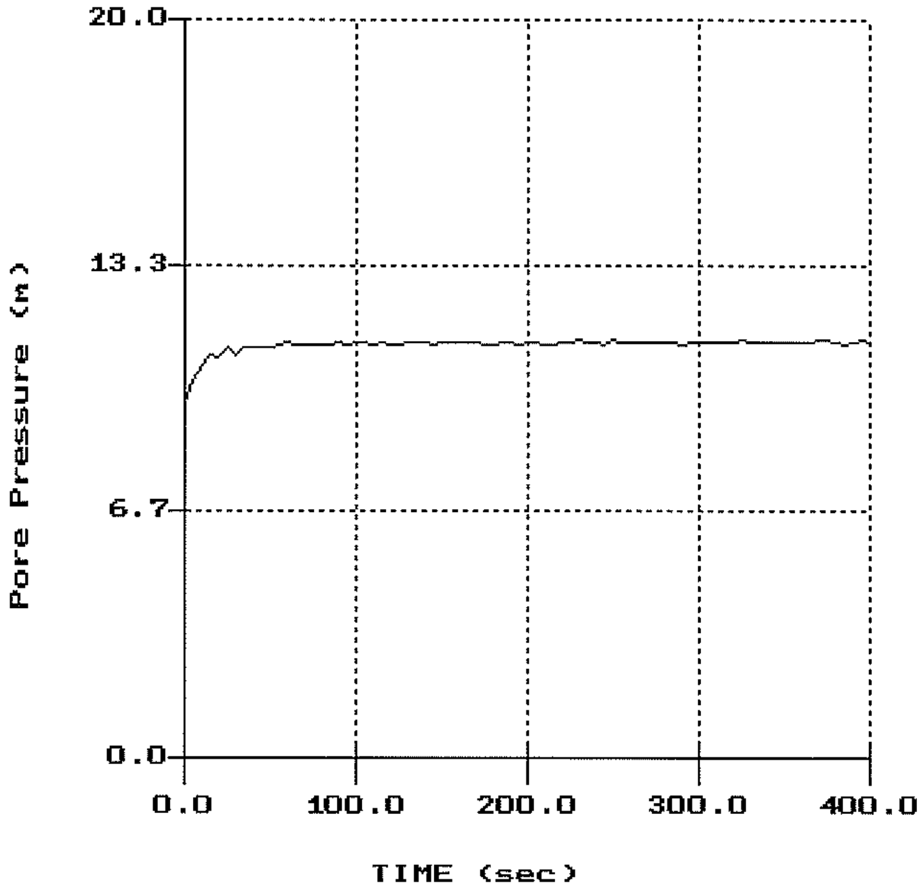
File: 090G04.PPF
Depth (m): 7.00
(ft): 22.97
Duration : 400.0s
U-min: 8.17 85.0s
U-max: 8.27 75.0s

AMEC

Hole:GCPT10-04
Location:PKC

Cone:272:T375F10U200
Date:09:10:10 09:10

PORE PRESSURE DISSIPATION RECORD



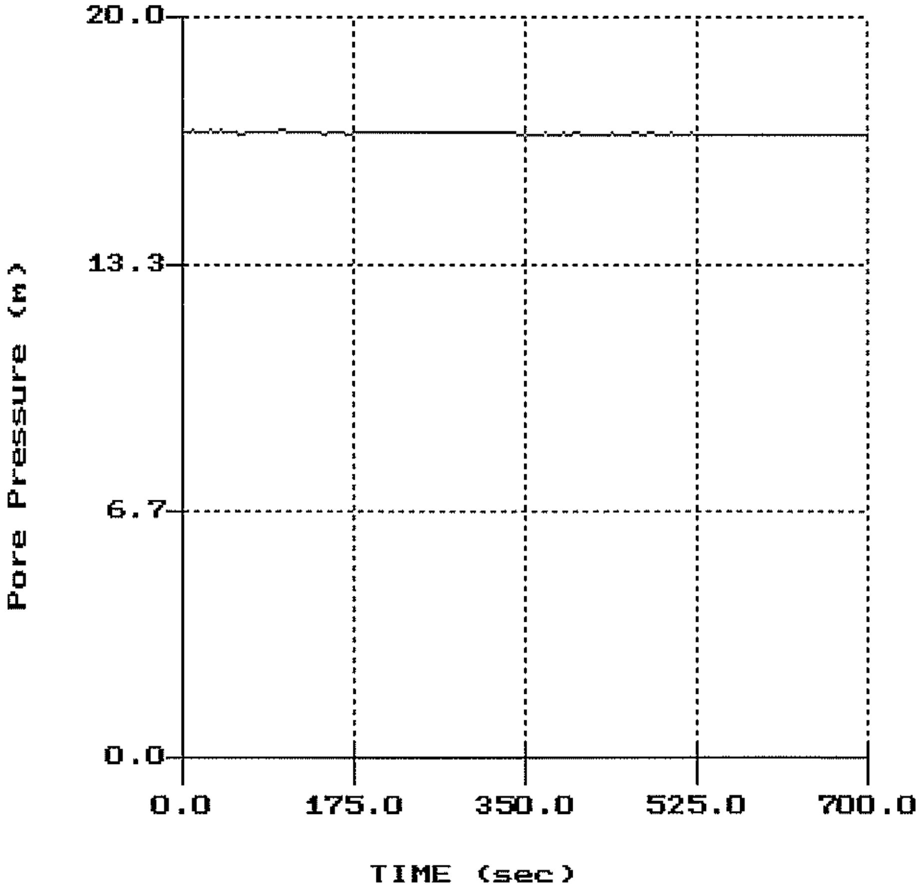
File: 090G04.PPF
Depth (m): 9.10
(ft): 29.86
Duration : 400.0s
U-min: 9.62 0.0s
U-max: 11.32 375.0s

AMEC

Hole:GCPT10-04
Location:PKC

Cone:272:T375F10U200
Date:09:10:10 09:10

PORE PRESSURE DISSIPATION RECORD



File: 090G04.PPF
Depth (m): 12.65
(ft): 41.50
Duration : 700.0s
U-min: 16.84 635.0s
U-max: 17.03 10.0s

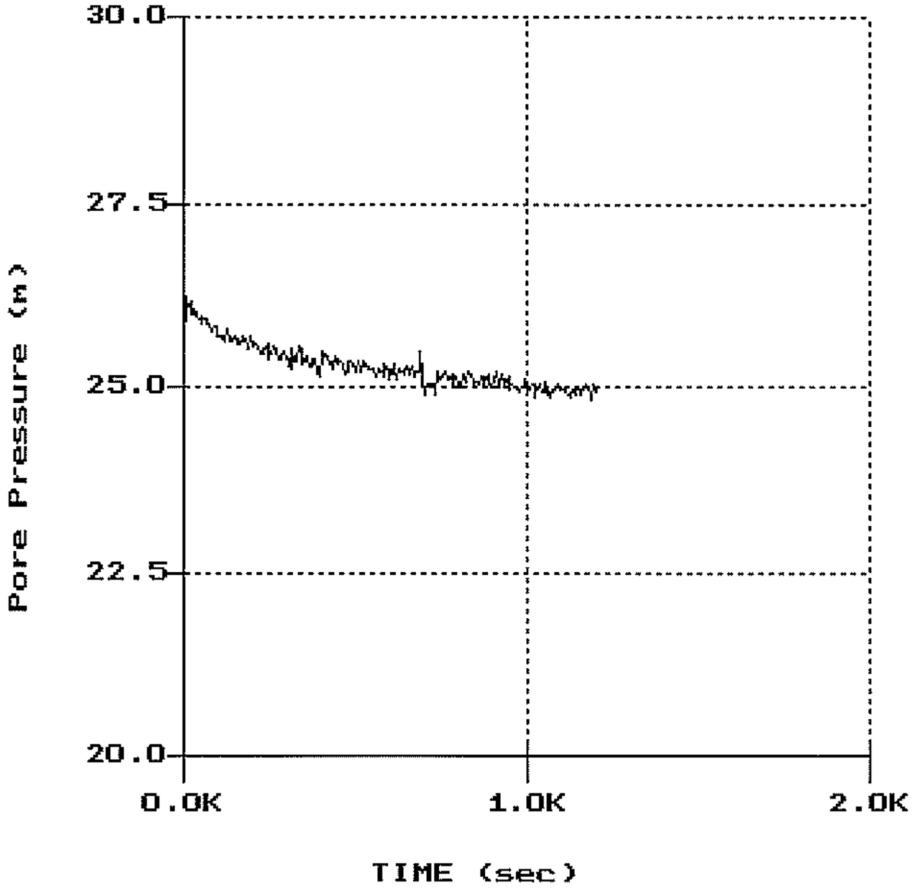
AMEC

Hole:GCPT 10-04
Location:PKC

Cone:272:T375F10U200
Date:09:10:10 09:10

File: 090G04.PPF
Depth (m): 17.65
(ft): 57.91
Duration : 1200.0s
U-min: 24.82 1190.0s
U-max: 26.24 5.0s

PORE PRESSURE DISSIPATION RECORD

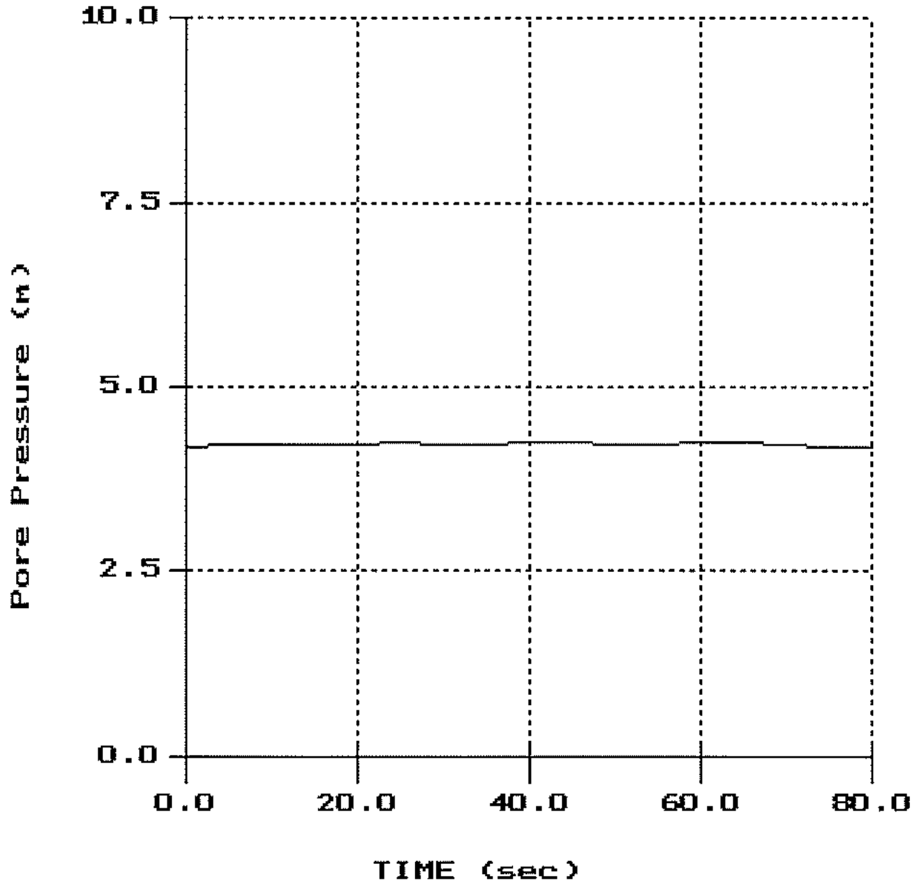


AMEC

Hole:GCPT10-05
Location:PKC

Cone:272:T375F10U200
Date:09:10:10 13:00

PORE PRESSURE DISSIPATION RECORD



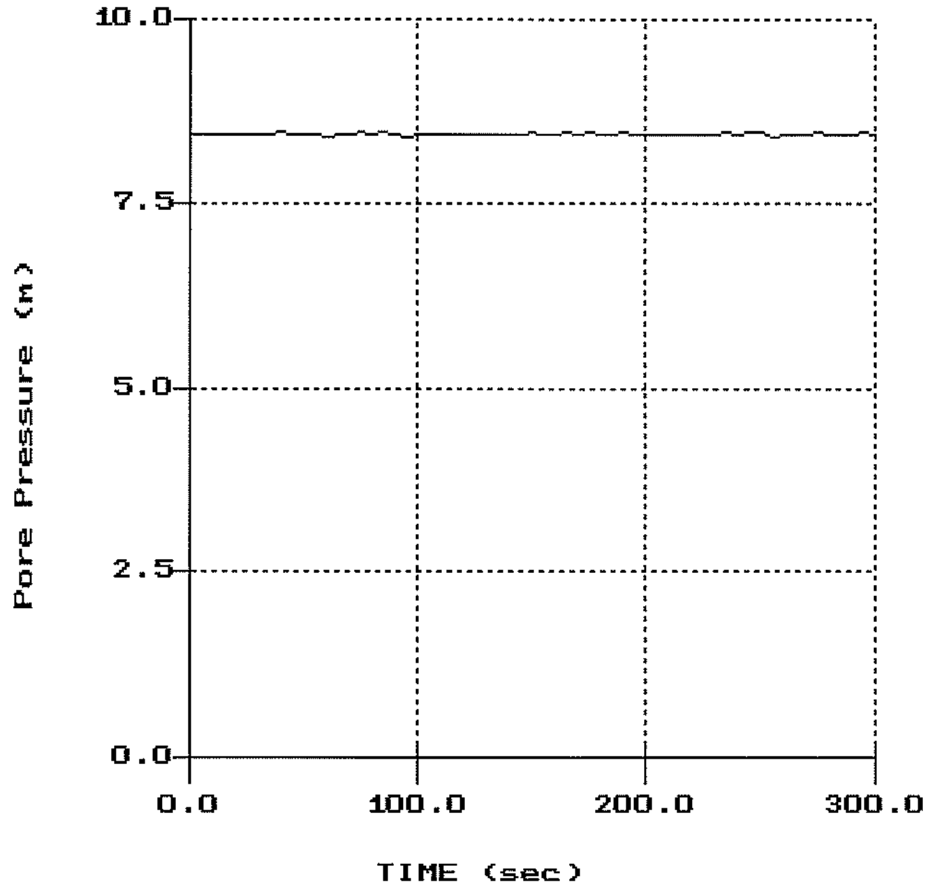
File: 090G05.PPF
Depth (m): 3.75
(ft): 12.30
Duration : 80.0s
U-min: 4.17 80.0s
U-max: 4.24 65.0s

AMEC

Hole:GCPT10-05
Location:PKC

Cone:272:T375F10U200
Date:09:10:10 13:00

PORE PRESSURE DISSIPATION RECORD



File: 090G05.PPF
Depth (m): 7.00
(ft): 22.97
Duration : 300.0s
U-min: 8.41 60.0s
U-max: 8.48 165.0s

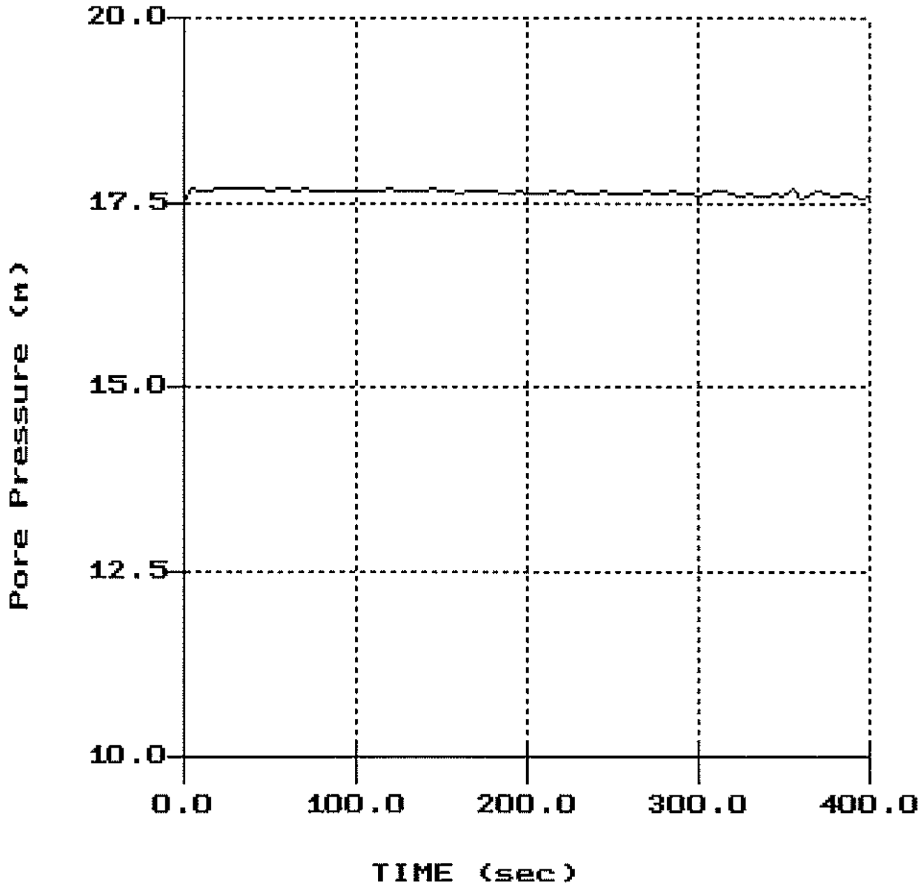
AMEC

Hole:GCPT10-05
Location:PKC

Cone:272:T375F10U200
Date:09:10:10 13:00

File: 090G05.PPF
Depth (m): 13.45
(ft): 44.13
Duration : 400.0s
U-min: 17.55 0.0s
U-max: 17.72 35.0s

PORE PRESSURE DISSIPATION RECORD

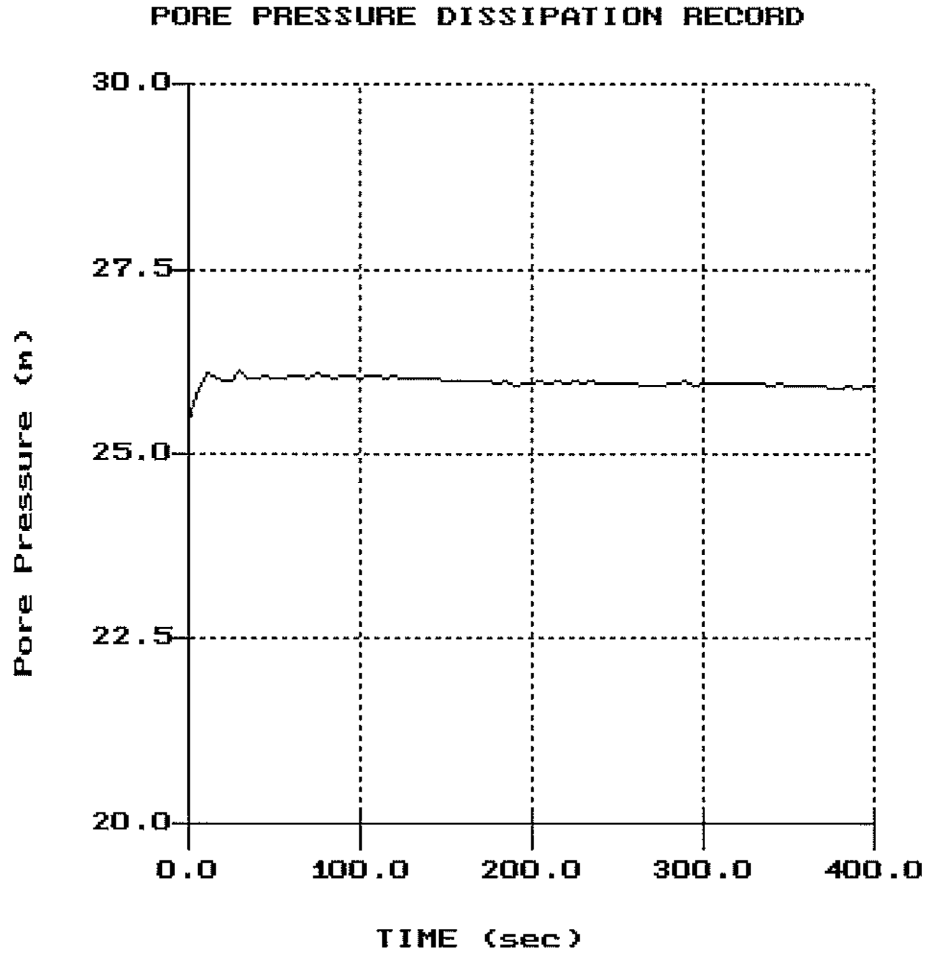


AMEC

Hole:GCPT10-05
Location:PKC

Cone:272:T375F10U200
Date:09:10:10 13:00

File: 090G05.PPF
Depth (m): 19.05
(ft): 62.50
Duration : 400.0s
U-min: 25.44 0.0s
U-max: 26.16 30.0s

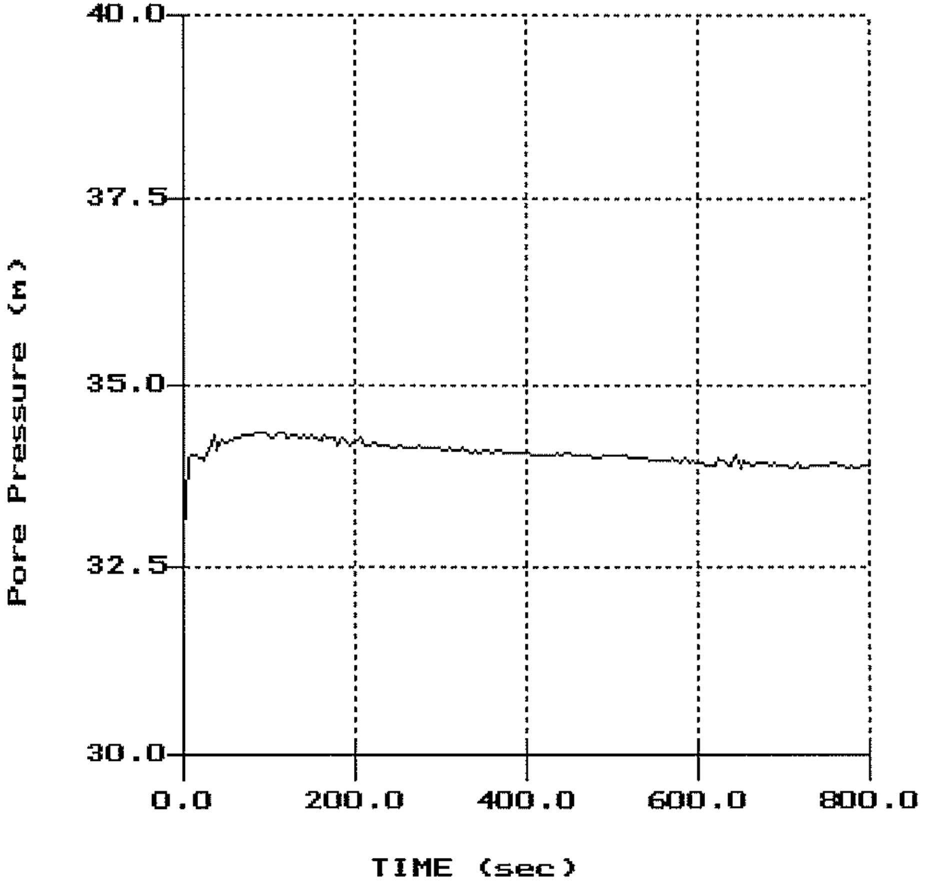


AMEC

Hole:GCPT10-05
Location:PKC

Cone:272:T375F10U200
Date:09:10:10 13:00

PORE PRESSURE DISSIPATION RECORD



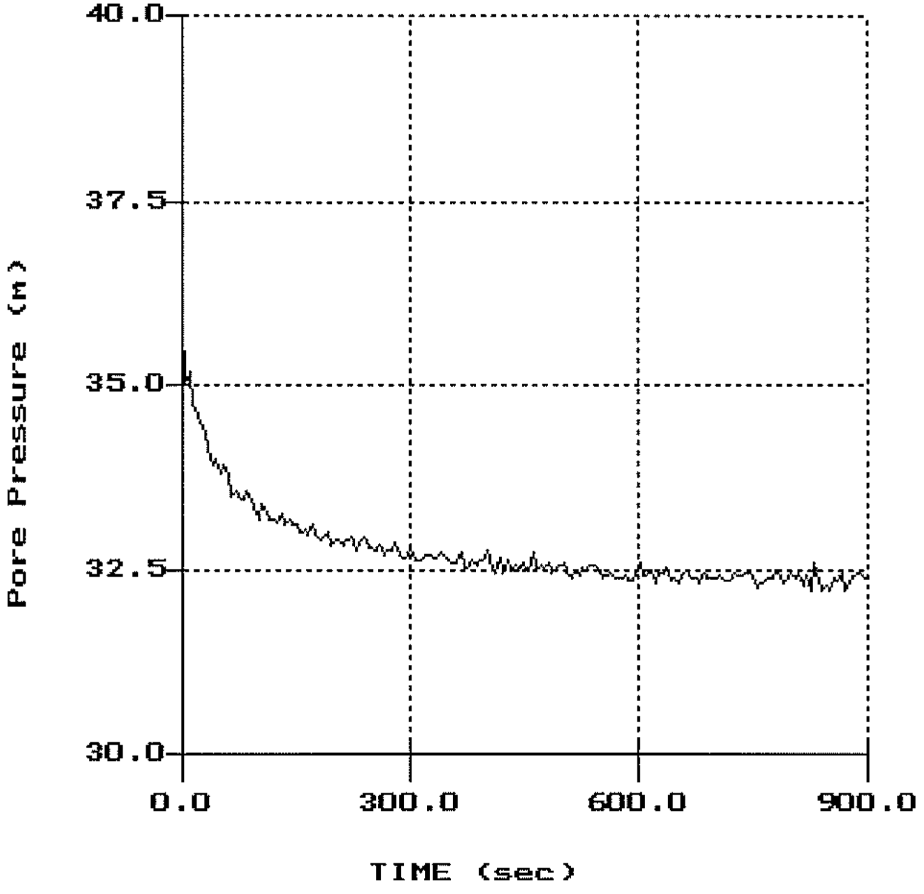
File: 090G05.PPF
Depth (m): 23.55
(ft): 77.26
Duration : 800.0s
U-min: 32.83 0.0s
U-max: 34.34 90.0s

AMEC

Hole:GCPT10-05
Location:PKC

Cone:272:T375F10U200
Date:09:10:10 13:00

PORE PRESSURE DISSIPATION RECORD



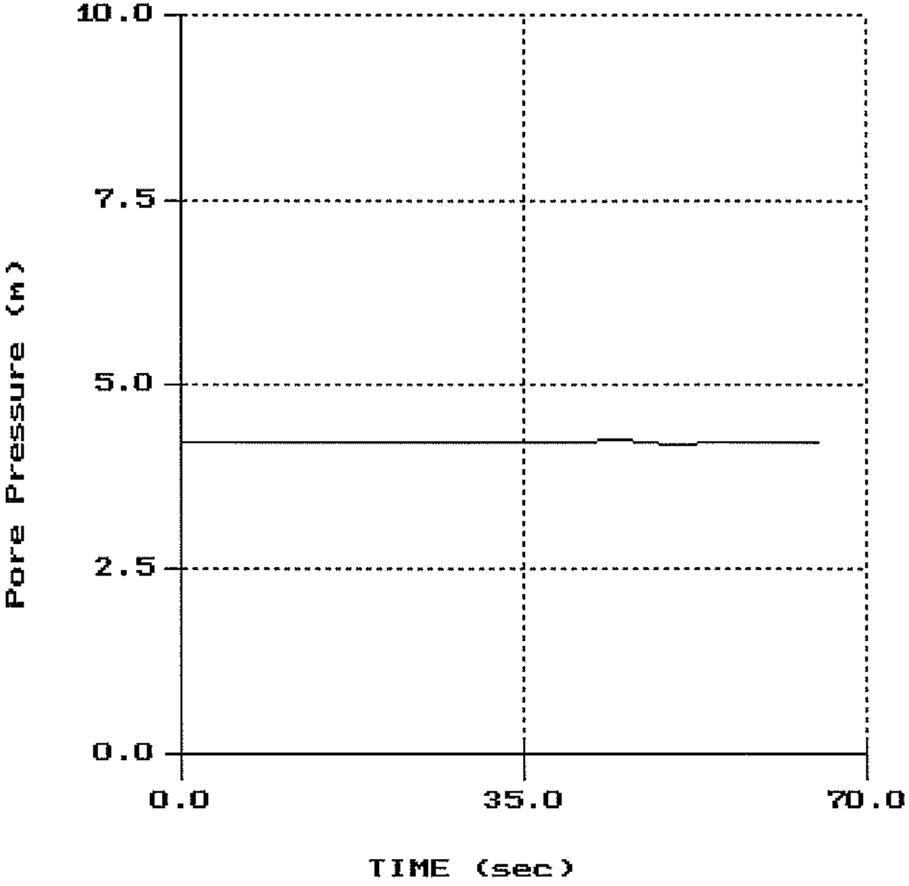
File: 090G05.PPF
Depth (m): 30.45
(ft): 99.90
Duration : 900.0s
U-min: 32.22 870.0s
U-max: 35.91 0.0s

AMEC

Hole:GCPT10-06
Location:PKC

Cone:267:T375F10U200
Date:09:12:10 15:56

File: 090G06.PPF
Depth (m): 3.70
(ft): 12.14
Duration : 65.0s
U-min: 4.16 50.0s
U-max: 4.23 45.0s

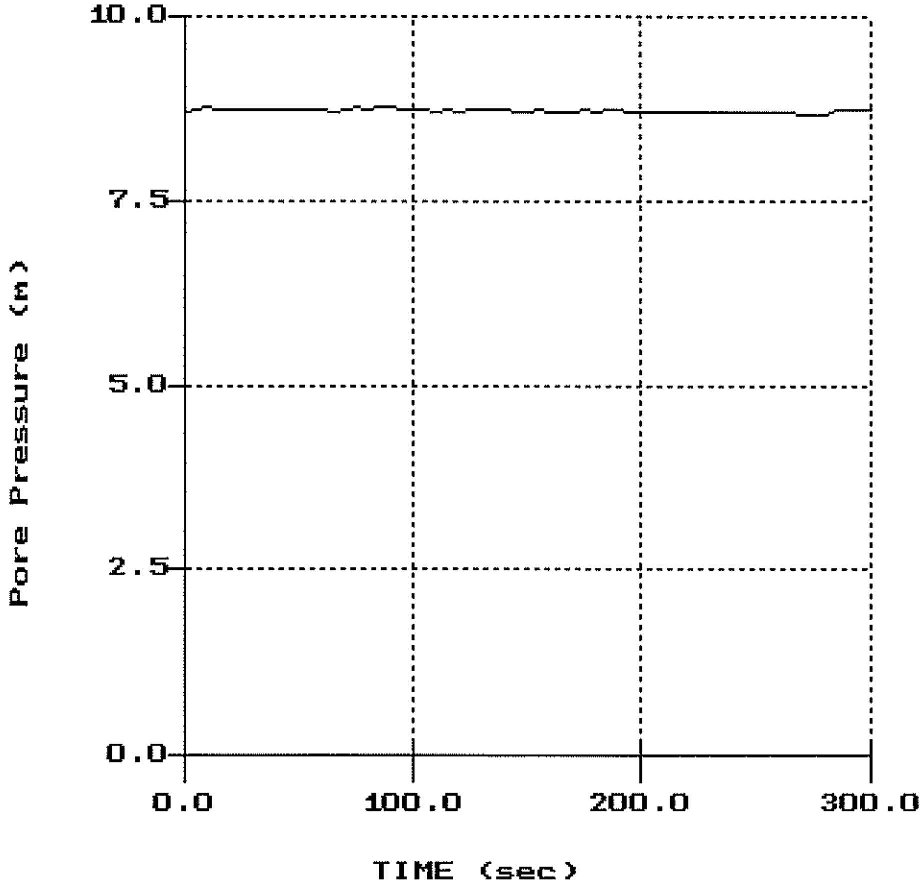

PORE PRESSURE DISSIPATION RECORD

AMEC

Hole:GCPT10-06
Location:PKC

Cone:267:T375F10U200
Date:09:12:10 15:56

PORE PRESSURE DISSIPATION RECORD



File: 090G06.PPF
Depth (m): 7.00
(ft): 22.97
Duration : 300.0s
U-min: 8.68 275.0s
U-max: 8.79 10.0s

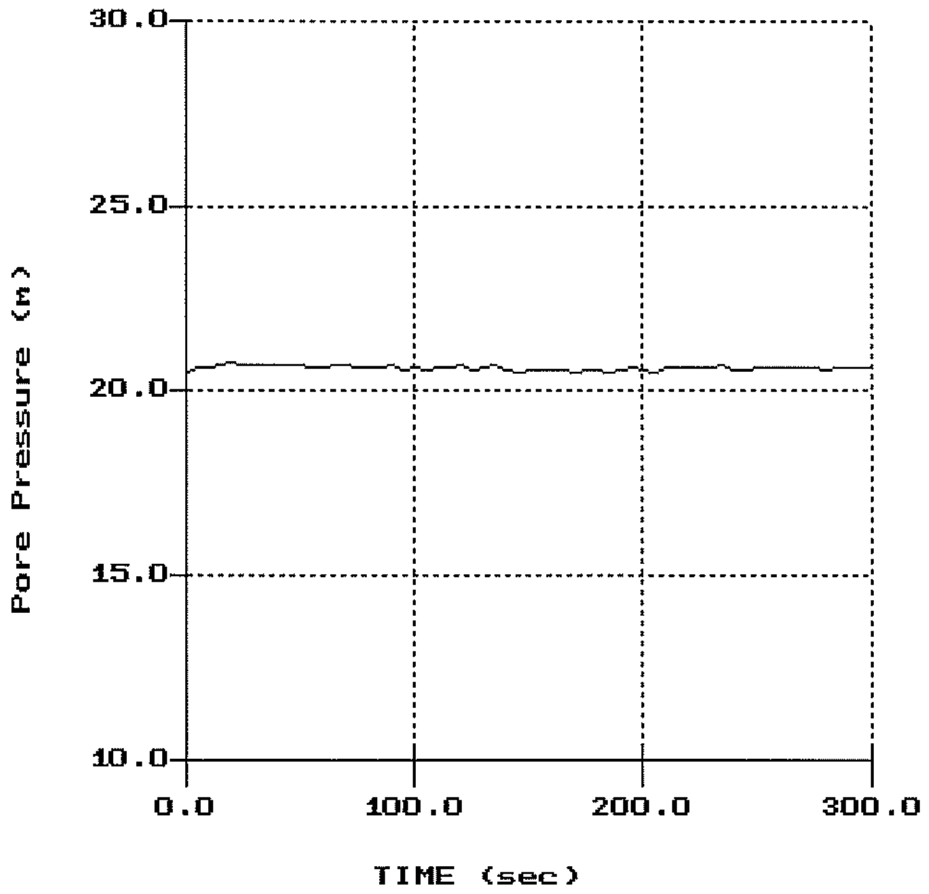
AMEC

Hole:GCPT10-06
Location:PKC

Cone:267:T375F10U200
Date:09:12:10 15:56

File: 090G06.PPF
Depth (m): 15.05
(ft): 49.38
Duration : 300.0s
U-min: 20.46 0.0s
U-max: 20.73 20.0s

PORE PRESSURE DISSIPATION RECORD

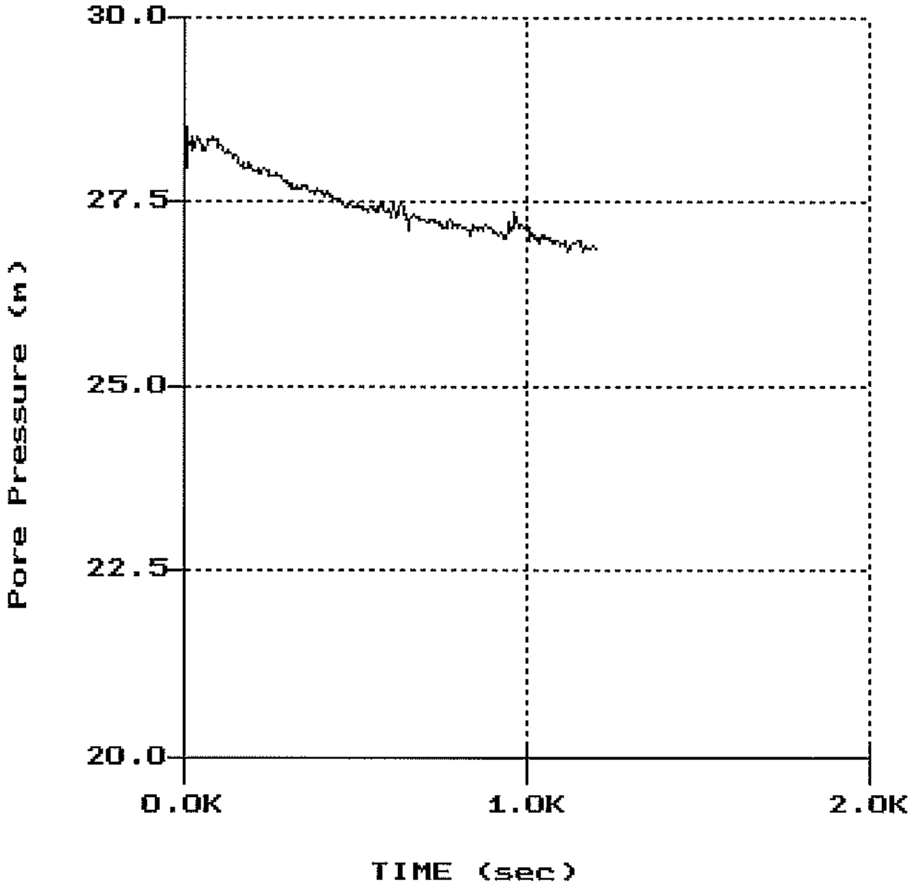


AMEC

Hole:GCPT10-06
Location:PKC

Cone:267:T375F10U200
Date:09:12:10 15:56

PORE PRESSURE DISSIPATION RECORD



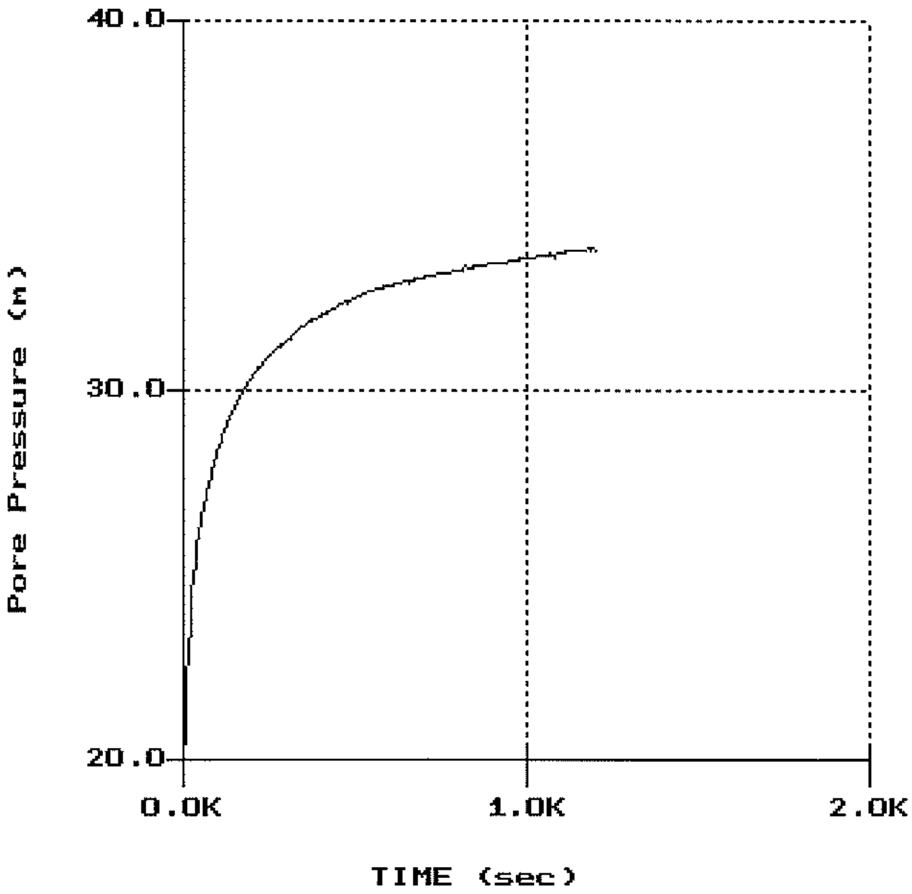
File: 090G06.PPF
Depth (m): 19.50
(ft): 63.98
Duration : 1200.0s
U-min: 26.85 1165.0s
U-max: 28.50 5.0s

AMEC

Hole:GCPT10-06
Location:PKC

Cone:267:T375F10U200
Date:09:12:10 15:56

PORE PRESSURE DISSIPATION RECORD



File: 090G06.PPF
Depth (m): 28.50
(ft): 93.50
Duration : 1200.0s
U-min: 20.41 5.0s
U-max: 33.87 1195.0s

APPENDIX C

Unit Weight Summary and Advanced CPT Plots with Su (N_{kt}) and Temperature

CONETEC

Job No: 10-090
Client: AMEC Earth & Environmental
Project: Diavik
Date: Sept 9 - Sept 12, 2010

CPT Assumed Unit Weight Summary

CPT Sounding	File Name	Date	Final Depth (m)	Depth Range for Assumed Unit Weight (m)	Assumed Unit Weight (kN/m3)*
GCPT10-01	090G01	09/09/10	11.85	0.050 - 3.000	10.21
				3.050 - 6.000	14.35
				6.050 - 9.000	14.16
GCPT10-02	090G02	09/09/10	8.55	0.050 - 3.000	9.81
				3.050 - 6.000	13.16
GCPT10-03	090G03	09/09/10	4.80	0.050 - 3.000	11.57
GCPT10-04	090G04	09/10/10	21.75	0.050 - 3.000	10.46
				3.050 - 6.000	12.82
				6.050 - 9.000	12.39
				9.000 - 11.950	16.72
				12.000 - 14.950	15.81
				15.000 - 17.950	16.89
GCPT10-05	090G05	09/10/10	30.45	0.050 - 3.000	10.47
				3.050 - 6.000	12.45
				6.050 - 9.000	14.02
				9.050 - 12.000	13.64
				12.050 - 15.000	13.36
				15.050 - 18.000	13.30
				18.050 - 21.000	16.70
				21.050 - 24.000	17.00
				24.050 - 27.000	10.55
GCPT10-06	090G06	09/12/10	28.50	0.050 - 3.000	11.34
				3.050 - 6.000	12.73
				6.050 - 9.000	13.28
				9.050 - 12.000	14.92
				12.050 - 15.000	13.67
				15.050 - 18.000	15.06
				18.050 - 21.000	14.38

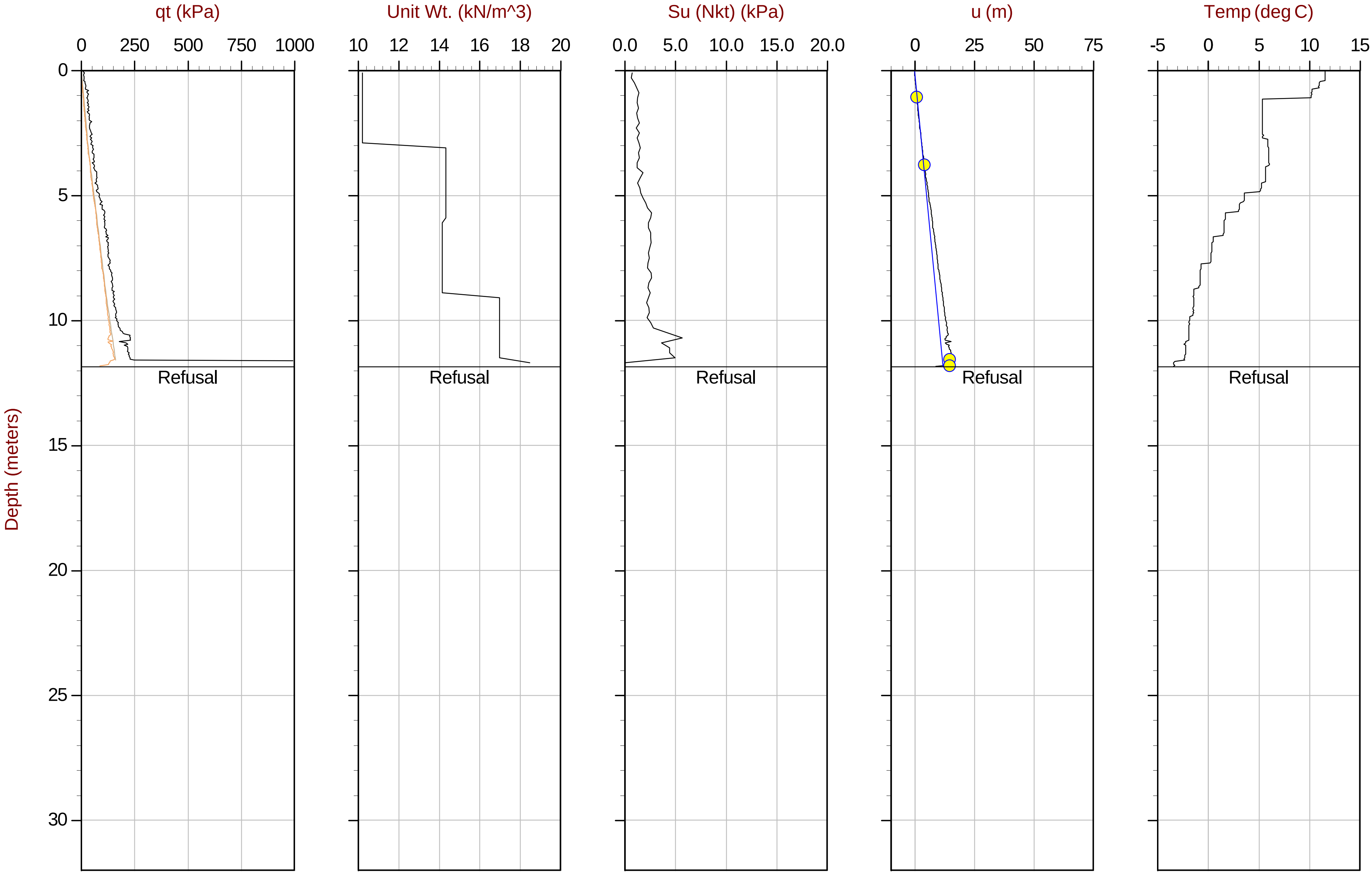
* Intervals outside of the specified ranges use the soil behavoiur type (SBT) defined unit weights

CONETEC

AMEC

Job No: 10-090
Date: 09:09:10 11:30
Site: Diavik PKC

Sounding: GCPT10-01
Cone: 272:T375F10U200



Max Depth: 11.850 m / 38.88 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.200 m

File: 090G01.COR
Unit Wt: User Defined Layers and SBT Zones
Su Nkt: 15.0

SBT: Lunne, Robertson and Powell, 1997
Coords: N: 7151876 E: 533254 Elev: 448.8

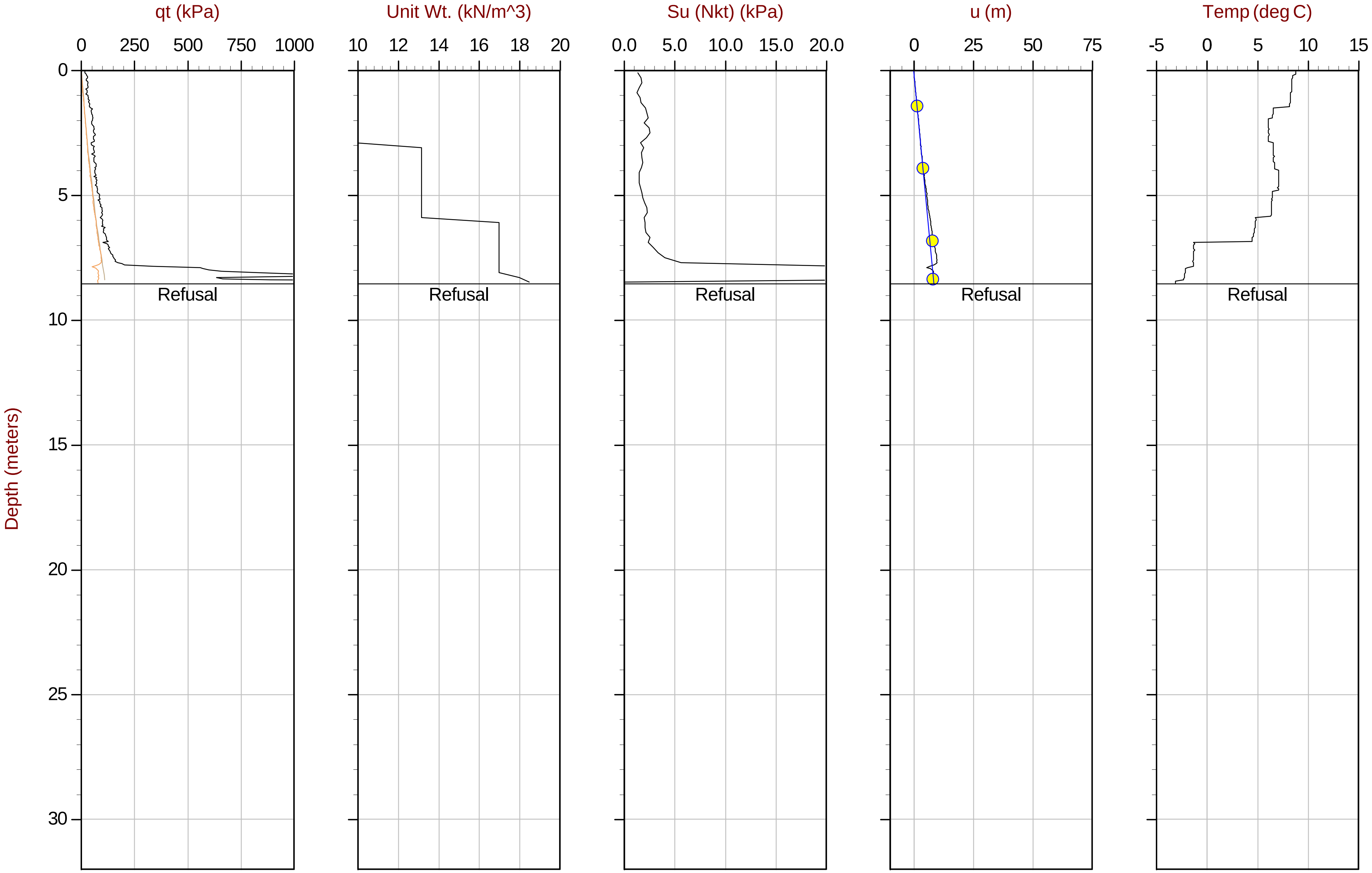
● U Equilibrium —— Dynamic U —— Hydrostatic Line

CONETEC

AMEC

Job No: 10-090
Date: 09:09:10 14:03
Site: Diavik PKC

Sounding: GCPT10-02
Cone: 272:T375F10U200



Max Depth: 8.550 m / 28.05 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.200 m

File: 090G02.COR
Unit Wt: User Defined Layers and SBT Zones
Su Nkt: 15.0

SBT: Lunne, Robertson and Powell, 1997
Coords: N: 7152023 E: 533308 Elev: 448.8

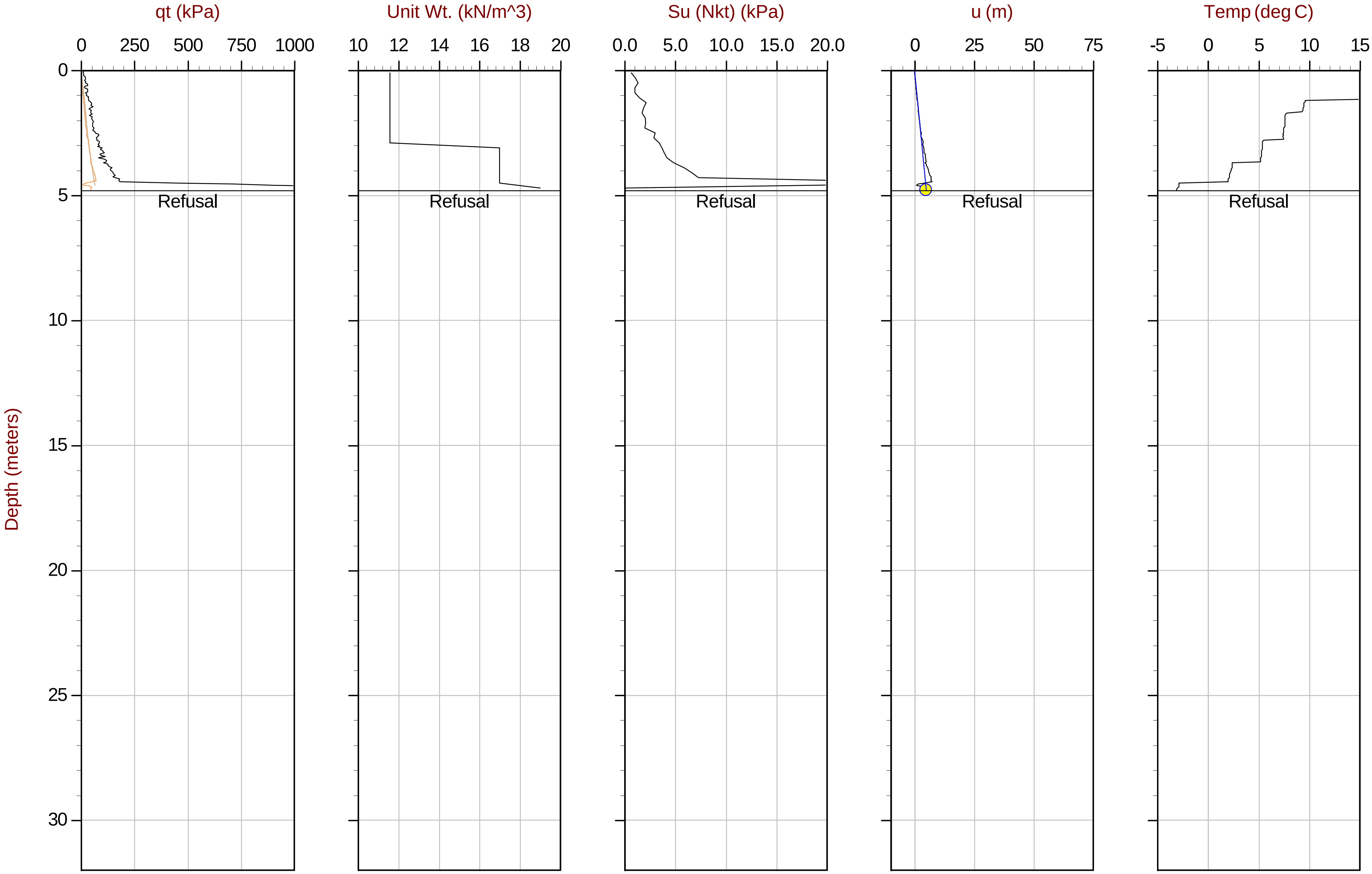
● U Equilibrium —— Dynamic U —— Hydrostatic Line

CONETEC

AMEC

Job No: 10-090
Date: 09:09:10 16:00
Site: Diavik PKC

Sounding: GCPT10-03
Cone: 272:T375F10U200



Max Depth: 4.800 m / 15.75 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.200 m

File: 090G03.COR
Unit Wt: User Defined Layers and SBT Zones
Su Nkt: 15.0

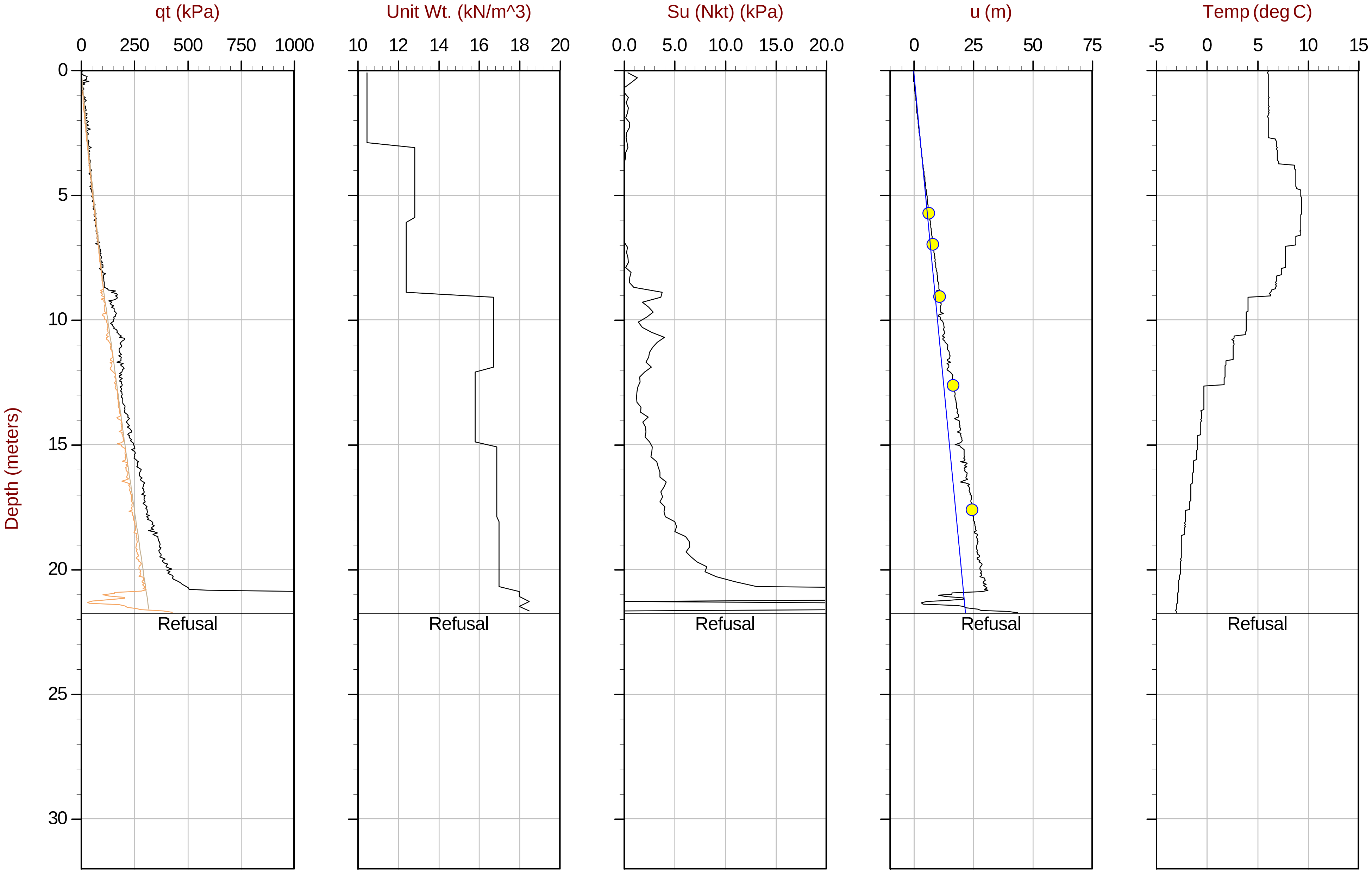
SBT: Lunne, Robertson and Powell, 1997
Coords: N: 7151985 E: 533439 Elev: 448.8

CONETEC

AMEC

Job No: 10-090
Date: 09:10:10 09:10
Site: Diavik PKC

Sounding: GCPT10-04
Cone: 272:T375F10U200



Max Depth: 21.750 m / 71.36 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.200 m

File: 090G04.COR
Unit Wt: User Defined Layers and SBT Zones
Su Nkt: 15.0

SBT: Lunne, Robertson and Powell, 1997
Coords: N: 7152113 E: 533195 Elev: 448.8

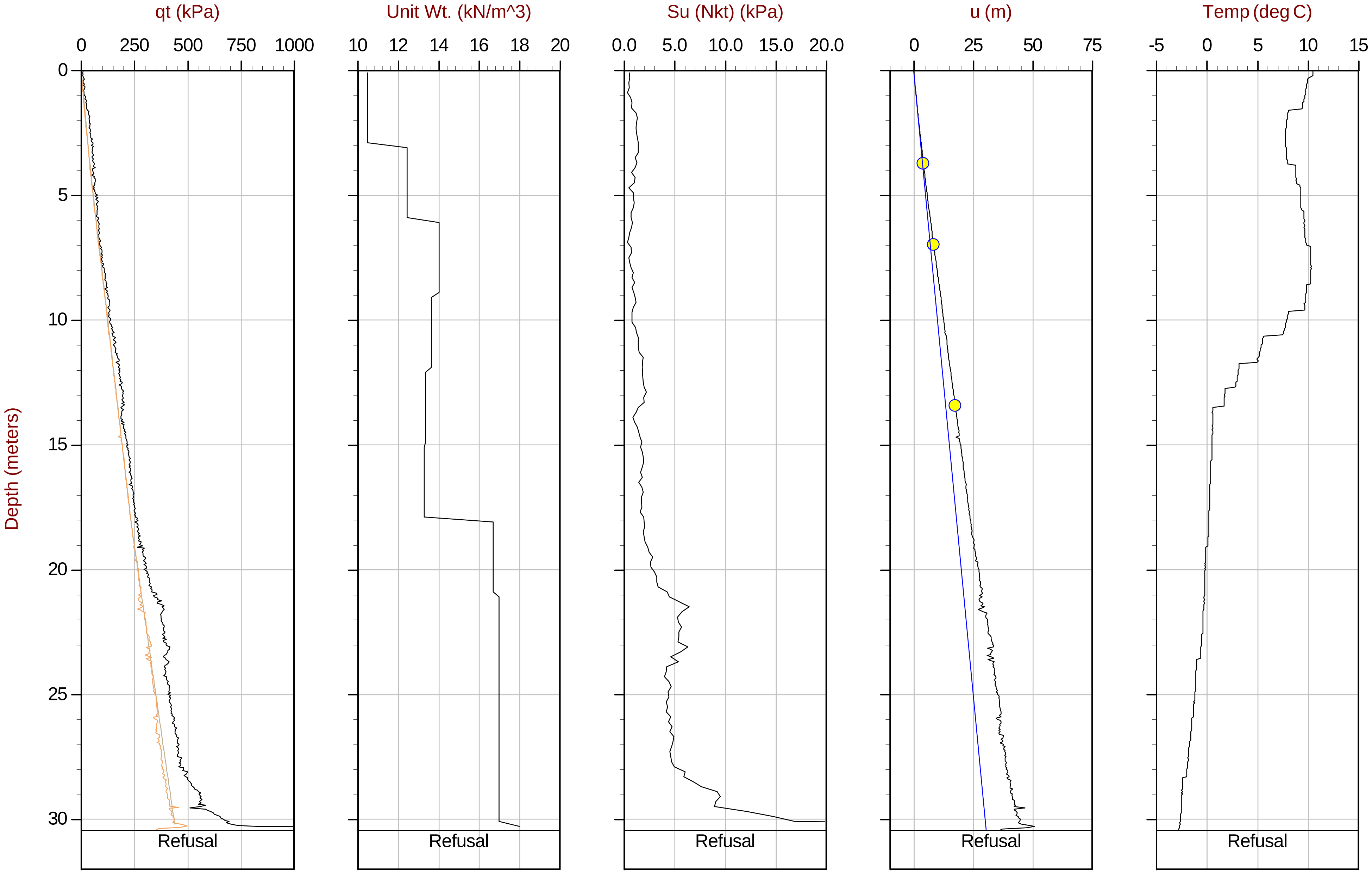
● U Equilibrium ——— Dynamic U ——— Hydrostatic Line

CONETEC

AMEC

Job No: 10-090
Date: 09:10:10 13:00
Site: Diavik PKC

Sounding: GCPT10-05
Cone: 272:T375F10U200



Max Depth: 30.450 m / 99.90 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.200 m

File: 090G05.COR
Unit Wt: User Defined Layers and SBT Zones
Su Nkt: 15.0

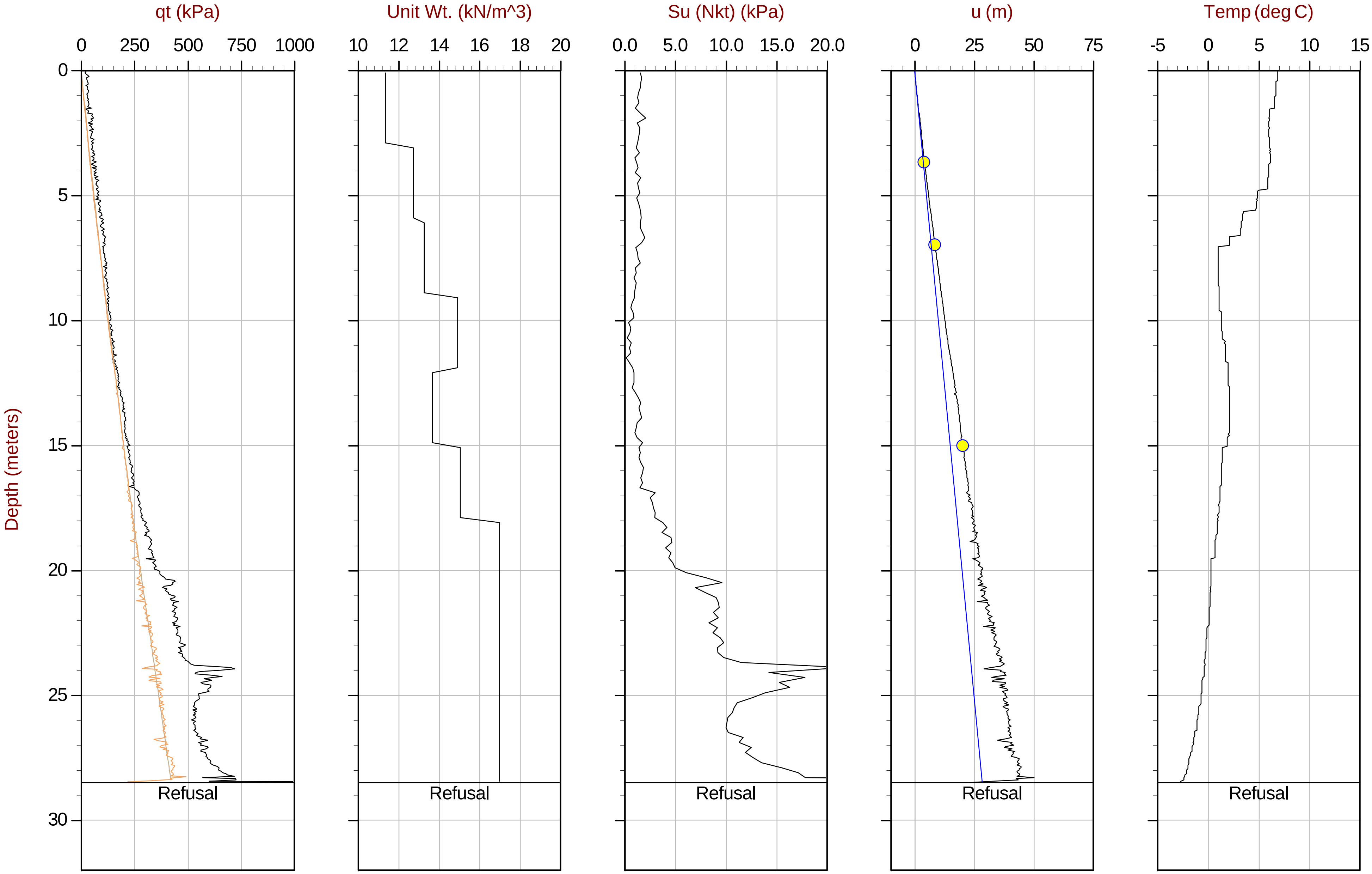
SBT: Lunne, Robertson and Powell, 1997
Coords: N: 7152028 E: 533094 Elev: 448.7

ConeTec

AMEC

Job No: 10-090
Date: 09:12:10 15:56
Site: Diavik PKC

Sounding: GCPT10-06
Cone: 272:T375F10U200



Max Depth: 28.500 m / 93.50 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.200 m

File: 090G06.COR
Unit Wt: User Defined Layers and SBT Zones
Su Nkt: 15.0

SBT: Lunne, Robertson and Powell, 1997
Coords: N: 7151945 E: 533179 Elev: 448.8

● U Equilibrium —— Dynamic U —— Hydrostatic Line

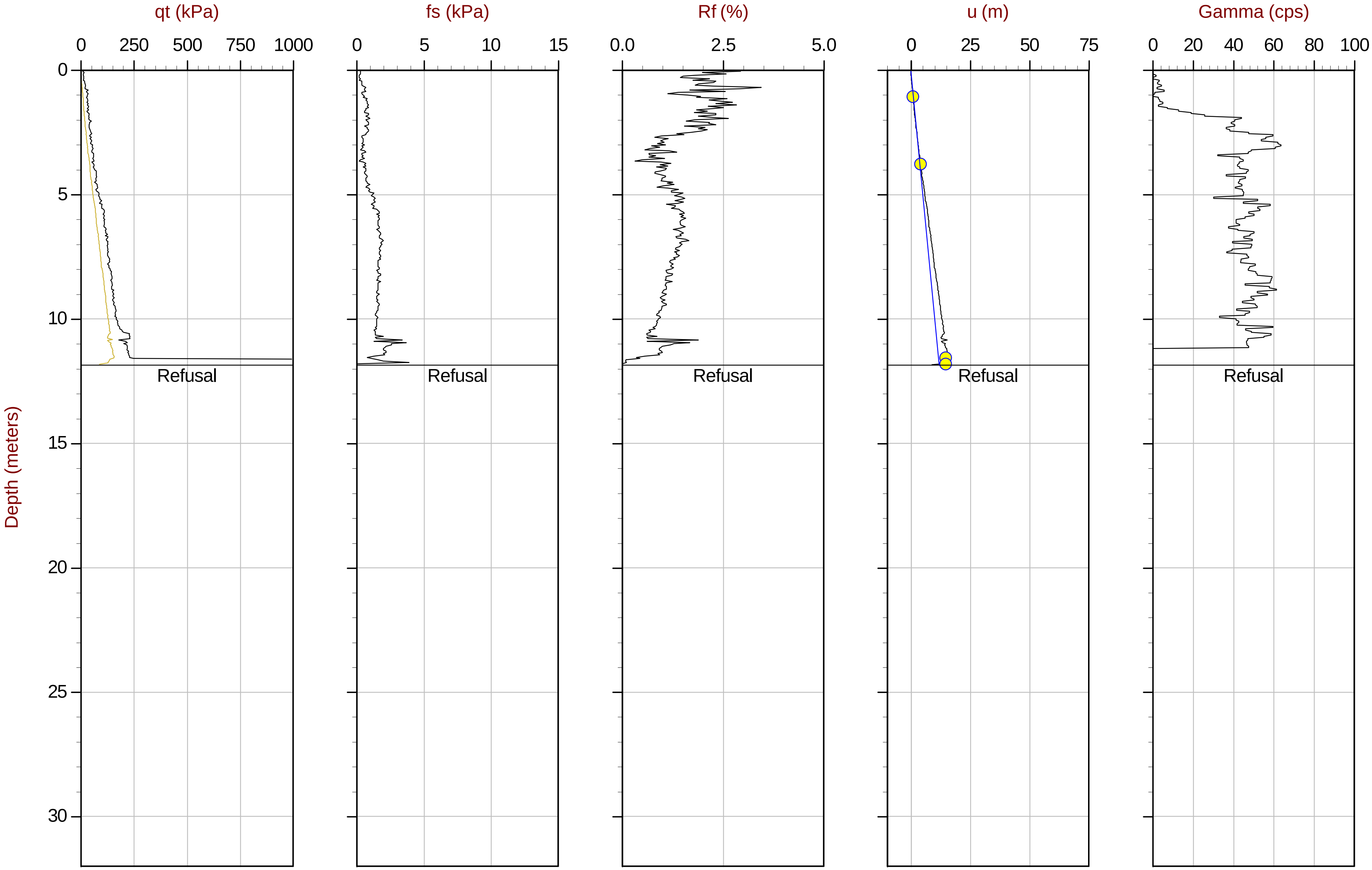
APPENDIX D

Passive Gamma CPT Plots

AMEC

Job No: 10-090
Date: 09:09:10 11:30
Site: Diavik PKC

Sounding: GCPT10-01
Cone: 272:T375F10U200



Max Depth: 11.850 m / 38.88 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.200 m

File: 090G01.COR
Unit Wt: User Defined Layers and SBT Zones

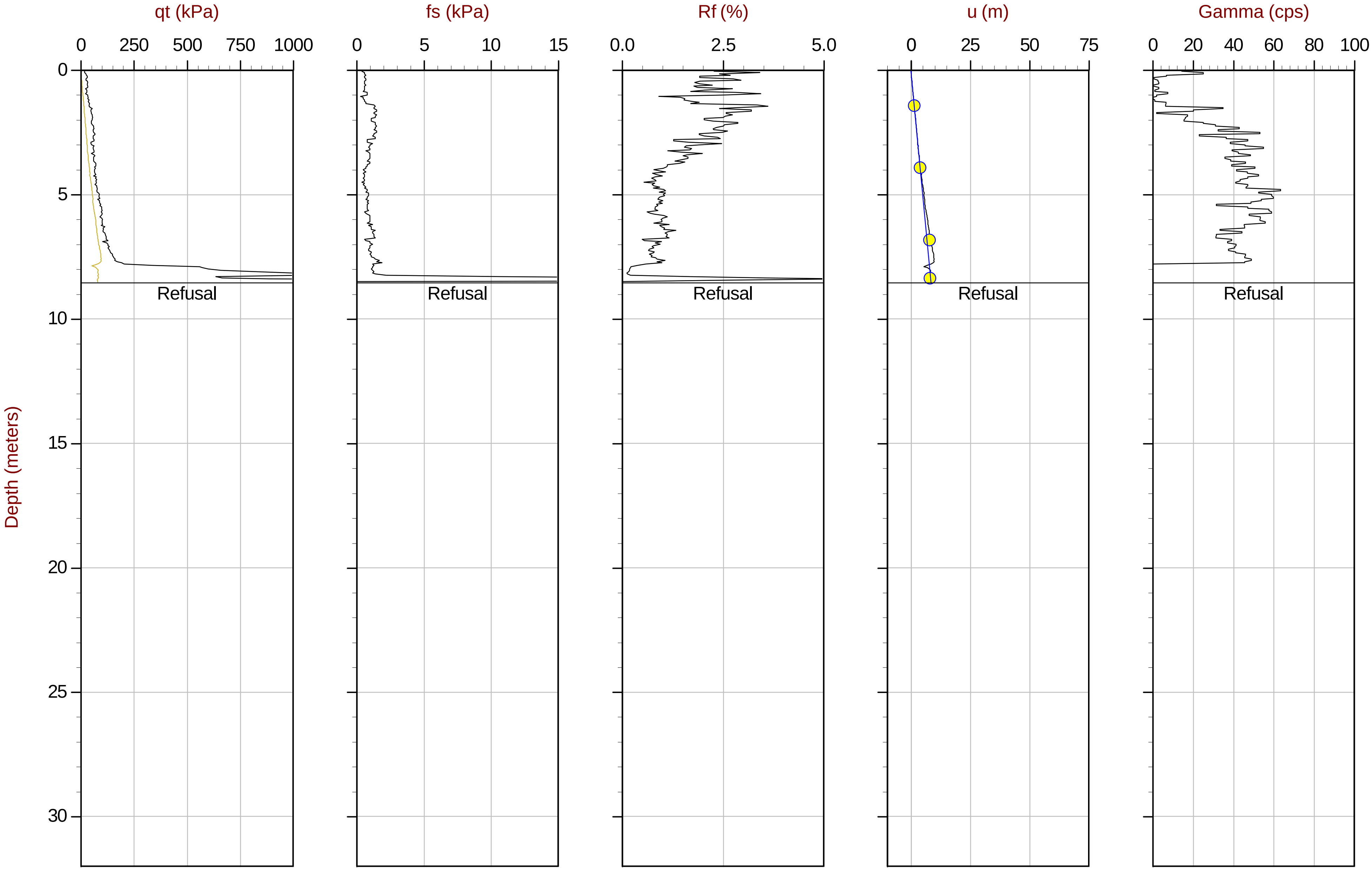
SBT: Lunne, Robertson and Powell, 1997
Coords: N: 7151876 E: 533254 Elev: 448.8

● U Equilibrium —— Dynamic U —— Hydrostatic Line

AMEC

Job No: 10-090
Date: 09:09:10 14:03
Site: Diavik PKC

Sounding: GCPT10-02
Cone: 272:T375F10U200



Max Depth: 8.550 m / 28.05 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.200 m

File: 090G02.COR
Unit Wt: User Defined Layers and SBT Zones

SBT: Lunne, Robertson and Powell, 1997
Coords: N: 7152023 E: 533308 Elev: 448.8

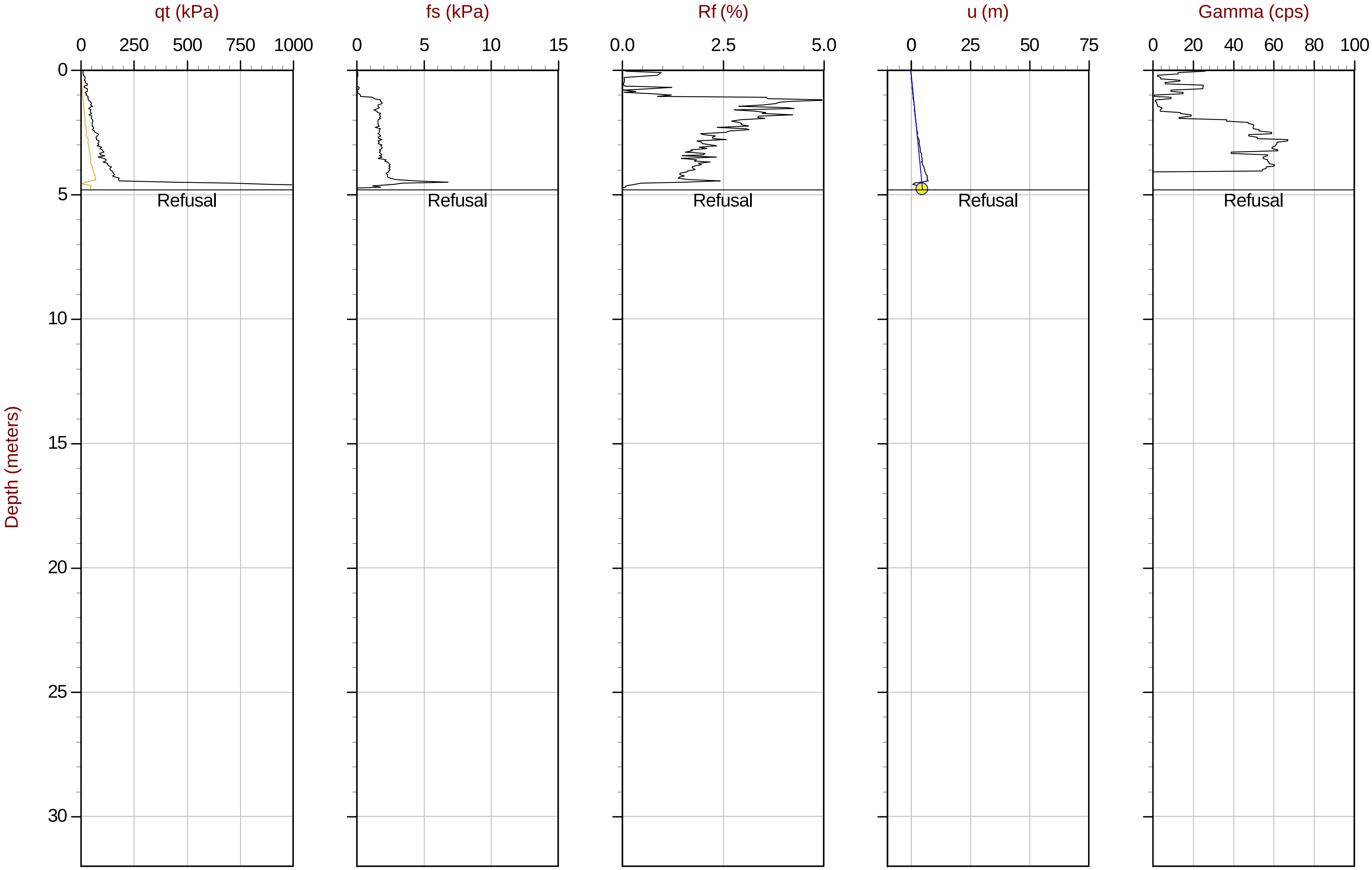
● U Equilibrium ——— Dynamic U ——— Hydrostatic Line

CONETEC

AMEC

Job No: 10-090
Date: 09:09:10 16:00
Site: Diavik PKC

Sounding: GCPT10-03
Cone: 272:T375F10U200



Max Depth: 4.800 m / 15.75 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.200 m

File: 090G03.COR
Unit Wt: User Defined Layers and SBT Zones

SBT: Lunne, Robertson and Powell, 1997
Coords: N: 7151985 E: 533439 Elev: 448.8

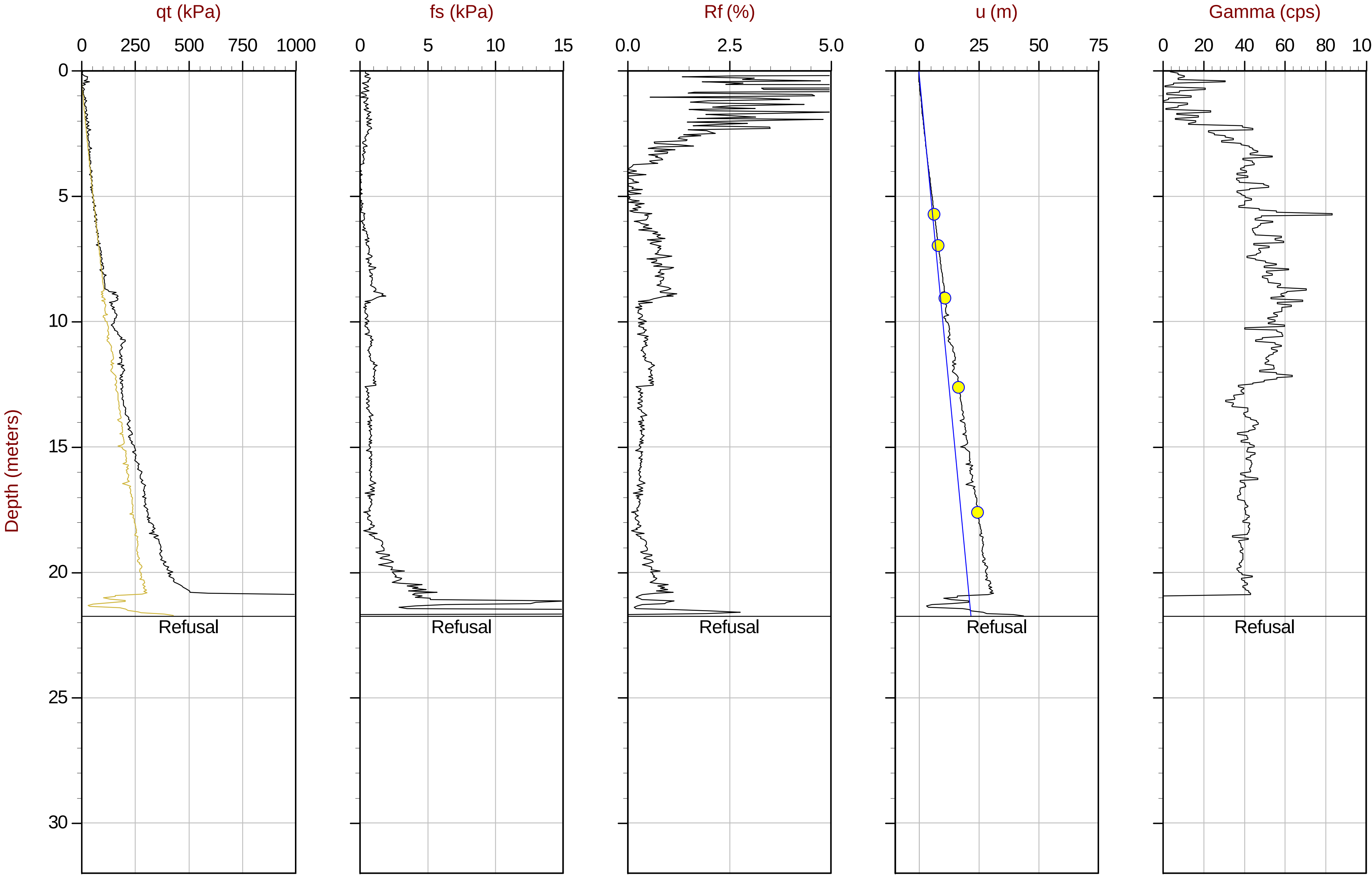
○ U Equilibrium —— Dynamic U —— Hydrostatic Line

CONETEC

AMEC

Job No: 10-090
Date: 09:10:10 09:10
Site: Diavik PKC

Sounding: GCPT10-04
Cone: 272:T375F10U200



Max Depth: 21.750 m / 71.36 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.200 m

File: 090G04.COR
Unit Wt: User Defined Layers and SBT Zones

SBT: Lunne, Robertson and Powell, 1997
Coords: N: 7152113 E: 533195 Elev: 448.8

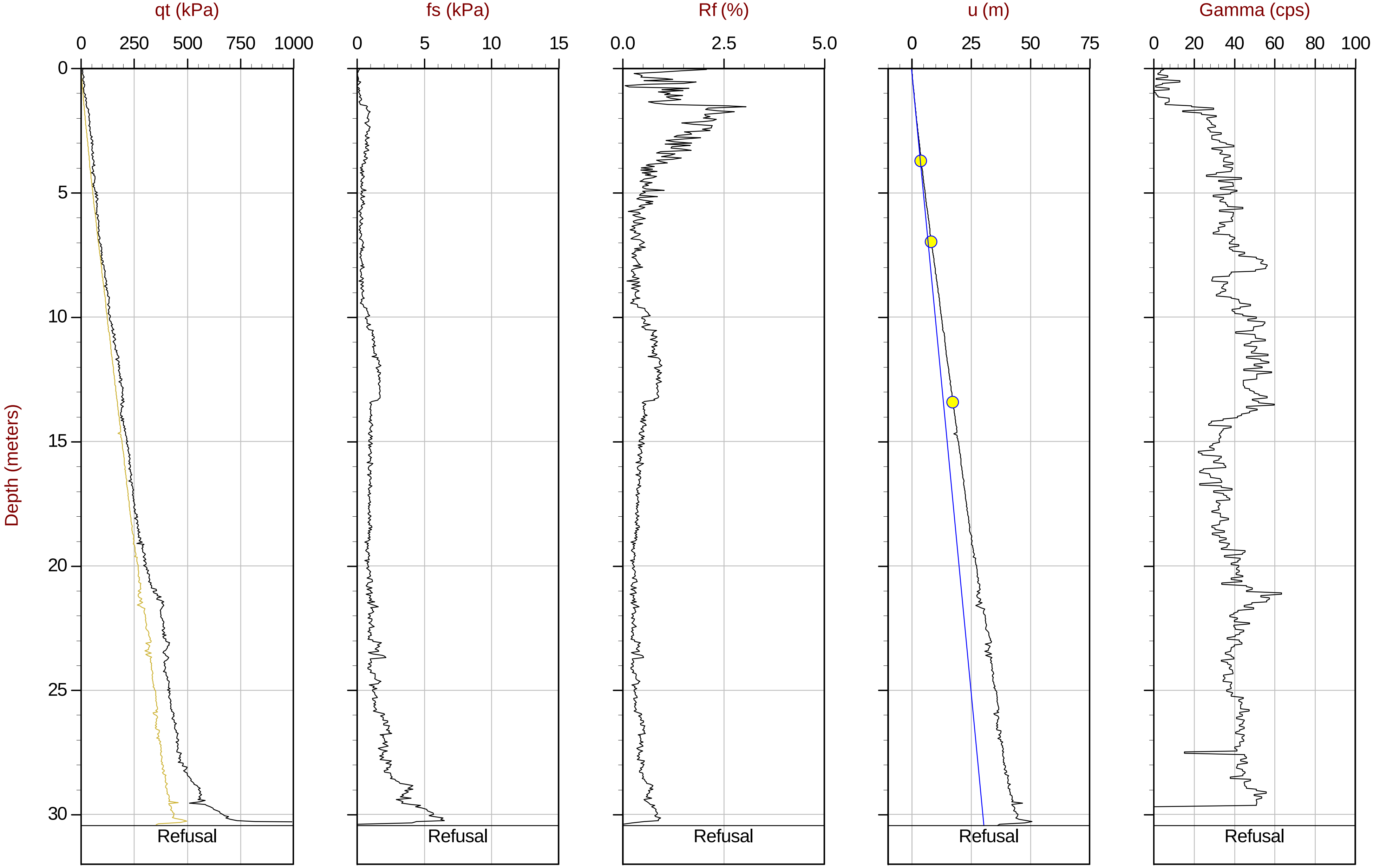
● U Equilibrium —— Dynamic U —— Hydrostatic Line

CONETEC

AMEC

Job No: 10-090
Date: 09:10:10 13:00
Site: Diavik PKC

Sounding: GCPT10-05
Cone: 272:T375F10U200



Max Depth: 30.450 m / 99.90 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.200 m

File: 090G05.COR
Unit Wt: User Defined Layers and SBT Zones

SBT: Lunne, Robertson and Powell, 1997
Coords: N: 7152028 E: 533094 Elev: 448.7

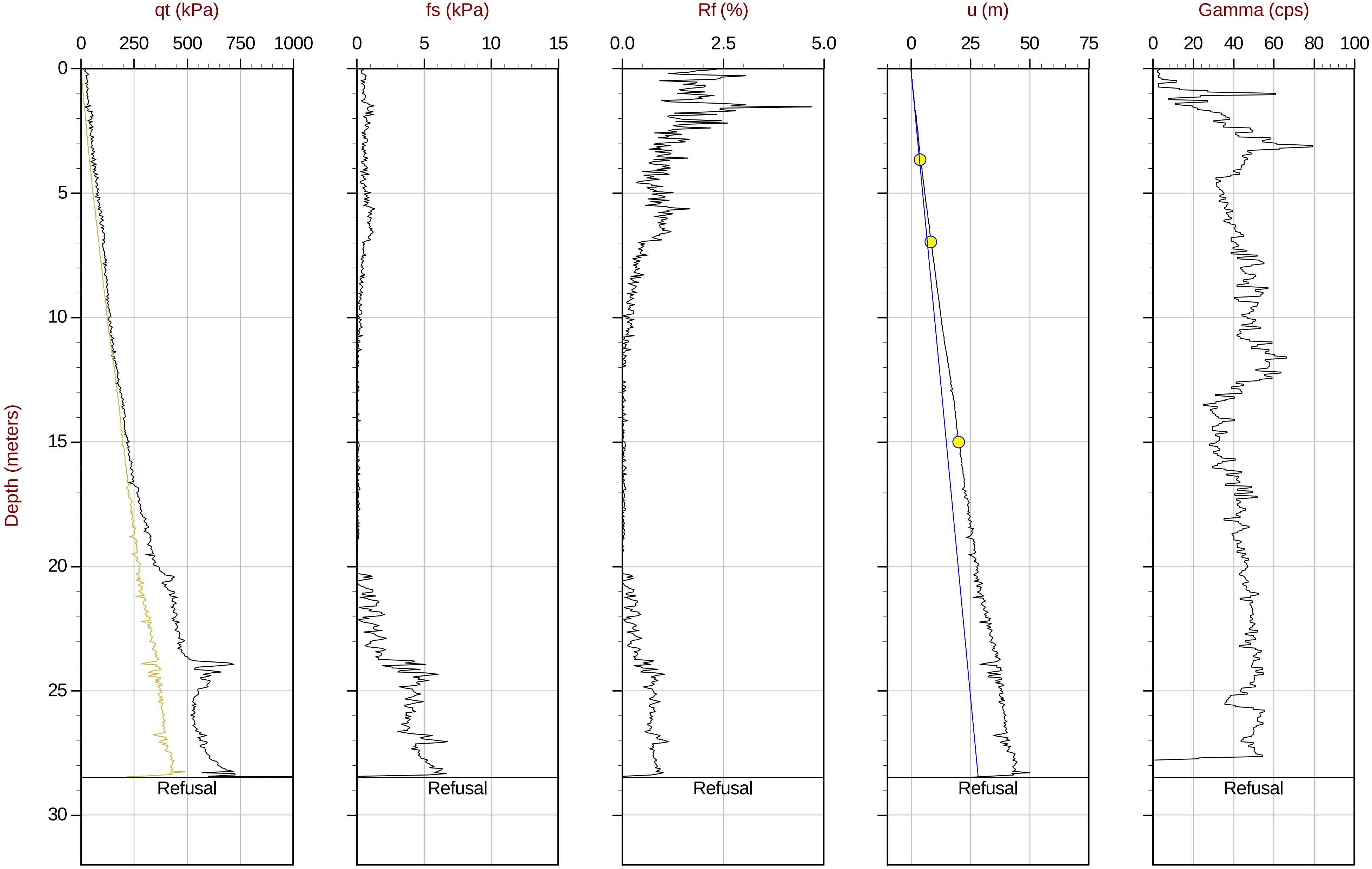
● U Equilibrium
Dynamic U
Hydrostatic Line

CONETEC

AMEC

Job No: 10-090
Date: 09:12:10 15:56
Site: Diavik PKC

Sounding: GCPT10-06
Cone: 272:T375F10U200



Max Depth: 28.500 m / 93.50 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.200 m

File: 090G06.COR
Unit Wt: User Defined Layers and SBT Zones

SBT: Lunne, Robertson and Powell, 1997
Coords: N: 7151945 E: 533179 Elev: 448.8

● U Equilibrium — Dynamic U — Hydrostatic Line

APPENDIX E

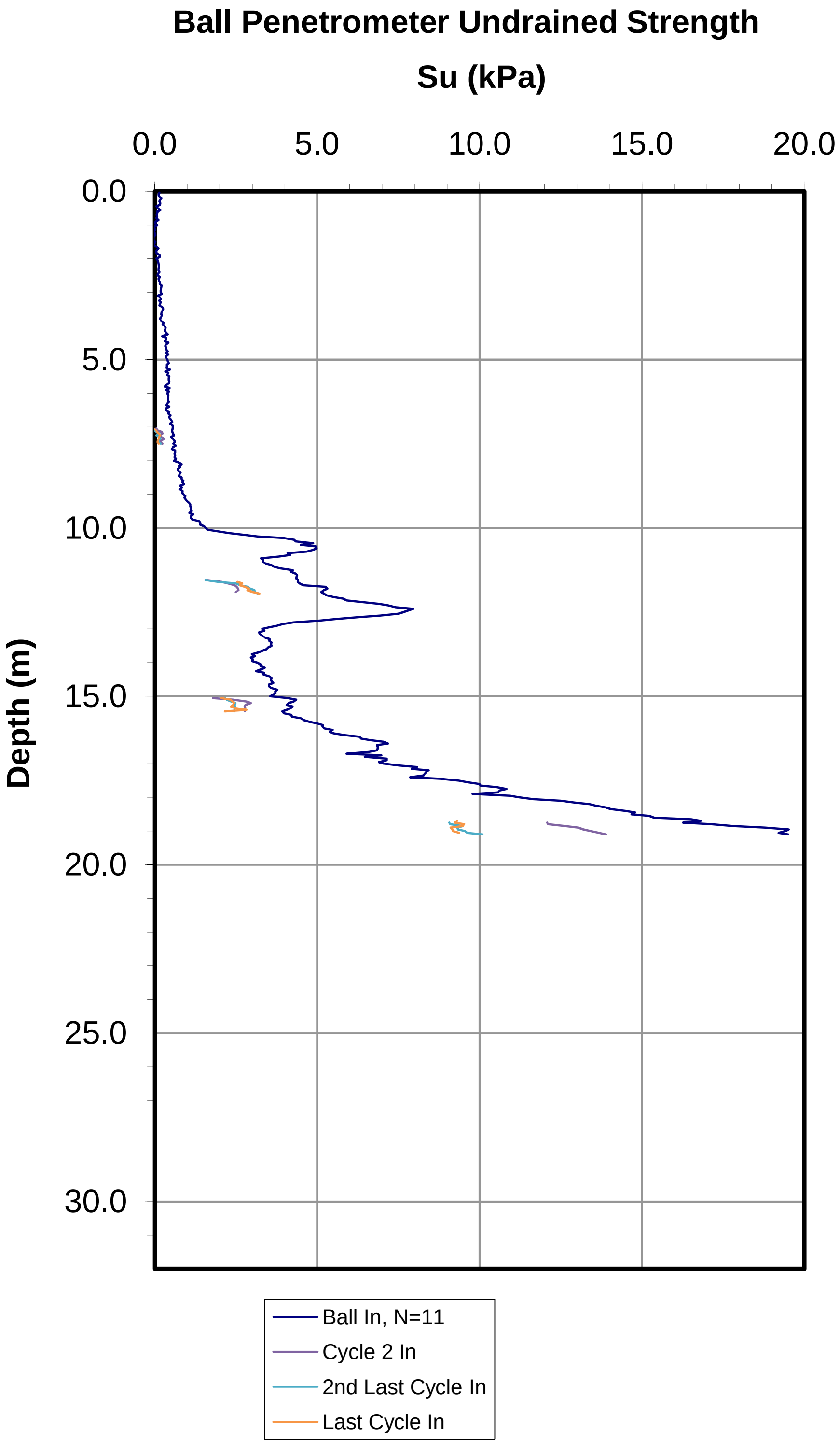
Ball Penetration Test Summary and Su Results

Job No: 10-090
Client: AMEC Earth & Environmental
Project: Diavik
Date: 09/11/10 to 09/12/10

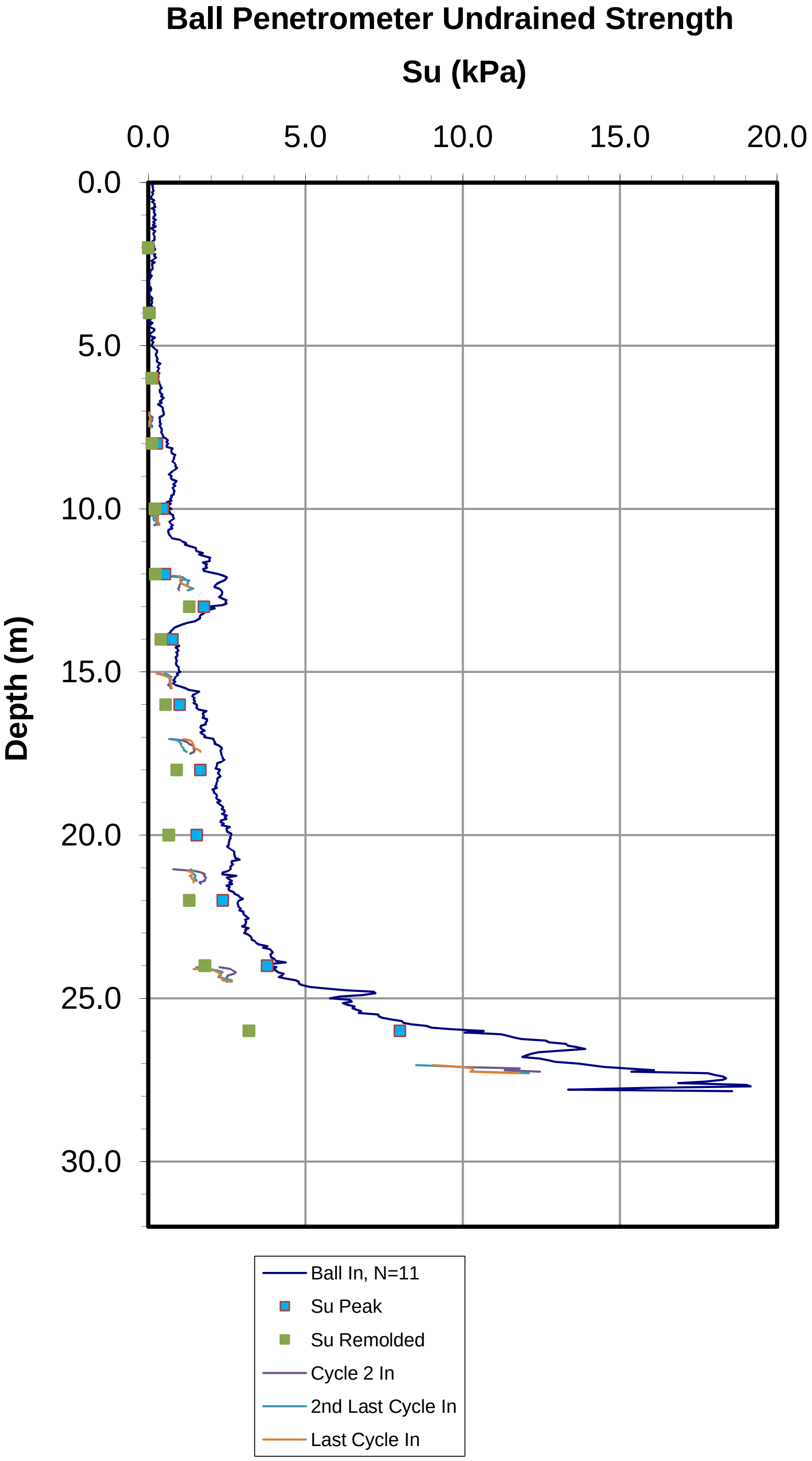
Ball Penetrometer Summary

Sounding	Date	Cone	Assumed Phreatic Surface (m)	Final Depth (m)	Coordinates - UTM 12W		
					Northing (m)	Easting (m)	Elevation (m)
BCPT10-04	09/12/10	267:T500F10U500	0.0	19.10	7152117.6	533195.6	448.72
BCPT10-05	09/11/10	267:T500F10U500	0.0	27.85	7152029.9	533099.7	448.73
BCPT10-06	09/12/10	267:T500F10U500	0.0	23.10	7151946.7	533180.0	448.74

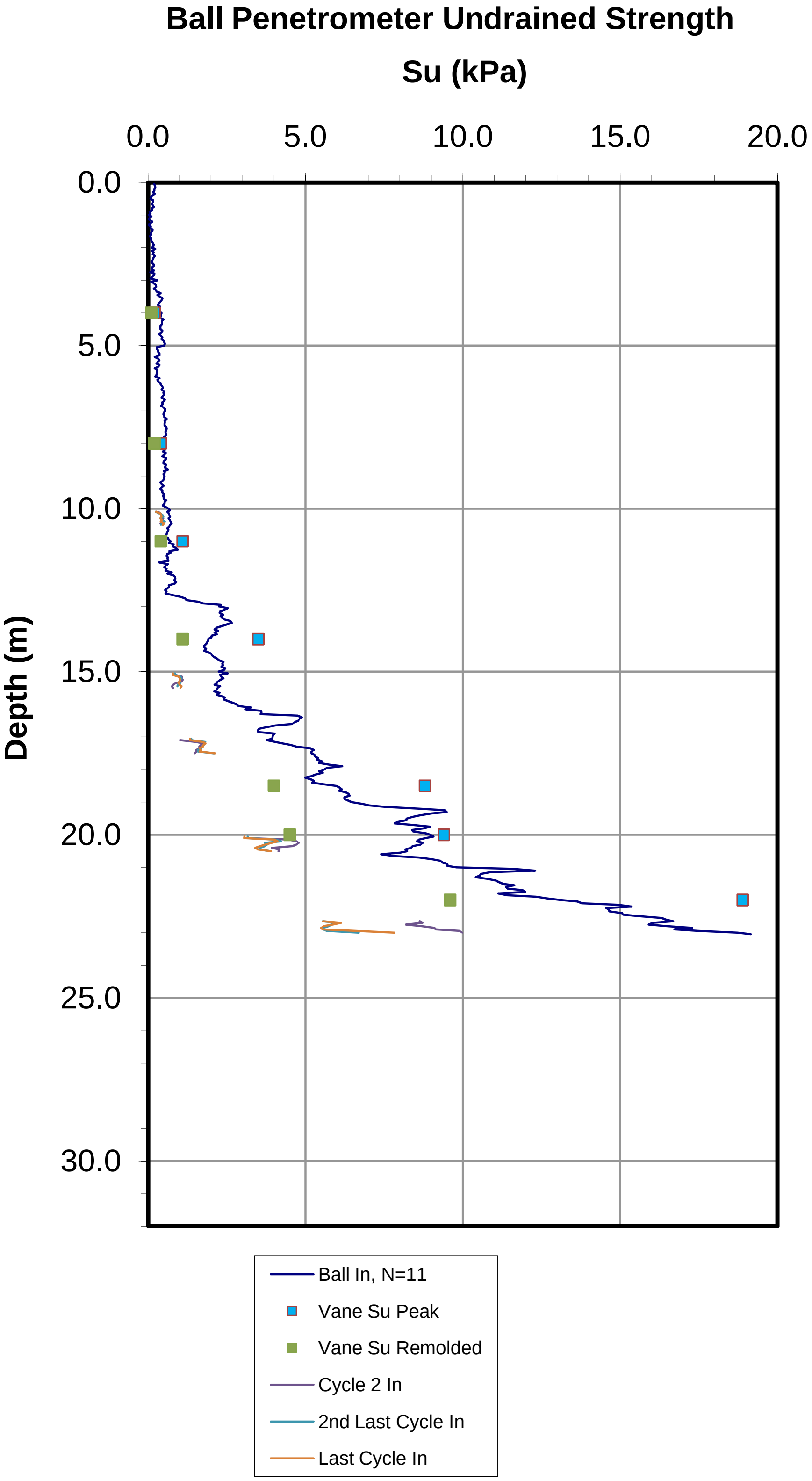
Project: 10-090
Client: AMEC
Project: Diavik
Sounding: BCPT10-04
Sounding Date: Sept 12, 2010



Project: 10-090
Client: AMEC
Project: Diavik
Sounding: BCPT10-05
Sounding Date: Sept 11, 2010



Project: 10-090
Client: AMEC
Project: Diavik
Sounding: BCPT10-06
Sounding Date: Sept 12, 2010



APPENDIX F

Ball Penetration Test Pore Pressure Dissipation Summary and Plots

CONETEC

Job No: 10-090
Client: AMEC Earth & Environmental
Project: Diavik
Date: 09/11/10 to 09/12/10

Ball Penetrometer PPD summary

Sounding	Duration (s)	Test Depth (m)	Equilibrium Pore Pressure U_{eq} (m)*	Calculated Phreatic Surface (m)*
BCPT10-04	300	5.00	5.7	-0.7
BCPT10-04	300	10.00	12.7	-2.7
BCPT10-04	300	15.00	20.5	-5.5
BCPT10-04	1100	18.00	not achieved	-
BCPT10-04	1100	19.10	not achieved	-
BCPT10-05	205	5.00	5.6	-0.6
BCPT10-05	300	10.00	12.6	-2.6
BCPT10-05	300	15.00	20.1	-5.1
BCPT10-05	300	25.00	not achieved	-
BCPT10-05	570	27.85	not achieved	-
BCPT10-06	650	5.00	5.9	-0.9
BCPT10-06	300	10.00	12.9	-2.9
BCPT10-06	650	21.00	not achieved	-
BCPT10-06	1200	23.05	not achieved	-

* Equilibrium pore pressure estimated from dissipation tests.

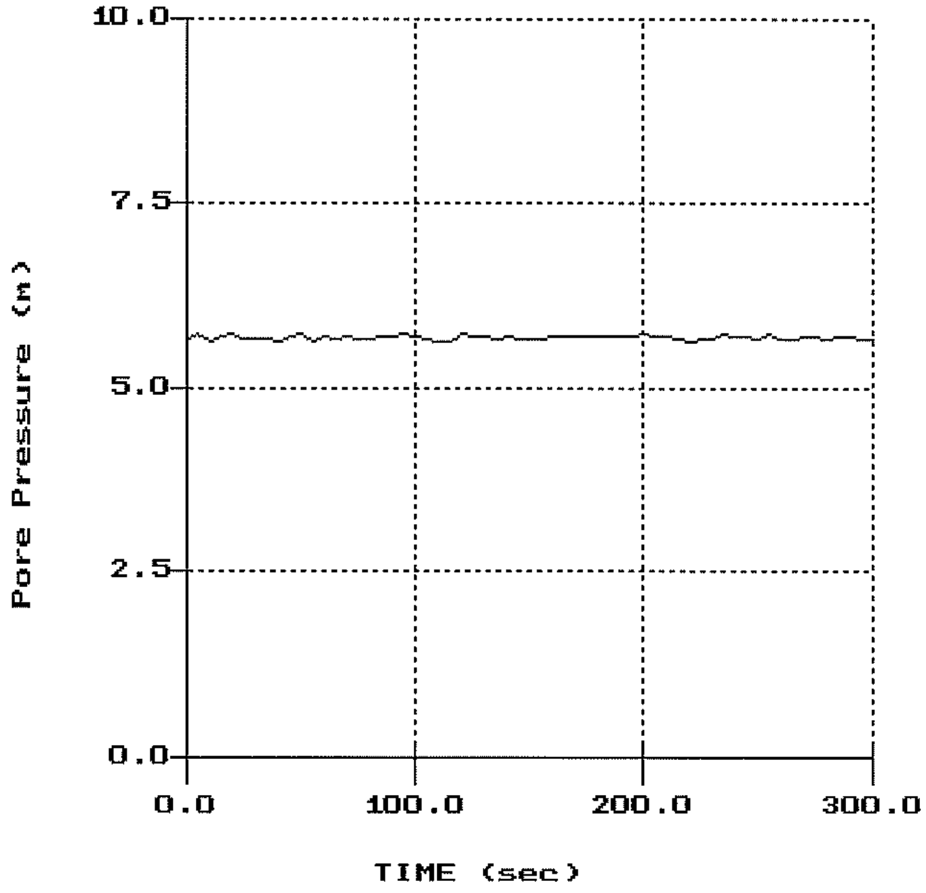
AMEC

Hole:BCPT10-04
Location:PKC

Cone:272:T500F10U500
Date:09:12:10 08:44

File: 090B04.PPF
Depth (m):   5.00
      (ft): 16.40
Duration : 300.0s
U-min: 5.61 110.0s
U-max: 5.74 50.0s

PORE PRESSURE DISSIPATION RECORD



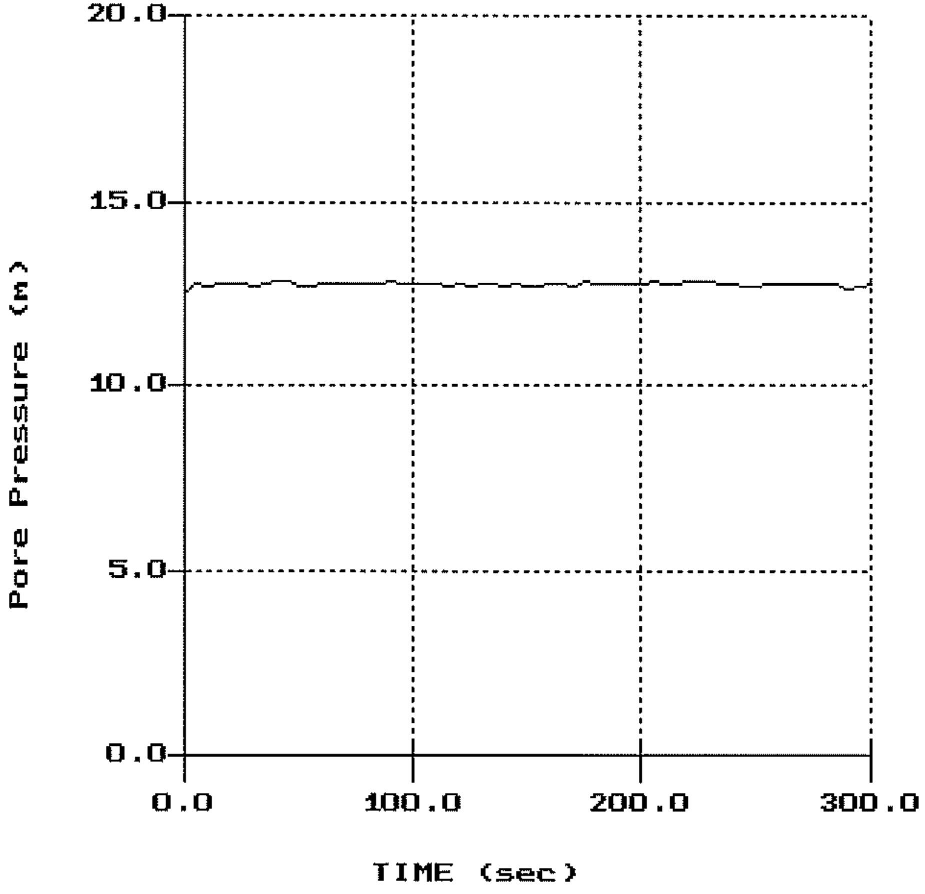
AMEC

Hole:BCPT10-04
Location:PKC

Cone:272:T500F10U500
Date:09:12:10 08:44

File: 090B04.PPF
Depth (m): 10.00
(ft): 32.81
Duration : 300.0s
U-min: 12.50 0.0s
U-max: 12.84 40.0s

PORE PRESSURE DISSIPATION RECORD



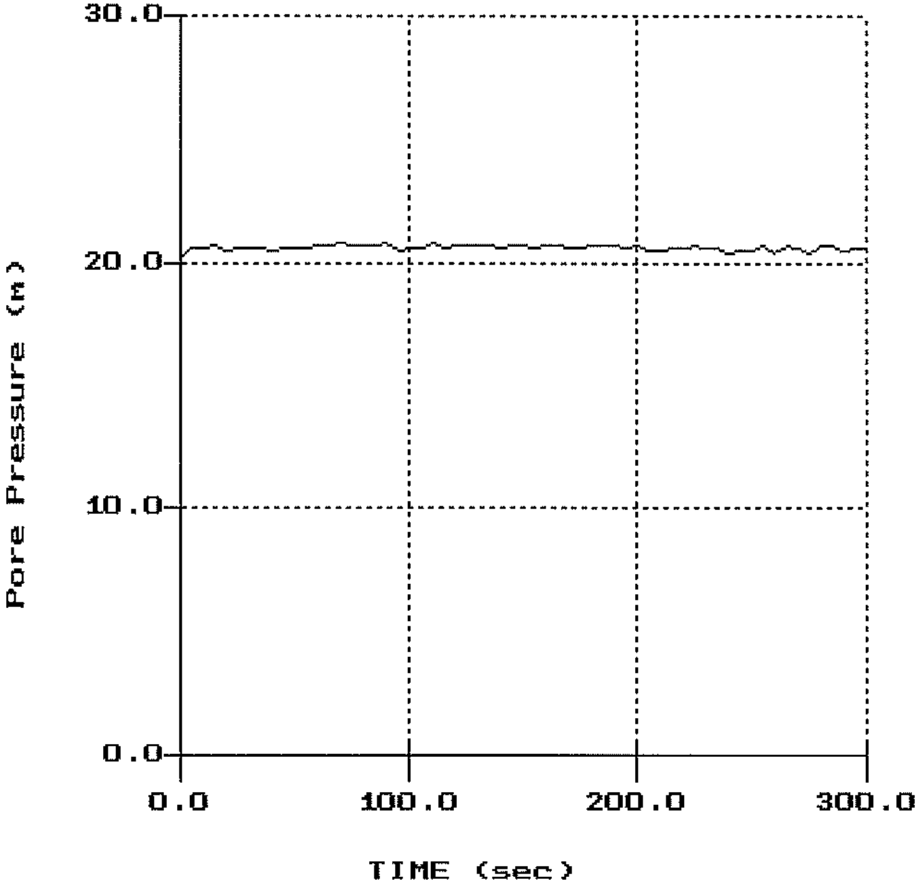
AMEC

Hole:BCPT 10-04
Location:PKC

Cone:272:T500F10U500
Date:09:12:10 08:44

File: 090B04.PPF
Depth (m): 15.00
(ft): 49.21
Duration : 300.0s
U-min: 20.19 0.0s
U-max: 20.83 70.0s

PORE PRESSURE DISSIPATION RECORD



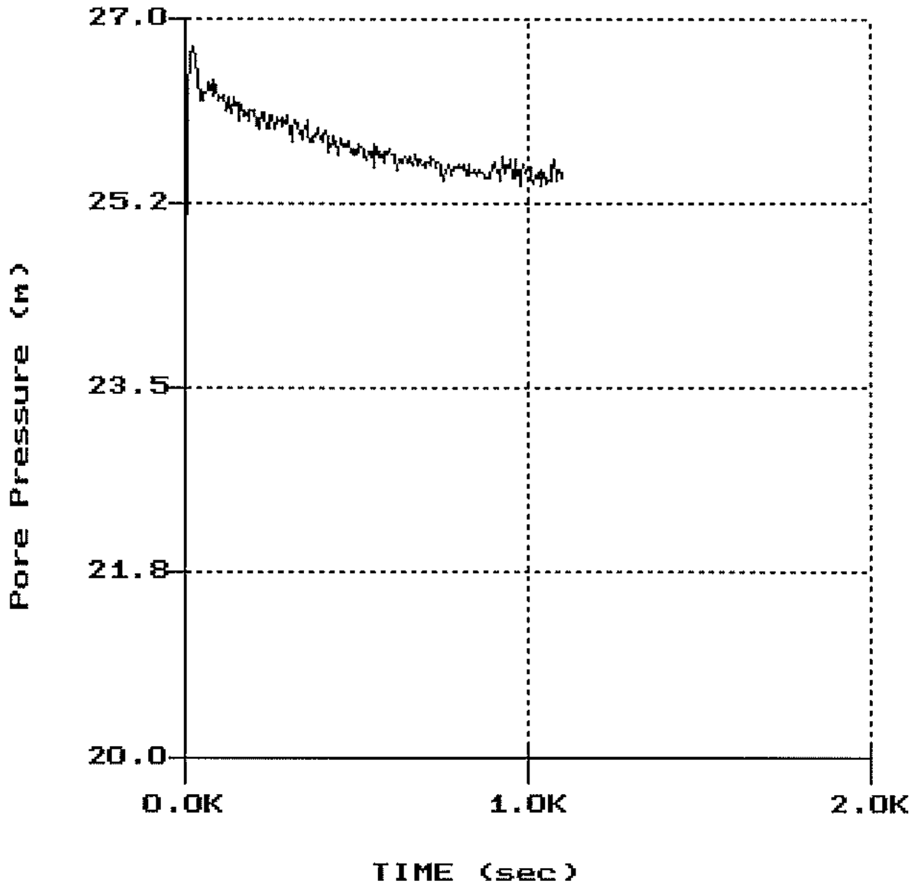
AMEC

Hole:BCPT 10-04
Location:PKC

Cone:272:T500F10U500
Date:09:12:10 08:44

File: 090B04.PPF
Depth (m): 18.00
(ft): 59.06
Duration : 1100.0s
U-min: 24.94 0.0s
U-max: 26.74 20.0s

PORE PRESSURE DISSIPATION RECORD

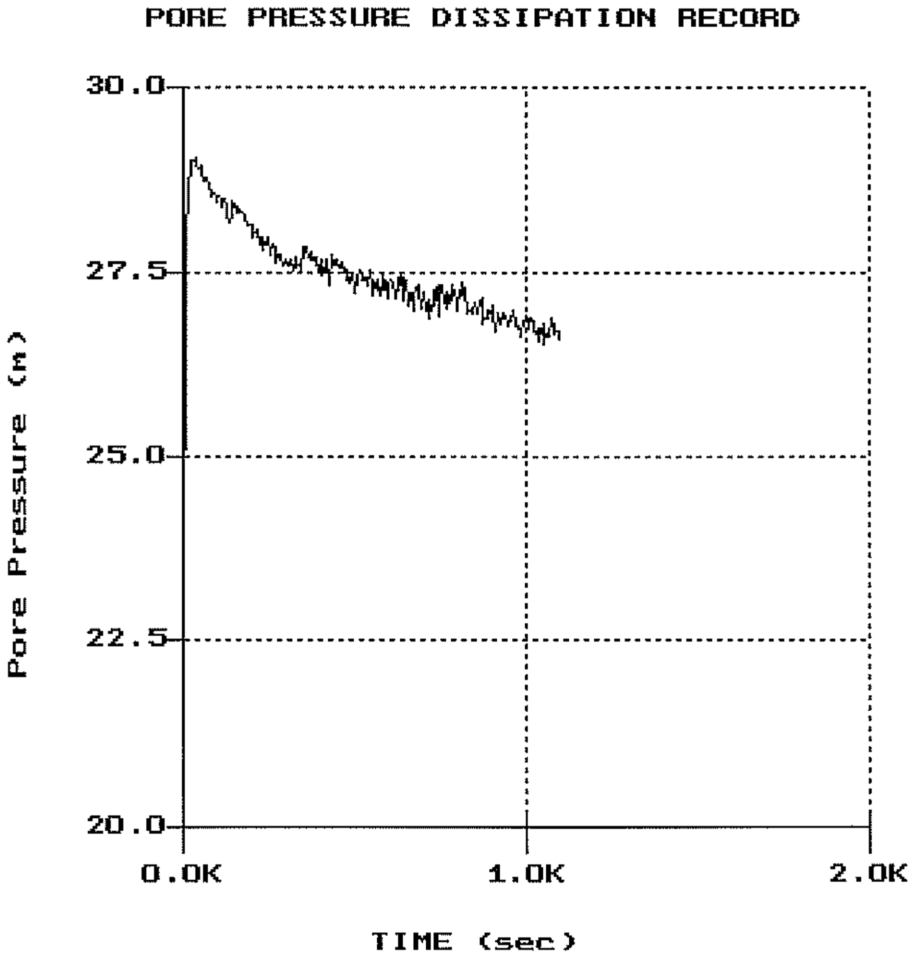


AMEC

Hole:BCPT10-04
Location:PKC

Cone:272:T500F10U500
Date:09:12:10 08:44

File: 090B04.PPF
Depth (m): 19.10
(ft): 62.66
Duration : 1100.0s
U-min: 24.09 0.0s
U-max: 29.06 35.0s



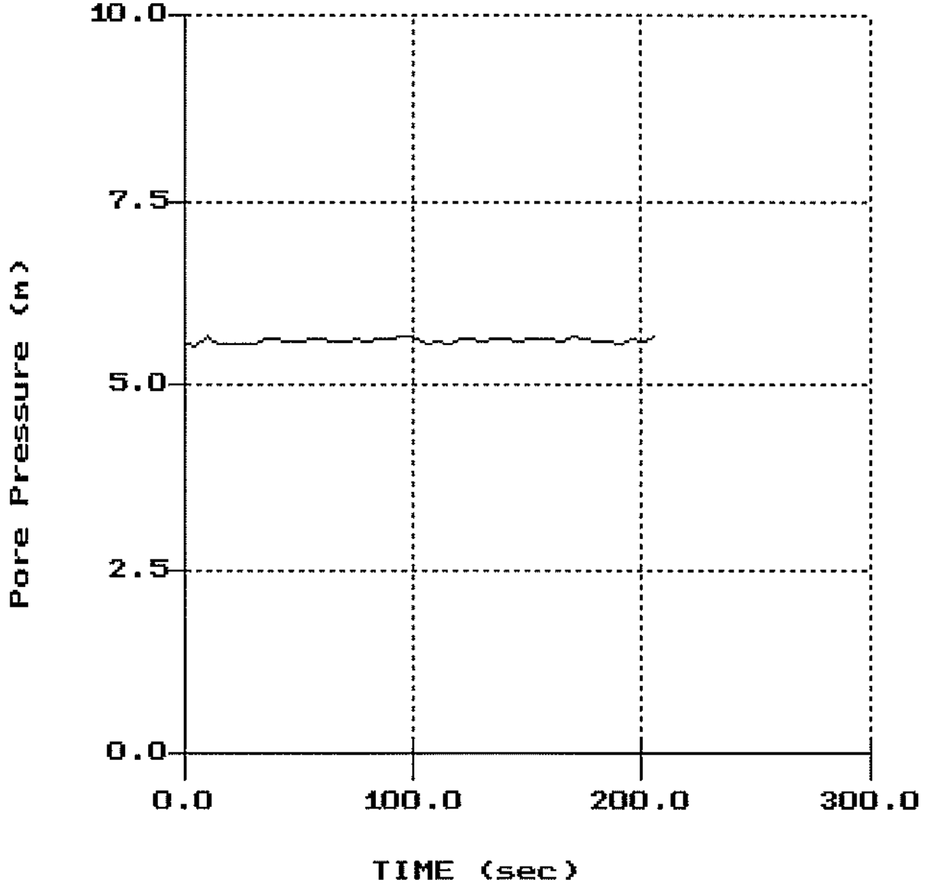
AMEC

Hole:GCPT10-05
Location:PKC

Cone:267:T500F10U500
Date:09:11:10   13:22

File: 090B05.PPF
Depth (m):   5.00
      (ft): 16.40
Duration : 205.0s
U-min: 5.51   5.0s
U-max: 5.67 205.0s

PORE PRESSURE DISSIPATION RECORD

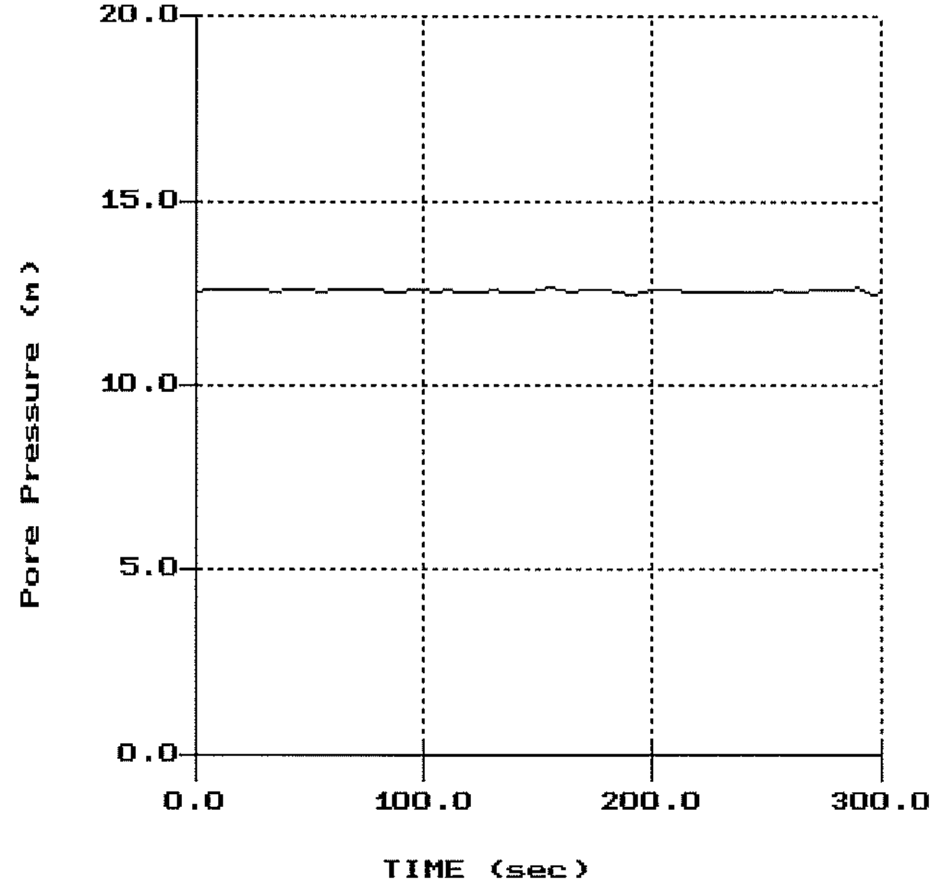


AMEC

Hole:GCPT 10-05
Location:PKC

Cone:267:T 500F 10U500
Date:09:11:10 13:22

PORE PRESSURE DISSIPATION RECORD



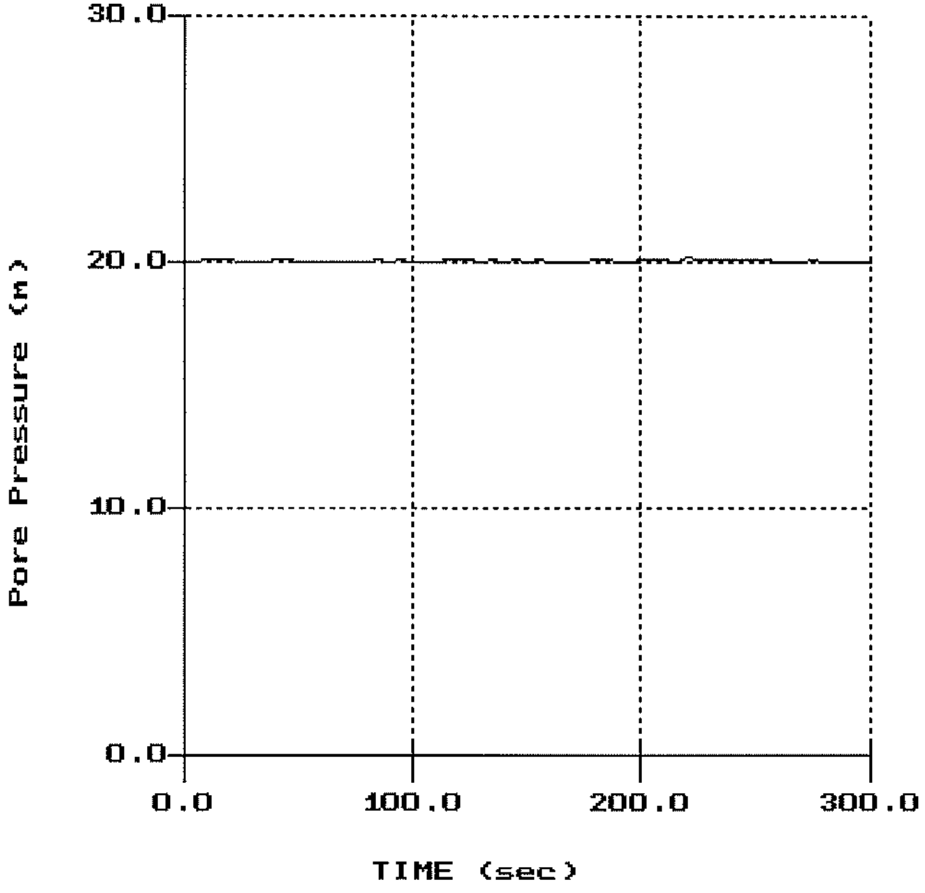
File: 090B05.PPF
Depth (m): 10.00
(ft): 32.81
Duration : 300.0s
U-min: 12.52 295.0s
U-max: 12.70 290.0s

AMEC

Hole:GCPT 10-05
Location:PKC

Cone:267:T500F10U500
Date:09:11:10 13:22

PORE PRESSURE DISSIPATION RECORD



File: 090B05.PPF
Depth (m): 15.00
(ft): 49.21
Duration : 300.0s
U-min: 19.96 190.0s
U-max: 20.16 220.0s

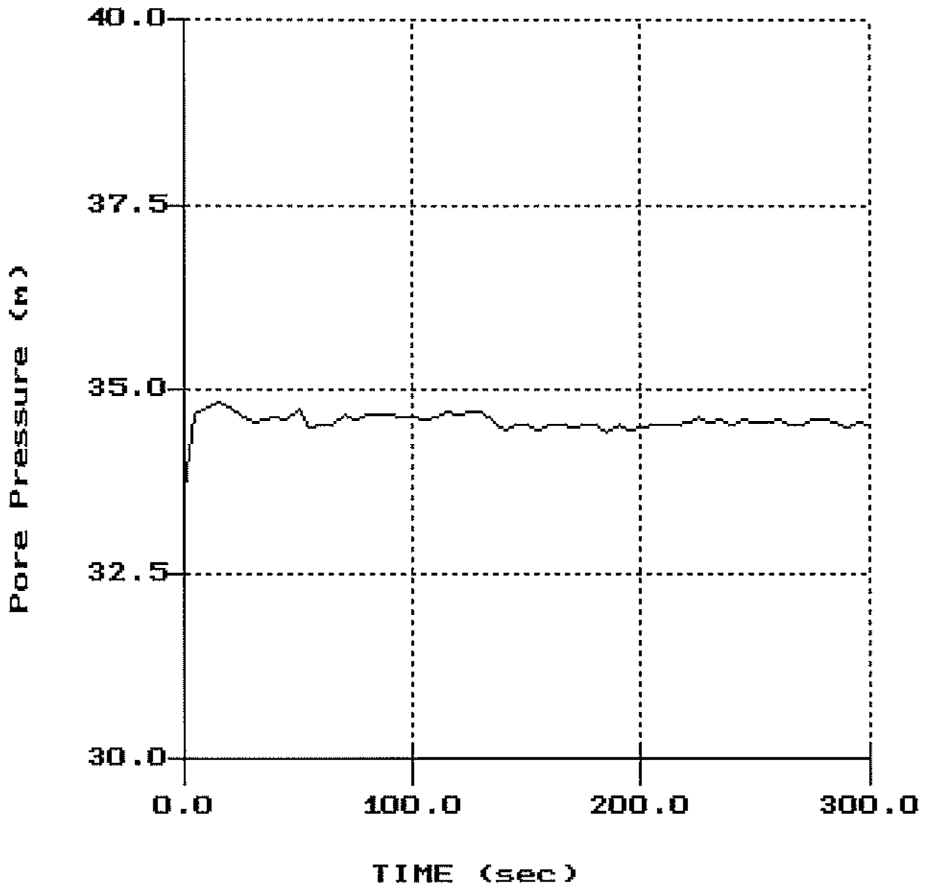
AMEC

Hole:GCPT 10-05
Location:PKC

Cone:267:T500F10U500
Date:09:11:10 13:22

File: 090B05.PPF
Depth (m): 25.00
(ft): 82.02
Duration : 300.0s
U-min: 33.62 0.0s
U-max: 34.84 15.0s

PORE PRESSURE DISSIPATION RECORD



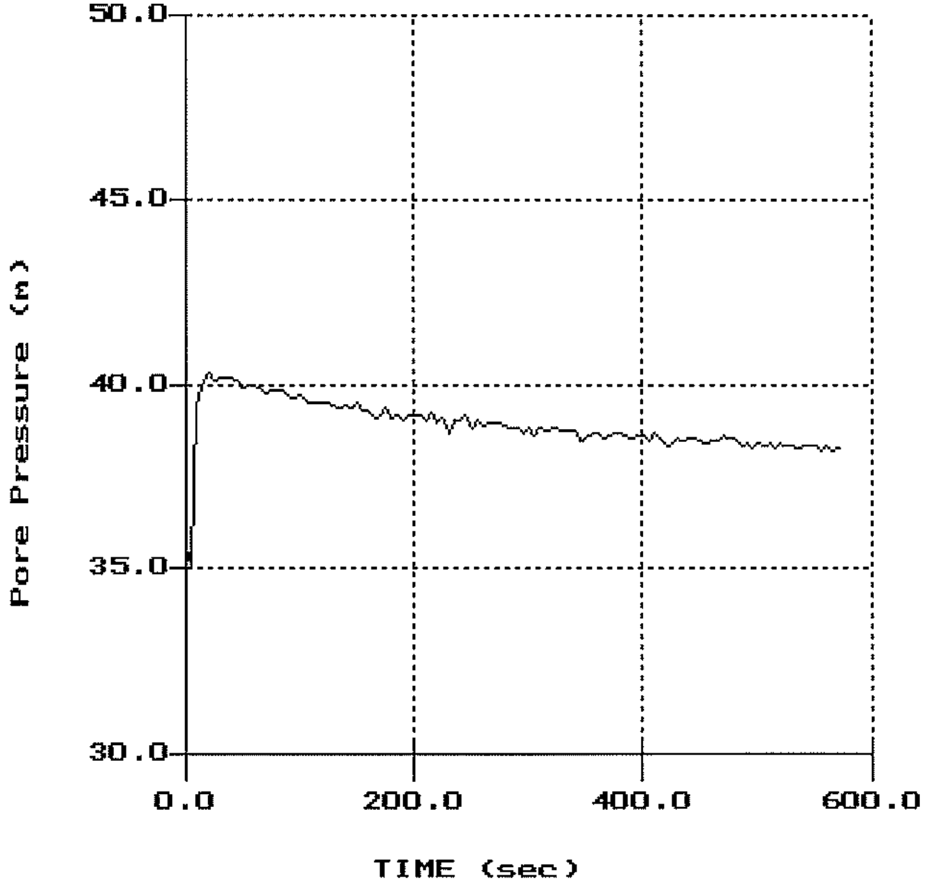
AMEC

Hole:GCPT 10-05
Location:PKC

Cone:267:T500F10U500
Date:09:11:10 13:22

File: 090B05.PPF
Depth (m): 27.85
(ft): 91.37
Duration : 570.0s
U-min: 35.05 5.0s
U-max: 40.38 20.0s

PORE PRESSURE DISSIPATION RECORD



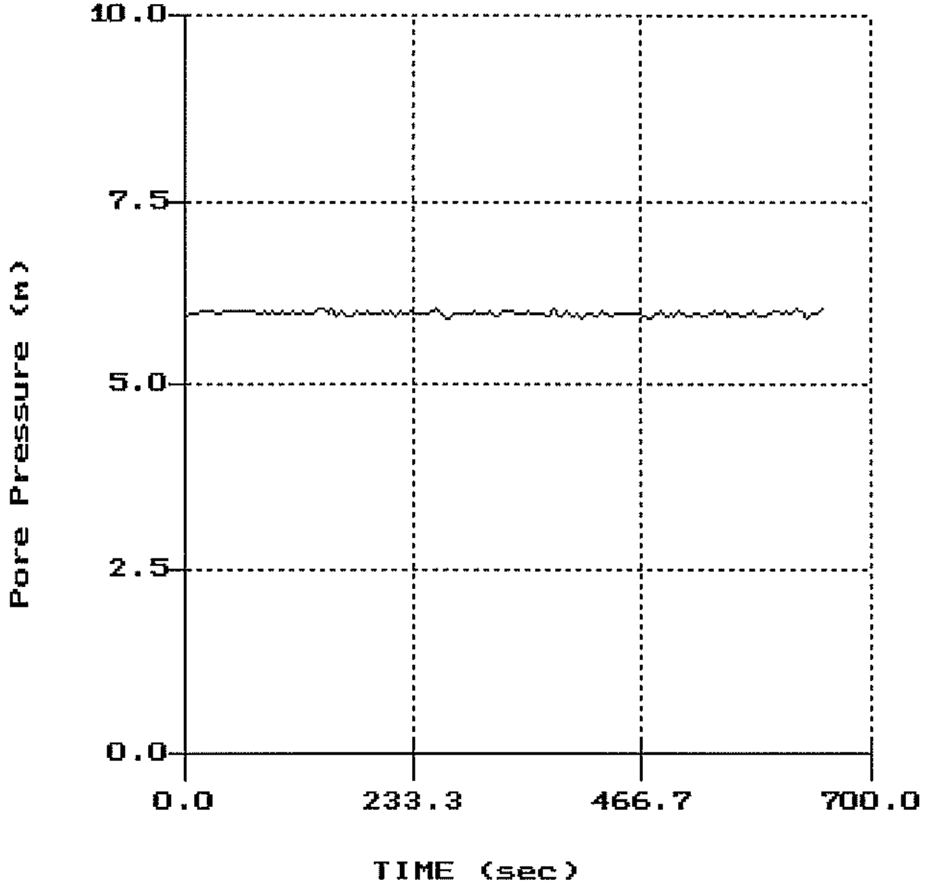
AMEC

Hole:BCPT 10-06
Location:PKC

Cone:272:T500F10U500
Date:09:12:10   12:18

File: 090B06.PPF
Depth (m): 5.00
(ft): 16.40
Duration : 650.0s
U-min: 5.90 475.0s
U-max: 6.03 625.0s

PORE PRESSURE DISSIPATION RECORD



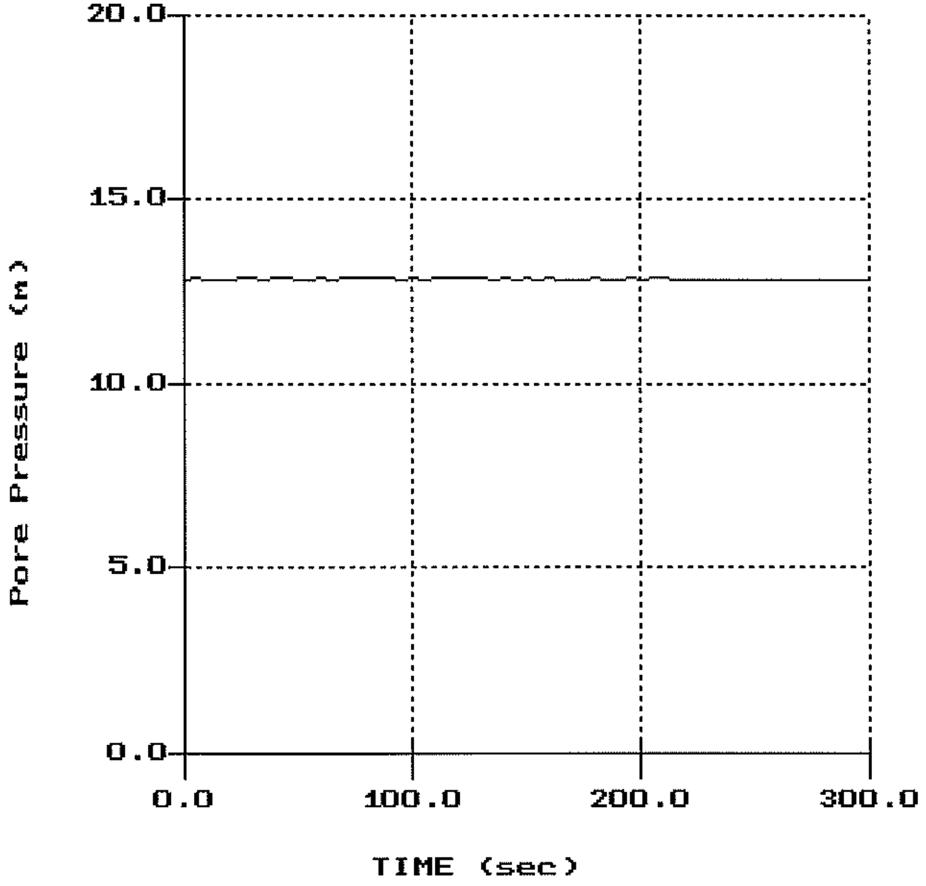
AMEC

Hole:BCPT10-06
Location:PKC

Cone:272:T500F10U500
Date:09:12:10   12:18

File: 090B06.PPF
Depth (m): 10.00
(ft): 32.81
Duration : 300.0s
U-min: 12.81 275.0s
U-max: 12.93 205.0s

PORE PRESSURE DISSIPATION RECORD

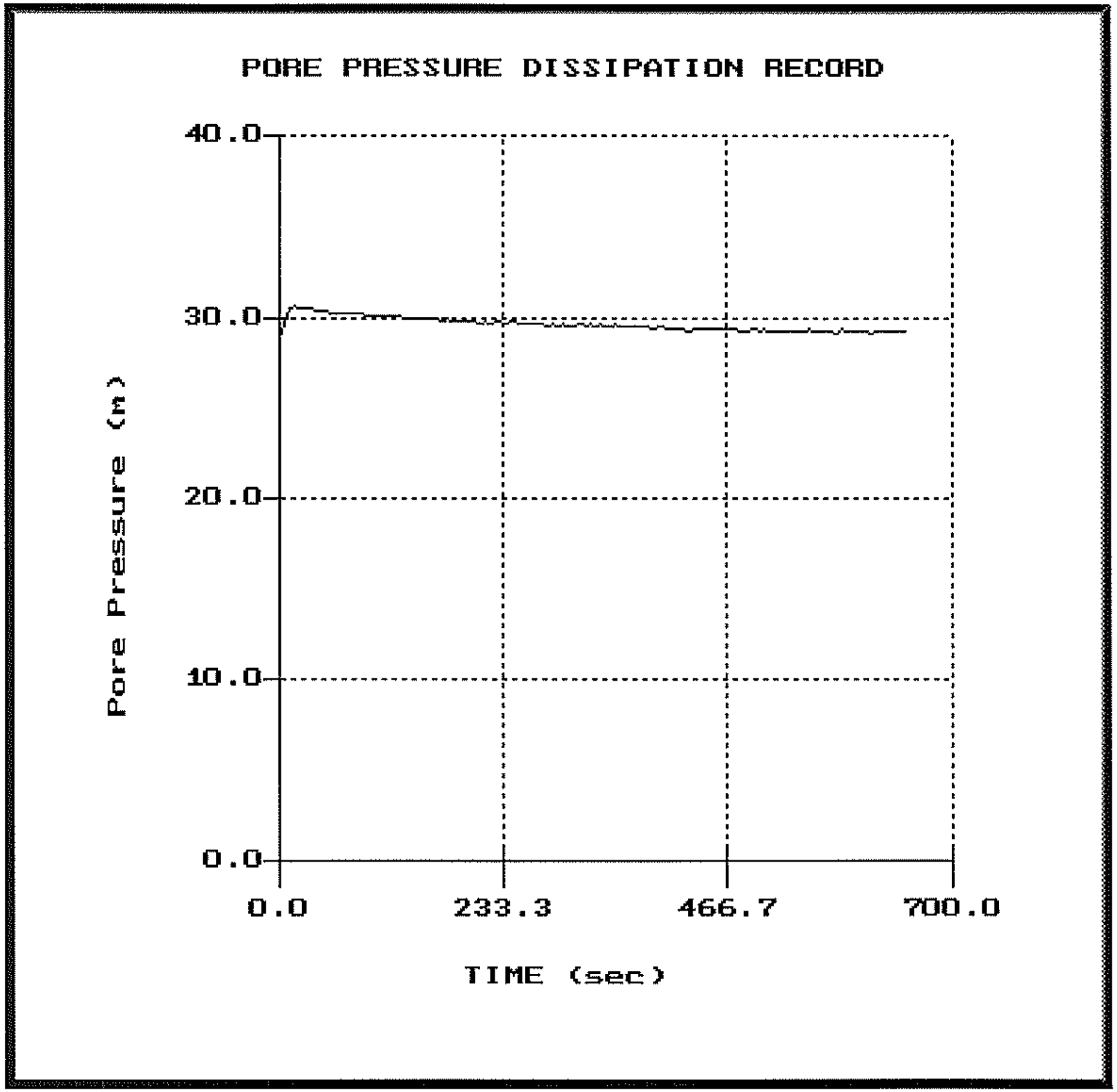


AMEC

Hole:BCPT 10-06
Location:PKC

Cone:272:T 500F 10U500
Date:09:12:10   12:18

File: 090B06.PPF
Depth (m): 21.00
(ft): 68.90
Duration : 650.0s
U-min: 28.95   0.0s
U-max: 30.66   15.0s



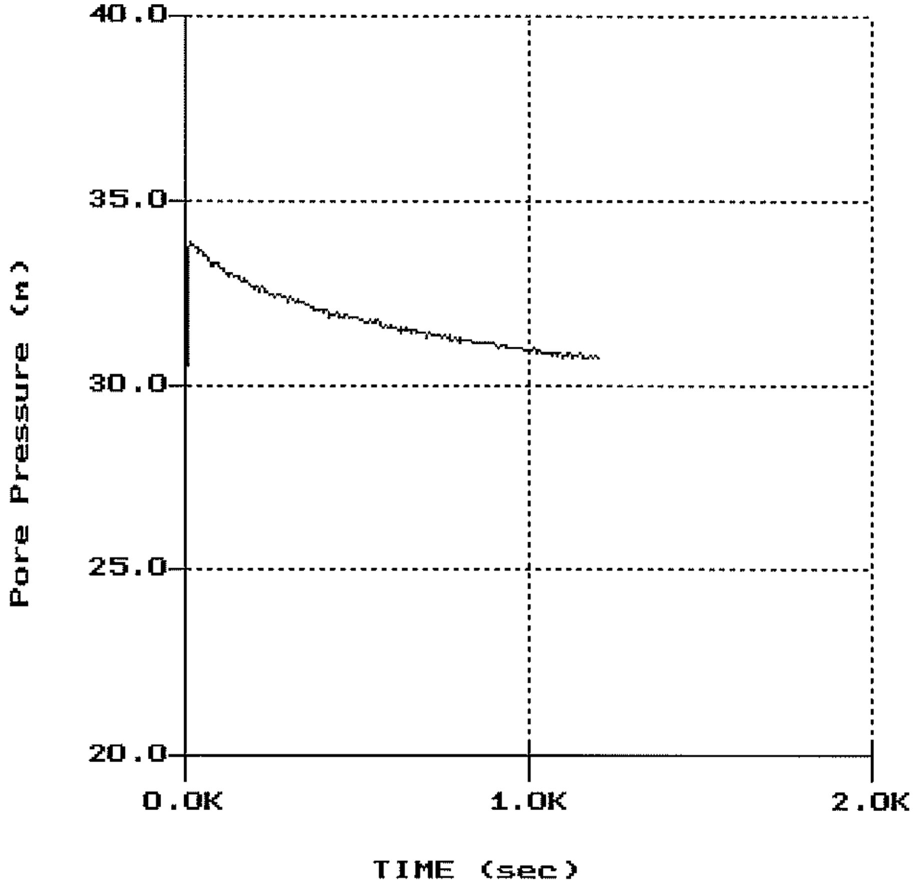
AMEC

Hole:BCPT10-06
Location:PKC

Cone:272:T500F10U500
Date:09:12:10 12:18

File: 090B06.PPF
Depth (m): 23.05
(ft): 75.62
Duration : 1200.0s
U-min: 28.97 0.0s
U-max: 33.91 15.0s

PORE PRESSURE DISSIPATION RECORD



APPENDIX G

Vane Shear Test Summary and Plots

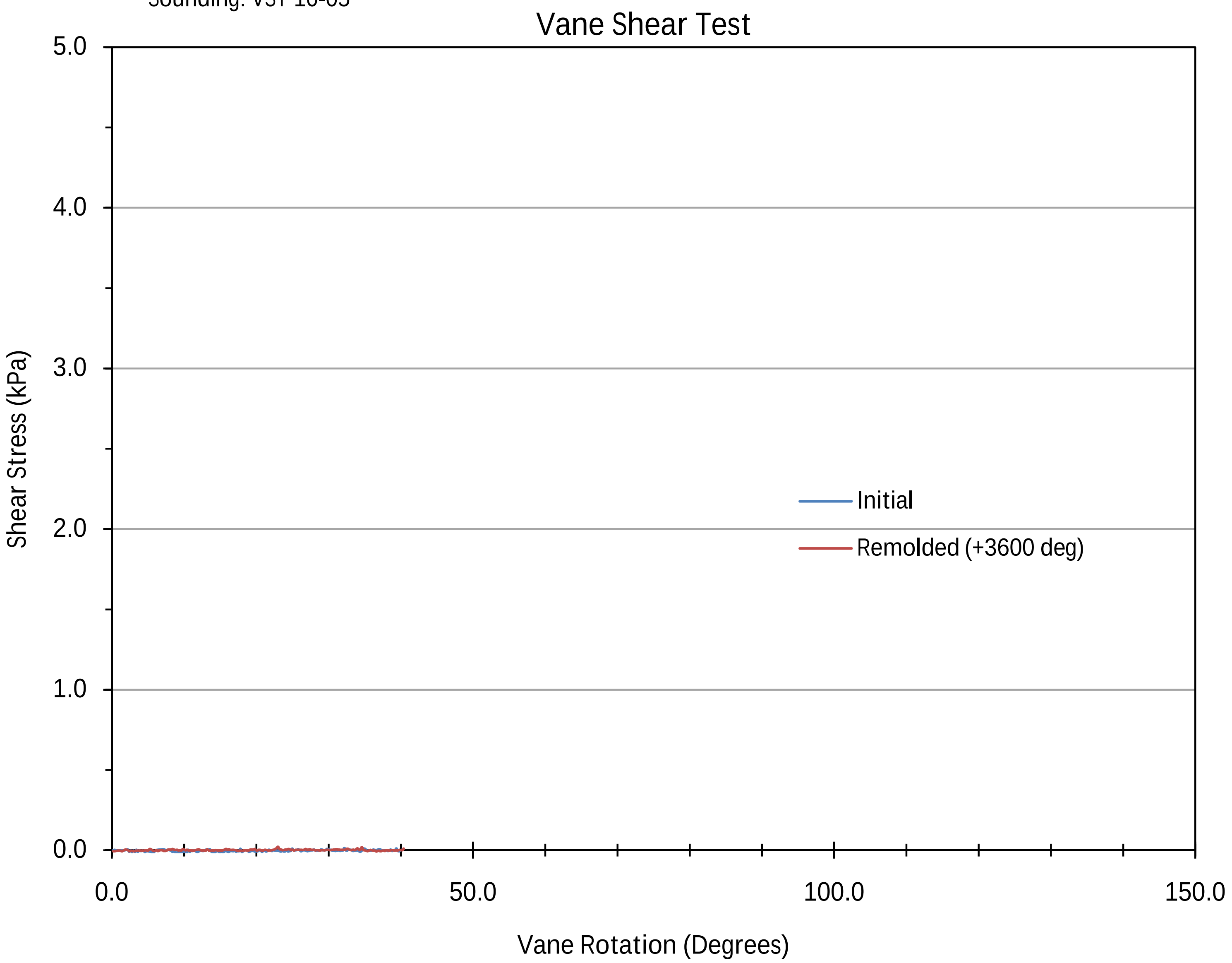
Project No: 10-090
Client: AMEC Earth & Environmental
Site: Diavik
Date: 13-Sep-10

VANE SHEAR TEST SUMMARY

Sounding	Location	Test Depth (m)	Vane Dimensions	Su (kPa) Peak	Su (kPa) Remolded	Coordinates - UTM 12W	
						Northing (m)	Easting (m)
VST 10-05	PKC	2.00	150mm x 300mm	0.0	0.0	7152035	533101
VST 10-05	PKC	4.00	150mm x 300mm	0.0	0.0	7152035	533101
VST 10-05	PKC	6.00	150mm x 300mm	0.2	0.1	7152035	533101
VST 10-05	PKC	8.00	150mm x 300mm	0.3	0.1	7152035	533101
VST 10-05	PKC	10.00	150mm x 300mm	0.5	0.2	7152035	533101
VST 10-05	PKC	12.00	150mm x 300mm	0.5	0.2	7152035	533101
VST 10-05	PKC	13.00	150mm x 300mm	1.8	1.4	7152035	533101
VST 10-05	PKC	14.00	150mm x 300mm	0.9	0.4	7152035	533101
VST 10-05	PKC	16.00	150mm x 300mm	1.0	0.6	7152035	533101
VST 10-05	PKC	18.00	150mm x 300mm	1.7	0.9	7152035	533101
VST 10-05	PKC	20.00	150mm x 300mm	1.6	0.8	7152035	533101
VST 10-05	PKC	22.00	150mm x 300mm	2.5	1.4	7152035	533101
VST 10-05	PKC	24.00	150mm x 300mm	3.8	1.9	7152035	533101
VST 10-05	PKC	26.00	150mm x 300mm	8.0	3.3	7152035	533101
VST 10-06	PKC	4.00	150mm x 300mm	0.2	0.1	7151939	533183
VST 10-06	PKC	8.00	150mm x 300mm	0.4	0.2	7151939	533183
VST 10-06	PKC	11.00	150mm x 300mm	1.1	0.4	7151939	533183
VST 10-06	PKC	14.00	150mm x 300mm	3.5	1.1	7151939	533183
VST 10-06	PKC	18.50	150mm x 300mm	8.8	4.0	7151939	533183
VST 10-06	PKC	20.00	75mm x 150mm	9.4	4.5	7151939	533183
VST 10-06	PKC	22.00	75mm x 150mm	18.9	9.6	7151939	533183

Job Number: 10-090
Client: AMEC
Project: Diavik
Sounding: VST 10-05

Test Depth (m): 2.00
Vane Dimensions: 150mm x 300mm
Sounding Date: September 13, 2010

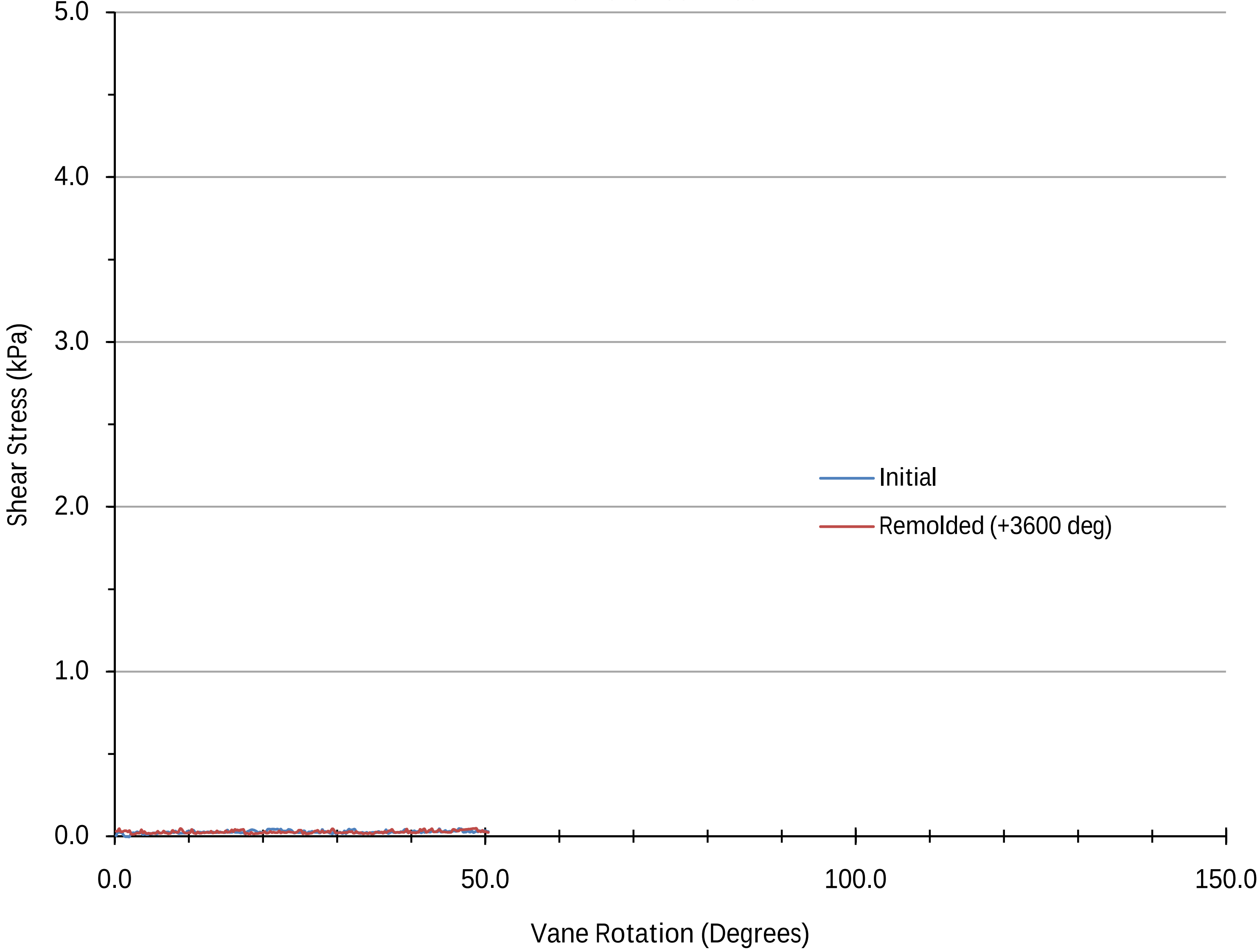


CONETEC

Job Number: 10-090
Client: AMEC
Project: Diavik
Sounding: VST 10-05

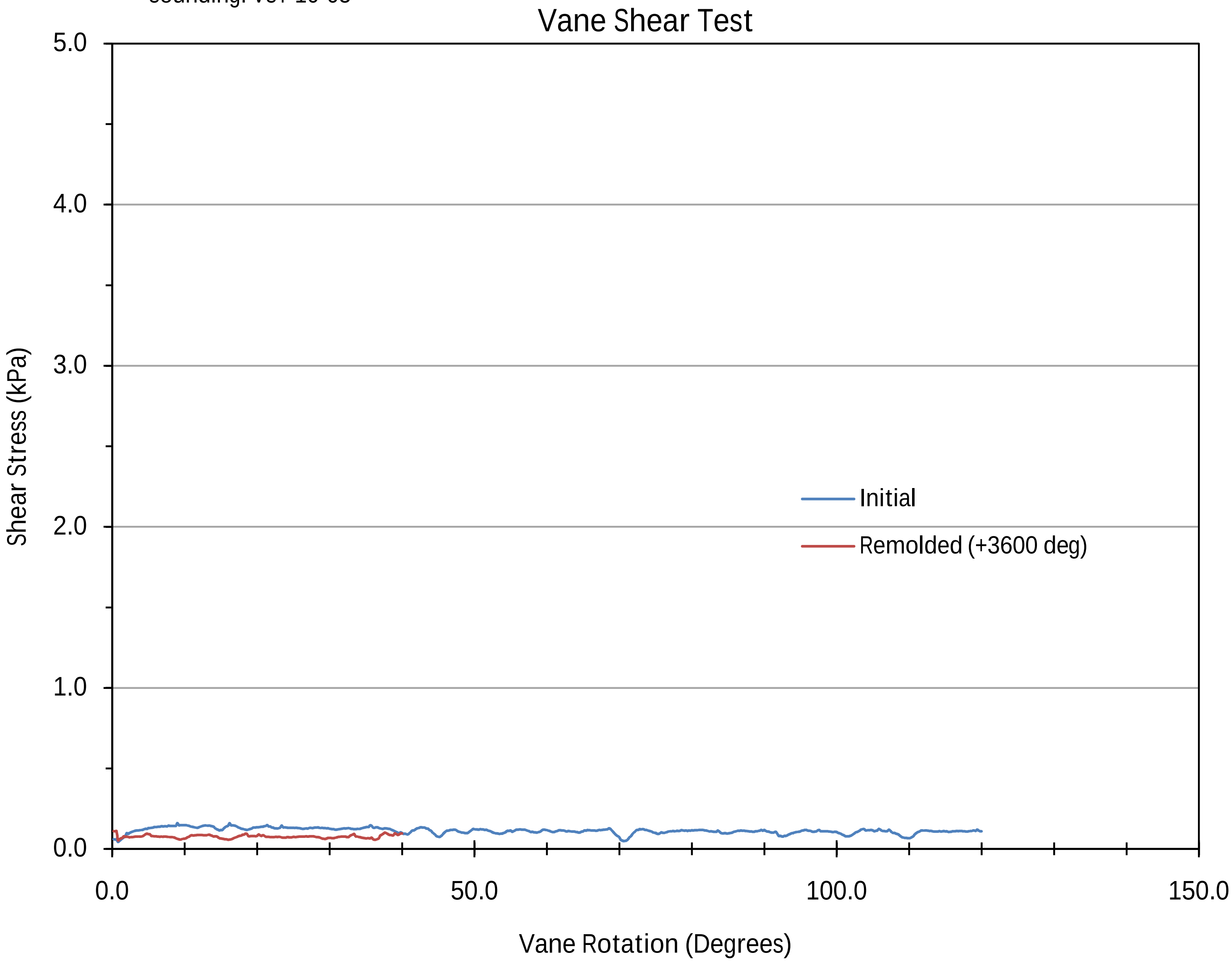
Test Depth (m): 4.00
Vane Dimensions: 150mm x 300mm
Sounding Date: September 13, 2010

Vane Shear Test



Job Number: 10-090
Client: AMEC
Project: Diavik
Sounding: VST 10-05

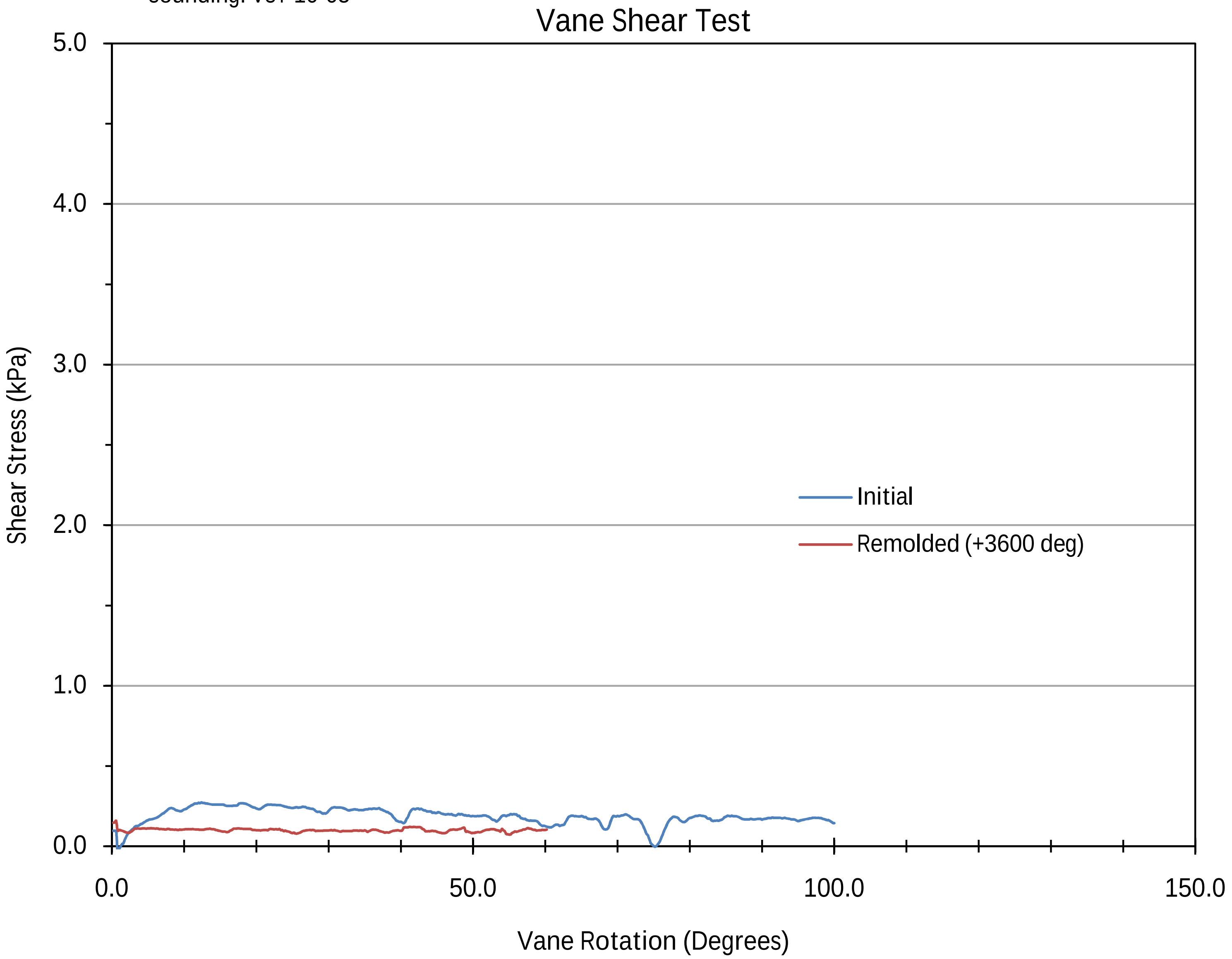
Test Depth (m): 6.00
Vane Dimensions: 150mm x 300mm
Sounding Date: September 13, 2010



CONETEC

Job Number: 10-090
Client: AMEC
Project: Diavik
Sounding: VST 10-05

Test Depth (m): 8.00
Vane Dimensions: 150mm x 300mm
Sounding Date: September 13, 2010

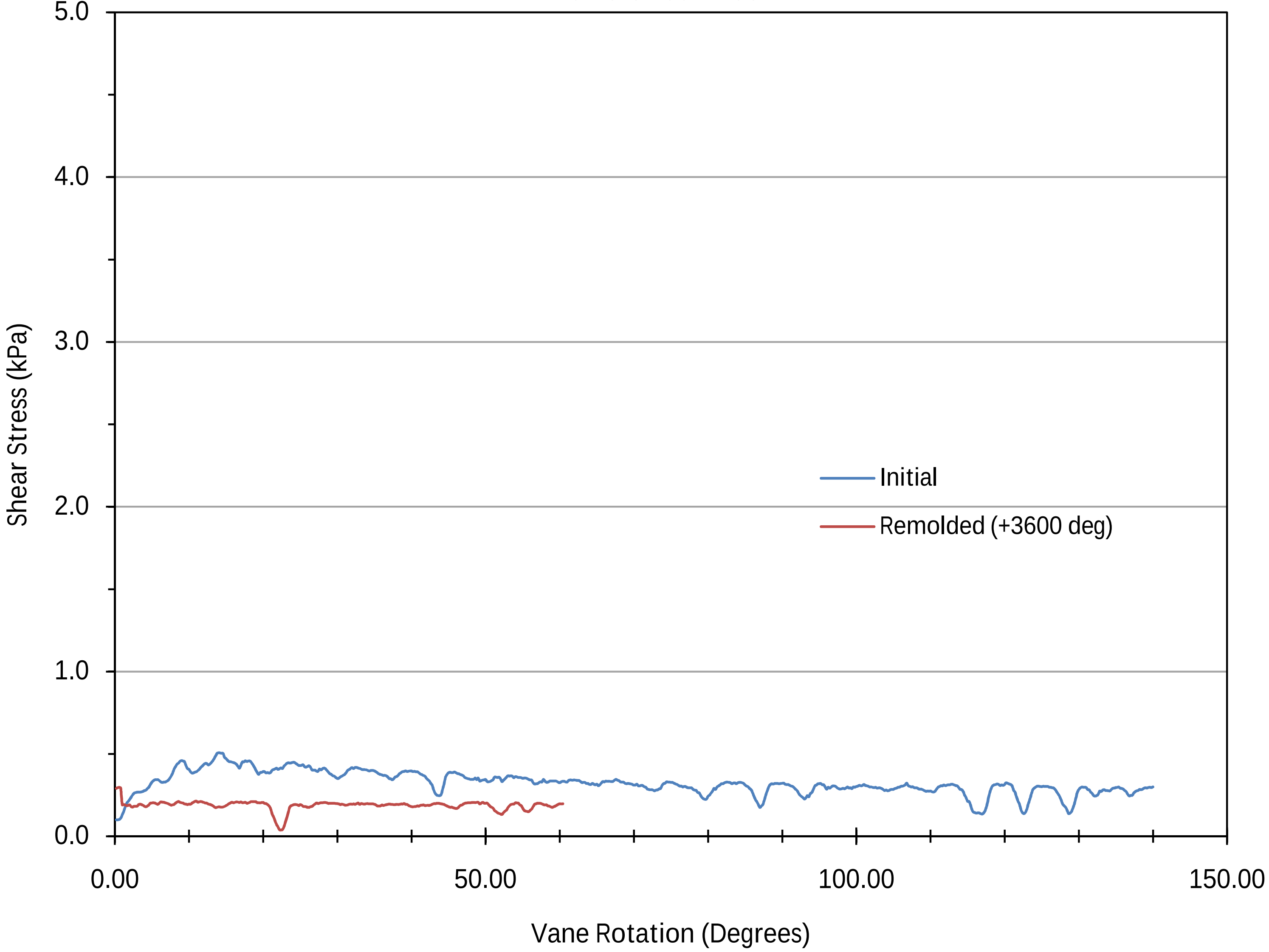


CONETEC

Job Number: 10-090
Client: AMEC
Project: Diavik
Sounding: VST 10-05

Test Depth (m): 10.00
Vane Dimensions: 150mm x 300mm
Sounding Date: September 13, 2010

Vane Shear Test

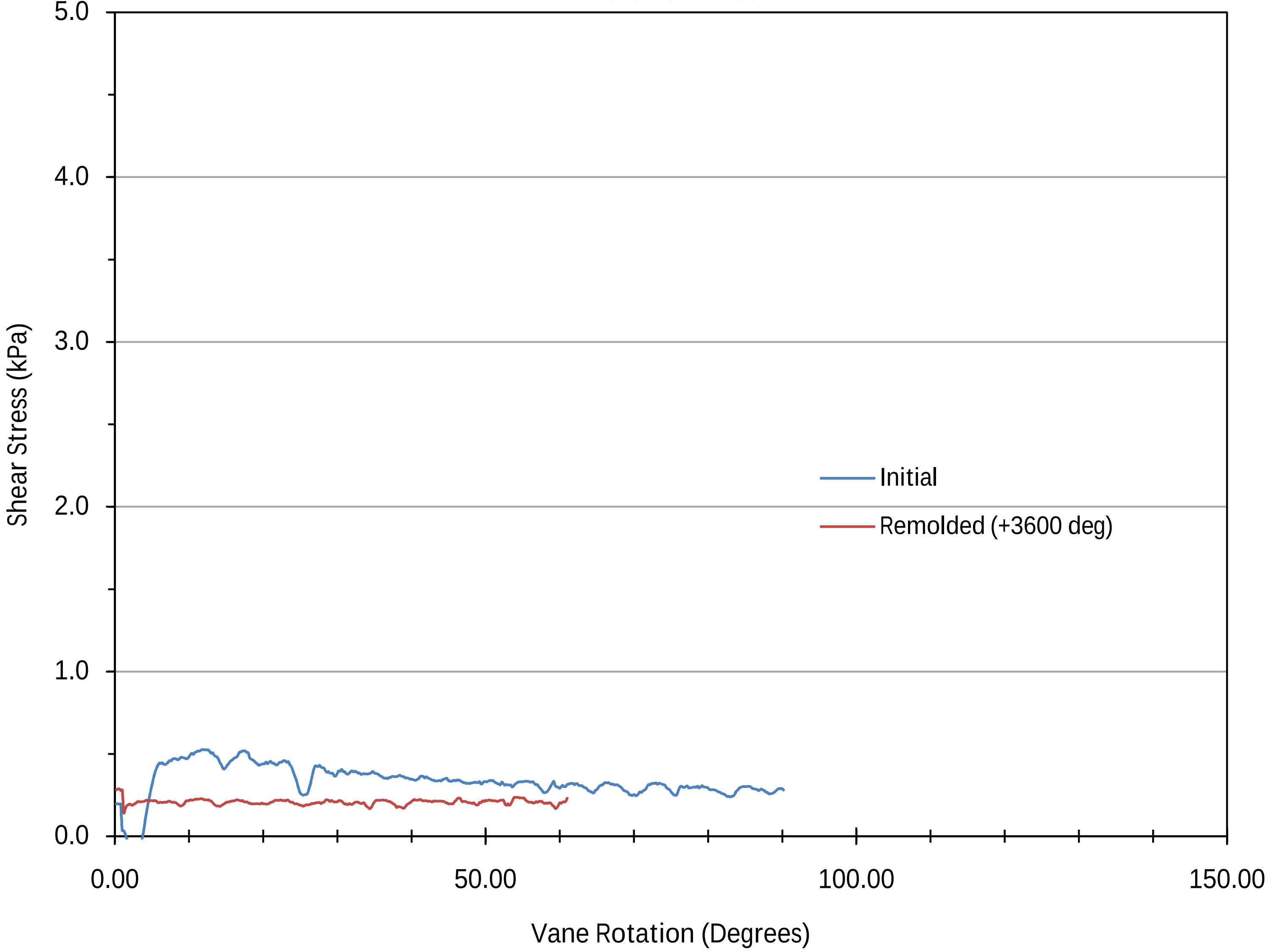


CONETEC

Job Number: 10-090
Client: AMEC
Project: Diavik
Sounding: VST 10-05

Test Depth (m): 12.00
Vane Dimensions: 150mm x 300mm
Sounding Date: September 13, 2010

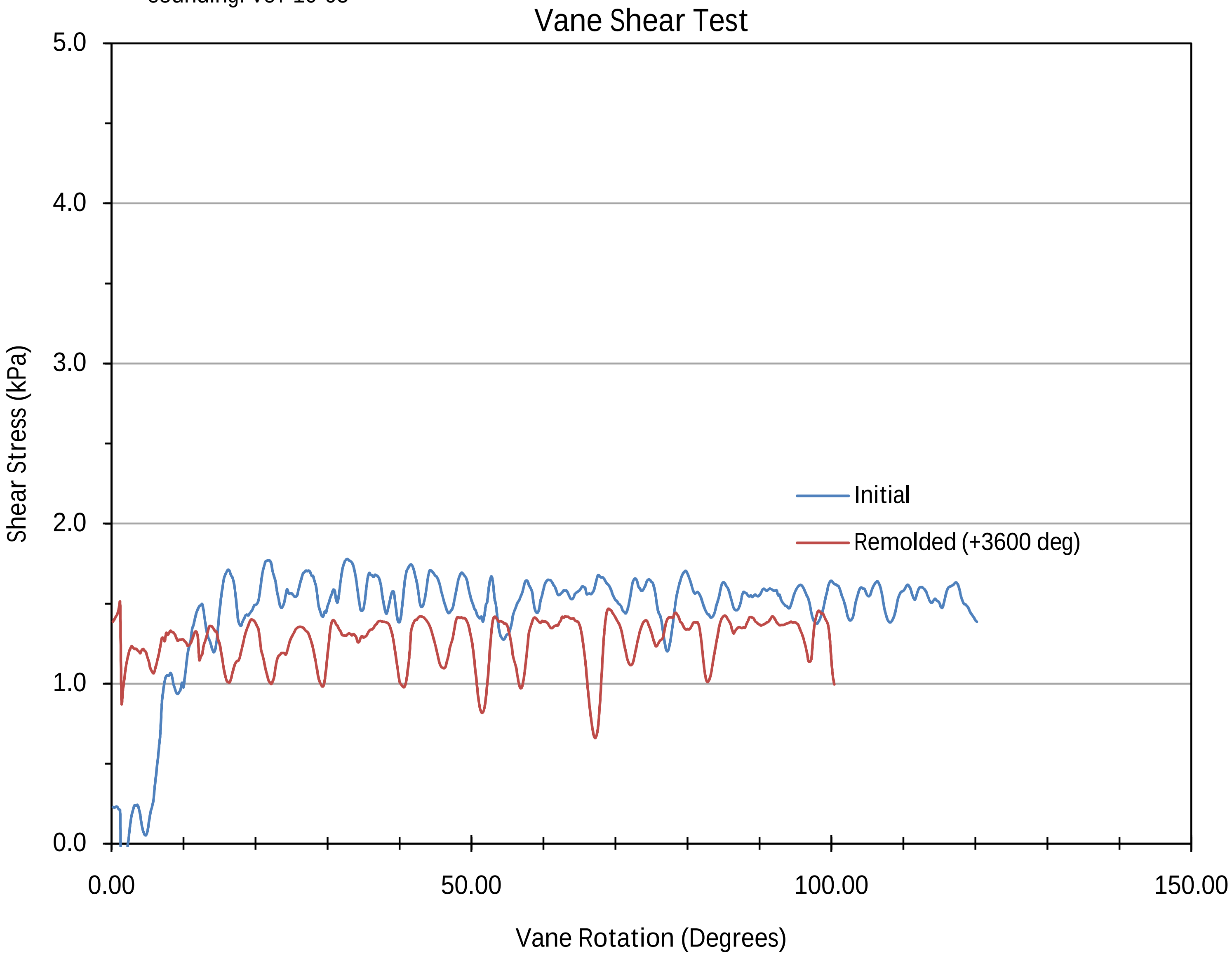
Vane Shear Test



CONETEC

Job Number: 10-090
Client: AMEC
Project: Diavik
Sounding: VST 10-05

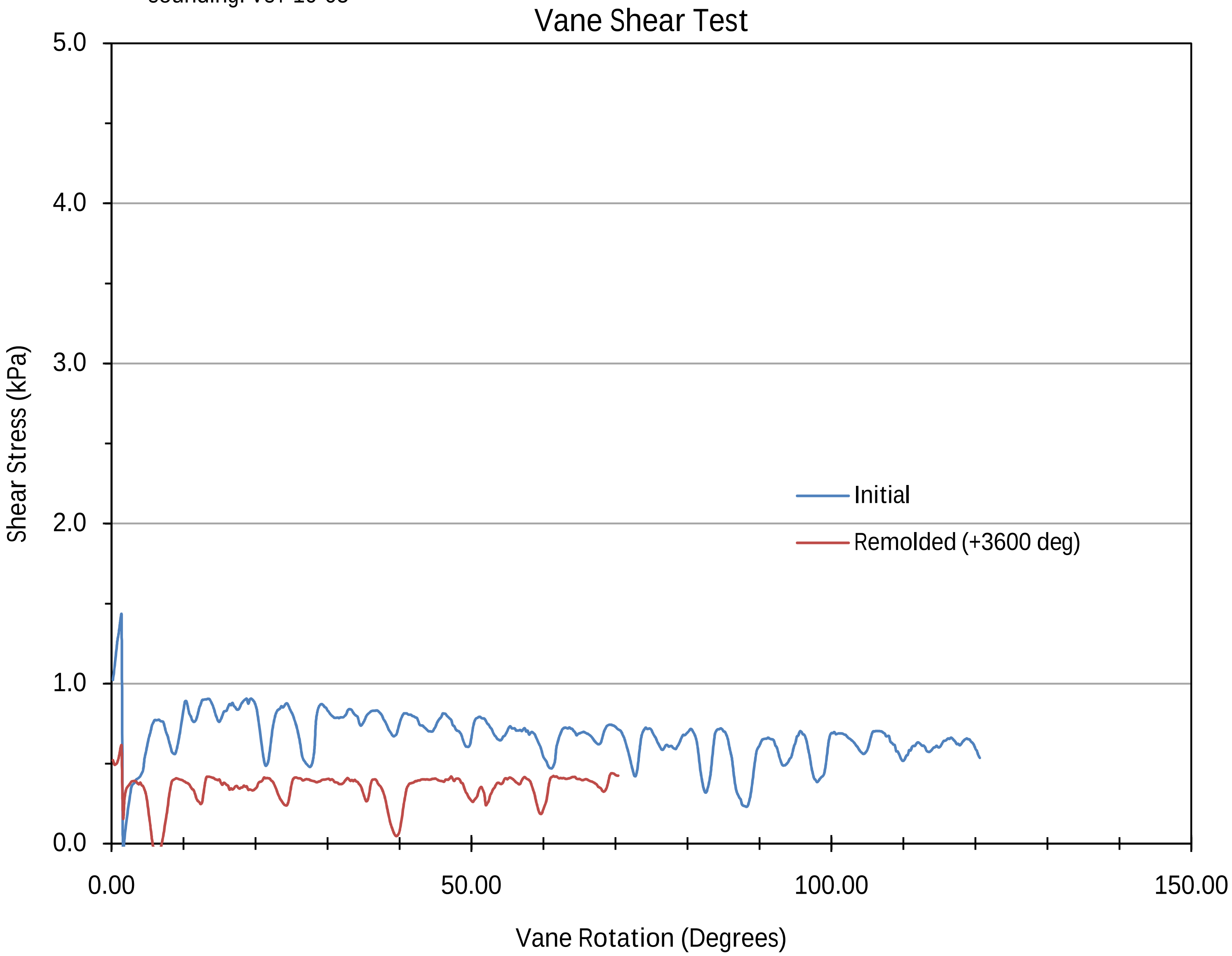
Test Depth (m): 13.00
Vane Dimensions: 150mm x 300mm
Sounding Date: September 13, 2010



CONETEC

Job Number: 10-090
Client: AMEC
Project: Diavik
Sounding: VST 10-05

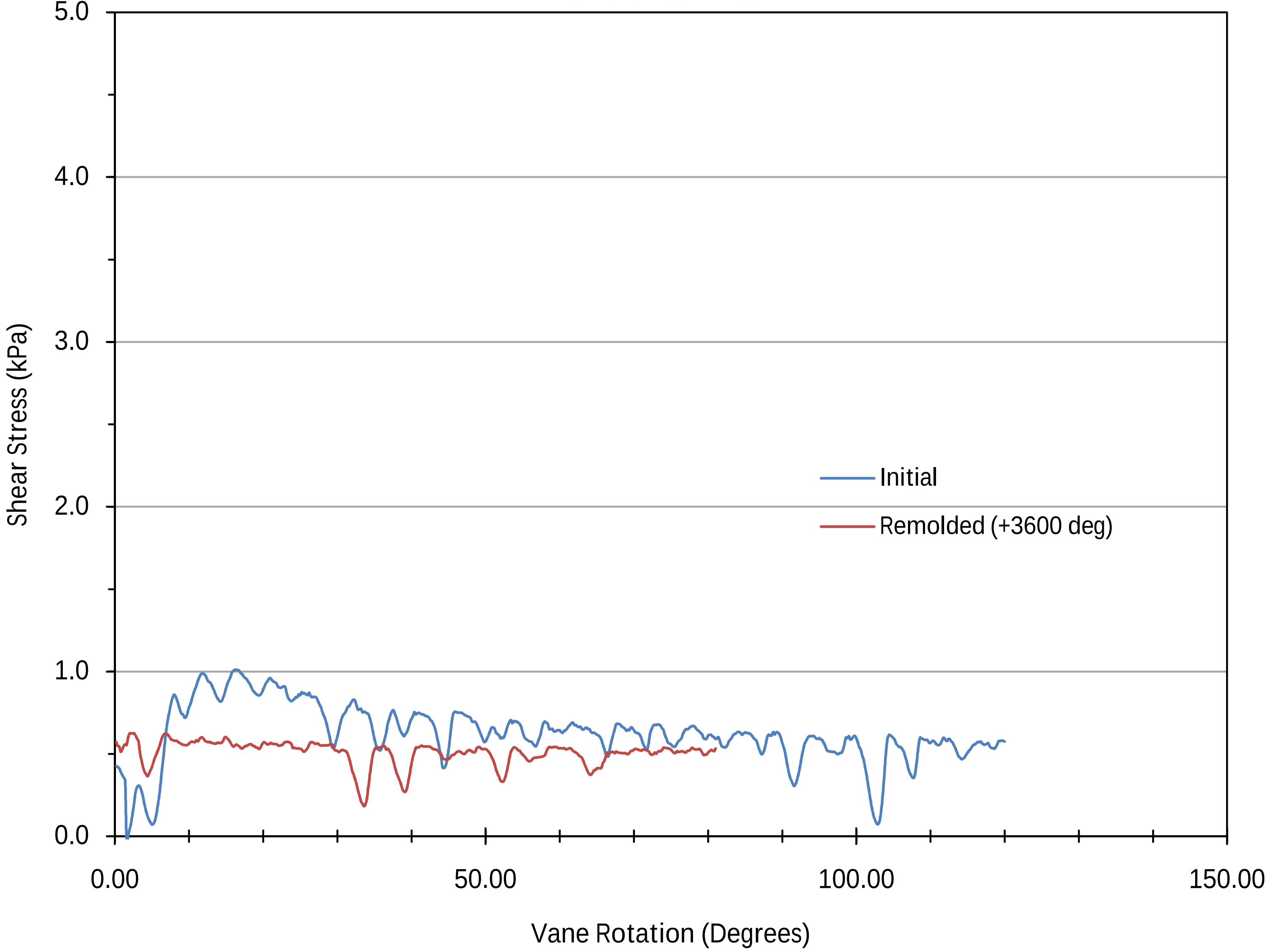
Test Depth (m): 14.00
Vane Dimensions: 150mm x 300mm
Sounding Date: September 13, 2010



Job Number: 10-090
Client: AMEC
Project: Diavik
Sounding: VST 10-05

Test Depth (m): 16.00
Vane Dimensions: 150mm x 300mm
Sounding Date: September 13, 2010

Vane Shear Test

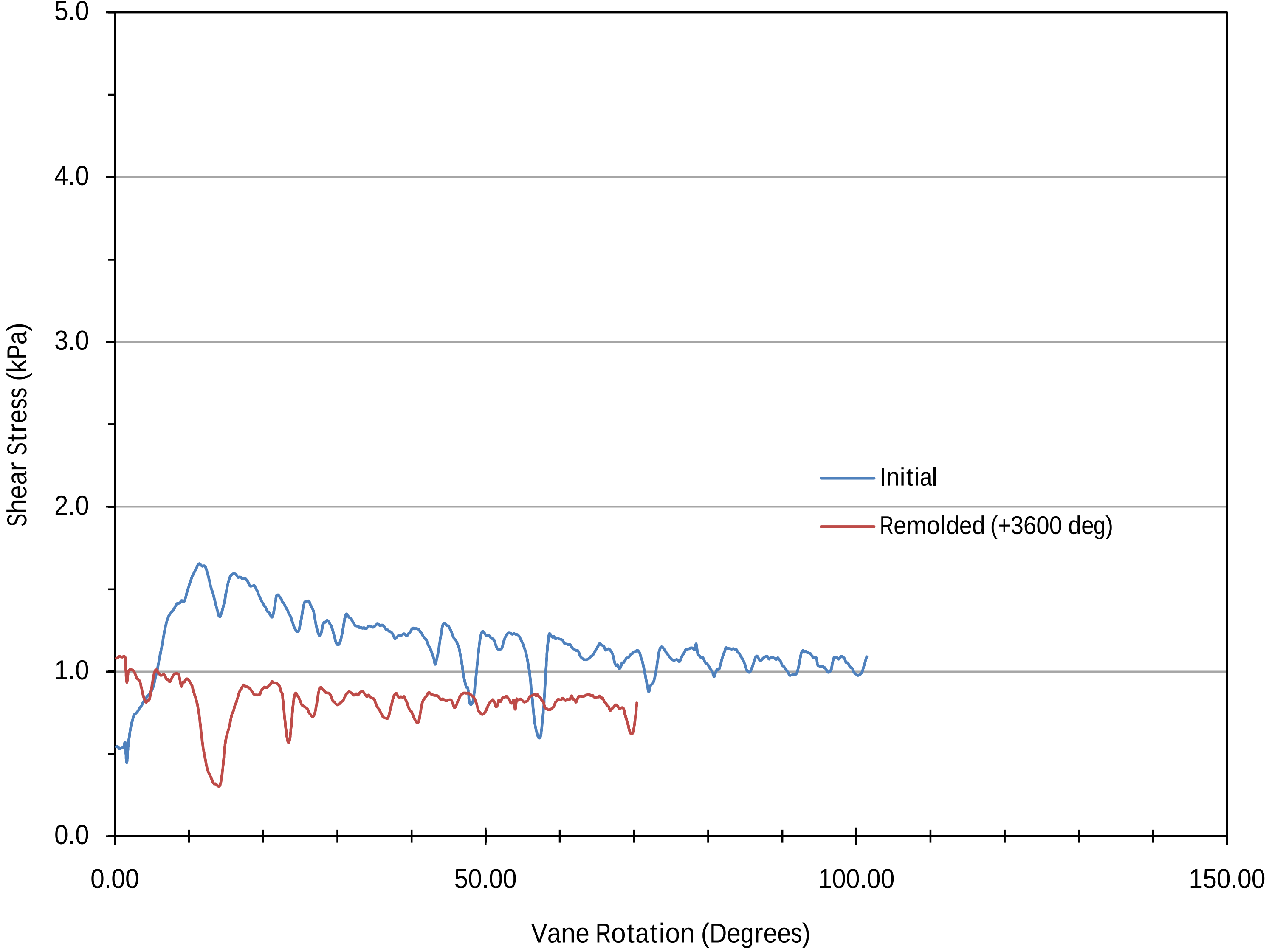


CONETEC

Job Number: 10-090
Client: AMEC
Project: Diavik
Sounding: VST 10-05

Test Depth (m): 18.00
Vane Dimensions: 150mm x 300mm
Sounding Date: September 13, 2010

Vane Shear Test

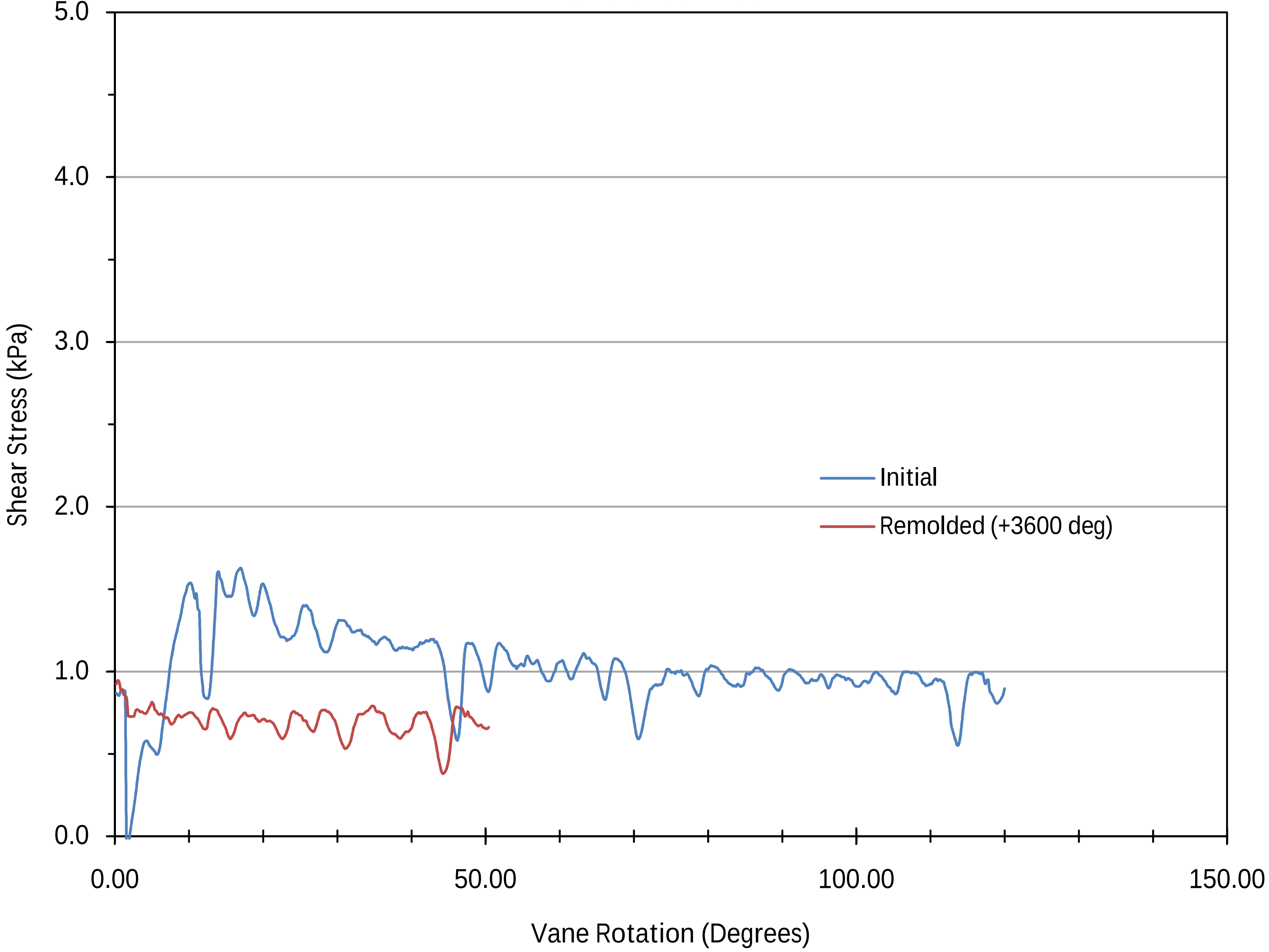


CONETEC

Job Number: 10-090
Client: AMEC
Project: Diavik
Sounding: VST 10-05

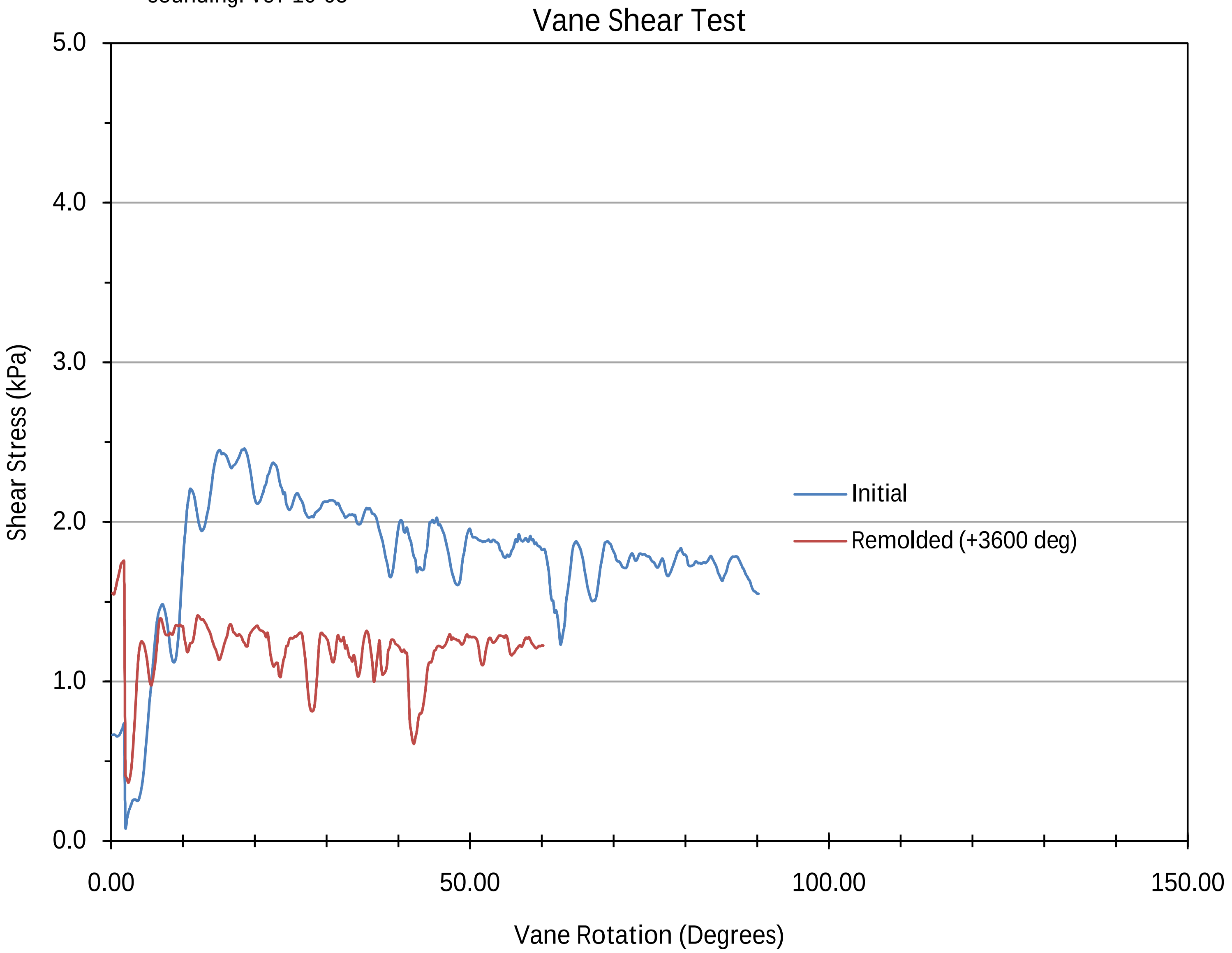
Test Depth (m): 20.00
Vane Dimensions: 150mm x 300mm
Sounding Date: September 13, 2010

Vane Shear Test



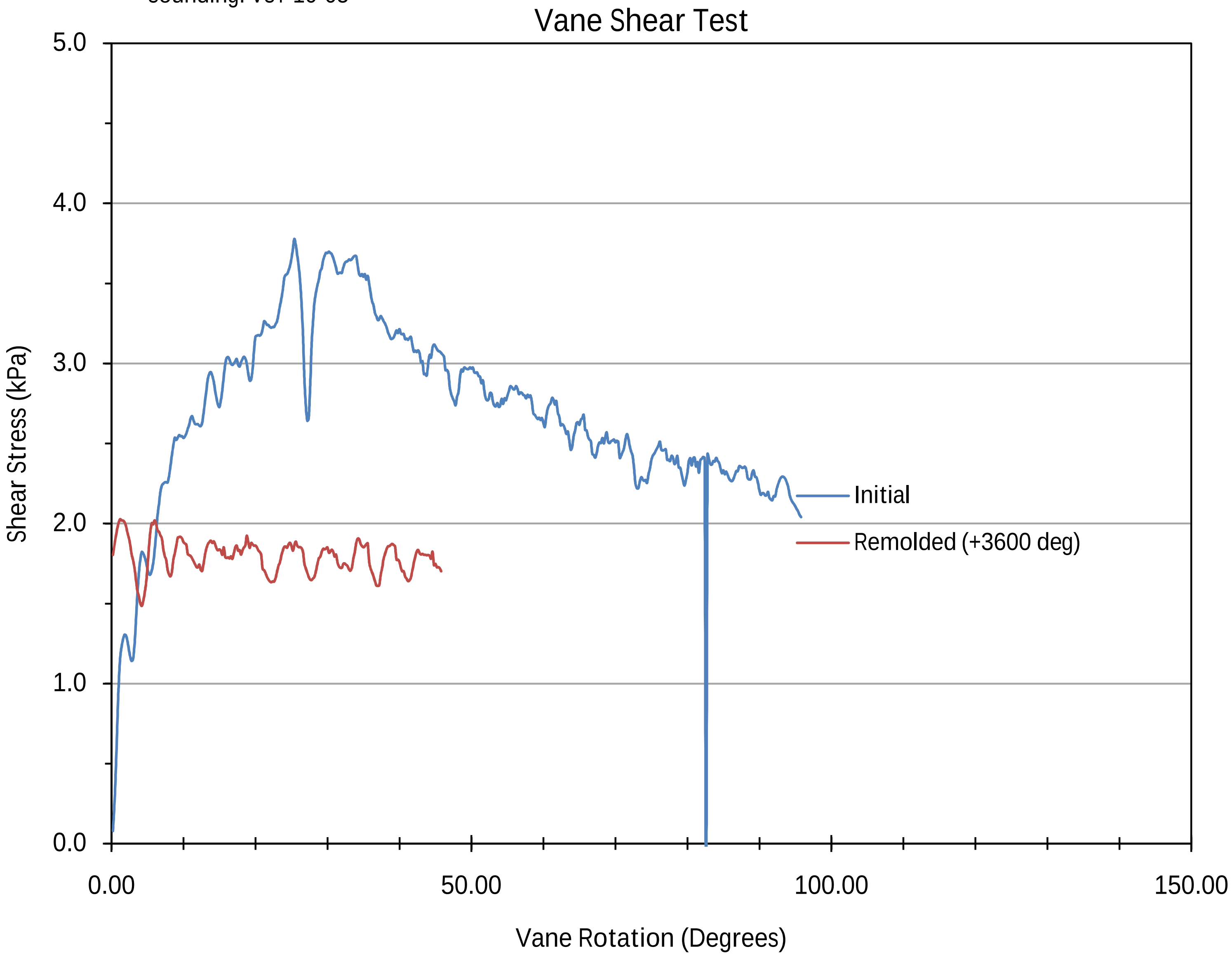
Job Number: 10-090
Client: AMEC
Project: Diavik
Sounding: VST 10-05

Test Depth (m): 22.00
Vane Dimensions: 150mm x 300mm
Sounding Date: September 13, 2010



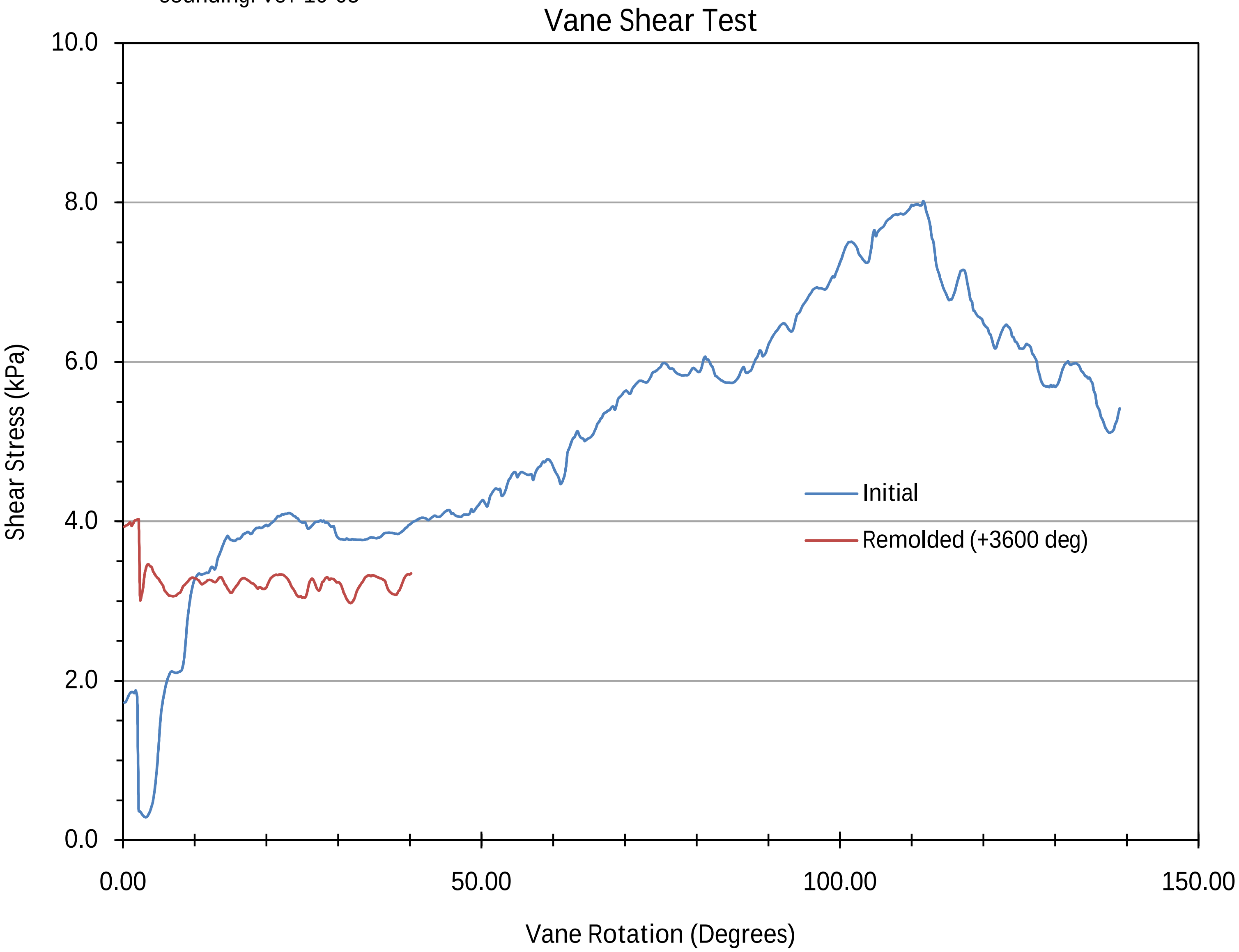
Job Number: 10-090
Client: AMEC
Project: Diavik
Sounding: VST 10-05

Test Depth (m): 24.00
Vane Dimensions: 150mm x 300mm
Sounding Date: September 13, 2010



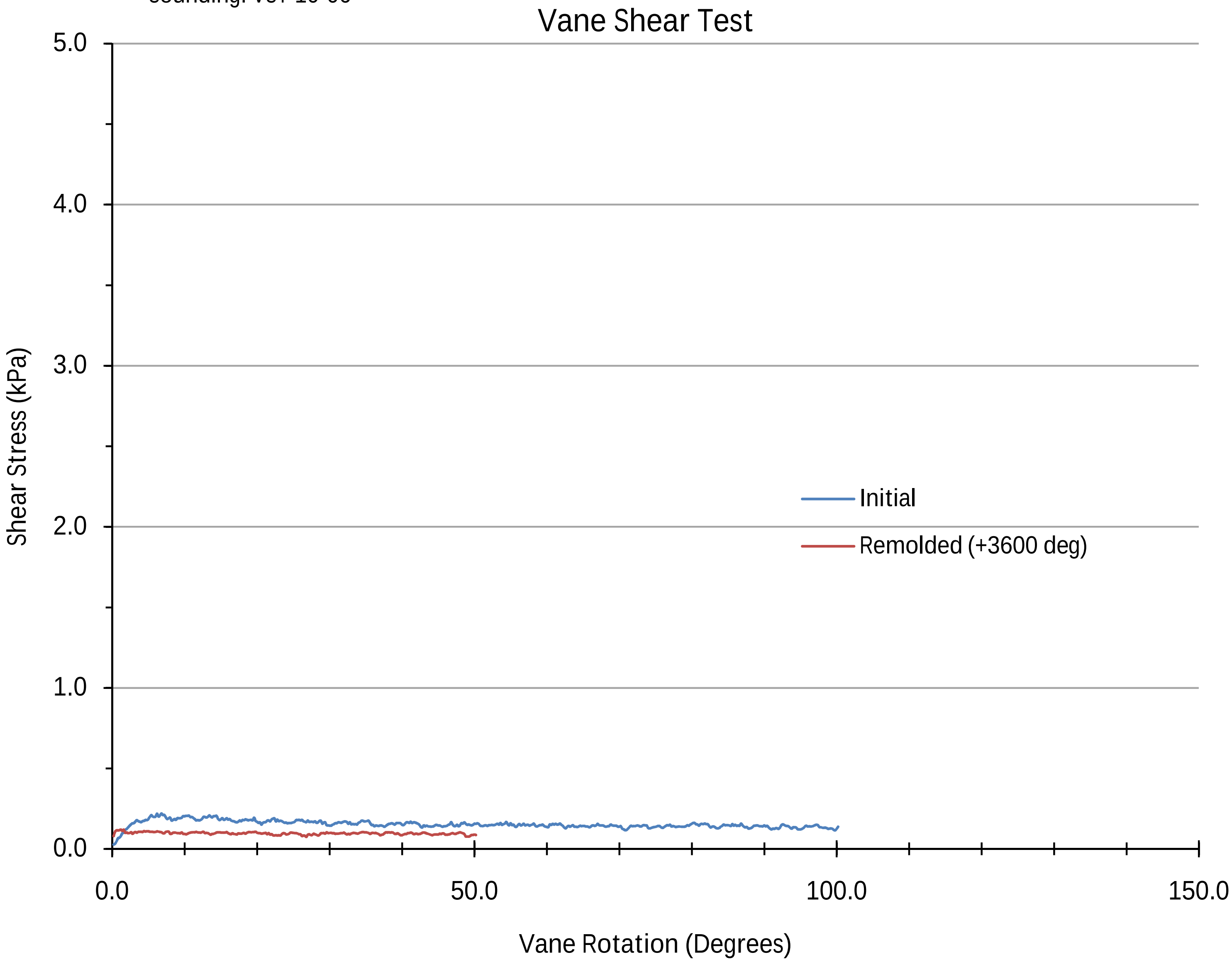
Job Number: 10-090
Client: AMEC
Project: Diavik
Sounding: VST 10-05

Test Depth (m): 26.00
Vane Dimensions: 150mm x 300mm
Sounding Date: September 13, 2010



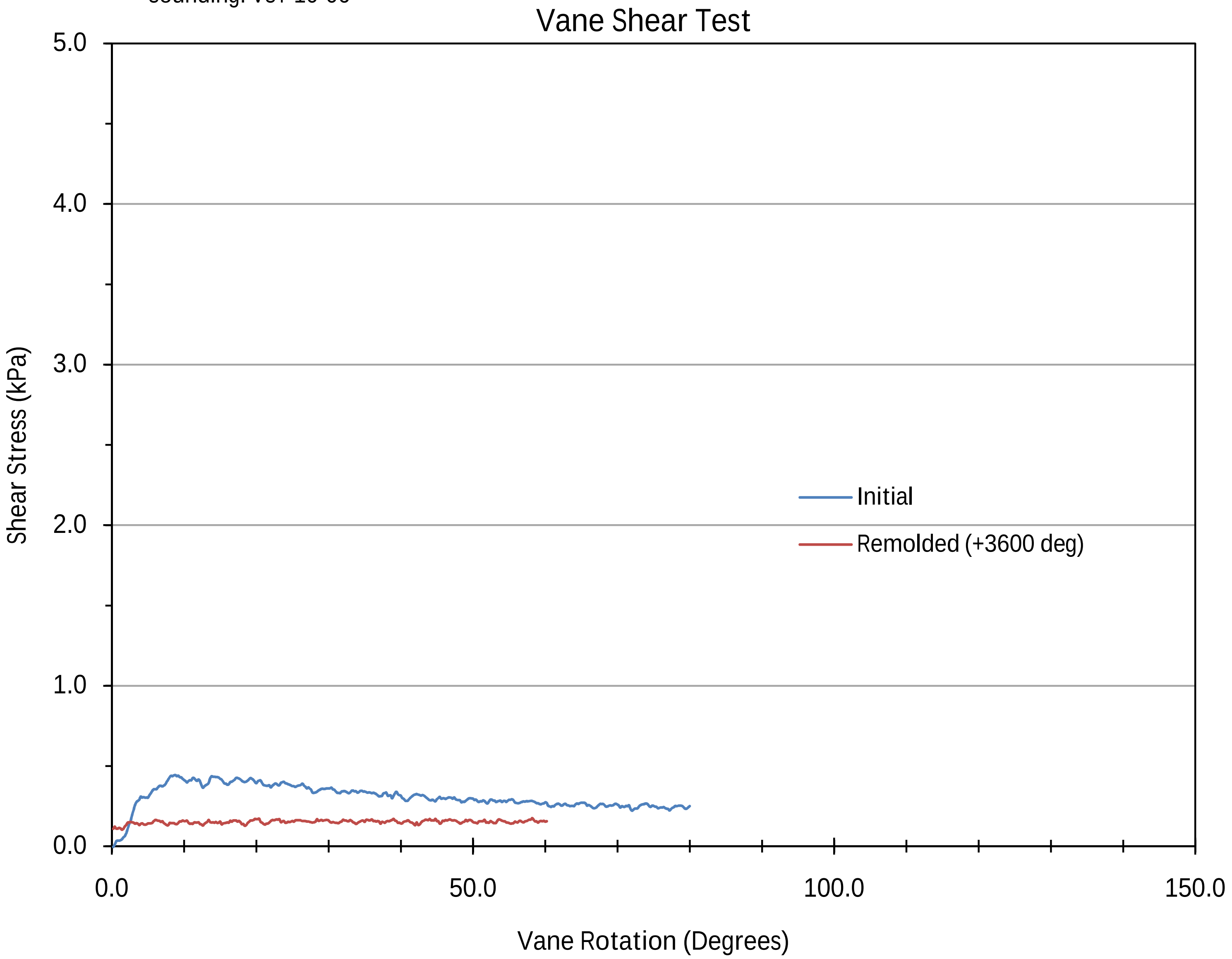
Job Number: 10-090
Client: AMEC
Project: Diavik
Sounding: VST 10-06

Test Depth (m): 4.00
Vane Dimensions: 150mm x 300mm
Sounding Date: September 13, 2010



Job Number: 10-090
Client: AMEC
Project: Diavik
Sounding: VST 10-06

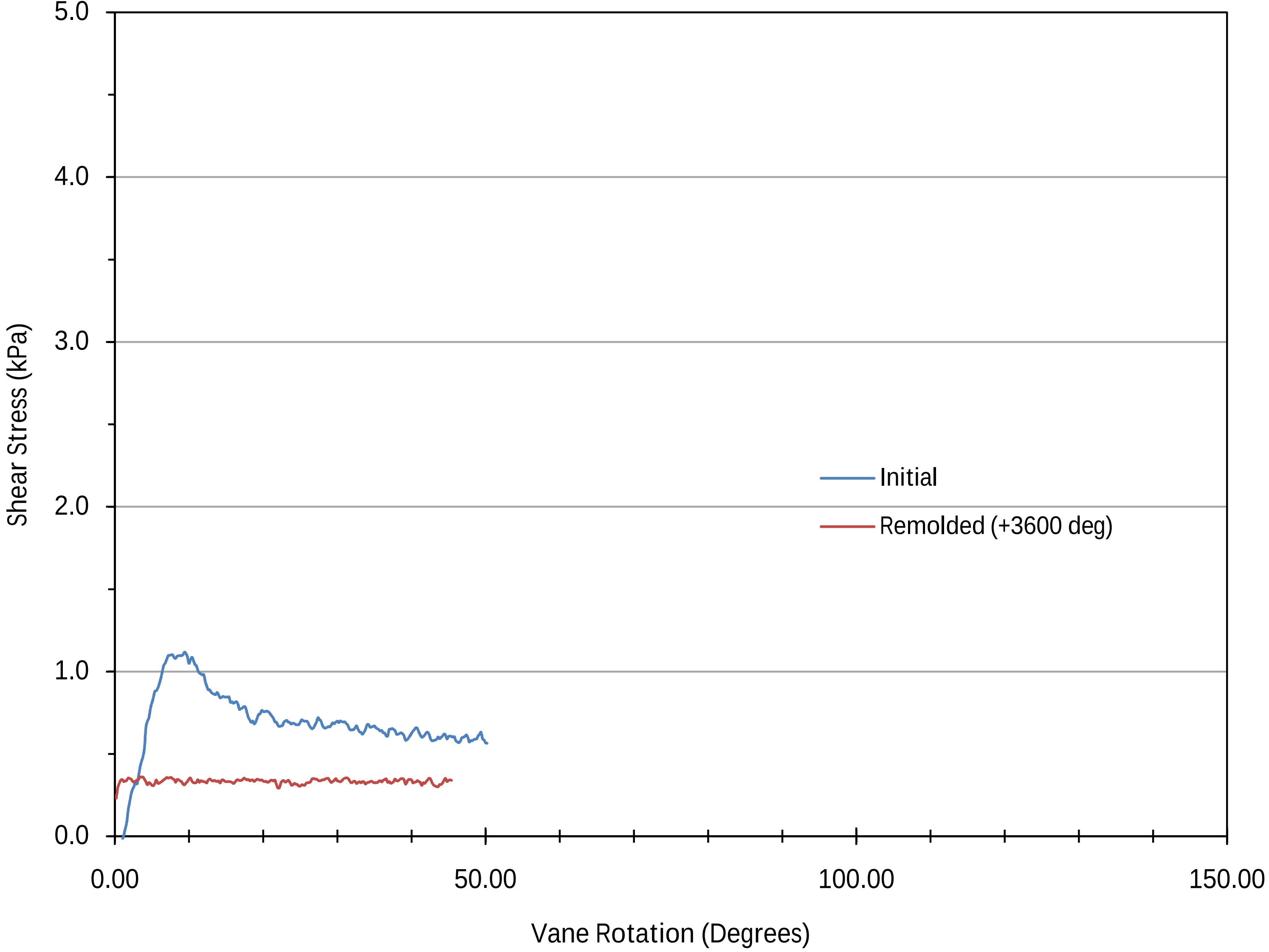
Test Depth (m): 8.00
Vane Dimensions: 150mm x 300mm
Sounding Date: September 13, 2010



Job Number: 10-090
Client: AMEC
Project: Diavik
Sounding: VST 10-06

Test Depth (m): 11.00
Vane Dimensions: 150mm x 300mm
Sounding Date: September 13, 2010

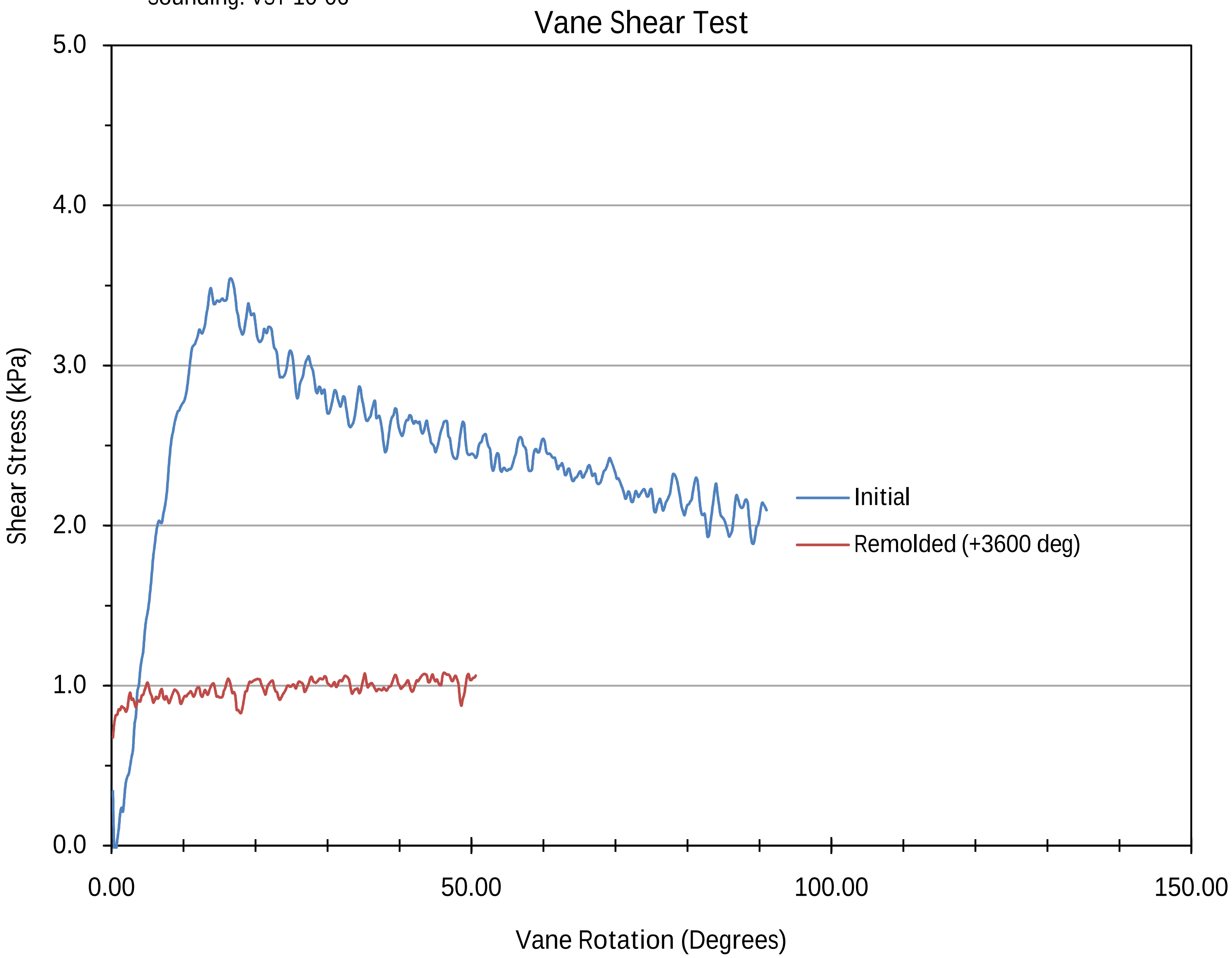
Vane Shear Test



CONETEC

Job Number: 10-090
Client: AMEC
Project: Diavik
Sounding: VST 10-06

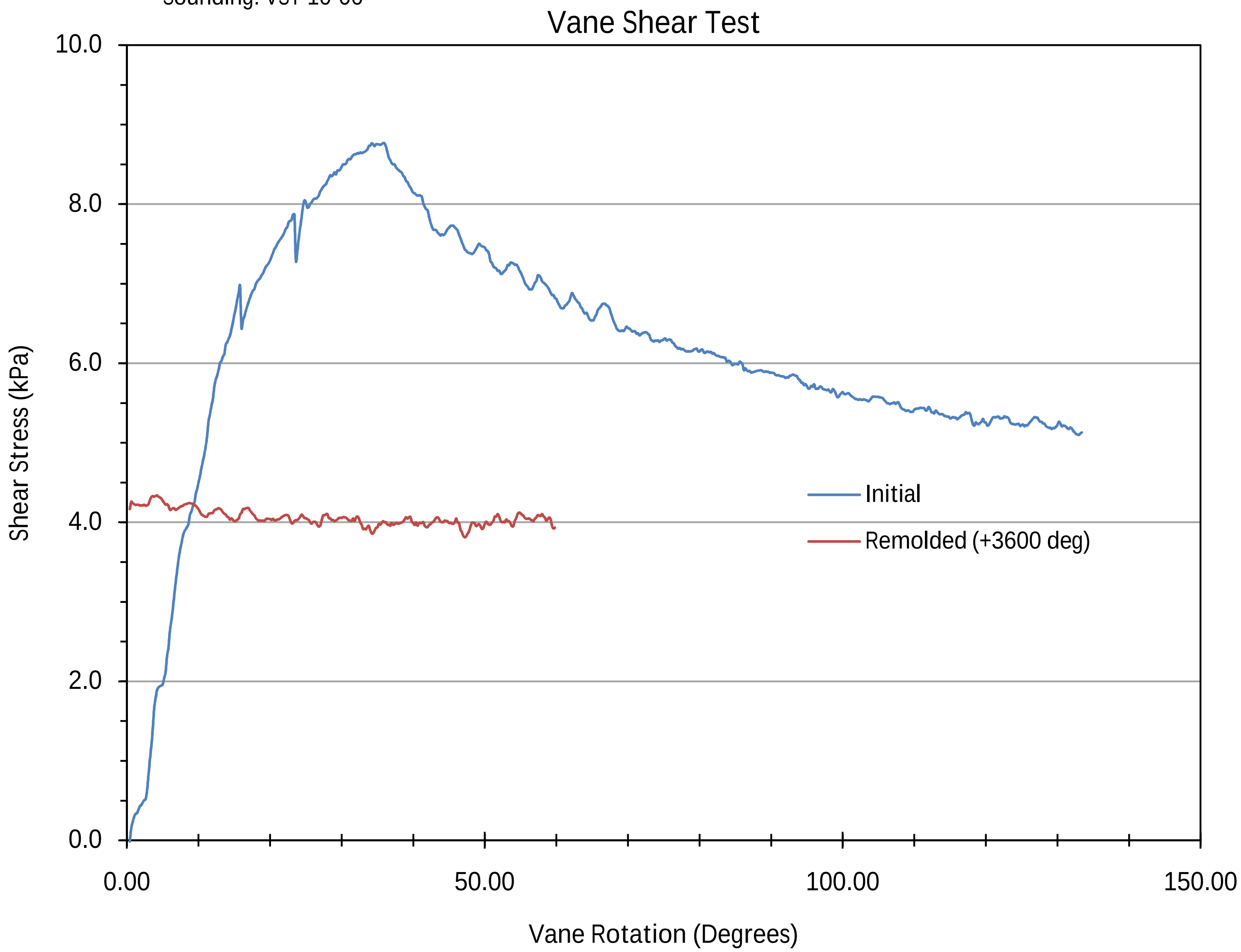
Test Depth (m): 14.00
Vane Dimensions: 150mm x 300mm
Sounding Date: September 13, 2010



CONETEC

Job Number: 10-090
Client: AMEC
Project: Diavik
Sounding: VST 10-06

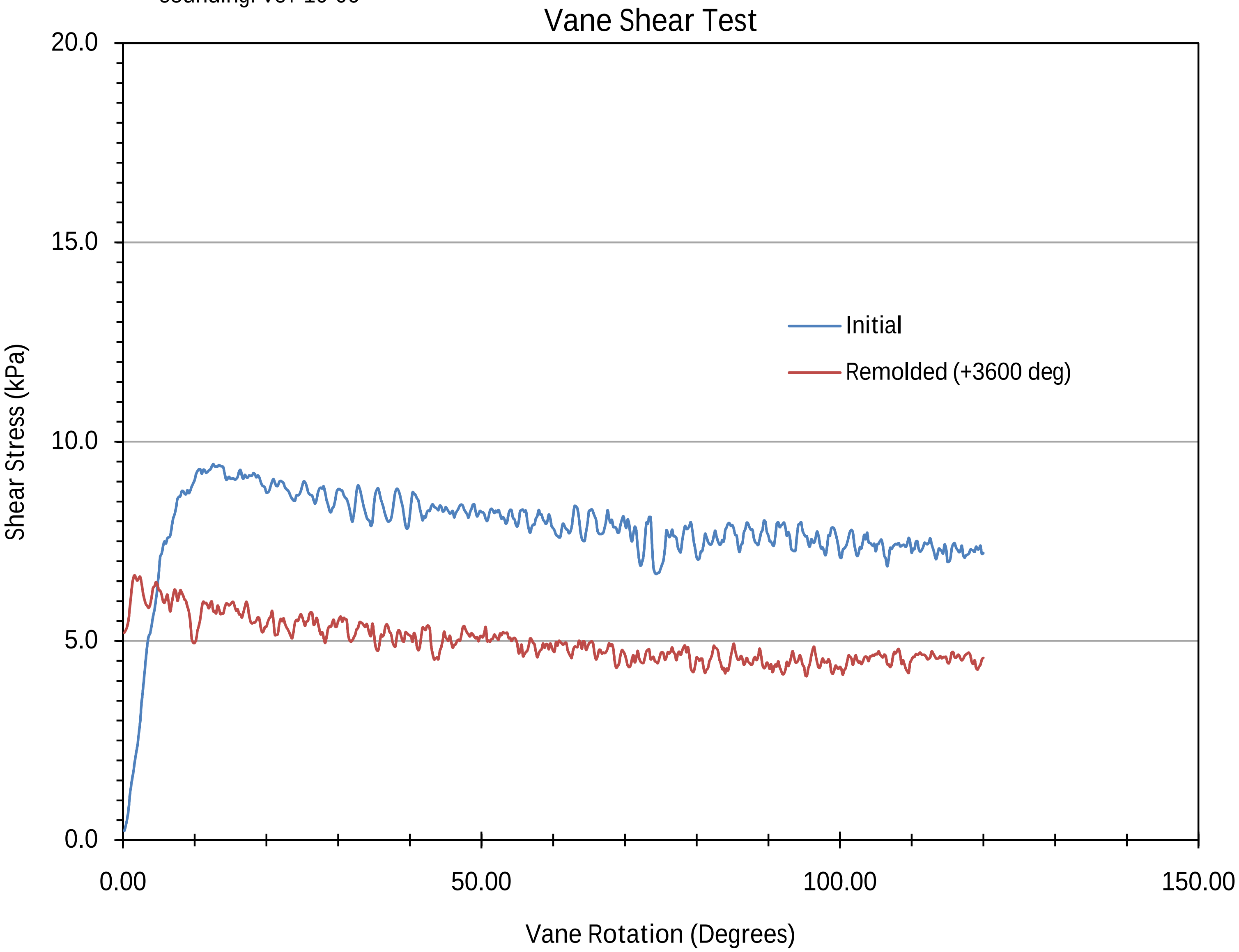
Test Depth (m): 18.50
Vane Dimensions: 150mm x 300mm
Sounding Date: September 13, 2010



CONETEC

Job Number: 10-090
Client: AMEC
Project: Diavik
Sounding: VST 10-06

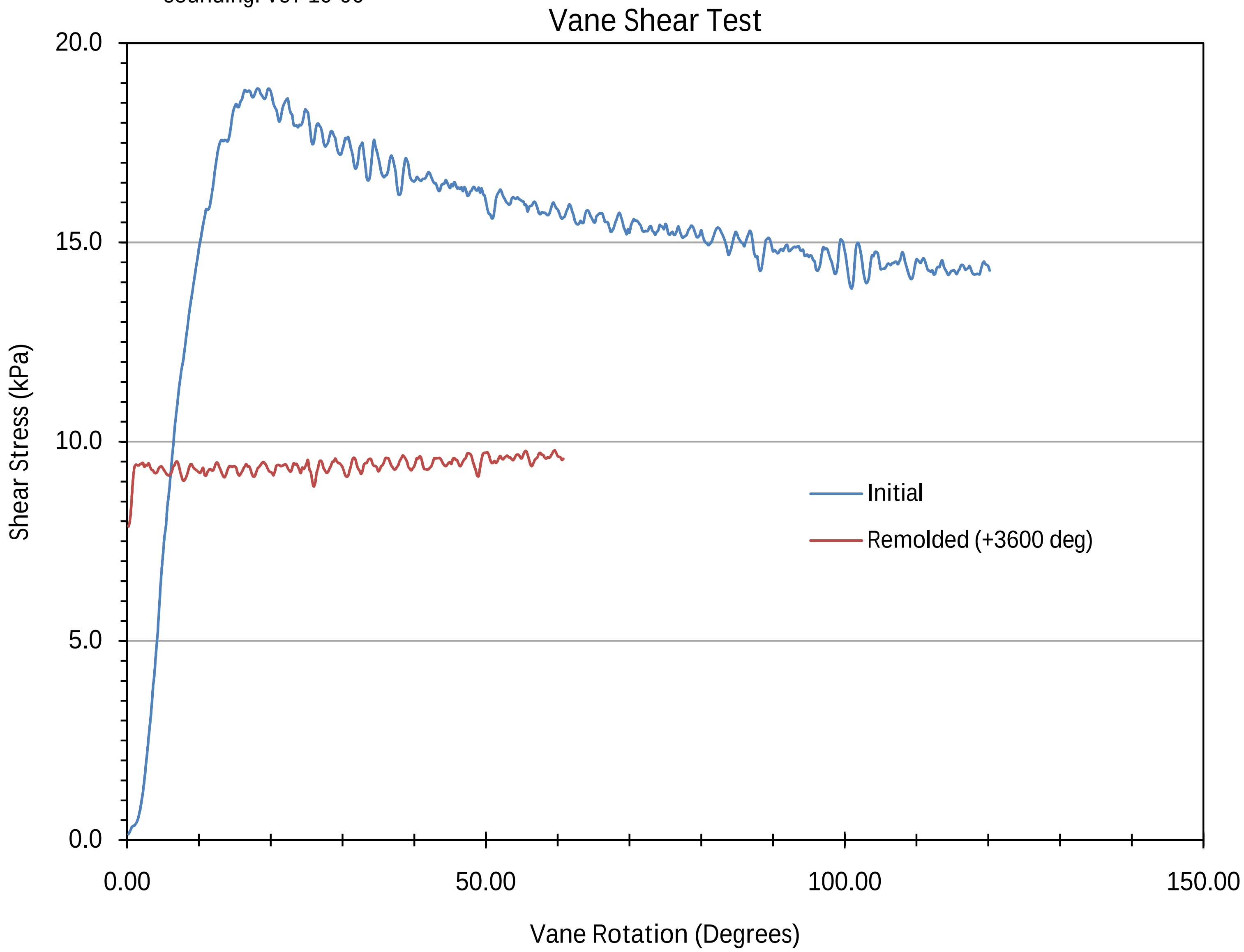
Test Depth (m): 20.00
Vane Dimensions: 75mm x 150mm
Sounding Date: September 13, 2010



CONETEC

Job Number: 10-090
Client: AMEC
Project: Diavik
Sounding: VST 10-06

Test Depth (m): 22.00
Vane Dimensions: 75mm x 150mm
Sounding Date: September 13, 2010



APPENDIX H

Sample Summary and Logs

Project No: 10-090
Client: AMEC Earth & Environmental
Site: Diavik
Date: Sept 14/2010

SAMPLE SUMMARY

Hole Name	Location	Date	Sampling Method	Test Depth (m)	Test Depth (ft)	Sample #	Coordinates (UTM Zone 12W)	
							Northing (m)	Easting (m)
10-04	PKC	Sept 14/2010	Fluid	4.0-16.0	13.1-52.5	13-19	7152116	533186
10-05	PKC	Sept 14/2010	Fluid/Piston	0.0-23.0	0.0-75.5	1-6	7152046	533103
10-06	PKC	Sept 14/2010	Fluid	4.0-17.0	13.1-55.8	7-12	7151952	533181

DAILY SAMPLE SUMMARY

SAMPLE SITE LOCATION NAME: 10-04

ConeTec Job #:	10-090	*Co-ordinate System:*	UTM Zone 12W
Location:	Diavik PKC	*Northing:*	7152116 m
Staff:	AM / DM / JM	*Easting:*	533186 m
Sampling Method (s):	Fluid	*Collar Elevation:*	

SAMPLE #	**SAMPLE IDENTIFIER**				**Sample Method***	**Date**	**Time**	**Recovery**	**pH**	**Redox (Oxidation-reduction - ORP)**	**Cond.**	**Temp.**	**Comments**
Sequential	Year	Site	Depth From (m)	Depth To (m)	C / P / S / F	mm/dd/yy	24hr clock	(m)	pH units	mV	µS	°C	
13	2010	PKC 10-04	4.0	4.0	F	9/14/2010	14:42	-	-	-	-	-	sample attempted at 4 m but not enough pressure to depress piston in sampling tube so no sample collected.
14	2010	PKC 10-04	6.0	6.0	F	9/14/2010	14:46	-	-	-	-	-	gray, slimes, odorless, 4 L paint can
15	2010	PKC 10-04	8.0	8.0	F	9/14/2010	14:49	-	-	-	-	-	gray, slimes, trace grit, odorless, 4L paint can
16	2010	PKC 10-04	10.0	10.0	F	9/14/2010	14:52	-	-	-	-	-	gray, slimes, holds some shape when disturbed, odorless, 4 L paint can
17	2010	PKC 10-04	13.0	13.0	F	9/14/2010	14:58	-	-	-	-	-	lighter gray, holds shape well, odorless, 4 L paint can
18	2010	PKC 10-04	15.0	15.0	F	9/14/2010	15:03	-	-	-	-	-	lighter gray, forms coils, odorless, 4 L paint can
19	2010	PKC 10-04	16.0	16.0	F	9/14/2010	15:10	-	-	-	-	-	lighter gray, forms coils, odorless, 4 L paint can

* C - Cyre Sampler P - Piston Sampler S - Sonic Sampler F - Fluid Sampler

DAILY SAMPLE SUMMARY

SAMPLE SITE LOCATION NAME: 10-05

ConeTec Job #: 10-090
Location: Diavik PKC
Staff: AM / DM / JM
Sampling Method (s): Fluid / Piston

Co-ordinate System: UTM Zone 12W
Northing: 7152046 m
Easting: 533103 m
Collar Elevation:

SAMPLE #	**SAMPLE IDENTIFIER**				**Sample Method***	**Date**	**Time**	**Recovery**	**pH**	**Redox (Oxidation-reduction - ORP)**	**Cond.**	**Temp.**	**Comments**
Sequential	Year	Site	Depth From (m)	Depth To (m)	C / P / S / F	mm/dd/yy	24hr clock	(m)	pH units	mV	µS	°C	
1	2010	PKC 10-05	6.0	6.0	F	9/14/2010	10:15	-	-	-	-	-	Grey, slime, odourless. index sample in 4L paint can
2	2010	PKC 10-05	8.0	8.0	F	9/14/2010	10:30	-	-	-	-	-	5 Gallon, slime, odourless, grey, slightly thicker than 6m Large Strain consolidation sample - representative of slimes according to ball penetrometer
3	2010	PKC 10-05	12.0	12.0	F	9/14/2010	10:50	-	-	-	-	-	4L paint can, grey slime, odourless
4	2010	PKC 10-05	18.0	18.0	F	9/14/2010	11:05	-	-	-	-	-	4L paint can, grey, holds some form
5	2010	PKC 10-05	23.0	24.0	P	9/14/2010	13:00	-	-	-	-	-	PK sandy silt, layering visible, dark gray, 4 L paint can
6	2010	PKC 10-05	0.0	0.0	F	9/14/2010	12:30	-	-	-	-	-	Water was scooped from the surface of the pond. 5 gallon pail.

* C - Cyre Sampler P - Piston Sampler S - Sonic Sampler F - Fluid Sampler

DAILY SAMPLE SUMMARY

SAMPLE SITE LOCATION NAME: 10-06

ConeTec Job #:	10-090	*Co-ordinate System:*	UTM Zone 12W
Location:	Diavik PKC	*Northing:*	7151952 m
Staff:	AM / DM / JM	*Easting:*	533181 m
Sampling Method (s):	Fluid	*Collar Elevation:*	

SAMPLE #	**SAMPLE IDENTIFIER**				**Sample Method***	**Date**	**Time**	**Recovery**	**pH**	**Redox (Oxidation-reduction - ORP)**	**Cond.**	**Temp.**	**Comments**
Sequential	Year	Site	Depth From (m)	Depth To (m)	C / P / S / F	mm/dd/yy	24hr clock	(m)	pH units	mV	µS	°C	
7	2010	PKC 10-06	4.0	4.0	F	9/14/2010	13:40	-	-	-	-	-	gray, slime, odorless, 4 L paint can
8	2010	PKC 10-06	8.0	8.0	F	9/14/2010	13:48	-	-	-	-	-	gray, slime, odorless, 4 L paint can
9	2010	PKC 10-06	12.0	12.0	F	9/14/2010	13:54	-	-	-	-	-	gray, slime holds some shape, odorless, some grit, 4 L paint can
10	2010	PKC 10-06	13.0	13.0	F	9/14/2010	13:59	-	-	-	-	-	gray, slime holds some shape, odorless, some grit, 4 L paint can
11	2010	PKC 10-06	15.0	15.0	F	9/14/2010	14:03	-	-	-	-	-	gray, slime, no grit, odorless, 4L paint can
12	2010	PKC 10-06	17.0	17.0	F	9/14/2010	14:13	-	-	-	-	-	gray, snake with some grit, odorless, 4 L paint can

* C - Cyre Sampler P - Piston Sampler S - Sonic Sampler F - Fluid Sampler

APPENDIX I

CPT Interpretation Methods

CONETEC INTERPRETATION METHODS

A Detailed Description of the Methods Used in ConeTec's CPT Interpretation and Plotting Software

Revision SZW-Rev 03
March 15, 2010

Prepared by Jim Greig

ConeTec Interpretations as of March 15, 2010

ConeTec's interpretation routine provides a tabular output of geotechnical parameters based on current published CPT correlations and is subject to change to reflect the current state of practice. The interpreted values are not considered valid for all soil types. The interpretations are presented only as a guide for geotechnical use and should be carefully scrutinized for consideration in any geotechnical design. Reference to current literature is strongly recommended. ConeTec does not warranty the correctness or the applicability of any of the geotechnical parameters interpreted by the program and does not assume liability for any use of the results in any design or review. Representative hand calculations should be made for any parameter that is critical for design purposes. The end user of the interpreted output should also be fully aware of the techniques and the limitations of any method used in this program. The purpose of this document is to inform the user as to which methods were used and what the appropriate papers and/or publications are for further reference.

The CPT interpretations are based on values of tip, sleeve friction and pore pressure averaged over a user specified interval (e.g. 0.20m). Note that q_t is the tip resistance corrected for pore pressure effects and q_c is the recorded tip resistance. Since all ConeTec cones have equal end area friction sleeves, pore pressure corrections to sleeve friction, f_S, are not required.

The tip correction is: $q_t = q_c + (1-a) \cdot u_2$

where: q_t is the corrected tip resistance
q_c is the recorded tip resistance
u_2 is the recorded dynamic pore pressure behind the tip (u_2 position)
a is the Net Area Ratio for the cone (typically 0.80 for ConeTec cones)

The total stress calculations are based on soil unit weights that have been assigned to the Soil Behavior Type zones, from a user defined unit weight profile or by using a single value throughout the profile.

Effective vertical overburden stresses are calculated based on a hydrostatic distribution of equilibrium pore pressures below the water table or from a user defined equilibrium pore pressure profile (this can be obtained from CPT dissipation tests). For over water projects the effects of the column of water have been taken into account as has the appropriate unit weight of water. How this is done depends on where the instruments were zeroed (i.e. on deck or at mud line).

Details regarding the interpretation methods for all of the interpreted parameters are provided in Table 1. The appropriate references cited in Table 1 are listed in Table 2. Where methods are based on charts or techniques that are too complex to describe in this summary the user should refer to the cited material.

The estimated Soil Behavior Types (normalized and non-normalized) are based on the charts developed by Robertson and Campanella shown in Figures 1 and 2. The Bq classification charts are not reproduced in this document but can be reviewed in Lunne, Robertson and Powell (1997) or Robertson (1990).

Where the results of a calculation/interpretation are declared *'invalid'* the value will be represented by the text strings "-9999" or "-9999.0". In some cases the value 0 will be used. Invalid results will occur because of (and not limited to) one or a combination of:

1. Invalid or undefined CPT data (e.g. drilled out section or data gap).
2. Where the interpretation method is inappropriate, for example, drained parameters in an undrained material (and vice versa).
3. Where interpretation input values are beyond the range of the referenced charts or specified limitations of the interpretation method.
4. Where pre-requisite or intermediate interpretation calculations are invalid.

The parameters selected for output from the program are often specific to a particular project. As such, not all of the interpreted parameters listed in Table 1 may be included in the output files delivered with this report.

The output files are provided in Microsoft Excel XLS format. The ConeTec software has several options for output depending on the number or types of interpreted parameters desired. Each output file will be named using the original COR file basename followed by a three or four letter indicator of the interpretation set selected (e.g. BSC, TBL, NLI or IFI) and possibly followed by an operator selected suffix identifying the characteristics of the particular interpretation run.

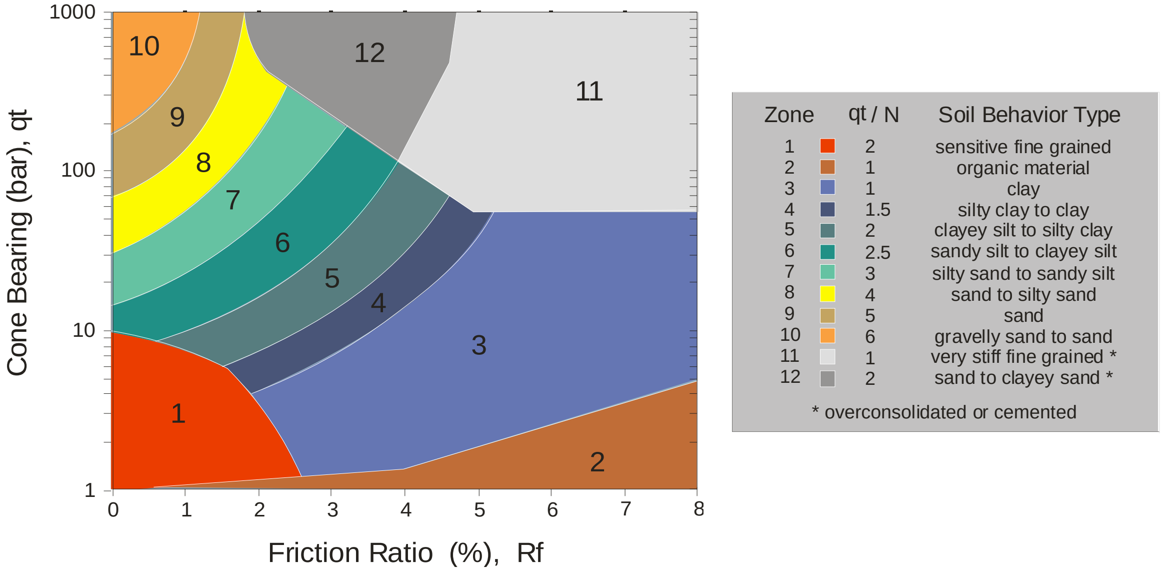
Table 1
CPT Interpretation Methods

Interpreted Parameter	Description	Equation	Ref
Depth	Mid Layer Depth *(where interpretations are done at each point then Mid Layer Depth = Recorded Depth)*	*Depth (Layer Top) + Depth (Layer Bottom) / 2.0*	
Elevation	Elevation of Mid Layer based on sounding collar elevation supplied by client	Elevation = Collar Elevation - Depth	
Avgqc	Averaged recorded tip value (q_c)	$Avgqc = \frac{1}{n}\sum_{i=1}^{n} q_c$ *n=1 when interpretations are done at each point*	
Avgqt	Averaged corrected tip (q_t) where: $q_t = q_c + (1-a) \bullet u$	$Avgqt = \frac{1}{n}\sum_{i=1}^{n} q_t$ *n=1 when interpretations are done at each point*	
Avgfs	Averaged sleeve friction (f_s)	$Avgfs = \frac{1}{n}\sum_{i=1}^{n} fs$ *n=1 when interpretations are done at each point*	
AvgRf	Averaged friction ratio (Rf) where friction ratio is defined as: $Rf = 100\% \bullet \frac{fs}{qt}$	$AvgRf = 100\% \cdot \frac{Avgfs}{Avgqt}$ *n=1 when interpretations are done at each point*	
Avgu	Averaged dynamic pore pressure *(u)*	$Avgu = \frac{1}{n}\sum_{i=1}^{n} u_i$ *n=1 when interpretations are done at each point*	
AvgRes	Averaged Resistivity (this data is not always available since it is a specialized test requiring an additional module)	$Avgu = \frac{1}{n}\sum_{i=1}^{n} RESISTIVITY_i$ *n=1 when interpretations are done at each point*	
AvgUVIF	Averaged UVIF ultra-violet induced fluorescence (this data is not always available since it is a specialized test requiring an additional module)	$Avgu = \frac{1}{n}\sum_{i=1}^{n} UVIF_i$ *n=1 when interpretations are done at each point*	
AvgTemp	Averaged Temperature (this data is not always available since it is a specialized test)	$Avgu = \frac{1}{n}\sum_{i=1}^{n} TEMPERATURE_i$ *n=1 when interpretations are done at each point*	
AvgGamma	Averaged Gamma Counts (this data is not always available since it is a specialized test requiring an additional module)	$Avgu = \frac{1}{n}\sum_{i=1}^{n} GAMMA_i$ *n=1 when interpretations are done at each point*	
SBT	Soil Behavior Type as defined by Robertson and Campanella	See Figure 1	2, 5

Interpreted Parameter	Description	Equation	Ref
U.Wt.	Unit Weight of soil determined from one of the following user selectable options: 1) uniform value 2) value assigned to each SBT zone 3) user supplied unit weight profile	See references	5
T. Stress σ_v	Total vertical overburden stress at Mid Layer Depth. *A layer is defined as the averaging interval specified by the user. For data interpreted at each point the Mid Layer Depth is the same as the recorded depth.*	$TStress = \sum_{i=1}^{n} \gamma_i h_i$ *where* γ_i is layer unit weight h_i is layer thickness	
E. Stress σ_v'	Effective vertical overburden stress at Mid Layer Depth	$Estress = Tstress - u_{eq}$	
Ueq	Equilibrium pore pressure determined from one of the following user selectable options: 1) hydrostatic from water table depth 2) user supplied profile	For hydrostatic option: $u_{eq} = \gamma_w \cdot (D - D_{wt})$ where u_{eq} is equilibrium pore pressure γ_w is unit weight of water D is the current depth D_{wt} is the depth to the water table	
Cn	SPT N_{60} overburden correction factor	$Cn=(\sigma_v')^{-0.5}$ where σ_v' *is in tsf* $0.5 < C_n < 2.0$	
N_{60}	SPT N value at 60% energy calculated from qt/N ratios assigned to each SBT zone. This method has abrupt N value changes at zone boundaries.	*See Figure 1*	4, 5
$(N_1)_{60}$	SPT N_{60} value corrected for overburden pressure	$(N_1)_{60} = Cn \cdot N_{60}$	4
$N_{60}I_c$	SPT N_{60} values based on the Ic parameter	$(qt/pa)/ N_{60} = 8.5 (1 – Ic/4.6)$	5
$(N_1)_{60}Ic$	SPT N_{60} value corrected for overburden pressure (using N_{60} $I_{c)}$. User has 2 options.	1) $(N_1)_{60}Ic= Cn \cdot (N_{60}\ Ic)$ 2) $q_{c1n}/ (N_1)_{60}Ic = 8.5 (1 – Ic/4.6)$	4 5
$(N_1)_{60cs}Ic$	Clean sand equivalent SPT $(N_1)_{60}Ic$. User has 3 options.	1) $(N_1)_{60cs}Ic = \alpha + \beta((N_1)_{60}Ic)$ 2) $(N_1)_{60cs}Ic = K_{SPT} * ((N_1)_{60}Ic)$ 3) $q_{c1ncs})/ (N_1)_{60cs}Ic = 8.5 (1 – Ic/4.6)$ FC ≤ 5%: $\alpha = 0$, $\beta=1.0$ FC ≥ 35% $\alpha = 5.0$, $\beta=1.2$ 5% < FC < 35% $\alpha = \exp[1.76 – (190/FC^2)]$ $\beta = [0.99 + (FC^{1.5}/1000)]$	10 10 5
Su	Undrained shear strength - N_{kt} is user selectable	$Su = \frac{qt - \sigma_v}{N_{kt}}$	1, 5
k	Coefficient of permeability (assigned to each SBT zone)		5
Bq	Pore pressure parameter	$Bq = \frac{\Delta u}{qt - \sigma_v}$ *where:* $\Delta u = u - u_{eq}$ *and u = dynamic pore pressure* u_{eq} *= equilibrium pore pressure*	1, 5
Q_t	Normalized q_t for Soil Behavior Type classification as defined by Robertson, 1990	$Qt = \frac{qt - \sigma_v}{\sigma_v'}$	2, 5

Interpreted Parameter	Description	Equation	Ref
F_r	Normalized Friction Ratio for Soil Behavior Type classification as defined by Robertson, 1990	$Fr = 100\% \cdot \frac{fs}{qt - \sigma_v}$	2, 5
SBTn	Normalized Soil Behavior Type as defined by Robertson and Campanella	See Figure 2	2, 5
SBT-BQ	Non-normalized soil behavior type based on the Bq parameter	See Figure 5.7 (reference 5)	2, 5
SBT-BQn	Normalized Soil Behavior base on the Bq parameter	See Figure 5.8 (reference 5) or Figure 3 (reference 2)	2, 5
I_c	Soil index for estimating grain characteristics	$Ic = [(3.47 - \log_{10}Q)^2 + (\log_{10} Fr + 1.22)^2]^{0.5}$ *Where:* $Q = \left(\frac{qt - \sigma_v}{P_{a2}}\right)\left(\frac{P_a}{\sigma_v'}\right)^n$ *And* *Fr is in percent* P_a *= atmospheric pressure* P_{a2} *= atmospheric pressure* *n varies from 0.5 to 1.0 and is selected in an iterative manner based on the resulting* I_c	3, 8
FC	Apparent fines content (%)	*FC=1.75(*$Ic^{3.25}$*) - 3.7* *FC=100 for Ic > 3.5* *FC=0 for Ic < 1.26* *FC = 5% if 1.64 < Ic < 2.6 AND* F_r*<0.5*	3
Ic Zone	This parameter is the Soil Behavior Type zone based on the Ic parameter (valid for zones 2 through 7 on SBTn chart)	Ic < 1.31 Zone = 7 1.31 < Ic < 2.05 Zone = 6 2.05 < Ic < 2.60 Zone = 5 2.60 < Ic < 2.95 Zone = 4 2.95 < Ic < 3.60 Zone = 3 Ic > 3.60 Zone = 2	3
PHI ϕ	Friction Angle determined from one of the following user selectable options: a) Campanella and Robertson b) Durgunoglu and Mitchel c) Janbu d) Kulhawy and Mayne	See reference	5 5 5 11
Dr	Relative Density determined from one of the following user selectable options: a) Ticino Sand b) Hokksund Sand c) Schmertmann 1976 d) Jamiolkowski - All Sands	See reference	5
OCR	Over Consolidation Ratio	a) Based on Schmertmann's method involving a plot of S_u/σ_v' /(S_u/σ_v')$_{NC}$ and OCR where the Su/p' ratio for NC clay is user selectable	9
State Parameter	The state parameter is used to describe whether a soil is contractive (SP is positive) or dilative (SP is negative) at large strains based on the work by Been and Jefferies	See reference	8, 6, 5
Es/qt	Intermediate parameter for calculating Young's Modulus, E, in sands. It is the Y axis of the reference chart.	Based on Figure 5.59 in the reference	5

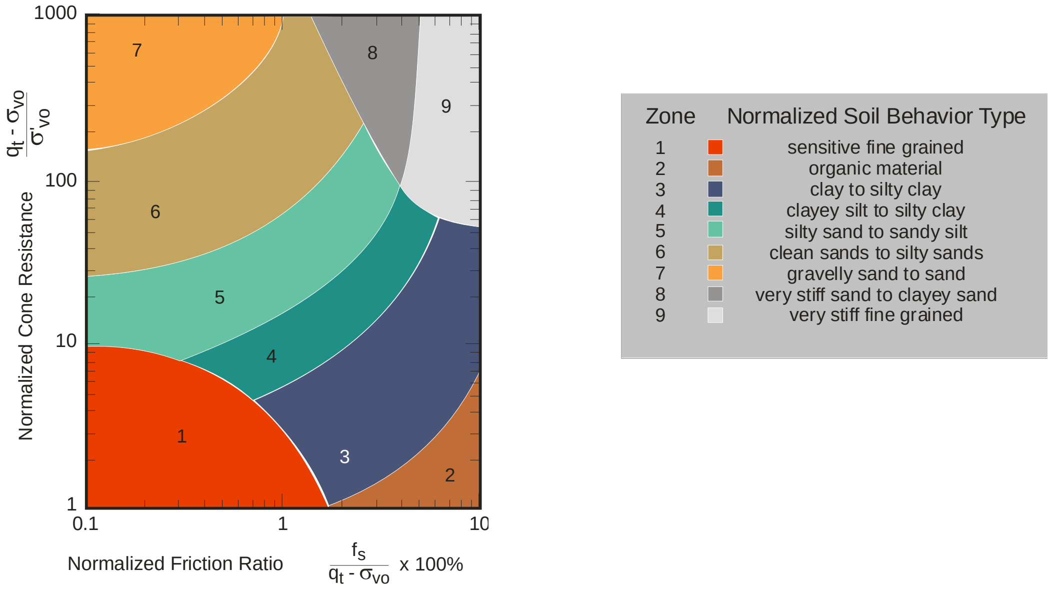
Interpreted Parameter	Description	Equation	Ref
Young's Modulus E	Young's Modulus based on the work done in Italy. There are three types of sands considered in this technique. The user selects the appropriate type for the site from: a) OC Sands b) Aged NC Sands c) Recent NC Sands Each sand type has a family of curves that depend on mean normal stress. The program calculates mean normal stress and linearly interpolates between the two extremes provided in the Es/qt chart.	Mean normal stress is evaluated from: $\sigma'_m = \frac{1}{3}\left(\sigma'_v + \sigma'_h + \sigma'_h\right)^3$ where σ_v'= vertical effective stress σ_h'= horizontal effective stress and $\sigma_h = K_o \cdot \sigma_v{}'$ with Ko assumed to be 0.5	5
q_{c1}	q_t normalized for overburden stress used for seismic analysis	$q_{c1} = q_t \cdot (Pa/\sigma_v')^{0.5}$ where: Pa = atm. Pressure q_t is in MPa	3
q_{c1n}	q_{c1} in dimensionless form used for seismic analysis	$q_{c1n} = (q_{c1} / Pa)(Pa/\sigma_v')^n$ where: Pa = atm. Pressure and n ranges from 0.5 to 0.75 based on Ic.	3
K_{SPT}	Equivalent clean sand factor for $(N_1)60$	$K_{SPT} = 1 + ((0.75/30) \cdot (FC – 5))$	10
K_{CPT}	Equivalent clean sand correction for q_{c1N}	$K_{cpt} = 1.0$ for $I_c \leq 1.64$ $K_{cpt} = f(I_c)$ for $I_c > 1.64$ (see reference)	10
q_{c1ncs}	Clean sand equivalent q_{c1n}	$q_{c1ncs} = q_{c1n} \cdot K_{cpt}$	3
CRR	Cyclic Resistance Ratio (for Magnitude 7.5)	$q_{c1ncs} < 50$: $CRR_{7.5} = 0.833\ [(q_{c1ncs}/1000] + 0.05$ $50 \leq q_{c1ncs} < 160$: $CRR_{7.5} = 93\ [(q_{c1ncs}/1000]^3 + 0.08$	10
CSR	Cyclic Stress Ratio	$CSR = (\tau_{av}/\sigma_v') = 0.65\ (a_{max} / g)\ (\sigma_v/ \sigma_v')\ r_d$ $r_d = 1.0 – 0.00765\ z$ $z \leq 9.15m$ $r_d = 1.174 – 0.0267\ z$ $9.15 < z \leq 23m$ $r_d = 0.744 – 0.008\ z$ $23 < z \leq 30m$ $r_d = 0.50$ $z > 30m$	10
MSF	Magnitude Scaling Factor	See Reference	10
FofS	Factor of Safety against Liquefaction	$FS = (CRR_{7.5} / CSR)\ MSF$	10
Liquefaction Status	Statement indicating possible liquefaction	Takes into account FofS and limitations based on I_c and q_{c1ncs}.	10



Zone		qt / N	Soil Behavior Type
1	🟥	2	sensitive fine grained
2	🟫	1	organic material
3	🟦	1	clay
4	🟦	1.5	silty clay to clay
5	🟩	2	clayey silt to silty clay
6	🟩	2.5	sandy silt to clayey silt
7	🟩	3	silty sand to sandy silt
8	🟨	4	sand to silty sand
9	🟫	5	sand
10	🟧	6	gravelly sand to sand
11	⬜	1	very stiff fine grained *
12	⬜	2	sand to clayey sand *

* overconsolidated or cemented

Figure 1 Non-Normalized Behavior Type Classification Chart



Zone		Normalized Soil Behavior Type
1	🟥	sensitive fine grained
2	🟫	organic material
3	🟦	clay to silty clay
4	🟩	clayey silt to silty clay
5	🟩	silty sand to sandy silt
6	🟫	clean sands to silty sands
7	🟧	gravelly sand to sand
8	⬜	very stiff sand to clayey sand
9	⬜	very stiff fine grained

Figure 2 Normalized Behavior Type Classification Chart

Table 2 References

No.	References
1	Robertson, P.K., Campanella, R.G., Gillespie, D. and Greig, J., 1986, “Use of Piezometer Cone Data”, Proceedings of InSitu 86, ASCE Specialty Conference, Blacksburg, Virginia.
2	Robertson, P.K., 1990, “Soil Classification Using the Cone Penetration Test”, Canadian Geotechnical Journal, Volume 27.
3	Robertson, P.K. and Fear, C.E., 1998, “Evaluating cyclic liquefaction potential using the cone penetration test”, Canadian Geotechnical Journal, 35: 442-459.
4	Robertson, P.K. and Wride, C.E., 1998, “Cyclic Liquefaction and its Evaluation Based on SPT and CPT”, NCEER Workshop Paper, January 22, 1997
5	Lunne, T., Robertson, P.K. and Powell, J. J. M., 1997, “ Cone Penetration Testing in Geotechnical Practice,” Blackie Academic and Professional.
6	Plewes, H.D., Davies, M.P. and Jefferies, M.G., 1992, “CPT Based Screening Procedure for Evaluating Liquefaction Susceptibility”, 45th Canadian Geotechnical Conference, Toronto, Ontario, October 1992.
7	Jefferies, M.G. and Davies, M.P., 1993. “Use of CPTu to Estimate equivalent N_{60}”, Geotechnical Testing Journal, 16(4): 458-467.
8	Been, K. and Jefferies, M.P., 1985, “A state parameter for sands”, Geotechnique, 35(2), 99-112.
9	Schmertmann, 1977, “Guidelines for Cone Penetration Test Performance and Design”, Federal Highway Administration Report FHWA-TS-78-209, U.S. Department of Transportation
10	Proceedings of theNCEER Workshop on Evaluation of Liquefaction Resistance of Soils, Salt LakeCity, 1996. Chaired by Leslie Youd. 11
11	Kulhawy, F.H. and Mayne, P.W. ,1990, Manual on Estimating Soil Properties for Foundation Design, *Report No. EL-6800*, Electric Power Research Institute, Palo Alto, CA, August 1990, 306 p.

APPENDIX J

CD Contents and File Formats

CD CONTENTS

The accompanying CD contains the following folders:

Folder	Contents
Ball Penetration Test Data	Ball Penetration Test Undrained Shear Strength Results in Excel format
CPT Data	CPT data files in ConeTec's traditional ASCII format / Excel format
PPD Data	CPT and Ball Penetrometer dissipation data files in Excel format
Interpretations	CPT Interpretations (NLI) in Excel format
Summaries	CPT, PPD, Ball Penetration Test, Vane Shear Test, CPT Assumed Unit Weight and Soil Sample summaries in Excel format
Sample Logs	Sample Logs in Excel format
Pdf\Report	Field Data Report and Appendices
Pdf\Plots	CPT, CPT Advanced, GCPT, PPD, Ball Penetration Test, and Vane Shear Test Plots
Pdf\summaries	CPT, PPD, Ball Penetration Test Data, Assumed Unit Weight, Soil Sample summaries and Vane Shear results in PDF format
Pdf\Sample Logs	Sample logs in PDF format
Pdf\Sample Pictures	Sample Pictures in PDF format

ConeTec Digital File Formats

CPT Data Files (COR Extension)

ConeTec data files are stored in ASCII text files that are readable by almost any text editor. ConeTec CPT data files are named such that the first 3 characters contain the job number; the next two characters are CP followed by two characters indicating the sounding number. The last 8th character position is reserved for the letters a, b, c, d etc to uniquely identify multiple soundings at the same location. The CPT sounding file has the extension COR, and the pore pressure dissipation file has the extension PPD or PPF. As an example, for job number 08-127 the first sounding will have file names 127CP01.COR and 127CP01.PPD.

The sounding (COR) file consists of the following components:

1. Two lines of header information
2. Data records
3. End of data marker
4. Units information

Header Lines

Line 1: Columns 1-6 may be blank or may indicate the version number of the recording software
Columns 7-21 contain the sounding Date and Time
Columns 22-36 contain the sounding Operator
Columns 51-100 contain extended Job Location information

Line 2: Columns 1-16 contain the Job Location
Columns 17-31 contain the Cone ID
Columns 32-47 contain the sounding number

Data Records

The data records contain 4 or more columns of data in floating point format. A comma (and spaces) separates each data item:

Column 1:	Sounding Depth (meters)
Column 2:	Tip (q_c) data (kPa)
Column 3:	Sleeve (f_s) data in (kPa)
Column 4:	Dynamic pore pressure (kPa) data)
Column 5:	Empty or may contain other requested data such as Gamma, Resistivity or UVIF data

End of Data Marker

After the last line of data there will be a line containing an ASCII 26 (CTL-Z) character (small rectangular shaped character) followed by a newline (carriage return / line feed). This is used to mark the end of data.

Units Information

The last section of the file contains information about the units that were selected for the sounding. A separator bar makes up the first line. The second line contains the type of units used for depth, q_c, f_s and u. The third line contains the conversion values required for ConeTec's software to convert the recorded data to an internal set of base units (bar for q_c, bar for f_s and meters for u).

CPT Dissipation Files (PPx Extension)

CPT Dissipation files have the same naming convention as the CPT sounding files and have the extension PPD, PPF or PPM. PPF (PPM and PPD) files consist of the following components:

1. Two lines of header information
2. Data records

Header Lines (same as COR file):

Line 1: Columns 1-6 may be blank or may indicate the version number of the recording software
Columns 7-21 contain the sounding Date and Time
Columns 22-36 contain the sounding Operator

Line 2: Columns 1-16 contain the Job Location
Columns 17-31 contain the Cone ID
Columns 32-47 contain the sounding number

Data Records

The data records immediately follow the header lines. Each data record can occupy several lines in the file and is a complete record of a dissipation test at a particular depth. Each data record starts with a line containing two values separated by spaces; the first value being an index number (not currently used by the Software) and the second being the dissipation test depth in meters. Following this line are the dissipation pore pressure values stored at 5 second intervals with a maximum of 12 entries per line. The last line of the dissipation record may not contain a full 12 entries. The data record is terminated with an ASCII 30 character (appears as a triangle in some editors).

This sequence is repeated for every dissipation test in the sounding. No marker is used to indicate end of file. Unit information is not stored in this file. Users need to check the CPT file for the units that were used.

CPT Basic Interpretations (TBL Extension)

ConeTec's basic CPT interpretation output files are generally delivered in text files with a TBL extension. The root file name is the same as the COR files. A number of calculated geotechnical parameters are presented in these files. The files are stored as ASCII text files that can be viewed using any text editor such as Notepad or Wordpad. The files do not contain any page formatting. These files are not distributed if the enhanced interpretation files are provided.

CPT Enhanced Interpretations (IFI, IFP, XLS Extension)

ConeTec's enhanced CPT interpretation output files are delivered in several formats, each file type containing the exact same information but formatted slightly differently. The files typically have any of the following file extensions:

1. IFI an importable TAB delimited ASCII text file containing approximately 47 data columns of geotechnical interpretations. The file is designed for easy import to Excel. A companion document describes the techniques used for the interpretations (usually reproduced at the beginning of the Interpretation Appendix). Text editors can be used to view the file contents, however, they may remove the tabs or replace the tabs with spaces upon saving the file destroying the feature that makes them easy to import into Excel.

   Because Excel imports the data as text and the sheet is protected two steps may be necessary to modify the data or use the values in certain Excel functions:

   a) Under Tools (Excel 2000) Select the Protection Option and then Unprotect the sheet
   b) Select the entire sheet, copy and then use Paste Special to paste as values to a second sheet.

   Future versions of our interpretation routine will address these inconveniences.

2. IFP a printable ASCII text file containing the same 47 columns of geotechnical interpretations as the IFI file. This file type has been formatted as a multi-page document with up to 132 characters per line and up to 68 lines per page. Each page has been separated into multiple sections to accommodate all the data fields. Each physical page has a header section and a page/section number. The file is designed for direct printing to laser printers set into compressed font mode. This output is typically provided in the Interpretation Appendix.

   An abbreviated set of interpretations (containing 36 columns of output) may be generated instead. These files usually have the extensions NLI and NLP. XLS files can be generated from these as well.

3. XLS an Excel format file that has been generated directly from the corresponding IFI file. IFI and IFP files are not distributed if the XLS files are generated. The XLS files may have been generated from abbreviated NLI interpretation files.

In each case root file name is the same as the COR files.

CPT Interpretations (Excel Format)

ConeTec's latest software (September 2007) outputs CPT interpretations directly to Excel format (XLS extension) without creating intermediate ASCII files. Because of the desires of various clients, there are several different configurations of output parameters in ConeTec's interpretation files. Since the Excel format file must have the XLS extension a suffix is used after the base name of the source CPT data file (COR) to identify the format of the file. The configurations still follow the formats described above and use the same extensions but now as suffixes. To allow for various runs (e.g. using a different water table, or user supplied equilibrium profile, or different methods for a particular parameter) of the same data an additional suffix may be specified by the engineer post processing the data to identify each particular run. This suffix will follow the one used to identify the format of the file.

For example:

If the selected format is ConeTec's TBL configuration and each run is identified by a run number. The resultant files generated for 278CP01.COR would be:

78CP01-TBL-RUN01.XLS
78CP01-TBL-RUN02.XLS
78CP01-TBL-RUN03.XLS

CPT Data in Excel Format

ConeTec can now provide the equivalent of the ASCII COR files in Excel Format. These files will have the same base name as the COR files and an XLS extension.

Pore Pressure Dissipation Data in Excel Format

ConeTec can now provide the equivalent of the ASCII PPD format files in Excel format. These files will contain each dissipation trace that exceeds a minimum duration (selected by the engineer during post-processing) in a particular Excel spreadsheet column. The first column (Column A) will contain the time in seconds and the second column (Column B) will contain the time in minutes. Subsequent columns will contain dissipation trace data. The time columns will extend to the longest trace of the data set.

Detailed header information is provided at the top of the spreadsheet. The test depth in meters and feet, the number of points in the trace and the particular units are identified at the top of each trace column.

The Excel format file names will have the same base name as the original PPD format file followed by the suffix -PPD and then followed by a second suffix that the engineer doing the post processing can specify. Because the engineer can select various types of units for the dissipation data output (which can be different from the units used in the original recording) the secondary suffix is often used to identify the units in the XLS file, however, the original recorded units and the output units are clearly identified within the XLS spreadsheet file.

APPENDIX C

Mineralogy

AGAT Laboratories

AMEC Earth & Environmental

COMBINED BULK AND CLAY XRD ANALYSES OF FOUR MUD SAMPLES IDENTIFIED AS 'BH 10-05 (12m), BH 10-05 (8m), BH 10-06 (12m) AND BH 10-04 (10m)'

Work Order A 14977

April, 2011

AGAT Laboratories Ltd.

3801 - 21 Street N.E.

Calgary, Alberta

T2E 6T5

COMBINED X-RAY DIFFRACTION ANALYSIS

Four mud-like samples identified as BH 10-05 (12m), BH 10-05 (8m), BH 10-06 (12m) and BH 10-04 (10m) were analyzed by AGAT Laboratories Ltd. for bulk and clay XRD mineralogy. The samples were cleaned of water and any hydrocarbons prior analysis and "cleaned" solids were analyzed. The samples were examined using XRD technique to determine their crystalline mineralogical composition.

In order to separate the particles less than 3μm (clay fraction) from the bulk fraction, the samples were treated in an ultrasonic bath using sodium metaphosphate as a deflocculating agent. The materials were then centrifuged at different speed, which separates the clay fraction from the bulk materials. Weight fraction was measured for both bulk and clay portions of the samples.

The combined bulk and clay XRD results (Table 1) indicate that the samples consist mainly of clinochrysotile (13%-29%) [magnesium iron silicate hydroxide, $(Mg,Fe)_3Si_2O_5(OH)_4$], calcite (11% to 22%) [calcium carbonate, $(CaCO_3)$], quartz (16% to 20%) [silicon dioxide, SiO_2] and plagioclase feldspar (20%, **only in sample #2**) [sodium aluminum silicate, $Na(AlSi_3O_8)$]. Lesser amounts of dolomite (6% to 11%) [magnesium calcium carbonate, $CaMg(CO_3)_2$], smectite (7% to 11%) [$(1/2\ Ca,Na)0.7(Al,Mg,Fe)_4\ (Si,Al)_8O_{20}(OH)4.nH_2O$], siderite (4% to 10%) [iron carbonate, $FeCO_3$], pyrite (5% to 9%) [iron sulfide, FeS_2], illite (1% & 7%) [potassium aluminum silicate hydroxide, $KAl_2(OH)_2AlSi_3(O,OH)_{10}$], potassium feldspar (6%, **only in sample #4**) (potassium aluminum silicate, $K[SiAl_3O_8]$ and muscovite (3% to 4%) [$K_2Al_4[Si_6Al_2O_{20}](OH,F)_4$] are also detected.

The clay fraction (<3μm) weights are 13.38% and 22.15% respectively of the total rock volume. The clay fraction XRD (Table 1) results indicate that these clay fraction samples consist mainly of smectite (40% & 78%), with lesser amounts of clinochrysotile (9% to 40%) and calcite (2% to 10%). A minor amount of illite (1% to 7%) is also present.

The analyses indicate that these samples are composed of sand/silt/clay (quartz, calcite, semctite, dolomite, albite, microcline, pyrite, siderite and illite – formation materials) and serpentine (clinochrysoltile). Moderate amounts of smectite means that the samples are sensitive to swelling and significant volume increase when in the presence of fresh water. This swelling clay smectite would increase the ductile (plasticity) nature of these mud samples. The calcite could be from limestone or precipitated from calcium rich ground water. Siderite could be a daigenitic cement in shale or sandstone or iron corrosion product associated with water corroding an iron source.

Table 1- Summary of XRD Analysis

Company: **AMEC Earth & Environmental** **Work Order No. A-14977**
Location: **April, 2011**

SAMPLE ID.	TYPE OF ANALYSIS	WEIGHT %											←		CLAYS		→	Total
			Qtz	Plag	K-Feld	Cal	Dol	Chryso	Pyr	Musc	Bar	Sider	Kaol	Chl	Ill	ML	Smec	Clay
1	BULK FRACTION:	82.19	17	0	0	24	7	26	9	5	0	11	0	0	0	0	0	0
BH 10-05	CLAY FRACTION:	17.81	5	0	0	10	0	40	0	0	0	0	0	0	5	0	40	45
(12m)	BULK & CLAY	100	17	0	0	21	6	29	7	4	0	9	0	0	1	0	7	8
2	BULK FRACTION:	86.62	23	23	0	13	8	13	6	3	0	11	0	0	0	0	0	0
BH 10-05	CLAY FRACTION:	13.38	3	0	0	2	0	12	0	0	0	0	0	0	11	0	71	82
(8m)	BULK & CLAY	100	20	20	0	11	7	13	5	3	0	10	0	0	1	0	10	11
3	BULK FRACTION:	86.09	22	0	0	25	9	18	11	5	0	10	0	0	0	0	0	0
BH 10-06	CLAY FRACTION:	13.91	2	0	0	2	0	9	0	0	0	0	0	0	8	0	78	86
(12m)	BULK & CLAY	100	19	0	0	22	8	17	9	4	0	9	0	0	1	0	11	12
4	BULK FRACTION:	77.85	20	0	7	21	13	21	8	5	0	5	0	0	0	0	0	0
BH 10-04	CLAY FRACTION:	22.15	2	0	0	3	0	14	0	0	0	0	0	0	30	0	51	81
(10m)	BULK & CLAY	100	16	0	6	17	10	19	6	4	0	4	0	0	7	0	11	18

Table 1- Summary of XRD Analysis

Company: **AMEC Earth & Environmental** **Work Order No. A-14977**

Location: **April, 2011**

SAMPLE ID.	TYPE OF ANALYSIS	WEIGHT %	Qtz	Plag	K-Feld	Cal	Dol	Chryso	Pyr	Musc	Bar	Sider	← CLAYS → Kaol	Chl	Ill	ML	Smec	Total Clay
1	BULK FRACTION:	82.19	17	0	0	24	7	26	9	5	0	11	0	0	0	0	0	0
BH 10-05	CLAY FRACTION:	17.81	5	0	0	10	0	40	0	0	0	0	0	0	5	0	40	45
(12m)	BULK & CLAY	100	17	0	0	21	6	29	7	4	0	9	0	0	1	0	7	8
2	BULK FRACTION:	86.62	23	23	0	13	8	13	6	3	0	11	0	0	0	0	0	0
BH 10-05	CLAY FRACTION:	13.38	3	0	0	2	0	12	0	0	0	0	0	0	11	0	71	82
(8m)	BULK & CLAY	100	20	20	0	11	7	13	5	3	0	10	0	0	1	0	10	11
3	BULK FRACTION:	86.09	22	0	0	25	9	18	11	5	0	10	0	0	0	0	0	0
BH 10-06	CLAY FRACTION:	13.91	2	0	0	2	0	9	0	0	0	0	0	0	8	0	78	86
(12m)	BULK & CLAY	100	19	0	0	22	8	17	9	4	0	9	0	0	1	0	11	12
4	BULK FRACTION:	77.85	20	0	7	21	13	21	8	5	0	5	0	0	0	0	0	0
BH 10-04	CLAY FRACTION:	22.15	2	0	0	3	0	14	0	0	0	0	0	0	30	0	51	81
(10m)	BULK & CLAY	100	16	0	6	17	10	19	6	4	0	4	0	0	7	0	11	18

XRD LEGEND

- XRD Analysis is semi-quantitative (approx. 10% at best) and identifies only crystalline substances; amorphous (non-crystalline) substances will not be detected.
- Bulk Fraction – greater than 3 micron size fraction.
- Clay Fraction – less than 3 micron size fraction.
- Bulk and Clay – mathematical recalculation including the bulk and clay fraction representing the whole sample.
- Total Clay – sum of the clay minerals (may include authigenic and matrix clays plus clays in rock fragments).

ABBREVIATIONS

Amp - Amphiboles
Ana - Analcime
Anhy- Anhydrite
Ank - Ankerite
Apa - Apatite
Bar - Barite
Cal - Calcite
Chl - Chlorite
Chryso - Clinochrysotile

Dol - Dolomite
Gyp - Gypsum
Hal - Halite
Hem - Hematite
Ill - Illite
Kaol - Kaolinite
K-Feld- Potassic Feldspar
Mack - Mackinawite

Marc - Marcasite
ML* - Illite-Smectite
ML** - Corrensite (chlorite-smectite)
Plag - Plagioclase Feldspar
Pyr - Pyrite
Qtz - Quartz
Sider - Siderite
Smec - Smectite (montmorillonite)

Pr - Pure (95 – 100%)
NPr - Near Pure (90 – 95%)
Abnt - Abundant (60 – 90%)
Com - Common (30 – 60%)
Mnr - Minor (10 – 30%)
Rre - Rare (1 – 10%)
Tr - Trace; detectable, but not measurable (0 – 1%)

AGAT Laboratories

Page 1 of 1

AGAT® Laboratories

2910 - 12 Street N.E.
Calgary, Alberta
T2E 7P7

Tel: (403) 735-2005
Fax: (403) 735-2770

AMEC
MAY 16 2011
RECEIVED

INVOICE NO. 11K04010H

Date: 10/May/11

GST #: R100073238

Customer No	WorkOrder No	Branch	Customer P.O.	Division ID	AFE	Acct Code	District	Product
3535516	11C481429	C		10				0

Product ID	Product Description	Quantity	Unit Price	Extended Price
	RE: Project number VM00503.PKC.3 BH 10-05,BH 10-06,BH 10-04			
04-603	Dean Stark - large extractor for cleaning	4.00	$60.00	$240.00
11-202	Combined XRD analysis	4.00	$400.00	$1,600.00
39-105	Hard Copy Report and Invoice Delivery Costs	1.00	$8.00	$8.00
39-200	Environmental Waste Disposal, per sample	1.00	$11.00	$11.00
			Subtotal:	$1,859.00
			GST:	$92.95
			Total:	**$1,951.95**

****

Should you require any information regarding this analysis, please contact a Technical Service Rep @ (403) 299-2000 or Toll Free @ 1-800-661-7174

We appreciate and welcome your feedback which can be provided by submitting a Client Review at http://www.agatlabs.com/content/clientreview.htm

****

TERMS: NET 30 DAYS . INTEREST CHARGED ON OVERDUE ACCOUNTS AT THE RATE OF 2% PER MONTH (24% PER ANNUM).

Project	Phase	Task	Org.	GL	Amount ($)
VM100503	PKC.3		~~2210~~		
Pay When	Yes	☐	GST	2603-20	92.95
Paid	No	☐	HST	2603-21	
Vendor No.			QST	2604-06	
Approval		Date		Total	1951.95

FORWARDED TO OPS
MAY 18 2011

Corporate Office:

AMEC
140 QUARRY PARK BOULEVARD
Calgary AB T2C3G3

Invoice To:

AMEC EARTH & ENVIRONMENTAL
5681 - 70 STREET
EDMONTON AB T6B3P6

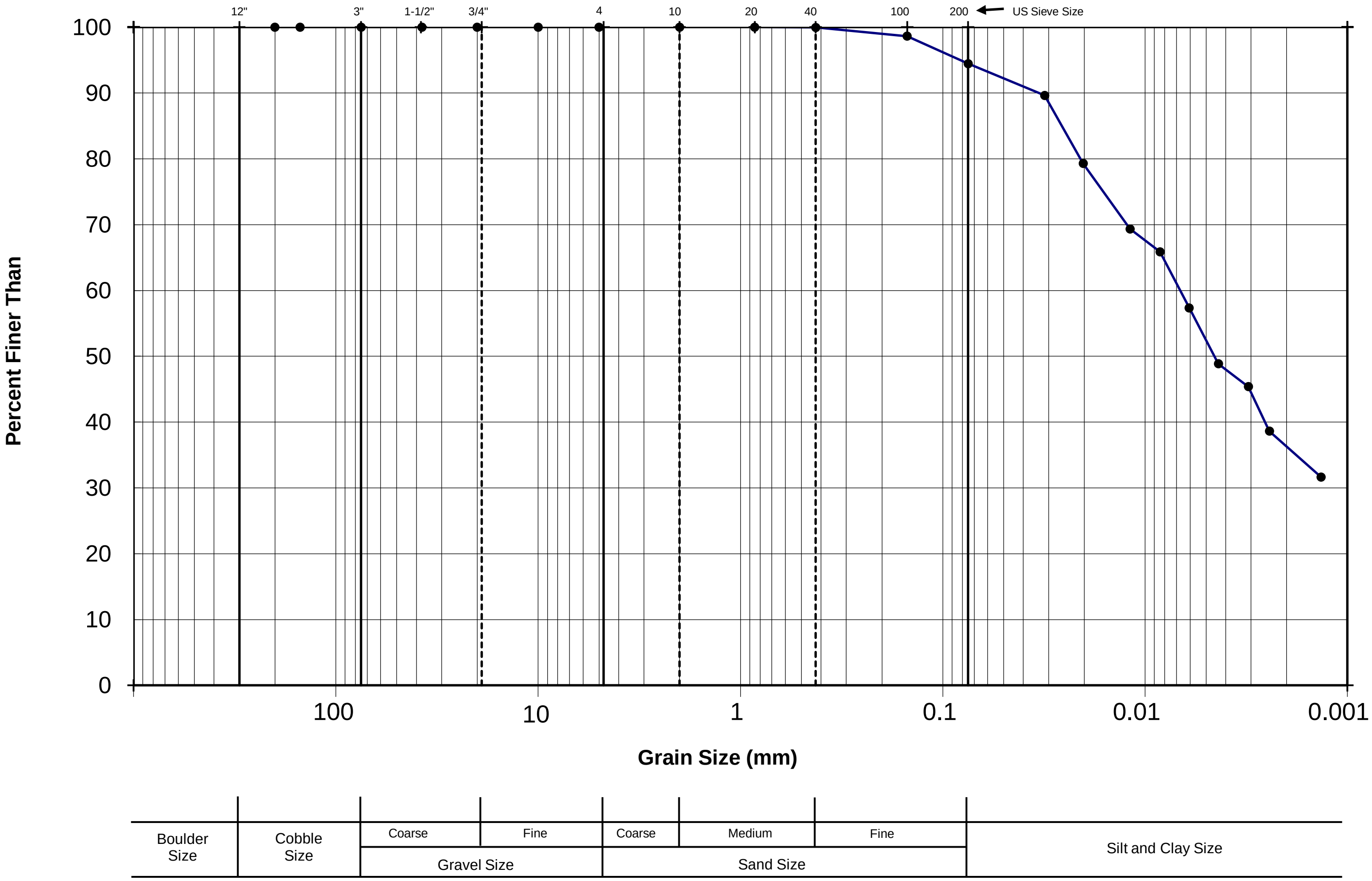
Attn To: Stephen Horsley

APPENDIX D

Grain Size Testing (Sieve and Hydrometer)

PARTICLE SIZE ANALYSIS OF SOIL
(ASTM D422)

Project No.: 11-1359-0001 Lab No.: 999201
Project Title: AMEC E&E/Lab Testing
Borehole: 10-05 Sample No.: 2
Depth: 8.0 m
Date Tested: 17-Feb-11 By: CG/AR



Diameter of Sieve (mm)	Percent Passing (%)
200.0	100.0
150.0	100.0
75.0	100.0
37.5	100.0
20.0	100.0
10.0	100.0
5.00	100.0
2.0	100.0
0.850	100.0
0.425	100.0
0.150	98.6
0.075	94.5
0.031	89.6
0.020	79.3
0.012	69.4
0.008	65.9
0.006	57.4
0.004	48.9
0.003	45.4
0.002	38.6
0.001	31.6

Comments:

Reviewed:

PARTICLE SIZE ANALYSIS OF SOIL

(ASTM D422)

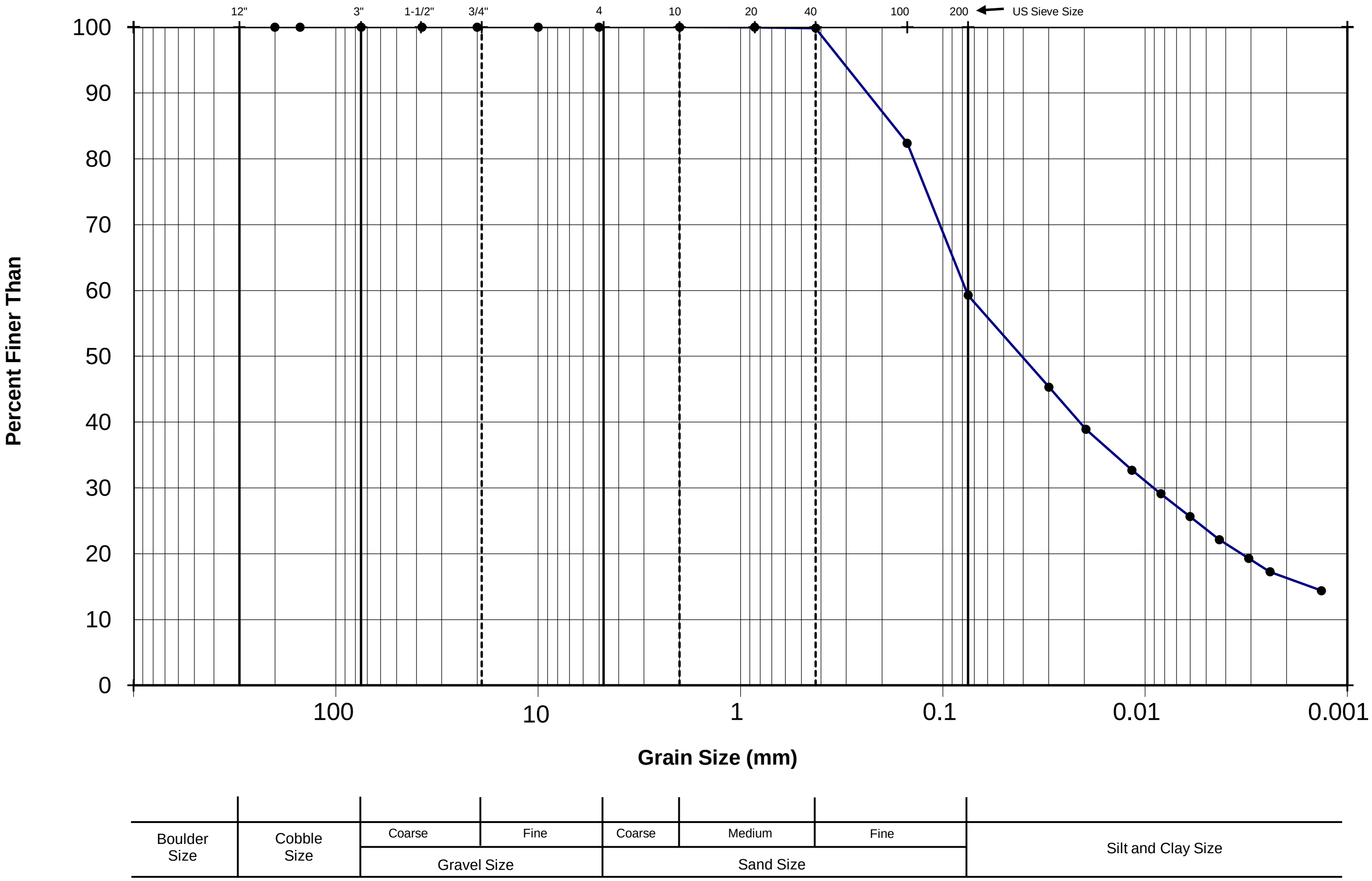
Project No.: 11-1359-0001 Lab No.: 999202

Project Title: AMEC E&E/Lab Testing

Borehole: 10-06 Sample No.: 12

Depth: 17.0 m

Date Tested: 17-Feb-11 By: CG/AR



Diameter of Sieve (mm)	Percent Passing (%)
200.0	100.0
150.0	100.0
75.0	100.0
37.5	100.0
20.0	100.0
10.0	100.0
5.00	100.0
2.0	100.0
0.850	100.0
0.425	99.8
0.150	82.4
0.075	59.3
0.030	45.3
0.020	38.9
0.012	32.7
0.008	29.1
0.006	25.6
0.004	22.2
0.003	19.3
0.002	17.2
0.001	14.4

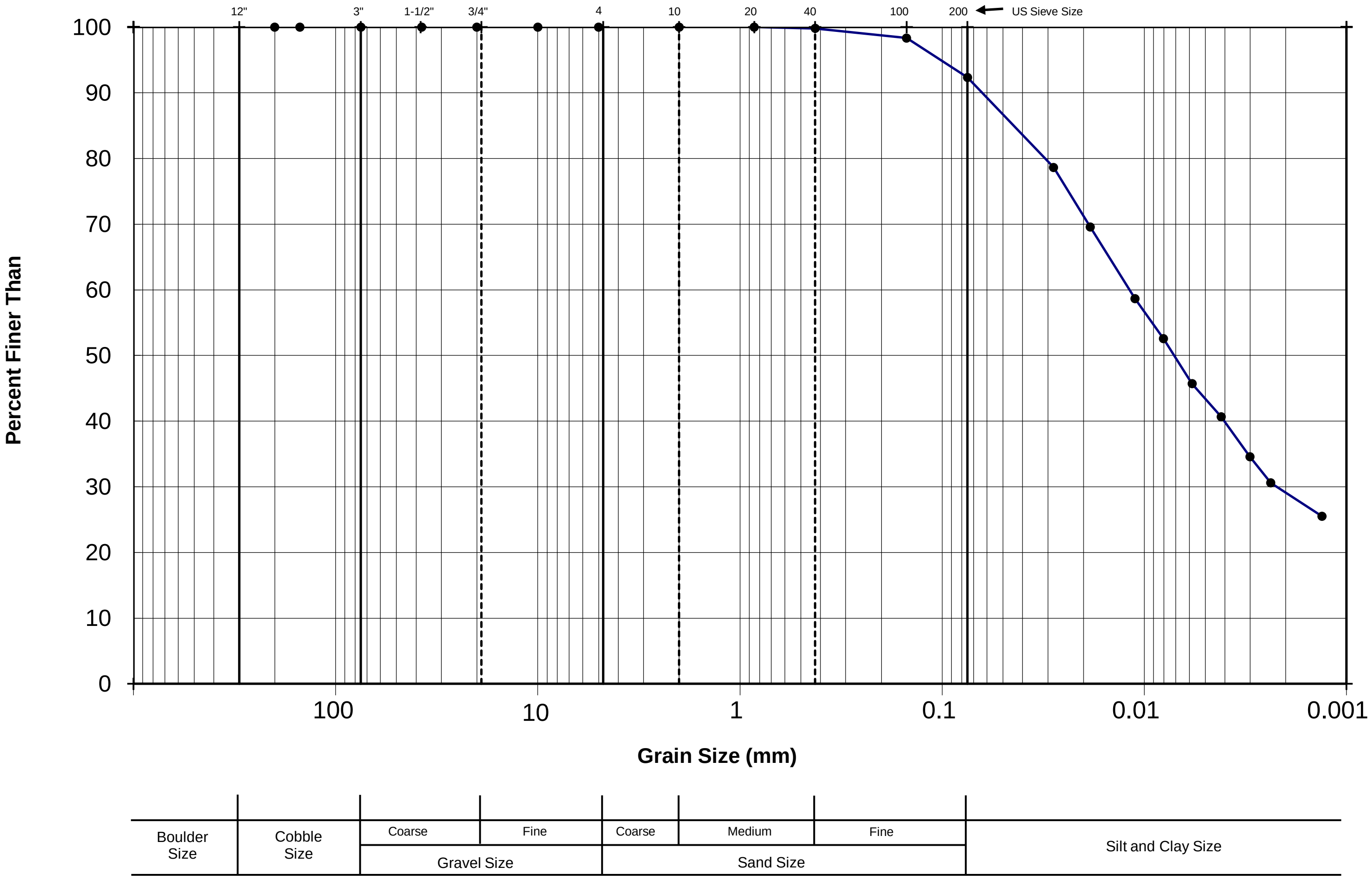
Comments:

Reviewed:

Project No.: 11-1359-0001 Lab No.: 999203
Project Title: AMEC E&E/Lab Testing
Borehole: 10-04 Sample No.: 17
Depth: 13.0 m
Date Tested: 17-Feb-11 By: CG/AR

PARTICLE SIZE ANALYSIS OF SOIL

(ASTM D422)



Diameter of Sieve (mm)	Percent Passing (%)
200.0	100.0
150.0	100.0
75.0	100.0
37.5	100.0
20.0	100.0
10.0	100.0
5.00	100.0
2.0	100.0
0.850	100.0
0.425	99.8
0.150	98.3
0.075	92.4
0.028	78.6
0.018	69.6
0.011	58.6
0.008	52.6
0.006	45.7
0.004	40.7
0.003	34.6
0.002	30.6
0.001	25.5

Comments:

Reviewed:

amec

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE
Project No.	VM00503.PKC.3
Lab No.	S-9383
Sample	SAMPLE 1
Hole	BH10-04
Depth	6.0 m
Technician	CR/SH
Date	2-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 2

Air Dried Wt. of Soil Tested 45.3 g Dry Wt. of Soil Tested 45.3

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 1-Feb-11

Mechanical Sieve Results

Total Wt of Sample Dry 96.0 g

+ # 10 0.0 g

- # 10 96.0 g

Hydrometer Test

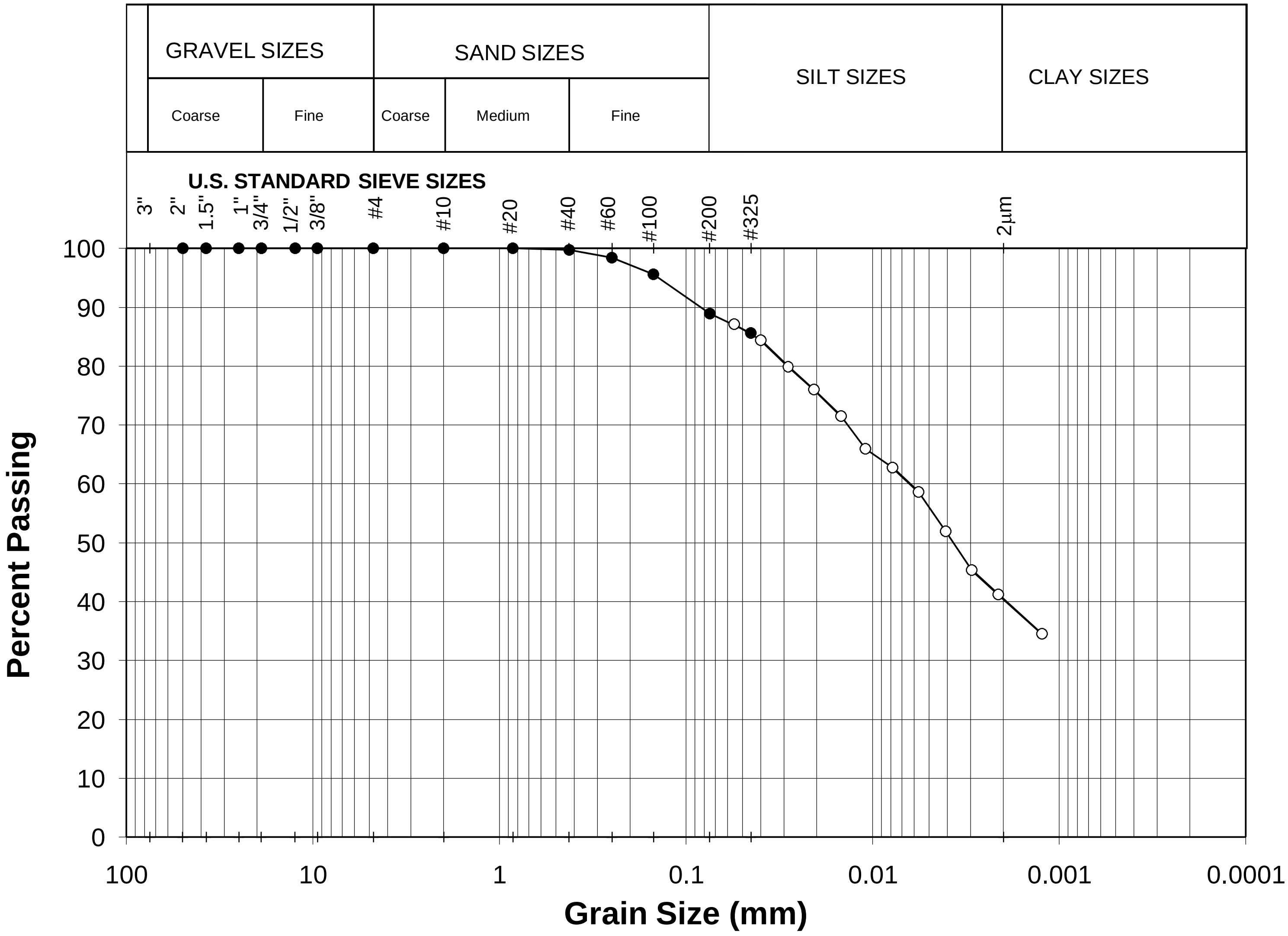
(Adjusted for + # 10 Material)

Total Dry Wt. 45.3 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		96.00	100	10	2.000		45.30	100
1 1/2 in.	37.5		96.00	100	20	0.850		45.30	100
1 in.	25.0		96.00	100	40	0.425	0.1	45.20	100
3/4 in.	19.0		96.00	100	60	0.250	0.6	44.60	98
1/2 in.	12.5		96.00	100	100	0.150	1.3	43.30	96
3/8 in.	9.5		96.00	100	200	0.075	3.0	40.30	89
4	4.8		96.00	100	325	0.045	1.5	38.80	86
10	2.0		96.00	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. ^oC	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/2/2011	8:42:00	0							
2/2/2011	8:42:30	0.5	28.1	22.0	8.9	3.0753	25.0247	0.0554	87
2/2/2011	8:43:00	1	27.3	22.0	9.2	3.0753	24.2247	0.0398	84
2/2/2011	8:44:00	2	26.0	22.0	9.4	3.0753	22.9247	0.0284	80
2/2/2011	8:46:00	4	24.9	22.0	10.0	3.0753	21.8247	0.0207	76
2/2/2011	8:50:00	8	23.6	22.0	10.2	3.0753	20.5247	0.0148	71
2/2/2011	8:57:00	15	22.0	22.0	10.5	3.0753	18.9247	0.0110	66
2/2/2011	9:12:00	30	21.1	22.0	10.7	3.0753	18.0247	0.0078	63
2/2/2011	9:42:00	60	19.9	22.0	11.3	3.0753	16.8247	0.0057	59
2/2/2011	10:42:00	120	18.0	22.0	11.5	3.0753	14.9247	0.0041	52
2/2/2011	12:42:00	240	16.1	22.0	12.1	3.0753	13.0247	0.0029	45
2/2/2011	16:42:00	480	14.9	22.0	12.6	3.0753	11.8247	0.0021	41
2/3/2011	8:42:00	1440	13.0	22.0	12.9	3.0753	9.9247	0.0012	35



Remarks	SUMMARY			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	#N/A	Sand	11.0 %
	D_{50} =	0.004	Silt Sizes	48.7 %
	D_{60} =	0.006	Clay Sizes	40.3 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

amec

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-04	Depth	6.0 m
Technician	CR/SH	Date	2-Feb-11

amec

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-04	Depth	10.0 m
Technician	CR/SH	Date	1-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 17

Air Dried Wt. of Soil Tested 50.1 g Dry Wt. of Soil Tested 50.1

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 31-Jan-11

Mechanical Sieve Results

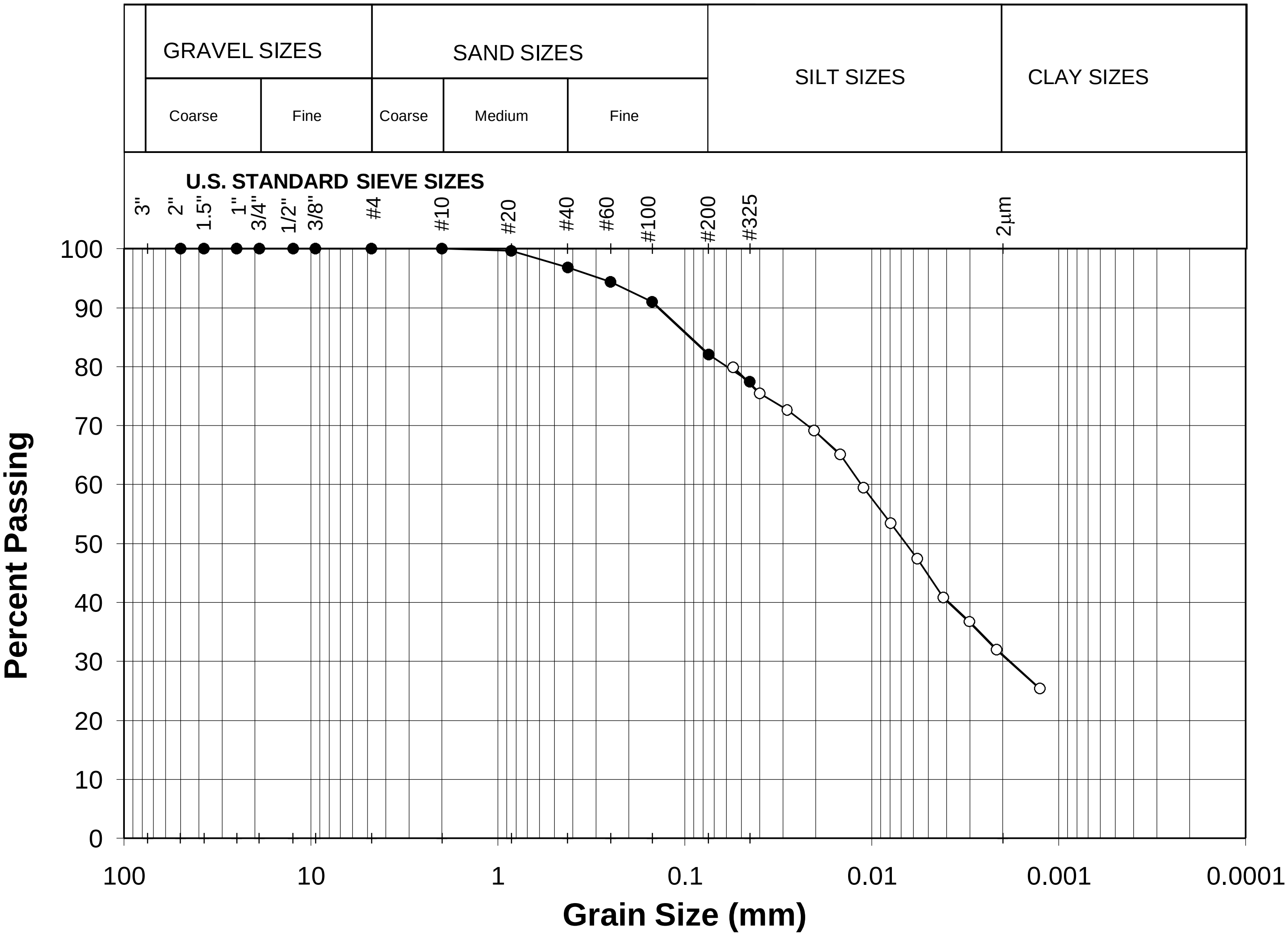
Total Wt of Sample Dry 118.1 g
+ # 10 0.0 g
- # 10 118.1 g

Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 50.1 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		118.10	100	10	2.000		50.10	100
1 1/2 in.	37.5		118.10	100	20	0.850	0.2	49.90	100
1 in.	25.0		118.10	100	40	0.425	1.4	48.50	97
3/4 in.	19.0		118.10	100	60	0.250	1.2	47.30	94
1/2 in.	12.5		118.10	100	100	0.150	1.7	45.60	91
3/8 in.	9.5		118.10	100	200	0.075	4.5	41.10	82
4	4.8		118.10	100	325	0.045	2.3	38.80	77
10	2.0		118.10	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. °C	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/1/2011	8:42:00	0							
2/1/2011	8:42:30	0.5	28.4	22.2	8.9	3.0296	25.3704	0.0554	80
2/1/2011	8:43:00	1	27.0	22.2	9.2	3.0296	23.9704	0.0398	76
2/1/2011	8:44:00	2	26.1	22.2	9.4	3.0296	23.0704	0.0284	73
2/1/2011	8:46:00	4	25.0	22.2	9.7	3.0296	21.9704	0.0204	69
2/1/2011	8:50:00	8	23.7	22.2	10.2	3.0296	20.6704	0.0148	65
2/1/2011	8:57:00	15	21.9	22.2	10.7	3.0296	18.8704	0.0111	59
2/1/2011	9:12:00	30	20.0	22.2	11.0	3.0296	16.9704	0.0079	53
2/1/2011	9:42:00	60	18.1	22.2	11.5	3.0296	15.0704	0.0057	47
2/1/2011	10:42:00	120	16.0	22.2	12.1	3.0296	12.9704	0.0042	41
2/1/2011	12:42:00	240	14.7	22.2	12.6	3.0296	11.6704	0.0030	37
2/1/2011	16:42:00	480	13.2	22.2	12.9	3.0296	10.1704	0.0022	32
2/2/2011	8:42:00	1440	11.1	22.2	13.4	3.0296	8.0704	0.0013	25



Remarks	SUMMARY			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	0.002	Sand	18.0 %
	D_{50} =	0.007	Silt Sizes	51.1 %
	D_{60} =	0.011	Clay Sizes	30.9 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

amec

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-04	Depth	10.0 m
Technician	CR/SH	Date	1-Feb-11

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-04	Depth	13.0 m
Technician	CR/SH	Date	1-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 27

Air Dried Wt. of Soil Tested 50.4 g Dry Wt. of Soil Tested 50.4

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 31-Jan-11

Mechanical Sieve Results

Total Wt of Sample Dry 264.0 g
+ # 10 0.0 g
- # 10 264.0 g

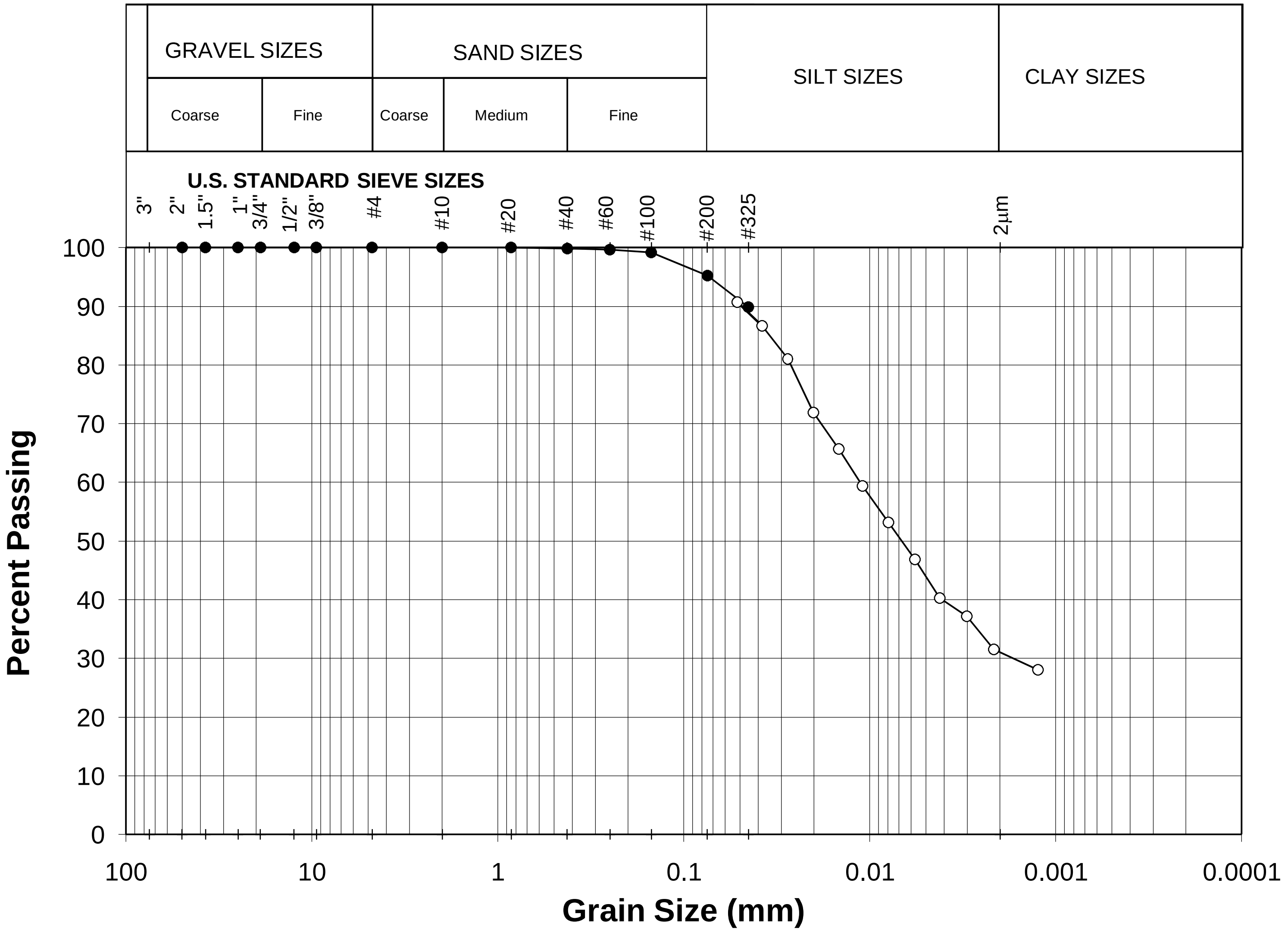
Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 50.4 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		264.00	100	10	2.000		50.40	100
1 1/2 in.	37.5		264.00	100	20	0.850		50.40	100
1 in.	25.0		264.00	100	40	0.425	0.1	50.30	100
3/4 in.	19.0		264.00	100	60	0.250	0.1	50.20	100
1/2 in.	12.5		264.00	100	100	0.150	0.2	50.00	99
3/8 in.	9.5		264.00	100	200	0.075	2.0	48.00	95
4	4.8		264.00	100	325	0.045	2.7	45.30	90
10	2.0		264.00	100	pan				

0.0

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. ^oC	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/1/2011	8:42:00	0							
2/1/2011	8:42:30	0.5	32.0	22.2	7.8	3.0296	28.9704	0.0518	91
2/1/2011	8:43:00	1	30.7	22.2	8.4	3.0296	27.6704	0.0380	87
2/1/2011	8:44:00	2	28.9	22.2	8.9	3.0296	25.8704	0.0277	81
2/1/2011	8:46:00	4	26.0	22.2	9.4	3.0296	22.9704	0.0201	72
2/1/2011	8:50:00	8	24.0	22.2	10.0	3.0296	20.9704	0.0147	66
2/1/2011	8:57:00	15	22.0	22.2	10.5	3.0296	18.9704	0.0110	59
2/1/2011	9:12:00	30	20.0	22.2	11.0	3.0296	16.9704	0.0079	53
2/1/2011	9:42:00	60	18.0	22.2	11.5	3.0296	14.9704	0.0057	47
2/1/2011	10:42:00	120	15.9	22.2	12.3	3.0296	12.8704	0.0042	40
2/1/2011	12:42:00	240	14.9	22.2	12.6	3.0296	11.8704	0.0030	37
2/1/2011	16:42:00	480	13.1	22.2	12.9	3.0296	10.0704	0.0022	32
2/2/2011	8:42:00	1440	12.0	22.2	13.1	3.0296	8.9704	0.0013	28



Remarks	SUMMARY			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	0.002	Sand	4.8 %
	D_{50} =	0.007	Silt Sizes	64.3 %
	D_{60} =	0.011	Clay Sizes	31.0 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-04	Depth	13.0 m
Technician	CR/SH	Date	1-Feb-11

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-04	Depth	15.0 m
Technician	CR/SH	Date	2-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 7

Air Dried Wt. of Soil Tested 50.2 g Dry Wt. of Soil Tested 50.2

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 1-Feb-11

Mechanical Sieve Results

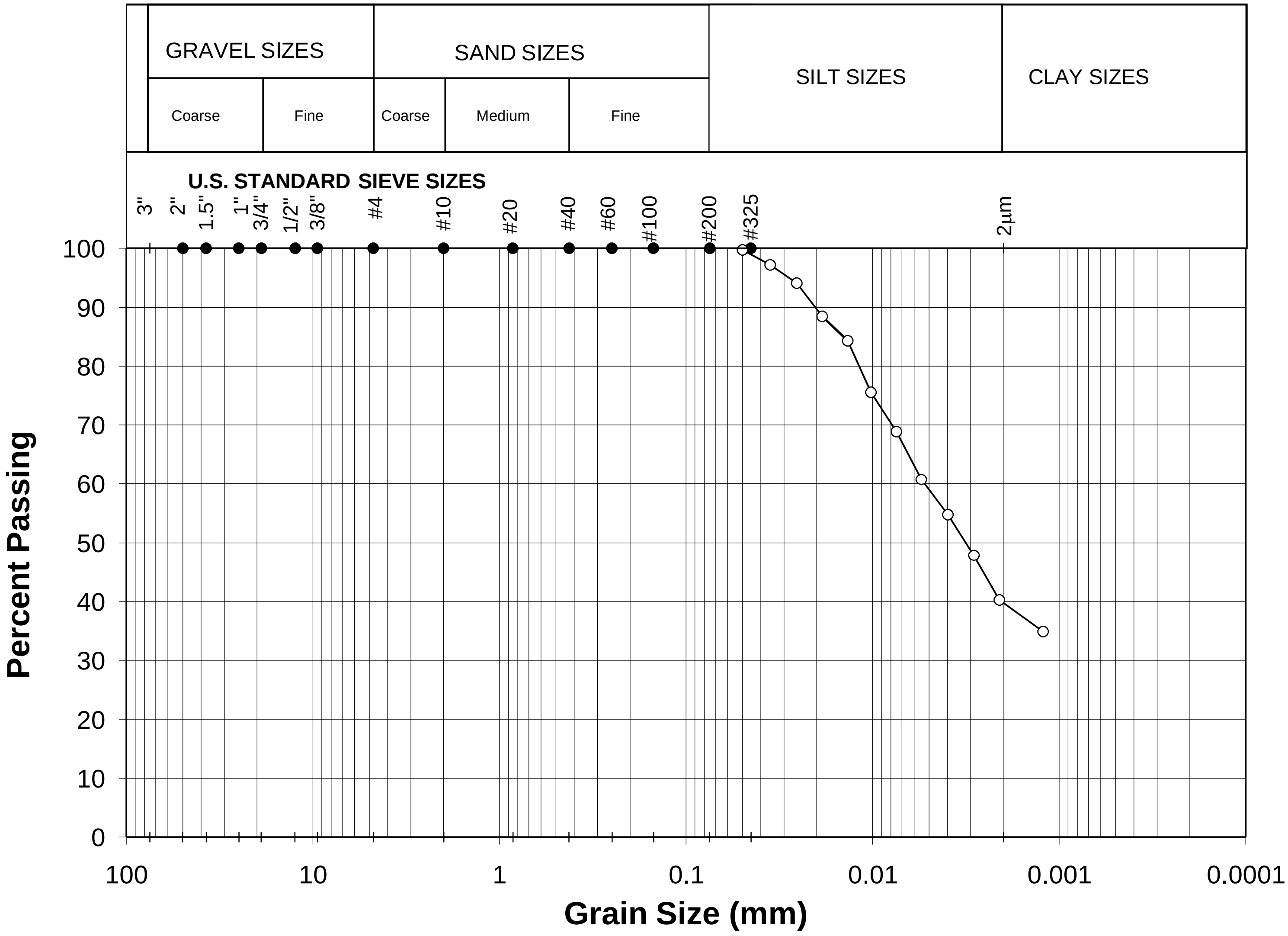
Total Wt of Sample Dry 179.6 g
+ # 10 0.0 g
- # 10 179.6 g

Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 50.2 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		179.60	100	10	2.000		50.20	100
1 1/2 in.	37.5		179.60	100	20	0.850		50.20	100
1 in.	25.0		179.60	100	40	0.425		50.20	100
3/4 in.	19.0		179.60	100	60	0.250		50.20	100
1/2 in.	12.5		179.60	100	100	0.150		50.20	100
3/8 in.	9.5		179.60	100	200	0.075		50.20	100
4	4.8		179.60	100	325	0.045		50.20	100
10	2.0		179.60	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. °C	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/2/2011	8:42:00	0							
2/2/2011	8:42:30	0.5	34.8	22.0	7.3	3.0753	31.7247	0.0501	100
2/2/2011	8:43:00	1	34.0	22.0	7.3	3.0753	30.9247	0.0354	97
2/2/2011	8:44:00	2	33.0	22.0	7.6	3.0753	29.9247	0.0256	94
2/2/2011	8:46:00	4	31.2	22.0	8.1	3.0753	28.1247	0.0187	88
2/2/2011	8:50:00	8	29.9	22.0	8.6	3.0753	26.8247	0.0136	84
2/2/2011	8:57:00	15	27.1	22.0	9.2	3.0753	24.0247	0.0103	76
2/2/2011	9:12:00	30	25.0	22.0	9.7	3.0753	21.9247	0.0075	69
2/2/2011	9:42:00	60	22.4	22.0	10.5	3.0753	19.3247	0.0055	61
2/2/2011	10:42:00	120	20.5	22.0	11.0	3.0753	17.4247	0.0040	55
2/2/2011	12:42:00	240	18.3	22.0	11.5	3.0753	15.2247	0.0029	48
2/2/2011	16:42:00	480	15.9	22.0	12.3	3.0753	12.8247	0.0021	40
2/3/2011	8:42:00	1440	14.2	22.0	12.6	3.0753	11.1247	0.0012	35



Remarks	SUMMARY			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	#N/A	Sand	0.0 %
	D_{50} =	0.003	Silt Sizes	60.3 %
	D_{60} =	0.005	Clay Sizes	39.7 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

amec

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-04	Depth	15.0 m
Technician	CR/SH	Date	2-Feb-11

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-04	Depth	16.0 m
Technician	CR/SH	Date	1-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 2

Air Dried Wt. of Soil Tested 50.2 g Dry Wt. of Soil Tested 50.2

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 31-Jan-11

Mechanical Sieve Results

Total Wt of Sample Dry 191.0 g

\+ # 10 0.0 g

\- # 10 191.0 g

Hydrometer Test

(Adjusted for + # 10 Material)

Total Dry Wt. 50.2 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		191.00	100	10	2.000		50.20	100
1 1/2 in.	37.5		191.00	100	20	0.850		50.20	100
1 in.	25.0		191.00	100	40	0.425	0.1	50.10	100
3/4 in.	19.0		191.00	100	60	0.250	0.1	50.00	100
1/2 in.	12.5		191.00	100	100	0.150	0.4	49.60	99
3/8 in.	9.5		191.00	100	200	0.075	3.2	46.40	92
4	4.8		191.00	100	325	0.045	2.6	43.80	87
10	2.0		191.00	100	pan				

0.0

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. ^oC	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/1/2011	8:42:00	0							
2/1/2011	8:42:30	0.5	31.3	22.2	8.1	3.0296	28.2704	0.0528	89
2/1/2011	8:43:00	1	30.0	22.2	8.4	3.0296	26.9704	0.0380	85
2/1/2011	8:44:00	2	28.0	22.2	8.9	3.0296	24.9704	0.0277	78
2/1/2011	8:46:00	4	26.2	22.2	9.4	3.0296	23.1704	0.0201	73
2/1/2011	8:50:00	8	24.5	22.2	10.0	3.0296	21.4704	0.0147	67
2/1/2011	8:57:00	15	22.1	22.2	10.5	3.0296	19.0704	0.0110	60
2/1/2011	9:12:00	30	20.2	22.2	11.0	3.0296	17.1704	0.0079	54
2/1/2011	9:42:00	60	18.2	22.2	11.5	3.0296	15.1704	0.0057	48
2/1/2011	10:42:00	120	16.1	22.2	12.1	3.0296	13.0704	0.0042	41
2/1/2011	12:42:00	240	14.0	22.2	12.6	3.0296	10.9704	0.0030	34
2/1/2011	16:42:00	480	13.0	22.2	12.9	3.0296	9.9704	0.0022	31
2/2/2011	8:42:00	1440	11.0	22.2	13.4	3.0296	7.9704	0.0013	25

Remarks	SUMMARY			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	0.002	Sand	7.6 %
	D_{50} =	0.007	Silt Sizes	62.2 %
	D_{60} =	0.011	Clay Sizes	30.3 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-04	Depth	16.0 m
Technician	CR/SH	Date	1-Feb-11

amec

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-04	Depth	8.0 m
Technician	CR/SH	Date	1-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 8

Air Dried Wt. of Soil Tested 50.3 g Dry Wt. of Soil Tested 50.3

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 31-Jan-11

Mechanical Sieve Results

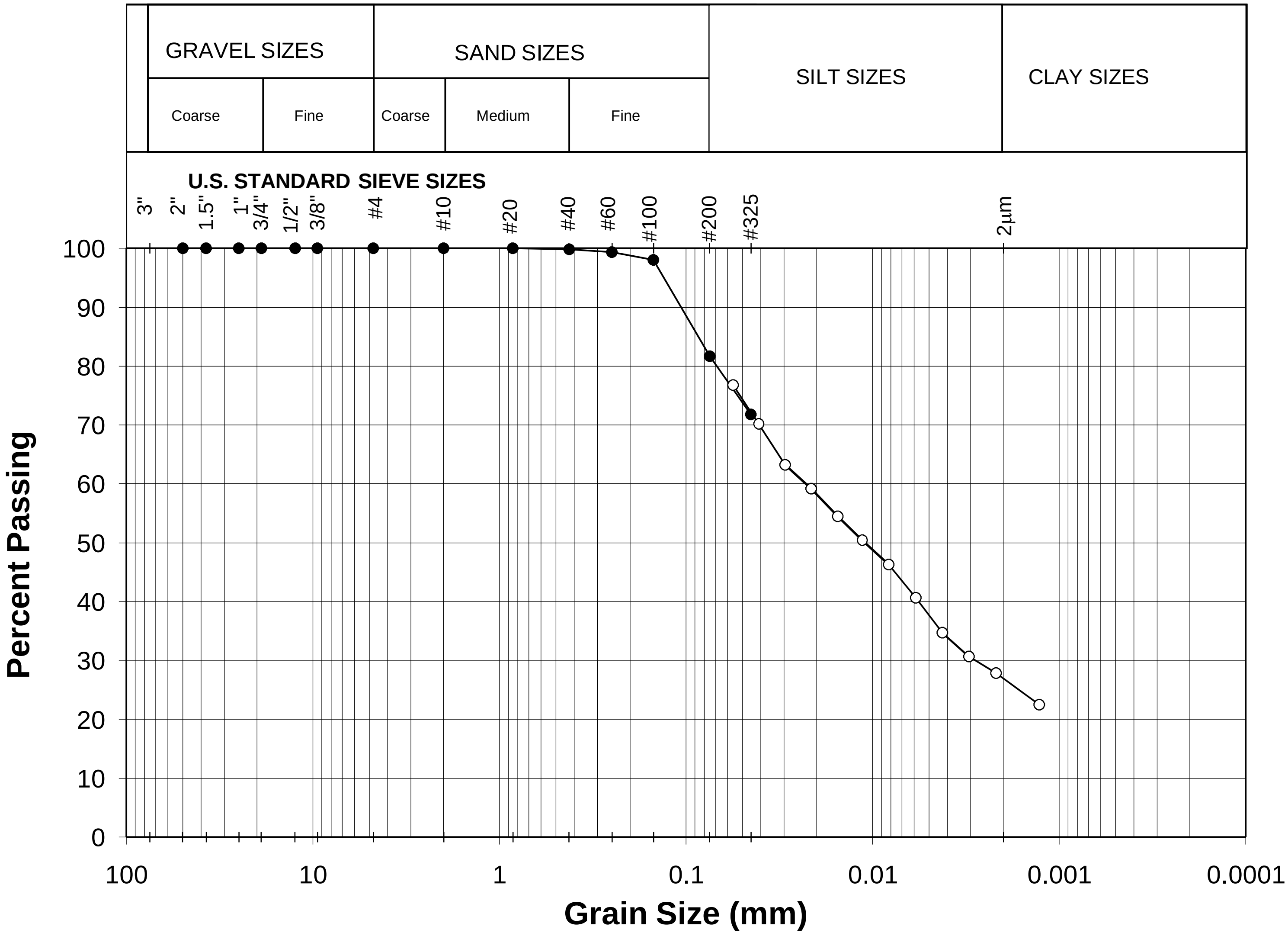
Total Wt of Sample Dry 143.5 g
+ # 10 0.0 g
- # 10 143.5 g

Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 50.3 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		143.50	100	10	2.000		50.30	100
1 1/2 in.	37.5		143.50	100	20	0.850		50.30	100
1 in.	25.0		143.50	100	40	0.425	0.1	50.20	100
3/4 in.	19.0		143.50	100	60	0.250	0.2	50.00	99
1/2 in.	12.5		143.50	100	100	0.150	0.7	49.30	98
3/8 in.	9.5		143.50	100	200	0.075	8.2	41.10	82
4	4.8		143.50	100	325	0.045	5.0	36.10	72
10	2.0		143.50	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. ^oC	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/1/2011	8:42:00	0							
2/1/2011	8:42:30	0.5	27.5	22.2	9.2	3.0296	24.4704	0.0563	77
2/1/2011	8:43:00	1	25.4	22.2	9.7	3.0296	22.3704	0.0409	70
2/1/2011	8:44:00	2	23.2	22.2	10.2	3.0296	20.1704	0.0296	63
2/1/2011	8:46:00	4	21.9	22.2	10.7	3.0296	18.8704	0.0215	59
2/1/2011	8:50:00	8	20.4	22.2	11.0	3.0296	17.3704	0.0154	54
2/1/2011	8:57:00	15	19.1	22.2	11.3	3.0296	16.0704	0.0114	50
2/1/2011	9:12:00	30	17.8	22.2	11.8	3.0296	14.7704	0.0082	46
2/1/2011	9:42:00	60	16.0	22.2	12.1	3.0296	12.9704	0.0059	41
2/1/2011	10:42:00	120	14.1	22.2	12.6	3.0296	11.0704	0.0043	35
2/1/2011	12:42:00	240	12.8	22.2	13.1	3.0296	9.7704	0.0031	31
2/1/2011	16:42:00	480	11.9	22.2	13.4	3.0296	8.8704	0.0022	28
2/2/2011	8:42:00	1440	10.2	22.2	13.7	3.0296	7.1704	0.0013	22



Remarks	**SUMMARY**			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	0.003	Sand	18.3 %
	D_{50} =	0.011	Silt Sizes	55.0 %
	D_{60} =	0.023	Clay Sizes	26.7 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-04	Depth	8.0 m
Technician	CR/SH	Date	1-Feb-11

amec

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-04	Depth	10.0 m
Technician	CR/SH	Date	1-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 7

Air Dried Wt. of Soil Tested 50.5 g Dry Wt. of Soil Tested 50.5

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 31-Jan-11

Mechanical Sieve Results

Total Wt of Sample Dry 118.1 g

+ # 10 0.0 g

- # 10 118.1 g

Hydrometer Test

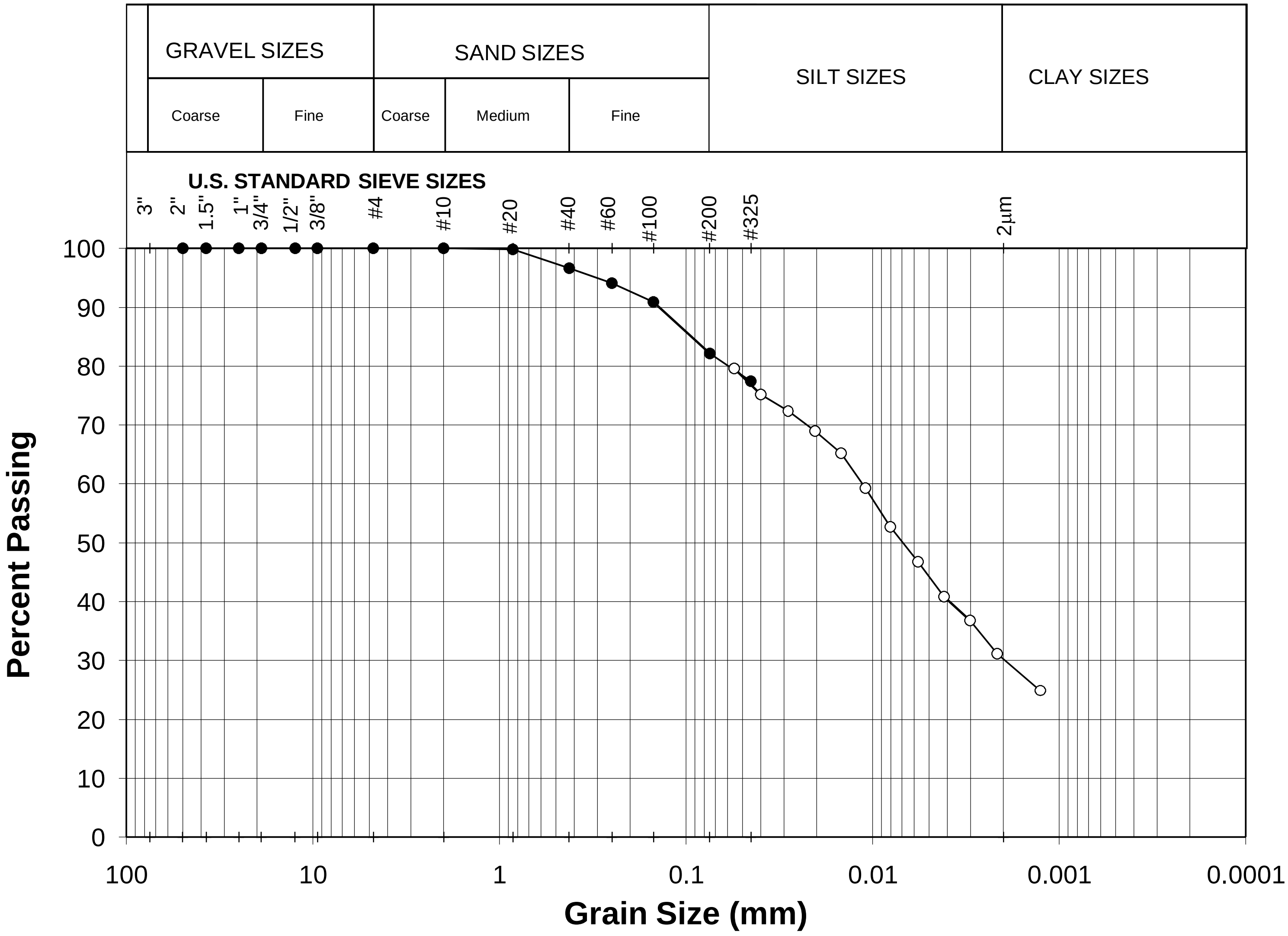
(Adjusted for + # 10 Material)

Total Dry Wt. 50.5 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		118.10	100	10	2.000		50.50	100
1 1/2 in.	37.5		118.10	100	20	0.850	0.1	50.40	100
1 in.	25.0		118.10	100	40	0.425	1.6	48.80	97
3/4 in.	19.0		118.10	100	60	0.250	1.3	47.50	94
1/2 in.	12.5		118.10	100	100	0.150	1.6	45.90	91
3/8 in.	9.5		118.10	100	200	0.075	4.4	41.50	82
4	4.8		118.10	100	325	0.045	2.4	39.10	77
10	2.0		118.10	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. ^oC	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/1/2011	8:42:00	0							
2/1/2011	8:42:30	0.5	28.5	22.2	8.9	3.0296	25.4704	0.0554	80
2/1/2011	8:43:00	1	27.1	22.2	9.2	3.0296	24.0704	0.0398	75
2/1/2011	8:44:00	2	26.2	22.2	9.4	3.0296	23.1704	0.0284	72
2/1/2011	8:46:00	4	25.1	22.2	9.7	3.0296	22.0704	0.0204	69
2/1/2011	8:50:00	8	23.9	22.2	10.2	3.0296	20.8704	0.0148	65
2/1/2011	8:57:00	15	22.0	22.2	10.5	3.0296	18.9704	0.0110	59
2/1/2011	9:12:00	30	19.9	22.2	11.3	3.0296	16.8704	0.0081	53
2/1/2011	9:42:00	60	18.0	22.2	11.5	3.0296	14.9704	0.0057	47
2/1/2011	10:42:00	120	16.1	22.2	12.1	3.0296	13.0704	0.0042	41
2/1/2011	12:42:00	240	14.8	22.2	12.6	3.0296	11.7704	0.0030	37
2/1/2011	16:42:00	480	13.0	22.2	12.9	3.0296	9.9704	0.0022	31
2/2/2011	8:42:00	1440	11.0	22.2	13.4	3.0296	7.9704	0.0013	25



Remarks	SUMMARY			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	0.002	Sand	17.8 %
	D_{50} =	0.007	Silt Sizes	52.1 %
	D_{60} =	0.011	Clay Sizes	30.1 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

amec

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-04	Depth	10.0 m
Technician	CR/SH	Date	1-Feb-11

amec

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-04	Depth	13.0 m
Technician	CR/SH	Date	1-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 6

Air Dried Wt. of Soil Tested 50.3 g Dry Wt. of Soil Tested 50.3

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 31-Jan-11

Mechanical Sieve Results

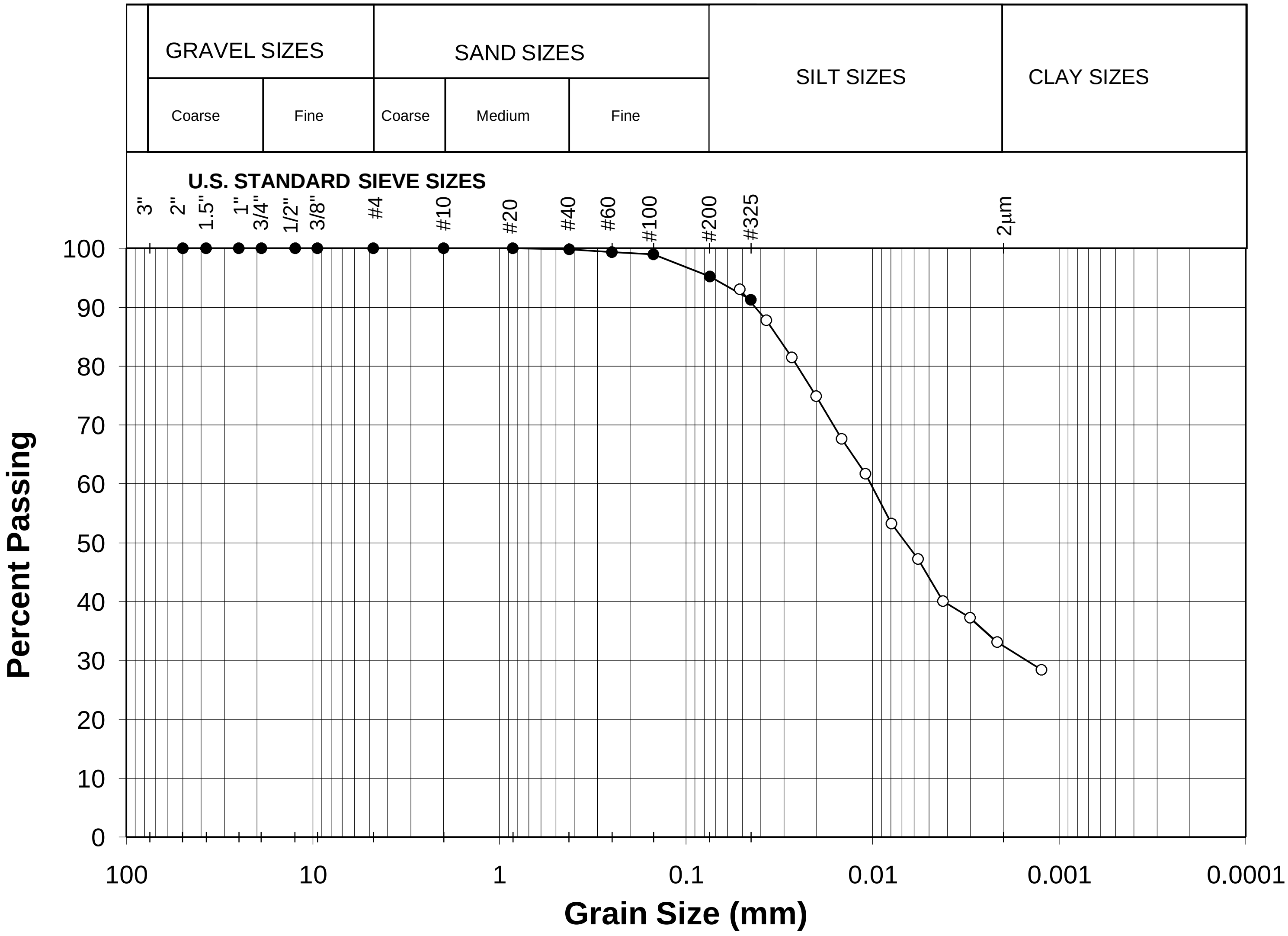
Total Wt of Sample Dry 264.0 g
+ # 10 0.0 g
- # 10 264.0 g

Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 50.3 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		264.00	100	10	2.000		50.30	100
1 1/2 in.	37.5		264.00	100	20	0.850		50.30	100
1 in.	25.0		264.00	100	40	0.425	0.1	50.20	100
3/4 in.	19.0		264.00	100	60	0.250	0.2	50.00	99
1/2 in.	12.5		264.00	100	100	0.150	0.2	49.80	99
3/8 in.	9.5		264.00	100	200	0.075	1.9	47.90	95
4	4.8		264.00	100	325	0.045	2.0	45.90	91
10	2.0		264.00	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. ^oC	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/1/2011	8:42:00	0							
2/1/2011	8:42:30	0.5	32.7	22.2	7.8	3.0296	29.6704	0.0518	93
2/1/2011	8:43:00	1	31.0	22.2	8.1	3.0296	27.9704	0.0373	88
2/1/2011	8:44:00	2	29.0	22.2	8.6	3.0296	25.9704	0.0272	81
2/1/2011	8:46:00	4	26.9	22.2	9.4	3.0296	23.8704	0.0201	75
2/1/2011	8:50:00	8	24.6	22.2	10.0	3.0296	21.5704	0.0147	68
2/1/2011	8:57:00	15	22.7	22.2	10.5	3.0296	19.6704	0.0110	62
2/1/2011	9:12:00	30	20.0	22.2	11.0	3.0296	16.9704	0.0079	53
2/1/2011	9:42:00	60	18.1	22.2	11.5	3.0296	15.0704	0.0057	47
2/1/2011	10:42:00	120	15.8	22.2	12.3	3.0296	12.7704	0.0042	40
2/1/2011	12:42:00	240	14.9	22.2	12.6	3.0296	11.8704	0.0030	37
2/1/2011	16:42:00	480	13.6	22.2	12.9	3.0296	10.5704	0.0022	33
2/2/2011	8:42:00	1440	12.1	22.2	13.1	3.0296	9.0704	0.0013	28



Remarks	SUMMARY			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	0.002	Sand	4.8 %
	D_{50} =	0.007	Silt Sizes	62.9 %
	D_{60} =	0.010	Clay Sizes	32.4 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

amec

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-04	Depth	13.0 m
Technician	CR/SH	Date	1-Feb-11

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-04	Depth	15.0 m
Technician	MR/SH	Date	2-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 17

Air Dried Wt. of Soil Tested 50.6 g Dry Wt. of Soil Tested 50.6

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 1-Feb-11

Mechanical Sieve Results

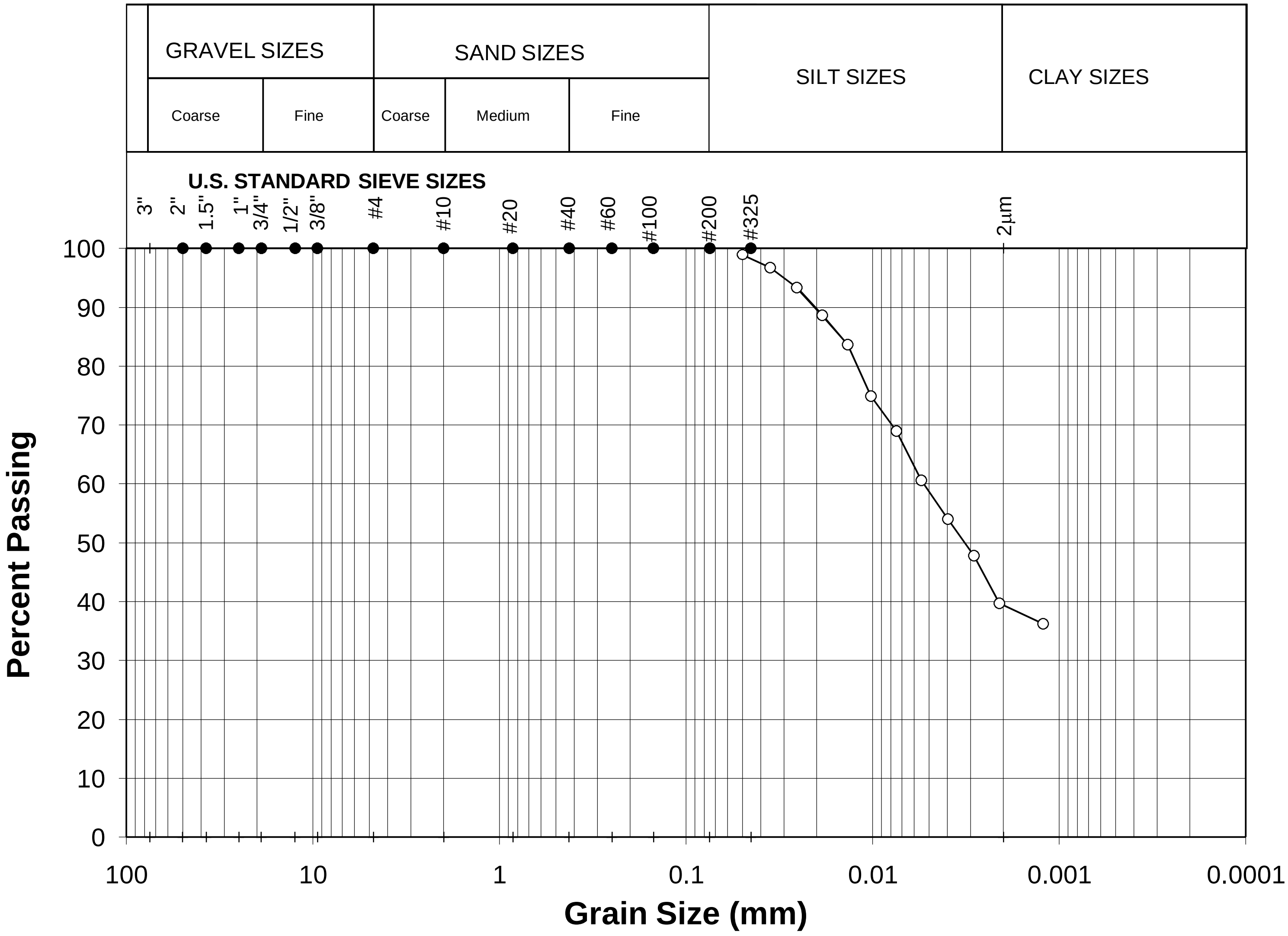
Total Wt of Sample Dry 179.6 g
+ # 10 0.0 g
- # 10 179.6 g

Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 50.6 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		179.60	100	10	2.000		50.60	100
1 1/2 in.	37.5		179.60	100	20	0.850		50.60	100
1 in.	25.0		179.60	100	40	0.425		50.60	100
3/4 in.	19.0		179.60	100	60	0.250		50.60	100
1/2 in.	12.5		179.60	100	100	0.150		50.60	100
3/8 in.	9.5		179.60	100	200	0.075		50.60	100
4	4.8		179.60	100	325	0.045		50.60	100
10	2.0		179.60	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'$_h$	Temp. ^{o}C	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/2/2011	8:42:00	0							
2/2/2011	8:42:30	0.5	34.8	22.0	7.3	3.0753	31.7247	0.0501	99
2/2/2011	8:43:00	1	34.1	22.0	7.3	3.0753	31.0247	0.0354	97
2/2/2011	8:44:00	2	33.0	22.0	7.6	3.0753	29.9247	0.0256	93
2/2/2011	8:46:00	4	31.5	22.0	8.1	3.0753	28.4247	0.0187	89
2/2/2011	8:50:00	8	29.9	22.0	8.6	3.0753	26.8247	0.0136	84
2/2/2011	8:57:00	15	27.1	22.0	9.2	3.0753	24.0247	0.0103	75
2/2/2011	9:12:00	30	25.2	22.0	9.7	3.0753	22.1247	0.0075	69
2/2/2011	9:42:00	60	22.5	22.0	10.5	3.0753	19.4247	0.0055	61
2/2/2011	10:42:00	120	20.4	22.0	11.0	3.0753	17.3247	0.0040	54
2/2/2011	12:42:00	240	18.4	22.0	11.5	3.0753	15.3247	0.0029	48
2/2/2011	16:42:00	480	15.8	22.0	12.3	3.0753	12.7247	0.0021	40
2/3/2011	8:42:00	1440	14.7	22.0	12.6	3.0753	11.6247	0.0012	36



Remarks	SUMMARY			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	#N/A	Sand	0.0 %
	D_{50} =	0.003	Silt Sizes	60.7 %
	D_{60} =	0.005	Clay Sizes	39.3 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

amec

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-04	Depth	15.0 m
Technician	MR/SH	Date	2-Feb-11

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-04	Depth	16.0 m
Technician	CR/SH	Date	1-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 16

Air Dried Wt. of Soil Tested 50.2 g Dry Wt. of Soil Tested 50.2

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 31-Jan-11

Mechanical Sieve Results

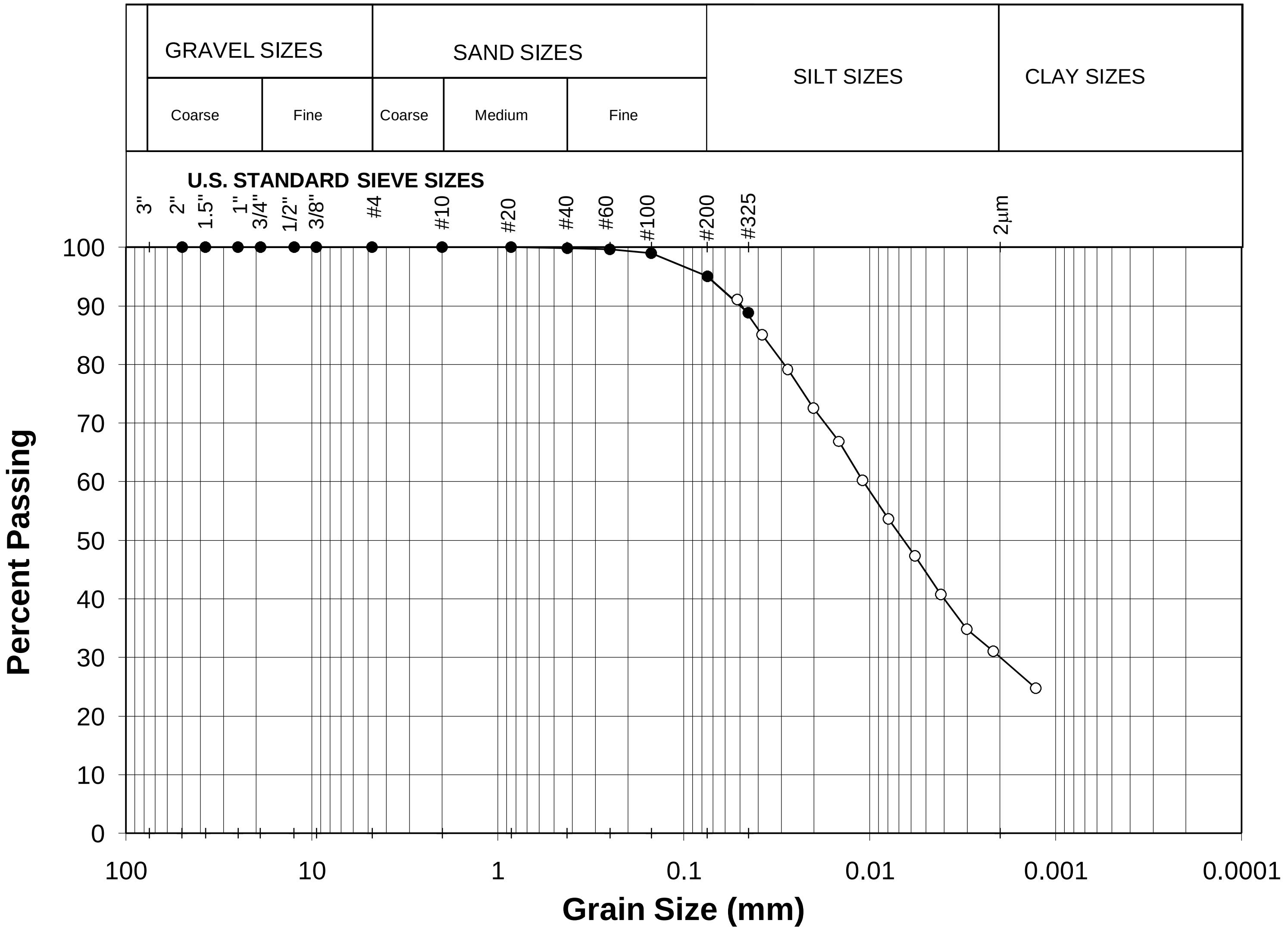
Total Wt of Sample Dry 191.0 g
+ # 10 0.0 g
- # 10 191.0 g

Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 50.2 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		191.00	100	10	2.000		50.20	100
1 1/2 in.	37.5		191.00	100	20	0.850		50.20	100
1 in.	25.0		191.00	100	40	0.425	0.1	50.10	100
3/4 in.	19.0		191.00	100	60	0.250	0.1	50.00	100
1/2 in.	12.5		191.00	100	100	0.150	0.3	49.70	99
3/8 in.	9.5		191.00	100	200	0.075	2.0	47.70	95
4	4.8		191.00	100	325	0.045	3.1	44.60	89
10	2.0		191.00	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. ^oC	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/1/2011	8:42:00	0							
2/1/2011	8:42:30	0.5	32.0	22.2	7.8	3.0296	28.9704	0.0518	91
2/1/2011	8:43:00	1	30.1	22.2	8.4	3.0296	27.0704	0.0380	85
2/1/2011	8:44:00	2	28.2	22.2	8.9	3.0296	25.1704	0.0277	79
2/1/2011	8:46:00	4	26.1	22.2	9.4	3.0296	23.0704	0.0201	73
2/1/2011	8:50:00	8	24.3	22.2	10.0	3.0296	21.2704	0.0147	67
2/1/2011	8:57:00	15	22.2	22.2	10.5	3.0296	19.1704	0.0110	60
2/1/2011	9:12:00	30	20.1	22.2	11.0	3.0296	17.0704	0.0079	54
2/1/2011	9:42:00	60	18.1	22.2	11.5	3.0296	15.0704	0.0057	47
2/1/2011	10:42:00	120	16.0	22.2	12.1	3.0296	12.9704	0.0042	41
2/1/2011	12:42:00	240	14.1	22.2	12.6	3.0296	11.0704	0.0030	35
2/1/2011	16:42:00	480	12.9	22.2	13.1	3.0296	9.8704	0.0022	31
2/2/2011	8:42:00	1440	10.9	22.2	13.7	3.0296	7.8704	0.0013	25



Remarks	SUMMARY			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	0.002	Sand	5.0 %
	D_{50} =	0.007	Silt Sizes	65.2 %
	D_{60} =	0.011	Clay Sizes	29.8 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-04	Depth	16.0 m
Technician	CR/SH	Date	1-Feb-11

amec

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-04	Depth	6.0 m
Technician	CR/SH	Date	2-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 27

Air Dried Wt. of Soil Tested 45.1 g Dry Wt. of Soil Tested 45.1

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 1-Feb-11

Mechanical Sieve Results

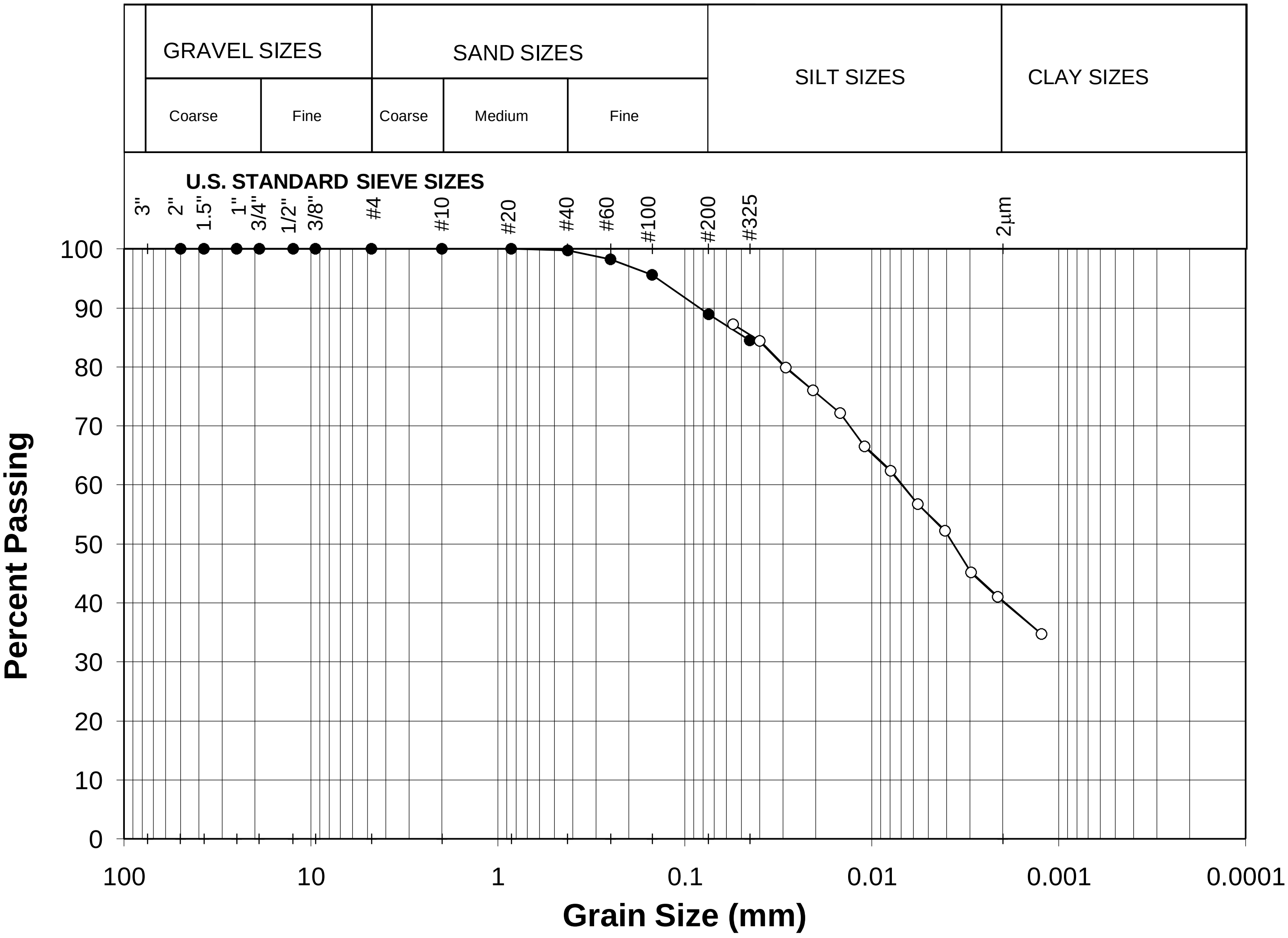
Total Wt of Sample Dry 96.0 g
+ # 10 0.0 g
- # 10 96.0 g

Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 45.1 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		96.00	100	10	2.000		45.10	100
1 1/2 in.	37.5		96.00	100	20	0.850		45.10	100
1 in.	25.0		96.00	100	40	0.425	0.1	45.00	100
3/4 in.	19.0		96.00	100	60	0.250	0.7	44.30	98
1/2 in.	12.5		96.00	100	100	0.150	1.2	43.10	96
3/8 in.	9.5		96.00	100	200	0.075	3.0	40.10	89
4	4.8		96.00	100	325	0.045	2.0	38.10	84
10	2.0		96.00	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. °C	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/2/2011	8:42:00	0							
2/2/2011	8:42:30	0.5	28.0	22.0	8.9	3.0753	24.9247	0.0554	87
2/2/2011	8:43:00	1	27.2	22.0	9.2	3.0753	24.1247	0.0398	84
2/2/2011	8:44:00	2	25.9	22.0	9.7	3.0753	22.8247	0.0289	80
2/2/2011	8:46:00	4	24.8	22.0	10.0	3.0753	21.7247	0.0207	76
2/2/2011	8:50:00	8	23.7	22.0	10.2	3.0753	20.6247	0.0148	72
2/2/2011	8:57:00	15	22.1	22.0	10.5	3.0753	19.0247	0.0110	67
2/2/2011	9:12:00	30	20.9	22.0	11.0	3.0753	17.8247	0.0079	62
2/2/2011	9:42:00	60	19.3	22.0	11.3	3.0753	16.2247	0.0057	57
2/2/2011	10:42:00	120	18.0	22.0	11.5	3.0753	14.9247	0.0041	52
2/2/2011	12:42:00	240	16.0	22.0	12.1	3.0753	12.9247	0.0029	45
2/2/2011	16:42:00	480	14.8	22.0	12.6	3.0753	11.7247	0.0021	41
2/3/2011	8:42:00	1440	13.0	22.0	12.9	3.0753	9.9247	0.0012	35



Remarks	SUMMARY			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	#N/A	Sand	11.1 %
	D_{50} =	0.004	Silt Sizes	48.8 %
	D_{60} =	0.007	Clay Sizes	40.1 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

amec

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-04	Depth	6.0 m
Technician	CR/SH	Date	2-Feb-11

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-04	Depth	8.0 m
Technician	CR/SH	Date	1-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 3

Air Dried Wt. of Soil Tested 50.5 g Dry Wt. of Soil Tested 50.5

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 31-Jan-11

Mechanical Sieve Results

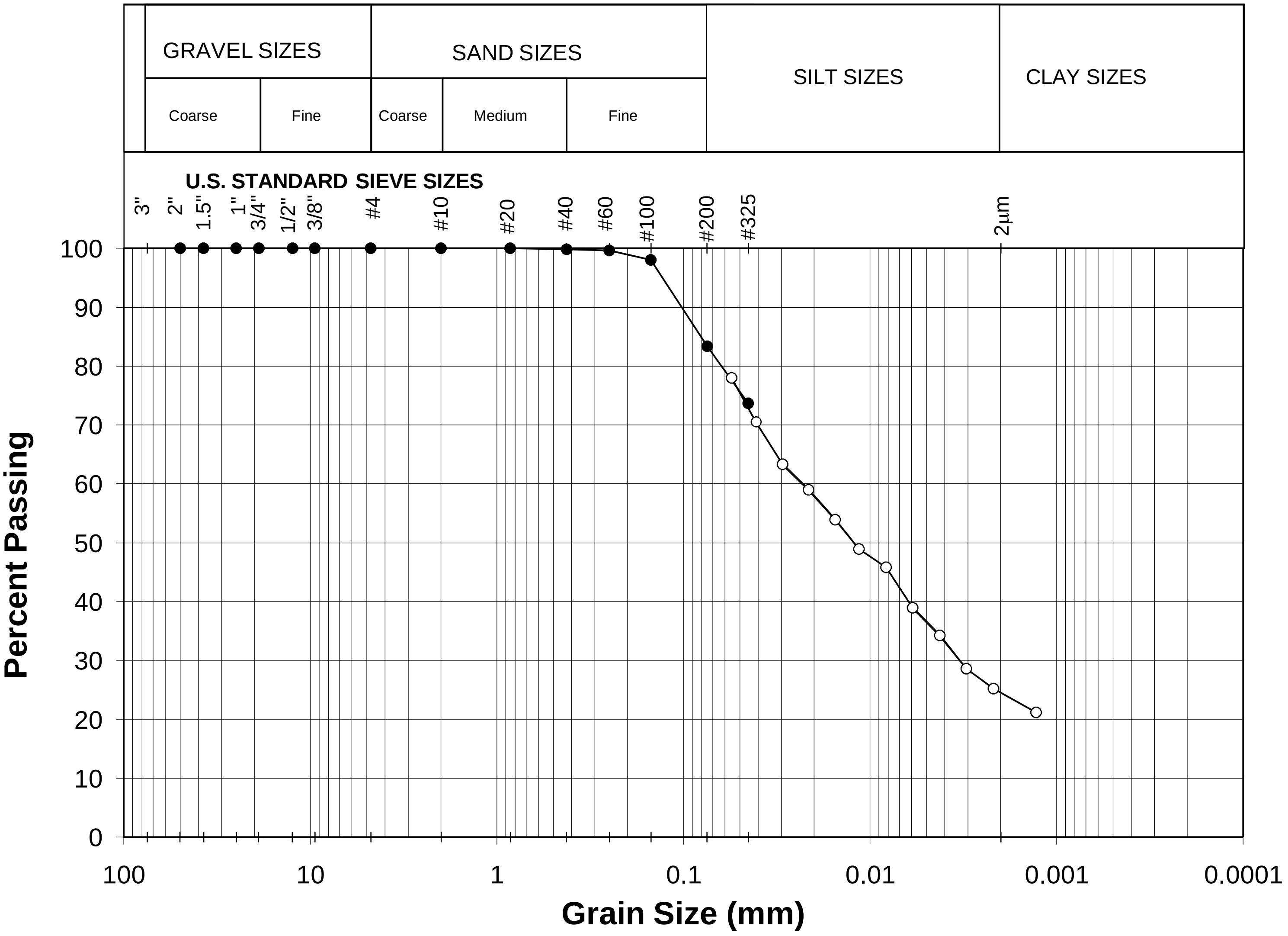
Total Wt of Sample Dry 143.5 g
+ # 10 0.0 g
- # 10 143.5 g

Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 50.5 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		143.50	100	10	2.000		50.50	100
1 1/2 in.	37.5		143.50	100	20	0.850		50.50	100
1 in.	25.0		143.50	100	40	0.425	0.1	50.40	100
3/4 in.	19.0		143.50	100	60	0.250	0.1	50.30	100
1/2 in.	12.5		143.50	100	100	0.150	0.8	49.50	98
3/8 in.	9.5		143.50	100	200	0.075	7.4	42.10	83
4	4.8		143.50	100	325	0.045	4.9	37.20	74
10	2.0		143.50	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. ^oC	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/1/2011	8:42:00	0							
2/1/2011	8:42:30	0.5	28.0	22.2	8.9	3.0296	24.9704	0.0554	78
2/1/2011	8:43:00	1	25.6	22.2	9.7	3.0296	22.5704	0.0409	71
2/1/2011	8:44:00	2	23.3	22.2	10.2	3.0296	20.2704	0.0296	63
2/1/2011	8:46:00	4	21.9	22.2	10.7	3.0296	18.8704	0.0215	59
2/1/2011	8:50:00	8	20.3	22.2	11.0	3.0296	17.2704	0.0154	54
2/1/2011	8:57:00	15	18.7	22.2	11.5	3.0296	15.6704	0.0115	49
2/1/2011	9:12:00	30	17.7	22.2	11.8	3.0296	14.6704	0.0082	46
2/1/2011	9:42:00	60	15.5	22.2	12.3	3.0296	12.4704	0.0059	39
2/1/2011	10:42:00	120	14.0	22.2	12.6	3.0296	10.9704	0.0043	34
2/1/2011	12:42:00	240	12.2	22.2	13.1	3.0296	9.1704	0.0031	29
2/1/2011	16:42:00	480	11.1	22.2	13.4	3.0296	8.0704	0.0022	25
2/2/2011	8:42:00	1440	9.8	22.2	13.9	3.0296	6.7704	0.0013	21



Remarks	SUMMARY			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	0.003	Sand	16.6 %
	D_{50} =	0.012	Silt Sizes	59.0 %
	D_{60} =	0.023	Clay Sizes	24.4 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

amec

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-04	Depth	8.0 m
Technician	CR/SH	Date	1-Feb-11

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-05	Depth	12.0 m
Technician	CR/SH	Date	2-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 6

Air Dried Wt. of Soil Tested 50.4 g Dry Wt. of Soil Tested 50.4

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 1-Feb-11

Mechanical Sieve Results

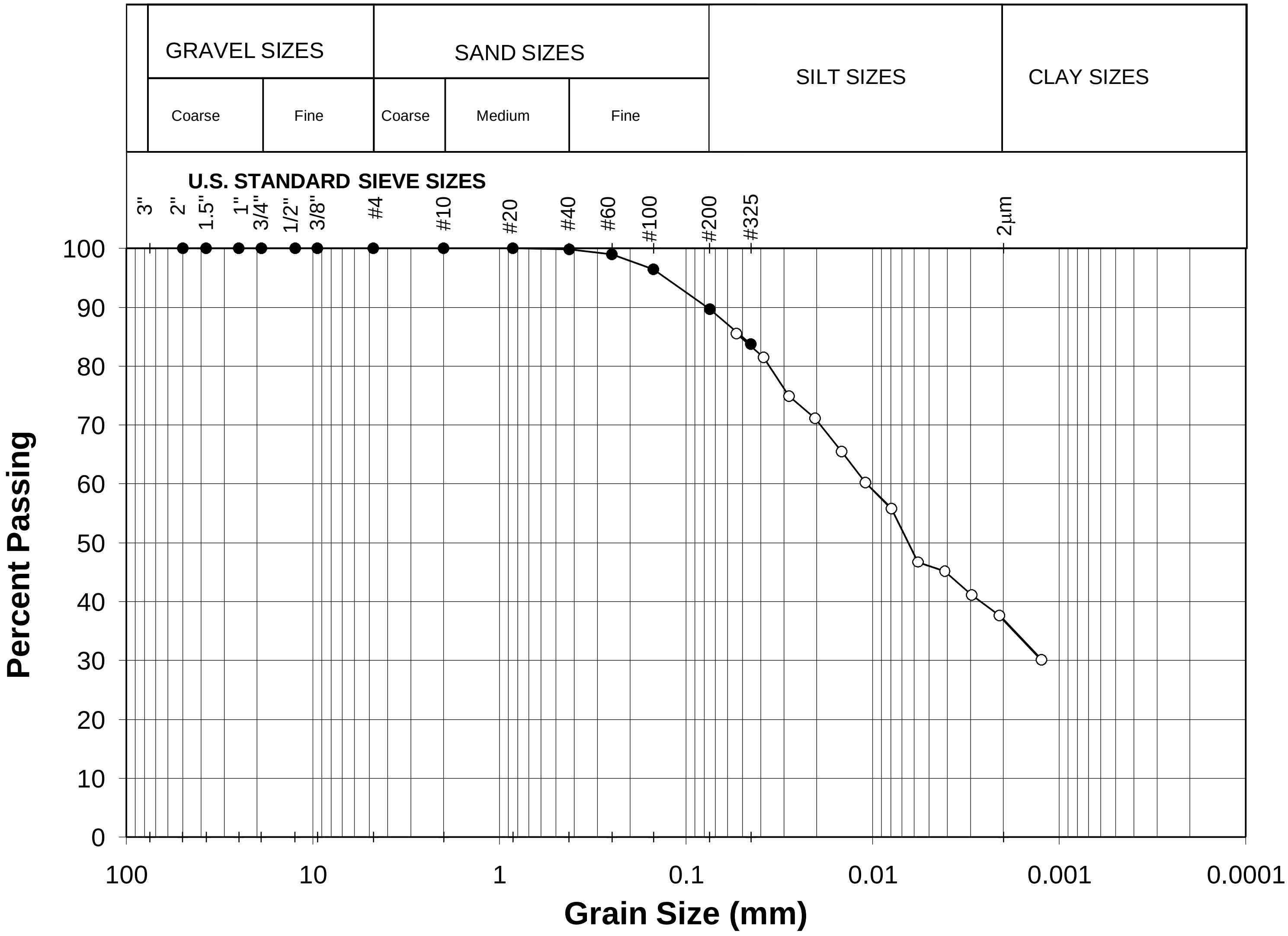
Total Wt of Sample Dry 226.2 g
+ # 10 0.0 g
- # 10 226.2 g

Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 50.4 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		226.20	100	10	2.000		50.40	100
1 1/2 in.	37.5		226.20	100	20	0.850		50.40	100
1 in.	25.0		226.20	100	40	0.425	0.1	50.30	100
3/4 in.	19.0		226.20	100	60	0.250	0.4	49.90	99
1/2 in.	12.5		226.20	100	100	0.150	1.3	48.60	96
3/8 in.	9.5		226.20	100	200	0.075	3.4	45.20	90
4	4.8		226.20	100	325	0.045	3.0	42.20	84
10	2.0		226.20	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. ^oC	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/2/2011	8:42:00	0							
2/2/2011	8:42:30	0.5	30.4	22.0	8.4	3.0753	27.3247	0.0538	86
2/2/2011	8:43:00	1	29.1	22.0	8.6	3.0753	26.0247	0.0385	81
2/2/2011	8:44:00	2	27.0	22.0	9.2	3.0753	23.9247	0.0281	75
2/2/2011	8:46:00	4	25.8	22.0	9.7	3.0753	22.7247	0.0204	71
2/2/2011	8:50:00	8	24.0	22.0	10.0	3.0753	20.9247	0.0147	66
2/2/2011	8:57:00	15	22.3	22.0	10.5	3.0753	19.2247	0.0110	60
2/2/2011	9:12:00	30	20.9	22.0	11.0	3.0753	17.8247	0.0079	56
2/2/2011	9:42:00	60	18.0	22.0	11.5	3.0753	14.9247	0.0057	47
2/2/2011	10:42:00	120	17.5	22.0	11.8	3.0753	14.4247	0.0041	45
2/2/2011	12:42:00	240	16.2	22.0	12.1	3.0753	13.1247	0.0029	41
2/2/2011	16:42:00	480	15.1	22.0	12.3	3.0753	12.0247	0.0021	38
2/3/2011	8:42:00	1440	12.7	22.0	13.1	3.0753	9.6247	0.0013	30



Remarks	SUMMARY			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	#N/A	Sand	10.3 %
	D_{50} =	0.007	Silt Sizes	52.9 %
	D_{60} =	0.011	Clay Sizes	36.8 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

amec

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-05	Depth	12.0 m
Technician	CR/SH	Date	2-Feb-11

amec

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-05	Depth	18.0 m
Technician	CR/SH	Date	2-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 15

Air Dried Wt. of Soil Tested 50.4 g Dry Wt. of Soil Tested 50.4

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 1-Feb-11

Mechanical Sieve Results

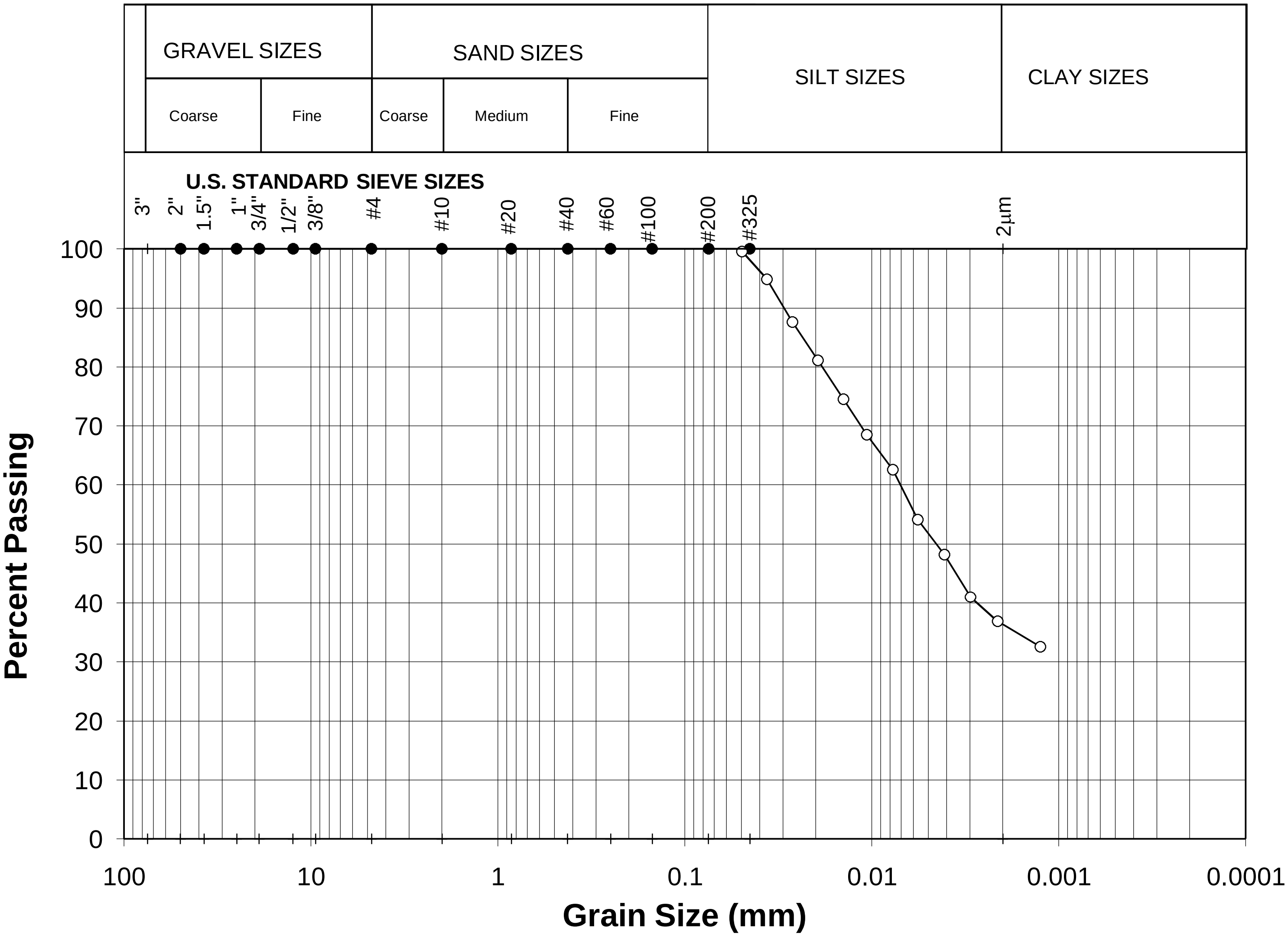
Total Wt of Sample Dry 219.3 g
+ # 10 0.0 g
- # 10 219.3 g

Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 50.4 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		219.30	100	10	2.000		50.40	100
1 1/2 in.	37.5		219.30	100	20	0.850		50.40	100
1 in.	25.0		219.30	100	40	0.425		50.40	100
3/4 in.	19.0		219.30	100	60	0.250		50.40	100
1/2 in.	12.5		219.30	100	100	0.150		50.40	100
3/8 in.	9.5		219.30	100	200	0.075		50.40	100
4	4.8		219.30	100	325	0.045		50.40	100
10	2.0		219.30	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. ^{o}C	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/2/2011	8:42:00	0							
2/2/2011	8:42:30	0.5	35.0	21.4	7.0	3.2073	31.7927	0.0497	100
2/2/2011	8:43:00	1	33.5	21.4	7.6	3.2073	30.2927	0.0366	95
2/2/2011	8:44:00	2	31.2	21.4	8.1	3.2073	27.9927	0.0267	88
2/2/2011	8:46:00	4	29.1	21.4	8.6	3.2073	25.8927	0.0195	81
2/2/2011	8:50:00	8	27.0	21.4	9.2	3.2073	23.7927	0.0142	74
2/2/2011	8:57:00	15	25.1	21.4	9.7	3.2073	21.8927	0.0107	69
2/2/2011	9:12:00	30	23.2	21.4	10.2	3.2073	19.9927	0.0077	63
2/2/2011	9:42:00	60	20.5	21.4	11.0	3.2073	17.2927	0.0057	54
2/2/2011	10:42:00	120	18.6	21.4	11.5	3.2073	15.3927	0.0041	48
2/2/2011	12:42:00	240	16.3	21.4	12.1	3.2073	13.0927	0.0030	41
2/2/2011	16:42:00	480	15.0	21.4	12.3	3.2073	11.7927	0.0021	37
2/3/2011	8:42:00	1440	13.6	21.4	12.9	3.2073	10.3927	0.0013	33



Remarks	SUMMARY			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	#N/A	Sand	0.0 %
	D_{50} =	0.005	Silt Sizes	63.7 %
	D_{60} =	0.007	Clay Sizes	36.3 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-05	Depth	18.0 m
Technician	CR/SH	Date	2-Feb-11

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-05	Depth	23.0 m
Technician	CR/SH	Date	2-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 8

Air Dried Wt. of Soil Tested 50.5 g Dry Wt. of Soil Tested 50.5

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 1-Feb-11

Mechanical Sieve Results

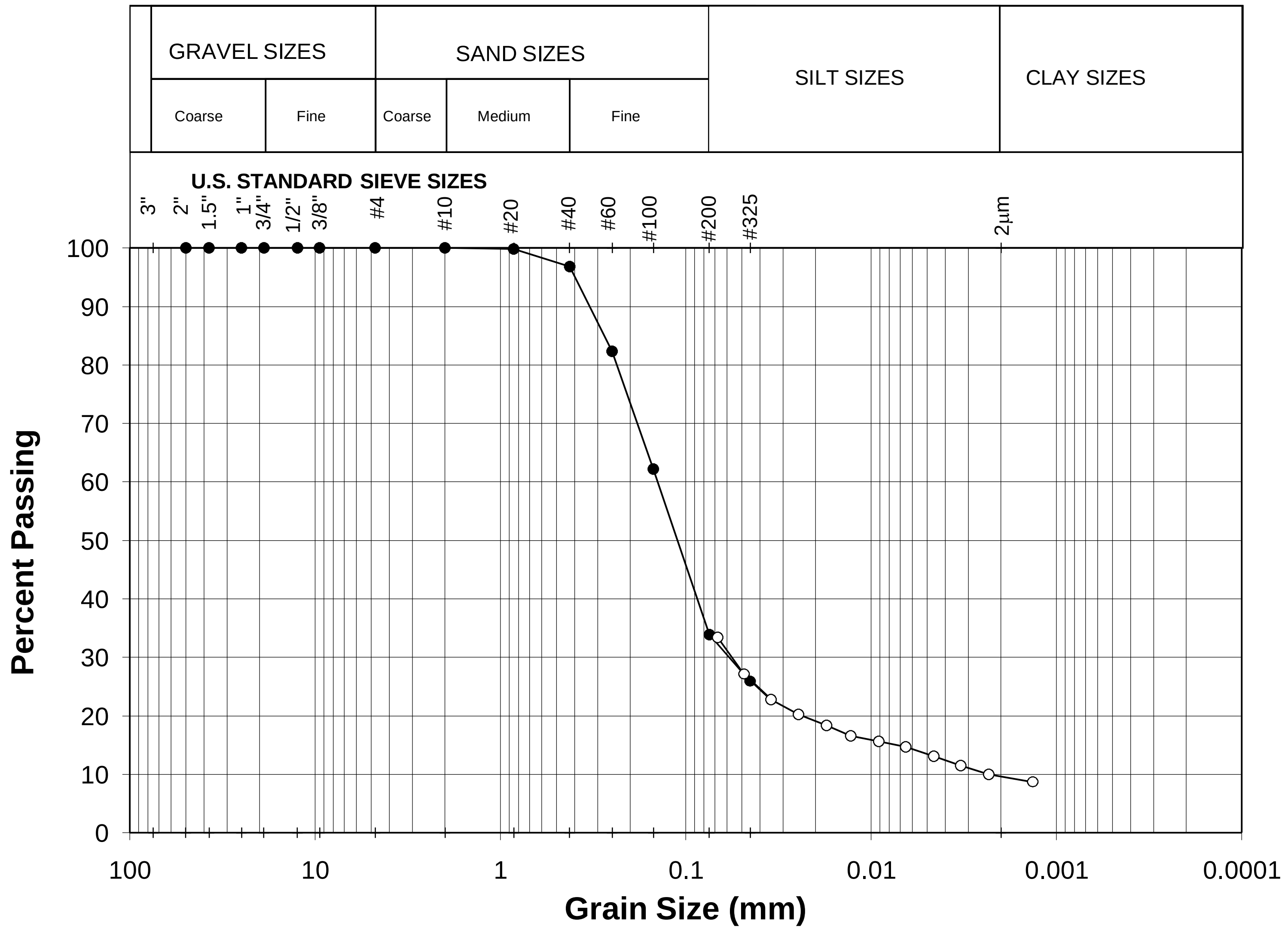
Total Wt of Sample Dry 143.5 g
+ # 10 0.0 g
- # 10 143.5 g

Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 50.5 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		143.50	100	10	2.000		50.50	100
1 1/2 in.	37.5		143.50	100	20	0.850	0.1	50.40	100
1 in.	25.0		143.50	100	40	0.425	1.5	48.90	97
3/4 in.	19.0		143.50	100	60	0.250	7.3	41.60	82
1/2 in.	12.5		143.50	100	100	0.150	10.2	31.40	62
3/8 in.	9.5		143.50	100	200	0.075	14.3	17.10	34
4	4.8		143.50	100	325	0.045	4.0	13.10	26
10	2.0		143.50	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. ^oC	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/2/2011	8:42:00	0							
2/2/2011	8:42:30	0.5	13.9	21.4	12.9	3.2073	10.6927	0.0675	33
2/2/2011	8:43:00	1	11.9	21.4	13.4	3.2073	8.6927	0.0486	27
2/2/2011	8:44:00	2	10.5	21.4	13.7	3.2073	7.2927	0.0348	23
2/2/2011	8:46:00	4	9.7	21.4	13.9	3.2073	6.4927	0.0248	20
2/2/2011	8:50:00	8	9.1	21.4	13.9	3.2073	5.8927	0.0175	18
2/2/2011	8:57:00	15	8.5	21.4	14.2	3.2073	5.2927	0.0129	17
2/2/2011	9:12:00	30	8.2	21.4	14.2	3.2073	4.9927	0.0091	16
2/2/2011	9:42:00	60	7.9	21.4	14.4	3.2073	4.6927	0.0065	15
2/2/2011	10:42:00	120	7.4	21.4	14.4	3.2073	4.1927	0.0046	13
2/2/2011	12:42:00	240	6.9	21.4	14.7	3.2073	3.6927	0.0033	12
2/2/2011	16:42:00	480	6.4	21.4	14.7	3.2073	3.1927	0.0023	10
2/3/2011	8:42:00	1440	6.0	21.4	14.7	3.2073	2.7927	0.0013	9



Remarks	SUMMARY			
	D_{10} =	0.002	Gravel	0.0 %
	D_{30} =	0.057	Sand	66.1 %
	D_{50} =	0.118	Silt Sizes	24.3 %
	D_{60} =	0.144	Clay Sizes	9.6 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL %
WP %
IP %

amec

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-05	Depth	23.0 m
Technician	CR/SH	Date	2-Feb-11

amec

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-05	Depth	6.0 m
Technician	MR/SH	Date	2-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 8

Air Dried Wt. of Soil Tested 50.2 g Dry Wt. of Soil Tested 50.2

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 1-Feb-11

Mechanical Sieve Results

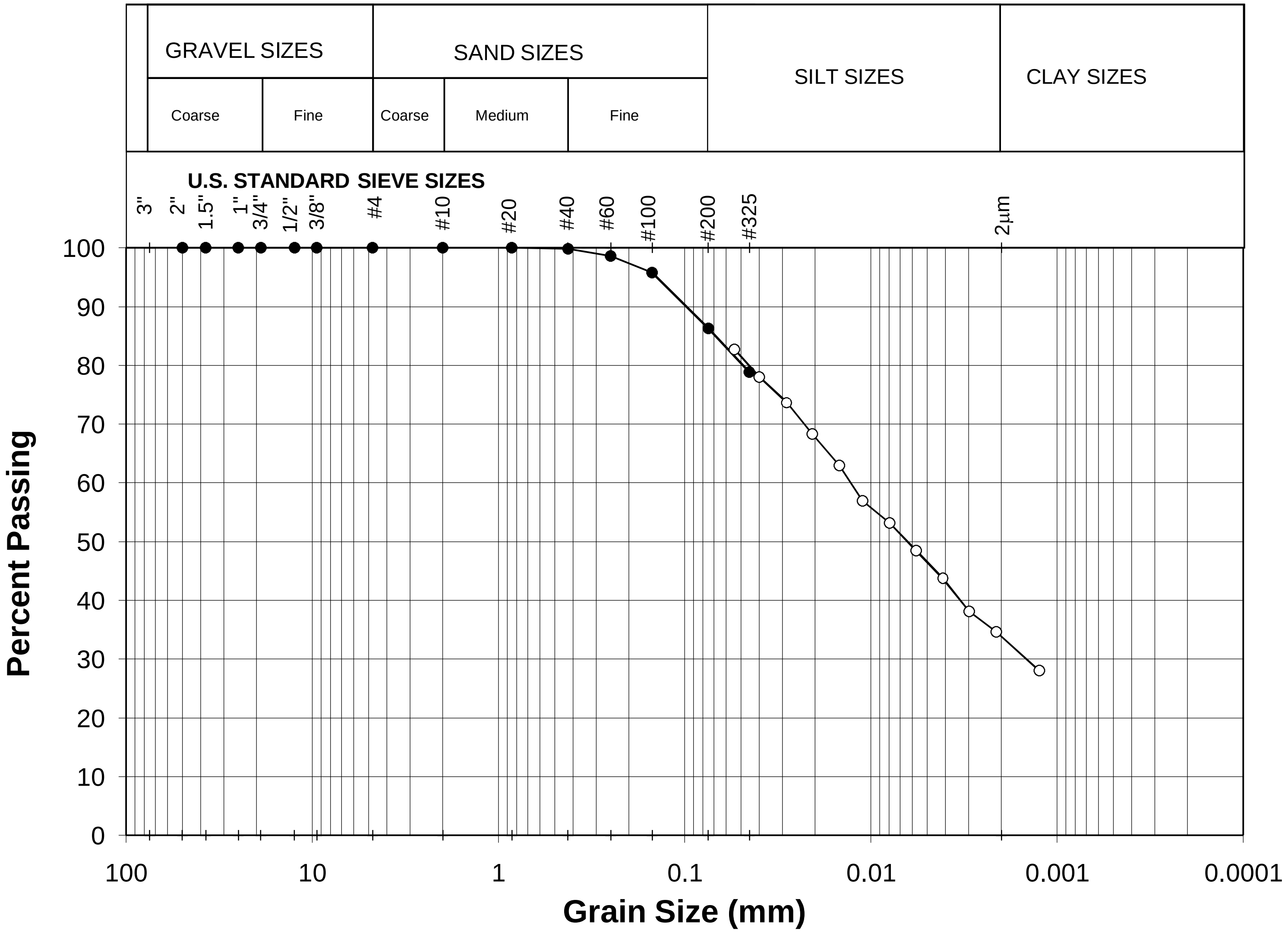
Total Wt of Sample Dry 123.0 g
+ # 10 0.0 g
- # 10 123.0 g

Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 50.2 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		123.00	100	10	2.000		50.20	100
1 1/2 in.	37.5		123.00	100	20	0.850		50.20	100
1 in.	25.0		123.00	100	40	0.425	0.1	50.10	100
3/4 in.	19.0		123.00	100	60	0.250	0.6	49.50	99
1/2 in.	12.5		123.00	100	100	0.150	1.4	48.10	96
3/8 in.	9.5		123.00	100	200	0.075	4.8	43.30	86
4	4.8		123.00	100	325	0.045	3.7	39.60	79
10	2.0		123.00	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. ^oC	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/2/2011	8:42:00	0							
2/2/2011	8:42:30	0.5	29.4	22.0	8.6	3.0753	26.3247	0.0544	83
2/2/2011	8:43:00	1	27.9	22.0	9.2	3.0753	24.8247	0.0398	78
2/2/2011	8:44:00	2	26.5	22.0	9.4	3.0753	23.4247	0.0284	74
2/2/2011	8:46:00	4	24.8	22.0	10.0	3.0753	21.7247	0.0207	68
2/2/2011	8:50:00	8	23.1	22.0	10.2	3.0753	20.0247	0.0148	63
2/2/2011	8:57:00	15	21.2	22.0	10.7	3.0753	18.1247	0.0111	57
2/2/2011	9:12:00	30	20.0	22.0	11.0	3.0753	16.9247	0.0079	53
2/2/2011	9:42:00	60	18.5	22.0	11.5	3.0753	15.4247	0.0057	48
2/2/2011	10:42:00	120	17.0	22.0	11.8	3.0753	13.9247	0.0041	44
2/2/2011	12:42:00	240	15.2	22.0	12.3	3.0753	12.1247	0.0030	38
2/2/2011	16:42:00	480	14.1	22.0	12.6	3.0753	11.0247	0.0021	35
2/3/2011	8:42:00	1440	12.0	22.0	13.1	3.0753	8.9247	0.0013	28



Remarks	SUMMARY			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	0.002	Sand	13.7 %
	D_{50} =	0.006	Silt Sizes	52.5 %
	D_{60} =	0.013	Clay Sizes	33.7 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

amec

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-05	Depth	6.0 m
Technician	MR/SH	Date	2-Feb-11

amec

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-05	Depth	12.0 m
Technician	CR/SH	Date	2-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 3

Air Dried Wt. of Soil Tested 50.3 g Dry Wt. of Soil Tested 50.3

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 1-Feb-11

Mechanical Sieve Results

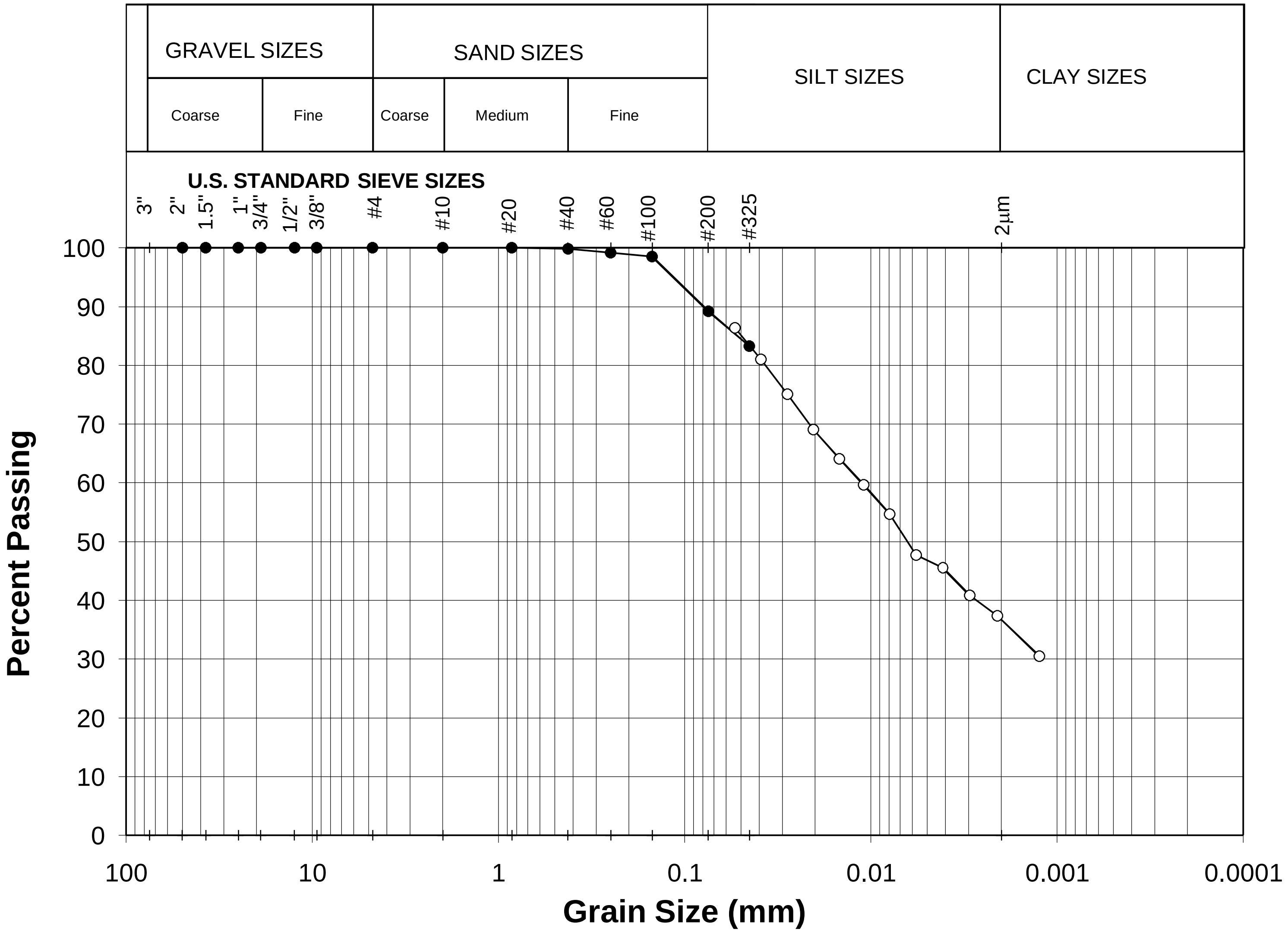
Total Wt of Sample Dry 226.2 g
+ # 10 0.0 g
- # 10 226.2 g

Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 50.3 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		226.20	100	10	2.000		50.30	100
1 1/2 in.	37.5		226.20	100	20	0.850		50.30	100
1 in.	25.0		226.20	100	40	0.425	0.1	50.20	100
3/4 in.	19.0		226.20	100	60	0.250	0.3	49.90	99
1/2 in.	12.5		226.20	100	100	0.150	0.3	49.57	99
3/8 in.	9.5		226.20	100	200	0.075	4.7	44.87	89
4	4.8		226.20	100	325	0.045	3.0	41.87	83
10	2.0		226.20	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. ^oC	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/2/2011	8:42:00	0							
2/2/2011	8:42:30	0.5	30.6	22.0	8.4	3.0753	27.5247	0.0538	86
2/2/2011	8:43:00	1	28.9	22.0	8.9	3.0753	25.8247	0.0391	81
2/2/2011	8:44:00	2	27.0	22.0	9.2	3.0753	23.9247	0.0281	75
2/2/2011	8:46:00	4	25.1	22.0	9.7	3.0753	22.0247	0.0204	69
2/2/2011	8:50:00	8	23.5	22.0	10.2	3.0753	20.4247	0.0148	64
2/2/2011	8:57:00	15	22.1	22.0	10.5	3.0753	19.0247	0.0110	60
2/2/2011	9:12:00	30	20.5	22.0	11.0	3.0753	17.4247	0.0079	55
2/2/2011	9:42:00	60	18.3	22.0	11.5	3.0753	15.2247	0.0057	48
2/2/2011	10:42:00	120	17.6	22.0	11.8	3.0753	14.5247	0.0041	46
2/2/2011	12:42:00	240	16.1	22.0	12.1	3.0753	13.0247	0.0029	41
2/2/2011	16:42:00	480	15.0	22.0	12.3	3.0753	11.9247	0.0021	37
2/3/2011	8:42:00	1440	12.8	22.0	13.1	3.0753	9.7247	0.0013	31



Remarks	SUMMARY			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	#N/A	Sand	10.8 %
	D_{50} =	0.006	Silt Sizes	52.6 %
	D_{60} =	0.011	Clay Sizes	36.6 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-05	Depth	12.0 m
Technician	CR/SH	Date	2-Feb-11

amec

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-05	Depth	18.0 m
Technician	CR/SH	Date	2-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 2

Air Dried Wt. of Soil Tested 50.5 g Dry Wt. of Soil Tested 50.5

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 1-Feb-11

Mechanical Sieve Results

Total Wt of Sample Dry 219.3 g

\+ # 10 0.0 g

\- # 10 219.3 g

Hydrometer Test

(Adjusted for + # 10 Material)

Total Dry Wt. 50.5 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		219.30	100	10	2.000		50.50	100
1 1/2 in.	37.5		219.30	100	20	0.850		50.50	100
1 in.	25.0		219.30	100	40	0.425		50.50	100
3/4 in.	19.0		219.30	100	60	0.250		50.50	100
1/2 in.	12.5		219.30	100	100	0.150		50.50	100
3/8 in.	9.5		219.30	100	200	0.075		50.50	100
4	4.8		219.30	100	325	0.045		50.50	100
10	2.0		219.30	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. °C	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/2/2011	8:42:00	0							
2/2/2011	8:42:30	0.5	35.0	21.4	7.0	3.2073	31.7927	0.0497	99
2/2/2011	8:43:00	1	33.1	21.4	7.6	3.2073	29.8927	0.0366	93
2/2/2011	8:44:00	2	31.3	21.4	8.1	3.2073	28.0927	0.0267	88
2/2/2011	8:46:00	4	29.2	21.4	8.6	3.2073	25.9927	0.0195	81
2/2/2011	8:50:00	8	27.1	21.4	9.2	3.2073	23.8927	0.0142	75
2/2/2011	8:57:00	15	24.9	21.4	10.0	3.2073	21.6927	0.0108	68
2/2/2011	9:12:00	30	22.9	21.4	10.5	3.2073	19.6927	0.0079	62
2/2/2011	9:42:00	60	20.4	21.4	11.0	3.2073	17.1927	0.0057	54
2/2/2011	10:42:00	120	18.2	21.4	11.5	3.2073	14.9927	0.0041	47
2/2/2011	12:42:00	240	16.1	21.4	12.1	3.2073	12.8927	0.0030	40
2/2/2011	16:42:00	480	15.0	21.4	12.3	3.2073	11.7927	0.0021	37
2/3/2011	8:42:00	1440	13.3	21.4	12.9	3.2073	10.0927	0.0013	32

Remarks	SUMMARY			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	#N/A	Sand	0.0 %
	D_{50} =	0.005	Silt Sizes	63.9 %
	D_{60} =	0.007	Clay Sizes	36.1 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-05	Depth	18.0 m
Technician	CR/SH	Date	2-Feb-11

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-05	Depth	23.0 m
Technician	CR/SH	Date	2-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 27

Air Dried Wt. of Soil Tested 50.0 g Dry Wt. of Soil Tested 50.0

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 1-Feb-11

Mechanical Sieve Results

Total Wt of Sample Dry g

+ # 10 0.0 g

- # 10 0.0 g

Hydrometer Test

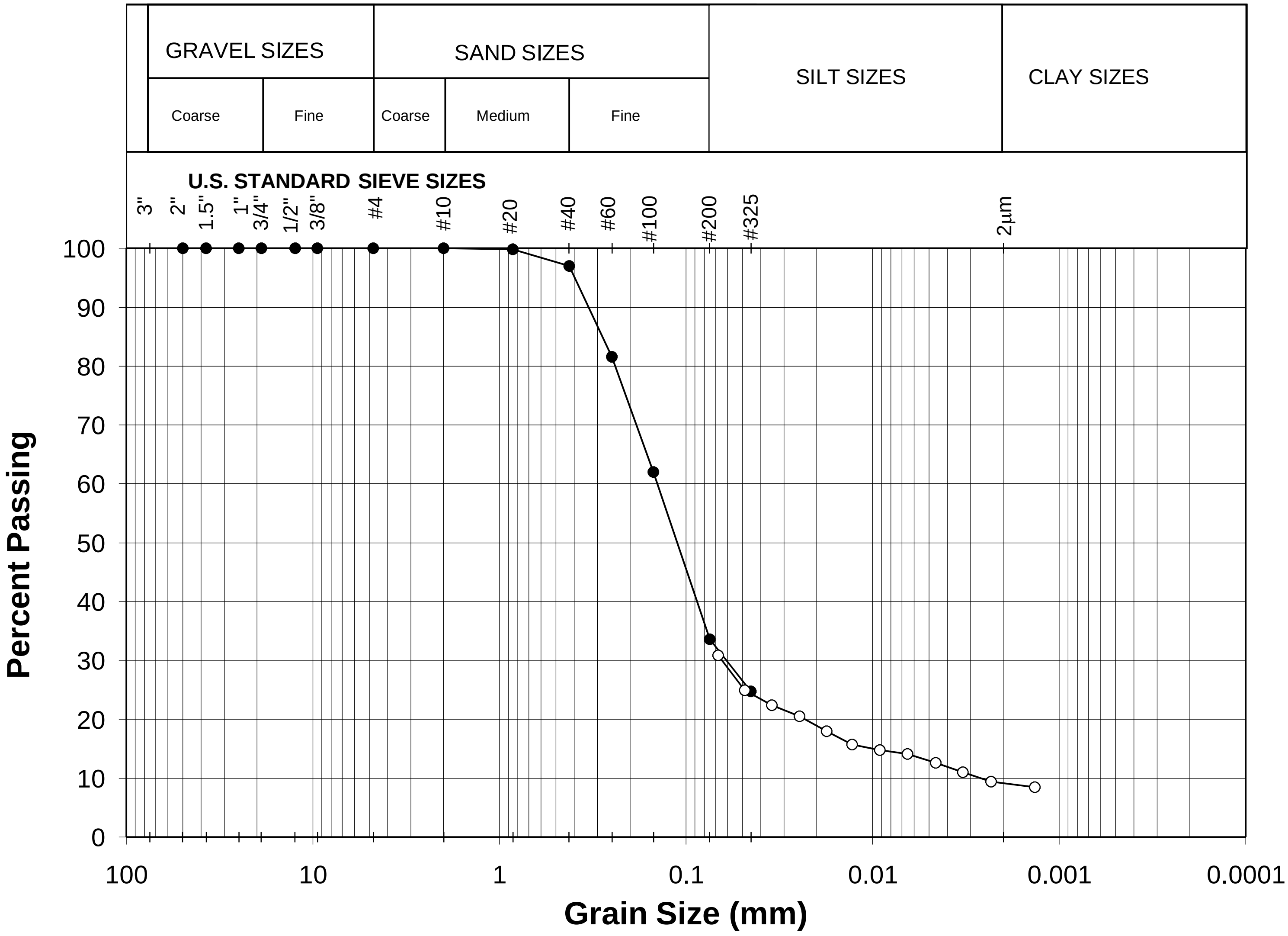
(Adjusted for + # 10 Material)

Total Dry Wt. 50.0 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		0.00	100	10	2.000		50.00	100
1 1/2 in.	37.5		0.00	100	20	0.850	0.1	49.90	100
1 in.	25.0		0.00	100	40	0.425	1.4	48.50	97
3/4 in.	19.0		0.00	100	60	0.250	7.7	40.80	82
1/2 in.	12.5		0.00	100	100	0.150	9.8	31.00	62
3/8 in.	9.5		0.00	100	200	0.075	14.2	16.80	34
4	4.8		0.00	100	325	0.045	4.4	12.40	25
10	2.0		0.00	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. ^oC	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/2/2011	8:42:00	0							
2/2/2011	8:42:30	0.5	13.0	21.4	12.9	3.2073	9.7927	0.0675	31
2/2/2011	8:43:00	1	11.1	21.4	13.4	3.2073	7.8927	0.0486	25
2/2/2011	8:44:00	2	10.3	21.4	13.7	3.2073	7.0927	0.0348	22
2/2/2011	8:46:00	4	9.7	21.4	13.9	3.2073	6.4927	0.0248	20
2/2/2011	8:50:00	8	8.9	21.4	14.2	3.2073	5.6927	0.0177	18
2/2/2011	8:57:00	15	8.2	21.4	14.2	3.2073	4.9927	0.0129	16
2/2/2011	9:12:00	30	7.9	21.4	14.4	3.2073	4.6927	0.0092	15
2/2/2011	9:42:00	60	7.7	21.4	14.4	3.2073	4.4927	0.0065	14
2/2/2011	10:42:00	120	7.2	21.4	14.4	3.2073	3.9927	0.0046	13
2/2/2011	12:42:00	240	6.7	21.4	14.7	3.2073	3.4927	0.0033	11
2/2/2011	16:42:00	480	6.2	21.4	14.7	3.2073	2.9927	0.0023	9
2/3/2011	8:42:00	1440	5.9	21.4	15.0	3.2073	2.6927	0.0014	8



Remarks	**SUMMARY**			
	D_{10} =	0.003	Gravel	0.0 %
	D_{30} =	0.065	Sand	66.4 %
	D_{50} =	0.118	Silt Sizes	24.5 %
	D_{60} =	0.145	Clay Sizes	9.1 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-05	Depth	23.0 m
Technician	CR/SH	Date	2-Feb-11

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-05	Depth	6.0 m
Technician	CR/SH	Date	2-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 16

Air Dried Wt. of Soil Tested 50.2 g Dry Wt. of Soil Tested 50.2

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 1-Feb-11

Mechanical Sieve Results

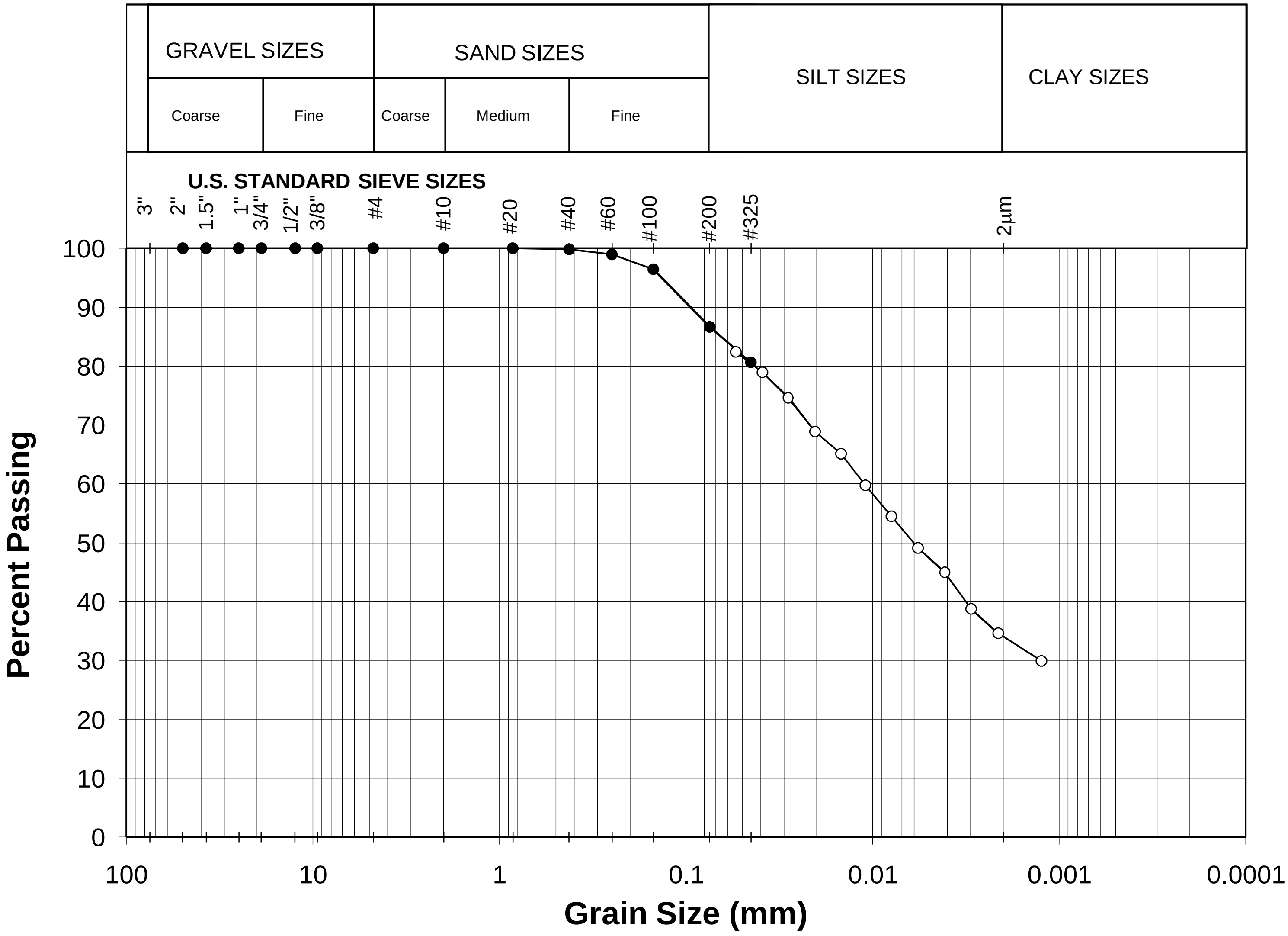
Total Wt of Sample Dry 123.0 g
+ # 10 0.0 g
- # 10 123.0 g

Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 50.2 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		123.00	100	10	2.000		50.20	100
1 1/2 in.	37.5		123.00	100	20	0.850		50.20	100
1 in.	25.0		123.00	100	40	0.425	0.1	50.10	100
3/4 in.	19.0		123.00	100	60	0.250	0.4	49.70	99
1/2 in.	12.5		123.00	100	100	0.150	1.3	48.40	96
3/8 in.	9.5		123.00	100	200	0.075	4.9	43.50	87
4	4.8		123.00	100	325	0.045	3.0	40.50	81
10	2.0		123.00	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. ^oC	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/2/2011	8:42:00	0							
2/2/2011	8:42:30	0.5	29.3	22.0	8.6	3.0753	26.2247	0.0544	82
2/2/2011	8:43:00	1	28.2	22.0	8.9	3.0753	25.1247	0.0391	79
2/2/2011	8:44:00	2	26.8	22.0	9.4	3.0753	23.7247	0.0284	75
2/2/2011	8:46:00	4	25.0	22.0	9.7	3.0753	21.9247	0.0204	69
2/2/2011	8:50:00	8	23.8	22.0	10.2	3.0753	20.7247	0.0148	65
2/2/2011	8:57:00	15	22.1	22.0	10.5	3.0753	19.0247	0.0110	60
2/2/2011	9:12:00	30	20.4	22.0	11.0	3.0753	17.3247	0.0079	54
2/2/2011	9:42:00	60	18.7	22.0	11.5	3.0753	15.6247	0.0057	49
2/2/2011	10:42:00	120	17.4	22.0	11.8	3.0753	14.3247	0.0041	45
2/2/2011	12:42:00	240	15.4	22.0	12.3	3.0753	12.3247	0.0030	39
2/2/2011	16:42:00	480	14.1	22.0	12.6	3.0753	11.0247	0.0021	35
2/3/2011	8:42:00	1440	12.6	22.0	13.1	3.0753	9.5247	0.0013	30



Remarks

SUMMARY

D_{10} =	#N/A	Gravel	0.0 %
D_{30} =	0.001	Sand	13.3 %
D_{50} =	0.006	Silt Sizes	52.7 %
D_{60} =	0.011	Clay Sizes	34.0 %
C_U =	#N/A		
C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

amec

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-05	Depth	6.0 m
Technician	CR/SH	Date	2-Feb-11

amec

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-06	Depth	12.0 m
Technician	CR/SH	Date	8-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 3

Air Dried Wt. of Soil Tested 50.9 g Dry Wt. of Soil Tested 50.9

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 7-Feb-11

Mechanical Sieve Results

Total Wt of Sample Dry 295.2 g

\+ # 10 0.0 g

\- # 10 295.2 g

Hydrometer Test

(Adjusted for + # 10 Material)

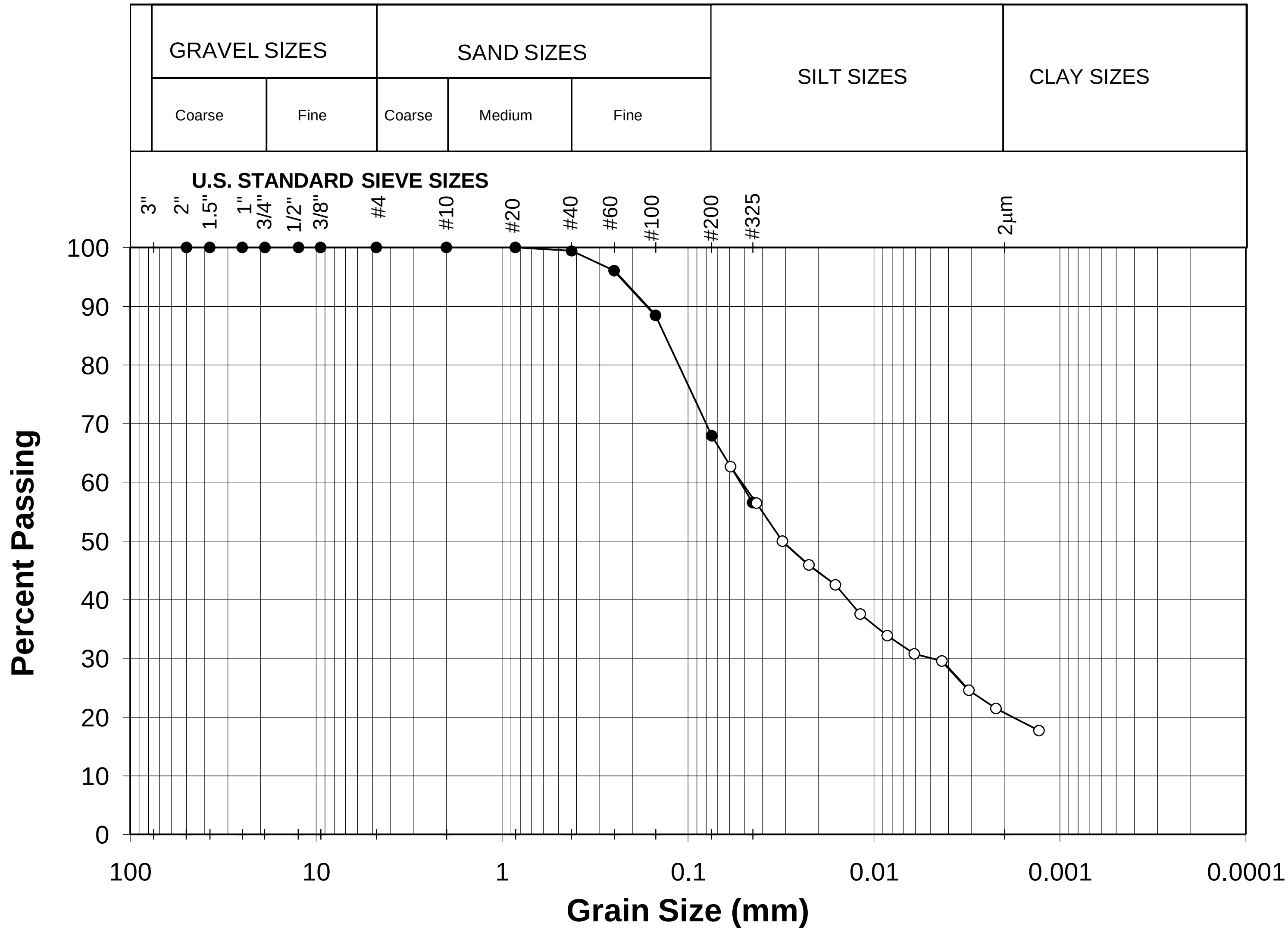
Total Dry Wt. 50.9 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		295.20	100	10	2.000		50.90	100
1 1/2 in.	37.5		295.20	100	20	0.850		50.90	100
1 in.	25.0		295.20	100	40	0.425	0.3	50.60	99
3/4 in.	19.0		295.20	100	60	0.250	1.7	48.90	96
1/2 in.	12.5		295.20	100	100	0.150	3.9	45.00	88
3/8 in.	9.5		295.20	100	200	0.075	10.4	34.60	68
4	4.8		295.20	100	325	0.045	5.8	28.80	57
10	2.0		295.20	100	pan				

0.0

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. ^oC	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/8/2011	8:42:00	0							
2/8/2011	8:42:30	0.5	23.3	22.0	10.2	3.0753	20.2247	0.0593	63
2/8/2011	8:43:00	1	21.3	22.0	10.7	3.0753	18.2247	0.0429	57
2/8/2011	8:44:00	2	19.2	22.0	11.3	3.0753	16.1247	0.0312	50
2/8/2011	8:46:00	4	17.9	22.0	11.8	3.0753	14.8247	0.0225	46
2/8/2011	8:50:00	8	16.8	22.0	12.1	3.0753	13.7247	0.0161	43
2/8/2011	8:57:00	15	15.2	22.0	12.3	3.0753	12.1247	0.0119	38
2/8/2011	9:12:00	30	14.0	22.0	12.6	3.0753	10.9247	0.0085	34
2/8/2011	9:42:00	60	13.0	22.0	12.9	3.0753	9.9247	0.0061	31
2/8/2011	10:42:00	120	12.6	22.0	13.1	3.0753	9.5247	0.0043	30
2/8/2011	12:42:00	240	11.0	22.0	13.4	3.0753	7.9247	0.0031	25
2/8/2011	16:42:00	480	10.0	22.0	13.7	3.0753	6.9247	0.0022	21
2/9/2011	8:42:00	1440	8.8	22.0	14.2	3.0753	5.7247	0.0013	18



Remarks	SUMMARY			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	0.005	Sand	32.0 %
	D_{50} =	0.031	Silt Sizes	47.4 %
	D_{60} =	0.052	Clay Sizes	20.6 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

amec

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-06	Depth	12.0 m
Technician	CR/SH	Date	8-Feb-11

amec

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-06	Depth	13.0 m
Technician	CR/SH	Date	8-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 17

Air Dried Wt. of Soil Tested 50.5 g Dry Wt. of Soil Tested 50.5

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 7-Feb-11

Mechanical Sieve Results

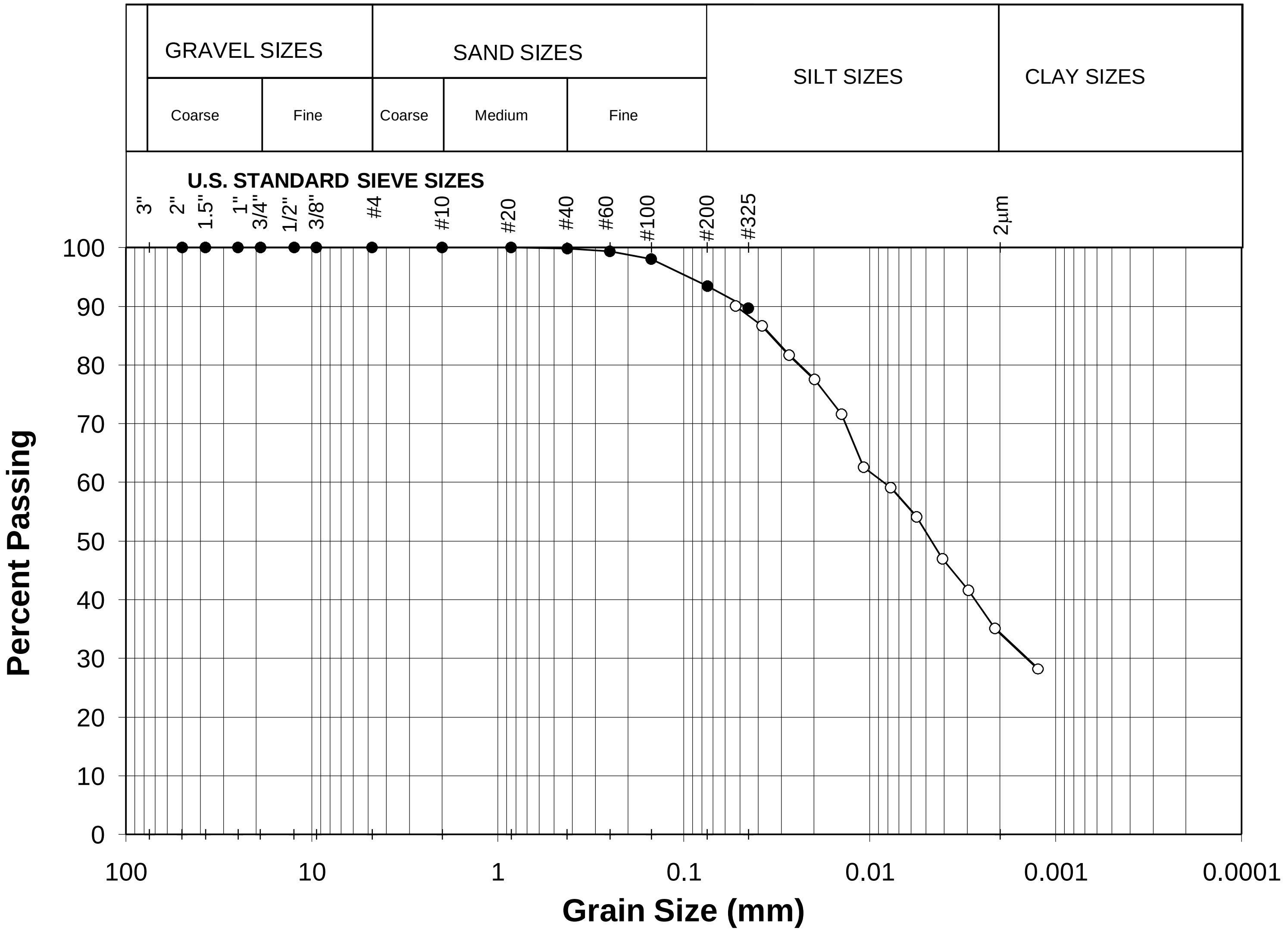
Total Wt of Sample Dry 221.2 g
+ # 10 0.0 g
- # 10 221.2 g

Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 50.5 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		221.20	100	10	2.000		50.50	100
1 1/2 in.	37.5		221.20	100	20	0.850		50.50	100
1 in.	25.0		221.20	100	40	0.425	0.1	50.40	100
3/4 in.	19.0		221.20	100	60	0.250	0.2	50.20	99
1/2 in.	12.5		221.20	100	100	0.150	0.7	49.50	98
3/8 in.	9.5		221.20	100	200	0.075	2.3	47.20	93
4	4.8		221.20	100	325	0.045	1.9	45.30	90
10	2.0		221.20	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. ^oC	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/8/2011	8:42:00	0							
2/8/2011	8:42:30	0.5	31.9	22.0	8.1	3.0753	28.8247	0.0528	90
2/8/2011	8:43:00	1	30.8	22.0	8.4	3.0753	27.7247	0.0380	87
2/8/2011	8:44:00	2	29.2	22.0	8.6	3.0753	26.1247	0.0272	82
2/8/2011	8:46:00	4	27.9	22.0	9.2	3.0753	24.8247	0.0199	78
2/8/2011	8:50:00	8	26.0	22.0	9.4	3.0753	22.9247	0.0142	72
2/8/2011	8:57:00	15	23.1	22.0	10.2	3.0753	20.0247	0.0108	63
2/8/2011	9:12:00	30	22.0	22.0	10.5	3.0753	18.9247	0.0078	59
2/8/2011	9:42:00	60	20.4	22.0	11.0	3.0753	17.3247	0.0056	54
2/8/2011	10:42:00	120	18.1	22.0	11.5	3.0753	15.0247	0.0041	47
2/8/2011	12:42:00	240	16.4	22.0	12.1	3.0753	13.3247	0.0029	42
2/8/2011	16:42:00	480	14.3	22.0	12.6	3.0753	11.2247	0.0021	35
2/9/2011	8:42:00	1440	12.1	22.0	13.1	3.0753	9.0247	0.0013	28



Remarks	**SUMMARY**			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	0.001	Sand	6.5 %
	D_{50} =	0.005	Silt Sizes	59.4 %
	D_{60} =	0.009	Clay Sizes	34.1 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-06	Depth	13.0 m
Technician	CR/SH	Date	8-Feb-11

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-06	Depth	15.0 m
Technician	CR/SH	Date	2-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 7

Air Dried Wt. of Soil Tested 50.5 g Dry Wt. of Soil Tested 50.5

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 1-Feb-11

Mechanical Sieve Results

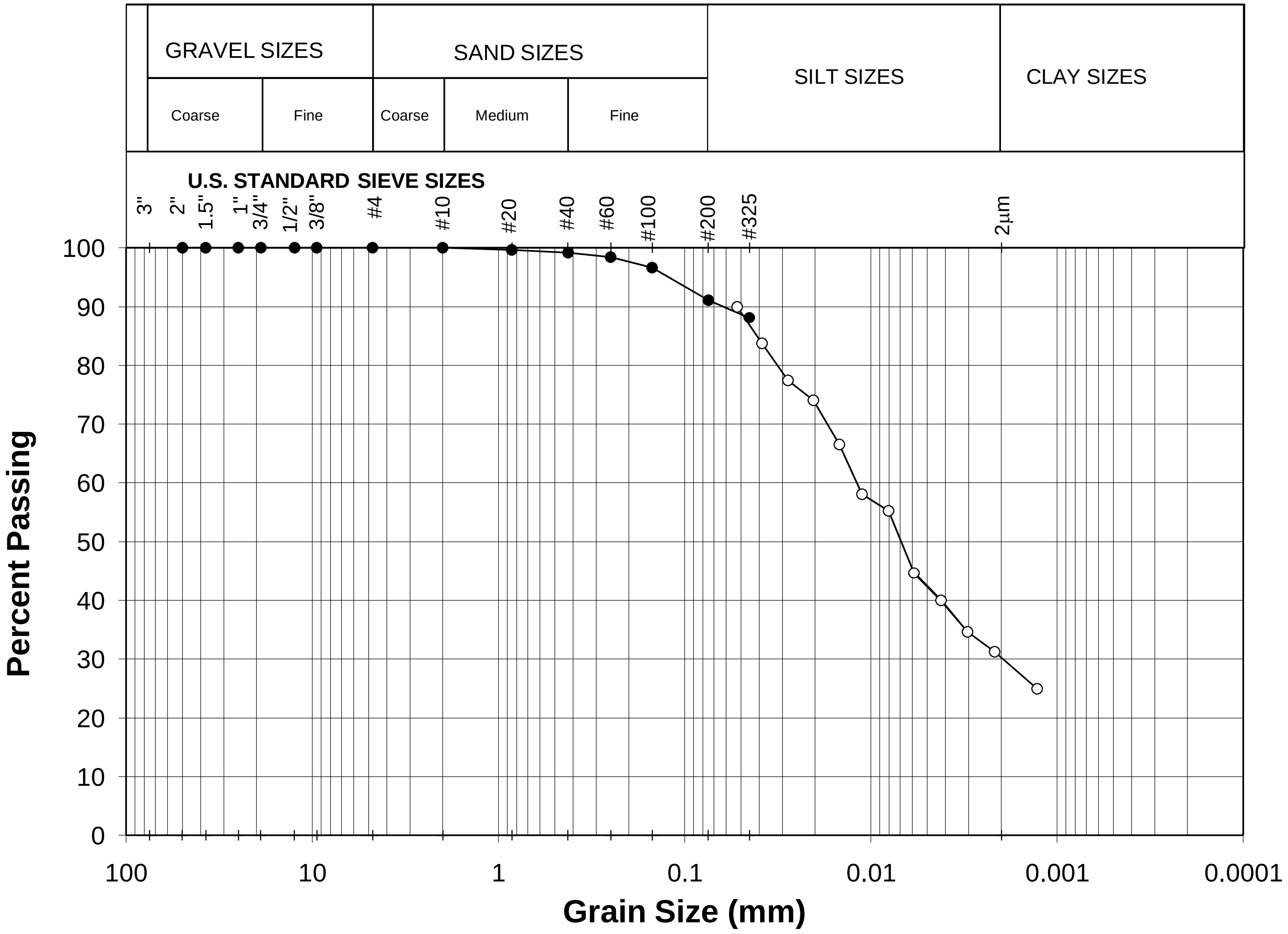
Total Wt of Sample Dry 182.8 g
\+ # 10 0.0 g
\- # 10 182.8 g

Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 50.5 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		182.80	100	10	2.000		50.50	100
1 1/2 in.	37.5		182.80	100	20	0.850	0.2	50.30	100
1 in.	25.0		182.80	100	40	0.425	0.2	50.10	99
3/4 in.	19.0		182.80	100	60	0.250	0.4	49.70	98
1/2 in.	12.5		182.80	100	100	0.150	0.9	48.80	97
3/8 in.	9.5		182.80	100	200	0.075	2.8	46.00	91
4	4.8		182.80	100	325	0.045	1.5	44.50	88
10	2.0		182.80	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. °C	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/2/2011	8:42:00	0							
2/2/2011	8:42:30	0.5	32.0	21.4	7.8	3.2073	28.7927	0.0525	90
2/2/2011	8:43:00	1	30.0	21.4	8.4	3.2073	26.7927	0.0385	84
2/2/2011	8:44:00	2	28.0	21.4	8.9	3.2073	24.7927	0.0280	77
2/2/2011	8:46:00	4	26.9	21.4	9.4	3.2073	23.6927	0.0204	74
2/2/2011	8:50:00	8	24.5	21.4	10.0	3.2073	21.2927	0.0148	67
2/2/2011	8:57:00	15	21.8	21.4	10.7	3.2073	18.5927	0.0112	58
2/2/2011	9:12:00	30	20.9	21.4	11.0	3.2073	17.6927	0.0080	55
2/2/2011	9:42:00	60	17.5	21.4	11.8	3.2073	14.2927	0.0059	45
2/2/2011	10:42:00	120	16.0	21.4	12.1	3.2073	12.7927	0.0042	40
2/2/2011	12:42:00	240	14.3	21.4	12.6	3.2073	11.0927	0.0030	35
2/2/2011	16:42:00	480	13.2	21.4	12.9	3.2073	9.9927	0.0022	31
2/3/2011	8:42:00	1440	11.2	21.4	13.4	3.2073	7.9927	0.0013	25



Remarks	SUMMARY			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	0.002	Sand	8.9 %
	D_{50} =	0.007	Silt Sizes	61.1 %
	D_{60} =	0.012	Clay Sizes	30.0 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

amec

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-06	Depth	15.0 m
Technician	CR/SH	Date	2-Feb-11

amec

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-06	Depth	17.0 m
Technician	CR/SH	Date	8-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 16

Air Dried Wt. of Soil Tested 50.5 g Dry Wt. of Soil Tested 50.5

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 7-Feb-11

Mechanical Sieve Results

Total Wt of Sample Dry 459.7 g
+ # 10 0.0 g
- # 10 459.7 g

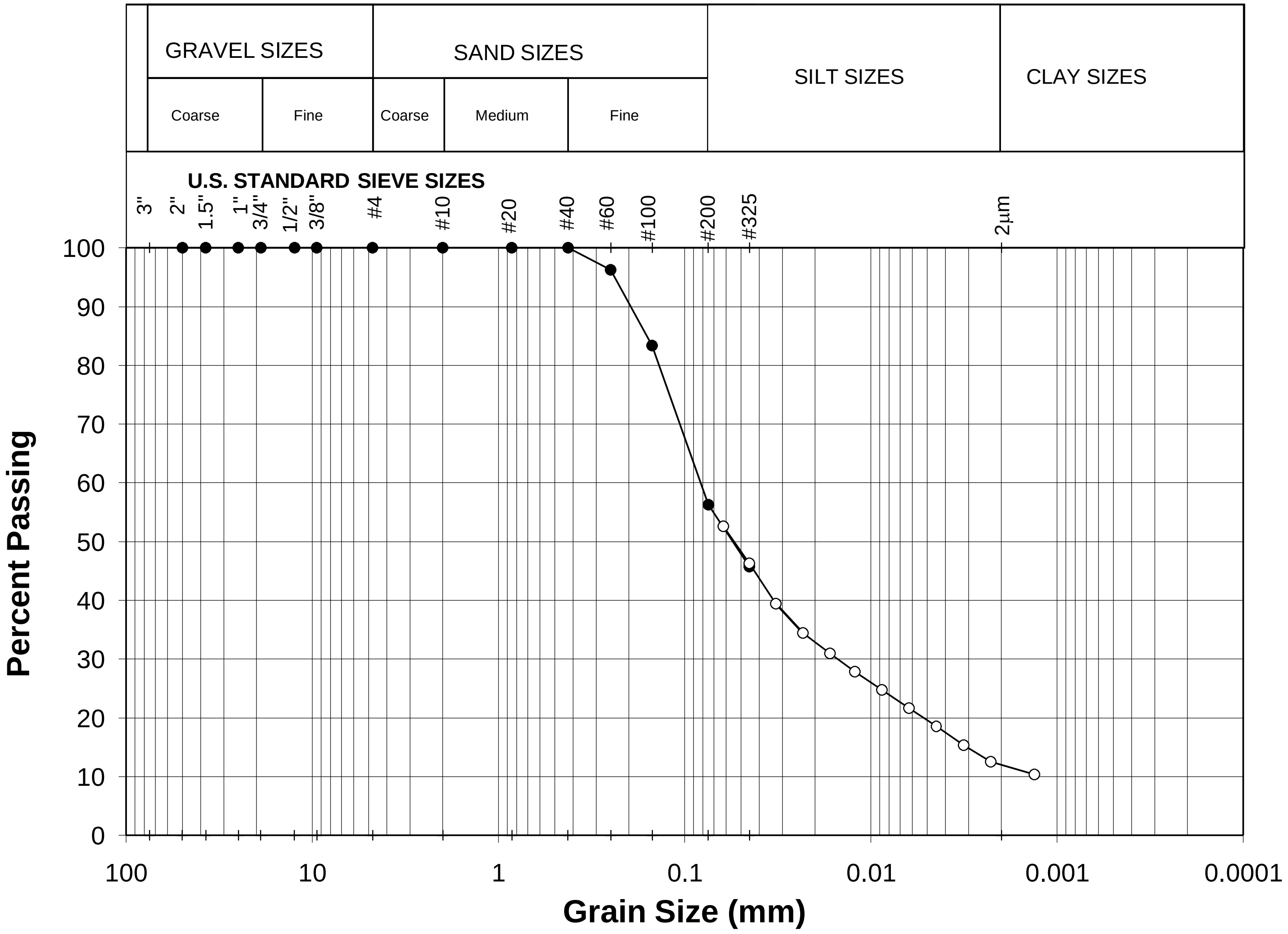
Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 50.5 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		459.70	100	10	2.000		50.50	100
1 1/2 in.	37.5		459.70	100	20	0.850		50.50	100
1 in.	25.0		459.70	100	40	0.425		50.50	100
3/4 in.	19.0		459.70	100	60	0.250	1.9	48.60	96
1/2 in.	12.5		459.70	100	100	0.150	6.5	42.10	83
3/8 in.	9.5		459.70	100	200	0.075	13.7	28.40	56
4	4.8		459.70	100	325	0.045	5.3	23.10	46
10	2.0		459.70	100	pan				

0.0

Hydrometer Results

Date	Time	Elapsed Time (min)	R'$_h$	Temp. ^{o}C	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/8/2011	8:42:00	0							
2/8/2011	8:42:30	0.5	19.9	22.0	11.3	3.0753	16.8247	0.0624	53
2/8/2011	8:43:00	1	17.9	22.0	11.8	3.0753	14.8247	0.0451	46
2/8/2011	8:44:00	2	15.7	22.0	12.3	3.0753	12.6247	0.0325	39
2/8/2011	8:46:00	4	14.1	22.0	12.6	3.0753	11.0247	0.0233	34
2/8/2011	8:50:00	8	13.0	22.0	12.9	3.0753	9.9247	0.0167	31
2/8/2011	8:57:00	15	12.0	22.0	13.1	3.0753	8.9247	0.0123	28
2/8/2011	9:12:00	30	11.0	22.0	13.4	3.0753	7.9247	0.0088	25
2/8/2011	9:42:00	60	10.0	22.0	13.7	3.0753	6.9247	0.0063	22
2/8/2011	10:42:00	120	9.0	22.0	13.9	3.0753	5.9247	0.0045	19
2/8/2011	12:42:00	240	8.0	22.0	14.2	3.0753	4.9247	0.0032	15
2/8/2011	16:42:00	480	7.1	22.0	14.4	3.0753	4.0247	0.0023	13
2/9/2011	8:42:00	1440	6.4	22.0	14.7	3.0753	3.3247	0.0013	10



Remarks	SUMMARY			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	0.015	Sand	43.8 %
	D_{50} =	0.055	Silt Sizes	44.3 %
	D_{60} =	0.085	Clay Sizes	11.9 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

amec

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-06	Depth	17.0 m
Technician	CR/SH	Date	8-Feb-11

amec

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-06	Depth	4.0 m
Technician	CR/SH	Date	8-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 15
Air Dried Wt. of Soil Tested 50.7 g Dry Wt. of Soil Tested 50.7

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 7-Feb-11

Mechanical Sieve Results

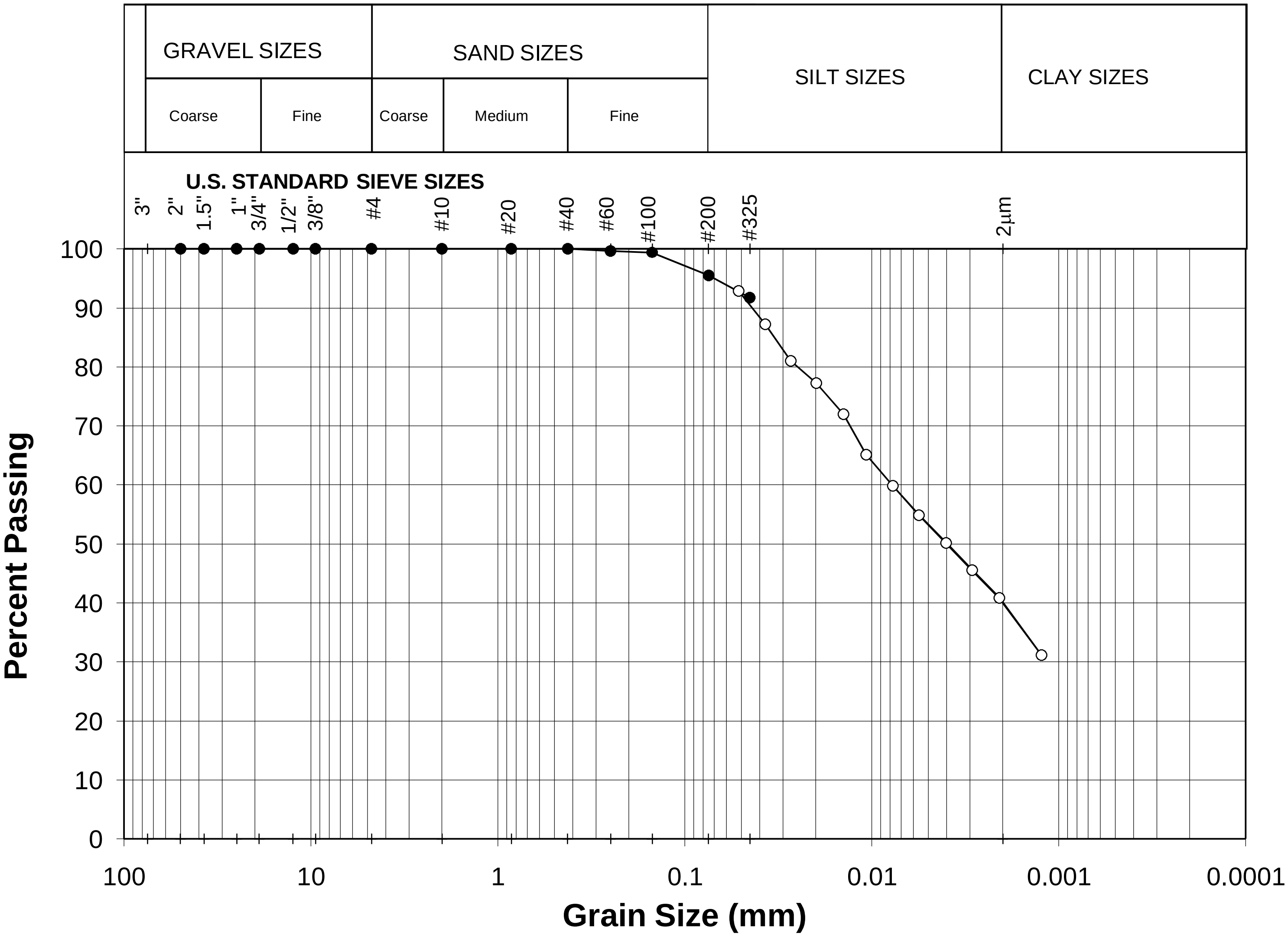
Total Wt of Sample Dry 117.4 g
+ # 10 0.0 g
- # 10 117.4 g

Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 50.7 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		117.40	100	10	2.000		50.70	100
1 1/2 in.	37.5		117.40	100	20	0.850		50.70	100
1 in.	25.0		117.40	100	40	0.425		50.70	100
3/4 in.	19.0		117.40	100	60	0.250	0.2	50.50	100
1/2 in.	12.5		117.40	100	100	0.150	0.1	50.40	99
3/8 in.	9.5		117.40	100	200	0.075	2.0	48.40	95
4	4.8		117.40	100	325	0.045	1.9	46.50	92
10	2.0		117.40	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'$_h$	Temp. ^{o}C	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/8/2011	8:42:00	0							
2/8/2011	8:42:30	0.5	32.9	22.0	7.8	3.0753	29.8247	0.0518	93
2/8/2011	8:43:00	1	31.1	22.0	8.1	3.0753	28.0247	0.0373	87
2/8/2011	8:44:00	2	29.1	22.0	8.6	3.0753	26.0247	0.0272	81
2/8/2011	8:46:00	4	27.9	22.0	9.2	3.0753	24.8247	0.0199	77
2/8/2011	8:50:00	8	26.2	22.0	9.4	3.0753	23.1247	0.0142	72
2/8/2011	8:57:00	15	24.0	22.0	10.0	3.0753	20.9247	0.0107	65
2/8/2011	9:12:00	30	22.3	22.0	10.5	3.0753	19.2247	0.0078	60
2/8/2011	9:42:00	60	20.7	22.0	11.0	3.0753	17.6247	0.0056	55
2/8/2011	10:42:00	120	19.2	22.0	11.3	3.0753	16.1247	0.0040	50
2/8/2011	12:42:00	240	17.7	22.0	11.8	3.0753	14.6247	0.0029	46
2/8/2011	16:42:00	480	16.2	22.0	12.1	3.0753	13.1247	0.0021	41
2/9/2011	8:42:00	1440	13.1	22.0	12.9	3.0753	10.0247	0.0012	31



Remarks	SUMMARY			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	#N/A	Sand	4.5 %
	D_{50} =	0.004	Silt Sizes	55.6 %
	D_{60} =	0.008	Clay Sizes	39.9 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

amec

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-06	Depth	4.0 m
Technician	CR/SH	Date	8-Feb-11

amec

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-06	Depth	8.0 m
Technician	CR/SH	Date	2-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 3

Air Dried Wt. of Soil Tested 50.9 g Dry Wt. of Soil Tested 50.9

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 1-Feb-11

Mechanical Sieve Results

Total Wt of Sample Dry 217.8 g

+ # 10 0.0 g

- # 10 217.8 g

Hydrometer Test

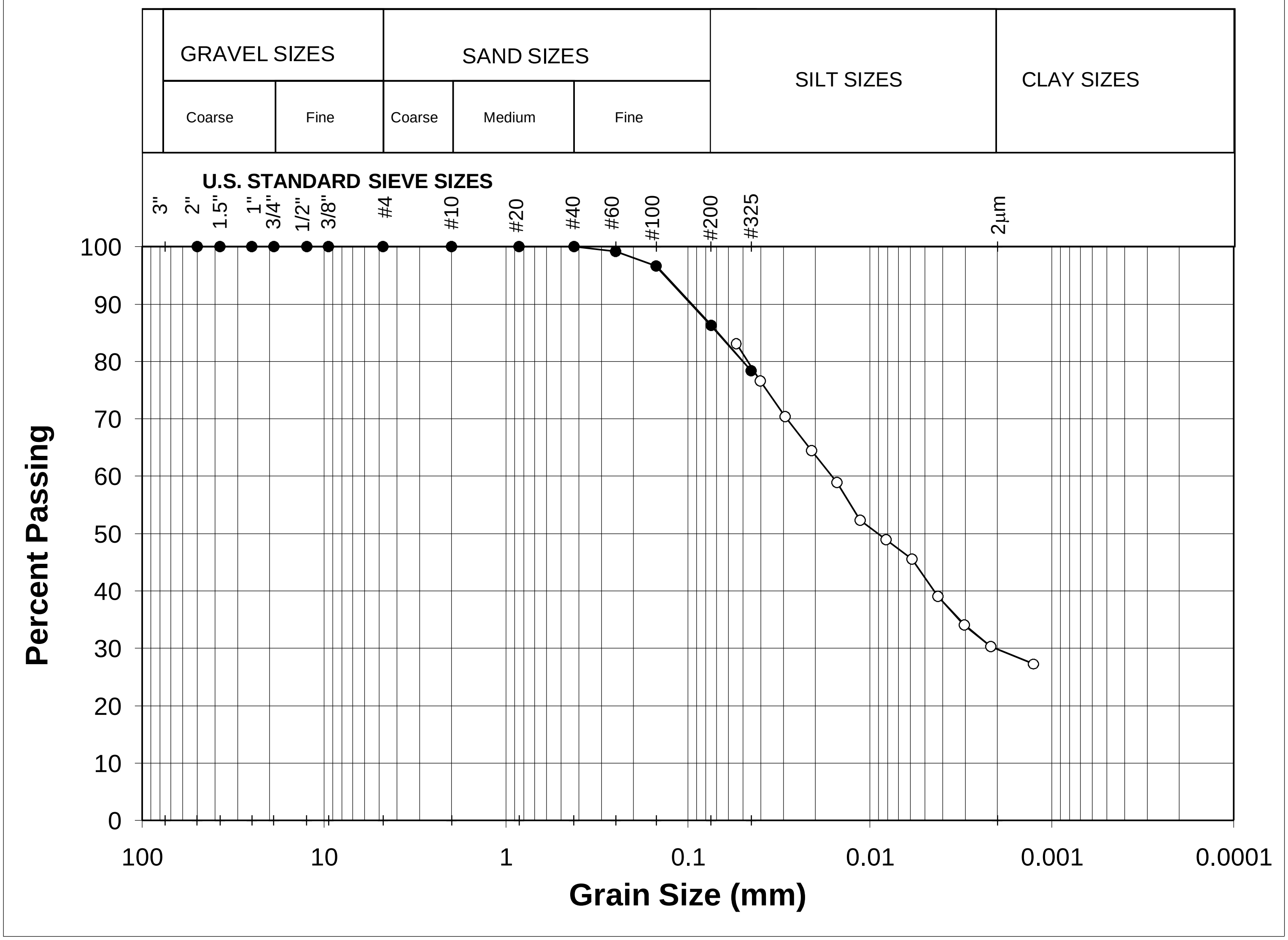
(Adjusted for + # 10 Material)

Total Dry Wt. 50.9 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		217.80	100	10	2.000		50.90	100
1 1/2 in.	37.5		217.80	100	20	0.850		50.90	100
1 in.	25.0		217.80	100	40	0.425		50.90	100
3/4 in.	19.0		217.80	100	60	0.250	0.4	50.50	99
1/2 in.	12.5		217.80	100	100	0.150	1.3	49.20	97
3/8 in.	9.5		217.80	100	200	0.075	5.3	43.90	86
4	4.8		217.80	100	325	0.045	4.0	39.90	78
10	2.0		217.80	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. ^oC	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/2/2011	8:42:00	0							
2/2/2011	8:42:30	0.5	30.0	21.4	8.4	3.2073	26.7927	0.0544	83
2/2/2011	8:43:00	1	27.9	21.4	9.2	3.2073	24.6927	0.0403	77
2/2/2011	8:44:00	2	25.9	21.4	9.7	3.2073	22.6927	0.0292	70
2/2/2011	8:46:00	4	24.0	21.4	10.0	3.2073	20.7927	0.0210	64
2/2/2011	8:50:00	8	22.2	21.4	10.5	3.2073	18.9927	0.0152	59
2/2/2011	8:57:00	15	20.1	21.4	11.0	3.2073	16.8927	0.0114	52
2/2/2011	9:12:00	30	19.0	21.4	11.3	3.2073	15.7927	0.0082	49
2/2/2011	9:42:00	60	17.9	21.4	11.8	3.2073	14.6927	0.0059	46
2/2/2011	10:42:00	120	15.8	21.4	12.3	3.2073	12.5927	0.0043	39
2/2/2011	12:42:00	240	14.2	21.4	12.6	3.2073	10.9927	0.0030	34
2/2/2011	16:42:00	480	13.0	21.4	12.9	3.2073	9.7927	0.0022	30
2/3/2011	8:42:00	1440	12.0	21.4	13.1	3.2073	8.7927	0.0013	27



Remarks	SUMMARY			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	0.002	Sand	13.8 %
	D_{50} =	0.009	Silt Sizes	56.5 %
	D_{60} =	0.016	Clay Sizes	29.8 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 1		
Hole	BH10-06	Depth	8.0 m
Technician	CR/SH	Date	2-Feb-11

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-06	Depth	12.0 m
Technician	CR/SH	Date	8-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 2

Air Dried Wt. of Soil Tested 50.4 g Dry Wt. of Soil Tested 50.4

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 7-Feb-11

Mechanical Sieve Results

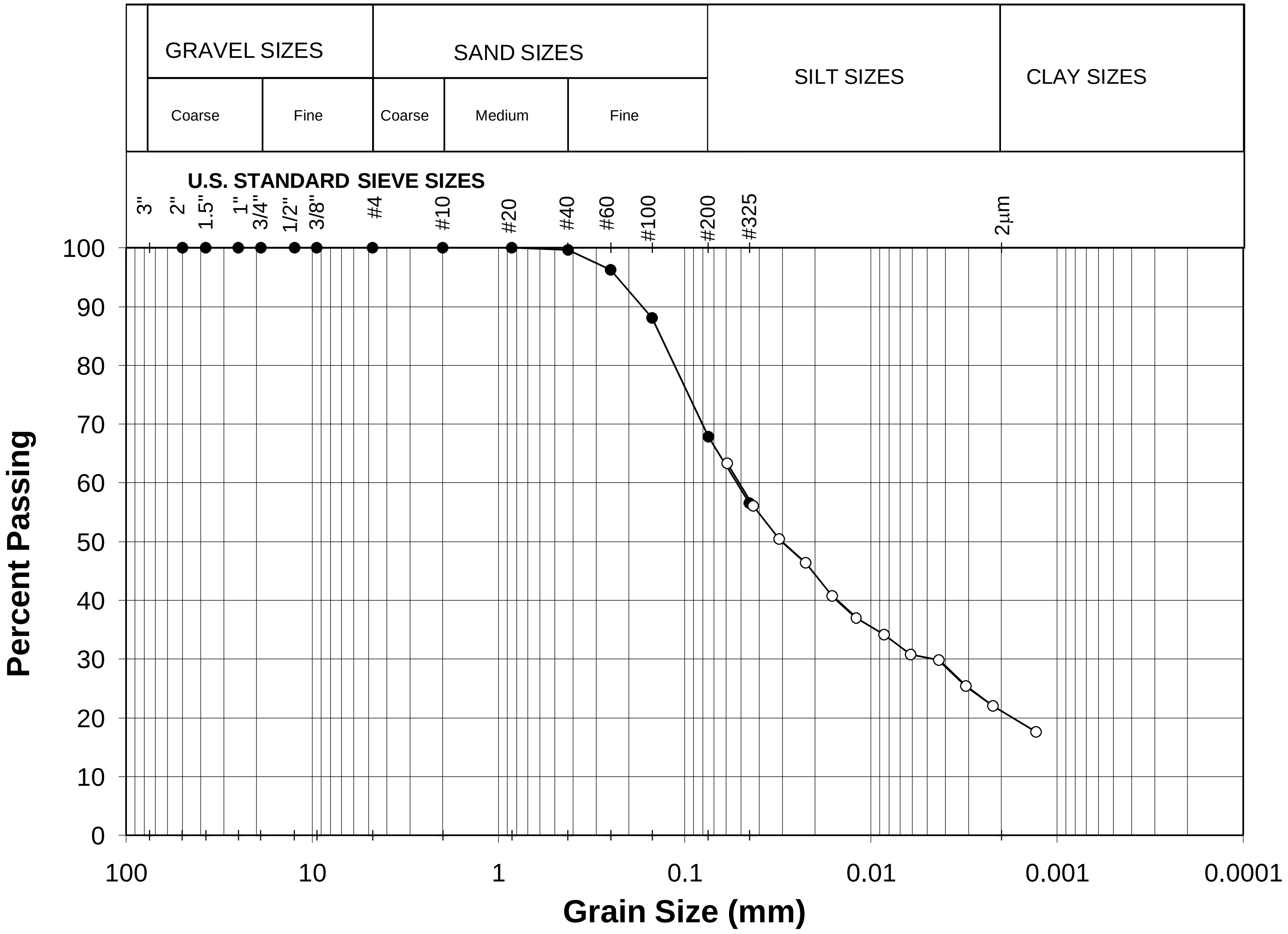
Total Wt of Sample Dry 295.2 g
+ # 10 0.0 g
- # 10 295.2 g

Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 50.4 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		295.20	100	10	2.000		50.40	100
1 1/2 in.	37.5		295.20	100	20	0.850		50.40	100
1 in.	25.0		295.20	100	40	0.425	0.2	50.20	100
3/4 in.	19.0		295.20	100	60	0.250	1.7	48.50	96
1/2 in.	12.5		295.20	100	100	0.150	4.1	44.40	88
3/8 in.	9.5		295.20	100	200	0.075	10.2	34.20	68
4	4.8		295.20	100	325	0.045	5.7	28.50	57
10	2.0		295.20	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. ^oC	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/8/2011	8:42:00	0							
2/8/2011	8:42:30	0.5	23.3	22.0	10.2	3.0753	20.2247	0.0593	63
2/8/2011	8:43:00	1	21.0	22.0	10.7	3.0753	17.9247	0.0429	56
2/8/2011	8:44:00	2	19.2	22.0	11.3	3.0753	16.1247	0.0312	50
2/8/2011	8:46:00	4	17.9	22.0	11.8	3.0753	14.8247	0.0225	46
2/8/2011	8:50:00	8	16.1	22.0	12.1	3.0753	13.0247	0.0161	41
2/8/2011	8:57:00	15	14.9	22.0	12.6	3.0753	11.8247	0.0120	37
2/8/2011	9:12:00	30	14.0	22.0	12.6	3.0753	10.9247	0.0085	34
2/8/2011	9:42:00	60	12.9	22.0	13.1	3.0753	9.8247	0.0061	31
2/8/2011	10:42:00	120	12.6	22.0	13.1	3.0753	9.5247	0.0043	30
2/8/2011	12:42:00	240	11.2	22.0	13.4	3.0753	8.1247	0.0031	25
2/8/2011	16:42:00	480	10.1	22.0	13.7	3.0753	7.0247	0.0022	22
2/9/2011	8:42:00	1440	8.7	22.0	14.2	3.0753	5.6247	0.0013	18



Remarks	SUMMARY			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	0.005	Sand	32.1 %
	D_{50} =	0.030	Silt Sizes	46.9 %
	D_{60} =	0.052	Clay Sizes	21.0 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-06	Depth	12.0 m
Technician	CR/SH	Date	8-Feb-11

amec

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-06	Depth	13.0 m
Technician	CR/SH	Date	8-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 7

Air Dried Wt. of Soil Tested 50.2 g Dry Wt. of Soil Tested 50.2

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 7-Feb-11

Mechanical Sieve Results

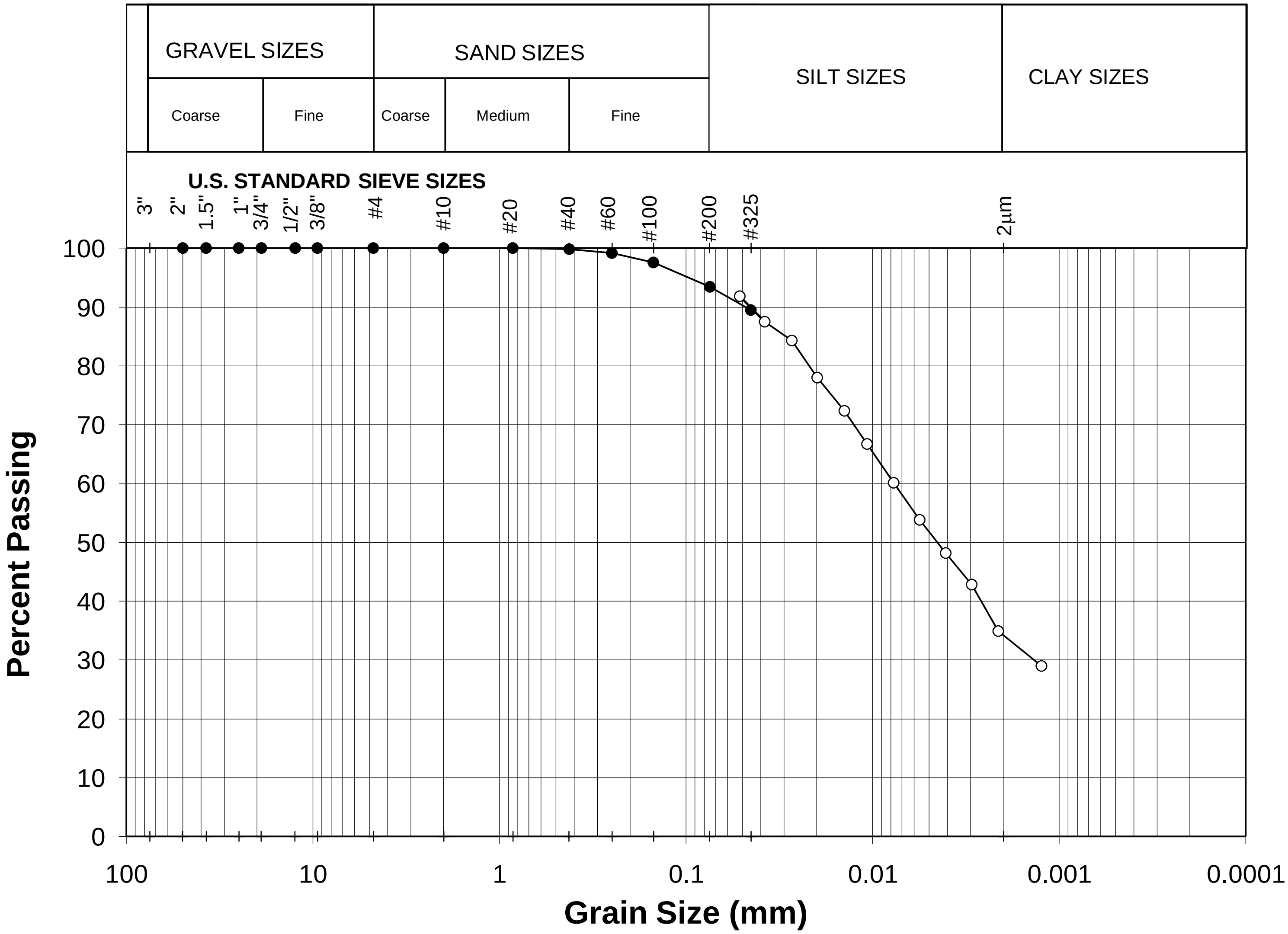
Total Wt of Sample Dry 221.2 g
+ # 10 0.0 g
- # 10 221.2 g

Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 50.2 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		221.20	100	10	2.000		50.20	100
1 1/2 in.	37.5		221.20	100	20	0.850		50.20	100
1 in.	25.0		221.20	100	40	0.425	0.1	50.10	100
3/4 in.	19.0		221.20	100	60	0.250	0.3	49.80	99
1/2 in.	12.5		221.20	100	100	0.150	0.8	49.00	98
3/8 in.	9.5		221.20	100	200	0.075	2.1	46.90	93
4	4.8		221.20	100	325	0.045	2.0	44.90	89
10	2.0		221.20	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. ^oC	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/8/2011	8:42:00	0							
2/8/2011	8:42:30	0.5	32.3	22.0	7.8	3.0753	29.2247	0.0518	92
2/8/2011	8:43:00	1	30.9	22.0	8.4	3.0753	27.8247	0.0380	87
2/8/2011	8:44:00	2	29.9	22.0	8.6	3.0753	26.8247	0.0272	84
2/8/2011	8:46:00	4	27.9	22.0	9.2	3.0753	24.8247	0.0199	78
2/8/2011	8:50:00	8	26.1	22.0	9.4	3.0753	23.0247	0.0142	72
2/8/2011	8:57:00	15	24.3	22.0	10.0	3.0753	21.2247	0.0107	67
2/8/2011	9:12:00	30	22.2	22.0	10.5	3.0753	19.1247	0.0078	60
2/8/2011	9:42:00	60	20.2	22.0	11.0	3.0753	17.1247	0.0056	54
2/8/2011	10:42:00	120	18.4	22.0	11.5	3.0753	15.3247	0.0041	48
2/8/2011	12:42:00	240	16.7	22.0	12.1	3.0753	13.6247	0.0029	43
2/8/2011	16:42:00	480	14.2	22.0	12.6	3.0753	11.1247	0.0021	35
2/9/2011	8:42:00	1440	12.3	22.0	13.1	3.0753	9.2247	0.0013	29



Remarks	SUMMARY			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	0.001	Sand	6.6 %
	D_{50} =	0.005	Silt Sizes	59.3 %
	D_{60} =	0.008	Clay Sizes	34.1 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-06	Depth	13.0 m
Technician	CR/SH	Date	8-Feb-11

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-06	Depth	15.0 m
Technician	CR/SH	Date	3-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 17

Air Dried Wt. of Soil Tested 50.3 g Dry Wt. of Soil Tested 50.3

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 2-Feb-11

Mechanical Sieve Results

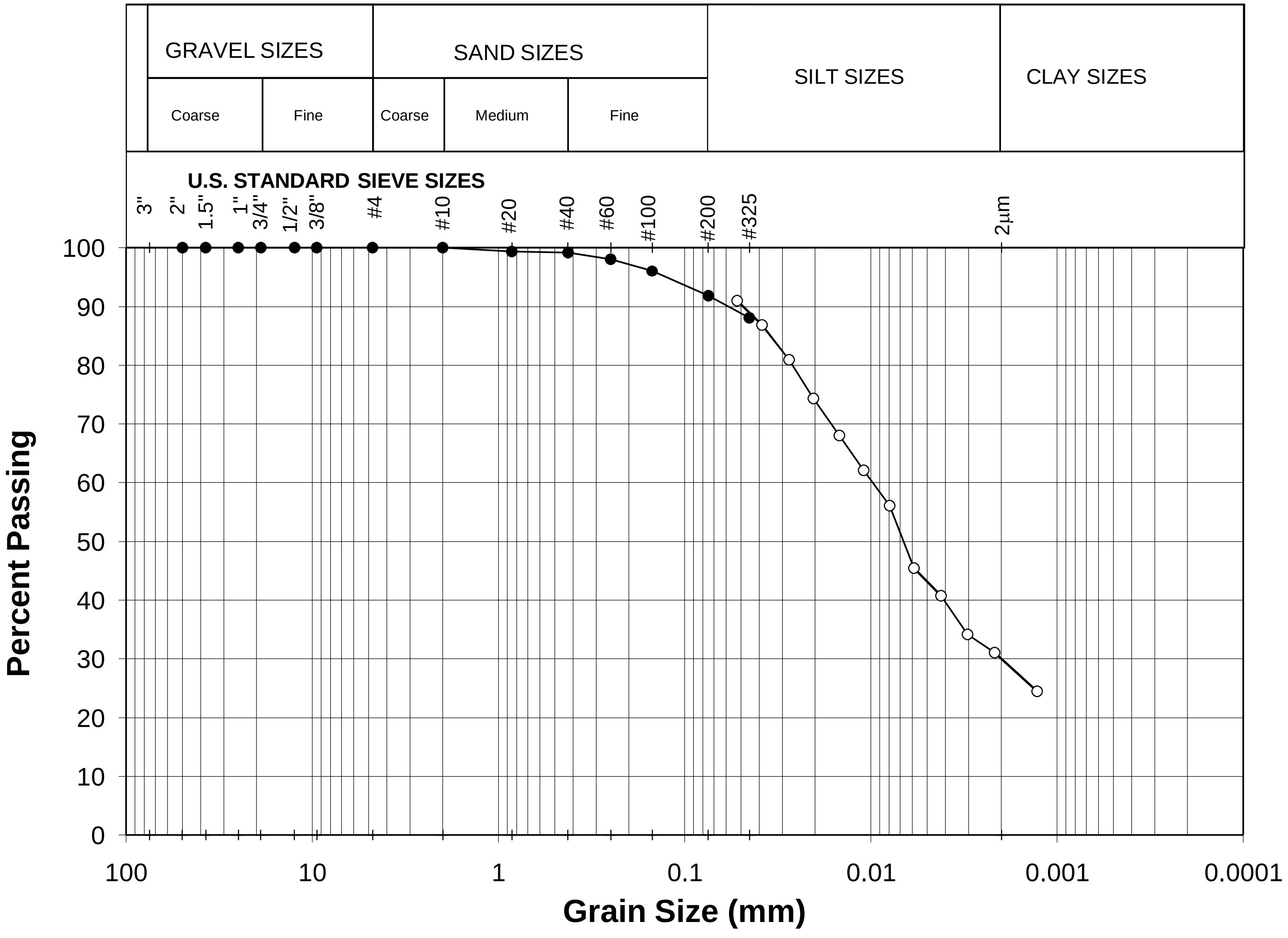
Total Wt of Sample Dry 182.8 g
+ # 10 0.0 g
- # 10 182.8 g

Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 50.3 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		182.80	100	10	2.000		50.30	100
1 1/2 in.	37.5		182.80	100	20	0.850	0.3	50.00	99
1 in.	25.0		182.80	100	40	0.425	0.1	49.90	99
3/4 in.	19.0		182.80	100	60	0.250	0.6	49.30	98
1/2 in.	12.5		182.80	100	100	0.150	1.0	48.30	96
3/8 in.	9.5		182.80	100	200	0.075	2.1	46.20	92
4	4.8		182.80	100	325	0.045	1.9	44.30	88
10	2.0		182.80	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. ^oC	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/3/2011	8:42:00	0							
2/3/2011	8:42:30	0.5	32.2	21.4	7.8	3.2073	28.9927	0.0525	91
2/3/2011	8:43:00	1	30.9	21.4	8.4	3.2073	27.6927	0.0385	87
2/3/2011	8:44:00	2	29.0	21.4	8.6	3.2073	25.7927	0.0275	81
2/3/2011	8:46:00	4	26.9	21.4	9.4	3.2073	23.6927	0.0204	74
2/3/2011	8:50:00	8	24.9	21.4	10.0	3.2073	21.6927	0.0148	68
2/3/2011	8:57:00	15	23.0	21.4	10.2	3.2073	19.7927	0.0110	62
2/3/2011	9:12:00	30	21.1	21.4	10.7	3.2073	17.8927	0.0079	56
2/3/2011	9:42:00	60	17.7	21.4	11.8	3.2073	14.4927	0.0059	45
2/3/2011	10:42:00	120	16.2	21.4	12.1	3.2073	12.9927	0.0042	41
2/3/2011	12:42:00	240	14.1	21.4	12.6	3.2073	10.8927	0.0030	34
2/3/2011	16:42:00	480	13.1	21.4	12.9	3.2073	9.8927	0.0022	31
2/4/2011	8:42:00	1440	11.0	21.4	13.4	3.2073	7.7927	0.0013	24



Remarks	**SUMMARY**			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	0.002	Sand	8.2 %
	D_{50} =	0.007	Silt Sizes	62.1 %
	D_{60} =	0.010	Clay Sizes	29.7 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-06	Depth	15.0 m
Technician	CR/SH	Date	3-Feb-11

amec

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-06	Depth	17.0 m
Technician	MR/SH	Date	8-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 8

Air Dried Wt. of Soil Tested 50.4 g Dry Wt. of Soil Tested 50.4

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 7-Feb-11

Mechanical Sieve Results

Total Wt of Sample Dry 459.7 g
+ # 10 0.0 g
- # 10 459.7 g

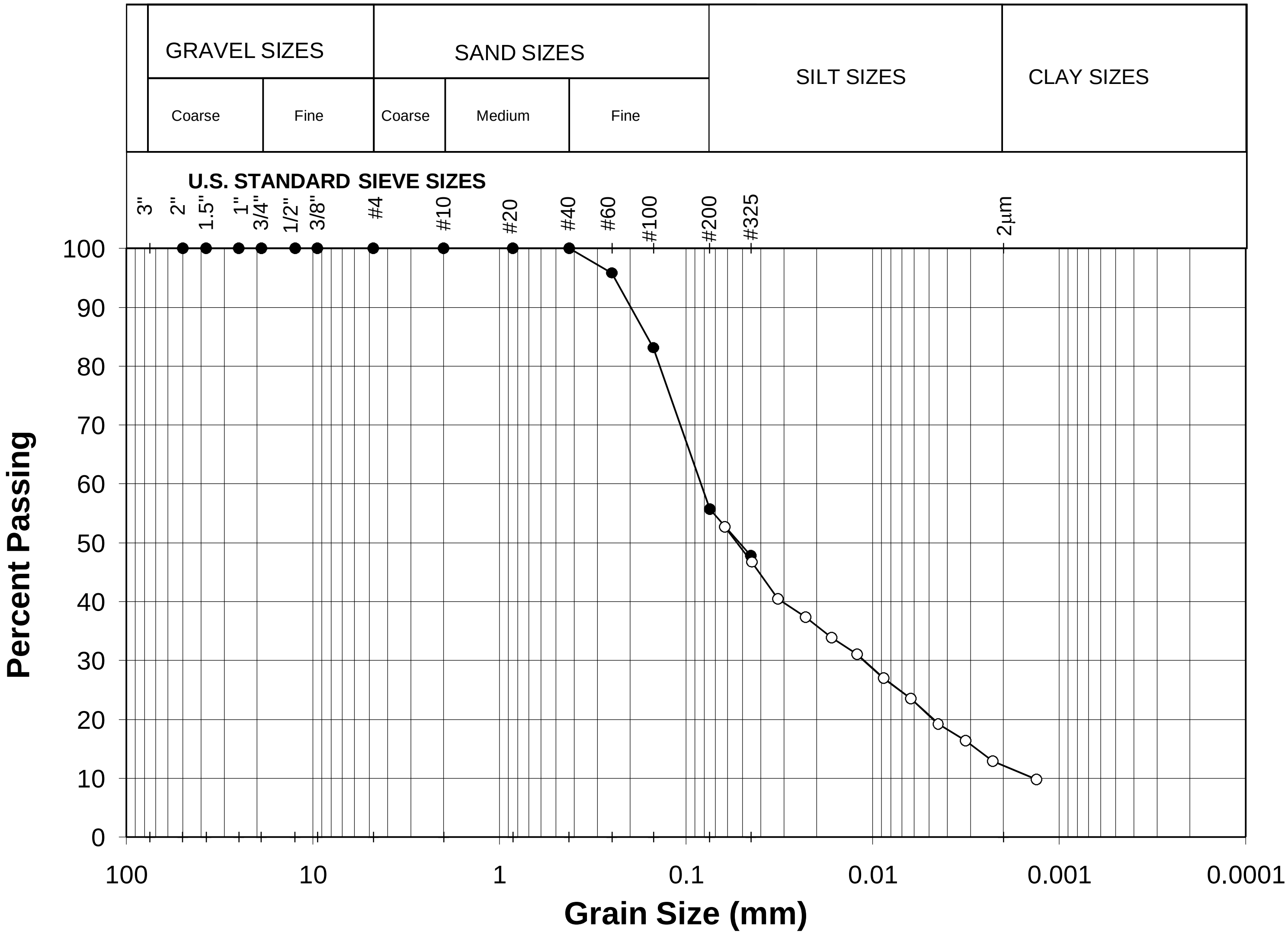
Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 50.4 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		459.70	100	10	2.000		50.40	100
1 1/2 in.	37.5		459.70	100	20	0.850		50.40	100
1 in.	25.0		459.70	100	40	0.425		50.40	100
3/4 in.	19.0		459.70	100	60	0.250	2.1	48.30	96
1/2 in.	12.5		459.70	100	100	0.150	6.4	41.90	83
3/8 in.	9.5		459.70	100	200	0.075	13.8	28.10	56
4	4.8		459.70	100	325	0.045	4.0	24.10	48
10	2.0		459.70	100	pan				

0.0

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. ^oC	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/8/2011	8:42:00	0							
2/8/2011	8:42:30	0.5	19.9	22.0	11.3	3.0753	16.8247	0.0624	53
2/8/2011	8:43:00	1	18.0	22.0	11.5	3.0753	14.9247	0.0445	47
2/8/2011	8:44:00	2	16.0	22.0	12.1	3.0753	12.9247	0.0323	40
2/8/2011	8:46:00	4	15.0	22.0	12.3	3.0753	11.9247	0.0230	37
2/8/2011	8:50:00	8	13.9	22.0	12.9	3.0753	10.8247	0.0167	34
2/8/2011	8:57:00	15	13.0	22.0	12.9	3.0753	9.9247	0.0122	31
2/8/2011	9:12:00	30	11.7	22.0	13.4	3.0753	8.6247	0.0088	27
2/8/2011	9:42:00	60	10.6	22.0	13.7	3.0753	7.5247	0.0063	24
2/8/2011	10:42:00	120	9.2	22.0	13.9	3.0753	6.1247	0.0045	19
2/8/2011	12:42:00	240	8.3	22.0	14.2	3.0753	5.2247	0.0032	16
2/8/2011	16:42:00	480	7.2	22.0	14.4	3.0753	4.1247	0.0023	13
2/9/2011	8:42:00	1440	6.2	22.0	14.7	3.0753	3.1247	0.0013	10



Remarks	SUMMARY			
	D_{10} =	0.001	Gravel	0.0 %
	D_{30} =	0.011	Sand	44.2 %
	D_{50} =	0.054	Silt Sizes	43.7 %
	D_{60} =	0.087	Clay Sizes	12.0 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

amec

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-06	Depth	17.0 m
Technician	MR/SH	Date	8-Feb-11

amec

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-06	Depth	4.0 m
Technician	CR/SH	Date	8-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 27

Air Dried Wt. of Soil Tested 50.1 g Dry Wt. of Soil Tested 50.1

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 7-Feb-11

Mechanical Sieve Results

Total Wt of Sample Dry 117.4 g
\+ # 10 0.0 g
\- # 10 117.4 g

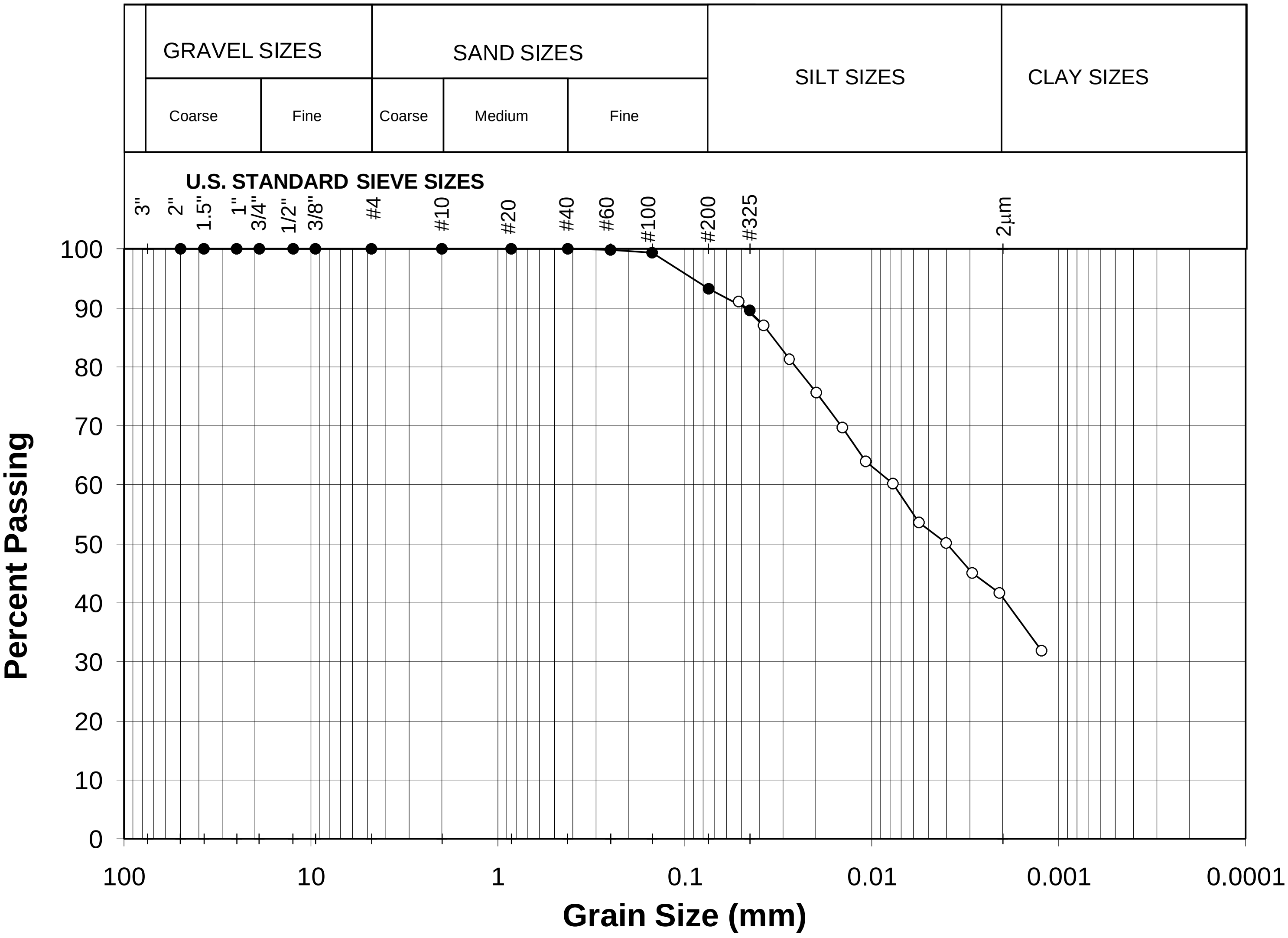
Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 50.1 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		117.40	100	10	2.000		50.10	100
1 1/2 in.	37.5		117.40	100	20	0.850		50.10	100
1 in.	25.0		117.40	100	40	0.425		50.10	100
3/4 in.	19.0		117.40	100	60	0.250	0.1	50.00	100
1/2 in.	12.5		117.40	100	100	0.150	0.2	49.80	99
3/8 in.	9.5		117.40	100	200	0.075	3.1	46.70	93
4	4.8		117.40	100	325	0.045	1.8	44.90	90
10	2.0		117.40	100	pan				

0.0

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. °C	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/8/2011	8:42:00	0							
2/8/2011	8:42:30	0.5	32.0	22.0	7.8	3.0753	28.9247	0.0518	91
2/8/2011	8:43:00	1	30.7	22.0	8.4	3.0753	27.6247	0.0380	87
2/8/2011	8:44:00	2	28.9	22.0	8.9	3.0753	25.8247	0.0277	81
2/8/2011	8:46:00	4	27.1	22.0	9.2	3.0753	24.0247	0.0199	76
2/8/2011	8:50:00	8	25.2	22.0	9.7	3.0753	22.1247	0.0144	70
2/8/2011	8:57:00	15	23.4	22.0	10.2	3.0753	20.3247	0.0108	64
2/8/2011	9:12:00	30	22.2	22.0	10.5	3.0753	19.1247	0.0078	60
2/8/2011	9:42:00	60	20.1	22.0	11.0	3.0753	17.0247	0.0056	54
2/8/2011	10:42:00	120	19.0	22.0	11.3	3.0753	15.9247	0.0040	50
2/8/2011	12:42:00	240	17.4	22.0	11.8	3.0753	14.3247	0.0029	45
2/8/2011	16:42:00	480	16.3	22.0	12.1	3.0753	13.2247	0.0021	42
2/9/2011	8:42:00	1440	13.2	22.0	12.9	3.0753	10.1247	0.0012	32



Remarks	SUMMARY			
	D_{10} =	#N/A	Gravel	0.0 %
	D_{30} =	#N/A	Sand	6.8 %
	D_{50} =	0.004	Silt Sizes	52.5 %
	D_{60} =	0.008	Clay Sizes	40.7 %
	C_U =	#N/A		
	C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

amec

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-06	Depth	4.0 m
Technician	CR/SH	Date	8-Feb-11

HYDROMETER TEST

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-06	Depth	8.0 m
Technician	MR/SH	Date	2-Feb-11

Hydrometer No. 799 Hydrometer Type 151 Graduate No. 16

Air Dried Wt. of Soil Tested 50.4 g Dry Wt. of Soil Tested 50.4

Moisture Content

Tare 20. g Wet + Tare 40. g Dry + Tare 40. g M.C. 0.00%

Composite Correction Factors

Factor -0.0084697temp^2+0.1196543temp+3.2870133 Specific Gravity G_s 2.73

Dispersant

Type 10 % Sodium Hexametaphosphate Amount 125 Date Mixed & Jug No. 1-Feb-11

Mechanical Sieve Results

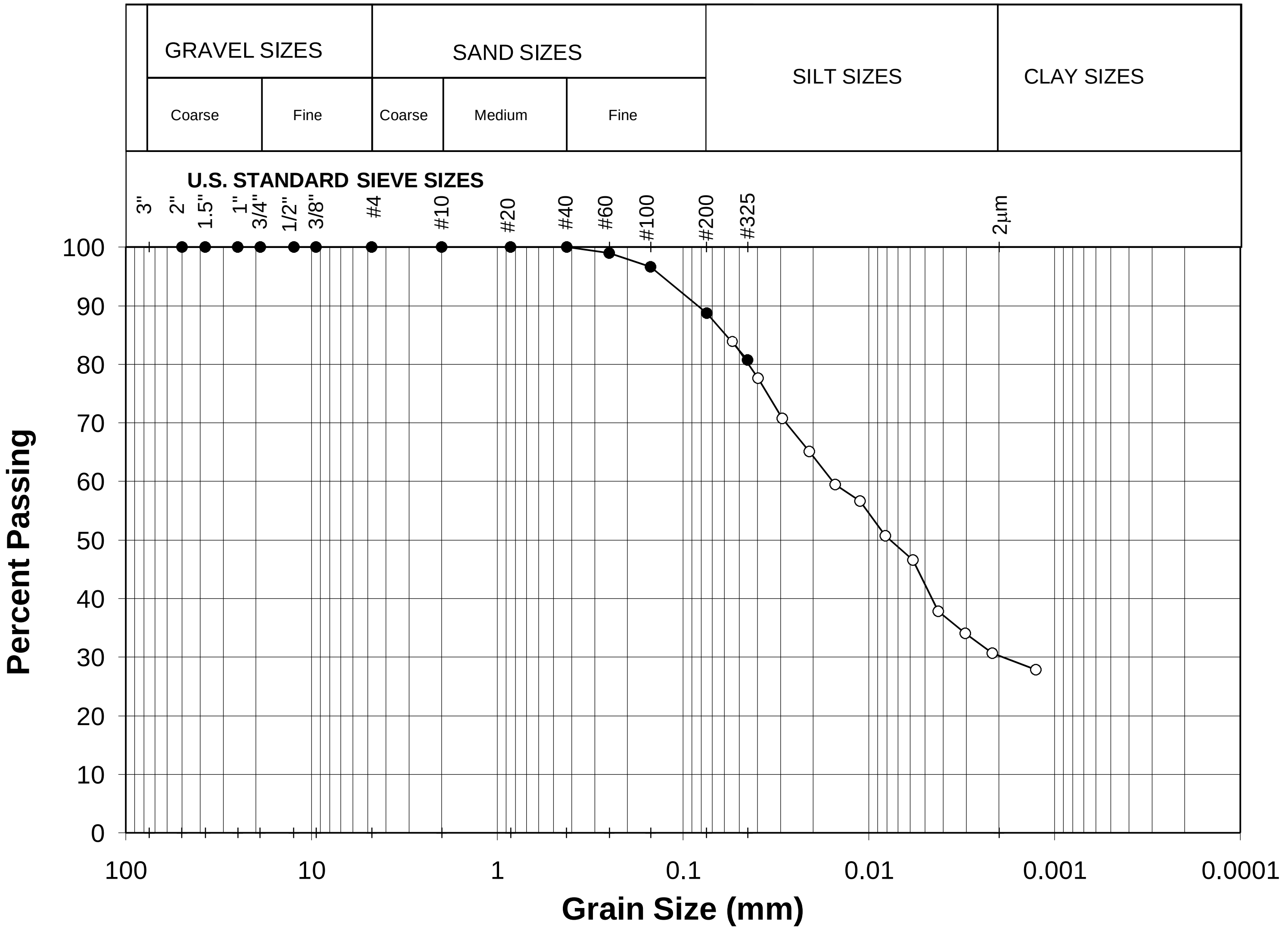
Total Wt of Sample Dry 300.0 g
+ # 10 0.0 g
- # 10 300.0 g

Hydrometer Test
(Adjusted for + # 10 Material)
Total Dry Wt. 50.4 g

Sieve Size	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than	Sieve #	Particle Size (mm)	Weight Retained (g)	Weight Passing (g)	Percent Finer Than
2 in.	50.0		300.00	100	10	2.000		50.40	100
1 1/2 in.	37.5		300.00	100	20	0.850		50.40	100
1 in.	25.0		300.00	100	40	0.425		50.40	100
3/4 in.	19.0		300.00	100	60	0.250	0.5	49.90	99
1/2 in.	12.5		300.00	100	100	0.150	1.2	48.70	97
3/8 in.	9.5		300.00	100	200	0.075	4.0	44.70	89
4	4.8		300.00	100	325	0.045	4.0	40.70	81
10	2.0		300.00	100	pan				
		0.0							

Hydrometer Results

Date	Time	Elapsed Time (min)	R'_h	Temp. ^oC	Effective Length (cm)	Comp. Corr.	Corrected Reading	Diam. (mm)	% Soil in Susp.
2/2/2011	8:42:00	0							
2/2/2011	8:42:30	0.5	30.0	21.4	8.4	3.2073	26.7927	0.0544	84
2/2/2011	8:43:00	1	28.0	21.4	8.9	3.2073	24.7927	0.0396	78
2/2/2011	8:44:00	2	25.8	21.4	9.7	3.2073	22.5927	0.0292	71
2/2/2011	8:46:00	4	24.0	21.4	10.0	3.2073	20.7927	0.0210	65
2/2/2011	8:50:00	8	22.2	21.4	10.5	3.2073	18.9927	0.0152	59
2/2/2011	8:57:00	15	21.3	21.4	10.7	3.2073	18.0927	0.0112	57
2/2/2011	9:12:00	30	19.4	21.4	11.3	3.2073	16.1927	0.0082	51
2/2/2011	9:42:00	60	18.1	21.4	11.5	3.2073	14.8927	0.0058	47
2/2/2011	10:42:00	120	15.3	21.4	12.3	3.2073	12.0927	0.0043	38
2/2/2011	12:42:00	240	14.1	21.4	12.6	3.2073	10.8927	0.0030	34
2/2/2011	16:42:00	480	13.0	21.4	12.9	3.2073	9.7927	0.0022	31
2/3/2011	8:42:00	1440	12.1	21.4	13.1	3.2073	8.8927	0.0013	28



Remarks

SUMMARY

D_{10} =	#N/A	Gravel	0.0 %
D_{30} =	0.002	Sand	11.3 %
D_{50} =	0.008	Silt Sizes	58.6 %
D_{60} =	0.016	Clay Sizes	30.1 %
C_U =	#N/A		
C_C =	#N/A		

Results of Other Testing

WL	%
WP	%
IP	%

Grain Size Distribution

Project	DIAVIK PKC FACILITY SITE		
Project No.	VM00503.PKC.3		
Lab No.	S-9383		
Sample	SAMPLE 2		
Hole	BH10-06	Depth	8.0 m
Technician	MR/SH	Date	2-Feb-11

APPENDIX E

Moisture Content and Specific Gravity Results

Golder Associates

SPECIFIC GRAVITY OF SOIL
(Pycnometer Method)

Project No.: 11-1359-0001
Short Title: AMEC E&E/LSC Testing
Tested By: CG

Phase: -
Lab No.: 999201
Date: 01-Mar-11

Borehole: 10-05
Sample: 002

Depth from: -
Depth to: 8.0 m

Determination Number		1	2
Bottle Number		3	4
Air Removal Method		Vacuum	Vacuum
Weight of bottle		163.9	165.54
Weight of bottle + soil + water	w1	683.31	684.80
Weight of bottle and water	w2	662.61	663.98
Weight of dish and dry soil		129.45	127.80
Weight of dish		96.37	94.67
Temperature, C		21.0	20.9
Weight of soil	ws	33.08	33.13
Fluid Type		Water	Water
Gs of Fluid	Gt	0.9977	0.9979
	Gt*ws	33.00	33.06
	w1-w2	20.70	20.82
	ws-(w1-w2)	12.38	12.31
Specific gravity, Gs	ws/(ws-(w1-w2))	2.67	2.69

Reviewed:

amec

MOISTURE CONTENT WORKSHEET

Project No.	**VM00503.PKC.3**
Lab No.	S-9352
Technician	MR
Date	28-Jan-11

Hole No.	BH10-04	BH10-04	BH10-04	BH10-04	BH10-04	BH10-04
Sample Number	1	2	1	2	1	2
Depth(m)	6.0	6.0	16.0	16.0	10.0	10.0
	Record Tare Weight (zero or actual weight)					
Wt. Sample Wet + Tare	117.02	89.44	175.21	140.78	190.15	146.18
Wt. Sample Dry + Tare	40.31	30.73	90.75	72.12	77.79	60.03
Wt. Water	76.71	58.71	84.46	68.66	112.36	86.15
Tare Container	0.00	0.00	0.00	0.00	0.00	0.00
Wt. Dry Sample	40.31	30.73	90.75	72.12	77.79	60.03
Moisture Content %	190.3	191.1	93.1	95.2	144.4	143.5

Hole No.	BH10-04	BH10-04	BH10-04	BH10-04	BH10-04	BH10-04
Sample Number	1	2	1	2	1	2
Depth(m)	8.0	8.0	15.0	15.0	13.0	13.0
Tare No.	**Record Tare Weight (zero or actual weight)**					
Wt. Sample Wet + Tare	217.24	173.18	253.56	244.36	186.73	274.95
Wt. Sample Dry + Tare	88.99	71.21	116.13	110.67	89.17	131.26
Wt. Water	128.25	101.97	137.43	133.69	97.56	143.69
Tare Container	0.00	0.00	0.00	0.00	0.00	0.00
Wt. Dry Sample	88.99	71.21	116.13	110.67	89.17	131.26
Moisture Content %	144.1	143.2	118.3	120.8	109.4	109.5

Hole No.	BH10-05	BH10-05	BH10-05	BH10-05	BH10-05	BH10-05
Sample Number	1	2	1	2	1	2
Depth(m)	6.0	6.0	12.0	12.0	18.0	18.0
Tare No.	**Record Tare Weight (zero or actual weight)**					
Wt. Sample Wet + Tare	203.47	160.92	180.01	165.12	175.14	200.94
Wt. Sample Dry + Tare	68.20	53.96	86.42	79.11	88.10	100.97
Wt. Water	135.27	106.96	93.59	86.01	87.04	99.97
Tare Container	0.00	0.00	0.00	0.00	0.00	0.00
Wt. Dry Sample	68.20	53.96	86.42	79.11	88.10	100.97
Moisture Content %	198.3	198.2	108.3	108.7	98.8	99.0

Hole No.	BH10-05	BH10-05		BH10-06	BH10-06	BH10-06
Sample Number	1	2		1	2	1
Depth(m)	23.0	23.0		15.0	15.0	17.0
Tare No.	**Record Tare Weight (zero or actual weight)**					
Wt. Sample Wet + Tare	113.35	126.61		187.10	202.67	248.17
Wt. Sample Dry + Tare	76.31	85.37		81.84	89.20	157.25
Wt. Water	37.04	41.24		105.26	113.47	90.92
Tare Container	0.00	0.00		0.00	0.00	0.00
Wt. Dry Sample	76.31	85.37		81.84	89.20	157.25
Moisture Content %	48.5	48.3		128.6	127.2	57.8

Hole No.	BH10-06	BH10-06	BH10-06	BH10-06	BH10-06	BH10-06
Sample Number	2	1	2	1	2	1
Depth(m)	17.0	4.0	4.0	8.0	8.0	12.0
Tare No.	**Record Tare Weight (zero or actual weight)**					
Wt. Sample Wet + Tare	200.87	221.68	172.00	240.90	261.82	248.37
Wt. Sample Dry + Tare	127.64	74.04	57.42	103.83	112.97	132.92
Wt. Water	73.23	147.64	114.58	137.07	148.85	115.45
Tare Container	0.00	0.00	0.00	0.00	0.00	0.00
Wt. Dry Sample	127.64	74.04	57.42	103.83	112.97	132.92
Moisture Content %	57.4	199.4	199.5	132.0	131.8	86.9

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Project No.	**VM00503.PKC.3**
Lab No.	S-9352
Technician	MR
Date	28-Jan-11

MOISTURE CONTENT WORKSHEET

Hole No.	BH10-06	BH10-06	BH10-06			
Sample Number	2	1	2			
Depth(m)	12.00	13.0	13.0			
	Record Tare Weight (zero or actual weight)					
Wt. Sample Wet + Tare	239.01	201.57	169.30			
Wt. Sample Dry + Tare	127.70	92.02	76.83			
Wt. Water	111.31	109.55	92.47			
Tare Container	0.00	0.00	0.00			
Wt. Dry Sample	127.70	92.02	76.83			
Moisture Content %	87.2	119.1	120.4			
Hole No.						
Sample Number						
Depth(m)						
Tare No.	**Record Tare Weight (zero or actual weight)**					
Wt. Sample Wet + Tare						
Wt. Sample Dry + Tare						
Wt. Water						
Tare Container						
Wt. Dry Sample						
Moisture Content %						
Hole No.						
Sample Number						
Depth(m)						
Tare No.	**Record Tare Weight (zero or actual weight)**					
Wt. Sample Wet + Tare						
Wt. Sample Dry + Tare						
Wt. Water						
Tare Container						
Wt. Dry Sample						
Moisture Content %						
Hole No.						
Sample Number						
Depth(m)						
Tare No.	**Record Tare Weight (zero or actual weight)**					
Wt. Sample Wet + Tare						
Wt. Sample Dry + Tare						
Wt. Water						
Tare Container						
Wt. Dry Sample						
Moisture Content %						
Hole No.						
Sample Number						
Depth(m)						
Tare No.	**Record Tare Weight (zero or actual weight)**					
Wt. Sample Wet + Tare						
Wt. Sample Dry + Tare						
Wt. Water						
Tare Container						
Wt. Dry Sample						
Moisture Content %						

AMEC Earth & Environmental

Project: Diavik PKC Facility

Project No.: VM00503.PKC.6

SPECIFIC GRAVITY AND ABSORPTION
ASTM D854, C127, C128

Location: BH10-04 @ 6.0 m

Technician: GM

Date: 16-Feb-11

SOIL - D854	Trial Number						Average
	Bottle Number		4	12			
	Weight of Bottle and Water and Soil	"Wb"	734	737.6			
	Temperature of Water	"Tx"	23	23			
	Weight of Bottle and Water	"Wa"	686.5	690			
	Evaporating Dish Number						
	Weight Dish and Dry Soil						
	Weight of Dish						
	Weight of Dry Soil	"Wo"	75	75			
	Specific Gravity of Soil		2.727	2.737			2.732
SAND - C128	Trial Number						Average
	Bottle Number						
	Weight of Bottle						
	Weight of S.S.D. Sand in Air	"D"					
	Weight of Bottle, Water and Sand	"C"					
	Temperature of Water						
	Weight of Bottle and Water (chart)	"B"					
	Tare Number						
	Weight Dry Sand and Tare						
	Weight of Tare						
	Weight of Dry Sand	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						
GRAVEL - C127	Trial Number						Average
	Weight of S.S.D. Rock and Tare in Air						
	Weight of Tare						
	Weight of S.S.D. Rock (in Air)	"B"					
	Weight of S.S.D. Rock (in Water)	"C"					
	Weight of Tare and Dry Rock						
	Weight of Tare						
	Weight of Dry Rock	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						

Calculation

Soil: Gs = Wo/ (Wo+(Wa - Wb))

Sand: Bulk Sp. Gr. = A/ (B+D-C)

Sand: S.S.D. Sp. Gr. = D/ (B+D-C)

Gravel: Bulk Sp. Gr. = A/ (B-C)

Gravel: S.S.D. Sp. Gr. = B/ (B-C)

Absorption: Sand % Abs. = ((D-A) /A) x 100

Absorption: Gravel % Abs. = ((B-A) /A) x 100

Remarks:

p:forms\specificgravity.xls

AMEC Earth & Environmental

SPECIFIC GRAVITY AND ABSORPTION
ASTM D854, C127, C128

Project: Diavik PKC Facility

Project No.: VM00503.PKC.6

Location: BH10-04 @ 8m

Technician: GM

Date: 16-Feb-11

SOIL - D854	Trial Number						Average
	Bottle Number		A	B			
	Weight of Bottle and Water and Soil	"Wb"	772.3	773.4			
	Temperature of Water	"Tx"	23	23			
	Weight of Bottle and Water	"Wa"	708.5	709.3			
	Evaporating Dish Number						
	Weight Dish and Dry Soil						
	Weight of Dish						
	Weight of Dry Soil	"Wo"	100	100.4			
	Specific Gravity of Soil		2.762	2.766			2.764
SAND - C128	Trial Number						Average
	Bottle Number						
	Weight of Bottle						
	Weight of S.S.D. Sand in Air	"D"					
	Weight of Bottle, Water and Sand	"C"					
	Temperature of Water						
	Weight of Bottle and Water (chart)	"B"					
	Tare Number						
	Weight Dry Sand and Tare						
	Weight of Tare						
	Weight of Dry Sand	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						
GRAVEL - C127	Trial Number						Average
	Weight of S.S.D. Rock and Tare in Air						
	Weight of Tare						
	Weight of S.S.D. Rock (in Air)	"B"					
	Weight of S.S.D. Rock (in Water)	"C"					
	Weight of Tare and Dry Rock						
	Weight of Tare						
	Weight of Dry Rock	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						

Calculation

Soil: Gs = Wo/ (Wo+(Wa - Wb))

Sand: Bulk Sp. Gr. = A/ (B+D-C)

Sand: S.S.D. Sp. Gr. = D/ (B+D-C)

Gravel: Bulk Sp. Gr. = A/ (B-C)

Gravel: S.S.D. Sp. Gr. = B/ (B-C)

Absorption: Sand % Abs. = ((D-A) /A) x 100

Absorption: Gravel % Abs. = ((B-A) /A) x 100

Remarks:

AMEC Earth & Environmental

SPECIFIC GRAVITY AND ABSORPTION
ASTM D854, C127, C128

Project: Diavik PKC Facility
Project No.: VM00503.PKC.6
Location: BH10-04 @ 10.0 m
Technician: GM
Date: 16-Feb-11

SOIL - D854	Trial Number						Average
	Bottle Number		4	12			
	Weight of Bottle and Water and Soil	"Wb"	749.9	753.7			
	Temperature of Water	"Tx"	23	23			
	Weight of Bottle and Water	"Wa"	686.5	690			
	Evaporating Dish Number						
	Weight Dish and Dry Soil						
	Weight of Dish						
	Weight of Dry Soil	"Wo"	100.1	100.5			
	Specific Gravity of Soil		2.728	2.731			2.730
SAND - C128	Trial Number						Average
	Bottle Number						
	Weight of Bottle						
	Weight of S.S.D. Sand in Air	"D"					
	Weight of Bottle, Water and Sand	"C"					
	Temperature of Water						
	Weight of Bottle and Water (chart)	"B"					
	Tare Number						
	Weight Dry Sand and Tare						
	Weight of Tare						
	Weight of Dry Sand	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						
GRAVEL - C127	Trial Number						Average
	Weight of S.S.D. Rock and Tare in Air						
	Weight of Tare						
	Weight of S.S.D. Rock (in Air)	"B"					
	Weight of S.S.D. Rock (in Water)	"C"					
	Weight of Tare and Dry Rock						
	Weight of Tare						
	Weight of Dry Rock	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						

Calculation

Soil: Gs = Wo/ (Wo+(Wa - Wb))
Sand: Bulk Sp. Gr. = A/ (B+D-C)
Sand: S.S.D. Sp. Gr. = D/ (B+D-C)
Gravel: Bulk Sp. Gr. = A/ (B-C)
Gravel: S.S.D. Sp. Gr. = B/ (B-C)
Absorption: Sand % Abs. = ((D-A) /A) x 100
Absorption: Gravel % Abs. = ((B-A) /A) x 100

Remarks:

AMEC Earth & Environmental

SPECIFIC GRAVITY AND ABSORPTION
ASTM D854, C127, C128

Project: Diavik PKC Facility

Project No. VM00503.PKC.6

Location: BH10-04 @ 13.0 m

Technician: GM

Date: 16-Feb-11

SOIL - D854	Trial Number						Average
	Bottle Number		A	B			
	Weight of Bottle and Water and Soil	"Wb"	772.7	773.6			
	Temperature of Water	"Tx"	23	23			
	Weight of Bottle and Water	"Wa"	708.5	709.3			
	Evaporating Dish Number						
	Weight Dish and Dry Soil						
	Weight of Dish						
	Weight of Dry Soil	"Wo"	100.9	100.9			
	Specific Gravity of Soil		2.749	2.757			2.753
SAND - C128	Trial Number						Average
	Bottle Number						
	Weight of Bottle						
	Weight of S.S.D. Sand in Air	"D"					
	Weight of Bottle, Water and Sand	"C"					
	Temperature of Water						
	Weight of Bottle and Water (chart)	"B"					
	Tare Number						
	Weight Dry Sand and Tare						
	Weight of Tare						
	Weight of Dry Sand	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						
GRAVEL - C127	Trial Number						Average
	Weight of S.S.D. Rock and Tare in Air						
	Weight of Tare						
	Weight of S.S.D. Rock (in Air)	"B"					
	Weight of S.S.D. Rock (in Water)	"C"					
	Weight of Tare and Dry Rock						
	Weight of Tare						
	Weight of Dry Rock	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						

Calculation

Soil: Gs = Wo/ (Wo+(Wa - Wb))

Sand: Bulk Sp. Gr. = A/ (B+D-C)

Sand: S.S.D. Sp. Gr. = D/ (B+D-C)

Gravel: Bulk Sp. Gr. = A/ (B-C)

Gravel: S.S.D. Sp. Gr. = B/ (B-C)

Absorption: Sand % Abs. = ((D-A) /A) x 100

Absorption: Gravel % Abs. = ((B-A) /A) x 100

Remarks:

AMEC Earth & Environmental	**Project:** Diavik PKC Facility	**Project No.** VM00503.PKC.6
SPECIFIC GRAVITY AND ABSORPTION **ASTM D854, C127, C128**	**Location:** BH10-04 @ 15m	
	Technician: GM	**Date:** 16-Feb-11

SOIL - D854	Trial Number						Average
	Bottle Number		4	12			
	Weight of Bottle and Water and Soil	"Wb"	750.4	753.4			
	Temperature of Water	"Tx"	23	23			
	Weight of Bottle and Water	"Wa"	686.5	690			
	Evaporating Dish Number						
	Weight Dish and Dry Soil						
	Weight of Dish						
	Weight of Dry Soil	"Wo"	101.1	100.5			
	Specific Gravity of Soil		2.718	2.709			2.714
SAND - C128	Trial Number						Average
	Bottle Number						
	Weight of Bottle						
	Weight of S.S.D. Sand in Air	"D"					
	Weight of Bottle, Water and Sand	"C"					
	Temperature of Water						
	Weight of Bottle and Water (chart)	"B"					
	Tare Number						
	Weight Dry Sand and Tare						
	Weight of Tare						
	Weight of Dry Sand	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						
GRAVEL - C127	Trial Number						Average
	Weight of S.S.D. Rock and Tare in Air						
	Weight of Tare						
	Weight of S.S.D. Rock (in Air)	"B"					
	Weight of S.S.D. Rock (in Water)	"C"					
	Weight of Tare and Dry Rock						
	Weight of Tare						
	Weight of Dry Rock	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						

<u>Calculation</u>

Soil: Gs = Wo/ (Wo+(Wa - Wb))

Sand: Bulk Sp. Gr. = A/ (B+D-C)

Sand: S.S.D. Sp. Gr. = D/ (B+D-C)

Gravel: Bulk Sp. Gr. = A/ (B-C)

Gravel: S.S.D. Sp. Gr. = B/ (B-C)

Absorption: Sand % Abs. = ((D-A) /A) x 100

Absorption: Gravel % Abs. = ((B-A) /A) x 100

<u>Remarks:</u>

AMEC Earth & Environmental

SPECIFIC GRAVITY AND ABSORPTION
ASTM D854, C127, C128

Project: Diavik PKC Facility
Project No. VM00503.PKC.6
Location: BH10-04 @ 16 m
Technician: GM
Date: 16-Feb-11

SOIL - D854	Trial Number						Average
	Bottle Number		A	B			
	Weight of Bottle and Water and Soil	"Wb"	772.8	772.6			
	Temperature of Water	"Tx"	23	23			
	Weight of Bottle and Water	"Wa"	708.5	709.3			
	Evaporating Dish Number						
	Weight Dish and Dry Soil						
	Weight of Dish						
	Weight of Dry Soil	"Wo"	101.4	100			
	Specific Gravity of Soil		2.733	2.725			2.729
SAND - C128	Trial Number						Average
	Bottle Number						
	Weight of Bottle						
	Weight of S.S.D. Sand in Air	"D"					
	Weight of Bottle, Water and Sand	"C"					
	Temperature of Water						
	Weight of Bottle and Water (chart)	"B"					
	Tare Number						
	Weight Dry Sand and Tare						
	Weight of Tare						
	Weight of Dry Sand	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						
GRAVEL - C127	Trial Number						Average
	Weight of S.S.D. Rock and Tare in Air						
	Weight of Tare						
	Weight of S.S.D. Rock (in Air)	"B"					
	Weight of S.S.D. Rock (in Water)	"C"					
	Weight of Tare and Dry Rock						
	Weight of Tare						
	Weight of Dry Rock	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						

Calculation
Soil: Gs = Wo/ (Wo+(Wa - Wb))
Sand: Bulk Sp. Gr. = A/ (B+D-C)
Sand: S.S.D. Sp. Gr. = D/ (B+D-C)
Gravel: Bulk Sp. Gr. = A/ (B-C)
Gravel: S.S.D. Sp. Gr. = B/ (B-C)
Absorption: Sand % Abs. = ((D-A) /A) x 100
Absorption: Gravel % Abs. = ((B-A) /A) x 100

Remarks:

AMEC Earth & Environmental	**Project:** Diavik PKC Facility		**Project No.** VM00503.PKC.6
SPECIFIC GRAVITY AND ABSORPTION ASTM D854, C127, C128	**Location:** BH10-05 @ 6.0 m		
	Technician: GM		**Date:** 16-Feb-11

SOIL - D854	Trial Number						Average
	Bottle Number		4	12			
	Weight of Bottle and Water and Soil	"Wb"	743.8	748.6			
	Temperature of Water	"Tx"	23	23			
	Weight of Bottle and Water	"Wa"	686.5	690			
	Evaporating Dish Number						
	Weight Dish and Dry Soil						
	Weight of Dish						
	Weight of Dry Soil	"Wo"	90	91.9			
	Specific Gravity of Soil		2.752	2.76			2.756
SAND - C128	Trial Number						Average
	Bottle Number						
	Weight of Bottle						
	Weight of S.S.D. Sand in Air	"D"					
	Weight of Bottle, Water and Sand	"C"					
	Temperature of Water						
	Weight of Bottle and Water (chart)	"B"					
	Tare Number						
	Weight Dry Sand and Tare						
	Weight of Tare						
	Weight of Dry Sand	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						
GRAVEL - C127	Trial Number						Average
	Weight of S.S.D. Rock and Tare in Air						
	Weight of Tare						
	Weight of S.S.D. Rock (in Air)	"B"					
	Weight of S.S.D. Rock (in Water)	"C"					
	Weight of Tare and Dry Rock						
	Weight of Tare						
	Weight of Dry Rock	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						

Calculation

Soil: Gs = Wo/ (Wo+(Wa - Wb))

Sand: Bulk Sp. Gr. = A/ (B+D-C)

Sand: S.S.D. Sp. Gr. = D/ (B+D-C)

Gravel: Bulk Sp. Gr. = A/ (B-C)

Gravel: S.S.D. Sp. Gr. = B/ (B-C)

Absorption: Sand % Abs. = ((D-A) /A) x 100

Absorption: Gravel % Abs. = ((B-A) /A) x 100

Remarks:

AMEC Earth & Environmental	**Project:** Diavik PKC Facility	**Project No.:** VM00503.PKC.6	
SPECIFIC GRAVITY AND ABSORPTION ASTM D854, C127, C128	**Location:** BH10-05 @ 12.0 m		
	Technician: GM	**Date:** 16-Feb-11	

SOIL - D854	Trial Number						Average
	Bottle Number		A	B			
	Weight of Bottle and Water and Soil	"Wb"	772.5	773.4			
	Temperature of Water	"Tx"	23	23			
	Weight of Bottle and Water	"Wa"	708.5	709.3			
	Evaporating Dish Number						
	Weight Dish and Dry Soil						
	Weight of Dish						
	Weight of Dry Soil	"Wo"	100.4	100.7			
	Specific Gravity of Soil		2.758	2.751			2.755
SAND - C128	Trial Number						Average
	Bottle Number						
	Weight of Bottle						
	Weight of S.S.D. Sand in Air	"D"					
	Weight of Bottle, Water and Sand	"C"					
	Temperature of Water						
	Weight of Bottle and Water (chart)	"B"					
	Tare Number						
	Weight Dry Sand and Tare						
	Weight of Tare						
	Weight of Dry Sand	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						
GRAVEL - C127	Trial Number						Average
	Weight of S.S.D. Rock and Tare in Air						
	Weight of Tare						
	Weight of S.S.D. Rock (in Air)	"B"					
	Weight of S.S.D. Rock (in Water)	"C"					
	Weight of Tare and Dry Rock						
	Weight of Tare						
	Weight of Dry Rock	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						

Calculation

Soil: Gs = Wo/ (Wo+(Wa - Wb))

Sand: Bulk Sp. Gr. = A/ (B+D-C)

Sand: S.S.D. Sp. Gr. = D/ (B+D-C)

Gravel: Bulk Sp. Gr. = A/ (B-C)

Gravel: S.S.D. Sp. Gr. = B/ (B-C)

Absorption: Sand % Abs. = ((D-A) /A) x 100

Absorption: Gravel % Abs. = ((B-A) /A) x 100

Remarks:

AMEC Earth & Environmental

SPECIFIC GRAVITY AND ABSORPTION
ASTM D854, C127, C128

Project: Diavik PKC Facility

Project No.: VM00503.PKC.6

Location: BH10-05 @ 18.0 m

Technician: GM

Date: 16-Feb-11

SOIL - D854	Trial Number						Average
	Bottle Number		4	12			
	Weight of Bottle and Water and Soil	"Wb"	749.8	753.4			
	Temperature of Water	"Tx"	23	23			
	Weight of Bottle and Water	"Wa"	686.5	690			
	Evaporating Dish Number						
	Weight Dish and Dry Soil						
	Weight of Dish						
	Weight of Dry Soil	"Wo"	100.6	100.6			
	Specific Gravity of Soil		2.697	2.704			2.701
SAND - C128	Trial Number						Average
	Bottle Number						
	Weight of Bottle						
	Weight of S.S.D. Sand in Air	"D"					
	Weight of Bottle, Water and Sand	"C"					
	Temperature of Water						
	Weight of Bottle and Water (chart)	"B"					
	Tare Number						
	Weight Dry Sand and Tare						
	Weight of Tare						
	Weight of Dry Sand	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						
GRAVEL - C127	Trial Number						Average
	Weight of S.S.D. Rock and Tare in Air						
	Weight of Tare						
	Weight of S.S.D. Rock (in Air)	"B"					
	Weight of S.S.D. Rock (in Water)	"C"					
	Weight of Tare and Dry Rock						
	Weight of Tare						
	Weight of Dry Rock	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						

Calculation

Soil: Gs = Wo/ (Wo+(Wa - Wb))

Sand: Bulk Sp. Gr. = A/ (B+D-C)

Sand: S.S.D. Sp. Gr. = D/ (B+D-C)

Gravel: Bulk Sp. Gr. = A/ (B-C)

Gravel: S.S.D. Sp. Gr. = B/ (B-C)

Absorption: Sand % Abs. = ((D-A) /A) x 100

Absorption: Gravel % Abs. = ((B-A) /A) x 100

Remarks:

p:forms\specificgravity.xls

AMEC Earth & Environmental	**Project:** Diavik PKC Facility		**Project No.** VM00503.PKC.6
SPECIFIC GRAVITY AND ABSORPTION ASTM D854, C127, C128	**Location:** BH10-05 @ 23.0 m		
	Technician: GM		**Date:** 16-Feb-11

SOIL - D854	Trial Number						Average
	Bottle Number		A	B			
	Weight of Bottle and Water and Soil	"Wb"	774.1	776			
	Temperature of Water	"Tx"	23	23			
	Weight of Bottle and Water	"Wa"	708.5	709.3			
	Evaporating Dish Number						
	Weight Dish and Dry Soil						
	Weight of Dish						
	Weight of Dry Soil	"Wo"	101.2	102.8			
	Specific Gravity of Soil		2.843	2.848			2.846
SAND - C128	Trial Number						Average
	Bottle Number						
	Weight of Bottle						
	Weight of S.S.D. Sand in Air	"D"					
	Weight of Bottle, Water and Sand	"C"					
	Temperature of Water						
	Weight of Bottle and Water (chart)	"B"					
	Tare Number						
	Weight Dry Sand and Tare						
	Weight of Tare						
	Weight of Dry Sand	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						
GRAVEL - C127	Trial Number						Average
	Weight of S.S.D. Rock and Tare in Air						
	Weight of Tare						
	Weight of S.S.D. Rock (in Air)	"B"					
	Weight of S.S.D. Rock (in Water)	"C"					
	Weight of Tare and Dry Rock						
	Weight of Tare						
	Weight of Dry Rock	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						

Calculation

Soil: Gs = Wo/ (Wo+(Wa - Wb))

Sand: Bulk Sp. Gr. = A/ (B+D-C)

Sand: S.S.D. Sp. Gr. = D/ (B+D-C)

Gravel: Bulk Sp. Gr. = A/ (B-C)

Gravel: S.S.D. Sp. Gr. = B/ (B-C)

Absorption: Sand % Abs. = ((D-A) /A) x 100

Absorption: Gravel % Abs. = ((B-A) /A) x 100

Remarks:

AMEC Earth & Environmental

SPECIFIC GRAVITY AND ABSORPTION
ASTM D854, C127, C128

Project: Diavik PKC Facility

Project No.: VM00503.PKC.6

Location: BH10-06 @ 4.0m

Technician: GM

Date: 16-Feb-11

SOIL - D854	Trial Number						Average
	Bottle Number		4	12			
	Weight of Bottle and Water and Soil	"Wb"	750	753.4			
	Temperature of Water	"Tx"	23	23			
	Weight of Bottle and Water	"Wa"	686.5	690			
	Evaporating Dish Number						
	Weight Dish and Dry Soil						
	Weight of Dish						
	Weight of Dry Soil	"Wo"	100.3	100.3			
	Specific Gravity of Soil		2.726	2.718			2.722
SAND - C128	Trial Number						Average
	Bottle Number						
	Weight of Bottle						
	Weight of S.S.D. Sand in Air	"D"					
	Weight of Bottle, Water and Sand	"C"					
	Temperature of Water						
	Weight of Bottle and Water (chart)	"B"					
	Tare Number						
	Weight Dry Sand and Tare						
	Weight of Tare						
	Weight of Dry Sand	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						
GRAVEL - C127	Trial Number						Average
	Weight of S.S.D. Rock and Tare in Air						
	Weight of Tare						
	Weight of S.S.D. Rock (in Air)	"B"					
	Weight of S.S.D. Rock (in Water)	"C"					
	Weight of Tare and Dry Rock						
	Weight of Tare						
	Weight of Dry Rock	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						

<u>Calculation</u>

Soil: Gs = Wo/ (Wo+(Wa - Wb))

Sand: Bulk Sp. Gr. = A/ (B+D-C)

Sand: S.S.D. Sp. Gr. = D/ (B+D-C)

Gravel: Bulk Sp. Gr. = A/ (B-C)

Gravel: S.S.D. Sp. Gr. = B/ (B-C)

Absorption: Sand % Abs. = ((D-A) /A) x 100

Absorption: Gravel % Abs. = ((B-A) /A) x 100

<u>Remarks:</u>

AMEC Earth & Environmental	**Project:**	Diavik PKC Facility	**Project No.:**	VM00503.PKC.6
SPECIFIC GRAVITY AND ABSORPTION **ASTM D854, C127, C128**	**Location:**	BH10-06 @ 8.0 m		
	Technician:	GM	**Date:**	16-Feb-11

SOIL - D854	Trial Number						Average
	Bottle Number		A	B			
	Weight of Bottle and Water and Soil	"Wb"	773.2	773.4			
	Temperature of Water	"Tx"	23	23			
	Weight of Bottle and Water	"Wa"	708.5	709.3			
	Evaporating Dish Number						
	Weight Dish and Dry Soil						
	Weight of Dish						
	Weight of Dry Soil	"Wo"	102	101.1			
	Specific Gravity of Soil		2.735	2.732			2.734
SAND - C128	Trial Number						Average
	Bottle Number						
	Weight of Bottle						
	Weight of S.S.D. Sand in Air	"D"					
	Weight of Bottle, Water and Sand	"C"					
	Temperature of Water						
	Weight of Bottle and Water (chart)	"B"					
	Tare Number						
	Weight Dry Sand and Tare						
	Weight of Tare						
	Weight of Dry Sand	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						
GRAVEL - C127	Trial Number						Average
	Weight of S.S.D. Rock and Tare in Air						
	Weight of Tare						
	Weight of S.S.D. Rock (in Air)	"B"					
	Weight of S.S.D. Rock (in Water)	"C"					
	Weight of Tare and Dry Rock						
	Weight of Tare						
	Weight of Dry Rock	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						

Calculation

Soil: Gs = Wo/ (Wo+(Wa - Wb))

Sand: Bulk Sp. Gr. = A/ (B+D-C)

Sand: S.S.D. Sp. Gr. = D/ (B+D-C)

Gravel: Bulk Sp. Gr. = A/ (B-C)

Gravel: S.S.D. Sp. Gr. = B/ (B-C)

Absorption: Sand % Abs. = ((D-A) /A) x 100

Absorption: Gravel % Abs. = ((B-A) /A) x 100

Remarks:

AMEC Earth & Environmental

SPECIFIC GRAVITY AND ABSORPTION
ASTM D854, C127, C128

Project: Diavik PKC Facility

Project No.: VM00503.PKC.6

Location: BH10-06 @ 12.0 m

Technician: GM

Date: 16-Feb-11

SOIL - D854	Trial Number						Average
	Bottle Number		4	12			
	Weight of Bottle and Water and Soil	"Wb"	750.7	754.4			
	Temperature of Water	"Tx"	23	23			
	Weight of Bottle and Water	"Wa"	686.5	690			
	Evaporating Dish Number						
	Weight Dish and Dry Soil						
	Weight of Dish						
	Weight of Dry Soil	"Wo"	100.3	100.4			
	Specific Gravity of Soil		2.778	2.788			2.783
SAND - C128	Trial Number						Average
	Bottle Number						
	Weight of Bottle						
	Weight of S.S.D. Sand in Air	"D"					
	Weight of Bottle, Water and Sand	"C"					
	Temperature of Water						
	Weight of Bottle and Water (chart)	"B"					
	Tare Number						
	Weight Dry Sand and Tare						
	Weight of Tare						
	Weight of Dry Sand	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						
GRAVEL - C127	Trial Number						Average
	Weight of S.S.D. Rock and Tare in Air						
	Weight of Tare						
	Weight of S.S.D. Rock (in Air)	"B"					
	Weight of S.S.D. Rock (in Water)	"C"					
	Weight of Tare and Dry Rock						
	Weight of Tare						
	Weight of Dry Rock	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						

Calculation

Soil: Gs = Wo/ (Wo+(Wa - Wb))

Sand: Bulk Sp. Gr. = A/ (B+D-C)

Sand: S.S.D. Sp. Gr. = D/ (B+D-C)

Gravel: Bulk Sp. Gr. = A/ (B-C)

Gravel: S.S.D. Sp. Gr. = B/ (B-C)

Absorption: Sand % Abs. = ((D-A) /A) x 100

Absorption: Gravel % Abs. = ((B-A) /A) x 100

Remarks:

AMEC Earth & Environmental

SPECIFIC GRAVITY AND ABSORPTION
ASTM D854, C127, C128

Project: Diavik PKC Facility

Project No. VM00503.PKC.6

Location: BH10-06 @ 13.0 m

Technician: GM

Date: 16-Feb-11

SOIL - D854	Trial Number						Average
	Bottle Number		A	B			
	Weight of Bottle and Water and Soil	"Wb"	774.3	773			
	Temperature of Water	"Tx"	23	23			
	Weight of Bottle and Water	"Wa"	708.5	709.3			
	Evaporating Dish Number						
	Weight Dish and Dry Soil						
	Weight of Dish						
	Weight of Dry Soil	"Wo"	103.8	100.5			
	Specific Gravity of Soil		2.732	2.731			2.732
SAND - C128	Trial Number						Average
	Bottle Number						
	Weight of Bottle						
	Weight of S.S.D. Sand in Air	"D"					
	Weight of Bottle, Water and Sand	"C"					
	Temperature of Water						
	Weight of Bottle and Water (chart)	"B"					
	Tare Number						
	Weight Dry Sand and Tare						
	Weight of Tare						
	Weight of Dry Sand	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						
GRAVEL - C127	Trial Number						Average
	Weight of S.S.D. Rock and Tare in Air						
	Weight of Tare						
	Weight of S.S.D. Rock (in Air)	"B"					
	Weight of S.S.D. Rock (in Water)	"C"					
	Weight of Tare and Dry Rock						
	Weight of Tare						
	Weight of Dry Rock	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						

Calculation

Soil: Gs = Wo/ (Wo+(Wa - Wb))

Sand: Bulk Sp. Gr. = A/ (B+D-C)

Sand: S.S.D. Sp. Gr. = D/ (B+D-C)

Gravel: Bulk Sp. Gr. = A/ (B-C)

Gravel: S.S.D. Sp. Gr. = B/ (B-C)

Absorption: Sand % Abs. = ((D-A) /A) x 100

Absorption: Gravel % Abs. = ((B-A) /A) x 100

Remarks:

AMEC Earth & Environmental	**Project:** Diavik PKC Facility	**Project No.:** VM00503.PKC.6
SPECIFIC GRAVITY AND ABSORPTION ASTM D854, C127, C128	**Location:** BH10-06 @ 15.0m **Technician:** GM	**Date:** 16-Feb-11

SOIL - D854	Trial Number							Average
	Bottle Number		4	12				
	Weight of Bottle and Water and Soil	"Wb"	750.6	753.9				
	Temperature of Water	"Tx"	23	23				
	Weight of Bottle and Water	"Wa"	686.5	690				
	Evaporating Dish Number							
	Weight Dish and Dry Soil							
	Weight of Dish							
	Weight of Dry Soil	"Wo"	101	100.6				
	Specific Gravity of Soil		2.737	2.741				2.739
SAND - C128	Trial Number							Average
	Bottle Number							
	Weight of Bottle							
	Weight of S.S.D. Sand in Air	"D"						
	Weight of Bottle, Water and Sand	"C"						
	Temperature of Water							
	Weight of Bottle and Water (chart)	"B"						
	Tare Number							
	Weight Dry Sand and Tare							
	Weight of Tare							
	Weight of Dry Sand	"A"						
	Bulk Specific Gravity							
	S.S.D. Specific Gravity							
	% Absorption							
GRAVEL - C127	Trial Number							Average
	Weight of S.S.D. Rock and Tare in Air							
	Weight of Tare							
	Weight of S.S.D. Rock (in Air)	"B"						
	Weight of S.S.D. Rock (in Water)	"C"						
	Weight of Tare and Dry Rock							
	Weight of Tare							
	Weight of Dry Rock	"A"						
	Bulk Specific Gravity							
	S.S.D. Specific Gravity							
	% Absorption							

Calculation

Soil: Gs = Wo/ (Wo+(Wa - Wb))

Sand: Bulk Sp. Gr. = A/ (B+D-C)

Sand: S.S.D. Sp. Gr. = D/ (B+D-C)

Gravel: Bulk Sp. Gr. = A/ (B-C)

Gravel: S.S.D. Sp. Gr. = B/ (B-C)

Absorption: Sand % Abs. = ((D-A) /A) x 100

Absorption: Gravel % Abs. = ((B-A) /A) x 100

Remarks:

AMEC Earth & Environmental	**Project:** Diavik PKC Facility	**Project No.** VM00503.PKC.6
SPECIFIC GRAVITY AND ABSORPTION ASTM D854, C127, C128	**Location:** BH10-06 @ 17 m	
	Technician: GM	**Date:** 16-Feb-11

SOIL - D854	Trial Number						Average
	Bottle Number		A	B			
	Weight of Bottle and Water and Soil	"Wb"	773.9	774.6			
	Temperature of Water	"Tx"	23	23			
	Weight of Bottle and Water	"Wa"	708.5	709.3			
	Evaporating Dish Number						
	Weight Dish and Dry Soil						
	Weight of Dish						
	Weight of Dry Soil	"Wo"	101.7	101.7			
	Specific Gravity of Soil		2.802	2.794			2.798

SAND - C128	Trial Number						Average
	Bottle Number						
	Weight of Bottle						
	Weight of S.S.D. Sand in Air	"D"					
	Weight of Bottle, Water and Sand	"C"					
	Temperature of Water						
	Weight of Bottle and Water (chart)	"B"					
	Tare Number						
	Weight Dry Sand and Tare						
	Weight of Tare						
	Weight of Dry Sand	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						

GRAVEL - C127	Trial Number						Average
	Weight of S.S.D. Rock and Tare in Air						
	Weight of Tare						
	Weight of S.S.D. Rock (in Air)	"B"					
	Weight of S.S.D. Rock (in Water)	"C"					
	Weight of Tare and Dry Rock						
	Weight of Tare						
	Weight of Dry Rock	"A"					
	Bulk Specific Gravity						
	S.S.D. Specific Gravity						
	% Absorption						

Calculation

Soil: Gs = Wo/ (Wo+(Wa - Wb))

Sand: Bulk Sp. Gr. = A/ (B+D-C)

Sand: S.S.D. Sp. Gr. = D/ (B+D-C)

Gravel: Bulk Sp. Gr. = A/ (B-C)

Gravel: S.S.D. Sp. Gr. = B/ (B-C)

Absorption: Sand % Abs. = ((D-A) /A) x 100

Absorption: Gravel % Abs. = ((B-A) /A) x 100

Remarks:

p:forms\specificgravity.xls

APPENDIX F

Atterberg Limits Testing

ATTERBERG LIMITS

PROJECT	Diavik PKC Facility Site		
JOB No.	**VM00503.PKC.3**	LAB No.	S-9383
DATE	02/01/11	TECH	MR

HOLE	BH10-04		BH10-04		BH10-04		BH10-04	
SAMPLE	Set 1		Set 1		Set 1		Set 1	
DEPTH(m)	6.0		13.0		15.0		16.0	
LIQUID LIMIT								
TRIAL NO.	1	2	1	2	1	2	1	2
NO. OF BLOWS	27	26	22	21	24	23	28	27
CONTAINER NO.	J-6	L-328	L-11	J-14	J-27	B-16	J-7	L-307
WT. OF WET SAMPLE + TARE	26.743	26.532	29.267	24.360	25.378	29.078	23.867	25.219
WT. OF DRY SAMPLE + TARE	22.579	22.844	25.050	20.389	21.006	25.055	20.355	22.318
TARE OF CONTAINER	16.419	17.378	18.015	13.759	14.668	19.191	14.447	17.408
WT. OF WATER	4.164	3.688	4.217	3.971	4.372	4.023	3.512	2.901
WT. OF DRY SOIL	6.160	5.466	7.035	6.630	6.338	5.864	5.908	4.910
WATER CONTENT %	67.6	67.5	59.9	59.9	69.0	68.6	59.4	59.1
CORR'D WATER CONTENT %	68.2	67.8	59.0	58.6	68.6	67.9	60.3	59.6
PLASTIC LIMIT								
TRIAL NO.	1	2	1	2	1	2	1	2
CONTAINER NO.	212	J-30	452	J-13	2	B-6	423	118
WT. OF WET SAMPLE + TARE	22.602	20.670	27.581	21.391	26.617	21.357	24.334	22.780
WT. OF DRY SAMPLE + TARE	21.021	19.150	26.009	19.878	24.896	19.786	22.774	21.558
TARE OF CONTAINER	15.690	14.001	20.281	14.404	19.183	14.529	16.999	17.078
WT. OF WATER	1.581	1.520	1.572	1.513	1.721	1.571	1.560	1.222
WT. OF DRY SOIL	5.331	5.149	5.728	5.474	5.713	5.257	5.775	4.480
WATER CONTENT %	29.7	29.5	27.4	27.6	30.1	29.9	27.0	27.3
SHRINKAGE LIMIT								
TRIAL NO.	1	2	1	2	1	2	1	2
CONTAINER NO.								
WT. OF WET SAMPLE + TARE								
WT. OF DRY SAMPLE + TARE								
TARE OF CONTAINER								
WT. OF WATER								
WT. OF DRY SOIL								
WATER CONTENT %								
VOL. OF CONTAINER								
VOL. OF DRY SOIL PAT								
SHRINKAGE VOL.								

BLOW FACTORS		W_L	68.0	58.8	68.3	60.0
NO.	ASTM	W_P	29.6	27.5	30.0	27.1
20	0.974	W_S				
21	0.979	W_n				
22	0.985	I_P	38.4	31.3	38.3	32.8
23	0.990	I_f				
24	0.995	I_t				
25	1.000	I_L				
26	1.005	A-LINE	35.0	28.3	35.2	29.2
27	1.009	PLASTICITY	**CH**	**CH**	**CH**	**CH**
28	1.014	REMARKS				
29	1.018					
30	1.022					

ATTERBERG LIMITS	PROJECT		Diavik PKC Facility Site		
	JOB No.	**VM00503.PKC.3**	LAB No.	S-9383	
	DATE	02/01/11	TECH	MR	

	HOLE	BH10-04		BH10-04					
	SAMPLE	Set 1		Set 1					
	DEPTH(m)	8.0		10.0					
LIQUID LIMIT									
TRIAL NO.		1	2	1	2				
NO. OF BLOWS		23	22	23	24				
CONTAINER NO.		B-17	142	10	204				
WT. OF WET SAMPLE + TARE		28.966	26.641	27.310	26.421				
WT. OF DRY SAMPLE + TARE		24.799	23.026	22.431	22.147				
TARE OF CONTAINER		18.150	17.233	16.286	16.750				
WT. OF WATER		4.167	3.615	4.879	4.274				
WT. OF DRY SOIL		6.649	5.793	6.145	5.397				
WATER CONTENT %		62.7	62.4	79.4	79.2				
CORR'D WATER CONTENT %		62.0	61.4	78.6	78.8				
PLASTIC LIMIT									
TRIAL NO.		1	2	1	2				
CONTAINER NO.		J-40	J-56	237	224				
WT. OF WET SAMPLE + TARE		21.214	21.412	28.826	23.886				
WT. OF DRY SAMPLE + TARE		19.754	19.729	26.842	22.061				
TARE OF CONTAINER		14.804	14.084	20.749	16.508				
WT. OF WATER		1.460	1.683	1.984	1.825				
WT. OF DRY SOIL		4.950	5.645	6.093	5.553				
WATER CONTENT %		29.5	29.8	32.6	32.9				
SHRINKAGE LIMIT									
TRIAL NO.		1	2	1	2				
CONTAINER NO.									
WT. OF WET SAMPLE + TARE									
WT. OF DRY SAMPLE + TARE									
TARE OF CONTAINER									
WT. OF WATER									
WT. OF DRY SOIL									
WATER CONTENT %									
VOL. OF CONTAINER									
VOL. OF DRY SOIL PAT									
SHRINKAGE VOL.									

BLOW FACTORS		W_L	61.7	78.7		
NO.	ASTM	W_P	29.7	32.7		
20	0.974	W_S				
21	0.979	W_n				
22	0.985	I_P	32.1	46.0		
23	0.990	I_f				
24	0.995	I_t				
25	1.000	I_L				
26	1.005	A-LINE	30.5	42.9		
27	1.009	PLASTICITY	**CH**	**CH**		
28	1.014	REMARKS				
29	1.018					
30	1.022					

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ATTERBERG LIMITS

PROJECT	Diavik PKC Facility Site		
JOB No.	**VM00503.PKC.3**	LAB No.	S-9383
DATE	02/01/11	TECH	MR

HOLE	BH10-04		BH10-04		BH10-04		BH10-04	
SAMPLE	Set 2		Set 2		Set 2		Set 2	
DEPTH(m)	6.0		13.0		15.0		16.0	
LIQUID LIMIT								
TRIAL NO.	1	2	1	2	1	2	1	2
NO. OF BLOWS	27	28	22	23	29	28	29	30
CONTAINER NO.	B-4	J-30	L-302	J-64	J-43	16	J-39	B-1
WT. OF WET SAMPLE + TARE	30.971	25.418	28.433	25.112	25.907	23.664	27.341	28.780
WT. OF DRY SAMPLE + TARE	26.277	21.599	23.723	21.049	21.938	20.582	22.756	25.423
TARE OF CONTAINER	19.405	15.984	15.709	14.090	16.293	16.159	15.083	19.774
WT. OF WATER	4.694	3.819	4.710	4.063	3.969	3.082	4.585	3.357
WT. OF DRY SOIL	6.872	5.615	8.014	6.959	5.645	4.423	7.673	5.649
WATER CONTENT %	68.3	68.0	58.8	58.4	70.3	69.7	59.8	59.4
CORR'D WATER CONTENT %	68.9	69.0	57.9	57.8	71.6	70.6	60.8	60.8
PLASTIC LIMIT								
TRIAL NO.	1	2	1	2	1	2	1	2
CONTAINER NO.	L-304	439	232	L-316	G-19	L-317	210	L-215
WT. OF WET SAMPLE + TARE	23.116	27.194	23.922	19.504	23.896	22.612	23.682	25.584
WT. OF DRY SAMPLE + TARE	21.386	25.058	21.929	17.745	22.086	21.075	21.903	23.894
TARE OF CONTAINER	15.734	18.207	14.855	11.447	16.315	16.122	15.734	18.082
WT. OF WATER	1.730	2.136	1.993	1.759	1.810	1.537	1.779	1.690
WT. OF DRY SOIL	5.652	6.851	7.074	6.298	5.771	4.953	6.169	5.812
WATER CONTENT %	30.6	31.2	28.2	27.9	31.4	31.0	28.8	29.1
SHRINKAGE LIMIT								
TRIAL NO.	1	2	1	2	1	2	1	2
CONTAINER NO.								
WT. OF WET SAMPLE + TARE								
WT. OF DRY SAMPLE + TARE								
TARE OF CONTAINER								
WT. OF WATER								
WT. OF DRY SOIL								
WATER CONTENT %								
VOL. OF CONTAINER								
VOL. OF DRY SOIL PAT								
SHRINKAGE VOL.								

BLOW FACTORS		W_L	68.9	57.8	71.1	60.8
NO.	ASTM	W_P	30.9	28.1	31.2	29.0
20	0.974	W_S				
21	0.979	W_n				
22	0.985	I_P	38.1	29.8	39.9	31.8
23	0.990	I_f				
24	0.995	I_t				
25	1.000	I_L				
26	1.005	A-LINE	35.7	27.6	37.3	29.8
27	1.009	PLASTICITY	**CH**	**CH**	**CH**	**CH**
28	1.014	REMARKS				
29	1.018					
30	1.022					

ATTERBERG LIMITS

PROJECT	Diavik PKC Facility Site		
JOB No.	**VM00503.PKC.3**	LAB No.	S-9383
DATE	02/01/11	TECH	MR

HOLE	BH10-04		BH10-04					
SAMPLE	Set 2		Set 2					
DEPTH(m)	8.0		10.0					
LIQUID LIMIT								
TRIAL NO.	1	2	1	2				
NO. OF BLOWS	21	22	30	29				
CONTAINER NO.	138	B-8	20	210				
WT. OF WET SAMPLE + TARE	27.599	23.025	24.715	28.484				
WT. OF DRY SAMPLE + TARE	23.228	19.884	20.515	24.624				
TARE OF CONTAINER	16.348	14.915	14.915	19.522				
WT. OF WATER	4.371	3.141	4.200	3.860				
WT. OF DRY SOIL	6.880	4.969	5.600	5.102				
WATER CONTENT %	63.5	63.2	75.0	75.7				
CORR'D WATER CONTENT %	62.2	62.2	76.7	77.0				
PLASTIC LIMIT								
TRIAL NO.	1	2	1	2				
CONTAINER NO.	208	245	18	L-318				
WT. OF WET SAMPLE + TARE	22.404	21.305	24.188	23.531				
WT. OF DRY SAMPLE + TARE	20.836	20.010	22.439	21.676				
TARE OF CONTAINER	15.357	15.591	17.164	16.181				
WT. OF WATER	1.568	1.295	1.749	1.855				
WT. OF DRY SOIL	5.479	4.419	5.275	5.495				
WATER CONTENT %	28.6	29.3	33.2	33.8				
SHRINKAGE LIMIT								
TRIAL NO.	1	2	1	2				
CONTAINER NO.								
WT. OF WET SAMPLE + TARE								
WT. OF DRY SAMPLE + TARE								
TARE OF CONTAINER								
WT. OF WATER								
WT. OF DRY SOIL								
WATER CONTENT %								
VOL. OF CONTAINER								
VOL. OF DRY SOIL PAT								
SHRINKAGE VOL.								

BLOW FACTORS		W_L	62.2	76.9		
NO.	ASTM	W_P	29.0	33.5		
20	0.974	W_S				
21	0.979	W_n				
22	0.985	I_P	33.3	43.4		
23	0.990	I_f				
24	0.995	I_t				
25	1.000	I_L				
26	1.005	A-LINE	30.8	41.5		
27	1.009	PLASTICITY	**CH**	**CH**		
28	1.014	REMARKS				
29	1.018					
30	1.022					

ATTERBERG LIMITS

PROJECT	Diavik PKC Facility Site		
JOB No.	**VM00503.PKC.3**	LAB No.	S-9383
DATE	02/02/11	TECH	MR

HOLE	BH10-05		BH10-05		BH10-5		BH10-05	
SAMPLE	Set 1		Set 1		Set 1		Set1	
DEPTH(m)	6.0		23.0		12.0		18.0	
LIQUID LIMIT								
TRIAL NO.	1	2	1	2	1	2	1	2
NO. OF BLOWS	21	22	20	20	24	23	24	26
CONTAINER NO.	8	B-3	J-4	J-23	J-24	L-303	105	203
WT. OF WET SAMPLE + TARE	27.846	28.312	23.974	25.460	27.027	28.362	29.280	25.642
WT. OF DRY SAMPLE + TARE	23.777	24.307	21.740	22.990	23.164	24.690	24.323	21.384
TARE OF CONTAINER	16.965	17.565	14.565	15.042	16.661	18.455	17.002	15.054
WT. OF WATER	4.069	4.005	2.234	2.470	3.863	3.672	4.957	4.258
WT. OF DRY SOIL	6.812	6.742	7.175	7.948	6.503	6.235	7.321	6.330
WATER CONTENT %	59.7	59.4	31.1	31.1	59.4	58.9	67.7	67.3
CORR'D WATER CONTENT %	58.5	58.5	30.3	30.2	59.1	58.3	67.4	67.6
PLASTIC LIMIT								
TRIAL NO.	1	2	1	2	1	2	1	2
CONTAINER NO.	L-304	232	B-19	L-316	J-60	L-305	272	437
WT. OF WET SAMPLE + TARE	21.404	20.733	24.223	18.371	21.670	22.901	22.631	24.385
WT. OF DRY SAMPLE + TARE	20.153	19.435	22.665	16.993	19.706	21.339	21.072	22.958
TARE OF CONTAINER	15.738	14.841	16.316	11.449	13.239	16.288	16.283	18.511
WT. OF WATER	1.251	1.298	1.558	1.378	1.964	1.562	1.559	1.427
WT. OF DRY SOIL	4.415	4.594	6.349	5.544	6.467	5.051	4.789	4.447
WATER CONTENT %	28.3	28.3	24.5	24.9	30.4	30.9	32.6	32.1
SHRINKAGE LIMIT								
TRIAL NO.	1	2	1	2	1	2	1	2
CONTAINER NO.								
WT. OF WET SAMPLE + TARE								
WT. OF DRY SAMPLE + TARE								
TARE OF CONTAINER								
WT. OF WATER								
WT. OF DRY SOIL								
WATER CONTENT %								
VOL. OF CONTAINER								
VOL. OF DRY SOIL PAT								
SHRINKAGE VOL.								

BLOW FACTORS		W_L	58.5	30.3	58.7	67.5
NO.	ASTM	W_P	28.3	24.7	30.6	32.3
20	0.974	W_S				
21	0.979	W_n				
22	0.985	I_P	30.2	5.6	28.1	35.2
23	0.990	I_f				
24	0.995	I_t				
25	1.000	I_L				
26	1.005	A-LINE	28.1	7.5	28.3	34.7
27	1.009	PLASTICITY	**CH**	**ML or OL**	**MH or OH**	**CH**
28	1.014	REMARKS				
29	1.018					
30	1.022					

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ATTERBERG LIMITS

PROJECT	Diavik PKC Facility Site		
JOB No.	**VM00503.PKC.3**	LAB No.	S-9383
DATE	02/02/11	TECH	MR

HOLE	BH10-05		BH10-05		BH10-5		BH10-05	
SAMPLE	Set 2		Set 2		Set 2		Set 2	
DEPTH(m)	6.0		23.0		12.0		18.0	
LIQUID LIMIT								
TRIAL NO.	1	2	1	2	1	2	1	2
NO. OF BLOWS	23	22	21	22	27	26	24	23
CONTAINER NO.	49	16	302	B-1	126	103	144	122
WT. OF WET SAMPLE + TARE	26.924	24.185	26.434	30.879	30.707	25.968	27.159	25.457
WT. OF DRY SAMPLE + TARE	23.532	21.164	23.811	28.172	26.633	22.931	23.219	21.626
TARE OF CONTAINER	17.893	16.160	15.718	19.776	19.777	17.829	17.305	15.875
WT. OF WATER	3.392	3.021	2.623	2.707	4.074	3.037	3.940	3.831
WT. OF DRY SOIL	5.639	5.004	8.093	8.396	6.856	5.102	5.914	5.751
WATER CONTENT %	60.2	60.4	32.4	32.2	59.4	59.5	66.6	66.6
CORR'D WATER CONTENT %	59.5	59.4	31.7	31.7	60.0	59.8	66.3	65.9
PLASTIC LIMIT								
TRIAL NO.	1	2	1	2	1	2	1	2
CONTAINER NO.	J-46	J-30	J-13	452	236	276	410	L-306
WT. OF WET SAMPLE + TARE	21.342	22.252	19.623	23.775	22.107	23.538	25.918	18.542
WT. OF DRY SAMPLE + TARE	19.850	20.488	18.622	23.106	20.321	21.846	24.634	17.262
TARE OF CONTAINER	14.473	14.004	14.420	20.288	14.289	16.219	20.538	13.236
WT. OF WATER	1.492	1.764	1.001	0.669	1.786	1.692	1.284	1.280
WT. OF DRY SOIL	5.377	6.484	4.202	2.818	6.032	5.627	4.096	4.026
WATER CONTENT %	27.7	27.2	23.8	23.7	29.6	30.1	31.3	31.8
SHRINKAGE LIMIT								
TRIAL NO.	1	2	1	2	1	2	1	2
CONTAINER NO.								
WT. OF WET SAMPLE + TARE								
WT. OF DRY SAMPLE + TARE								
TARE OF CONTAINER								
WT. OF WATER								
WT. OF DRY SOIL								
WATER CONTENT %								
VOL. OF CONTAINER								
VOL. OF DRY SOIL PAT								
SHRINKAGE VOL.								

BLOW FACTORS		W_L	59.5	31.7	59.9	66.1
NO.	ASTM	W_P	27.5	23.8	29.8	31.6
20	0.974	W_S				
21	0.979	W_n				
22	0.985	I_P	32.0	8.0	30.1	34.5
23	0.990	I_f				
24	0.995	I_t				
25	1.000	I_L				
26	1.005	A-LINE	28.8	8.6	29.1	33.7
27	1.009	PLASTICITY	**CH**	**ML or OL**	**CH**	**CH**
28	1.014	REMARKS				
29	1.018					
30	1.022					

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ATTERBERG LIMITS

PROJECT	DIAVIK PKC FACILITY SITE		
JOB No.	**VM00503.PKC.3**	LAB No.	S-9383
DATE	7-Feb-11	TECH	MR

HOLE	BH10-06		BH10-06		BH10-06		BH10-06	
SAMPLE	SET-1		SET-1		SET-1		SET-1	
DEPTH(m)	12.0		13.0		15.0		17.0	
LIQUID LIMIT								
TRIAL NO.	1	2	1	2	1	2	1	2
NO. OF BLOWS	20	21	23	24	23	22	21	20
CONTAINER NO.	2-7	49	2-14	16	L-302	2-64	8	138
WT. OF WET SAMPLE + TARE	26.194	28.216	26.162	26.739	27.262	23.055	29.833	28.922
WT. OF DRY SAMPLE + TARE	22.022	24.539	21.021	22.372	22.539	19.394	26.399	25.548
TARE OF CONTAINER	14.456	17.899	13.761	16.134	15.710	14.092	16.991	16.345
WT. OF WATER	4.172	3.677	5.141	4.367	4.723	3.661	3.434	3.374
WT. OF DRY SOIL	7.566	6.640	7.260	6.238	6.829	5.302	9.408	9.203
WATER CONTENT %	55.1	55.4	70.8	70.0	69.2	69.0	36.5	36.7
CORR'D WATER CONTENT %	53.7	54.2	70.1	69.7	68.5	68.0	35.7	35.7
PLASTIC LIMIT								
TRIAL NO.	1	2	1	2	1	2	1	2
CONTAINER NO.	212	229	236	276	118	204	452	L-318
WT. OF WET SAMPLE + TARE	21.485	22.138	19.832	21.115	24.430	19.714	27.039	24.234
WT. OF DRY SAMPLE + TARE	20.406	21.154	18.596	20.025	22.862	18.301	25.886	22.878
TARE OF CONTAINER	15.662	16.722	14.284	16.215	17.091	13.025	20.284	16.174
WT. OF WATER	1.079	0.984	1.236	1.090	1.568	1.413	1.153	1.356
WT. OF DRY SOIL	4.744	4.432	4.312	3.810	5.771	5.276	5.602	6.704
WATER CONTENT %	22.7	22.2	28.7	28.6	27.2	26.8	20.6	20.2
SHRINKAGE LIMIT								
TRIAL NO.	1	2	1	2	1	2	1	2
CONTAINER NO.								
WT. OF WET SAMPLE + TARE								
WT. OF DRY SAMPLE + TARE								
TARE OF CONTAINER								
WT. OF WATER								
WT. OF DRY SOIL								
WATER CONTENT %								
VOL. OF CONTAINER								
VOL. OF DRY SOIL PAT								
SHRINKAGE VOL.								

BLOW FACTORS		W_L	53.9	69.9	68.2	35.7
NO.	ASTM	W_P	22.5	28.6	27.0	20.4
20	0.974	W_S				
21	0.979	W_n				
22	0.985	I_P	31.5	41.2	41.3	15.3
23	0.990	I_f				
24	0.995	I_t				
25	1.000	I_L				
26	1.005	A-LINE	24.8	36.4	35.2	11.5
27	1.009	PLASTICITY	**CH**	**CH**	**CH**	**CI**
28	1.014	REMARKS				
29	1.018					
30	1.022					

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ATTERBERG LIMITS

PROJECT	DIAVIK PKC FACILITY SITE		
JOB No.	**VM00503.PKC.3**	LAB No.	S-9383
DATE	7-Feb-11	TECH	MR

HOLE	BH10-06		BH10-06					
SAMPLE	SET-1		SET-1					
DEPTH(m)	4.0		8.0					
LIQUID LIMIT								
TRIAL NO.	1	2	1	2	1	2	1	2
NO. OF BLOWS	23	24	23	22				
CONTAINER NO.	2-43	2-14	20	B-15				
WT. OF WET SAMPLE + TARE	26.136	22.497	30.084	28.784				
WT. OF DRY SAMPLE + TARE	21.619	18.505	25.256	25.150				
TARE OF CONTAINER	16.297	13.761	17.751	19.487				
WT. OF WATER	4.517	3.992	4.828	3.634				
WT. OF DRY SOIL	5.322	4.744	7.505	5.663				
WATER CONTENT %	84.9	84.1	64.3	64.2				
CORR'D WATER CONTENT %	84.0	83.7	63.7	63.2				
PLASTIC LIMIT								
TRIAL NO.	1	2	1	2	1	2	1	2
CONTAINER NO.	L-215	210	439	L-317				
WT. OF WET SAMPLE + TARE	24.404	21.328	24.503	21.531				
WT. OF DRY SAMPLE + TARE	23.164	20.221	23.456	20.642				
TARE OF CONTAINER	18.086	15.760	18.209	16.100				
WT. OF WATER	1.240	1.107	1.047	0.889				
WT. OF DRY SOIL	5.078	4.461	5.247	4.542				
WATER CONTENT %	24.4	24.8	20.0	19.6				
SHRINKAGE LIMIT								
TRIAL NO.	1	2	1	2	1	2	1	2
CONTAINER NO.								
WT. OF WET SAMPLE + TARE								
WT. OF DRY SAMPLE + TARE								
TARE OF CONTAINER								
WT. OF WATER								
WT. OF DRY SOIL								
WATER CONTENT %								
VOL. OF CONTAINER								
VOL. OF DRY SOIL PAT								
SHRINKAGE VOL.								

BLOW FACTORS						
		W_L	83.9	63.4		
NO.	ASTM	W_P	24.6	19.8		
20	0.974	W_S				
21	0.979	W_n				
22	0.985	I_P	59.3	43.7		
23	0.990	I_f				
24	0.995	I_t				
25	1.000	I_L				
26	1.005	A-LINE	46.6	31.7		
27	1.009	PLASTICITY	**CH**	**CH**	**ML or OL**	**ML or OL**
28	1.014	REMARKS				
29	1.018					
30	1.022					

PROJECT	DIAVIK PKC FACILITY SITE		
JOB No.	**VM00503.PKC.3**	LAB No.	S-9383
DATE	7-Feb-11	TECH	MR

ATTERBERG LIMITS

HOLE	BH10-06		BH10-06		BH10-06		BH10-06	
SAMPLE	SET-2		SET-2		SET-2		SET-2	
DEPTH(m)	12.0		13.0		15.0		17.0	
LIQUID LIMIT								
TRIAL NO.	1	2	1	2	1	2	1	2
NO. OF BLOWS	21	22	23	22	21	22	22	21
CONTAINER NO.	122	103	203	210	L-303	105	2-4	B-8
WT. OF WET SAMPLE + TARE	27.216	30.384	25.911	28.744	28.981	26.494	24.433	25.447
WT. OF DRY SAMPLE + TARE	23.194	25.917	21.466	24.962	24.644	22.582	21.753	22.607
TARE OF CONTAINER	15.897	17.804	15.044	19.489	18.481	16.995	14.585	14.885
WT. OF WATER	4.022	4.467	4.445	3.782	4.337	3.912	2.680	2.840
WT. OF DRY SOIL	7.297	8.113	6.422	5.473	6.163	5.587	7.168	7.722
WATER CONTENT %	55.1	55.1	69.2	69.1	70.4	70.0	37.4	36.8
CORR'D WATER CONTENT %	54.0	54.2	68.5	68.0	68.9	68.9	36.8	36.0
PLASTIC LIMIT								
TRIAL NO.	1	2	1	2	1	2	1	2
CONTAINER NO.	B-19	L-316	L-215	210	L-304	232	439	L-317
WT. OF WET SAMPLE + TARE	23.620	19.268	24.108	21.756	21.866	19.571	24.801	23.712
WT. OF DRY SAMPLE + TARE	22.218	17.777	22.756	20.408	20.566	18.587	23.669	22.419
TARE OF CONTAINER	16.315	11.450	18.109	15.735	15.705	14.857	18.233	16.125
WT. OF WATER	1.402	1.491	1.352	1.348	1.300	0.984	1.132	1.293
WT. OF DRY SOIL	5.903	6.327	4.647	4.673	4.861	3.730	5.436	6.294
WATER CONTENT %	23.8	23.6	29.1	28.8	26.7	26.4	20.8	20.5
SHRINKAGE LIMIT								
TRIAL NO.	1	2	1	2	1	2	1	2
CONTAINER NO.								
WT. OF WET SAMPLE + TARE								
WT. OF DRY SAMPLE + TARE								
TARE OF CONTAINER								
WT. OF WATER								
WT. OF DRY SOIL								
WATER CONTENT %								
VOL. OF CONTAINER								
VOL. OF DRY SOIL PAT								
SHRINKAGE VOL.								

BLOW FACTORS						
		W_L	54.1	68.3	68.9	36.4
NO.	ASTM	W_P	23.7	29.0	26.6	20.7
20	0.974	W_S				
21	0.979	W_n				
22	0.985	I_P	30.4	39.3	42.4	15.7
23	0.990	I_f				
24	0.995	I_t				
25	1.000	I_L				
26	1.005	A-LINE	24.9	35.2	35.7	12.0
27	1.009	PLASTICITY	**CH**	**CH**	**CH**	**CI**
28	1.014	REMARKS				
29	1.018					
30	1.022					

amec

ATTERBERG LIMITS

PROJECT	DIAVIK PKC FACILITY SITE		
JOB No.	**VM00503.PKC.3**	LAB No.	S-9383
DATE	7-Feb-11	TECH	MR

HOLE	BH10-06		BH10-06					
SAMPLE	SET-2		SET-2					
DEPTH(m)	4.0		8.0					
LIQUID LIMIT								
TRIAL NO.	1	2	1	2	1	2	1	2
NO. OF BLOWS	24	23	30	29				
CONTAINER NO.	2-64	2-7	L-307	2-39				
WT. OF WET SAMPLE + TARE	22.447	21.614	27.015	22.278				
WT. OF DRY SAMPLE + TARE	18.601	18.321	23.296	19.490				
TARE OF CONTAINER	14.113	14.476	17.437	15.089				
WT. OF WATER	3.846	3.293	3.719	2.788				
WT. OF DRY SOIL	4.488	3.845	5.859	4.401				
WATER CONTENT %	85.7	85.6	63.5	63.3				
CORR'D WATER CONTENT %	85.3	84.8	64.9	64.5				
PLASTIC LIMIT								
TRIAL NO.	1	2	1	2	1	2	1	2
CONTAINER NO.	118	204	212	229				
WT. OF WET SAMPLE + TARE	23.288	19.411	22.521	23.373				
WT. OF DRY SAMPLE + TARE	22.101	18.196	21.338	22.221				
TARE OF CONTAINER	17.091	13.026	15.666	16.723				
WT. OF WATER	1.187	1.215	1.183	1.152				
WT. OF DRY SOIL	5.010	5.170	5.672	5.498				
WATER CONTENT %	23.7	23.5	20.9	21.0				
SHRINKAGE LIMIT								
TRIAL NO.	1	2	1	2	1	2	1	2
CONTAINER NO.								
WT. OF WET SAMPLE + TARE								
WT. OF DRY SAMPLE + TARE								
TARE OF CONTAINER								
WT. OF WATER								
WT. OF DRY SOIL								
WATER CONTENT %								
VOL. OF CONTAINER								
VOL. OF DRY SOIL PAT								
SHRINKAGE VOL.								

BLOW FACTORS		W_L	85.0	64.7		
NO.	ASTM	W_P	23.6	20.9		
20	0.974	W_S				
21	0.979	W_n				
22	0.985	I_P	61.4	43.8		
23	0.990	I_f				
24	0.995	I_t				
25	1.000	I_L				
26	1.005	A-LINE	47.5	32.6		
27	1.009	PLASTICITY	**CH**	**CH**	**ML or OL**	**ML or OL**
28	1.014	REMARKS				
29	1.018					
30	1.022					

APPENDIX G

Column Settling Tests

TSRU Laboratory Settling Test

Project	DIAVIK PKC FACILITY SITE		
Project #	VM00503.PKC.3		
Client			
Depth(m)	15.0		
AMEC Sample #	BH10-04	Technician	BRL/MS
Date	April 19,2011	Reviewer	CR

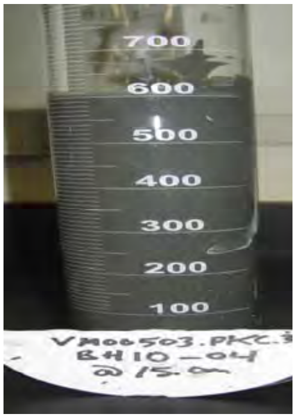
Sample Details

Weight of Sample	301.9 g
Weight of Pond Water	389.4 g
Weight of the test Sample in 1-L Graduated Cylinder	691.3 g
Volume of Sample in 1L Graduated Cylinder	600ml
Date (mm/dd/yyyy) =	04/19/11
Time =	3:26:00 PM

Remarks

Added 5.0ml pond water(5.0g) April 25,2011 12:20pm
Added 2.8ml pond water(2.8g) May 5,2011 14:15pm

Sample before test



Sample at the end of the test

Settlement Measurements

Date	Time	Volume Measurement of Top of Layer (ml)					Comments
		Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
4/19/2011	3:20 PM	600	0				
4/19/2011	4:50 PM	590	10				
4/19/2011	5:35 PM	586	14				
4/20/2011	7:05 AM	525	75				
4/20/2011	10:20 AM	515	85				
4/20/2011	12:00 PM	508	92				
4/20/2011	1:00 PM	505	95				
4/20/2011	2:00 PM	502	98				
4/20/2011	3:00 PM	499	101				
4/20/2011	4:00 PM	495	105				
4/20/2011	5:00 PM	492	108				
4/21/2011	9:55 AM	459	141				
4/21/2011	10:55 AM	454	146				
4/21/2011	12:00 PM	453	147				
4/21/2011	2:26 PM	450	150				
4/21/2011	4:00 PM	450	150				
4/22/2011	8:07 AM	435	165				
4/25/2011	7:46 AM	415	185				
4/25/2011	12:00 PM	415	185				
4/25/2011	4:00 PM	413	187				
4/26/2011	5:25 PM	410	190				
4/27/2011	9:30 PM	410	190				

Date	Time	Volume Measurement of Top of Layer (ml)					Comments
		Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
4/30/2011	10:45 AM	410	190				final weight: 1211.4 (g)
5/2/2011	11:16 AM	400	190	10			glass cylinder #2 weight 525 (g)
5/2/2011	4:16 PM	395	195	10			
5/5/2011	2:30 PM	395	195	10			
5/7/2011	11:01 AM	395	195	10			
5/11/2011	3:30 AM	390	195	15			
5/16/2011	8:46 AM	390	195	15			
5/18/2011	8:41 AM	390	210	15			

TSRU Laboratory Settling Test

Project	DIAVIK PKC FACILITY SITE		
Project #	VM00503.PKC.3		
Client			
Depth(m)	6.0		
AMEC Sample #	BH10-04	Technician	BRL/MS
Date	April 19,2011	Reviewer	CR

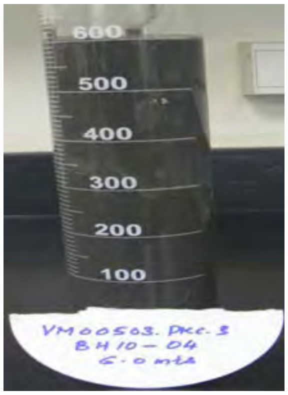
Sample Details

Weight of Sample	395.2 g
Weight of Pond Water	285.1 g
Weight of the test Sample in 1-L Graduated Cylinder	680.3 g
Volume of Sample in 1L Graduated Cylinder	600ml
Date (mm/dd/yyyy) =	04/19/11
Time =	2:11:00 PM

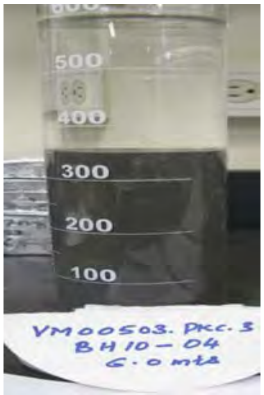
Remarks

Added 4.9ml pond water(4.9g) April 25,2011 12:15pm
Added 3.0ml pond water(3.0g) May 5,2011 14:15pm

Sample before test



Sample at the end of the test



Settlement Measurements

Date	Time	Volume Measurement of Top of Layer (ml)					Comments
		Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
4/19/2011	2:11 PM	600	0				
4/19/2011	6:50 PM	595	5				
4/19/2011	5:35 PM	590	10				
4/20/2011	7:05 AM	565	35				
4/20/2011	10:20 AM	560	40				
4/20/2011	12:00 PM	555	45				
4/20/2011	1:00 PM	554	46				
4/20/2011	2:00 PM	552	48				
4/20/2011	3:00 PM	550	50				
4/20/2011	4:00 PM	549	51				
4/20/2011	5:00 PM	548	52				
4/21/2011	9:55 AM	528	72				
4/21/2011	10:55 AM	524	76				
4/21/2011	12:00 PM	521	79				
4/21/2011	2:26 PM	517	83				
4/21/2011	4:00 PM	515	85				
4/22/2011	8:06 AM	498	102				
4/25/2011	7:45 AM	430	170				
4/25/2011	12:00 PM	425	175				
4/25/2011	4:00 PM	422	178				
4/26/2011	5:25 PM	408	192				
4/27/2011	9:30 PM	395	205				

Date	Time	Volume Measurement of Top of Layer (ml)					Comments
		Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
4/30/2011	10:45 AM	380	220				final weight: 1213.4 (g)
5/2/2011	11:16 AM	370	230				glass cylinder #1 weight 535.3 (g)
5/3/2011	4:16 PM	368	232				
5/5/2011	2:30 PM	368	232				
5/7/2011	11:00 AM	362	238				
5/11/2011	3:30 AM	360	240				
5/16/2011	8:45 AM	355	245				
5/18/2011	8:40 AM	355	245				

TSRU Laboratory Settling Test

Project	DIAVIK PKC FACILITY SITE
Project #	VM00503.PKC.3
Client	
Depth(m)	12.0
AMEC Sample #	BH10-05
Technician	BRL/MS
Date	April 19,2011
Reviewer	CR

Sample Details

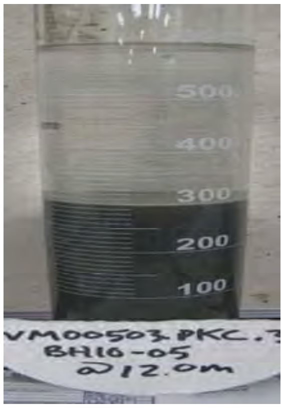
Weight of Sample	287.2 g
Weight of Pond Water	402.2 g
Weight of the test Sample in 1-L Graduated Cylinder	689.4 g
Volume of Sample in 1L Graduated Cylinder	605 g
Date (mm/dd/yyyy) =	04/19/11
Time =	4:34:00 PM

Remarks

Added 3.9ml pond water(3.9g) April 25,2011 12:20pm
Added 3.0ml pond water(3.0g) May 5,2011 14:15pm

Sample before test

Sample at the end of the test



Settlement Measurements

Date	Time	Volume Measurement of Top of Layer (ml)					Comments
		Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
4/19/2011	4:34 PM	605	0				
4/19/2011	5:35 PM	592	13				
4/20/2011	7:36 AM	510	95				
4/20/2011	10:20 AM	495	110				
4/20/2011	12:00 PM	490	115				
4/20/2011	1:00 PM	485	120				
4/20/2011	2:00 PM	481	124				
4/20/2011	3:00 PM	477	128				
4/20/2011	4:00 AM	474	131				
4/20/2011	5:00 AM	470	135				
4/21/2011	9:56 AM	420	185				
4/21/2011	10:56 AM	417	188				
4/21/2011	12:01 PM	415	190				
4/21/2011	2:27 PM	410	195				
4/21/2011	4:02 PM	405	200				
4/22/2011	8:09 AM	380	225				
4/25/2011	7:47 AM	330	275				
4/25/2011	12:01 PM	326	279				
4/25/2011	4:01 PM	325	280				
4/26/2011	5:26 PM	320	285				
4/27/2011	9:31 PM	315	290				
4/30/2011	10:48 AM	310	295				

Date	Time	Volume Measurement of Top of Layer (ml)					Comments
		Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
5/2/2011	11:20 AM	290	303	12			final weight: 1223.6 (g) glass cylinder #4 weight 534.0 (g)
5/3/2011	4:20 PM	285	305	15			
5/5/2011	2:31 PM	285	305	15			
5/7/2011	11:03 AM	285	305	15			
5/11/2011	3:31 AM	285	305	15			
5/16/2011	8:48 AM	280	307	18			
5/18/2011	8:42 AM	280	307	18			

TSRU Laboratory Settling Test

Project	DIAVIK PKC FACILITY SITE		
Project #	VM00503.PKC.3		
Client			
Depth(m)	18.0		
AMEC Sample #	BH10-05	Technician	BRL/MS
Date	April 20,2011	Reviewer	CR

Sample Details

Weight of Sample	276.3 g
Weight of Pond Water	417.9 g
Weight of the test Sample in 1-L Graduated Cylinder	694.2 g
Volume of Sample in 1L Graduated Cylinder	605 g
Date (mm/dd/yyyy) =	04/20/11
Time =	11:04:00 AM

Remarks

Added 5.0ml pond water(5.1g) April 25,2011 12:20pm
Added 2.8ml pond water(2.8g) May 5,2011 14:15pm

Sample before test

Sample at the end of the test

Settlement Measurements

Date	Time	Volume Measurement of Top of Layer (ml)					Comments
		Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
4/20/2011	11:04 AM	605	0				
4/20/2011	11:40 AM	582	23				
4/20/2011	12:00 PM	573	32				
4/20/2011	12:20 PM	565	40				
4/20/2011	12:40 PM	555	50				
4/20/2011	1:00 PM	550	55				
4/20/2011	2:00 PM	529	76				
4/20/2011	3:00 PM	513	92				
4/20/2011	4:00 PM	500	105				
4/20/2011	5:00 PM	448	157				
4/21/2011	9:57 AM	404	201				
4/21/2011	10:57 AM	402	203				
4/21/2011	12:01 PM	400	205				
4/21/2011	2:27 PM	396	109				
4/21/2011	4:02 PM	392	213				
4/22/2011	8:09 AM	380	225				
4/25/2011	7:48 AM	361	244				
4/25/2011	12:01 PM	361	244				
4/25/2011	4:01 PM	360	245				
4/26/2011	5:26 PM	358	247				
4/27/2011	9:31 PM	358	247				
4/30/2011	10:48 AM	358	247				

Date	Time	Volume Measurement of Top of Layer (ml)					Comments
		Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
5/2/2011	11:17 AM	350	245	10			final weight: 1220.2 (g) glass cylinder #5 weight 530.4 (g)
5/3/2011	4:22 PM	345	248	12			
5/5/2011	2:32 PM	345	248	12			
5/7/2011	11:04 AM	345	248	12			
5/11/2011	3:32 AM	345	248	12			
5/16/2011	8:50 AM	345	248	12			
5/18/2011	8:43 AM	345	248	12			

TSRU Laboratory Settling Test

Project	DIAVIK PKC FACILITY SITE		
Project #	VM00503.PKC.3		
Client			
Depth(m)	6.0		
AMEC Sample #	BH10-05	Technician	BRL/MS
Date	April 19,2011	Reviewer	CR

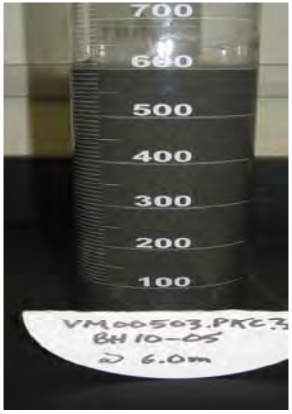
Sample Details

Weight of Sample	404.7 g
Weight of Pond Water	273.6 g
Weight of the test Sample in 1-L Graduated Cylinder	678.3 g
Volume of Sample in 1L Graduated Cylinder	600ml
Date (mm/dd/yyyy) =	04/19/11
Time =	4:00:00 PM

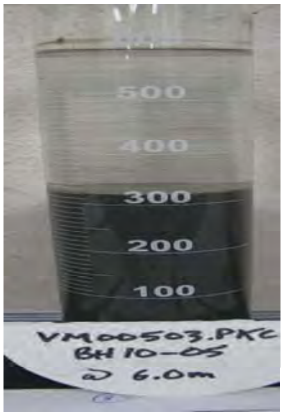
Remarks

Added 8.1ml pond water(8.1g) April 25,2011 12:20pm
Added 3.2ml pond water(3.2g) May 5,2011 14:15pm

Sample before test



Sample at the end of the test



Settlement Measurements

Date	Time	Volume Measurement of Top of Layer (ml)					Comments
		Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
4/19/2011	4:00 PM	600	0				
4/19/2011	5:35 PM	590	10				
4/20/2011	7:36 AM	530	70				
4/20/2011	10:20 AM	520	80				
4/20/2011	12:00 PM	515	85				
4/20/2011	1:00 PM	512	88				
4/20/2011	2:00 PM	510	90				
4/20/2011	3:00 PM	507	93				
4/20/2011	4:00 AM	504	96				
4/20/2011	5:00 AM	501	99				
4/21/2011	9:56 AM	464	136				
4/21/2011	10:56 AM	462	138				
4/21/2011	12:01 PM	460	140				
4/21/2011	2:27 PM	455	145				
4/22/2011	8:08 AM	425	175				
4/22/2011	7:46 AM	364	236				
4/25/2011	12:01 PM	362	238				
4/25/2011	4:01 PM	360	240				
4/26/2011	5:26 PM	352	248				
4/27/2011	12:30 PM	345	255				
4/30/2011	10:46 AM	340	260				

Date	Time	Volume Measurement of Top of Layer (ml)					Comments
		Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
5/2/2011	11:20 AM	332	268				final weight: 1211.3 (g) glass cylinder #3 weight 534.8 (g)
5/3/2011	4:20 PM	330	270				
5/5/2011	2:30 PM	330	270				
5/7/2011	11:01 AM	328	272				
5/11/2011	3:30 AM	328	272				
5/16/2011	8:47 AM	322	278				
5/18/2011	8:42 AM	322	278				

TSRU Laboratory Settling Test

Project	DIAVIK PKC FACILITY SITE		
Project #	VM00503.PKC.3		
Client			
Depth(m)	13.0		
AMEC Sample #	BH10-06	Technician	BRL/MS
Date	April 20,2011	Reviewer	CR

Sample Details

Weight of Sample	301.9 g
Weight of Pond Water	387.2 g
Weight of the test Sample in 1-L Graduated Cylinder	689.1 g
Volume of Sample in 1L Graduated Cylinder	610 g
Date (mm/dd/yyyy) =	04/20/11
Time =	1:00:00 PM

Remarks

Added 8.4ml pond water(8.4g) April 25,2011 12:20pm
Added 3.0ml pond water(3.0g) May 5,2011 14:15pm

Sample before test

Sample at the end of the test

Settlement Measurements

Date	Time	Volume Measurement of Top of Layer (ml)					Comments
		Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
4/20/2011	1:00 PM	610	0				
4/20/2011	2:00 PM	603	7				
4/20/2011	3:00 PM	596	14				
4/20/2011	4:00 PM	591	19				
4/20/2011	5:00 PM	588	22				
4/21/2011	9:58 AM	539	71				
4/21/2011	10:58 AM	534	76				
4/21/2011	12:02 PM	530	80				
4/21/2011	2:28 PM	526	84				
4/21/2011	4:10 PM	523	87				
4/22/2011	8:11 AM	493	117				
4/25/2011	7:48 AM	521	89				
4/25/2011	12:02 PM	519	91				
4/25/2011	4:02 PM	517	93				
4/26/2011	5:27 PM	404	206				
4/27/2011	9:32 PM	395	215				
4/30/2011	10:50 AM	372	228	10			
5/2/2011	11:15 AM	365	230	15			
5/3/2011	4:25 PM	360	235	15			
5/5/2011	2:35 PM	356	239	15			
5/7/2011	11:05 AM	356	239	15			
5/11/2011	3:34 AM	356	239	15			

Date	Time	Volume Measurement of Top of Layer (ml)					Comments
		Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
5/16/2011	9:52 AM	351	239	20			final weight: 1220.5 (g) glass cylinder #7 weight 532.2 (g)
5/18/2011	8:41 AM	351	239	20			

TSRU Laboratory Settling Test

Project	DIAVIK PKC FACILITY SITE
Project #	VM00503.PKC.3
Client	
Depth(m)	4.0

AMEC Sample #	BH10-06	Technician	BRL/MS
Date	April 20,2011	Reviewer	CR

Sample Details

Weight of Sample	417.2 g
Weight of Pond Water	279.4 g
Weight of the test Sample in 1-L Graduated Cylinder	696.6 g
Volume of Sample in 1L Graduated Cylinder	618 g
Date (mm/dd/yyyy) =	04/20/11
Time =	12:08:00 PM

Remarks

Added 7.8ml pond water(7.8g) April 25,2011 12:20pm
Added 3.4ml pond water(3.4g) May 5,2011 14:15pm

Sample before test

Sample at the end of the test

Settlement Measurements

Date	Time	Volume Measurement of Top of Layer (ml)					Comments
		Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
4/20/2011	12:08 PM	618	0				
4/20/2011	1:00 PM	615	3				
4/20/2011	2:00 PM	613	5				
4/20/2011	3:00 PM	611	7				
4/20/2011	4:00 PM	610	8				
4/20/2011	5:00 PM	610	8				
4/21/2011	9:57 AM	590	28				
4/21/2011	10:57 AM	589	29				
4/21/2011	12:02 PM	587	31				
4/21/2011	2:28 PM	585	33				
4/21/2011	4:10 PM	583	35				
4/22/2011	8:10 AM	570	48				
4/25/2011	7:48 AM	520	98				
4/25/2011	12:02 PM	516	102				
4/25/2011	4:02 PM	513	105				
4/26/2011	5:27 PM	498	120				
4/27/2011	9:32 PM	485	133				
4/30/2011	10:48 AM	460	158				
5/2/2011	11:16 AM	449	169				
5/3/2011	4:25 PM	440	178				
5/5/2011	2:33 PM	431	187				
5/7/2011	11:05 AM	427	191				

Date	Time	Volume Measurement of Top of Layer (ml)					Comments
		Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
5/11/2011	3:33 PM	415	203				final weight: 1230.3 (g)
5/16/2011	9:50 AM	411	207				glass cylinder #6 weight 535.6 (g)
5/18/2011	8:45 AM	411	207				

APPENDIX H

Large-Strain Consolidation Testing

Consolidation Test - Large Strain for Low Solids and Paste Sample

Project Number	11-1359-0001		Initial Water Content	173.12	%	Initial Wet Density	1255.00	kg/m^3
Borehole	BH10-05		Initial Solids Content	36.61	%	Inital Dry Density	459.50	kg/m^3
Sample	SA 02		Sample Diameter	152.40	mm	Initial Void Ratio	4.832	
Depth	8 m		Initial Height	120.00	mm	Initial Saturation	96.01	%
Lab No.	999201		Inital Mass(wet)	2747.16	g	Height of Solids	20.57	mm
INITIAL CELL READINGS:			Mass of Solids	1005.83	g			
Hc	29.7	cm	Specific Gravity	2.68	(assumed)			
Hb	27.2	cm	Sample Area	0.018241	m^2	Final Water Content	44.20	%
Hs	9.5	cm	Sample Volume	0.002189	m^3	Final Height (Measured):	45.00	mm
Hs(after S.W.	8.5	cm	Self Weight Load	0.369	kPa	Final Mass	1447.14	gm
Load Arm Ratio	12 :1		Height _after S.W.	110.00	mm	Final Void Ratio (from ht)	1.187	

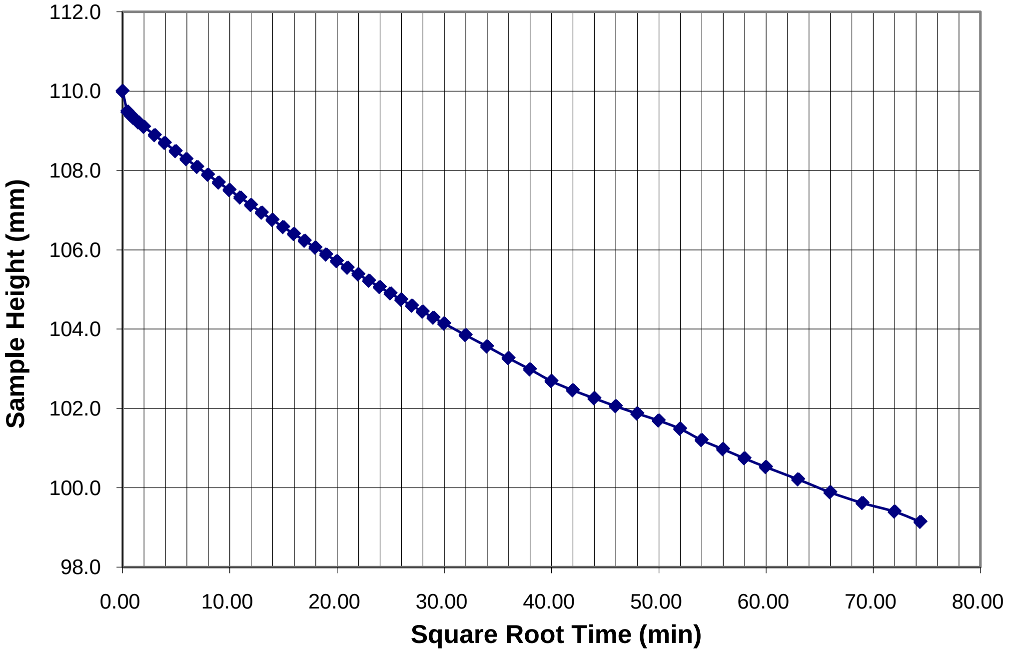
Load No.	H_{sample} (mm)	H_{D50} (mm)	t_{50} (min)	Stress (kPa)	Void Ratio	K(measured) (cm/s)	Strain (%)	Dry Density (kg/m³)
1	99.14			1.49	3.819		17.38	556
2	87.24			2.49	3.240		27.30	632
3	78.39			5.18	2.810		34.67	703
4	70.96			10.56	2.449	1.17E-06	40.86	777
5	62.87			19.63	2.056	2.46E-08	47.61	877
6	61.32			35.77	1.980		48.90	899
7	54.33			84.17	1.641		54.73	1015
8	48.93			180.97	1.378	7.68E-09	59.23	1127
9	44.95			374.57	1.185	3.81E-09	62.54	1227

Golder Associates

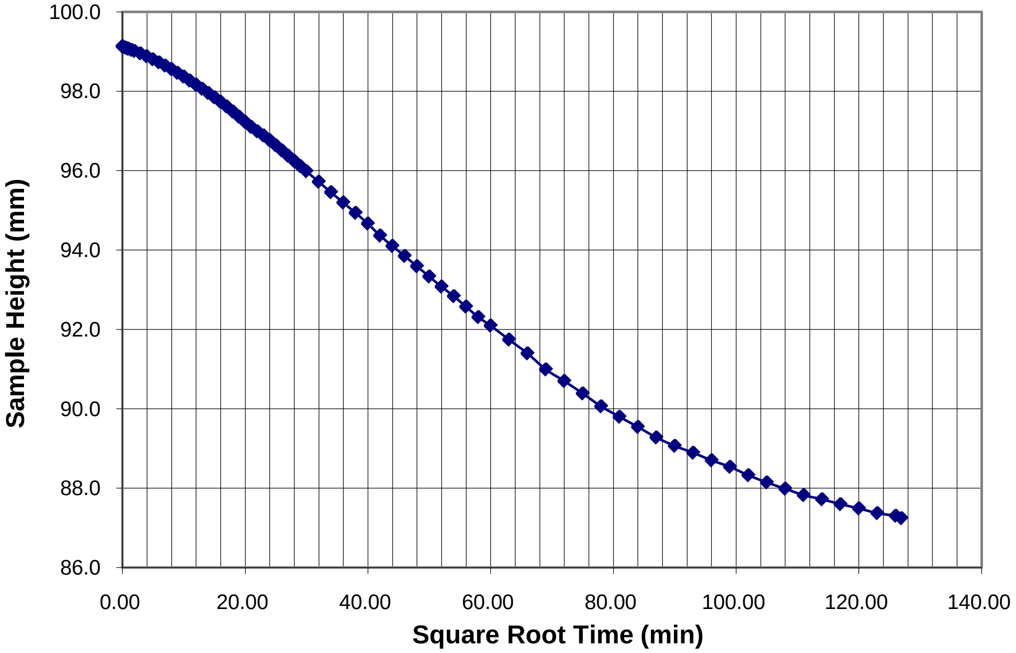
CONSOLIDATION TEST
(ASTM D2435)

Project No.: 11-1359-0001
Lab No.: 999201
BH No.: BH10-05
Sample No.: SA 02
Depth: 8 m

SAMPLE HEIGHT vs. SQUARE ROOT TIME



Total Stress: 1.49 kPa
H_{Sample}: ____ mm
H_{D50}: ____ mm
T_{50}: ____ min

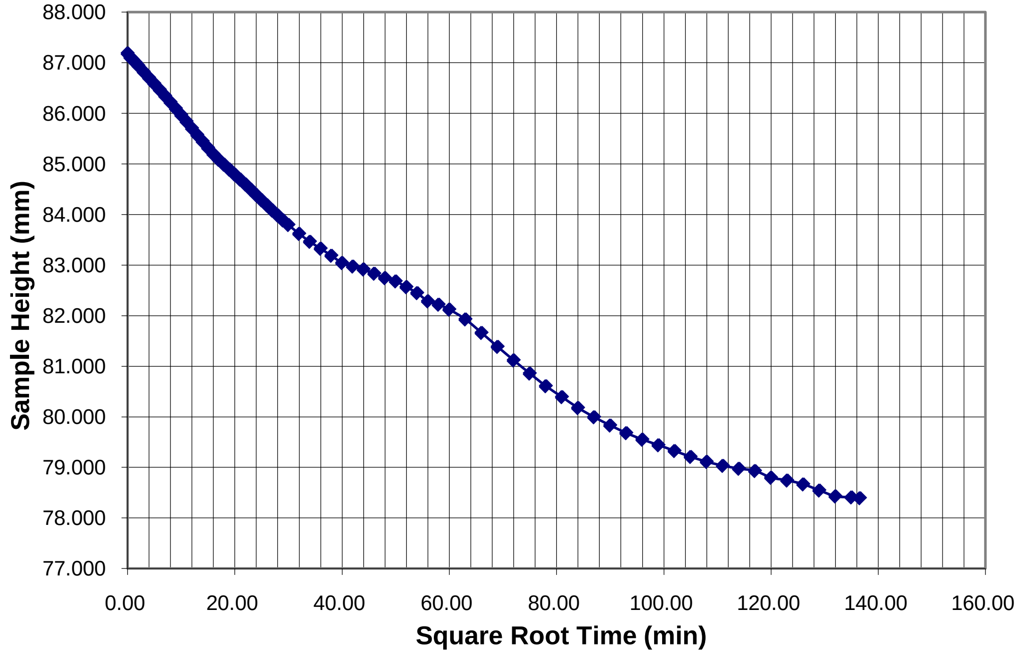


Total Stress: 2.49 kPa
H_{Sample}: ____ mm
H_{D50}: ____ mm
T_{50}: ____ min

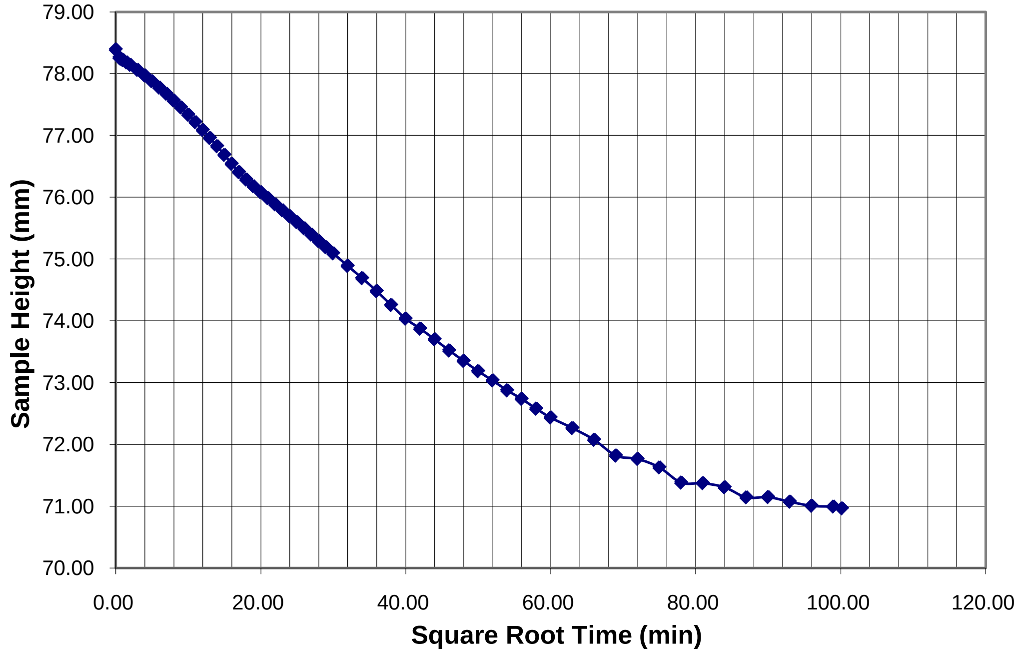
CONSOLIDATION TEST
(ASTM D2435)

Project No.: 11-1359-0001
Lab No.: 999201
BH No.: BH10-05
Sample No.: SA 02
Depth: 8 m

SAMPLE HEIGHT vs. SQUARE ROOT TIME



Total Stress: 5.18 kPa
H_{Sample}: ______ mm
H_{D50}: ______ mm
T_{50}: ______ min

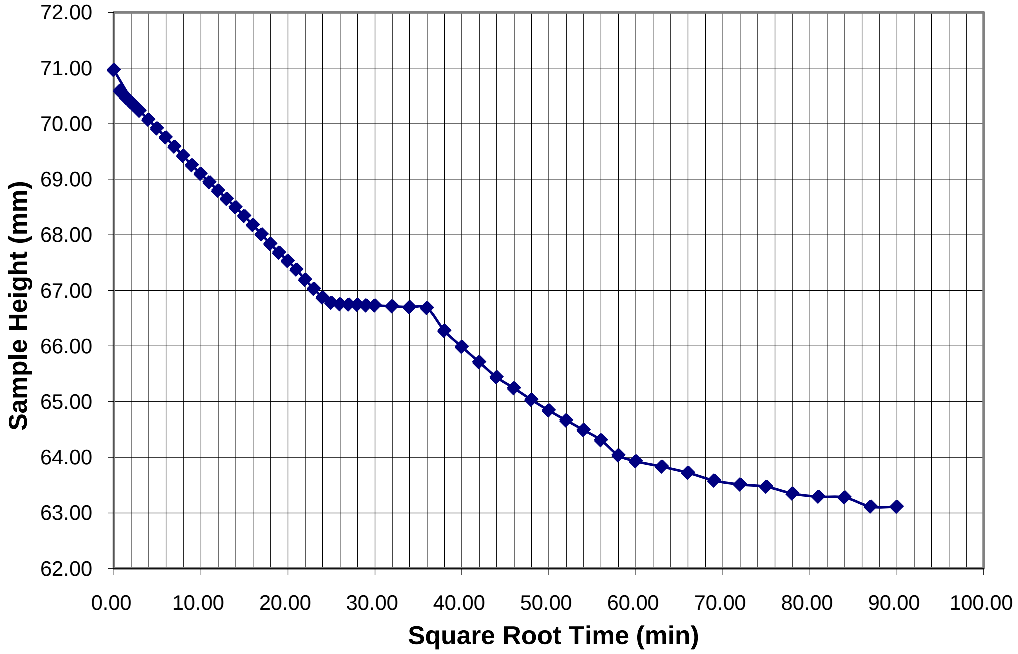


Total Stress: 10.56 kPa
H_{Sample}: ______ mm
H_{D50}: ______ mm
T_{50}: ______ min

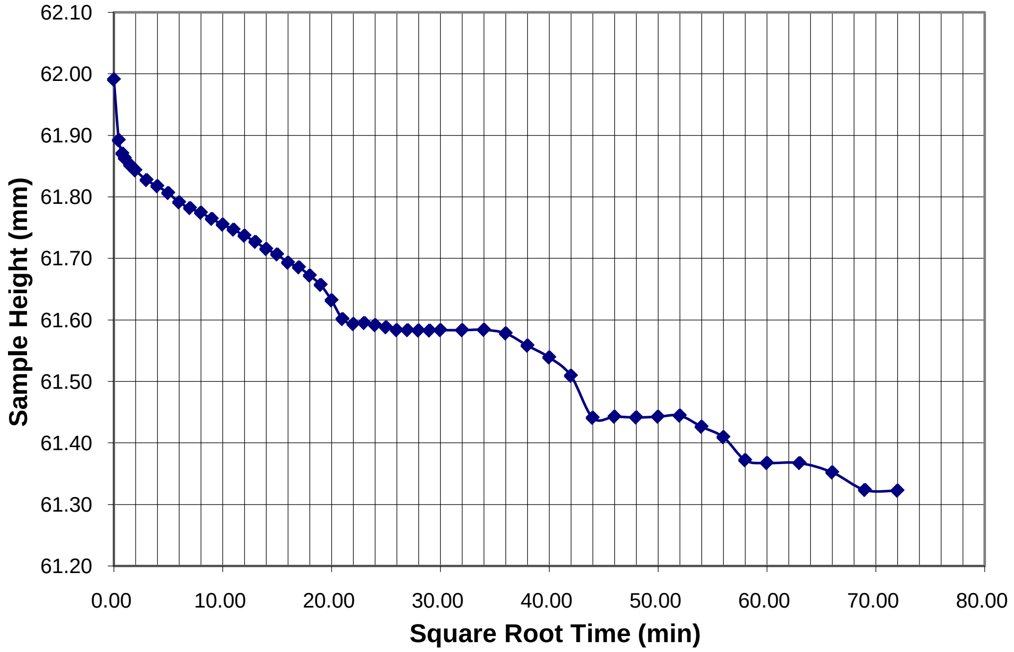
CONSOLIDATION TEST
(ASTM D2435)

Project No.: 11-1359-0001
Lab No.: 999201
BH No.: BH10-05
Sample No.: SA 02
Depth: 8 m

SAMPLE HEIGHT vs. SQUARE ROOT TIME



Total Stress: 19.63 kPa
H_{Sample}: ______ mm
H_{D50}: ______ mm
T_{50}: ______ min

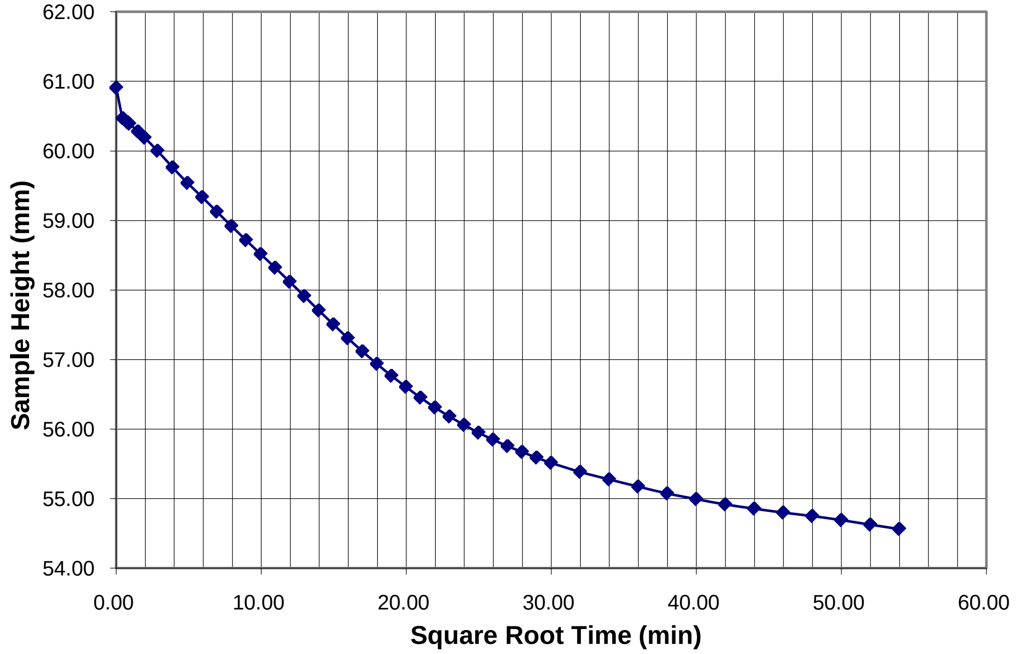


Total Stress: 35.77 kPa
H_{Sample}: ______ mm
H_{D50}: ______ mm
T_{50}: ______ min

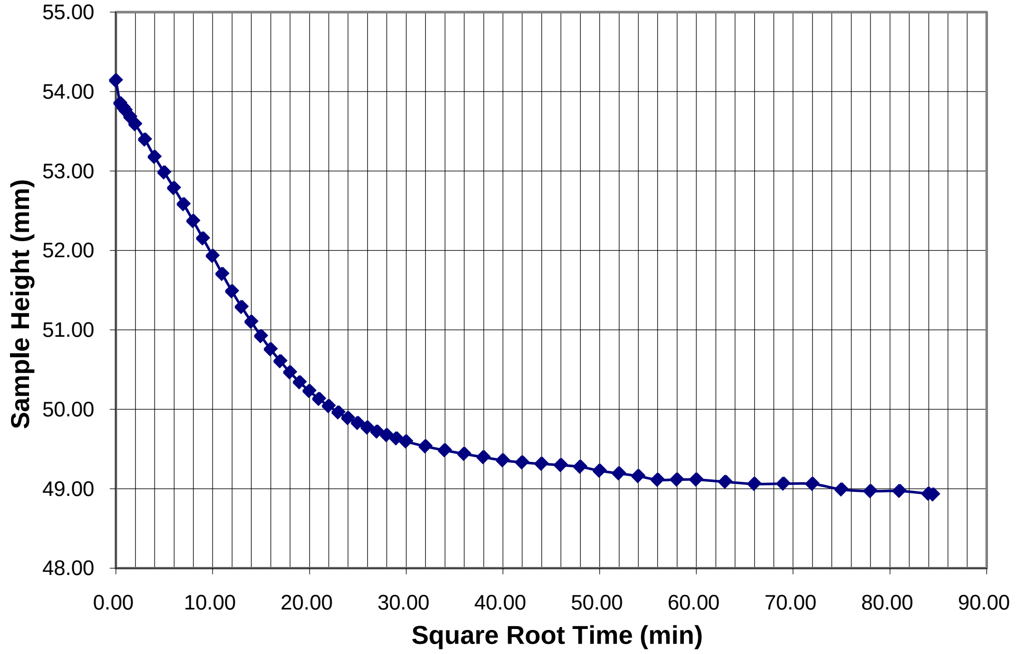
CONSOLIDATION TEST
(ASTM D2435)

Project No.: 11-1359-0001
Lab No.: 999201
BH No.: BH10-05
Sample No.: SA 02
Depth: 8 m

SAMPLE HEIGHT vs. SQUARE ROOT TIME



Total Stress: 84.17 kPa
H_{Sample}: mm
H_{D50}: mm
T_{50}: min

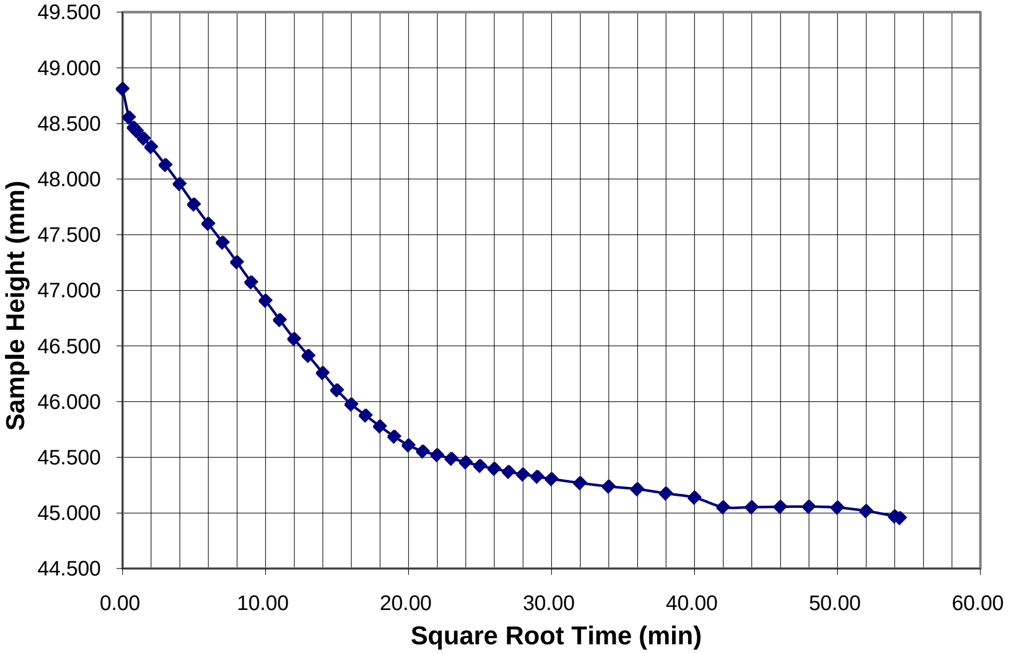


Total Stress: 180.97 kPa
H_{Sample}: mm
H_{D50}: mm
T_{50}: min

CONSOLIDATION TEST
(ASTM D2435)

Project No.: 11-1359-0001
Lab No.: 999201
BH No.: BH10-05
Sample No.: SA 02
Depth: 8 m

SAMPLE HEIGHT vs. SQUARE ROOT TIME

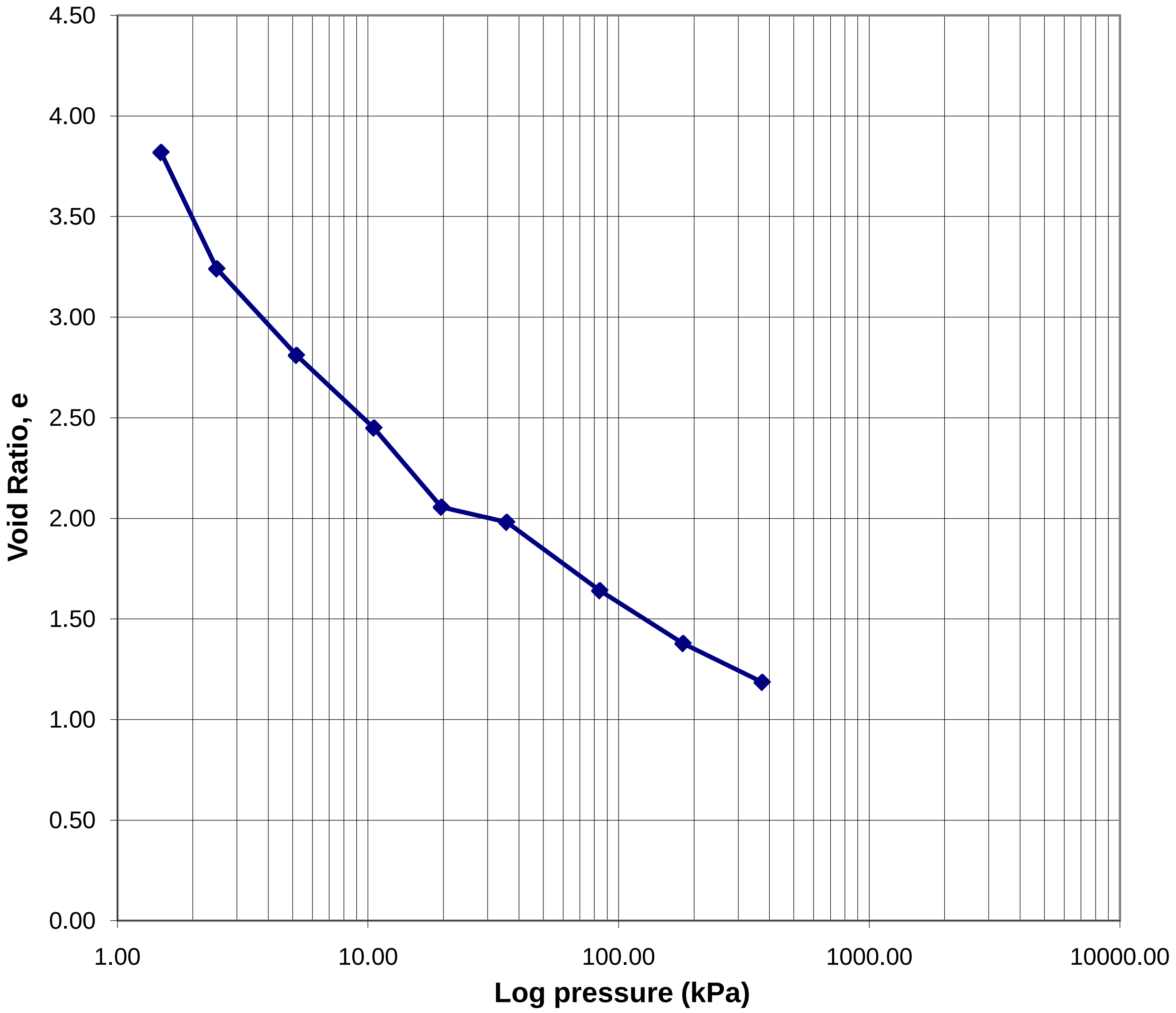


Total Stress: 374.57 kPa
H_{Sample}: ______ mm
H_{D50}: ______ mm
T_{50}: ______ min

CONSOLIDATION TEST
(ASTM D2435)

Project No.: 11-1359-0001
Lab No.: 999201
BH No.: BH10-05
Sample No.: SA 02
Depth: 8 m

Void Ratio vs Log Pressure



Project Number	11-1359-0001		Initial Water Content	173.12	%	Initial Wet Density	1255.00	kg/m^3
Borehole	BH10-05		Initial Solids Content	36.61	%	Inital Dry Density	459.50	kg/m^3
Sample	SA 02		Sample Diameter	152.40	mm	Initial Void Ratio	4.832	
Depth	8 m		Initial Height	120.00	mm	Initial Saturation	96.01	%
Lab No.	999201		Inital Mass(wet)	2747.16	g	Height of Solids	20.57	mm
INITIAL CELL READINGS:			Mass of Solids	1005.83	g			
Hc	29.7	cm	Specific Gravity	2.68	(measured)			
Hb	27.2	cm	Sample Area	0.018241	m^2	Final Water Content	44.20	%
Hs	9.5	cm	Sample Volume	0.002189	m^3	Final Height (Measured):	45.000	mm
Hs(after S.W.)	8.5	cm	Self Weight Load	0.369	kPa	Final Mass	1447.14	gm
Load Arm Ratio	12 :1		Height _after S.W.	110.00	mm	Final Void Ratio (from ht)	1.187	

Load No.	1	
Stress:	1.493	kPa
Add Mass:	2.09	kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP (ms/mm^3)	Hydraulic Conductivity (cm/sec)
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)		
03-Mar-11	13:27:09	-3.560	0.00	0.00	110.00	18.6	25.9	34.7	16.1	-	-
03-Mar-11	13:27:21	-4.071	0.20	0.45	109.49	-	-	-	-	-	-
03-Mar-11	13:27:45	-4.170	0.60	0.77	109.39	-	-	-	-	-	-
03-Mar-11	13:28:09	-4.229	1.00	1.00	109.33	-	-	-	-	-	-
03-Mar-11	13:29:21	-4.346	2.20	1.48	109.21	-	-	-	-	-	-
03-Mar-11	13:31:09	-4.460	4.00	2.00	109.10	-	-	-	-	-	-
03-Mar-11	13:36:09	-4.669	9.00	3.00	108.89	-	-	-	-	-	-
03-Mar-11	13:42:39	-4.865	15.50	3.94	108.69	-	-	-	-	-	-
03-Mar-11	13:51:39	-5.072	24.50	4.95	108.49	-	-	-	-	-	-
03-Mar-11	14:02:39	-5.274	35.50	5.96	108.29	-	-	-	-	-	-
03-Mar-11	14:15:39	-5.470	48.50	6.96	108.09	-	-	-	-	-	-
03-Mar-11	14:30:39	-5.667	63.50	7.97	107.89	-	-	-	-	-	-
03-Mar-11	14:47:39	-5.865	80.50	8.97	107.70	-	-	-	-	-	-
03-Mar-11	15:06:39	-6.053	99.50	9.97	107.51	-	-	-	-	-	-
03-Mar-11	15:27:39	-6.240	120.50	10.98	107.32	-	-	-	-	-	-
03-Mar-11	15:50:39	-6.431	143.50	11.98	107.13	-	-	-	-	-	-
03-Mar-11	16:15:39	-6.624	168.50	12.98	106.94	-	-	-	-	-	-
03-Mar-11	16:42:39	-6.807	195.50	13.98	106.75	-	-	-	-	-	-
03-Mar-11	17:11:39	-6.986	224.50	14.98	106.57	-	-	-	-	-	-
03-Mar-11	17:42:39	-7.161	255.50	15.98	106.40	-	-	-	-	-	-
03-Mar-11	18:15:39	-7.332	288.50	16.99	106.23	-	-	-	-	-	-
03-Mar-11	18:50:39	-7.504	323.50	17.99	106.06	-	-	-	-	-	-
03-Mar-11	19:27:39	-7.679	360.50	18.99	105.88	-	-	-	-	-	-
03-Mar-11	20:06:39	-7.847	399.50	19.99	105.71	-	-	-	-	-	-
03-Mar-11	20:47:39	-8.012	440.50	20.99	105.55	-	-	-	-	-	-
03-Mar-11	21:30:39	-8.178	483.50	21.99	105.38	-	-	-	-	-	-
03-Mar-11	22:15:39	-8.339	528.50	22.99	105.22	-	-	-	-	-	-
03-Mar-11	23:02:39	-8.500	575.50	23.99	105.06	-	-	-	-	-	-
03-Mar-11	23:51:39	-8.659	624.50	24.99	104.90	-	-	-	-	-	-
04-Mar-11	0:42:39	-8.817	675.50	25.99	104.74	-	-	-	-	-	-
04-Mar-11	1:35:39	-8.969	728.50	26.99	104.59	-	-	-	-	-	-
04-Mar-11	2:30:39	-9.120	783.50	27.99	104.44	-	-	-	-	-	-
04-Mar-11	3:27:40	-9.271	840.52	28.99	104.29	-	-	-	-	-	-
04-Mar-11	4:26:40	-9.418	899.52	29.99	104.14	-	-	-	-	-	-
04-Mar-11	6:30:40	-9.711	1023.52	31.99	103.85	-	-	-	-	-	-
04-Mar-11	8:42:40	-9.996	1155.52	33.99	103.56	-	-	-	-	-	-
04-Mar-11	11:02:40	-10.292	1295.52	35.99	103.27	-	-	-	-	-	-
04-Mar-11	13:30:40	-10.574	1443.52	37.99	102.99	-	-	-	-	-	-
04-Mar-11	16:06:58	-10.871	1599.82	40.00	102.69	-	-	-	-	-	-
04-Mar-11	18:50:58	-11.101	1763.82	42.00	102.46	-	-	-	-	-	-
04-Mar-11	21:42:58	-11.304	1935.82	44.00	102.26	-	-	-	-	-	-
05-Mar-11	0:42:58	-11.503	2115.82	46.00	102.06	-	-	-	-	-	-
05-Mar-11	3:50:59	-11.687	2303.83	48.00	101.87	-	-	-	-	-	-
05-Mar-11	7:06:59	-11.864	2499.83	50.00	101.70	-	-	-	-	-	-
05-Mar-11	10:30:59	-12.073	2703.83	52.00	101.49	20.3	27.5	35.0	14.7	-	-
05-Mar-11	14:02:59	-12.358	2915.83	54.00	101.20	-	-	-	-	-	-
05-Mar-11	17:42:59	-12.587	3135.83	56.00	100.97	-	-	-	-	-	-
05-Mar-11	21:31:00	-12.817	3363.85	58.00	100.74	-	-	-	-	-	-
06-Mar-11	1:27:00	-13.037	3599.85	60.00	100.52	-	-	-	-	-	-
06-Mar-11	7:36:00	-13.347	3968.85	63.00	100.21	-	-	-	-	-	-
06-Mar-11	14:03:01	-13.674	4355.87	66.00	99.89	-	-	-	-	-	-
06-Mar-11	20:48:01	-13.943	4760.87	69.00	99.62	-	-	-	-	-	-
07-Mar-11	3:51:01	-14.160	5183.87	72.00	99.40	-	-	-	-	-	-
07-Mar-11	9:44:01	-14.420	5536.87	74.41	99.14	19.4	29.4	33.8	14.4	-	-

Load No. 2
Stress: 2.5 kPa
Add Mass: 1.86 kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP (ms/mm^3)	Hydraulic Conductivity (cm/sec)
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)		
07-Mar-11	9:50:52	-14.430	0.00	0.00	99.13	18.4	29.4	33.8	15.4	-	-
07-Mar-11	9:51:04	-14.461	0.20	0.45	99.10	-	-	-	-	-	-
07-Mar-11	9:51:28	-14.481	0.60	0.77	99.08	-	-	-	-	-	-
07-Mar-11	9:51:52	-14.495	1.00	1.00	99.06	18.4	29.0	37.0	18.6	-	-
07-Mar-11	9:53:04	-14.522	2.20	1.48	99.04	-	-	-	-	-	-
07-Mar-11	9:54:46	-14.550	3.90	1.97	99.01	-	-	-	-	-	-
07-Mar-11	9:59:28	-14.611	8.60	2.93	98.95	-	-	-	-	-	-
07-Mar-11	10:06:28	-14.683	15.60	3.95	98.88	-	-	-	-	-	-
07-Mar-11	10:15:28	-14.761	24.60	4.96	98.80	-	-	-	-	-	-
07-Mar-11	10:26:28	-14.837	35.60	5.97	98.72	-	-	-	-	-	-
07-Mar-11	10:39:28	-14.918	48.60	6.97	98.64	-	-	-	-	-	-
07-Mar-11	10:54:28	-15.004	63.60	7.97	98.56	-	-	-	-	-	-
07-Mar-11	11:11:28	-15.101	80.60	8.98	98.46	-	-	-	-	-	-
07-Mar-11	11:30:28	-15.193	99.60	9.98	98.37	-	-	-	-	-	-
07-Mar-11	11:51:28	-15.295	120.60	10.98	98.26	-	-	-	-	-	-
07-Mar-11	12:14:29	-15.397	143.62	11.98	98.16	-	-	-	-	-	-
07-Mar-11	12:39:29	-15.502	168.62	12.99	98.06	-	-	-	-	-	-
07-Mar-11	13:06:29	-15.607	195.62	13.99	97.95	-	-	-	-	-	-
07-Mar-11	13:35:29	-15.715	224.62	14.99	97.85	-	-	-	-	-	-
07-Mar-11	14:06:29	-15.828	255.62	15.99	97.73	-	-	-	-	-	-
07-Mar-11	14:39:29	-15.947	288.62	16.99	97.61	-	-	-	-	-	-
07-Mar-11	15:14:29	-16.073	323.62	17.99	97.49	-	-	-	-	-	-
07-Mar-11	15:51:29	-16.203	360.62	18.99	97.36	-	-	-	-	-	-
07-Mar-11	16:30:29	-16.334	399.62	19.99	97.23	-	-	-	-	-	-
07-Mar-11	17:11:29	-16.463	440.62	20.99	97.10	-	-	-	-	-	-
07-Mar-11	17:54:29	-16.574	483.62	21.99	96.99	-	-	-	-	-	-
07-Mar-11	18:39:29	-16.677	528.62	22.99	96.88	-	-	-	-	-	-
07-Mar-11	19:26:29	-16.795	575.62	23.99	96.76	-	-	-	-	-	-
07-Mar-11	20:15:29	-16.924	624.62	24.99	96.64	-	-	-	-	-	-
07-Mar-11	21:06:29	-17.054	675.62	25.99	96.51	-	-	-	-	-	-
07-Mar-11	21:59:29	-17.188	728.62	26.99	96.37	-	-	-	-	-	-
07-Mar-11	22:54:30	-17.318	783.63	27.99	96.24	-	-	-	-	-	-
07-Mar-11	23:51:30	-17.449	840.63	28.99	96.11	-	-	-	-	-	-
08-Mar-11	0:50:30	-17.579	899.63	29.99	95.98	-	-	-	-	-	-
08-Mar-11	2:54:30	-17.844	1023.63	31.99	95.72	-	-	-	-	-	-
08-Mar-11	5:06:30	-18.108	1155.63	33.99	95.45	-	-	-	-	-	-
08-Mar-11	7:26:30	-18.368	1295.63	35.99	95.19	-	-	-	-	-	-
08-Mar-11	9:54:31	-18.628	1443.65	38.00	94.93	-	-	-	-	-	-
08-Mar-11	12:30:31	-18.898	1599.65	40.00	94.66	-	-	-	-	-	-
08-Mar-11	15:14:31	-19.200	1763.65	42.00	94.36	18.6	29.4	40.4	21.8	-	-
08-Mar-11	18:06:31	-19.461	1935.65	44.00	94.10	-	-	-	-	-	-
08-Mar-11	21:06:31	-19.714	2115.65	46.00	93.85	-	-	-	-	-	-
09-Mar-11	0:14:31	-19.972	2303.65	48.00	93.59	-	-	-	-	-	-
09-Mar-11	3:30:32	-20.230	2499.67	50.00	93.33	-	-	-	-	-	-
09-Mar-11	6:54:32	-20.486	2703.67	52.00	93.07	-	-	-	-	-	-
09-Mar-11	10:26:32	-20.726	2915.67	54.00	92.83	-	-	-	-	-	-
09-Mar-11	14:06:32	-20.991	3135.67	56.00	92.57	-	-	-	-	-	-
09-Mar-11	17:54:33	-21.253	3363.68	58.00	92.31	-	-	-	-	-	-
09-Mar-11	21:50:33	-21.467	3599.68	60.00	92.09	-	-	-	-	-	-
10-Mar-11	3:59:33	-21.820	3968.68	63.00	91.74	-	-	-	-	-	-
10-Mar-11	10:26:33	-22.167	4355.68	66.00	91.39	-	-	-	-	-	-
10-Mar-11	17:11:35	-22.572	4760.72	69.00	90.99	-	-	-	-	-	-
11-Mar-11	0:14:35	-22.864	5183.72	72.00	90.70	-	-	-	-	-	-
11-Mar-11	7:35:35	-23.176	5624.72	75.00	90.38	-	-	-	-	-	-
11-Mar-11	15:14:06	-23.501	6083.23	78.00	90.06	17.4	30.4	39.2	21.8	-	-
11-Mar-11	23:11:07	-23.764	6560.25	81.00	89.80	-	-	-	-	-	-
12-Mar-11	7:26:07	-24.020	7055.25	84.00	89.54	-	-	-	-	-	-
12-Mar-11	15:59:08	-24.285	7568.27	87.00	89.27	-	-	-	-	-	-
13-Mar-11	0:50:08	-24.496	8099.27	90.00	89.06	-	-	-	-	-	-
13-Mar-11	9:59:08	-24.670	8648.27	93.00	88.89	-	-	-	-	-	-
13-Mar-11	19:26:10	-24.861	9215.30	96.00	88.70	-	-	-	-	-	-
14-Mar-11	5:11:11	-25.025	9800.32	99.00	88.53	-	-	-	-	-	-
14-Mar-11	15:14:11	-25.237	10403.32	102.00	88.32	-	-	-	-	-	-
15-Mar-11	1:35:12	-25.418	11024.33	105.00	88.14	-	-	-	-	-	-
15-Mar-11	12:14:13	-25.576	11663.35	108.00	87.98	17.2	29.5	37.7	20.5	-	-
15-Mar-11	23:11:14	-25.737	12320.37	111.00	87.82	-	-	-	-	-	-
16-Mar-11	10:26:14	-25.842	12995.37	114.00	87.72	-	-	-	-	-	-
16-Mar-11	21:59:16	-25.965	13688.40	117.00	87.59	-	-	-	-	-	-
17-Mar-11	9:50:16	-26.071	14399.40	120.00	87.49	-	-	-	-	-	-
17-Mar-11	21:59:18	-26.191	15128.43	123.00	87.37	-	-	-	-	-	-
18-Mar-11	10:26:18	-26.256	15875.43	126.00	87.30	-	-	-	-	-	-
18-Mar-11	14:25:19	-26.318	16114.45	126.94	87.24	16.0	29.2	37.7	21.7	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-

Load No. 3
Stress: 5.2 kPa
Add Mass: 5 kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP (ms/mm^3)	Hydraulic Conductivity (cm/sec)
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)		
18-Mar-11	14:31	-26.377	0.00	0.00	87.18	16.0	29.2	37.7	21.7	-	-
18-Mar-11	14:31	-26.453	0.25	0.50	87.11	-	-	-	-	-	-
18-Mar-11	14:31	-26.474	0.50	0.71	87.09	-	-	-	-	-	-
18-Mar-11	14:32	-26.505	1.00	1.00	87.05	-	-	-	-	-	-
18-Mar-11	14:33	-26.561	2.25	1.50	87.00	-	-	-	-	-	-
18-Mar-11	14:35	-26.621	4.00	2.00	86.94	-	-	-	-	-	-
18-Mar-11	14:40	-26.741	9.00	3.00	86.82	-	-	-	-	-	-
18-Mar-11	14:47	-26.860	16.00	4.00	86.70	-	-	-	-	-	-
18-Mar-11	14:55	-26.975	24.75	4.97	86.58	-	-	-	-	-	-
18-Mar-11	15:07	-27.097	36.00	6.00	86.46	-	-	-	-	-	-
18-Mar-11	15:20	-27.219	49.00	7.00	86.34	-	-	-	-	-	-
18-Mar-11	15:35	-27.342	64.00	8.00	86.22	-	-	-	-	-	-
18-Mar-11	15:52	-27.468	81.00	9.00	86.09	-	-	-	-	-	-
18-Mar-11	16:11	-27.596	100.00	10.00	85.96	-	-	-	-	-	-
18-Mar-11	16:31	-27.724	120.75	10.99	85.84	-	-	-	-	-	-
18-Mar-11	16:55	-27.859	144.00	12.00	85.70	-	-	-	-	-	-
18-Mar-11	17:19	-27.990	168.75	12.99	85.57	-	-	-	-	-	-
18-Mar-11	17:47	-28.117	196.00	14.00	85.44	-	-	-	-	-	-
18-Mar-11	18:16	-28.245	225.00	15.00	85.32	-	-	-	-	-	-
18-Mar-11	18:47	-28.367	256.00	16.00	85.19	-	-	-	-	-	-
18-Mar-11	19:19	-28.476	288.75	16.99	85.08	-	-	-	-	-	-
18-Mar-11	19:55	-28.575	323.90	18.00	84.98	-	-	-	-	-	-
18-Mar-11	20:32	-28.672	360.90	19.00	84.89	-	-	-	-	-	-
18-Mar-11	21:11	-28.771	399.90	20.00	84.79	-	-	-	-	-	-
18-Mar-11	21:52	-28.869	440.90	21.00	84.69	-	-	-	-	-	-
18-Mar-11	22:35	-28.966	483.90	22.00	84.59	-	-	-	-	-	-
18-Mar-11	23:20	-29.069	528.90	23.00	84.49	-	-	-	-	-	-
19-Mar-11	0:07	-29.175	575.90	24.00	84.38	-	-	-	-	-	-
19-Mar-11	0:56	-29.278	624.90	25.00	84.28	-	-	-	-	-	-
19-Mar-11	1:47	-29.378	675.92	26.00	84.18	-	-	-	-	-	-
19-Mar-11	2:40	-29.481	728.92	27.00	84.08	-	-	-	-	-	-
19-Mar-11	3:35	-29.578	783.92	28.00	83.98	-	-	-	-	-	-
19-Mar-11	4:32	-29.677	840.92	29.00	83.88	-	-	-	-	-	-
19-Mar-11	5:31	-29.768	899.92	30.00	83.79	-	-	-	-	-	-
19-Mar-11	7:35	-29.943	1023.92	32.00	83.62	-	-	-	-	-	-
19-Mar-11	9:47	-30.100	1155.92	34.00	83.46	-	-	-	-	-	-
19-Mar-11	12:07	-30.237	1295.92	36.00	83.32	-	-	-	-	-	-
19-Mar-11	14:35	-30.376	1443.92	38.00	83.18	-	-	-	-	-	-
19-Mar-11	17:11	-30.519	1599.92	40.00	83.04	-	-	-	-	-	-
19-Mar-11	19:55	-30.589	1763.92	42.00	82.97	-	-	-	-	-	-
19-Mar-11	22:47	-30.646	1935.92	44.00	82.91	-	-	-	-	-	-
20-Mar-11	1:47	-30.730	2115.92	46.00	82.83	-	-	-	-	-	-
20-Mar-11	4:55	-30.818	2303.92	48.00	82.74	-	-	-	-	-	-
20-Mar-11	8:11	-30.882	2499.92	50.00	82.68	-	-	-	-	-	-
20-Mar-11	11:35	-30.996	2703.92	52.00	82.56	-	-	-	-	-	-
20-Mar-11	15:07	-31.114	2915.97	54.00	82.45	-	-	-	-	-	-
20-Mar-11	18:47	-31.277	3135.97	56.00	82.28	-	-	-	-	-	-
20-Mar-11	22:35	-31.343	3363.97	58.00	82.22	-	-	-	-	-	-
21-Mar-11	2:31	-31.441	3599.98	60.00	82.12	-	-	-	-	-	-
21-Mar-11	8:40	-31.634	3968.98	63.00	81.93	15.8	30.4	45.8	30.0	-	-
21-Mar-11	15:07	-31.901	4356.00	66.00	81.66	-	-	-	-	-	-
21-Mar-11	21:52	-32.176	4761.00	69.00	81.38	-	-	-	-	-	-
22-Mar-11	4:54	-32.444	5183.02	71.99	81.12	-	-	-	-	-	-
22-Mar-11	12:15	-32.704	5624.02	74.99	80.86	-	-	-	-	-	-
22-Mar-11	19:54	-32.954	6083.02	77.99	80.61	-	-	-	-	-	-
23-Mar-11	3:51	-33.169	6560.03	80.99	80.39	-	-	-	-	-	-
23-Mar-11	12:06	-33.385	7055.03	83.99	80.17	-	-	-	-	-	-
23-Mar-11	20:39	-33.567	7568.05	86.99	79.99	-	-	-	-	-	-
24-Mar-11	5:30	-33.731	8099.07	89.99	79.83	-	-	-	-	-	-
24-Mar-11	14:39	-33.882	8648.08	93.00	79.68	-	-	-	-	-	-
25-Mar-11	0:06	-34.011	9215.10	96.00	79.55	-	-	-	-	-	-
25-Mar-11	9:51	-34.121	9800.10	99.00	79.44	-	-	-	-	-	-
25-Mar-11	19:54	-34.235	10403.12	102.00	79.32	-	-	-	-	-	-
26-Mar-11	6:15	-34.352	11024.12	105.00	79.21	-	-	-	-	-	-
26-Mar-11	16:54	-34.450	11663.15	108.00	79.11	-	-	-	-	-	-
27-Mar-11	3:51	-34.528	12320.17	111.00	79.03	-	-	-	-	-	-
27-Mar-11	15:06	-34.585	12995.17	114.00	78.97	-	-	-	-	-	-
28-Mar-11	2:39	-34.630	13688.20	117.00	78.93	-	-	-	-	-	-
28-Mar-11	14:30	-34.763	14399.20	120.00	78.80	-	-	-	-	-	-
29-Mar-11	2:39	-34.818	15128.22	123.00	78.74	-	-	-	-	-	-
29-Mar-11	15:06	-34.895	15875.23	126.00	78.67	-	-	-	-	-	-
30-Mar-11	3:51	-35.016	16640.25	129.00	78.54	-	-	-	-	-	-
30-Mar-11	16:54	-35.132	17423.27	132.00	78.43	-	-	-	-	-	-
31-Mar-11	6:15	-35.152	18224.28	135.00	78.41	-	-	-	-	-	-
31-Mar-11	13:21	-35.167	18650.30	136.57	78.39	13.8	28.6	44.7	30.9	-	-

Load No. 4
Stress: 10.6 kPa
Add Mass: 10 kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP (ms/mm^3)	Hydraulic Conductivity (cm/sec)
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)		
31-Mar-11	13:27	-35.170	0.00	0.00	78.39	29.2	37.8	29.3	0.1	-	-
31-Mar-11	13:27	-35.301	0.25	0.50	78.26	-	-	-	-	-	-
31-Mar-11	13:27	-35.322	0.50	0.71	78.24	-	-	-	-	-	-
31-Mar-11	13:28	-35.342	1.00	1.00	78.22	-	-	-	-	-	-
31-Mar-11	13:29	-35.379	2.25	1.50	78.18	-	-	-	-	-	-
31-Mar-11	13:31	-35.419	4.00	2.00	78.14	-	-	-	-	-	-
31-Mar-11	13:36	-35.500	9.00	3.00	78.06	-	-	-	-	-	-
31-Mar-11	13:43	-35.590	16.00	4.00	77.97	-	-	-	-	-	-
31-Mar-11	13:52	-35.683	24.75	4.97	77.88	-	-	-	-	-	-
31-Mar-11	14:03	-35.785	36.00	6.00	77.77	-	-	-	-	-	-
31-Mar-11	14:16	-35.887	49.00	7.00	77.67	-	-	-	-	-	-
31-Mar-11	14:31	-35.997	64.00	8.00	77.56	-	-	-	-	-	-
31-Mar-11	14:48	-36.108	81.00	9.00	77.45	-	-	-	-	-	-
31-Mar-11	15:07	-36.225	100.00	10.00	77.33	-	-	-	-	-	-
31-Mar-11	15:28	-36.346	120.75	10.99	77.21	-	-	-	-	-	-
31-Mar-11	15:51	-36.475	144.00	12.00	77.08	-	-	-	-	-	-
31-Mar-11	16:16	-36.603	168.75	12.99	76.96	-	-	-	-	-	-
31-Mar-11	16:43	-36.735	195.75	13.99	76.82	-	-	-	-	-	-
31-Mar-11	17:12	-36.877	224.75	14.99	76.68	-	-	-	-	-	-
31-Mar-11	17:43	-37.021	255.75	15.99	76.54	-	-	-	-	-	-
31-Mar-11	18:16	-37.154	288.75	16.99	76.41	-	-	-	-	-	-
31-Mar-11	18:51	-37.273	323.75	17.99	76.29	-	-	-	-	-	-
31-Mar-11	19:28	-37.382	360.75	18.99	76.18	-	-	-	-	-	-
31-Mar-11	20:07	-37.480	399.75	19.99	76.08	-	-	-	-	-	-
31-Mar-11	20:48	-37.576	440.75	20.99	75.98	-	-	-	-	-	-
31-Mar-11	21:31	-37.675	483.75	21.99	75.88	-	-	-	-	-	-
31-Mar-11	22:16	-37.772	528.75	22.99	75.79	-	-	-	-	-	-
31-Mar-11	23:03	-37.869	575.75	23.99	75.69	-	-	-	-	-	-
31-Mar-11	23:52	-37.965	624.75	24.99	75.59	-	-	-	-	-	-
01-Apr-11	0:43	-38.063	675.75	26.00	75.50	-	-	-	-	-	-
01-Apr-11	1:36	-38.166	728.75	27.00	75.39	-	-	-	-	-	-
01-Apr-11	2:31	-38.271	783.75	28.00	75.29	-	-	-	-	-	-
01-Apr-11	3:28	-38.370	840.75	29.00	75.19	-	-	-	-	-	-
01-Apr-11	4:27	-38.469	899.75	30.00	75.09	-	-	-	-	-	-
01-Apr-11	6:31	-38.673	1023.75	32.00	74.89	-	-	-	-	-	-
01-Apr-11	8:43	-38.871	1155.75	34.00	74.69	-	-	-	-	-	-
01-Apr-11	11:03	-39.081	1295.75	36.00	74.48	-	-	-	-	-	-
01-Apr-11	13:31	-39.307	1443.75	38.00	74.25	-	-	-	-	-	-
01-Apr-11	16:07	-39.528	1599.78	40.00	74.03	-	-	-	-	-	-
01-Apr-11	18:51	-39.688	1763.78	42.00	73.87	-	-	-	-	-	-
01-Apr-11	21:43	-39.862	1935.78	44.00	73.70	-	-	-	-	-	-
02-Apr-11	0:43	-40.041	2115.78	46.00	73.52	-	-	-	-	-	-
02-Apr-11	3:51	-40.211	2303.78	48.00	73.35	-	-	-	-	-	-
02-Apr-11	7:07	-40.377	2499.80	50.00	73.18	-	-	-	-	-	-
02-Apr-11	10:31	-40.528	2703.80	52.00	73.03	-	-	-	-	-	-
02-Apr-11	14:03	-40.687	2915.80	54.00	72.87	-	-	-	-	-	-
02-Apr-11	17:43	-40.825	3135.80	56.00	72.73	-	-	-	-	-	-
02-Apr-11	21:31	-40.983	3363.82	58.00	72.58	-	-	-	-	-	-
03-Apr-11	1:27	-41.128	3599.82	60.00	72.43	-	-	-	-	-	-
03-Apr-11	7:36	-41.297	3968.83	63.00	72.26	-	-	-	-	-	-
03-Apr-11	14:03	-41.487	4355.83	66.00	72.07	-	-	-	-	-	-
03-Apr-11	20:48	-41.743	4760.83	69.00	71.82	-	-	-	-	-	-
04-Apr-11	3:51	-41.797	5183.83	72.00	71.76	-	-	-	-	-	-
04-Apr-11	11:12	-41.934	5624.85	75.00	71.63	-	-	-	-	-	-
04-Apr-11	18:51	-42.180	6083.87	78.00	71.38	-	-	-	-	-	-
05-Apr-11	2:48	-42.189	6560.88	81.00	71.37	-	-	-	-	-	-
05-Apr-11	11:03	-42.256	7055.90	84.00	71.30	-	-	-	-	-	-
05-Apr-11	19:36	-42.418	7568.90	87.00	71.14	-	-	-	-	-	-
06-Apr-11	4:27	-42.414	8099.92	90.00	71.15	-	-	-	-	-	-
06-Apr-11	13:36	-42.489	8648.93	93.00	71.07	-	-	-	-	-	-
06-Apr-11	23:03	-42.555	9215.93	96.00	71.00	-	-	-	-	-	-
07-Apr-11	8:48	-42.568	9800.93	99.00	70.99	-	-	-	-	-	-
07-Apr-11	12:45	-42.597	10037.93	100.19	70.96	-	-	-	-	-	-
						-	-	-	-	-	-
08-Apr-11	6:27	-42.597	11099.58	105.35	70.96	12.0	-	87.8	75.8	3500.00	1.47E-06
08-Apr-11	16:57	-42.597	11729.58	108.30	70.96	12.2	-	101.2	89.0	3500.00	1.25E-06
10-Apr-11	12:10	-42.597	14322.58	119.68	70.96	11.6	-	107.8	96.2	3500.00	1.16E-06
11-Apr-11	6:31	-42.597	15423.58	124.19	70.96	11.6	-	109.0	97.4	3500.00	1.14E-06
11-Apr-11	10:25	-42.597	15657.58	125.13	70.96	11.6	-	110.0	98.4	3500.00	1.13E-06
						-	-	-	-	**Average:**	**1.17E-06**
						-	-	-	-	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-

Load No. 5
Stress: 19.6 kPa
Add Mass: 2.5 kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP (ms/mm^3)	Hydraulic Conductivity (cm/sec)
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)		
27-Apr-11	10:34	-12.341	0.00	0.00	70.96	-	-	-	-	-	-
27-Apr-11	10:40	-12.971	5.25	2.29	70.33	-	-	-	-	-	-
27-Apr-11	10:35	-12.712	0.50	0.71	70.59	-	-	-	-	-	-
27-Apr-11	10:35	-12.745	0.75	0.87	70.56	-	-	-	-	-	-
27-Apr-11	10:36	-12.837	2.00	1.41	70.47	-	-	-	-	-	-
27-Apr-11	10:38	-12.916	3.75	1.94	70.39	-	-	-	-	-	-
27-Apr-11	10:43	-13.075	8.75	2.96	70.23	-	-	-	-	-	-
27-Apr-11	10:50	-13.235	15.75	3.97	70.07	-	-	-	-	-	-
27-Apr-11	10:59	-13.391	24.50	4.95	69.91	-	-	-	-	-	-
27-Apr-11	11:10	-13.554	35.50	5.96	69.75	-	-	-	-	-	-
27-Apr-11	11:23	-13.719	48.50	6.96	69.58	-	-	-	-	-	-
27-Apr-11	11:38	-13.885	63.50	7.97	69.42	-	-	-	-	-	-
27-Apr-11	11:55	-14.052	80.50	8.97	69.25	-	-	-	-	-	-
27-Apr-11	12:14	-14.208	99.50	9.97	69.10	-	-	-	-	-	-
27-Apr-11	12:35	-14.359	120.50	10.98	68.94	-	-	-	-	-	-
27-Apr-11	12:58	-14.509	143.50	11.98	68.79	-	-	-	-	-	-
27-Apr-11	13:23	-14.658	168.50	12.98	68.64	-	-	-	-	-	-
27-Apr-11	13:50	-14.809	195.50	13.98	68.49	-	-	-	-	-	-
27-Apr-11	14:19	-14.966	224.50	14.98	68.34	-	-	-	-	-	-
27-Apr-11	14:50	-15.128	255.50	15.98	68.17	-	-	-	-	-	-
27-Apr-11	15:23	-15.297	288.50	16.99	68.01	-	-	-	-	-	-
27-Apr-11	15:58	-15.468	323.50	17.99	67.84	-	-	-	-	-	-
27-Apr-11	16:35	-15.624	360.50	18.99	67.68	-	-	-	-	-	-
27-Apr-11	17:14	-15.774	399.50	19.99	67.53	-	-	-	-	-	-
27-Apr-11	17:55	-15.930	440.50	20.99	67.37	-	-	-	-	-	-
27-Apr-11	18:38	-16.112	483.50	21.99	67.19	-	-	-	-	-	-
27-Apr-11	19:23	-16.276	528.52	22.99	67.03	-	-	-	-	-	-
27-Apr-11	20:10	-16.432	575.52	23.99	66.87	-	-	-	-	-	-
27-Apr-11	20:59	-16.526	624.52	24.99	66.78	-	-	-	-	-	-
27-Apr-11	21:50	-16.552	675.52	25.99	66.75	-	-	-	-	-	-
27-Apr-11	22:43	-16.559	728.52	26.99	66.74	-	-	-	-	-	-
27-Apr-11	23:38	-16.563	783.52	27.99	66.74	-	-	-	-	-	-
28-Apr-11	0:35	-16.573	840.52	28.99	66.73	-	-	-	-	-	-
28-Apr-11	1:34	-16.576	899.52	29.99	66.73	-	-	-	-	-	-
28-Apr-11	3:38	-16.589	1023.52	31.99	66.71	-	-	-	-	-	-
28-Apr-11	5:50	-16.606	1155.52	33.99	66.70	-	-	-	-	-	-
28-Apr-11	8:10	-16.621	1295.52	35.99	66.68	-	-	-	-	-	-
28-Apr-11	10:38	-17.031	1443.52	37.99	66.27	-	-	-	-	-	-
28-Apr-11	13:14	-17.319	1599.52	39.99	65.98	-	-	-	-	-	-
28-Apr-11	15:58	-17.594	1763.53	41.99	65.71	-	-	-	-	-	-
28-Apr-11	18:50	-17.865	1935.53	43.99	65.44	-	-	-	-	-	-
28-Apr-11	21:50	-18.062	2115.53	45.99	65.24	-	-	-	-	-	-
29-Apr-11	0:58	-18.271	2303.53	48.00	65.03	-	-	-	-	-	-
29-Apr-11	4:14	-18.462	2499.53	50.00	64.84	-	-	-	-	-	-
29-Apr-11	7:38	-18.641	2703.55	52.00	64.66	-	-	-	-	-	-
29-Apr-11	11:10	-18.815	2915.57	54.00	64.49	-	-	-	-	-	-
29-Apr-11	14:50	-18.997	3135.57	56.00	64.31	-	-	-	-	-	-
29-Apr-11	18:38	-19.270	3363.57	58.00	64.03	-	-	-	-	-	-
29-Apr-11	22:34	-19.377	3599.57	60.00	63.93	-	-	-	-	-	-
30-Apr-11	4:43	-19.474	3968.58	63.00	63.83	-	-	-	-	-	-
30-Apr-11	11:10	-19.583	4355.60	66.00	63.72	-	-	-	-	-	-
30-Apr-11	17:55	-19.723	4760.60	69.00	63.58	-	-	-	-	-	-
01-May-11	0:58	-19.794	5183.60	72.00	63.51	-	-	-	-	-	-
01-May-11	8:19	-19.834	5624.62	75.00	63.47	-	-	-	-	-	-
01-May-11	15:58	-19.957	6083.63	78.00	63.35	-	-	-	-	-	-
01-May-11	23:55	-20.013	6560.63	81.00	63.29	-	-	-	-	-	-
02-May-11	8:10	-20.027	7055.63	84.00	63.28	-	-	-	-	-	-
02-May-11	16:43	-20.191	7568.65	87.00	63.11	-	-	-	-	-	-
03-May-11	1:34	-20.194	8099.67	90.00	63.11	-	-	-	-	-	-
03-May-11	10:43	-20.227	8648.68	93.00	63.08	-	-	-	-	-	-
03-May-11	20:10	-20.372	9215.68	96.00	62.93	-	-	-	-	-	-
04-May-11	5:55	-20.352	9800.70	99.00	62.95	-	-	-	-	-	-
04-May-11	15:58	-20.436	10403.72	102.00	62.87	-	-	-	-	-	-
						-	-	-	-	-	-
Perm						-	-	-	-	-	-
19-May-11	6:49	-21.005	31454.22	177.35	62.30	7.0	29.2	44.0	37.0	6000.00	1.54E-07
19-May-11	16:48	-21.005	32053.22	179.03	62.30	7.0	29.0	129.0	122.0	6000.00	4.67E-08
20-May-11	10:49	-21.005	33134.22	182.03	62.30	7.0	29.0	336.0	329.0	6000.00	1.73E-08
20-May-11	16:58	-21.005	33503.22	183.04	62.30	7.0	29.0	336.0	329.0	6000.00	1.73E-08
21-May-11	8:24	-21.005	34429.22	185.55	62.30	7.0	29.0	336.0	329.0	6000.00	1.73E-08
						-	-	**Average Permeability:**			**2.46E-08**
						-	-	-	-	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-

Load No. 6
Stress: 35.8 kPa
Add Mass: 2.5 kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP (ms/mm^3)	Hydraulic Conductivity (cm/sec)
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)		
30-May-11	9:56	-21.313	0.00	0.00	61.99	-	-	-	-	-	-
30-May-11	9:56	-21.411	0.20	0.45	61.89	-	-	-	-	-	-
30-May-11	9:56	-21.433	0.60	0.77	61.87	-	-	-	-	-	-
30-May-11	9:57	-21.440	1.00	1.00	61.86	-	-	-	-	-	-
30-May-11	9:58	-21.452	2.20	1.48	61.85	-	-	-	-	-	-
30-May-11	10:00	-21.460	3.90	1.97	61.84	-	-	-	-	-	-
30-May-11	10:05	-21.476	9.00	3.00	61.83	-	-	-	-	-	-
30-May-11	10:12	-21.486	15.90	3.99	61.82	-	-	-	-	-	-
30-May-11	10:21	-21.497	24.90	4.99	61.81	-	-	-	-	-	-
30-May-11	10:32	-21.512	35.90	5.99	61.79	-	-	-	-	-	-
30-May-11	10:45	-21.522	48.90	6.99	61.78	-	-	-	-	-	-
30-May-11	11:00	-21.529	63.90	7.99	61.77	-	-	-	-	-	-
30-May-11	11:17	-21.539	80.90	8.99	61.76	-	-	-	-	-	-
30-May-11	11:36	-21.548	99.90	9.99	61.75	-	-	-	-	-	-
30-May-11	11:57	-21.557	120.92	11.00	61.75	-	-	-	-	-	-
30-May-11	12:20	-21.567	143.92	12.00	61.74	-	-	-	-	-	-
30-May-11	12:45	-21.577	168.92	13.00	61.73	-	-	-	-	-	-
30-May-11	13:12	-21.588	195.92	14.00	61.72	-	-	-	-	-	-
30-May-11	13:41	-21.597	224.92	15.00	61.71	-	-	-	-	-	-
30-May-11	14:12	-21.610	255.92	16.00	61.69	-	-	-	-	-	-
30-May-11	14:45	-21.618	288.92	17.00	61.69	-	-	-	-	-	-
30-May-11	15:20	-21.631	323.92	18.00	61.67	-	-	-	-	-	-
30-May-11	15:57	-21.647	360.92	19.00	61.66	-	-	-	-	-	-
30-May-11	16:36	-21.672	399.97	20.00	61.63	-	-	-	-	-	-
30-May-11	17:17	-21.702	440.97	21.00	61.60	-	-	-	-	-	-
30-May-11	18:00	-21.710	483.97	22.00	61.59	-	-	-	-	-	-
30-May-11	18:45	-21.708	528.97	23.00	61.59	-	-	-	-	-	-
30-May-11	19:32	-21.712	576.00	24.00	61.59	-	-	-	-	-	-
30-May-11	20:21	-21.715	625.00	25.00	61.59	-	-	-	-	-	-
30-May-11	21:11	-21.720	675.00	25.98	61.58	-	-	-	-	-	-
30-May-11	22:04	-21.720	728.00	26.98	61.58	-	-	-	-	-	-
30-May-11	22:59	-21.721	783.00	27.98	61.58	-	-	-	-	-	-
30-May-11	23:57	-21.721	841.00	29.00	61.58	-	-	-	-	-	-
31-May-11	0:56	-21.720	900.00	30.00	61.58	-	-	-	-	-	-
31-May-11	3:00	-21.720	1024.00	32.00	61.58	-	-	-	-	-	-
31-May-11	5:12	-21.720	1156.00	34.00	61.58	-	-	-	-	-	-
31-May-11	7:32	-21.725	1296.00	36.00	61.58	-	-	-	-	-	-
31-May-11	10:00	-21.745	1444.00	38.00	61.56	-	-	-	-	-	-
31-May-11	12:36	-21.765	1600.00	40.00	61.54	-	-	-	-	-	-
31-May-11	15:19	-21.794	1763.02	41.99	61.51	-	-	-	-	-	-
31-May-11	18:11	-21.863	1935.02	43.99	61.44	-	-	-	-	-	-
31-May-11	21:11	-21.861	2115.02	45.99	61.44	-	-	-	-	-	-
01-Jun-11	0:19	-21.862	2303.03	47.99	61.44	-	-	-	-	-	-
01-Jun-11	3:35	-21.861	2499.03	49.99	61.44	-	-	-	-	-	-
01-Jun-11	6:59	-21.859	2703.03	51.99	61.44	-	-	-	-	-	-
01-Jun-11	10:31	-21.877	2915.03	53.99	61.43	-	-	-	-	-	-
01-Jun-11	14:12	-21.894	3135.73	56.00	61.41	-	-	-	-	-	-
01-Jun-11	18:00	-21.932	3363.75	58.00	61.37	-	-	-	-	-	-
01-Jun-11	21:56	-21.936	3599.75	60.00	61.37	-	-	-	-	-	-
02-Jun-11	4:05	-21.936	3968.75	63.00	61.37	-	-	-	-	-	-
02-Jun-11	10:32	-21.951	4355.75	66.00	61.35	-	-	-	-	-	-
02-Jun-11	17:16	-21.980	4760.55	69.00	61.32	-	-	-	-	-	-
03-Jun-11	0:19	-21.981	5183.58	72.00	61.32	-	-	-	-	-	-
03-Jun-11	7:40	-21.989	5624.60	75.00	61.31	-	-	-	-	-	-
03-Jun-11	15:19	-22.017	6083.02	77.99	61.29	-	-	-	-	-	-
03-Jun-11	23:16	-22.034	6560.02	80.99	61.27	-	-	-	-	-	-
04-Jun-11	7:31	-22.029	7055.02	83.99	61.27	-	-	-	-	-	-
04-Jun-11	16:04	-22.076	7568.03	86.99	61.23	-	-	-	-	-	-
05-Jun-11	0:55	-22.099	8099.05	89.99	61.20	-	-	-	-	-	-
05-Jun-11	10:04	-22.096	8648.05	92.99	61.21	-	-	-	-	-	-
05-Jun-11	19:31	-22.153	9215.05	96.00	61.15	-	-	-	-	-	-
06-Jun-11	5:16	-22.152	9800.08	99.00	61.15	-	-	-	-	-	-
06-Jun-11	15:19	-22.156	10403.10	102.00	61.15	-	-	-	-	-	-
07-Jun-11	1:40	-22.163	11024.12	105.00	61.14	-	-	-	-	-	-
07-Jun-11	12:19	-22.179	11663.12	108.00	61.12	-	-	-	-	-	-
07-Jun-11	23:16	-22.210	12320.13	111.00	61.09	-	-	-	-	-	-
08-Jun-11	10:31	-22.214	12995.13	114.00	61.09	-	-	-	-	-	-
08-Jun-11	22:04	-22.239	13688.17	117.00	61.06	-	-	-	-	-	-
09-Jun-11	9:55	-22.240	14399.17	120.00	61.06	-	-	-	-	-	-
09-Jun-11	22:04	-22.318	15128.20	123.00	60.99	-	-	-	-	-	-
10-Jun-11	10:31	-22.314	15875.22	126.00	60.99	-	-	-	-	-	-
10-Jun-11	15:48	-22.335	16192.22	127.25	60.97	-	-	-	-	-	-
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						-	-	-	-	-	-

Load No. 7
Stress: 84.2 kPa
Add Mass: 7.5 kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP (ms/mm^3)	Hydraulic Conductivity (cm/sec)
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)		
10-Jun-11	16:00	-22.394	0.00	0.00	60.91	-	-	-	-	-	-
10-Jun-11	16:00	-22.831	0.20	0.45	60.47	-	-	-	-	-	-
10-Jun-11	16:00	-22.890	0.60	0.77	60.41	-	-	-	-	-	-
10-Jun-11	16:00	-22.913	0.82	0.90	60.39	-	-	-	-	-	-
10-Jun-11	16:02	-23.022	2.23	1.49	60.28	-	-	-	-	-	-
10-Jun-11	16:03	-23.114	3.85	1.96	60.19	-	-	-	-	-	-
10-Jun-11	16:08	-23.302	8.08	2.84	60.00	-	-	-	-	-	-
10-Jun-11	16:15	-23.540	15.10	3.89	59.76	-	-	-	-	-	-
10-Jun-11	16:24	-23.763	24.10	4.91	59.54	-	-	-	-	-	-
10-Jun-11	16:35	-23.967	35.10	5.92	59.34	-	-	-	-	-	-
10-Jun-11	16:48	-24.177	48.10	6.94	59.13	-	-	-	-	-	-
10-Jun-11	17:03	-24.384	63.10	7.94	58.92	-	-	-	-	-	-
10-Jun-11	17:20	-24.586	80.10	8.95	58.72	-	-	-	-	-	-
10-Jun-11	17:39	-24.786	99.10	9.95	58.52	-	-	-	-	-	-
10-Jun-11	18:00	-24.983	120.10	10.96	58.32	-	-	-	-	-	-
10-Jun-11	18:23	-25.185	143.10	11.96	58.12	-	-	-	-	-	-
10-Jun-11	18:48	-25.390	168.10	12.97	57.91	-	-	-	-	-	-
10-Jun-11	19:15	-25.597	195.10	13.97	57.71	-	-	-	-	-	-
10-Jun-11	19:44	-25.797	224.10	14.97	57.51	-	-	-	-	-	-
10-Jun-11	20:15	-25.996	255.10	15.97	57.31	-	-	-	-	-	-
10-Jun-11	20:48	-26.184	288.12	16.97	57.12	-	-	-	-	-	-
10-Jun-11	21:23	-26.365	323.12	17.98	56.94	-	-	-	-	-	-
10-Jun-11	22:00	-26.537	360.12	18.98	56.77	-	-	-	-	-	-
10-Jun-11	22:39	-26.696	399.12	19.98	56.61	-	-	-	-	-	-
10-Jun-11	23:20	-26.851	440.12	20.98	56.45	-	-	-	-	-	-
11-Jun-11	0:03	-26.993	483.12	21.98	56.31	-	-	-	-	-	-
11-Jun-11	0:48	-27.122	528.12	22.98	56.18	-	-	-	-	-	-
11-Jun-11	1:35	-27.243	575.12	23.98	56.06	-	-	-	-	-	-
11-Jun-11	2:24	-27.355	624.12	24.98	55.95	-	-	-	-	-	-
11-Jun-11	3:15	-27.455	675.12	25.98	55.85	-	-	-	-	-	-
11-Jun-11	4:08	-27.548	728.12	26.98	55.76	-	-	-	-	-	-
11-Jun-11	5:03	-27.632	783.12	27.98	55.67	-	-	-	-	-	-
11-Jun-11	6:00	-27.713	840.12	28.98	55.59	-	-	-	-	-	-
11-Jun-11	6:59	-27.789	899.12	29.99	55.51	-	-	-	-	-	-
11-Jun-11	9:03	-27.919	1023.12	31.99	55.38	-	-	-	-	-	-
11-Jun-11	11:15	-28.026	1155.13	33.99	55.28	-	-	-	-	-	-
11-Jun-11	13:35	-28.130	1295.13	35.99	55.17	-	-	-	-	-	-
11-Jun-11	16:03	-28.228	1443.13	37.99	55.08	-	-	-	-	-	-
11-Jun-11	18:39	-28.309	1599.13	39.99	54.99	-	-	-	-	-	-
11-Jun-11	21:23	-28.386	1763.13	41.99	54.92	-	-	-	-	-	-
12-Jun-11	0:15	-28.447	1935.15	43.99	54.86	-	-	-	-	-	-
12-Jun-11	3:15	-28.504	2115.15	45.99	54.80	-	-	-	-	-	-
12-Jun-11	6:23	-28.553	2303.15	47.99	54.75	-	-	-	-	-	-
12-Jun-11	9:39	-28.611	2499.15	49.99	54.69	-	-	-	-	-	-
12-Jun-11	13:03	-28.677	2703.17	51.99	54.63	-	-	-	-	-	-
12-Jun-11	16:35	-28.740	2915.17	53.99	54.56	-	-	-	-	-	-
12-Jun-11	20:15	-28.855	3135.17	55.99	54.45	-	-	-	-	-	-
13-Jun-11	0:03	-28.856	3363.17	57.99	54.45	-	-	-	-	-	-
13-Jun-11	3:59	-28.886	3599.18	59.99	54.42	-	-	-	-	-	-
13-Jun-11	10:08	-28.931	3968.18	62.99	54.37	-	-	-	-	-	-
13-Jun-11	16:09	-28.975	4329.40	65.80	54.33	-	-	-	-	-	-
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Load No. 8
Stress: 181.0 kPa
Add Mass: 15 kg

DATE	TIME	DIAL	ELAPSED	ROOT	SAMPLE	PRESSURE				RAMP	Hydraulic
		READING	TIME	TIME	HEIGHT	TOP	MIDDLE	BOTTOM	h_L		Conductivity
		(mm)	(min)	(min)	(mm)	(cm)	(cm)	(cm)	(cm)	(ms/mm^3)	(cm/sec)
15-Jun-11	16:20	-29.164	0.00	0.00	54.14	-	-	-	-	-	-
15-Jun-11	16:20	-29.451	0.20	0.45	53.85	-	-	-	-	-	-
15-Jun-11	16:20	-29.505	0.60	0.77	53.80	-	-	-	-	-	-
15-Jun-11	16:21	-29.541	1.00	1.00	53.76	-	-	-	-	-	-
15-Jun-11	16:22	-29.625	2.20	1.48	53.68	-	-	-	-	-	-
15-Jun-11	16:24	-29.716	4.00	2.00	53.59	-	-	-	-	-	-
15-Jun-11	16:29	-29.909	9.00	3.00	53.39	-	-	-	-	-	-
15-Jun-11	16:36	-30.128	16.00	4.00	53.18	-	-	-	-	-	-
15-Jun-11	16:45	-30.322	25.00	5.00	52.98	-	-	-	-	-	-
15-Jun-11	16:56	-30.520	36.00	6.00	52.78	-	-	-	-	-	-
15-Jun-11	17:09	-30.723	49.00	7.00	52.58	-	-	-	-	-	-
15-Jun-11	17:24	-30.935	63.90	7.99	52.37	-	-	-	-	-	-
15-Jun-11	17:41	-31.153	81.00	9.00	52.15	-	-	-	-	-	-
15-Jun-11	18:00	-31.374	100.00	10.00	51.93	-	-	-	-	-	-
15-Jun-11	18:21	-31.601	120.90	11.00	51.70	-	-	-	-	-	-
15-Jun-11	18:44	-31.820	144.00	12.00	51.48	-	-	-	-	-	-
15-Jun-11	19:09	-32.018	168.90	13.00	51.29	-	-	-	-	-	-
15-Jun-11	19:36	-32.204	196.00	14.00	51.10	-	-	-	-	-	-
15-Jun-11	20:05	-32.384	225.00	15.00	50.92	-	-	-	-	-	-
15-Jun-11	20:36	-32.550	256.00	16.00	50.75	-	-	-	-	-	-
15-Jun-11	21:09	-32.700	288.90	17.00	50.60	-	-	-	-	-	-
15-Jun-11	21:44	-32.840	324.00	18.00	50.46	-	-	-	-	-	-
15-Jun-11	22:21	-32.965	361.00	19.00	50.34	-	-	-	-	-	-
15-Jun-11	23:00	-33.075	400.00	20.00	50.23	-	-	-	-	-	-
15-Jun-11	23:41	-33.175	441.00	21.00	50.13	-	-	-	-	-	-
16-Jun-11	0:24	-33.265	484.00	22.00	50.04	-	-	-	-	-	-
16-Jun-11	1:09	-33.345	529.00	23.00	49.96	-	-	-	-	-	-
16-Jun-11	1:56	-33.416	575.92	24.00	49.89	-	-	-	-	-	-
16-Jun-11	2:45	-33.478	624.92	25.00	49.83	-	-	-	-	-	-
16-Jun-11	3:36	-33.535	675.92	26.00	49.77	-	-	-	-	-	-
16-Jun-11	4:29	-33.586	728.92	27.00	49.72	-	-	-	-	-	-
16-Jun-11	5:24	-33.631	783.92	28.00	49.67	-	-	-	-	-	-
16-Jun-11	6:21	-33.672	840.92	29.00	49.63	-	-	-	-	-	-
16-Jun-11	7:20	-33.711	899.92	30.00	49.59	-	-	-	-	-	-
16-Jun-11	9:24	-33.772	1023.92	32.00	49.53	-	-	-	-	-	-
16-Jun-11	11:36	-33.822	1155.92	34.00	49.48	-	-	-	-	-	-
16-Jun-11	13:56	-33.867	1295.92	36.00	49.44	-	-	-	-	-	-
16-Jun-11	16:24	-33.908	1443.93	38.00	49.39	-	-	-	-	-	-
16-Jun-11	19:00	-33.948	1599.93	40.00	49.36	-	-	-	-	-	-
16-Jun-11	21:44	-33.974	1763.93	42.00	49.33	-	-	-	-	-	-
17-Jun-11	0:36	-33.992	1935.93	44.00	49.31	-	-	-	-	-	-
17-Jun-11	3:36	-34.008	2115.95	46.00	49.30	-	-	-	-	-	-
17-Jun-11	6:44	-34.029	2303.95	48.00	49.27	-	-	-	-	-	-
17-Jun-11	10:00	-34.079	2499.95	50.00	49.22	-	-	-	-	-	-
17-Jun-11	13:24	-34.113	2703.95	52.00	49.19	-	-	-	-	-	-
17-Jun-11	16:56	-34.147	2915.97	54.00	49.16	-	-	-	-	-	-
17-Jun-11	20:36	-34.193	3135.97	56.00	49.11	-	-	-	-	-	-
18-Jun-11	0:24	-34.190	3363.97	58.00	49.11	-	-	-	-	-	-
18-Jun-11	4:20	-34.190	3599.98	60.00	49.11	-	-	-	-	-	-
18-Jun-11	10:29	-34.219	3968.98	63.00	49.08	-	-	-	-	-	-
18-Jun-11	16:56	-34.245	4355.98	66.00	49.06	-	-	-	-	-	-
18-Jun-11	23:41	-34.242	4761.00	69.00	49.06	-	-	-	-	-	-
19-Jun-11	6:44	-34.245	5184.00	72.00	49.06	-	-	-	-	-	-
19-Jun-11	14:05	-34.315	5624.92	75.00	48.99	-	-	-	-	-	-
19-Jun-11	21:44	-34.336	6083.93	78.00	48.97	-	-	-	-	-	-
20-Jun-11	5:41	-34.334	6560.93	81.00	48.97	-	-	-	-	-	-
20-Jun-11	13:56	-34.369	7055.95	84.00	48.93	-	-	-	-	-	-
20-Jun-11	15:15	-34.378	7135.35	84.47	48.93	-	-	-	-	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-
Perm						-	-	-	-	-	-
21-Jun-11	6:42	-34.378	15281.95	123.62	48.93	29.4	-	473.4	444.0	6000.00	1.01E-08
21-Jun-11	16:21	-34.378	15860.95	125.94	48.93	29.4	-	551.8	522.4	6000.00	8.56E-09
21-Jun-11	17:45	-34.378	15944.95	126.27	48.93	29.4	-	679.4	650.0	6000.00	6.88E-09
22-Jun-11	6:40	-34.378	16719.95	129.31	48.93	29.4	-	708.8	679.4	6000.00	6.58E-09
22-Jun-11	11:38	-34.378	17017.95	130.45	48.93	29.4	-	738.2	708.8	6000.00	6.31E-09
						-	-	-	-	**Average:**	**7.68E-09**
						-	-	-	-	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-

Load No. 9
Stress: 374.6 kPa
Add Mass: 30 kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP (ms/mm^3)	Hydraulic Conductivity (cm/sec)
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)		
22-Jun-11	13:53	-34.494	0.00	0.00	48.81	-	-	-	-	-	-
22-Jun-11	13:53	-34.750	0.20	0.45	48.55	-	-	-	-	-	-
22-Jun-11	13:53	-34.842	0.60	0.77	48.46	-	-	-	-	-	-
22-Jun-11	13:54	-34.873	1.00	1.00	48.43	-	-	-	-	-	-
22-Jun-11	13:55	-34.940	2.20	1.48	48.36	-	-	-	-	-	-
22-Jun-11	13:57	-35.016	4.00	2.00	48.29	-	-	-	-	-	-
22-Jun-11	14:02	-35.177	9.00	3.00	48.13	-	-	-	-	-	-
22-Jun-11	14:09	-35.348	15.90	3.99	47.96	-	-	-	-	-	-
22-Jun-11	14:18	-35.532	24.90	4.99	47.77	-	-	-	-	-	-
22-Jun-11	14:29	-35.705	35.90	5.99	47.60	-	-	-	-	-	-
22-Jun-11	14:42	-35.875	49.00	7.00	47.43	-	-	-	-	-	-
22-Jun-11	14:57	-36.051	64.00	8.00	47.25	-	-	-	-	-	-
22-Jun-11	15:14	-36.231	80.92	9.00	47.07	-	-	-	-	-	-
22-Jun-11	15:33	-36.397	99.92	10.00	46.91	-	-	-	-	-	-
22-Jun-11	15:54	-36.570	120.92	11.00	46.73	-	-	-	-	-	-
22-Jun-11	16:17	-36.741	143.92	12.00	46.56	-	-	-	-	-	-
22-Jun-11	16:42	-36.892	168.92	13.00	46.41	-	-	-	-	-	-
22-Jun-11	17:09	-37.046	195.92	14.00	46.26	-	-	-	-	-	-
22-Jun-11	17:38	-37.201	224.92	15.00	46.10	-	-	-	-	-	-
22-Jun-11	18:09	-37.329	255.92	16.00	45.97	-	-	-	-	-	-
22-Jun-11	18:42	-37.428	288.92	17.00	45.88	-	-	-	-	-	-
22-Jun-11	19:17	-37.526	323.92	18.00	45.78	-	-	-	-	-	-
22-Jun-11	19:54	-37.618	360.92	19.00	45.69	-	-	-	-	-	-
22-Jun-11	20:33	-37.697	399.92	20.00	45.61	-	-	-	-	-	-
22-Jun-11	21:14	-37.751	440.92	21.00	45.55	-	-	-	-	-	-
22-Jun-11	21:57	-37.784	483.92	22.00	45.52	-	-	-	-	-	-
22-Jun-11	22:42	-37.816	528.92	23.00	45.49	-	-	-	-	-	-
22-Jun-11	23:29	-37.848	575.92	24.00	45.46	-	-	-	-	-	-
23-Jun-11	0:18	-37.880	624.92	25.00	45.42	-	-	-	-	-	-
23-Jun-11	1:09	-37.907	675.92	26.00	45.40	-	-	-	-	-	-
23-Jun-11	2:02	-37.934	728.92	27.00	45.37	-	-	-	-	-	-
23-Jun-11	2:57	-37.958	783.93	28.00	45.35	-	-	-	-	-	-
23-Jun-11	3:54	-37.978	840.93	29.00	45.33	-	-	-	-	-	-
23-Jun-11	4:53	-37.999	899.93	30.00	45.30	-	-	-	-	-	-
23-Jun-11	6:57	-38.035	1023.93	32.00	45.27	-	-	-	-	-	-
23-Jun-11	9:09	-38.066	1155.93	34.00	45.24	-	-	-	-	-	-
23-Jun-11	11:29	-38.090	1295.93	36.00	45.21	-	-	-	-	-	-
23-Jun-11	13:57	-38.129	1443.93	38.00	45.17	-	-	-	-	-	-
23-Jun-11	16:33	-38.166	1599.93	40.00	45.14	-	-	-	-	-	-
23-Jun-11	19:17	-38.252	1763.95	42.00	45.05	-	-	-	-	-	-
23-Jun-11	22:09	-38.252	1935.95	44.00	45.05	-	-	-	-	-	-
24-Jun-11	1:09	-38.249	2115.95	46.00	45.05	-	-	-	-	-	-
24-Jun-11	4:17	-38.247	2303.97	48.00	45.06	-	-	-	-	-	-
24-Jun-11	7:33	-38.255	2499.97	50.00	45.05	-	-	-	-	-	-
24-Jun-11	10:57	-38.286	2703.98	52.00	45.02	-	-	-	-	-	-
24-Jun-11	14:29	-38.334	2915.98	54.00	44.97	-	-	-	-	-	-
24-Jun-11	15:09	-38.349	2955.88	54.37	44.95	-	-	-	-	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-
Perm						-	-	-	-	-	-
29-Jun-11	16:50	-38.349	10256.65	101.28	44.95	27.8	-	473.4	445.6	5000.00	1.11E-08
30-Jun-11	6:30	-38.349	11076.65	105.25	44.95	27.8	-	649.9	622.1	5000.00	7.92E-09
30-Jun-11	17:16	-38.349	11722.65	108.27	44.95	27.8	-	846.1	818.3	5000.00	6.02E-09
01-Jul-11	8:01	-38.349	12607.65	112.28	44.95	27.8	-	1317.0	1289.2	5000.00	3.82E-09
01-Jul-11	12:06	-38.349	12852.65	113.37	44.95	27.8	-	1326.8	1299.0	5000.00	3.79E-09
						-	-	-	-	**Average:**	**3.81E-09**
						-	-	-	-	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-
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						-	-	-	-	-	-

Consolidation Test - Large Strain for Low Solids and Paste Sample

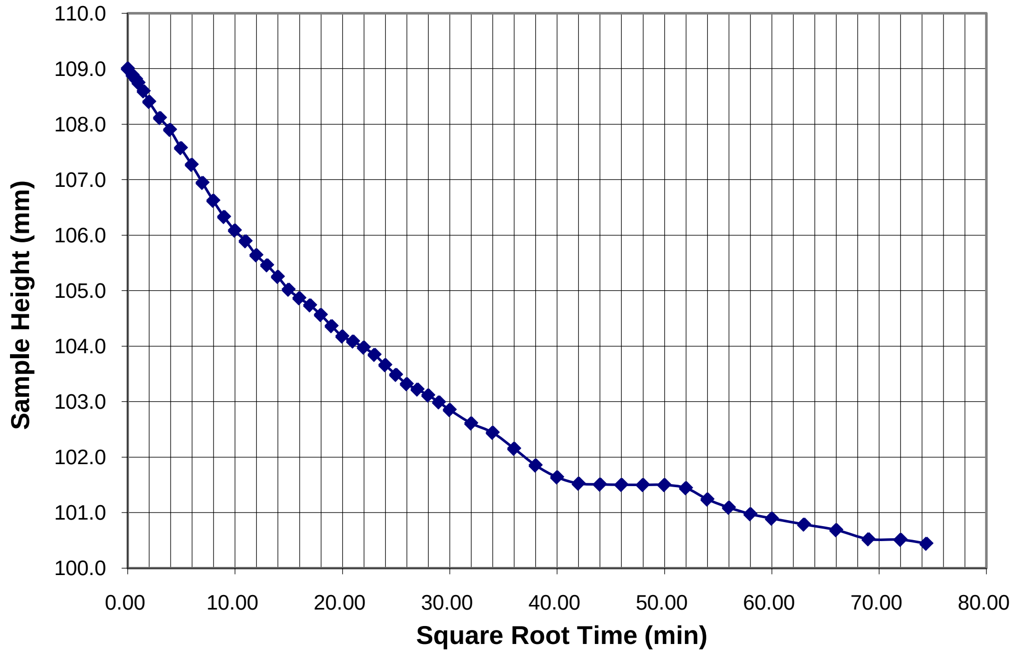
Project Number	11-1359-0001		Initial Water Content	92.85	%	Initial Wet Density	1483.10	kg/m^3
Borehole	BH10-06		Initial Solids Content	51.85	%	Inital Dry Density	769.05	kg/m^3
Sample	SA 12		Sample Diameter	151.20	mm	Initial Void Ratio	2.485	
Depth	17 M		Initial Height	122.00	mm	Initial Saturation	100.14	%
Lab No.	999202		Inital Mass(wet)	3248.80	g	Height of Solids	35.01	mm
INITIAL CELL READINGS:			Mass of Solids	1684.65	g			
Hc	29.7	cm	Specific Gravity	2.68	(assumed)			
Hb	27.2	cm	Sample Area	0.017955	m^2	Final Water Content	28.68	%
Hs	9.7	cm	Sample Volume	0.002191	m^3	Final Height (Measured):	56.80	mm
Hs(after S.W.	8.4	cm	Self Weight Load	0.444	kPa	Final Mass	2150.19	gm
Load Arm Ratio	12.5 :1		Height _after S.W.	109.00	mm	Final Void Ratio (from ht)	0.622	

Load No.	H_{sample} (mm)	H_{D50} (mm)	t_{50} (min)	Stress (kPa)	Void Ratio	K(measured) (cm/s)	Strain (%)	Dry Density (kg/m^3)
1	100.44			1.69	1.869		17.67	934
2	94.62			2.53	1.703		22.45	992
3	84.62			5.26	1.417		30.64	1109
4	78.24			10.73	1.235	8.22E-06	35.87	1199
5	72.90			20.57	1.082		40.25	1287
6	68.78			37.65	0.965	2.94E-06	43.62	1364
7	63.18			88.87	0.805		48.21	1485
8	59.11			191.31	0.688	1.45E-07	51.55	1587
9	55.30			396.19	0.579		54.68	1697

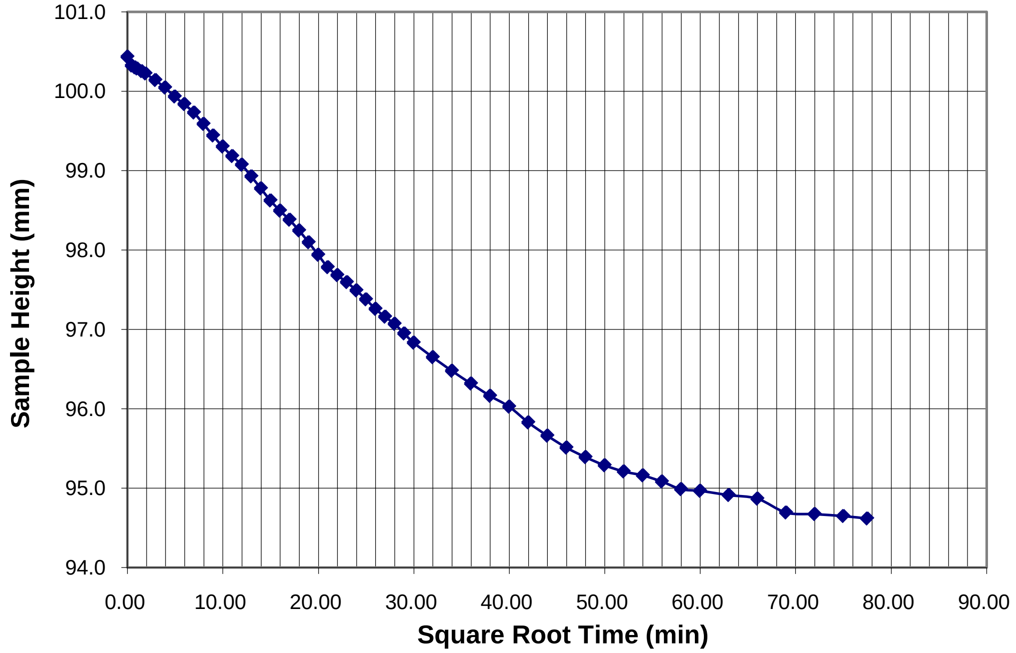
CONSOLIDATION TEST
(ASTM D2435)

Project No.: 11-1359-0001
Lab No.: 999202
BH No.: BH10-06
Sample No.: SA 12
Depth: 17 M

SAMPLE HEIGHT vs. SQUARE ROOT TIME



Total Stress: 1.69 kPa
H_{Sample}: ______ mm
H_{D50}: ______ mm
T_{50}: ______ min

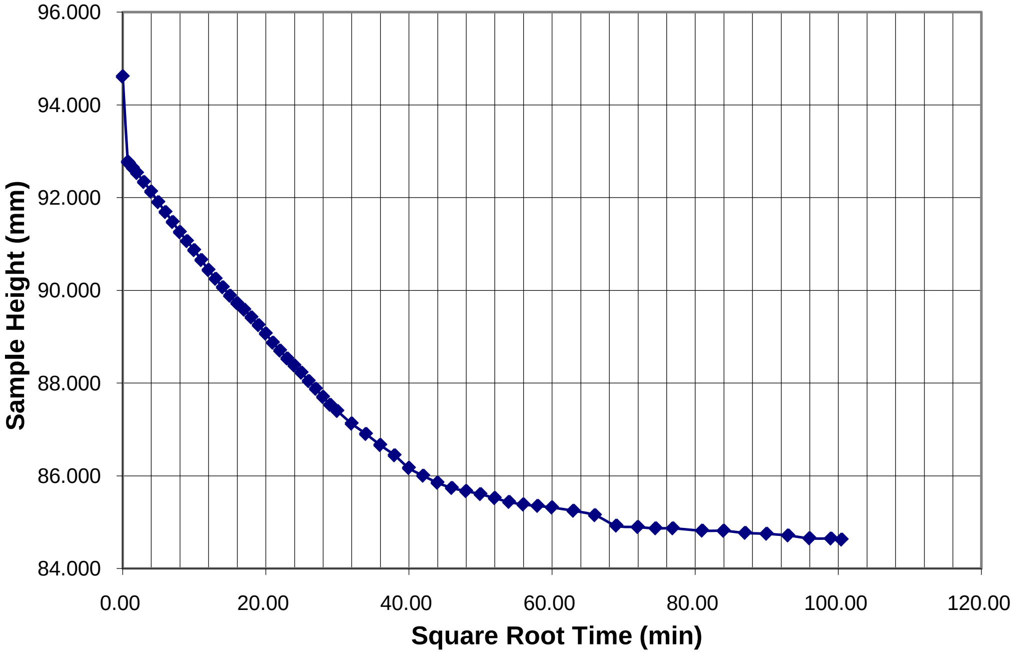


Total Stress: 2.53 kPa
H_{Sample}: ______ mm
H_{D50}: ______ mm
T_{50}: ______ min

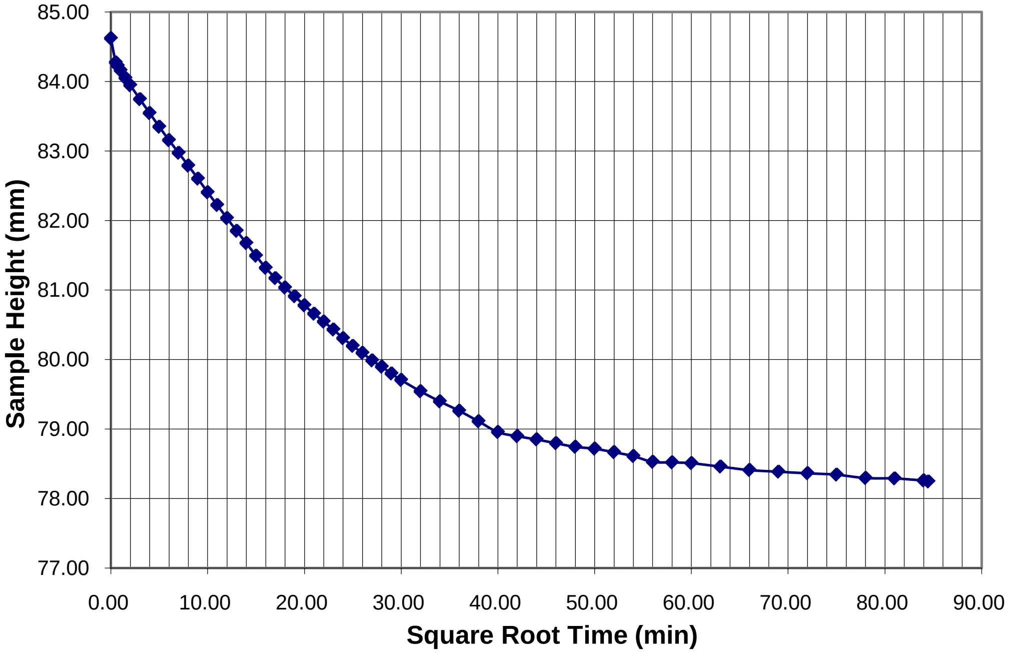
CONSOLIDATION TEST
(ASTM D2435)

Project No.: 11-1359-0001
Lab No.: 999202
BH No.: BH10-06
Sample No.: SA 12
Depth: 17 M

SAMPLE HEIGHT vs. SQUARE ROOT TIME



Total Stress: 5.26 kPa
H_{Sample}: mm
H_{D50}: mm
T_{50}: min

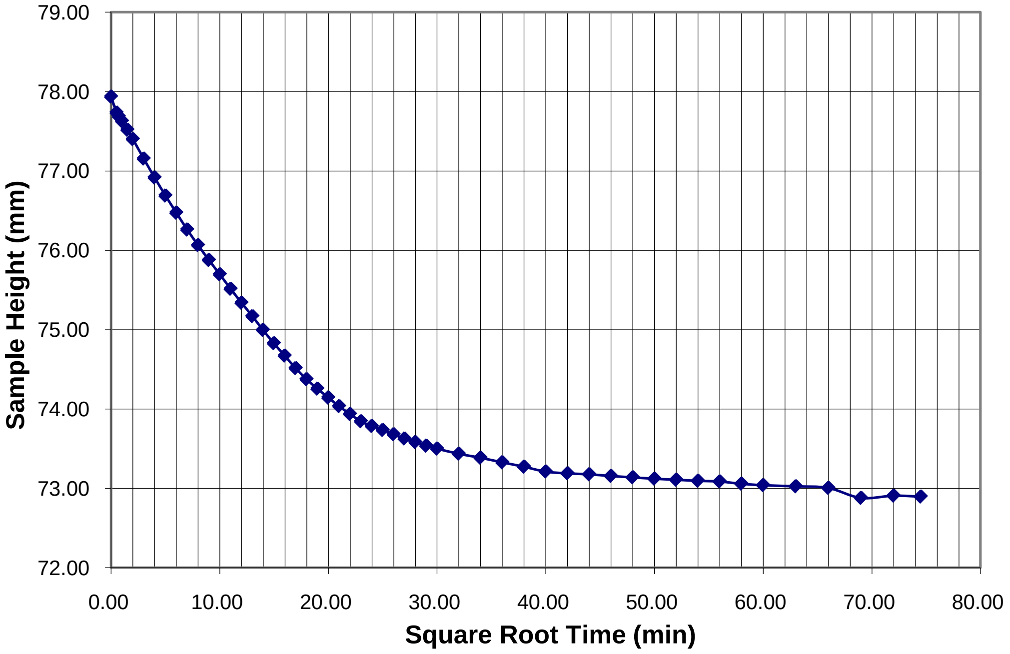


Total Stress: 10.73 kPa
H_{Sample}: mm
H_{D50}: mm
T_{50}: min

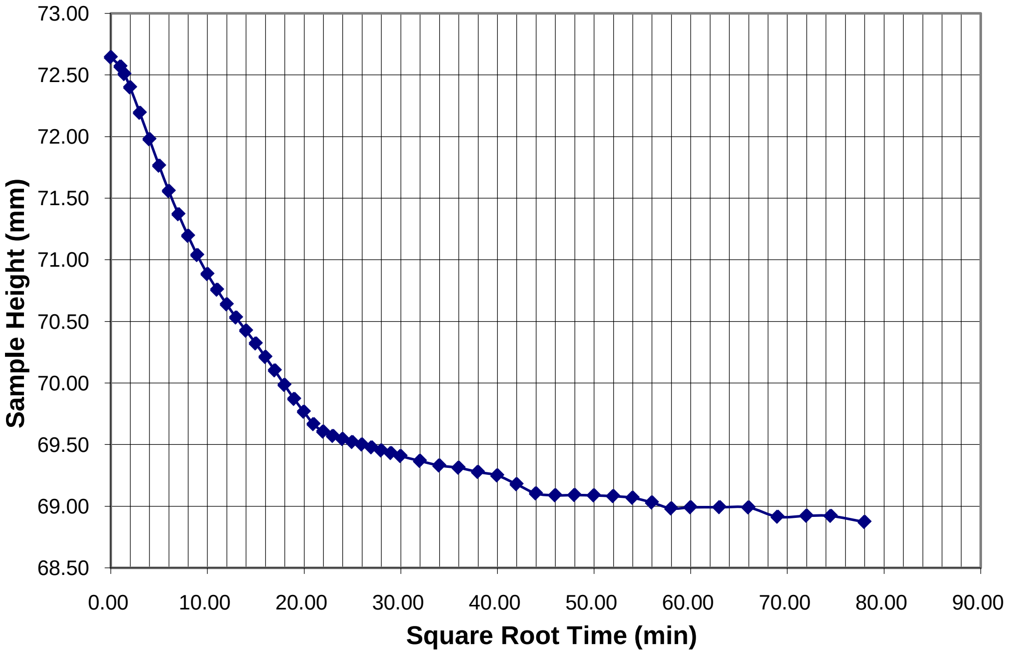
CONSOLIDATION TEST
(ASTM D2435)

Project No.: 11-1359-0001
Lab No.: 999202
BH No.: BH10-06
Sample No.: SA 12
Depth: 17 M

SAMPLE HEIGHT vs. SQUARE ROOT TIME



Total Stress: 20.57 kPa
H_{Sample}: ______ mm
H_{D50}: ______ mm
T_{50}: ______ min



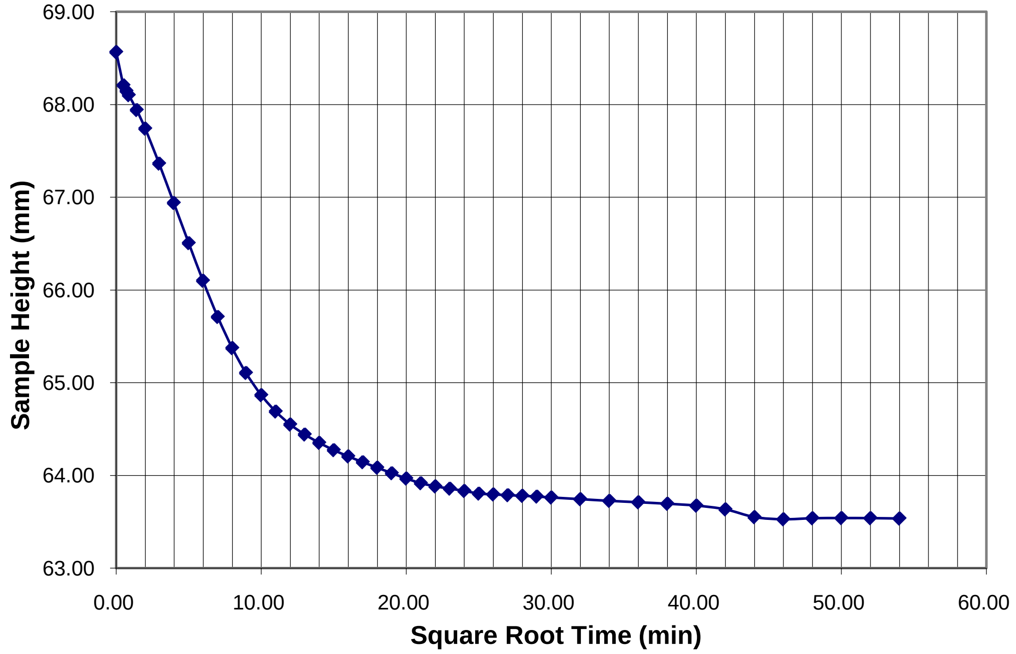
Total Stress: 37.65 kPa
H_{Sample}: ______ mm
H_{D50}: ______ mm
T_{50}: ______ min

Golder Associates

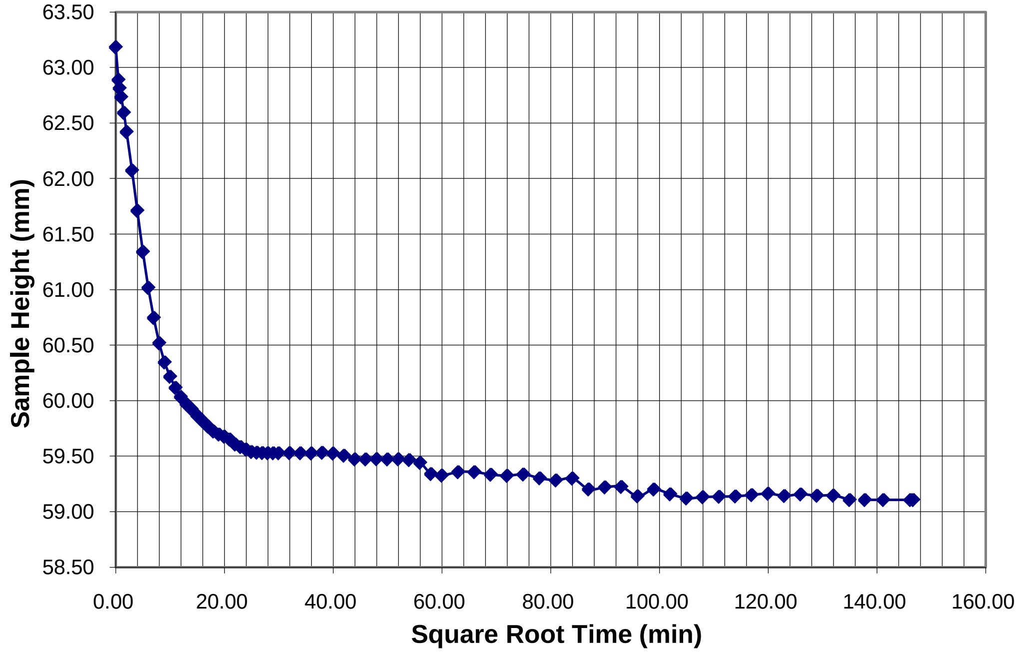
CONSOLIDATION TEST
(ASTM D2435)

Project No.: 11-1359-0001
Lab No.: 999202
BH No.: BH10-06
Sample No.: SA 12
Depth: 17 M

SAMPLE HEIGHT vs. SQUARE ROOT TIME



Total Stress: 88.87 kPa
H_{Sample}: ______ mm
H_{D50}: ______ mm
T_{50}: ______ min

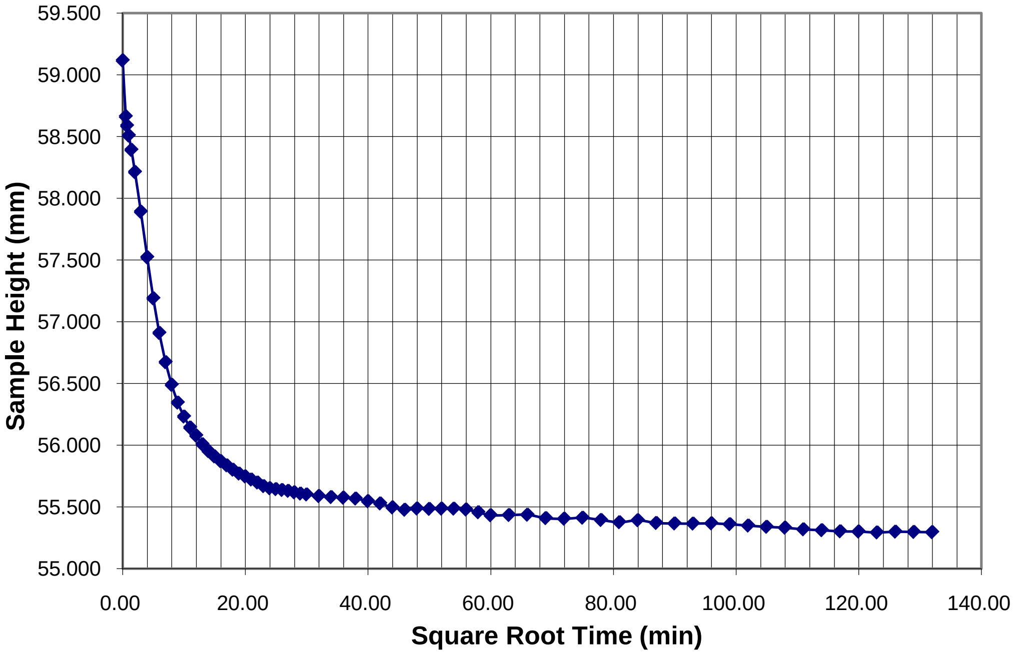


Total Stress: 191.31 kPa
H_{Sample}: ______ mm
H_{D50}: ______ mm
T_{50}: ______ min

CONSOLIDATION TEST
(ASTM D2435)

Project No.: 11-1359-0001
Lab No.: 999202
BH No.: BH10-06
Sample No.: SA 12
Depth: 17 M

SAMPLE HEIGHT vs. SQUARE ROOT TIME

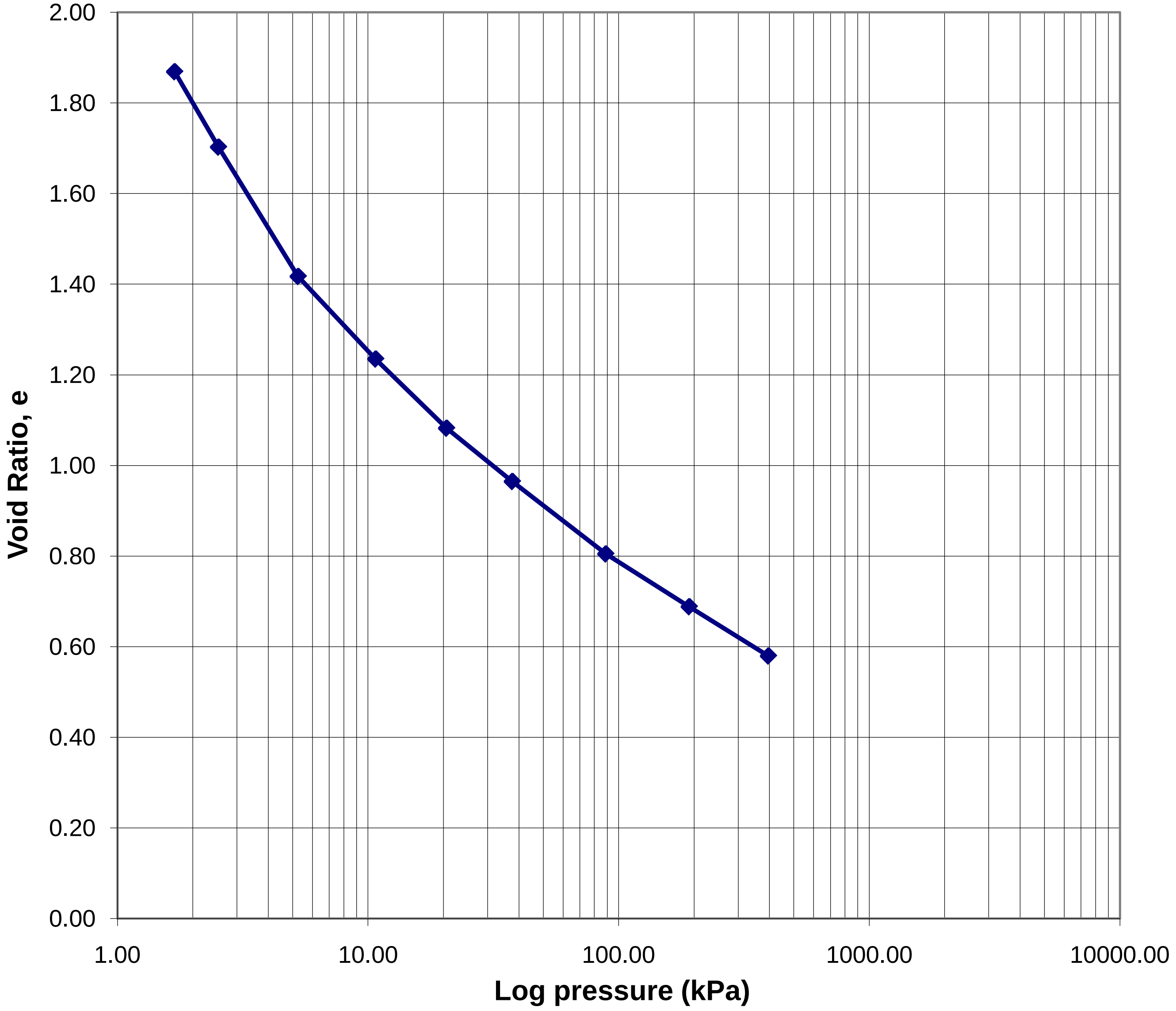


Total Stress: 396.19 kPa
H_{Sample}: ______ mm
H_{D50}: ______ mm
T_{50}: ______ min

CONSOLIDATION TEST
(ASTM D2435)

Project No.: 11-1359-0001
Lab No.: 999202
BH No.: BH10-06
Sample No.: SA 12
Depth: 17 M

Void Ratio vs Log Pressure



Project Number	11-1359-0001		Initial Water Content	92.85	%	Initial Wet Density	1483.10	kg/m^3
Borehole	BH10-06		Initial Solids Content	51.85	%	Inital Dry Density	769.05	kg/m^3
Sample	SA 12		Sample Diameter	151.20	mm	Initial Void Ratio	2.485	
Depth	17 M		Initial Height	122.00	mm	Initial Saturation	100.14	%
Lab No.	999202		Inital Mass(wet)	3248.80	g	Height of Solids	35.01	mm
INITIAL CELL READINGS:			Mass of Solids	1684.65	g			
Hc	29.7	cm	Specific Gravity	2.68	(measured)			
Hb	27.2	cm	Sample Area	0.017955	m^2	Final Water Content	28.68	%
Hs	9.7	cm	Sample Volume	0.002191	m^3	Final Height (Measured):	56.800	mm
Hs(after S.W.)	8.4	cm	Self Weight Load	0.444	kPa	Final Mass	2150.19	gm
Load Arm Ratio	12.5	:1	Height _after S.W.	109.00	mm	Final Void Ratio (from ht)	0.622	

Load No. 1
Stress: 1.691 kPa
Add Mass: 2.282 kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP	Hydraulic Conductivity
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)	(ms/mm^3)	(cm/sec)
03-Mar-11	13:29:09	21.092	0.00	0.00	109.00	38.8	38.5	34.7	-4.1	-	-
03-Mar-11	13:29:21	20.974	0.20	0.45	108.88	-	-	-	-	-	-
03-Mar-11	13:29:45	20.900	0.60	0.77	108.81	-	-	-	-	-	-
03-Mar-11	13:30:09	20.833	1.00	1.00	108.74	-	-	-	-	-	-
03-Mar-11	13:31:21	20.683	2.20	1.48	108.59	-	-	-	-	-	-
03-Mar-11	13:33:09	20.492	4.00	2.00	108.40	-	-	-	-	-	-
03-Mar-11	13:38:09	20.202	9.00	3.00	108.11	-	-	-	-	-	-
03-Mar-11	13:44:39	19.989	15.50	3.94	107.90	-	-	-	-	-	-
03-Mar-11	13:53:39	19.660	24.50	4.95	107.57	-	-	-	-	-	-
03-Mar-11	14:04:39	19.359	35.50	5.96	107.27	-	-	-	-	-	-
03-Mar-11	14:17:39	19.033	48.50	6.96	106.94	-	-	-	-	-	-
03-Mar-11	14:32:39	18.712	63.50	7.97	106.62	-	-	-	-	-	-
03-Mar-11	14:49:39	18.420	80.50	8.97	106.33	-	-	-	-	-	-
03-Mar-11	15:08:39	18.175	99.50	9.97	106.08	-	-	-	-	-	-
03-Mar-11	15:29:39	17.981	120.50	10.98	105.89	-	-	-	-	-	-
03-Mar-11	15:52:39	17.730	143.50	11.98	105.64	-	-	-	-	-	-
03-Mar-11	16:17:39	17.549	168.50	12.98	105.46	-	-	-	-	-	-
03-Mar-11	16:44:39	17.341	195.50	13.98	105.25	-	-	-	-	-	-
03-Mar-11	17:13:39	17.110	224.50	14.98	105.02	-	-	-	-	-	-
03-Mar-11	17:44:39	16.956	255.50	15.98	104.86	-	-	-	-	-	-
03-Mar-11	18:17:39	16.828	288.50	16.99	104.74	-	-	-	-	-	-
03-Mar-11	18:52:39	16.654	323.50	17.99	104.56	-	-	-	-	-	-
03-Mar-11	19:29:39	16.453	360.50	18.99	104.36	-	-	-	-	-	-
03-Mar-11	20:08:39	16.266	399.50	19.99	104.17	-	-	-	-	-	-
03-Mar-11	20:49:39	16.177	440.50	20.99	104.08	-	-	-	-	-	-
03-Mar-11	21:32:39	16.067	483.50	21.99	103.97	-	-	-	-	-	-
03-Mar-11	22:17:39	15.936	528.50	22.99	103.84	-	-	-	-	-	-
03-Mar-11	23:04:39	15.751	575.50	23.99	103.66	-	-	-	-	-	-
03-Mar-11	23:53:39	15.575	624.50	24.99	103.48	-	-	-	-	-	-
04-Mar-11	0:44:39	15.408	675.50	25.99	103.32	-	-	-	-	-	-
04-Mar-11	1:37:39	15.311	728.50	26.99	103.22	-	-	-	-	-	-
04-Mar-11	2:32:39	15.204	783.50	27.99	103.11	-	-	-	-	-	-
04-Mar-11	3:29:40	15.080	840.52	28.99	102.99	-	-	-	-	-	-
04-Mar-11	4:28:40	14.942	899.52	29.99	102.85	-	-	-	-	-	-
04-Mar-11	6:32:40	14.701	1023.52	31.99	102.61	-	-	-	-	-	-
04-Mar-11	8:44:40	14.532	1155.52	33.99	102.44	-	-	-	-	-	-
04-Mar-11	11:04:40	14.244	1295.52	35.99	102.15	-	-	-	-	-	-
04-Mar-11	13:32:40	13.943	1443.52	37.99	101.85	-	-	-	-	-	-
04-Mar-11	16:08:58	13.729	1599.82	40.00	101.64	-	-	-	-	-	-
04-Mar-11	18:52:58	13.615	1763.82	42.00	101.52	-	-	-	-	-	-
04-Mar-11	21:44:58	13.599	1935.82	44.00	101.51	-	-	-	-	-	-
05-Mar-11	0:44:58	13.593	2115.82	46.00	101.50	-	-	-	-	-	-
05-Mar-11	3:52:59	13.591	2303.83	48.00	101.50	-	-	-	-	-	-
05-Mar-11	7:08:59	13.590	2499.83	50.00	101.50	-	-	-	-	-	-
05-Mar-11	10:32:59	13.534	2703.83	52.00	101.44	-	-	-	-	-	-
05-Mar-11	14:04:59	13.330	2915.83	54.00	101.24	-	-	-	-	-	-
05-Mar-11	17:44:59	13.182	3135.83	56.00	101.09	-	-	-	-	-	-
05-Mar-11	21:33:00	13.065	3363.85	58.00	100.97	-	-	-	-	-	-
06-Mar-11	1:29:00	12.986	3599.85	60.00	100.89	-	-	-	-	-	-
06-Mar-11	7:38:00	12.879	3968.85	63.00	100.79	-	-	-	-	-	-
06-Mar-11	14:05:01	12.778	4355.87	66.00	100.69	-	-	-	-	-	-
06-Mar-11	20:50:01	12.614	4760.87	69.00	100.52	-	-	-	-	-	-
07-Mar-11	3:53:01	12.604	5183.87	72.00	100.51	-	-	-	-	-	-
07-Mar-11	9:44:01	12.533	5534.87	74.40	100.44	-	-	-	-	-	-

Load No. 2
Stress: 2.5 kPa
Add Mass: 1.536 kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP (ms/mm³)	Hydraulic Conductivity (cm/sec)
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)		
07-Mar-11	9:51:52	12.524	0.00	0.00	100.43	-	-	-	-	-	-
07-Mar-11	9:52:04	12.413	0.20	0.45	100.32	-	-	-	-	-	-
07-Mar-11	9:52:28	12.391	0.60	0.77	100.30	-	-	-	-	-	-
07-Mar-11	9:52:52	12.376	1.00	1.00	100.28	-	-	-	-	-	-
07-Mar-11	9:54:04	12.343	2.20	1.48	100.25	-	-	-	-	-	-
07-Mar-11	9:55:28	12.313	3.60	1.90	100.22	-	-	-	-	-	-
07-Mar-11	10:00:28	12.231	8.60	2.93	100.14	-	-	-	-	-	-
07-Mar-11	10:07:28	12.136	15.60	3.95	100.04	-	-	-	-	-	-
07-Mar-11	10:16:28	12.023	24.60	4.96	99.93	-	-	-	-	-	-
07-Mar-11	10:27:28	11.929	35.60	5.97	99.84	-	-	-	-	-	-
07-Mar-11	10:40:28	11.822	48.60	6.97	99.73	-	-	-	-	-	-
07-Mar-11	10:55:28	11.679	63.60	7.97	99.59	-	-	-	-	-	-
07-Mar-11	11:12:28	11.533	80.60	8.98	99.44	-	-	-	-	-	-
07-Mar-11	11:31:28	11.393	99.60	9.98	99.30	-	-	-	-	-	-
07-Mar-11	11:52:28	11.274	120.60	10.98	99.18	-	-	-	-	-	-
07-Mar-11	12:15:29	11.165	143.62	11.98	99.07	-	-	-	-	-	-
07-Mar-11	12:40:29	11.018	168.62	12.99	98.93	-	-	-	-	-	-
07-Mar-11	13:07:29	10.866	195.62	13.99	98.77	-	-	-	-	-	-
07-Mar-11	13:36:29	10.714	224.62	14.99	98.62	-	-	-	-	-	-
07-Mar-11	14:07:29	10.586	255.62	15.99	98.49	-	-	-	-	-	-
07-Mar-11	14:40:29	10.471	288.62	16.99	98.38	-	-	-	-	-	-
07-Mar-11	15:15:29	10.336	323.62	17.99	98.24	-	-	-	-	-	-
07-Mar-11	15:52:29	10.187	360.62	18.99	98.10	-	-	-	-	-	-
07-Mar-11	16:31:29	10.030	399.62	19.99	97.94	-	-	-	-	-	-
07-Mar-11	17:12:29	9.874	440.62	20.99	97.78	-	-	-	-	-	-
07-Mar-11	17:55:29	9.774	483.62	21.99	97.68	-	-	-	-	-	-
07-Mar-11	18:40:29	9.685	528.62	22.99	97.59	-	-	-	-	-	-
07-Mar-11	19:27:29	9.582	575.62	23.99	97.49	-	-	-	-	-	-
07-Mar-11	20:16:29	9.469	624.62	24.99	97.38	-	-	-	-	-	-
07-Mar-11	21:07:29	9.349	675.62	25.99	97.26	-	-	-	-	-	-
07-Mar-11	22:00:29	9.250	728.62	26.99	97.16	-	-	-	-	-	-
07-Mar-11	22:55:30	9.161	783.63	27.99	97.07	-	-	-	-	-	-
07-Mar-11	23:52:30	9.040	840.63	28.99	96.95	-	-	-	-	-	-
08-Mar-11	0:51:30	8.924	899.63	29.99	96.83	-	-	-	-	-	-
08-Mar-11	2:55:30	8.740	1023.63	31.99	96.65	-	-	-	-	-	-
08-Mar-11	5:07:30	8.569	1155.63	33.99	96.48	-	-	-	-	-	-
08-Mar-11	7:27:30	8.409	1295.63	35.99	96.32	-	-	-	-	-	-
08-Mar-11	9:55:31	8.254	1443.65	38.00	96.16	-	-	-	-	-	-
08-Mar-11	12:31:31	8.118	1599.65	40.00	96.03	-	-	-	-	-	-
08-Mar-11	15:15:31	7.919	1763.65	42.00	95.83	-	-	-	-	-	-
08-Mar-11	18:07:31	7.752	1935.65	44.00	95.66	-	-	-	-	-	-
08-Mar-11	21:07:31	7.602	2115.65	46.00	95.51	-	-	-	-	-	-
09-Mar-11	0:15:31	7.482	2303.65	48.00	95.39	-	-	-	-	-	-
09-Mar-11	3:31:32	7.379	2499.67	50.00	95.29	-	-	-	-	-	-
09-Mar-11	6:55:32	7.301	2703.67	52.00	95.21	-	-	-	-	-	-
09-Mar-11	10:27:32	7.252	2915.67	54.00	95.16	-	-	-	-	-	-
09-Mar-11	14:07:32	7.174	3135.67	56.00	95.08	-	-	-	-	-	-
09-Mar-11	17:55:33	7.079	3363.68	58.00	94.99	-	-	-	-	-	-
09-Mar-11	21:51:33	7.058	3599.68	60.00	94.97	-	-	-	-	-	-
10-Mar-11	4:00:33	7.004	3968.68	63.00	94.91	-	-	-	-	-	-
10-Mar-11	10:27:33	6.959	4355.68	66.00	94.87	-	-	-	-	-	-
10-Mar-11	17:12:35	6.784	4760.72	69.00	94.69	-	-	-	-	-	-
11-Mar-11	0:15:35	6.764	5183.72	72.00	94.67	-	-	-	-	-	-
11-Mar-11	7:36:35	6.740	5624.72	75.00	94.65	-	-	-	-	-	-
11-Mar-11	13:58:21	6.709	6006.48	77.50	94.62	-	-	-	-	-	-
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Load No. 3
Stress: 5.3 kPa
Add Mass: 5 kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP	Hydraulic Conductivity (cm/sec)
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)	(ms/mm^3)	
11-Mar-11	14:08	6.707	0.00	0.00	94.61	-	-	-	-	-	-
11-Mar-11	14:08	4.865	0.50	0.71	92.77	-	-	-	-	-	-
11-Mar-11	14:09	4.835	0.75	0.87	92.74	-	-	-	-	-	-
11-Mar-11	14:10	4.736	2.00	1.41	92.64	-	-	-	-	-	-
11-Mar-11	14:12	4.625	4.00	2.00	92.53	-	-	-	-	-	-
11-Mar-11	14:17	4.431	8.75	2.96	92.34	-	-	-	-	-	-
11-Mar-11	14:24	4.222	15.75	3.97	92.13	-	-	-	-	-	-
11-Mar-11	14:33	3.995	24.75	4.97	91.90	-	-	-	-	-	-
11-Mar-11	14:44	3.782	35.75	5.98	91.69	-	-	-	-	-	-
11-Mar-11	14:57	3.567	48.75	6.98	91.48	-	-	-	-	-	-
11-Mar-11	15:12	3.349	63.75	7.98	91.26	-	-	-	-	-	-
11-Mar-11	15:29	3.155	80.75	8.99	91.06	-	-	-	-	-	-
11-Mar-11	15:48	2.960	99.75	9.99	90.87	-	-	-	-	-	-
11-Mar-11	16:09	2.747	120.75	10.99	90.65	-	-	-	-	-	-
11-Mar-11	16:32	2.531	143.75	11.99	90.44	-	-	-	-	-	-
11-Mar-11	16:57	2.342	168.75	12.99	90.25	-	-	-	-	-	-
11-Mar-11	17:24	2.159	195.75	13.99	90.07	-	-	-	-	-	-
11-Mar-11	17:53	1.977	224.77	14.99	89.88	-	-	-	-	-	-
11-Mar-11	18:24	1.816	255.77	15.99	89.72	-	-	-	-	-	-
11-Mar-11	18:57	1.676	288.77	16.99	89.58	-	-	-	-	-	-
11-Mar-11	19:32	1.509	323.77	17.99	89.42	-	-	-	-	-	-
11-Mar-11	20:09	1.341	360.77	18.99	89.25	-	-	-	-	-	-
11-Mar-11	20:48	1.160	399.77	19.99	89.07	-	-	-	-	-	-
11-Mar-11	21:29	0.963	440.77	20.99	88.87	-	-	-	-	-	-
11-Mar-11	22:12	0.793	483.77	21.99	88.70	-	-	-	-	-	-
11-Mar-11	22:57	0.623	528.77	22.99	88.53	-	-	-	-	-	-
11-Mar-11	23:44	0.471	575.77	24.00	88.38	-	-	-	-	-	-
12-Mar-11	0:33	0.315	624.77	25.00	88.22	-	-	-	-	-	-
12-Mar-11	1:24	0.135	675.77	26.00	88.04	-	-	-	-	-	-
12-Mar-11	2:17	-0.032	728.77	27.00	87.88	-	-	-	-	-	-
12-Mar-11	3:12	-0.209	783.77	28.00	87.70	-	-	-	-	-	-
12-Mar-11	4:09	-0.377	840.77	29.00	87.53	-	-	-	-	-	-
12-Mar-11	5:08	-0.511	899.77	30.00	87.40	-	-	-	-	-	-
12-Mar-11	7:12	-0.782	1023.77	32.00	87.13	-	-	-	-	-	-
12-Mar-11	9:24	-1.007	1155.77	34.00	86.90	-	-	-	-	-	-
12-Mar-11	11:44	-1.245	1295.78	36.00	86.66	-	-	-	-	-	-
12-Mar-11	14:12	-1.467	1443.78	38.00	86.44	-	-	-	-	-	-
12-Mar-11	16:48	-1.741	1599.78	40.00	86.17	-	-	-	-	-	-
12-Mar-11	19:32	-1.907	1763.78	42.00	86.00	-	-	-	-	-	-
12-Mar-11	22:24	-2.059	1935.78	44.00	85.85	-	-	-	-	-	-
13-Mar-11	1:24	-2.171	2115.78	46.00	85.74	-	-	-	-	-	-
13-Mar-11	4:32	-2.240	2303.78	48.00	85.67	-	-	-	-	-	-
13-Mar-11	7:48	-2.304	2499.78	50.00	85.60	-	-	-	-	-	-
13-Mar-11	11:12	-2.390	2703.78	52.00	85.52	-	-	-	-	-	-
13-Mar-11	14:44	-2.473	2915.80	54.00	85.44	-	-	-	-	-	-
13-Mar-11	18:24	-2.528	3135.82	56.00	85.38	-	-	-	-	-	-
13-Mar-11	22:12	-2.558	3363.82	58.00	85.35	-	-	-	-	-	-
14-Mar-11	2:08	-2.593	3599.83	60.00	85.32	-	-	-	-	-	-
14-Mar-11	8:17	-2.663	3968.83	63.00	85.24	-	-	-	-	-	-
14-Mar-11	14:44	-2.759	4355.83	66.00	85.15	-	-	-	-	-	-
14-Mar-11	21:29	-2.985	4760.85	69.00	84.92	-	-	-	-	-	-
15-Mar-11	4:32	-3.015	5183.87	72.00	84.89	-	-	-	-	-	-
15-Mar-11	10:38	-3.042	5549.87	74.50	84.87	-	-	-	-	-	-
15-Mar-11	16:41	10.147	5912.88	76.90	84.87	-	-	-	-	-	-
16-Mar-11	3:29	10.097	6560.88	81.00	84.82	-	-	-	-	-	-
16-Mar-11	11:44	10.094	7055.88	84.00	84.81	-	-	-	-	-	-
16-Mar-11	20:17	10.048	7568.92	87.00	84.77	-	-	-	-	-	-
17-Mar-11	5:08	10.029	8099.92	90.00	84.75	-	-	-	-	-	-
17-Mar-11	14:17	9.993	8648.93	93.00	84.71	-	-	-	-	-	-
17-Mar-11	23:44	9.931	9215.95	96.00	84.65	-	-	-	-	-	-
18-Mar-11	9:29	9.926	9800.95	99.00	84.65	-	-	-	-	-	-
18-Mar-11	14:25	9.903	10096.97	100.48	84.62	-	-	-	-	-	-
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Load No. 4
Stress: 10.7 kPa
Add Mass: 10 kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP (ms/mm^3)	Hydraulic Conductivity (cm/sec)
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)		
18-Mar-11	14:33	9.900	0.00	0.00	84.62	29.8	34.7	29.6	-0.2	-	-
18-Mar-11	14:33	9.554	0.25	0.50	84.27	-	-	-	-	-	-
18-Mar-11	14:34	9.506	0.50	0.71	84.23	-	-	-	-	-	-
18-Mar-11	14:34	9.440	1.00	1.00	84.16	-	-	-	-	-	-
18-Mar-11	14:35	9.330	2.25	1.50	84.05	-	-	-	-	-	-
18-Mar-11	14:37	9.225	4.00	2.00	83.94	-	-	-	-	-	-
18-Mar-11	14:42	9.024	9.00	3.00	83.74	-	-	-	-	-	-
18-Mar-11	14:49	8.825	16.00	4.00	83.54	-	-	-	-	-	-
18-Mar-11	14:58	8.627	25.00	5.00	83.35	-	-	-	-	-	-
18-Mar-11	15:09	8.435	36.00	6.00	83.15	-	-	-	-	-	-
18-Mar-11	15:22	8.253	49.00	7.00	82.97	-	-	-	-	-	-
18-Mar-11	15:37	8.068	64.00	8.00	82.79	-	-	-	-	-	-
18-Mar-11	15:54	7.881	81.00	9.00	82.60	-	-	-	-	-	-
18-Mar-11	16:13	7.684	100.00	10.00	82.40	-	-	-	-	-	-
18-Mar-11	16:34	7.502	120.75	10.99	82.22	-	-	-	-	-	-
18-Mar-11	16:57	7.312	144.00	12.00	82.03	-	-	-	-	-	-
18-Mar-11	17:22	7.130	169.00	13.00	81.85	-	-	-	-	-	-
18-Mar-11	17:49	6.954	196.00	14.00	81.67	-	-	-	-	-	-
18-Mar-11	18:18	6.772	225.00	15.00	81.49	-	-	-	-	-	-
18-Mar-11	18:49	6.598	256.00	16.00	81.32	-	-	-	-	-	-
18-Mar-11	19:22	6.450	289.00	17.00	81.17	-	-	-	-	-	-
18-Mar-11	19:57	6.314	323.90	18.00	81.03	-	-	-	-	-	-
18-Mar-11	20:34	6.189	360.90	19.00	80.91	-	-	-	-	-	-
18-Mar-11	21:13	6.059	399.90	20.00	80.78	-	-	-	-	-	-
18-Mar-11	21:54	5.938	440.90	21.00	80.66	-	-	-	-	-	-
18-Mar-11	22:37	5.824	483.90	22.00	80.54	-	-	-	-	-	-
18-Mar-11	23:22	5.710	528.90	23.00	80.43	-	-	-	-	-	-
19-Mar-11	0:09	5.585	575.90	24.00	80.30	-	-	-	-	-	-
19-Mar-11	0:58	5.475	624.90	25.00	80.19	-	-	-	-	-	-
19-Mar-11	1:49	5.374	675.92	26.00	80.09	-	-	-	-	-	-
19-Mar-11	2:42	5.266	728.92	27.00	79.98	-	-	-	-	-	-
19-Mar-11	3:37	5.175	783.92	28.00	79.89	-	-	-	-	-	-
19-Mar-11	4:34	5.078	840.92	29.00	79.80	-	-	-	-	-	-
19-Mar-11	5:33	4.985	899.92	30.00	79.70	-	-	-	-	-	-
19-Mar-11	7:37	4.822	1023.92	32.00	79.54	-	-	-	-	-	-
19-Mar-11	9:49	4.676	1155.92	34.00	79.40	-	-	-	-	-	-
19-Mar-11	12:09	4.541	1295.92	36.00	79.26	-	-	-	-	-	-
19-Mar-11	14:37	4.390	1443.92	38.00	79.11	-	-	-	-	-	-
19-Mar-11	17:13	4.235	1599.92	40.00	78.95	-	-	-	-	-	-
19-Mar-11	19:57	4.176	1763.92	42.00	78.89	-	-	-	-	-	-
19-Mar-11	22:49	4.129	1935.92	44.00	78.85	-	-	-	-	-	-
20-Mar-11	1:49	4.075	2115.92	46.00	78.79	-	-	-	-	-	-
20-Mar-11	4:57	4.023	2303.92	48.00	78.74	-	-	-	-	-	-
20-Mar-11	8:13	3.996	2499.92	50.00	78.72	-	-	-	-	-	-
20-Mar-11	11:37	3.946	2703.92	52.00	78.66	-	-	-	-	-	-
20-Mar-11	15:09	3.890	2915.97	54.00	78.61	-	-	-	-	-	-
20-Mar-11	18:49	3.807	3135.97	56.00	78.53	-	-	-	-	-	-
20-Mar-11	22:37	3.799	3363.97	58.00	78.52	-	-	-	-	-	-
21-Mar-11	2:33	3.788	3599.98	60.00	78.51	-	-	-	-	-	-
21-Mar-11	8:42	3.738	3968.98	63.00	78.46	-	-	-	-	-	-
21-Mar-11	15:09	3.689	4355.50	66.00	78.41	-	-	-	-	-	-
21-Mar-11	21:54	3.665	4760.50	69.00	78.38	-	-	-	-	-	-
22-Mar-11	4:57	3.643	5183.52	72.00	78.36	-	-	-	-	-	-
22-Mar-11	12:18	3.622	5624.52	75.00	78.34	-	-	-	-	-	-
22-Mar-11	19:57	3.574	6083.52	78.00	78.29	-	-	-	-	-	-
23-Mar-11	3:54	3.568	6560.53	81.00	78.29	-	-	-	-	-	-
23-Mar-11	12:09	3.539	7055.53	84.00	78.26	-	-	-	-	-	-
23-Mar-11	13:32	3.524	7138.55	84.49	78.24	-	-	-	-	-	-
						-	-	-	-	-	-
24-Mar-11	11:43	3.524	8469.27	92.03	78.24	29.8	-	44.7	14.9	3500.00	8.36E-06
24-Mar-11	17:42	3.524	8828.27	93.96	78.24	29.8	-	45.4	15.6	3500.00	7.98E-06
25-Mar-11	7:15	3.524	9641.27	98.19	78.24	29.8	-	44.9	15.1	3500.00	8.25E-06
25-Mar-11	9:44	3.524	9790.27	98.95	78.24	29.8	-	44.8	15.0	3500.00	8.30E-06
						-	-	-	-	**Average:**	**8.22E-06**
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Load No. 5
Stress: 20.6 kPa
Add Mass: 2.5 kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP (ms/mm^3)	Hydraulic Conductivity (cm/sec)
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)		
31-Mar-11	13:29	3.216	0.00	0.00	77.94	-	-	-	-	-	-
31-Mar-11	13:30	3.016	0.25	0.50	77.73	-	-	-	-	-	-
31-Mar-11	13:30	2.968	0.50	0.71	77.69	-	-	-	-	-	-
31-Mar-11	13:30	2.909	1.00	1.00	77.63	-	-	-	-	-	-
31-Mar-11	13:32	2.799	2.25	1.50	77.52	-	-	-	-	-	-
31-Mar-11	13:33	2.681	4.00	2.00	77.40	-	-	-	-	-	-
31-Mar-11	13:38	2.435	9.00	3.00	77.15	-	-	-	-	-	-
31-Mar-11	13:45	2.198	16.00	4.00	76.92	-	-	-	-	-	-
31-Mar-11	13:54	1.970	25.00	5.00	76.69	-	-	-	-	-	-
31-Mar-11	14:05	1.754	36.00	6.00	76.47	-	-	-	-	-	-
31-Mar-11	14:18	1.542	49.00	7.00	76.26	-	-	-	-	-	-
31-Mar-11	14:33	1.345	64.00	8.00	76.06	-	-	-	-	-	-
31-Mar-11	14:50	1.158	81.00	9.00	75.88	-	-	-	-	-	-
31-Mar-11	15:09	0.977	100.00	10.00	75.70	-	-	-	-	-	-
31-Mar-11	15:30	0.795	121.00	11.00	75.51	-	-	-	-	-	-
31-Mar-11	15:53	0.620	144.00	12.00	75.34	-	-	-	-	-	-
31-Mar-11	16:18	0.450	169.00	13.00	75.17	-	-	-	-	-	-
31-Mar-11	16:45	0.277	195.25	13.97	75.00	-	-	-	-	-	-
31-Mar-11	17:14	0.110	224.25	14.97	74.83	-	-	-	-	-	-
31-Mar-11	17:45	-0.047	255.25	15.98	74.67	-	-	-	-	-	-
31-Mar-11	18:18	-0.204	288.25	16.98	74.52	-	-	-	-	-	-
31-Mar-11	18:53	-0.344	323.25	17.98	74.38	-	-	-	-	-	-
31-Mar-11	19:30	-0.463	360.25	18.98	74.26	-	-	-	-	-	-
31-Mar-11	20:09	-0.574	399.25	19.98	74.14	-	-	-	-	-	-
31-Mar-11	20:50	-0.683	440.25	20.98	74.04	-	-	-	-	-	-
31-Mar-11	21:33	-0.782	483.25	21.98	73.94	-	-	-	-	-	-
31-Mar-11	22:18	-0.874	528.25	22.98	73.85	-	-	-	-	-	-
31-Mar-11	23:05	-0.933	575.25	23.98	73.79	-	-	-	-	-	-
31-Mar-11	23:54	-0.983	624.25	24.98	73.74	-	-	-	-	-	-
01-Apr-11	0:45	-1.037	675.25	25.99	73.68	-	-	-	-	-	-
01-Apr-11	1:38	-1.090	728.25	26.99	73.63	-	-	-	-	-	-
01-Apr-11	2:33	-1.137	783.25	27.99	73.58	-	-	-	-	-	-
01-Apr-11	3:30	-1.181	840.25	28.99	73.54	-	-	-	-	-	-
01-Apr-11	4:29	-1.218	899.25	29.99	73.50	-	-	-	-	-	-
01-Apr-11	6:33	-1.283	1023.25	31.99	73.44	-	-	-	-	-	-
01-Apr-11	8:45	-1.333	1155.25	33.99	73.39	-	-	-	-	-	-
01-Apr-11	11:05	-1.391	1295.25	35.99	73.33	-	-	-	-	-	-
01-Apr-11	13:33	-1.446	1443.25	37.99	73.27	-	-	-	-	-	-
01-Apr-11	16:09	-1.507	1599.28	39.99	73.21	-	-	-	-	-	-
01-Apr-11	18:53	-1.530	1763.28	41.99	73.19	-	-	-	-	-	-
01-Apr-11	21:45	-1.542	1935.28	43.99	73.18	-	-	-	-	-	-
02-Apr-11	0:45	-1.563	2115.28	45.99	73.16	-	-	-	-	-	-
02-Apr-11	3:53	-1.580	2303.28	47.99	73.14	-	-	-	-	-	-
02-Apr-11	7:09	-1.597	2499.30	49.99	73.12	-	-	-	-	-	-
02-Apr-11	10:33	-1.610	2703.30	51.99	73.11	-	-	-	-	-	-
02-Apr-11	14:05	-1.623	2915.30	53.99	73.10	-	-	-	-	-	-
02-Apr-11	17:45	-1.632	3135.30	55.99	73.09	-	-	-	-	-	-
02-Apr-11	21:33	-1.661	3363.32	57.99	73.06	-	-	-	-	-	-
03-Apr-11	1:29	-1.679	3599.32	59.99	73.04	-	-	-	-	-	-
03-Apr-11	7:38	-1.693	3968.33	62.99	73.03	-	-	-	-	-	-
03-Apr-11	14:05	-1.713	4355.33	65.99	73.01	-	-	-	-	-	-
03-Apr-11	20:50	-1.839	4760.33	69.00	72.88	-	-	-	-	-	-
04-Apr-11	3:53	-1.811	5183.33	72.00	72.91	-	-	-	-	-	-
04-Apr-11	9:59	-1.823	5549.35	74.49	72.90	-	-	-	-	-	-
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Load No. 6
Stress: 37.6 kPa
Add Mass: 2.5 kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP	Hydraulic Conductivity
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)	(ms/mm^3)	(cm/sec)
04-Apr-11	11:00	-2.076	0.00	0.00	72.64	-	-	-	-	-	-
04-Apr-11	11:01	-2.150	1.00	1.00	72.57	-	-	-	-	-	-
04-Apr-11	11:02	-2.212	2.00	1.41	72.51	-	-	-	-	-	-
04-Apr-11	11:04	-2.320	4.00	2.00	72.40	-	-	-	-	-	-
04-Apr-11	11:09	-2.526	9.00	3.00	72.19	-	-	-	-	-	-
04-Apr-11	11:16	-2.741	16.00	4.00	71.98	-	-	-	-	-	-
04-Apr-11	11:25	-2.955	25.00	5.00	71.76	-	-	-	-	-	-
04-Apr-11	11:36	-3.161	36.00	6.00	71.56	-	-	-	-	-	-
04-Apr-11	11:49	-3.349	49.00	7.00	71.37	-	-	-	-	-	-
04-Apr-11	12:04	-3.525	64.00	8.00	71.19	-	-	-	-	-	-
04-Apr-11	12:20	-3.681	80.00	8.94	71.04	-	-	-	-	-	-
04-Apr-11	12:40	-3.835	100.00	10.00	70.88	-	-	-	-	-	-
04-Apr-11	13:01	-3.962	121.00	11.00	70.76	-	-	-	-	-	-
04-Apr-11	13:24	-4.081	144.00	12.00	70.64	-	-	-	-	-	-
04-Apr-11	13:48	-4.188	168.00	12.96	70.53	-	-	-	-	-	-
04-Apr-11	14:16	-4.295	196.00	14.00	70.42	-	-	-	-	-	-
04-Apr-11	14:45	-4.398	225.00	15.00	70.32	-	-	-	-	-	-
04-Apr-11	15:16	-4.508	256.00	16.00	70.21	-	-	-	-	-	-
04-Apr-11	15:48	-4.617	288.02	16.97	70.10	-	-	-	-	-	-
04-Apr-11	16:23	-4.735	323.02	17.97	69.98	-	-	-	-	-	-
04-Apr-11	17:00	-4.849	360.02	18.97	69.87	-	-	-	-	-	-
04-Apr-11	17:39	-4.953	399.02	19.98	69.77	-	-	-	-	-	-
04-Apr-11	18:20	-5.053	440.02	20.98	69.67	-	-	-	-	-	-
04-Apr-11	19:03	-5.114	483.02	21.98	69.61	-	-	-	-	-	-
04-Apr-11	19:48	-5.149	528.02	22.98	69.57	-	-	-	-	-	-
04-Apr-11	20:35	-5.174	575.02	23.98	69.54	-	-	-	-	-	-
04-Apr-11	21:24	-5.198	624.02	24.98	69.52	-	-	-	-	-	-
04-Apr-11	22:15	-5.219	675.02	25.98	69.50	-	-	-	-	-	-
04-Apr-11	23:08	-5.242	728.02	26.98	69.48	-	-	-	-	-	-
05-Apr-11	0:03	-5.267	783.02	27.98	69.45	-	-	-	-	-	-
05-Apr-11	1:00	-5.288	840.03	28.98	69.43	-	-	-	-	-	-
05-Apr-11	1:59	-5.312	899.03	29.98	69.41	-	-	-	-	-	-
05-Apr-11	4:03	-5.352	1023.03	31.98	69.37	-	-	-	-	-	-
05-Apr-11	6:15	-5.389	1155.03	33.99	69.33	-	-	-	-	-	-
05-Apr-11	8:35	-5.407	1295.03	35.99	69.31	-	-	-	-	-	-
05-Apr-11	11:03	-5.441	1443.05	37.99	69.28	-	-	-	-	-	-
05-Apr-11	13:39	-5.470	1599.05	39.99	69.25	-	-	-	-	-	-
05-Apr-11	16:23	-5.541	1763.05	41.99	69.18	-	-	-	-	-	-
05-Apr-11	19:15	-5.616	1935.05	43.99	69.10	-	-	-	-	-	-
05-Apr-11	22:15	-5.631	2115.05	45.99	69.09	-	-	-	-	-	-
06-Apr-11	1:23	-5.629	2303.05	47.99	69.09	-	-	-	-	-	-
06-Apr-11	4:39	-5.632	2499.07	49.99	69.09	-	-	-	-	-	-
06-Apr-11	8:03	-5.638	2703.07	51.99	69.08	-	-	-	-	-	-
06-Apr-11	11:35	-5.651	2915.07	53.99	69.07	-	-	-	-	-	-
06-Apr-11	15:15	-5.689	3135.08	55.99	69.03	-	-	-	-	-	-
06-Apr-11	19:03	-5.738	3363.08	57.99	68.98	-	-	-	-	-	-
06-Apr-11	22:59	-5.728	3599.08	59.99	68.99	-	-	-	-	-	-
07-Apr-11	5:08	-5.727	3968.08	62.99	68.99	-	-	-	-	-	-
07-Apr-11	11:35	-5.729	4355.08	65.99	68.99	-	-	-	-	-	-
07-Apr-11	18:20	-5.805	4760.12	68.99	68.91	-	-	-	-	-	-
08-Apr-11	1:23	-5.797	5183.12	71.99	68.92	-	-	-	-	-	-
08-Apr-11	7:30	-5.798	5550.13	74.50	68.92	-	-	-	-	-	-
08-Apr-11	16:23	-5.847	6083.13	77.99	68.87	-	-	-	-	-	-
09-Apr-11	0:20	-5.887	6560.15	80.99	68.83	-	-	-	-	-	-
09-Apr-11	8:35	-5.884	7055.17	84.00	68.84	-	-	-	-	-	-
09-Apr-11	17:08	-5.923	7568.17	87.00	68.80	-	-	-	-	-	-
10-Apr-11	1:59	-5.917	8099.17	90.00	68.80	-	-	-	-	-	-
10-Apr-11	11:08	-5.906	8648.18	93.00	68.81	-	-	-	-	-	-
10-Apr-11	20:35	-5.948	9215.20	96.00	68.77	-	-	-	-	-	-
11-Apr-11	6:20	-5.934	9800.22	99.00	68.78	-	-	-	-	-	-
11-Apr-11	11:31	-5.937	10111.22	100.55	68.78	-	-	-	-	-	-
						-	-	-	-	-	-
12-May-11	15:18	-6.020	79244.27	281.50	68.70	29.8	-	53.2	23.4	3500.00	4.67E-06
13-May-11	6:38	-6.020	80164.27	283.13	68.70	29.8	-	68.2	38.4	3500.00	2.85E-06
13-May-11	16:26	-6.020	80752.27	284.17	68.70	29.8	-	84.0	54.2	3500.00	2.02E-06
14-May-11	6:34	-6.020	81600.27	285.66	68.70	29.8	-	78.6	48.8	3500.00	2.24E-06
						-	-	-	-	**Average:**	**2.94E-06**
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Load No.	7	
Stress:	88.9	kPa
Add Mass:	7.5	kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP	Hydraulic Conductivity
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)	(ms/mm^3)	(cm/sec)
19-Apr-11	9:45	-6.154	0.00	0.00	68.57	-	-	-	-	-	-
19-Apr-11	9:45	-6.511	0.25	0.50	68.21	-	-	-	-	-	-
19-Apr-11	9:45	-6.574	0.50	0.71	68.14	-	-	-	-	-	-
19-Apr-11	9:46	-6.618	0.75	0.87	68.10	-	-	-	-	-	-
19-Apr-11	9:47	-6.778	2.00	1.41	67.94	-	-	-	-	-	-
19-Apr-11	9:49	-6.979	4.00	2.00	67.74	-	-	-	-	-	-
19-Apr-11	9:54	-7.356	8.75	2.96	67.36	-	-	-	-	-	-
19-Apr-11	10:01	-7.780	15.75	3.97	66.94	-	-	-	-	-	-
19-Apr-11	10:10	-8.213	25.00	5.00	66.51	-	-	-	-	-	-
19-Apr-11	10:21	-8.618	35.75	5.98	66.10	-	-	-	-	-	-
19-Apr-11	10:34	-9.009	49.00	7.00	65.71	-	-	-	-	-	-
19-Apr-11	10:49	-9.345	64.00	8.00	65.37	-	-	-	-	-	-
19-Apr-11	11:05	-9.613	80.00	8.94	65.11	-	-	-	-	-	-
19-Apr-11	11:25	-9.853	100.00	10.00	64.87	-	-	-	-	-	-
19-Apr-11	11:46	-10.029	120.92	11.00	64.69	-	-	-	-	-	-
19-Apr-11	12:09	-10.169	143.92	12.00	64.55	-	-	-	-	-	-
19-Apr-11	12:34	-10.277	168.92	13.00	64.44	-	-	-	-	-	-
19-Apr-11	13:01	-10.367	195.92	14.00	64.35	-	-	-	-	-	-
19-Apr-11	13:30	-10.445	224.92	15.00	64.27	-	-	-	-	-	-
19-Apr-11	14:01	-10.513	255.92	16.00	64.21	-	-	-	-	-	-
19-Apr-11	14:34	-10.575	288.92	17.00	64.14	-	-	-	-	-	-
19-Apr-11	15:09	-10.635	323.92	18.00	64.08	-	-	-	-	-	-
19-Apr-11	15:46	-10.694	360.92	19.00	64.02	-	-	-	-	-	-
19-Apr-11	16:25	-10.752	399.93	20.00	63.97	-	-	-	-	-	-
19-Apr-11	17:06	-10.802	440.93	21.00	63.92	-	-	-	-	-	-
19-Apr-11	17:49	-10.836	483.93	22.00	63.88	-	-	-	-	-	-
19-Apr-11	18:34	-10.860	528.93	23.00	63.86	-	-	-	-	-	-
19-Apr-11	19:21	-10.886	575.93	24.00	63.83	-	-	-	-	-	-
19-Apr-11	20:10	-10.914	624.93	25.00	63.81	-	-	-	-	-	-
19-Apr-11	21:01	-10.923	675.95	26.00	63.80	-	-	-	-	-	-
19-Apr-11	21:54	-10.931	728.95	27.00	63.79	-	-	-	-	-	-
19-Apr-11	22:49	-10.938	783.95	28.00	63.78	-	-	-	-	-	-
19-Apr-11	23:46	-10.946	840.95	29.00	63.77	-	-	-	-	-	-
20-Apr-11	0:45	-10.956	899.95	30.00	63.76	-	-	-	-	-	-
20-Apr-11	2:49	-10.974	1023.95	32.00	63.74	-	-	-	-	-	-
20-Apr-11	5:01	-10.992	1155.95	34.00	63.73	-	-	-	-	-	-
20-Apr-11	7:21	-11.008	1295.95	36.00	63.71	-	-	-	-	-	-
20-Apr-11	9:49	-11.024	1443.97	38.00	63.70	-	-	-	-	-	-
20-Apr-11	12:25	-11.044	1599.95	40.00	63.68	-	-	-	-	-	-
20-Apr-11	15:09	-11.084	1763.95	42.00	63.63	-	-	-	-	-	-
20-Apr-11	18:01	-11.168	1935.97	44.00	63.55	-	-	-	-	-	-
20-Apr-11	21:01	-11.191	2115.97	46.00	63.53	-	-	-	-	-	-
21-Apr-11	0:09	-11.180	2303.97	48.00	63.54	-	-	-	-	-	-
21-Apr-11	3:25	-11.178	2499.97	50.00	63.54	-	-	-	-	-	-
21-Apr-11	6:49	-11.179	2703.98	52.00	63.54	-	-	-	-	-	-
21-Apr-11	10:21	-11.183	2915.98	54.00	63.54	-	-	-	-	-	-
21-Apr-11	14:01	-11.213	3135.98	56.00	63.51	-	-	-	-	-	-
21-Apr-11	17:48	-11.284	3363.20	57.99	63.44	-	-	-	-	-	-
21-Apr-11	21:44	-11.274	3599.20	59.99	63.45	-	-	-	-	-	-
22-Apr-11	3:53	-11.261	3968.20	62.99	63.46	-	-	-	-	-	-
22-Apr-11	10:20	-11.261	4355.20	65.99	63.46	-	-	-	-	-	-
22-Apr-11	17:05	-11.325	4760.22	68.99	63.39	-	-	-	-	-	-
23-Apr-11	0:08	-11.353	5183.23	71.99	63.37	-	-	-	-	-	-
23-Apr-11	7:29	-11.338	5624.23	74.99	63.38	-	-	-	-	-	-
23-Apr-11	15:08	-11.343	6083.25	78.00	63.38	-	-	-	-	-	-
23-Apr-11	23:05	-11.415	6560.25	81.00	63.30	-	-	-	-	-	-
24-Apr-11	7:20	-11.388	7055.27	84.00	63.33	-	-	-	-	-	-
24-Apr-11	15:53	-11.418	7568.28	87.00	63.30	-	-	-	-	-	-
25-Apr-11	0:44	-11.488	8099.28	90.00	63.23	-	-	-	-	-	-
25-Apr-11	9:53	-11.460	8648.30	93.00	63.26	-	-	-	-	-	-
25-Apr-11	19:20	-11.550	9215.30	96.00	63.17	-	-	-	-	-	-
26-Apr-11	5:05	-11.502	9800.33	99.00	63.22	-	-	-	-	-	-
26-Apr-11	15:08	-11.525	10403.33	102.00	63.19	-	-	-	-	-	-
27-Apr-11	1:29	-11.549	11024.35	105.00	63.17	-	-	-	-	-	-
27-Apr-11	10:28	-11.539	11563.37	107.53	63.18	-	-	-	-	-	-

Load No.	8	
Stress:	191.3	kPa
Add Mass:	15	kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP (ms/mm^3)	Hydraulic Conductivity (cm/sec)
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)		
27-Apr-11	10:32	-11.539	0.00	0.00	63.18	-	-	-	-	-	-
27-Apr-11	10:32	-11.833	0.25	0.50	62.89	-	-	-	-	-	-
27-Apr-11	10:32	-11.908	0.50	0.71	62.81	-	-	-	-	-	-
27-Apr-11	10:33	-11.988	1.00	1.00	62.73	-	-	-	-	-	-
27-Apr-11	10:34	-12.128	2.25	1.50	62.59	-	-	-	-	-	-
27-Apr-11	10:36	-12.301	4.00	2.00	62.42	-	-	-	-	-	-
27-Apr-11	10:41	-12.648	9.00	3.00	62.07	-	-	-	-	-	-
27-Apr-11	10:48	-13.010	15.75	3.97	61.71	-	-	-	-	-	-
27-Apr-11	10:57	-13.381	25.00	5.00	61.34	-	-	-	-	-	-
27-Apr-11	11:08	-13.704	36.00	6.00	61.01	-	-	-	-	-	-
27-Apr-11	11:21	-13.974	49.00	7.00	60.74	-	-	-	-	-	-
27-Apr-11	11:36	-14.202	64.00	8.00	60.52	-	-	-	-	-	-
27-Apr-11	11:53	-14.375	81.00	9.00	60.34	-	-	-	-	-	-
27-Apr-11	12:12	-14.504	100.00	10.00	60.21	-	-	-	-	-	-
27-Apr-11	12:33	-14.604	121.00	11.00	60.12	-	-	-	-	-	-
27-Apr-11	12:55	-14.686	143.00	11.96	60.03	-	-	-	-	-	-
27-Apr-11	13:21	-14.750	169.00	13.00	59.97	-	-	-	-	-	-
27-Apr-11	13:47	-14.797	195.00	13.96	59.92	-	-	-	-	-	-
27-Apr-11	14:17	-14.855	225.00	15.00	59.86	-	-	-	-	-	-
27-Apr-11	14:48	-14.904	256.00	16.00	59.81	-	-	-	-	-	-
27-Apr-11	15:21	-14.952	289.00	17.00	59.77	-	-	-	-	-	-
27-Apr-11	15:56	-14.997	324.00	18.00	59.72	-	-	-	-	-	-
27-Apr-11	16:33	-15.024	361.00	19.00	59.69	-	-	-	-	-	-
27-Apr-11	17:11	-15.043	399.00	19.97	59.68	-	-	-	-	-	-
27-Apr-11	17:52	-15.068	440.00	20.98	59.65	-	-	-	-	-	-
27-Apr-11	18:36	-15.114	484.00	22.00	59.61	-	-	-	-	-	-
27-Apr-11	19:20	-15.137	528.02	22.98	59.58	-	-	-	-	-	-
27-Apr-11	20:07	-15.159	575.02	23.98	59.56	-	-	-	-	-	-
27-Apr-11	20:56	-15.181	624.02	24.98	59.54	-	-	-	-	-	-
27-Apr-11	21:47	-15.187	675.02	25.98	59.53	-	-	-	-	-	-
27-Apr-11	22:40	-15.190	728.02	26.98	59.53	-	-	-	-	-	-
27-Apr-11	23:35	-15.192	783.02	27.98	59.53	-	-	-	-	-	-
28-Apr-11	0:32	-15.192	840.02	28.98	59.53	-	-	-	-	-	-
28-Apr-11	1:31	-15.192	899.02	29.98	59.53	-	-	-	-	-	-
28-Apr-11	3:35	-15.191	1023.02	31.98	59.53	-	-	-	-	-	-
28-Apr-11	5:47	-15.192	1155.02	33.99	59.53	-	-	-	-	-	-
28-Apr-11	8:07	-15.194	1295.02	35.99	59.52	-	-	-	-	-	-
28-Apr-11	10:35	-15.188	1443.02	37.99	59.53	-	-	-	-	-	-
28-Apr-11	13:11	-15.195	1599.02	39.99	59.52	-	-	-	-	-	-
28-Apr-11	15:55	-15.214	1763.03	41.99	59.50	-	-	-	-	-	-
28-Apr-11	18:47	-15.248	1935.03	43.99	59.47	-	-	-	-	-	-
28-Apr-11	21:47	-15.248	2115.03	45.99	59.47	-	-	-	-	-	-
29-Apr-11	0:55	-15.246	2303.03	47.99	59.47	-	-	-	-	-	-
29-Apr-11	4:11	-15.248	2499.03	49.99	59.47	-	-	-	-	-	-
29-Apr-11	7:35	-15.247	2703.05	51.99	59.47	-	-	-	-	-	-
29-Apr-11	11:07	-15.254	2915.07	53.99	59.47	-	-	-	-	-	-
29-Apr-11	14:47	-15.279	3135.07	55.99	59.44	-	-	-	-	-	-
29-Apr-11	18:35	-15.380	3363.07	57.99	59.34	-	-	-	-	-	-
29-Apr-11	22:31	-15.394	3599.07	59.99	59.33	-	-	-	-	-	-
30-Apr-11	4:40	-15.363	3968.08	62.99	59.36	-	-	-	-	-	-
30-Apr-11	11:07	-15.363	4355.10	65.99	59.36	-	-	-	-	-	-
30-Apr-11	17:52	-15.386	4760.10	68.99	59.33	-	-	-	-	-	-
01-May-11	0:55	-15.396	5183.10	71.99	59.32	-	-	-	-	-	-
01-May-11	8:16	-15.384	5624.12	74.99	59.34	-	-	-	-	-	-
01-May-11	15:55	-15.418	6083.13	77.99	59.30	-	-	-	-	-	-
01-May-11	23:52	-15.437	6560.13	80.99	59.28	-	-	-	-	-	-
02-May-11	8:07	-15.420	7055.13	83.99	59.30	-	-	-	-	-	-
02-May-11	16:40	-15.518	7568.15	87.00	59.20	-	-	-	-	-	-
03-May-11	1:31	-15.500	8099.17	90.00	59.22	-	-	-	-	-	-
03-May-11	10:40	-15.496	8648.18	93.00	59.22	-	-	-	-	-	-
03-May-11	20:07	-15.580	9215.18	96.00	59.14	-	-	-	-	-	-
04-May-11	5:52	-15.519	9800.20	99.00	59.20	-	-	-	-	-	-
04-May-11	15:55	-15.562	10403.22	102.00	59.16	-	-	-	-	-	-
05-May-11	2:16	-15.599	11024.23	105.00	59.12	-	-	-	-	-	-
05-May-11	12:55	-15.588	11663.23	108.00	59.13	-	-	-	-	-	-
05-May-11	23:52	-15.584	12320.25	111.00	59.13	-	-	-	-	-	-
06-May-11	11:07	-15.581	12995.27	114.00	59.14	-	-	-	-	-	-
06-May-11	22:40	-15.569	13688.28	117.00	59.15	-	-	-	-	-	-
07-May-11	10:31	-15.557	14399.30	120.00	59.16	-	-	-	-	-	-
07-May-11	22:40	-15.577	15128.32	123.00	59.14	-	-	-	-	-	-

Load No.	9	
Stress:	396.2	kPa
Add Mass:	30	kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP (ms/mm^3)	Hydraulic Conductivity (cm/sec)
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)		
13-May-11	8:58	-15.603	0.00	0.00	59.12	-	-	-	-	-	-
13-May-11	8:58	-16.057	0.25	0.50	58.66	-	-	-	-	-	-
13-May-11	8:58	-16.131	0.50	0.71	58.59	-	-	-	-	-	-
13-May-11	8:59	-16.211	1.00	1.00	58.51	-	-	-	-	-	-
13-May-11	9:00	-16.327	2.00	1.41	58.39	-	-	-	-	-	-
13-May-11	9:02	-16.506	4.00	2.00	58.21	-	-	-	-	-	-
13-May-11	9:06	-16.828	8.75	2.96	57.89	-	-	-	-	-	-
13-May-11	9:14	-17.196	16.00	4.00	57.52	-	-	-	-	-	-
13-May-11	9:23	-17.529	25.00	5.00	57.19	-	-	-	-	-	-
13-May-11	9:33	-17.809	35.75	5.98	56.91	-	-	-	-	-	-
13-May-11	9:47	-18.046	49.00	7.00	56.67	-	-	-	-	-	-
13-May-11	10:02	-18.229	64.00	8.00	56.49	-	-	-	-	-	-
13-May-11	10:18	-18.373	80.75	8.99	56.35	-	-	-	-	-	-
13-May-11	10:38	-18.486	100.00	10.00	56.23	-	-	-	-	-	-
13-May-11	10:59	-18.575	121.00	11.00	56.14	-	-	-	-	-	-
13-May-11	11:21	-18.640	143.75	11.99	56.08	-	-	-	-	-	-
13-May-11	11:46	-18.710	168.75	12.99	56.01	-	-	-	-	-	-
13-May-11	12:13	-18.765	195.75	13.99	55.95	-	-	-	-	-	-
13-May-11	12:42	-18.809	224.25	14.97	55.91	-	-	-	-	-	-
13-May-11	13:13	-18.847	255.25	15.98	55.87	-	-	-	-	-	-
13-May-11	13:46	-18.881	288.25	16.98	55.84	-	-	-	-	-	-
13-May-11	14:21	-18.917	323.25	17.98	55.80	-	-	-	-	-	-
13-May-11	14:58	-18.948	360.25	18.98	55.77	-	-	-	-	-	-
13-May-11	15:37	-18.971	399.25	19.98	55.75	-	-	-	-	-	-
13-May-11	16:18	-18.996	440.25	20.98	55.72	-	-	-	-	-	-
13-May-11	17:01	-19.020	483.25	21.98	55.70	-	-	-	-	-	-
13-May-11	17:46	-19.050	528.27	22.98	55.67	-	-	-	-	-	-
13-May-11	18:33	-19.067	575.27	23.98	55.65	-	-	-	-	-	-
13-May-11	19:22	-19.074	624.27	24.99	55.65	-	-	-	-	-	-
13-May-11	20:13	-19.081	675.27	25.99	55.64	-	-	-	-	-	-
13-May-11	21:06	-19.088	728.27	26.99	55.63	-	-	-	-	-	-
13-May-11	22:01	-19.100	783.27	27.99	55.62	-	-	-	-	-	-
13-May-11	22:58	-19.110	840.27	28.99	55.61	-	-	-	-	-	-
13-May-11	23:57	-19.117	899.27	29.99	55.60	-	-	-	-	-	-
14-May-11	2:01	-19.130	1023.27	31.99	55.59	-	-	-	-	-	-
14-May-11	4:13	-19.138	1155.28	33.99	55.58	-	-	-	-	-	-
14-May-11	6:33	-19.143	1295.28	35.99	55.58	-	-	-	-	-	-
14-May-11	9:01	-19.150	1443.28	37.99	55.57	-	-	-	-	-	-
14-May-11	11:37	-19.171	1599.28	39.99	55.55	-	-	-	-	-	-
14-May-11	14:21	-19.190	1763.28	41.99	55.53	-	-	-	-	-	-
14-May-11	17:13	-19.222	1935.28	43.99	55.50	-	-	-	-	-	-
14-May-11	20:13	-19.241	2115.28	45.99	55.48	-	-	-	-	-	-
14-May-11	23:21	-19.231	2303.28	47.99	55.49	-	-	-	-	-	-
15-May-11	2:37	-19.234	2499.28	49.99	55.48	-	-	-	-	-	-
15-May-11	6:01	-19.232	2703.30	51.99	55.49	-	-	-	-	-	-
15-May-11	9:33	-19.232	2915.32	53.99	55.49	-	-	-	-	-	-
15-May-11	13:13	-19.239	3135.32	55.99	55.48	-	-	-	-	-	-
15-May-11	17:01	-19.261	3363.32	57.99	55.46	-	-	-	-	-	-
15-May-11	20:57	-19.285	3599.32	59.99	55.43	-	-	-	-	-	-
16-May-11	3:06	-19.283	3968.33	62.99	55.44	-	-	-	-	-	-
16-May-11	9:33	-19.281	4355.35	66.00	55.44	-	-	-	-	-	-
16-May-11	16:18	-19.309	4760.35	69.00	55.41	-	-	-	-	-	-
16-May-11	23:21	-19.314	5183.35	72.00	55.41	-	-	-	-	-	-
17-May-11	6:42	-19.305	5624.37	75.00	55.41	-	-	-	-	-	-
17-May-11	14:21	-19.324	6083.37	78.00	55.40	-	-	-	-	-	-
17-May-11	22:18	-19.342	6560.37	81.00	55.38	-	-	-	-	-	-
18-May-11	6:33	-19.326	7055.37	84.00	55.39	-	-	-	-	-	-
18-May-11	15:06	-19.348	7568.40	87.00	55.37	-	-	-	-	-	-
18-May-11	23:57	-19.352	8099.42	90.00	55.37	-	-	-	-	-	-
19-May-11	9:06	-19.353	8648.42	93.00	55.37	-	-	-	-	-	-
19-May-11	18:33	-19.351	9215.43	96.00	55.37	-	-	-	-	-	-
20-May-11	4:18	-19.358	9800.45	99.00	55.36	-	-	-	-	-	-
20-May-11	14:21	-19.369	10403.45	102.00	55.35	-	-	-	-	-	-
21-May-11	0:42	-19.379	11024.45	105.00	55.34	-	-	-	-	-	-
21-May-11	11:21	-19.386	11663.48	108.00	55.33	-	-	-	-	-	-
21-May-11	22:18	-19.399	12320.50	111.00	55.32	-	-	-	-	-	-
22-May-11	9:33	-19.406	12995.52	114.00	55.31	-	-	-	-	-	-
22-May-11	21:06	-19.415	13688.53	117.00	55.30	-	-	-	-	-	-
23-May-11	8:57	-19.417	14399.55	120.00	55.30	-	-	-	-	-	-
23-May-11	21:06	-19.424	15128.55	123.00	55.29	-	-	-	-	-	-

Consolidation Test - Large Strain for Low Solids and Paste Sample

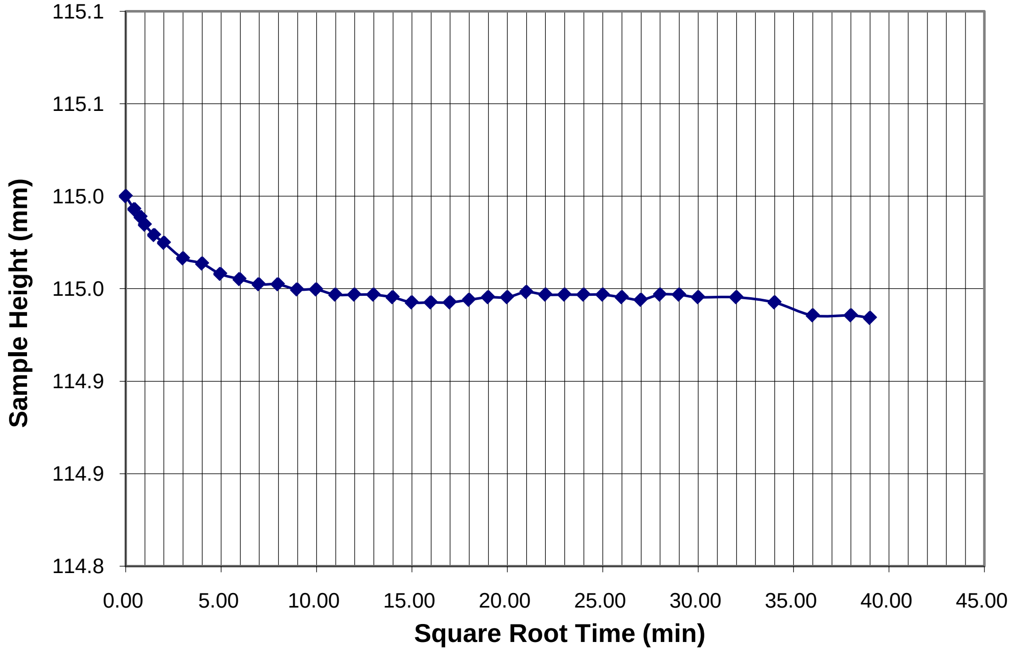
Project Number	11-1359-0001		Initial Water Content	166.28	%	Initial Wet Density	1269.56	kg/m^3
Borehole	BH10-04		Initial Solids Content	37.55	%	Inital Dry Density	476.78	kg/m^3
Sample	SA 17		Sample Diameter	151.78	mm	Initial Void Ratio	4.621	
Depth	13 m		Initial Height	131.00	mm	Initial Saturation	96.43	%
Lab No.	999203		Inital Mass(wet)	3008.96	g	Height of Solids	23.31	mm
INITIAL CELL READINGS:			Mass of Solids	1130.00	g			
Hc	29.7	cm	Specific Gravity	2.68	(assumed)			
Hb	27.2	cm	Sample Area	0.018092	m^2	Final Water Content	38.93	%
Hs	10.6	cm	Sample Volume	0.002370	m^3	Final Height (Measured):	47.60	mm
Hs(after S.W.	9	cm	Self Weight Load	0.408	kPa	Final Mass	1536.67	gm
Load Arm Ratio	13.3 :1		Height _after S.W.	115.00	mm	Final Void Ratio (from ht)	1.042	

Load No.	H_{sample} (mm)	H_{D50} (mm)	t_{50} (min)	Stress (kPa)	Void Ratio	K(measured) (cm/s)	Strain (%)	Dry Density (kg/m^3)
1	114.93			1.55	3.932		12.26	543
2	95.45			3.06	3.096		27.14	654
3	84.13			5.77	2.610		35.78	742
4	82.65			11.20	2.547	1.20E-05	36.90	756
5	62.42			21.53	1.678		52.35	1001
6	58.66			39.56	1.517	1.07E-07	55.22	1065
7	52.28			93.64	1.243		60.09	1195
8	47.76			201.82	1.050	9.08E-08	63.54	1308
9	44.07			418.17	0.891		66.36	1417

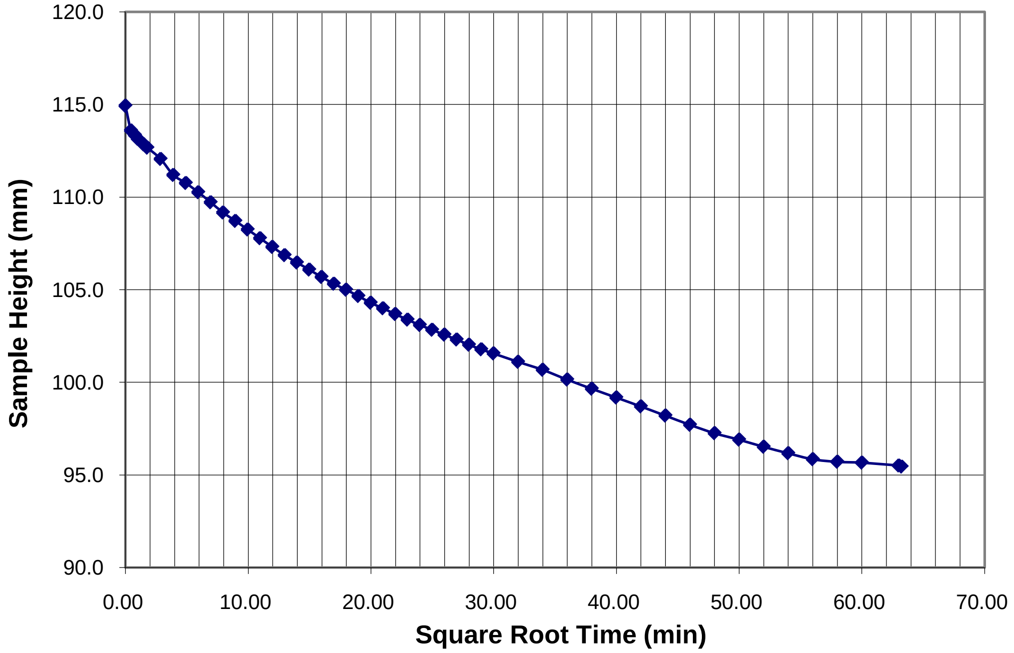
CONSOLIDATION TEST
(ASTM D2435)

Project No.: 11-1359-0001
Lab No.: 999203
BH No.: BH10-04
Sample No.: SA 17
Depth: 13 m

SAMPLE HEIGHT vs. SQUARE ROOT TIME



Total Stress: 1.55 kPa
H_{Sample}: ______ mm
H_{D50}: ______ mm
T_{50}: ______ min

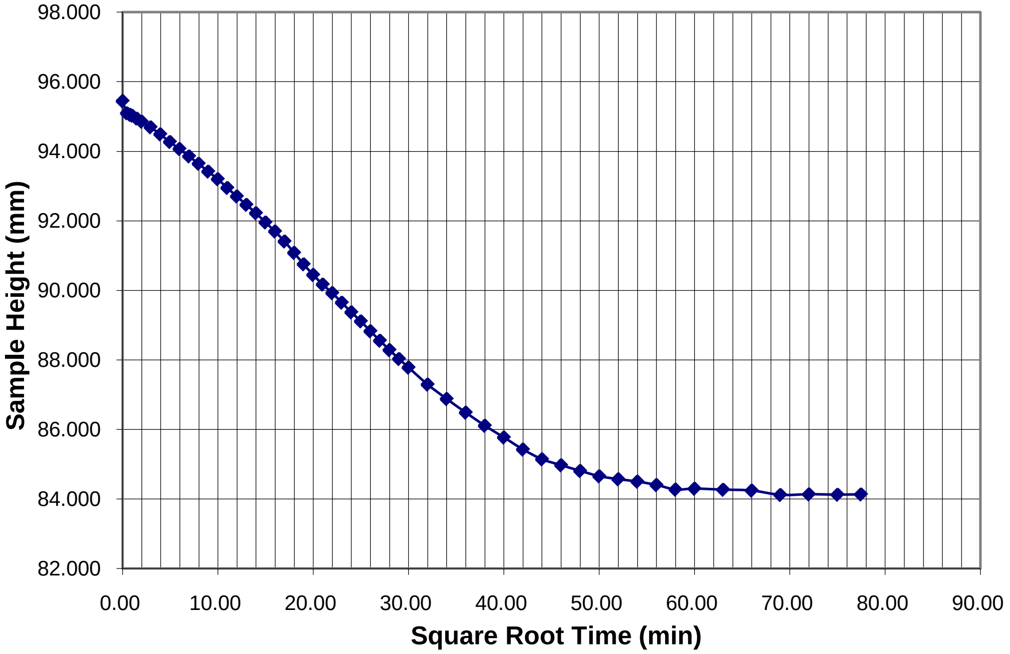


Total Stress: 3.06 kPa
H_{Sample}: ______ mm
H_{D50}: ______ mm
T_{50}: ______ min

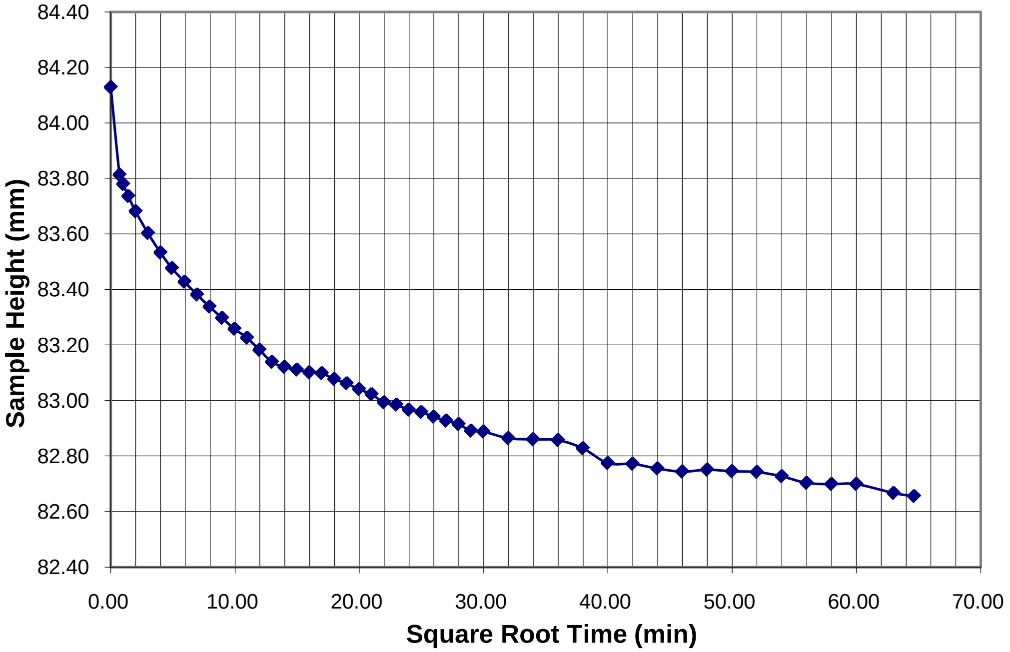
CONSOLIDATION TEST
(ASTM D2435)

Project No.: 11-1359-0001
Lab No.: 999203
BH No.: BH10-04
Sample No.: SA 17
Depth: 13 m

SAMPLE HEIGHT vs. SQUARE ROOT TIME



Total Stress: 5.77 kPa
H_{Sample}: ______ mm
H_{D50}: ______ mm
T_{50}: ______ min

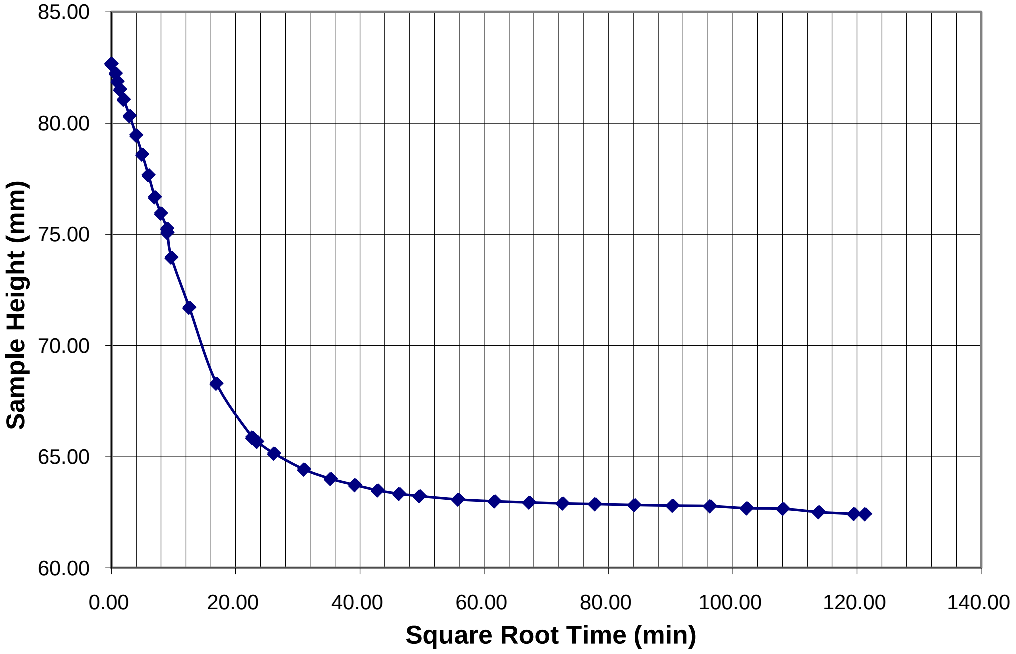


Total Stress: 11.20 kPa
H_{Sample}: ______ mm
H_{D50}: ______ mm
T_{50}: ______ min

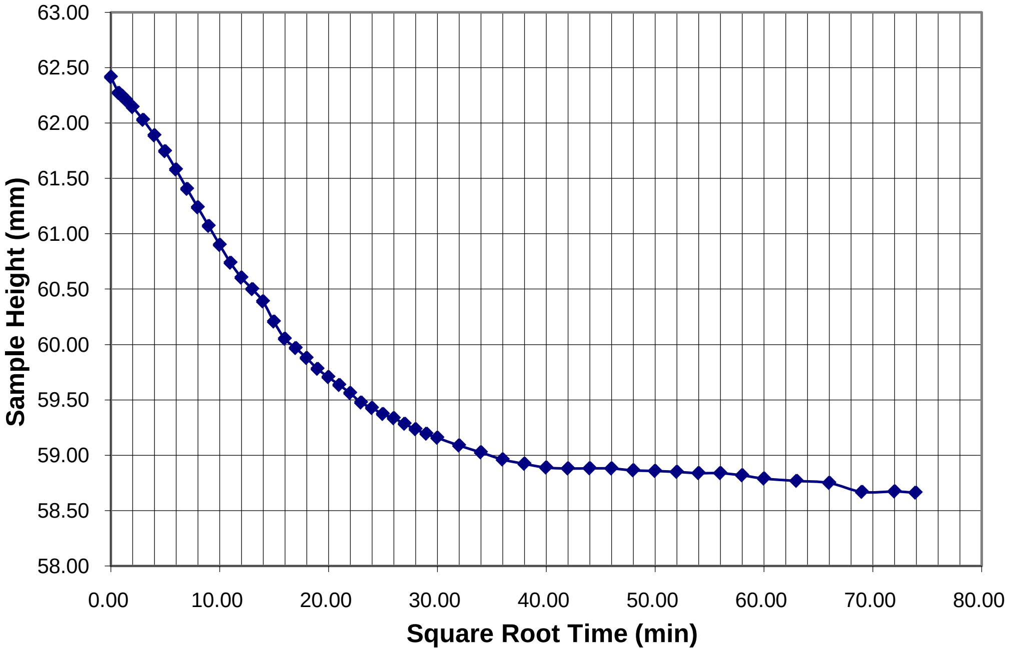
CONSOLIDATION TEST
(ASTM D2435)

Project No.: 11-1359-0001
Lab No.: 999203
BH No.: BH10-04
Sample No.: SA 17
Depth: 13 m

SAMPLE HEIGHT vs. SQUARE ROOT TIME



Total Stress: 21.53 kPa
H_{Sample}: ______ mm
H_{D50}: ______ mm
T_{50}: ______ min



Total Stress: 39.56 kPa
H_{Sample}: ______ mm
H_{D50}: ______ mm
T_{50}: ______ min

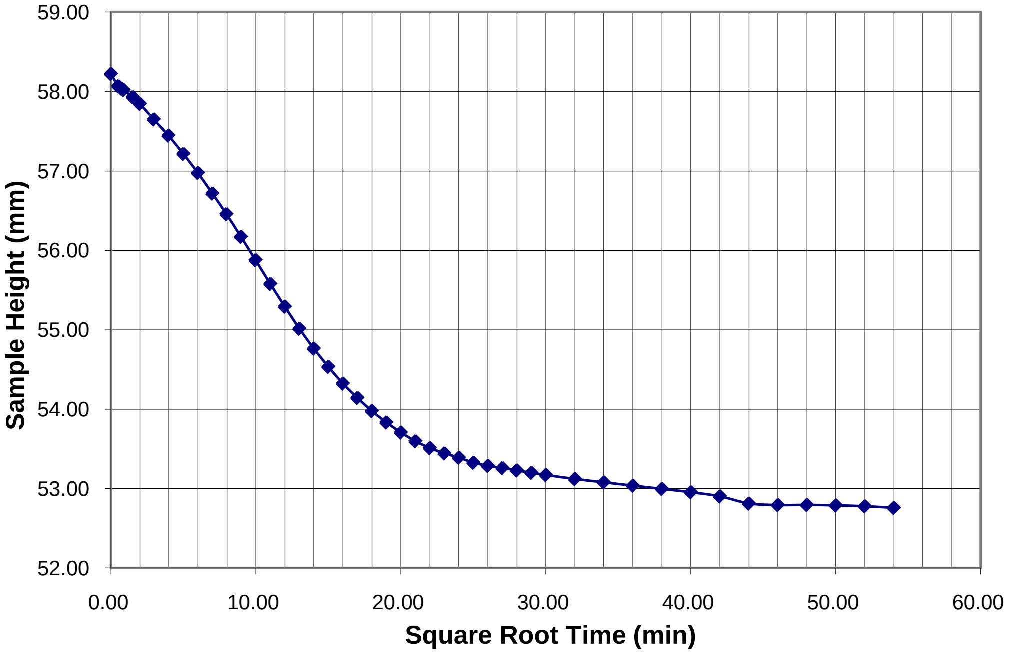
Golder Associates

CONSOLIDATION TEST

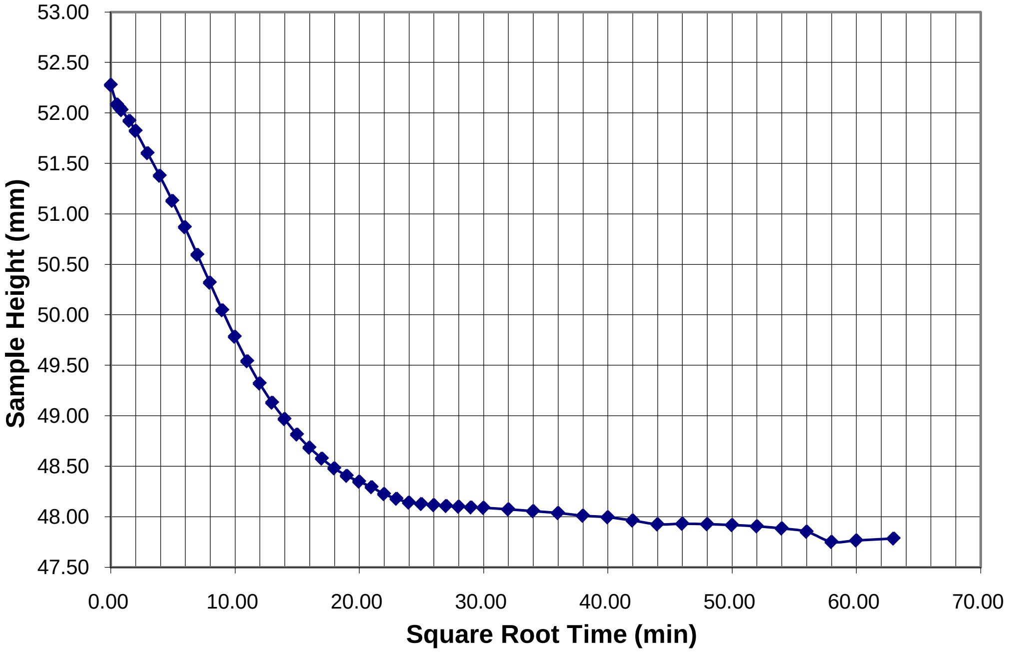
(ASTM D2435)

Project No.: 11-1359-0001
Lab No.: 999203
BH No.: BH10-04
Sample No.: SA 17
Depth: 13 m

SAMPLE HEIGHT vs. SQUARE ROOT TIME



Total Stress: 93.64 kPa
H_{Sample}: ______ mm
H_{D50}: ______ mm
T_{50}: ______ min

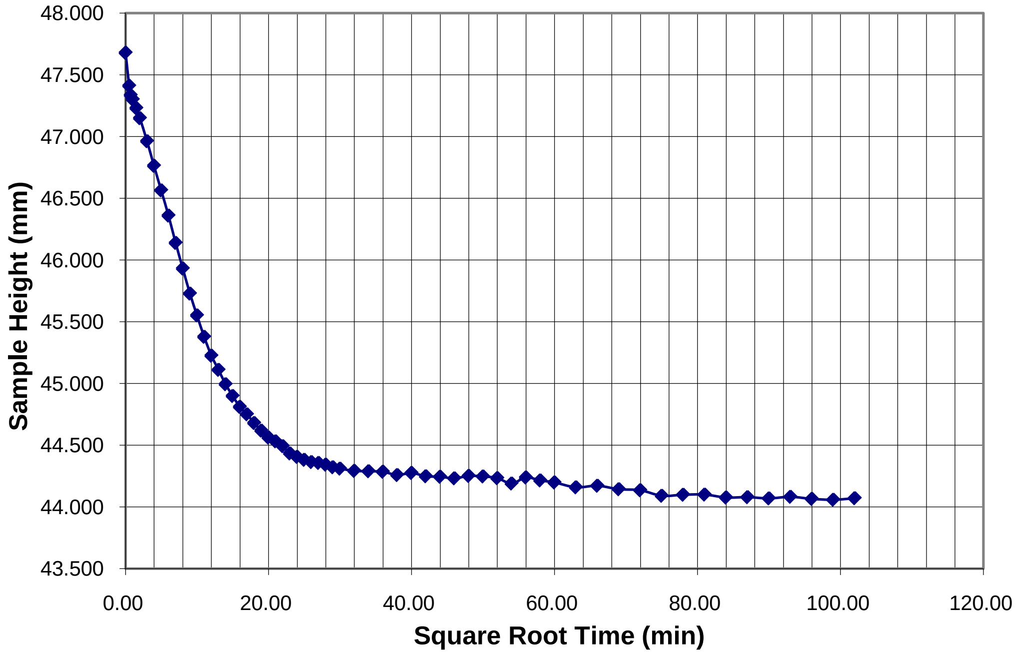


Total Stress: 201.82 kPa
H_{Sample}: ______ mm
H_{D50}: ______ mm
T_{50}: ______ min

CONSOLIDATION TEST
(ASTM D2435)

Project No.: 11-1359-0001
Lab No.: 999203
BH No.: BH10-04
Sample No.: SA 17
Depth: 13 m

SAMPLE HEIGHT vs. SQUARE ROOT TIME

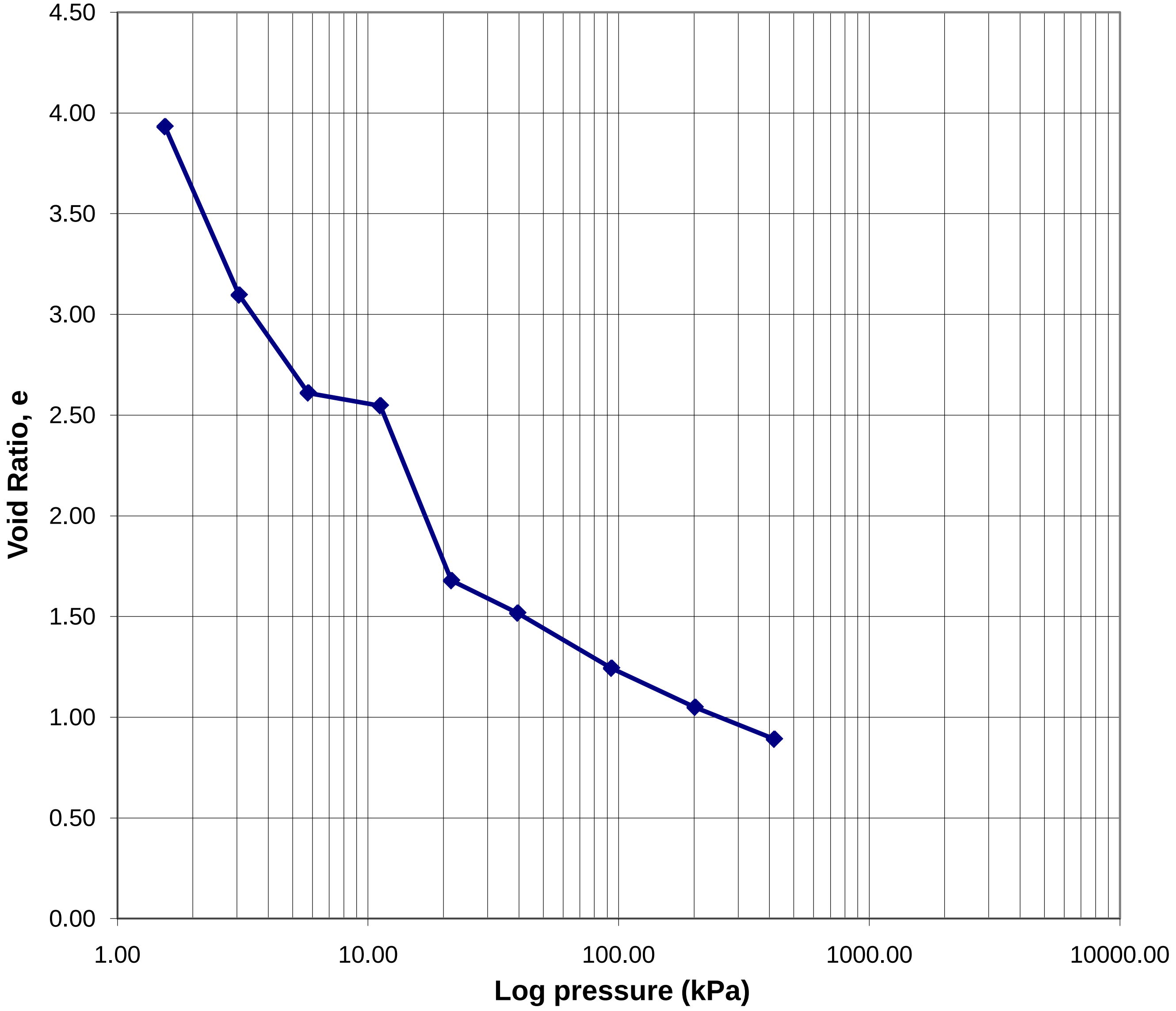


Total Stress: 418.17 kPa
H_{Sample}: ______ mm
H_{D50}: ______ mm
T_{50}: ______ min

CONSOLIDATION TEST
(ASTM D2435)

Project No.: 11-1359-0001
Lab No.: 999203
BH No.: BH10-04
Sample No.: SA 17
Depth: 13 m

Void Ratio vs Log Pressure



Project Number	11-1359-0001		Initial Water Content	166.28	%	Initial Wet Density	1269.56	kg/m^3
Borehole	BH10-04		Initial Solids Content	37.55	%	Inital Dry Density	476.78	kg/m^3
Sample	SA 17		Sample Diameter	151.78	mm	Initial Void Ratio	4.621	
Depth	13 m		Initial Height	131.00	mm	Initial Saturation	96.43	%
Lab No.	999203		Inital Mass(wet)	3008.96	g	Height of Solids	23.31	mm
INITIAL CELL READINGS:			Mass of Solids	1130.00	g			
Hc	29.7	cm	Specific Gravity	2.68	(measured)			
Hb	27.2	cm	Sample Area	0.018092	m^2	Final Water Content	38.93	%
Hs	10.6	cm	Sample Volume	0.002370	m^3	Final Height (Measured):	47.600	mm
Hs(after S.W.)	9	cm	Self Weight Load	0.408	kPa	Final Mass	1536.67	gm
Load Arm Ratio	13.3	:1	Height _after S.W.	115.00	mm	Final Void Ratio (from ht)	1.042	

Load No.	1	
Stress:	1.549	kPa
Add Mass:	2.10372	kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP	Hydraulic Conductivity
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)	(ms/mm^3)	(cm/sec)
03-Mar-11	13:22:09	-12.428	0.00	0.00	115.00	-	-	-	-	-	-
03-Mar-11	13:22:21	-12.435	0.20	0.45	114.99	-	-	-	-	-	-
03-Mar-11	13:22:45	-12.439	0.60	0.77	114.99	-	-	-	-	-	-
03-Mar-11	13:23:09	-12.443	1.00	1.00	114.98	-	-	-	-	-	-
03-Mar-11	13:24:21	-12.449	2.20	1.48	114.98	-	-	-	-	-	-
03-Mar-11	13:26:09	-12.453	4.00	2.00	114.97	-	-	-	-	-	-
03-Mar-11	13:31:09	-12.461	9.00	3.00	114.97	-	-	-	-	-	-
03-Mar-11	13:38:09	-12.464	16.00	4.00	114.96	26.4	27.0	30.7	4.3	-	-
03-Mar-11	13:46:39	-12.470	24.50	4.95	114.96	-	-	-	-	-	-
03-Mar-11	13:57:39	-12.472	35.50	5.96	114.96	-	-	-	-	-	-
03-Mar-11	14:10:39	-12.475	48.50	6.96	114.95	-	-	-	-	-	-
03-Mar-11	14:25:39	-12.475	63.50	7.97	114.95	-	-	-	-	-	-
03-Mar-11	14:42:39	-12.478	80.50	8.97	114.95	-	-	-	-	-	-
03-Mar-11	15:01:39	-12.478	99.50	9.97	114.95	-	-	-	-	-	-
03-Mar-11	15:22:39	-12.481	120.50	10.98	114.95	-	-	-	-	-	-
03-Mar-11	15:45:39	-12.481	143.50	11.98	114.95	-	-	-	-	-	-
03-Mar-11	16:10:39	-12.481	168.50	12.98	114.95	-	-	-	-	-	-
03-Mar-11	16:37:39	-12.482	195.50	13.98	114.95	-	-	-	-	-	-
03-Mar-11	17:06:39	-12.485	224.50	14.98	114.94	-	-	-	-	-	-
03-Mar-11	17:37:39	-12.485	255.50	15.98	114.94	-	-	-	-	-	-
03-Mar-11	18:10:39	-12.485	288.50	16.99	114.94	-	-	-	-	-	-
03-Mar-11	18:45:39	-12.484	323.50	17.99	114.94	-	-	-	-	-	-
03-Mar-11	19:22:39	-12.482	360.50	18.99	114.95	-	-	-	-	-	-
03-Mar-11	20:01:39	-12.482	399.50	19.99	114.95	-	-	-	-	-	-
03-Mar-11	20:42:39	-12.479	440.50	20.99	114.95	-	-	-	-	-	-
03-Mar-11	21:25:39	-12.481	483.50	21.99	114.95	-	-	-	-	-	-
03-Mar-11	22:10:39	-12.481	528.50	22.99	114.95	-	-	-	-	-	-
03-Mar-11	22:57:39	-12.481	575.50	23.99	114.95	-	-	-	-	-	-
03-Mar-11	23:46:39	-12.481	624.50	24.99	114.95	-	-	-	-	-	-
04-Mar-11	0:37:39	-12.482	675.50	25.99	114.95	-	-	-	-	-	-
04-Mar-11	1:30:39	-12.484	728.50	26.99	114.94	-	-	-	-	-	-
04-Mar-11	2:25:39	-12.481	783.50	27.99	114.95	-	-	-	-	-	-
04-Mar-11	3:22:40	-12.481	840.52	28.99	114.95	-	-	-	-	-	-
04-Mar-11	4:21:40	-12.482	899.52	29.99	114.95	-	-	-	-	-	-
04-Mar-11	6:25:40	-12.482	1023.52	31.99	114.95	-	-	-	-	-	-
04-Mar-11	8:37:40	-12.485	1155.52	33.99	114.94	-	-	-	-	-	-
04-Mar-11	10:57:40	-12.492	1295.52	35.99	114.94	26.3	28.7	29.4	3.1	-	-
04-Mar-11	13:25:40	-12.492	1443.52	37.99	114.94	-	-	-	-	-	-
04-Mar-11	14:42:40	-12.493	1520.52	38.99	114.93	26.4	28.8	29.4	3.0	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-
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						-	-	-	-	-	-
						-	-	-	-	-	-

Load No. 2
Stress: 3.1 kPa
Add Mass: 2.791 kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE TOP (cm)	PRESSURE MIDDLE (cm)	PRESSURE BOTTOM (cm)	PRESSURE h_L (cm)	RAMP (ms/mm^3)	Hydraulic Conductivity (cm/sec)
04-Mar-11	15:05:46	-12.496	0.00	0.00	114.93	26.4	28.8	29.4	3.0	-	-
04-Mar-11	15:05:58	-13.826	0.20	0.45	113.60	-	-	-	-	-	-
04-Mar-11	15:06:22	-14.079	0.60	0.77	113.35	-	-	-	-	-	-
04-Mar-11	15:06:46	-14.273	1.00	1.00	113.15	-	-	-	-	-	-
04-Mar-11	15:07:58	-14.578	2.20	1.48	112.85	-	-	-	-	-	-
04-Mar-11	15:08:58	-14.763	3.20	1.79	112.67	-	-	-	-	-	-
04-Mar-11	15:13:58	-15.369	8.20	2.86	112.06	-	-	-	-	-	-
04-Mar-11	15:20:58	-16.233	15.20	3.90	111.19	-	-	-	-	-	-
04-Mar-11	15:29:58	-16.667	24.20	4.92	110.76	-	-	-	-	-	-
04-Mar-11	15:40:58	-17.165	35.20	5.93	110.26	-	-	-	-	-	-
04-Mar-11	15:53:58	-17.709	48.20	6.94	109.72	-	-	-	-	-	-
04-Mar-11	16:08:58	-18.259	63.20	7.95	109.17	-	-	-	-	-	-
04-Mar-11	16:25:58	-18.714	80.20	8.96	108.71	-	-	-	-	-	-
04-Mar-11	16:44:58	-19.177	99.20	9.96	108.25	-	-	-	-	-	-
04-Mar-11	17:05:58	-19.647	120.20	10.96	107.78	-	-	-	-	-	-
04-Mar-11	17:28:58	-20.116	143.20	11.97	107.31	-	-	-	-	-	-
04-Mar-11	17:53:58	-20.562	168.20	12.97	106.87	-	-	-	-	-	-
04-Mar-11	18:20:58	-20.960	195.20	13.97	106.47	-	-	-	-	-	-
04-Mar-11	18:49:58	-21.341	224.20	14.97	106.09	-	-	-	-	-	-
04-Mar-11	19:20:58	-21.738	255.20	15.97	105.69	-	-	-	-	-	-
04-Mar-11	19:53:58	-22.104	288.20	16.98	105.32	-	-	-	-	-	-
04-Mar-11	20:28:58	-22.428	323.20	17.98	105.00	-	-	-	-	-	-
04-Mar-11	21:05:58	-22.768	360.20	18.98	104.66	-	-	-	-	-	-
04-Mar-11	21:44:58	-23.130	399.20	19.98	104.30	-	-	-	-	-	-
04-Mar-11	22:25:58	-23.428	440.20	20.98	104.00	-	-	-	-	-	-
04-Mar-11	23:08:58	-23.740	483.20	21.98	103.69	-	-	-	-	-	-
04-Mar-11	23:53:58	-24.042	528.20	22.98	103.39	-	-	-	-	-	-
05-Mar-11	0:40:58	-24.330	575.20	23.98	103.10	-	-	-	-	-	-
05-Mar-11	1:29:58	-24.589	624.20	24.98	102.84	-	-	-	-	-	-
05-Mar-11	2:20:59	-24.852	675.22	25.98	102.58	-	-	-	-	-	-
05-Mar-11	3:13:59	-25.116	728.22	26.99	102.31	-	-	-	-	-	-
05-Mar-11	4:08:59	-25.395	783.22	27.99	102.03	-	-	-	-	-	-
05-Mar-11	5:05:59	-25.644	840.22	28.99	101.78	-	-	-	-	-	-
05-Mar-11	6:04:59	-25.866	899.22	29.99	101.56	-	-	-	-	-	-
05-Mar-11	8:08:59	-26.318	1023.22	31.99	101.11	-	-	-	-	-	-
05-Mar-11	10:20:59	-26.749	1155.22	33.99	100.68	-	-	-	-	-	-
05-Mar-11	12:40:59	-27.277	1295.22	35.99	100.15	-	-	-	-	-	-
05-Mar-11	15:08:59	-27.770	1443.22	37.99	99.66	-	-	-	-	-	-
05-Mar-11	17:44:59	-28.245	1599.22	39.99	99.18	-	-	-	-	-	-
05-Mar-11	20:29:00	-28.725	1763.23	41.99	98.70	-	-	-	-	-	-
05-Mar-11	23:21:00	-29.221	1935.23	43.99	98.21	-	-	-	-	-	-
06-Mar-11	2:21:00	-29.717	2115.23	45.99	97.71	-	-	-	-	-	-
06-Mar-11	5:29:00	-30.170	2303.23	47.99	97.26	-	-	-	-	-	-
06-Mar-11	8:45:00	-30.519	2499.23	49.99	96.91	-	-	-	-	-	-
06-Mar-11	12:09:01	-30.903	2703.25	51.99	96.52	-	-	-	-	-	-
06-Mar-11	15:41:01	-31.252	2915.25	53.99	96.18	-	-	-	-	-	-
06-Mar-11	19:21:01	-31.576	3135.25	55.99	95.85	-	-	-	-	-	-
06-Mar-11	23:09:01	-31.713	3363.25	57.99	95.71	-	-	-	-	-	-
07-Mar-11	3:05:01	-31.761	3599.25	59.99	95.67	-	-	-	-	-	-
07-Mar-11	9:14:01	-31.915	3968.25	62.99	95.51	33.0	33.4	33.8	0.8	-	-
07-Mar-11	9:44:01	-31.976	3998.25	63.23	95.45	-	-	-	-	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-
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						-	-	-	-	-	-

Load No. 3
Stress: 5.8 kPa
Add Mass: 5 kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP	Hydraulic Conductivity
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)	(ms/mm^3)	(cm/sec)
07-Mar-11	9:49	-31.985	0.00	0.00	95.44	33.0	33.4	30.8	-2.2	-	-
07-Mar-11	9:50	-32.334	0.20	0.45	95.09	-	-	-	-	-	-
07-Mar-11	9:50	-32.376	0.60	0.77	95.05	-	-	-	-	-	-
07-Mar-11	9:50	-32.405	1.00	1.00	95.02	-	-	-	-	-	-
07-Mar-11	9:52	-32.487	2.20	1.48	94.94	33.8	34.5	55.7	21.9	-	-
07-Mar-11	9:53	-32.576	4.00	2.00	94.85	-	-	-	-	-	-
07-Mar-11	9:58	-32.737	8.60	2.93	94.69	-	-	-	-	-	-
07-Mar-11	10:05	-32.939	15.60	3.95	94.49	-	-	-	-	-	-
07-Mar-11	10:14	-33.159	24.60	4.96	94.27	-	-	-	-	-	-
07-Mar-11	10:25	-33.361	35.60	5.97	94.07	-	-	-	-	-	-
07-Mar-11	10:38	-33.574	48.60	6.97	93.85	-	-	-	-	-	-
07-Mar-11	10:53	-33.786	63.60	7.97	93.64	-	-	-	-	-	-
07-Mar-11	11:10	-34.011	80.60	8.98	93.42	-	-	-	-	-	-
07-Mar-11	11:29	-34.230	99.60	9.98	93.20	-	-	-	-	-	-
07-Mar-11	11:50	-34.481	120.60	10.98	92.95	-	-	-	-	-	-
07-Mar-11	12:13	-34.726	143.62	11.98	92.70	-	-	-	-	-	-
07-Mar-11	12:38	-34.967	168.62	12.99	92.46	-	-	-	-	-	-
07-Mar-11	13:05	-35.208	195.62	13.99	92.22	-	-	-	-	-	-
07-Mar-11	13:34	-35.473	224.62	14.99	91.95	-	-	-	-	-	-
07-Mar-11	14:05	-35.734	255.62	15.99	91.69	-	-	-	-	-	-
07-Mar-11	14:38	-36.021	288.62	16.99	91.41	-	-	-	-	-	-
07-Mar-11	15:13	-36.348	323.62	17.99	91.08	-	-	-	-	-	-
07-Mar-11	15:50	-36.677	360.62	18.99	90.75	-	-	-	-	-	-
07-Mar-11	16:29	-36.983	399.62	19.99	90.44	-	-	-	-	-	-
07-Mar-11	17:10	-37.259	440.62	20.99	90.17	-	-	-	-	-	-
07-Mar-11	17:53	-37.506	483.62	21.99	89.92	-	-	-	-	-	-
07-Mar-11	18:38	-37.780	528.62	22.99	89.65	-	-	-	-	-	-
07-Mar-11	19:25	-38.059	575.62	23.99	89.37	-	-	-	-	-	-
07-Mar-11	20:14	-38.318	624.62	24.99	89.11	-	-	-	-	-	-
07-Mar-11	21:05	-38.603	675.62	25.99	88.82	-	-	-	-	-	-
07-Mar-11	21:58	-38.875	728.62	26.99	88.55	-	-	-	-	-	-
07-Mar-11	22:53	-39.144	783.63	27.99	88.28	-	-	-	-	-	-
07-Mar-11	23:50	-39.400	840.63	28.99	88.03	-	-	-	-	-	-
08-Mar-11	0:49	-39.649	899.63	29.99	87.78	-	-	-	-	-	-
08-Mar-11	2:53	-40.136	1023.63	31.99	87.29	-	-	-	-	-	-
08-Mar-11	5:05	-40.551	1155.63	33.99	86.88	-	-	-	-	-	-
08-Mar-11	7:25	-40.944	1295.63	35.99	86.48	-	-	-	-	-	-
08-Mar-11	9:53	-41.321	1443.65	38.00	86.11	-	-	-	-	-	-
08-Mar-11	12:29	-41.658	1599.65	40.00	85.77	-	-	-	-	-	-
08-Mar-11	15:13	-42.005	1763.65	42.00	85.42	-	-	-	-	-	-
08-Mar-11	18:05	-42.286	1935.65	44.00	85.14	-	-	-	-	-	-
08-Mar-11	21:05	-42.457	2115.65	46.00	84.97	-	-	-	-	-	-
09-Mar-11	0:13	-42.621	2303.65	48.00	84.81	-	-	-	-	-	-
09-Mar-11	3:29	-42.774	2499.67	50.00	84.65	-	-	-	-	-	-
09-Mar-11	6:53	-42.859	2703.67	52.00	84.57	-	-	-	-	-	-
09-Mar-11	10:25	-42.928	2915.67	54.00	84.50	-	-	-	-	-	-
09-Mar-11	14:05	-43.026	3135.67	56.00	84.40	30.7	40.1	40.7	10.0	-	-
09-Mar-11	17:53	-43.157	3363.68	58.00	84.27	-	-	-	-	-	-
09-Mar-11	21:49	-43.131	3599.68	60.00	84.30	-	-	-	-	-	-
10-Mar-11	3:58	-43.161	3968.68	63.00	84.27	-	-	-	-	-	-
10-Mar-11	10:25	-43.186	4355.68	66.00	84.24	30.0	38.1	30.3	0.3	-	-
10-Mar-11	17:10	-43.311	4760.72	69.00	84.12	-	-	-	-	-	-
11-Mar-11	0:13	-43.294	5183.72	72.00	84.13	-	-	-	-	-	-
11-Mar-11	7:34	-43.304	5624.72	75.00	84.12	-	-	-	-	-	-
11-Mar-11	13:49	-43.295	5999.73	77.46	84.13	29.2	37.8	29.3	0.1	-	-
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Load No. 4
Stress: 11.2 kPa
Add Mass: 10 kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP	Hydraulic Conductivity (cm/sec)
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)	(ms/mm^3)	
11-Mar-11	13:55	-43.300	0.00	0.00	84.13	29.2	37.8	29.3	0.1	-	-
11-Mar-11	13:56	-43.615	0.50	0.71	83.81	-	-	-	-	-	-
11-Mar-11	13:56	-43.649	1.00	1.00	83.78	-	-	-	-	-	-
11-Mar-11	13:57	-43.692	2.00	1.41	83.74	-	-	-	-	-	-
11-Mar-11	13:59	-43.747	4.00	2.00	83.68	-	-	-	-	-	-
11-Mar-11	14:04	-43.825	9.00	3.00	83.60	-	-	-	-	-	-
11-Mar-11	14:11	-43.895	16.00	4.00	83.53	-	-	-	-	-	-
11-Mar-11	14:20	-43.951	24.25	4.92	83.48	-	-	-	-	-	-
11-Mar-11	14:31	-44.000	35.25	5.94	83.43	-	-	-	-	-	-
11-Mar-11	14:44	-44.047	48.25	6.95	83.38	-	-	-	-	-	-
11-Mar-11	14:59	-44.090	63.25	7.95	83.34	-	-	-	-	-	-
11-Mar-11	15:16	-44.131	80.25	8.96	83.30	-	-	-	-	-	-
11-Mar-11	15:35	-44.170	99.25	9.96	83.26	-	-	-	-	-	-
11-Mar-11	15:56	-44.202	120.25	10.97	83.23	-	-	-	-	-	-
11-Mar-11	16:19	-44.246	143.25	11.97	83.18	-	-	-	-	-	-
11-Mar-11	16:44	-44.289	168.25	12.97	83.14	-	-	-	-	-	-
11-Mar-11	17:11	-44.307	195.25	13.97	83.12	-	-	-	-	-	-
11-Mar-11	17:40	-44.317	224.27	14.98	83.11	-	-	-	-	-	-
11-Mar-11	18:11	-44.327	255.27	15.98	83.10	-	-	-	-	-	-
11-Mar-11	18:44	-44.330	288.27	16.98	83.10	-	-	-	-	-	-
11-Mar-11	19:19	-44.351	323.27	17.98	83.08	-	-	-	-	-	-
11-Mar-11	19:56	-44.366	360.27	18.98	83.06	-	-	-	-	-	-
11-Mar-11	20:35	-44.387	399.27	19.98	83.04	-	-	-	-	-	-
11-Mar-11	21:16	-44.405	440.27	20.98	83.02	-	-	-	-	-	-
11-Mar-11	21:59	-44.435	483.27	21.98	82.99	-	-	-	-	-	-
11-Mar-11	22:44	-44.443	528.27	22.98	82.98	-	-	-	-	-	-
11-Mar-11	23:31	-44.461	575.27	23.98	82.97	-	-	-	-	-	-
12-Mar-11	0:20	-44.470	624.27	24.99	82.96	-	-	-	-	-	-
12-Mar-11	1:11	-44.487	675.27	25.99	82.94	-	-	-	-	-	-
12-Mar-11	2:04	-44.501	728.27	26.99	82.93	-	-	-	-	-	-
12-Mar-11	2:59	-44.513	783.27	27.99	82.91	-	-	-	-	-	-
12-Mar-11	3:56	-44.537	840.27	28.99	82.89	-	-	-	-	-	-
12-Mar-11	4:55	-44.540	899.27	29.99	82.89	-	-	-	-	-	-
12-Mar-11	6:59	-44.564	1023.27	31.99	82.86	-	-	-	-	-	-
12-Mar-11	9:11	-44.568	1155.27	33.99	82.86	-	-	-	-	-	-
12-Mar-11	11:31	-44.571	1295.28	35.99	82.86	-	-	-	-	-	-
12-Mar-11	13:59	-44.600	1443.28	37.99	82.83	-	-	-	-	-	-
12-Mar-11	16:35	-44.653	1599.28	39.99	82.77	-	-	-	-	-	-
12-Mar-11	19:19	-44.656	1763.28	41.99	82.77	-	-	-	-	-	-
12-Mar-11	22:11	-44.673	1935.28	43.99	82.75	-	-	-	-	-	-
13-Mar-11	1:11	-44.684	2115.28	45.99	82.74	-	-	-	-	-	-
13-Mar-11	4:19	-44.677	2303.28	47.99	82.75	-	-	-	-	-	-
13-Mar-11	7:35	-44.683	2499.28	49.99	82.74	-	-	-	-	-	-
13-Mar-11	10:59	-44.686	2703.28	51.99	82.74	-	-	-	-	-	-
13-Mar-11	14:31	-44.701	2915.28	53.99	82.73	-	-	-	-	-	-
13-Mar-11	18:11	-44.725	3135.32	55.99	82.70	-	-	-	-	-	-
13-Mar-11	21:59	-44.729	3363.32	57.99	82.70	-	-	-	-	-	-
14-Mar-11	1:55	-44.729	3599.33	59.99	82.70	-	-	-	-	-	-
14-Mar-11	8:04	-44.761	3968.33	62.99	82.67	-	-	-	-	-	-
14-Mar-11	11:35	-44.773	4179.33	64.65	82.65	28.6	37.1	29.6	1.0	-	-
						-	-	-	-	-	-
Perm						-	-	-	-	-	-
16-Mar-11	15:15	-44.773	7279.15	85.32	82.65	28.4	-	41.0	12.6	3500.00	1.04E-05
16-Mar-11	17:52	-44.773	7436.15	86.23	82.65	28.5	-	39.2	10.7	3500.00	1.22E-05
17-Mar-11	6:50	-44.773	8214.15	90.63	82.65	28.4	-	38.1	9.7	3500.00	1.35E-05
17-Mar-11	13:39	-44.773	8623.15	92.86	82.65	28.4	-	38.4	10.0	3500.00	1.31E-05
17-Mar-11	17:40	-44.773	8864.15	94.15	82.65	28.3	-	40.2	11.9	3500.00	1.10E-05
18-Mar-11	11:48	-44.773	9952.15	99.76	82.65	28.3	-	39.2	10.9	3500.00	1.20E-05
						-	-	-	-	**Average :**	**1.20E-05**
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Load No. 5
Stress: 21.5 kPa
Add Mass: 2.5 kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP (ms/mm^3)	Hydraulic Conductivity (cm/sec)
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)		
18-Mar-11	14:28	-15.039	0.00	0.00	82.65	-	-	-	-	-	-
18-Mar-11	14:28	-15.039	0.00	0.00	82.65	-	-	-	-	-	-
18-Mar-11	14:29	-15.472	0.50	0.71	82.22	-	-	-	-	-	-
18-Mar-11	14:29	-15.835	1.00	1.00	81.86	-	-	-	-	-	-
18-Mar-11	14:30	-16.192	2.00	1.41	81.50	-	-	-	-	-	-
18-Mar-11	14:32	-16.646	4.00	2.00	81.05	-	-	-	-	-	-
18-Mar-11	14:37	-17.379	8.75	2.96	80.31	-	-	-	-	-	-
18-Mar-11	14:44	-18.244	16.00	4.00	79.45	-	-	-	-	-	-
18-Mar-11	14:53	-19.109	24.75	4.97	78.58	-	-	-	-	-	-
18-Mar-11	15:04	-20.038	35.75	5.98	77.66	-	-	-	-	-	-
18-Mar-11	15:17	-21.030	49.00	7.00	76.66	-	-	-	-	-	-
18-Mar-11	15:32	-21.758	63.75	7.98	75.94	-	-	-	-	-	-
18-Mar-11	15:49	-22.442	80.75	8.99	75.25	-	-	-	-	-	-
21-Mar-11	9:28	-22.627	81.48	9.03	75.07	-	-	-	-	-	-
21-Mar-11	9:40	-23.741	93.48	9.67	73.95	-	-	-	-	-	-
21-Mar-11	10:44	-25.995	157.48	12.55	71.70	-	-	-	-	-	-
21-Mar-11	12:53	-29.410	286.48	16.93	68.28	-	-	-	-	-	-
21-Mar-11	16:40	-31.828	513.50	22.66	65.87	-	-	-	-	-	-
21-Mar-11	16:41	-4.463	514.50	22.68	65.87	-	-	-	-	-	-
21-Mar-11	17:17	-4.662	550.50	23.46	65.67	-	-	-	-	-	-
21-Mar-11	19:32	-5.184	685.50	26.18	65.14	-	-	-	-	-	-
22-Mar-11	0:08	-5.902	961.50	31.01	64.43	-	-	-	-	-	-
22-Mar-11	4:52	-6.325	1245.52	35.29	64.00	-	-	-	-	-	-
22-Mar-11	9:44	-6.604	1537.52	39.21	63.72	-	-	-	-	-	-
22-Mar-11	14:44	-6.845	1837.52	42.87	63.48	-	-	-	-	-	-
22-Mar-11	19:52	-6.999	2145.52	46.32	63.33	-	-	-	-	-	-
23-Mar-11	1:08	-7.103	2461.53	49.61	63.23	-	-	-	-	-	-
23-Mar-11	12:04	-7.254	3117.53	55.83	63.07	-	-	-	-	-	-
23-Mar-11	23:32	-7.337	3805.57	61.69	62.99	-	-	-	-	-	-
24-Mar-11	11:32	-7.388	4525.58	67.27	62.94	-	-	-	-	-	-
25-Mar-11	0:04	-7.432	5277.60	72.65	62.90	-	-	-	-	-	-
25-Mar-11	13:08	-7.460	6061.62	77.86	62.87	-	-	-	-	-	-
26-Mar-11	6:13	-7.503	7086.62	84.18	62.83	-	-	-	-	-	-
27-Mar-11	0:08	-7.531	8161.67	90.34	62.80	-	-	-	-	-	-
27-Mar-11	18:53	-7.553	9286.68	96.37	62.78	-	-	-	-	-	-
28-Mar-11	14:28	-7.647	10461.70	102.28	62.68	-	-	-	-	-	-
29-Mar-11	10:53	-7.674	11686.72	108.11	62.65	-	-	-	-	-	-
30-Mar-11	8:08	-7.821	12961.75	113.85	62.51	-	-	-	-	-	-
31-Mar-11	6:13	-7.902	14286.78	119.53	62.43	-	-	-	-	-	-
31-Mar-11	13:21	-7.910	14714.80	121.30	62.42	-	-	-	-	-	-
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Load No.	6	
Stress:	39.6	kPa
Add Mass:	2.5	kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP	Hydraulic Conductivity
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)	(ms/mm^3)	(cm/sec)
31-Mar-11	13:24	-7.912	0.00	0.00	62.42	-	-	-	-	-	-
31-Mar-11	13:25	-8.055	0.50	0.71	62.27	-	-	-	-	-	-
31-Mar-11	13:25	-8.080	1.00	1.00	62.25	-	-	-	-	-	-
31-Mar-11	13:26	-8.121	2.00	1.41	62.21	-	-	-	-	-	-
31-Mar-11	13:28	-8.184	4.00	2.00	62.14	-	-	-	-	-	-
31-Mar-11	13:33	-8.299	8.75	2.96	62.03	-	-	-	-	-	-
31-Mar-11	13:40	-8.439	16.00	4.00	61.89	-	-	-	-	-	-
31-Mar-11	13:49	-8.582	24.75	4.97	61.75	-	-	-	-	-	-
31-Mar-11	14:00	-8.747	35.75	5.98	61.58	-	-	-	-	-	-
31-Mar-11	14:13	-8.922	49.00	7.00	61.41	-	-	-	-	-	-
31-Mar-11	14:28	-9.089	63.75	7.98	61.24	-	-	-	-	-	-
31-Mar-11	14:45	-9.257	80.75	8.99	61.07	-	-	-	-	-	-
31-Mar-11	15:04	-9.428	100.00	10.00	60.90	-	-	-	-	-	-
31-Mar-11	15:25	-9.589	120.75	10.99	60.74	-	-	-	-	-	-
31-Mar-11	15:48	-9.724	143.75	11.99	60.60	-	-	-	-	-	-
31-Mar-11	16:13	-9.828	168.75	12.99	60.50	-	-	-	-	-	-
31-Mar-11	16:40	-9.938	195.25	13.97	60.39	-	-	-	-	-	-
31-Mar-11	17:09	-10.121	224.25	14.97	60.21	-	-	-	-	-	-
31-Mar-11	17:40	-10.276	255.25	15.98	60.05	-	-	-	-	-	-
31-Mar-11	18:13	-10.360	288.25	16.98	59.97	-	-	-	-	-	-
31-Mar-11	18:48	-10.450	323.25	17.98	59.88	-	-	-	-	-	-
31-Mar-11	19:25	-10.548	360.25	18.98	59.78	-	-	-	-	-	-
31-Mar-11	20:04	-10.622	399.25	19.98	59.71	-	-	-	-	-	-
31-Mar-11	20:45	-10.694	440.25	20.98	59.63	-	-	-	-	-	-
31-Mar-11	21:28	-10.767	483.25	21.98	59.56	-	-	-	-	-	-
31-Mar-11	22:13	-10.852	528.25	22.98	59.48	-	-	-	-	-	-
31-Mar-11	23:00	-10.901	575.25	23.98	59.43	-	-	-	-	-	-
31-Mar-11	23:49	-10.956	624.25	24.98	59.37	-	-	-	-	-	-
01-Apr-11	0:40	-10.994	675.25	25.99	59.33	-	-	-	-	-	-
01-Apr-11	1:33	-11.044	728.25	26.99	59.28	-	-	-	-	-	-
01-Apr-11	2:28	-11.093	783.25	27.99	59.24	-	-	-	-	-	-
01-Apr-11	3:25	-11.134	840.25	28.99	59.19	-	-	-	-	-	-
01-Apr-11	4:24	-11.170	899.25	29.99	59.16	-	-	-	-	-	-
01-Apr-11	6:28	-11.240	1023.25	31.99	59.09	-	-	-	-	-	-
01-Apr-11	8:40	-11.302	1155.25	33.99	59.03	-	-	-	-	-	-
01-Apr-11	11:00	-11.367	1295.25	35.99	58.96	-	-	-	-	-	-
01-Apr-11	13:28	-11.406	1443.25	37.99	58.92	-	-	-	-	-	-
01-Apr-11	16:04	-11.439	1599.28	39.99	58.89	-	-	-	-	-	-
01-Apr-11	18:48	-11.448	1763.28	41.99	58.88	-	-	-	-	-	-
01-Apr-11	21:40	-11.446	1935.28	43.99	58.88	-	-	-	-	-	-
02-Apr-11	0:40	-11.448	2115.28	45.99	58.88	-	-	-	-	-	-
02-Apr-11	3:48	-11.465	2303.28	47.99	58.86	-	-	-	-	-	-
02-Apr-11	7:04	-11.470	2499.30	49.99	58.86	-	-	-	-	-	-
02-Apr-11	10:28	-11.479	2703.30	51.99	58.85	-	-	-	-	-	-
02-Apr-11	14:00	-11.490	2915.30	53.99	58.84	-	-	-	-	-	-
02-Apr-11	17:40	-11.490	3135.30	55.99	58.84	-	-	-	-	-	-
02-Apr-11	21:28	-11.510	3363.32	57.99	58.82	-	-	-	-	-	-
03-Apr-11	1:24	-11.539	3599.32	59.99	58.79	-	-	-	-	-	-
03-Apr-11	7:33	-11.560	3968.33	62.99	58.77	-	-	-	-	-	-
03-Apr-11	14:00	-11.578	4355.33	65.99	58.75	-	-	-	-	-	-
03-Apr-11	20:45	-11.660	4760.33	69.00	58.67	-	-	-	-	-	-
04-Apr-11	3:48	-11.655	5183.33	72.00	58.67	-	-	-	-	-	-
04-Apr-11	8:30	-11.667	5465.35	73.93	58.66	-	-	-	-	-	-
						-	-	-	-	-	-
Perm						-	-	-	-	-	-
04-Apr-11	11:50	-11.667	5665.08	75.27	58.66	28.1	34.0	65.6	37.5	3500.00	2.47E-07
06-Apr-11	11:53	-11.667	8548.08	92.46	58.66	28.2	34.7	120.0	91.8	3500.00	1.01E-07
06-Apr-11	17:47	-11.667	8902.08	94.35	58.66	28.1	34.5	120.0	91.9	3500.00	1.01E-07
07-Apr-11	6:35	-11.667	9670.08	98.34	58.66	28.1	34.5	112.4	84.3	3500.00	1.10E-07
07-Apr-11	10:08	-11.667	9883.08	99.41	58.66	28.1	34.5	112.4	84.3	3500.00	1.10E-07
						-	-	-	-	**Average:**	**1.07E-07**
						-	-	-	-	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-

Load No. 7
Stress: 93.6 kPa
Add Mass: 7.5 kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP (ms/mm^3)	Hydraulic Conductivity (cm/sec)
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)		
19-Apr-11	9:35	-12.108	0.00	0.00	58.22	-	-	-	-	-	-
19-Apr-11	9:36	-12.261	0.25	0.50	58.07	-	-	-	-	-	-
19-Apr-11	9:36	-12.289	0.50	0.71	58.04	-	-	-	-	-	-
19-Apr-11	9:36	-12.310	0.75	0.87	58.02	-	-	-	-	-	-
19-Apr-11	9:38	-12.398	2.25	1.50	57.93	-	-	-	-	-	-
19-Apr-11	9:39	-12.484	4.00	2.00	57.84	-	-	-	-	-	-
19-Apr-11	9:44	-12.680	8.75	2.96	57.65	-	-	-	-	-	-
19-Apr-11	9:51	-12.883	15.75	3.97	57.45	-	-	-	-	-	-
19-Apr-11	10:00	-13.114	25.00	5.00	57.21	-	-	-	-	-	-
19-Apr-11	10:11	-13.354	36.00	6.00	56.97	-	-	-	-	-	-
19-Apr-11	10:24	-13.613	49.00	7.00	56.72	-	-	-	-	-	-
19-Apr-11	10:39	-13.873	63.50	7.97	56.46	-	-	-	-	-	-
19-Apr-11	10:56	-14.158	80.50	8.97	56.17	-	-	-	-	-	-
19-Apr-11	11:15	-14.451	99.50	9.97	55.88	-	-	-	-	-	-
19-Apr-11	11:36	-14.751	120.92	11.00	55.58	-	-	-	-	-	-
19-Apr-11	11:59	-15.037	143.92	12.00	55.29	-	-	-	-	-	-
19-Apr-11	12:24	-15.315	168.92	13.00	55.01	-	-	-	-	-	-
19-Apr-11	12:51	-15.566	195.92	14.00	54.76	-	-	-	-	-	-
19-Apr-11	13:20	-15.796	224.92	15.00	54.53	-	-	-	-	-	-
19-Apr-11	13:51	-16.006	255.92	16.00	54.32	-	-	-	-	-	-
19-Apr-11	14:24	-16.187	288.92	17.00	54.14	-	-	-	-	-	-
19-Apr-11	14:59	-16.352	323.92	18.00	53.98	-	-	-	-	-	-
19-Apr-11	15:36	-16.495	360.92	19.00	53.83	-	-	-	-	-	-
19-Apr-11	16:15	-16.622	399.92	20.00	53.71	-	-	-	-	-	-
19-Apr-11	16:56	-16.732	440.93	21.00	53.60	-	-	-	-	-	-
19-Apr-11	17:39	-16.819	483.93	22.00	53.51	-	-	-	-	-	-
19-Apr-11	18:24	-16.885	528.93	23.00	53.44	-	-	-	-	-	-
19-Apr-11	19:11	-16.939	575.93	24.00	53.39	-	-	-	-	-	-
19-Apr-11	20:00	-17.002	624.93	25.00	53.33	-	-	-	-	-	-
19-Apr-11	20:51	-17.043	675.95	26.00	53.29	-	-	-	-	-	-
19-Apr-11	21:44	-17.070	728.95	27.00	53.26	-	-	-	-	-	-
19-Apr-11	22:39	-17.100	783.95	28.00	53.23	-	-	-	-	-	-
19-Apr-11	23:36	-17.130	840.95	29.00	53.20	-	-	-	-	-	-
20-Apr-11	0:35	-17.158	899.95	30.00	53.17	-	-	-	-	-	-
20-Apr-11	2:39	-17.208	1023.95	32.00	53.12	-	-	-	-	-	-
20-Apr-11	4:51	-17.250	1155.95	34.00	53.08	-	-	-	-	-	-
20-Apr-11	7:11	-17.292	1295.95	36.00	53.04	-	-	-	-	-	-
20-Apr-11	9:39	-17.333	1443.97	38.00	53.00	-	-	-	-	-	-
20-Apr-11	12:15	-17.375	1599.95	40.00	52.95	-	-	-	-	-	-
20-Apr-11	14:59	-17.427	1763.93	42.00	52.90	-	-	-	-	-	-
20-Apr-11	17:51	-17.517	1935.97	44.00	52.81	-	-	-	-	-	-
20-Apr-11	20:51	-17.536	2115.97	46.00	52.79	-	-	-	-	-	-
20-Apr-11	23:59	-17.535	2303.97	48.00	52.79	-	-	-	-	-	-
21-Apr-11	3:15	-17.540	2499.97	50.00	52.79	-	-	-	-	-	-
21-Apr-11	6:39	-17.552	2703.98	52.00	52.78	-	-	-	-	-	-
21-Apr-11	10:11	-17.571	2915.98	54.00	52.76	-	-	-	-	-	-
21-Apr-11	13:51	-17.616	3135.98	56.00	52.71	-	-	-	-	-	-
21-Apr-11	17:39	-17.688	3363.70	58.00	52.64	-	-	-	-	-	-
21-Apr-11	21:35	-17.683	3599.70	60.00	52.64	-	-	-	-	-	-
22-Apr-11	3:44	-17.685	3968.70	63.00	52.64	-	-	-	-	-	-
22-Apr-11	10:11	-17.692	4355.70	66.00	52.64	-	-	-	-	-	-
22-Apr-11	16:56	-17.753	4760.72	69.00	52.57	-	-	-	-	-	-
22-Apr-11	23:59	-17.789	5183.73	72.00	52.54	-	-	-	-	-	-
23-Apr-11	7:20	-17.786	5624.73	75.00	52.54	-	-	-	-	-	-
23-Apr-11	14:59	-17.803	6083.75	78.00	52.53	-	-	-	-	-	-
23-Apr-11	22:56	-17.871	6560.75	81.00	52.46	-	-	-	-	-	-
24-Apr-11	7:11	-17.867	7055.77	84.00	52.46	-	-	-	-	-	-
24-Apr-11	15:44	-17.894	7568.78	87.00	52.43	-	-	-	-	-	-
25-Apr-11	0:35	-17.960	8099.78	90.00	52.37	-	-	-	-	-	-
25-Apr-11	9:44	-17.961	8648.80	93.00	52.37	-	-	-	-	-	-
25-Apr-11	19:11	-18.031	9215.80	96.00	52.30	-	-	-	-	-	-
26-Apr-11	4:56	-17.992	9800.83	99.00	52.34	-	-	-	-	-	-
26-Apr-11	14:59	-18.027	10403.83	102.00	52.30	-	-	-	-	-	-
27-Apr-11	1:20	-18.044	11024.85	105.00	52.28	-	-	-	-	-	-
27-Apr-11	10:28	-18.045	11572.87	107.58	52.28	-	-	-	-	-	-

Load No. 8
Stress: 201.8 kPa
Add Mass: 15 kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP	Hydraulic Conductivity
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)	(ms/mm^3)	(cm/sec)
27-Apr-11	10:39	-18.053	0.00	0.00	52.27	-	-	-	-	-	-
27-Apr-11	10:40	-18.245	0.25	0.50	52.08	-	-	-	-	-	-
27-Apr-11	10:40	-18.278	0.50	0.71	52.05	-	-	-	-	-	-
27-Apr-11	10:40	-18.301	0.75	0.87	52.03	-	-	-	-	-	-
27-Apr-11	10:42	-18.408	2.25	1.50	51.92	-	-	-	-	-	-
27-Apr-11	10:43	-18.508	4.00	2.00	51.82	-	-	-	-	-	-
27-Apr-11	10:48	-18.728	8.75	2.96	51.60	-	-	-	-	-	-
27-Apr-11	10:55	-18.952	15.50	3.94	51.38	-	-	-	-	-	-
27-Apr-11	11:04	-19.200	24.50	4.95	51.13	-	-	-	-	-	-
27-Apr-11	11:15	-19.461	35.50	5.96	50.87	-	-	-	-	-	-
27-Apr-11	11:28	-19.734	48.50	6.96	50.59	-	-	-	-	-	-
27-Apr-11	11:43	-20.010	63.50	7.97	50.32	-	-	-	-	-	-
27-Apr-11	12:00	-20.283	80.50	8.97	50.05	-	-	-	-	-	-
27-Apr-11	12:19	-20.545	99.50	9.97	49.78	-	-	-	-	-	-
27-Apr-11	12:40	-20.788	120.50	10.98	49.54	-	-	-	-	-	-
27-Apr-11	13:03	-21.008	143.50	11.98	49.32	-	-	-	-	-	-
27-Apr-11	13:28	-21.198	168.50	12.98	49.13	-	-	-	-	-	-
27-Apr-11	13:55	-21.361	195.50	13.98	48.97	-	-	-	-	-	-
27-Apr-11	14:24	-21.514	224.50	14.98	48.81	-	-	-	-	-	-
27-Apr-11	14:55	-21.644	255.50	15.98	48.68	-	-	-	-	-	-
27-Apr-11	15:28	-21.752	288.50	16.99	48.58	-	-	-	-	-	-
27-Apr-11	16:03	-21.849	323.50	17.99	48.48	-	-	-	-	-	-
27-Apr-11	16:40	-21.923	360.50	18.99	48.41	-	-	-	-	-	-
27-Apr-11	17:19	-21.981	399.50	19.99	48.35	-	-	-	-	-	-
27-Apr-11	18:00	-22.035	440.50	20.99	48.29	-	-	-	-	-	-
27-Apr-11	18:43	-22.104	483.50	21.99	48.22	-	-	-	-	-	-
27-Apr-11	19:28	-22.150	528.52	22.99	48.18	-	-	-	-	-	-
27-Apr-11	20:15	-22.188	575.52	23.99	48.14	-	-	-	-	-	-
27-Apr-11	21:04	-22.202	624.52	24.99	48.13	-	-	-	-	-	-
27-Apr-11	21:55	-22.213	675.52	25.99	48.12	-	-	-	-	-	-
27-Apr-11	22:48	-22.222	728.52	26.99	48.11	-	-	-	-	-	-
27-Apr-11	23:43	-22.229	783.52	27.99	48.10	-	-	-	-	-	-
28-Apr-11	0:40	-22.236	840.52	28.99	48.09	-	-	-	-	-	-
28-Apr-11	1:39	-22.240	899.52	29.99	48.09	-	-	-	-	-	-
28-Apr-11	3:43	-22.255	1023.52	31.99	48.07	-	-	-	-	-	-
28-Apr-11	5:55	-22.273	1155.52	33.99	48.05	-	-	-	-	-	-
28-Apr-11	8:15	-22.292	1295.52	35.99	48.04	-	-	-	-	-	-
28-Apr-11	10:43	-22.318	1443.52	37.99	48.01	-	-	-	-	-	-
28-Apr-11	13:19	-22.334	1599.52	39.99	47.99	-	-	-	-	-	-
28-Apr-11	16:03	-22.366	1763.53	41.99	47.96	-	-	-	-	-	-
28-Apr-11	18:55	-22.404	1935.53	43.99	47.92	-	-	-	-	-	-
28-Apr-11	21:55	-22.398	2115.53	45.99	47.93	-	-	-	-	-	-
29-Apr-11	1:03	-22.402	2303.53	48.00	47.93	-	-	-	-	-	-
29-Apr-11	4:19	-22.411	2499.53	50.00	47.92	-	-	-	-	-	-
29-Apr-11	7:43	-22.423	2703.55	52.00	47.90	-	-	-	-	-	-
29-Apr-11	11:15	-22.444	2915.57	54.00	47.88	-	-	-	-	-	-
29-Apr-11	14:55	-22.477	3135.57	56.00	47.85	-	-	-	-	-	-
29-Apr-11	18:43	-22.578	3363.57	58.00	47.75	-	-	-	-	-	-
29-Apr-11	22:39	-22.564	3599.57	60.00	47.76	-	-	-	-	-	-
30-Apr-11	4:48	-22.544	3968.58	63.00	47.78	-	-	-	-	-	-
30-Apr-11	11:15	-22.551	4355.60	66.00	47.78	-	-	-	-	-	-
30-Apr-11	18:00	-22.586	4760.60	69.00	47.74	-	-	-	-	-	-
01-May-11	1:03	-22.589	5183.60	72.00	47.74	-	-	-	-	-	-
01-May-11	8:24	-22.582	5624.62	75.00	47.75	-	-	-	-	-	-
01-May-11	16:03	-22.638	6083.63	78.00	47.69	-	-	-	-	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-
						-	-	-	-	-	-
Perm						-	-	-	-	-	-
06-May-11	6:41	-24.163	12721.22	112.79	46.17	40.0	-	100.8	60.8	3500.00	1.20E-07
06-May-11	16:45	-24.163	13325.22	115.43	46.17	40.0	-	113.8	73.8	3500.00	9.88E-08
07-May-11	7:42	-24.163	14222.22	119.26	46.17	40.0	-	124.0	84.0	3500.00	8.68E-08
08-May-11	13:45	-24.163	16025.22	126.59	46.17	40.0	-	124.0	84.0	3500.00	8.68E-08
						-	-	-	-	**Average:**	**9.08E-08**

Load No.	9	
Stress:	418.2	kPa
Add Mass:	30	kg

DATE	TIME	DIAL READING (mm)	ELAPSED TIME (min)	ROOT TIME (min)	SAMPLE HEIGHT (mm)	PRESSURE				RAMP (ms/mm^3)	Hydraulic Conductivity (cm/sec)
						TOP (cm)	MIDDLE (cm)	BOTTOM (cm)	h_L (cm)		
13-May-11	8:53	-22.649	0.00	0.00	47.68	-	-	-	-	-	-
13-May-11	8:53	-22.917	0.25	0.50	47.41	-	-	-	-	-	-
13-May-11	8:53	-22.992	0.50	0.71	47.34	-	-	-	-	-	-
13-May-11	8:54	-23.028	1.00	1.00	47.30	-	-	-	-	-	-
13-May-11	8:55	-23.098	2.25	1.50	47.23	-	-	-	-	-	-
13-May-11	8:57	-23.179	4.00	2.00	47.15	-	-	-	-	-	-
13-May-11	9:02	-23.365	9.00	3.00	46.96	-	-	-	-	-	-
13-May-11	9:08	-23.564	15.75	3.97	46.76	-	-	-	-	-	-
13-May-11	9:17	-23.763	24.75	4.97	46.56	-	-	-	-	-	-
13-May-11	9:29	-23.968	36.00	6.00	46.36	-	-	-	-	-	-
13-May-11	9:42	-24.189	49.00	7.00	46.14	-	-	-	-	-	-
13-May-11	9:57	-24.397	64.00	8.00	45.93	-	-	-	-	-	-
13-May-11	10:14	-24.600	81.00	9.00	45.73	-	-	-	-	-	-
13-May-11	10:32	-24.777	99.75	9.99	45.55	-	-	-	-	-	-
13-May-11	10:53	-24.950	120.75	10.99	45.38	-	-	-	-	-	-
13-May-11	11:17	-25.103	144.00	12.00	45.23	-	-	-	-	-	-
13-May-11	11:42	-25.218	169.00	13.00	45.11	-	-	-	-	-	-
13-May-11	12:08	-25.334	195.75	13.99	44.99	-	-	-	-	-	-
13-May-11	12:37	-25.430	224.25	14.97	44.90	-	-	-	-	-	-
13-May-11	13:08	-25.518	255.25	15.98	44.81	-	-	-	-	-	-
13-May-11	13:41	-25.578	288.25	16.98	44.75	-	-	-	-	-	-
13-May-11	14:16	-25.648	323.25	17.98	44.68	-	-	-	-	-	-
13-May-11	14:53	-25.710	360.25	18.98	44.62	-	-	-	-	-	-
13-May-11	15:32	-25.766	399.25	19.98	44.56	-	-	-	-	-	-
13-May-11	16:13	-25.797	440.25	20.98	44.53	-	-	-	-	-	-
13-May-11	16:56	-25.836	483.25	21.98	44.49	-	-	-	-	-	-
13-May-11	17:41	-25.895	528.27	22.98	44.43	-	-	-	-	-	-
13-May-11	18:28	-25.923	575.27	23.98	44.41	-	-	-	-	-	-
13-May-11	19:17	-25.947	624.27	24.99	44.38	-	-	-	-	-	-
13-May-11	20:08	-25.965	675.27	25.99	44.36	-	-	-	-	-	-
13-May-11	21:01	-25.972	728.27	26.99	44.36	-	-	-	-	-	-
13-May-11	21:56	-25.986	783.27	27.99	44.34	-	-	-	-	-	-
13-May-11	22:53	-26.007	840.27	28.99	44.32	-	-	-	-	-	-
13-May-11	23:52	-26.018	899.27	29.99	44.31	-	-	-	-	-	-
14-May-11	1:56	-26.037	1023.27	31.99	44.29	-	-	-	-	-	-
14-May-11	4:08	-26.039	1155.28	33.99	44.29	-	-	-	-	-	-
14-May-11	6:28	-26.044	1295.28	35.99	44.28	-	-	-	-	-	-
14-May-11	8:56	-26.070	1443.28	37.99	44.26	-	-	-	-	-	-
14-May-11	11:32	-26.053	1599.28	39.99	44.27	-	-	-	-	-	-
14-May-11	14:16	-26.080	1763.28	41.99	44.25	-	-	-	-	-	-
14-May-11	17:08	-26.084	1935.28	43.99	44.24	-	-	-	-	-	-
14-May-11	20:08	-26.097	2115.28	45.99	44.23	-	-	-	-	-	-
14-May-11	23:16	-26.077	2303.28	47.99	44.25	-	-	-	-	-	-
15-May-11	2:32	-26.081	2499.28	49.99	44.25	-	-	-	-	-	-
15-May-11	5:56	-26.096	2703.30	51.99	44.23	-	-	-	-	-	-
15-May-11	9:28	-26.139	2915.32	53.99	44.19	-	-	-	-	-	-
15-May-11	13:08	-26.090	3135.32	55.99	44.24	-	-	-	-	-	-
15-May-11	16:56	-26.114	3363.32	57.99	44.21	-	-	-	-	-	-
15-May-11	20:52	-26.131	3599.32	59.99	44.20	-	-	-	-	-	-
16-May-11	3:01	-26.170	3968.33	62.99	44.16	-	-	-	-	-	-
16-May-11	9:28	-26.157	4355.35	66.00	44.17	-	-	-	-	-	-
16-May-11	16:13	-26.185	4760.35	69.00	44.14	-	-	-	-	-	-
16-May-11	23:16	-26.194	5183.35	72.00	44.13	-	-	-	-	-	-
17-May-11	6:37	-26.238	5624.37	75.00	44.09	-	-	-	-	-	-
17-May-11	14:16	-26.230	6083.37	78.00	44.10	-	-	-	-	-	-
17-May-11	22:13	-26.229	6560.37	81.00	44.10	-	-	-	-	-	-
18-May-11	6:28	-26.252	7055.37	84.00	44.08	-	-	-	-	-	-
18-May-11	15:01	-26.250	7568.40	87.00	44.08	-	-	-	-	-	-
18-May-11	23:52	-26.259	8099.42	90.00	44.07	-	-	-	-	-	-
19-May-11	9:01	-26.247	8648.42	93.00	44.08	-	-	-	-	-	-
19-May-11	18:28	-26.264	9215.43	96.00	44.06	-	-	-	-	-	-
20-May-11	4:13	-26.271	9800.45	99.00	44.06	-	-	-	-	-	-
20-May-11	14:16	-26.258	10403.45	102.00	44.07	-	-	-	-	-	-
						-	-	-	-	-	-

Appendix II-7

Hydrogeochemical Investigation of the Processed Kimberlite Facility at Diavik Diamond Mines Inc.

Hydrogeochemical Investigation of the Processed Kimberlite Facility at Diavik Diamond Mines Inc.
Final Report

***Submitted To**:*
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Alberta Innovates Technology Futures

July 2011

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1.0 INTRODUCTION

During the spring of 2008, a mass balance study of the Processed Kimberlite Containment (PKC) Pond was identified as a priority action item. Water samples collected from the PKC pond show that concentrations of total ions have increased over time. As part of the mass balance study, Alberta Innovates-Technology Futures (AITF) was retained by Diavik Diamond Mines Inc. (DDMI) to characterize groundwater geochemistry in the PKC facility to determine if the weathering if Processed Kimberlite (PK) could be contributing the increasing ion concentrations in the PKC pond water.

2.0 OBJECTIVES

The objective of this project is to characterize the porewater geochemistry in the PKC facility. Work to be performed by Alberta Innovates-Technology Futures includes:

- Using a squeezing technique extract porewater from the unsaturated zone of the PKC facility.
- Installing piezometers below the water table to collect groundwater samples.
- Sampling groundwater from all piezometers
- Collecting continuous cores of PK material from the PKC facility for geotechnical and possible mineralogical studies.
- Extracting water from core collected from the frost zone.
- Submitting all water and solid samples to the appropriate laboratories
- Performing geochemical modeling of the groundwater.
- Installing pressure transducers at two piezometer nest locations.
- Measuring water levels in all installed piezometers to determine horizontal and vertical hydraulic gradients within the PKC facility.
- Preparing an interim report detailing progress of study.
- Preparing a final report detailing the results and conclusions of the study.
- Providing recommendations in the final report for future studies.

3.0 SITE BACKGROUND

The Diavik Diamond Mine Inc. (DDMI) is located in the barrens lands on East Island in Lac de Gras, 300 km northeast of Yellowknife, NT. The mean annual temperature, rainfall, snowfall and lake evaporation at Diavik is -12^{0}C, 164 mm, 187 mm and 271 mm, respectively (Golder, 2007). Winter conditions persist from September through to June with a 1.5 to 5 m deep active layer developing during the warmer months. The maximum lake evaporation rate occurs in July, corresponding to the maximum air temperature.

The DDMI property contains four economic kimberlite pipes. Currently diamonds are extracted from pipes A154N, A154S and A418 through open pit mining. Kimberlite pipe A21 is not currently being mined. After diamonds are recovered from the kimberlite ore, the reject material is transported as a slurry to the PKC facility. Water from the processing plant is used in the PK slurry which contains both recycled PKC pond water (~57 %) and fresh water from

Lac de Gras (~24 %) (Moncur Groundwater, 2009). Since March 2010, fresh water from Lac de Gras is no longer used in the processing plant, water is now recycled from the north inlet. PK deposited in the PKC facility settles gravimetrically for permanent storage. The standing water in the PKC facility is decanted and recycled back to the processing plant. There are a number of small collection ponds on site that are used to control surface water runoff. Surface waters from the ponds are periodically pumped into the PKC pond to prevent the ponds from overflowing. Ponds 1 and 2 are located away from the PKC and used to collect and control overland surface runoff. Collection ponds 4 and 5 are located adjacent to the PKC and collect seepage from the PKC pond and control the local overland surface runoff. Pond waters discharged to the PKC pond make up approximately 15 % of the total input. Treated sewage waste water from mining operations is also discharged to the PKC pond. The monthly volume of treated sewage effluent discharged to the PKC pond makes up approximately 2 % of the total water volume (Moncur Groundwater, 2009).

4.0 MINERALOGY

4.1 PKC Mineralogy

The kimberlite pipes at DDMI are intrusions within supracrustal rocks and late Archean granitoids of the Slave structural province (Moss et al., 2008). The pipes are composed of bedded volcaniclastic kimberlite, consisting of both kimberlite and mudstone xenoliths. The dominate minerals commonly found in the kimberlite include olivine [$(Mg,Fe)_2SiO_4$ with sub-percentage amounts of Ni], enstatite [$MgSiO_3$], chromium diopside [$Cr\text{-}CaMgSi_2O_6$], and lizardite [$Mg_3Si_2O_5(OH)_4$], with accessory minerals of garnet [$(Mg,Ca)_3(Al,Cr)_2(SiO_4)_3$], phlogopite [$KMg_3AlSi_3O_{10}(OH)_2$] and ilmenite [$FeTiO_3$] (Baker et al., 2003). Traces of pyrite [FeS_2], pyrrhotite [$Fe_{(1-x)}S$], sphalerite [$(Zn,Fe)S$], pentlandite [$(Fe,Ni)_9S_8$], chalcopyrite [$CuFeS_2$], galena [PbS], marcasite [FeS_2] and millerite [NiS] have been observed in the kimberlite material (Baker et al., 2003). Dominant and accessory minerals are set in a fine-grained, smectite-rich calcite and serpentine matrix. The mean-total sulfur value for the processed kimberlite is 0.52 % ± 0.24 % (Baker et al., 2003). Mean values of the neutralization potential (NP) and maximum potential acidity (MPA) for the processed kimberlite reported by Baker et al. (2003) were 196 ± 131 $CaCO_3$ t^{-1} and 14.8 ± 6.6 $CaCO_3$ t^{-1}, respectively, indicating that the processed kimberlite is acid-consuming.

Baker at al. (2003) found that the mudstone was fine-grained and composed of quartz [SiO_2], feldspar [$NaAlSi_3O_8$], muscovite [$KAl_2(AlSi_3O_{10})(F,OH)_2$], framboidal pyrite, calcite, smectite and gypsum [$CaSO_4·2H_2O$]. The mean-total sulfur value for the mudstone is 0.70 % ± 0.86 %. Mean values of (NP) and MPA for the mudstone were 288 ± 186 $CaCO_3$ t^{-1} and 19.93 ± 25.36 $CaCO_3$ t^{-1}, respectively. Many of the mudstone samples had significantly lower NP and higher total S suggesting that the material is potentially acid generating (Baker at al., 2003).

Wilson et al., (2009) observed efflorescent crusts of secondary minerals on the surface of PKC facility where the processed kimberlite (PK) was beached adjacent to the ponded water. Calcite, gypsum [$CaSO_4·2H_2O$] and nesquehonite [$Mg(HCO_3)(OH)·2H_2O$] are the most pervasive secondary mineral phases in the PKC facility post deposition. Other secondary Ca-Mg mineral phases identified in trace amounts within the PK material include anhydrite [$CaSO_4$], epsomite [$MgSO_4 \cdot 7(H_2O)$], hexahydrite [$MgSO_4 \cdot 6H_2O$], syngenite [$K_2Ca(SO_4)_2 \cdot (H_2O)$], gaylussite [$Na_2Ca(CO_3)_2 \cdot 5H_2O$], natrite [$Na_2CO_3$], vaterite ($CaCO_3$) and portlandite [$Ca(OH)_2$]. Nesquehonite was the only secondary mineral identified to persist at depth within the PKC facility.

A study of the processed kimberlite by Paktunc and Thibault (2010) found that the PK material was composed of olivine, calcite, quartz, garnet, lizardite, biotite, albite, saponite, pyrite and an unidentified amorphous mineral. They found that olivine and calcite were the primary neutralizing minerals. Pyrite occurred in the form of framboidal and massive grains but did not show any indications of oxidation on the mineral surfaces.

5.0 METHODS

The most accessible area to the PKC facility was a beach along the east shore of the impoundment. The beach was approximately 200 m in length, extending from the toe of the containment dam to the edge of ponded water in the centre of the PKC facility. In 2009 five locations were mapped as areas to collect core and install piezometers: PKC1 located near the toe of the dam, then at a distance of 100 m (PKC2), 133 m (PKC5), 163 m (PKC4), 188 m (PKC3) from PKC1. PKC3 was located near the edge of the PKC pond, at the time of sampling (Figure 1). Two additional locations were investigated; exposed PKC material on the southwest portion of the PKC facility thought to have undergone the longest weathering in the facility (PKCSW); and the end of the barge where groundwater could be collected from beneath standing water of the PKC water column (Barge). In 2010 a piezometer nest was installed in the deepest area of the PKC pond (B2).

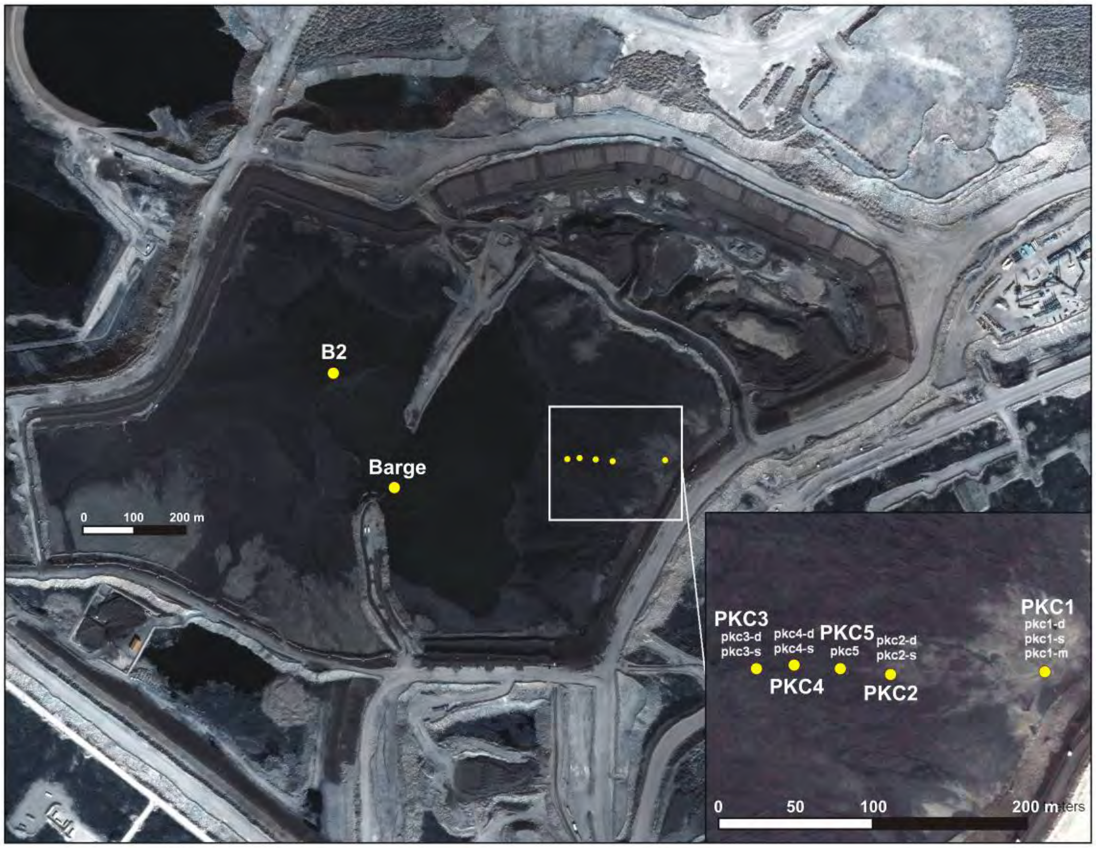


Figure 1: Aerial view of the PKC facility showing core collection and piezometer installation locations. Sampling site PKCSW is located to the west outside the current PKC facility perimeter.

5.1 PKC Solid and Pore Gas Collection

During the week of July 7, 2009, continuous vertical cores of PK material were collected from ground surface to refusal (frost) within the east beach of the PKC facility. At each location, core was collected by driving an aluminum core tube into the PK material with a gas-powered Pionjar rock drill (Figure 2). Three continuous vertical cores were collected from surface to the frost layer: one 3-inch (7.6 cm) core for porewater extraction and two 2-inch (5.1 cm) cores for geotechnical and whole rock analysis. At locations PKC2 and PKC3, it was possible to collect material from the frost layer (Figure 3). Three 1-meter long cores were also collected from location PKCSW. Immediately following the collection of a 3-inch continuous core, the core was cut into ~30 cm sections and transported to the DDMI environmental laboratory for porewater extraction. All 2-inch cores were immediately frozen.

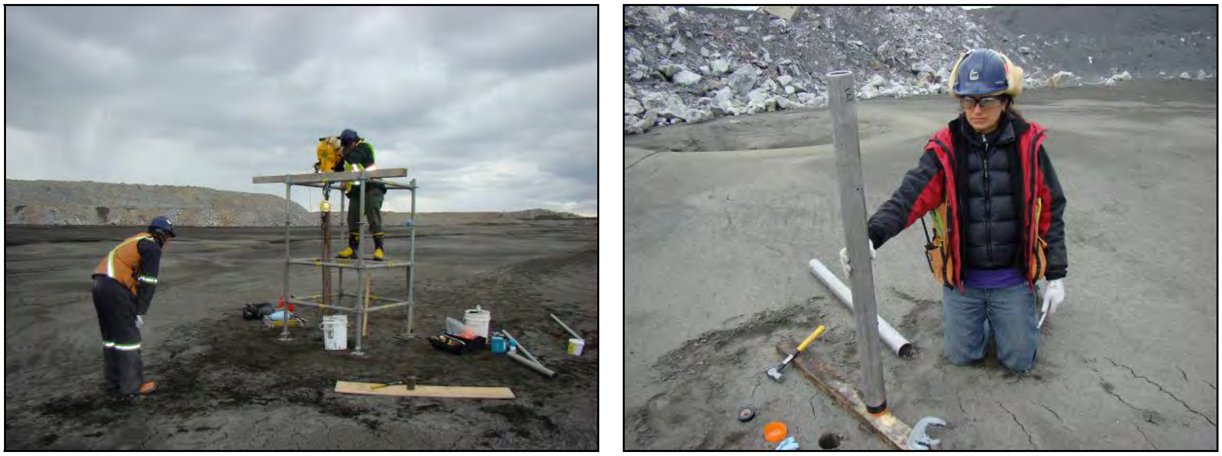


Figure 2: Core Collection at PKC Facility. Photo on the left shows the collection of core from the PKC facility. Photo on the right show a 1 m length of core with a 3-inch diameter collected at location PKCSW.

On September 27, 2009, at locations PKC1 and PKC3, one 10-ft (3.05 m) continuous core was collected from each location for mineralogical and geotechnical analysis. The core was collected using a Pionjar rock drill and piston core-barrel method described by Starr and Ingleton (1992). Approximately 1.5 m PK material was collected below frost level. The core was immediately frozen and shipped to AITF in Calgary, AB, where they were prepared for mineralogical examination and whole rock analysis.

During field investigations in 2010, one 3-inch core was collected from surface to the frost layer at locations PKC1 and PKC2 for porewater squeezing. Additional 2-inch cores were collected at PKC1 for water content and bacteria numerations.

DDMI provided AITF with data for 12 sieve analysis measured from samples collected across the PKC beach, PKC2, PKC3, PKC4 and PKC-SW. This data was used to calculate the hydraulic conductivity of the PK material using the Hazen (1957) method.

Figure 3: Core Photos from PKC2 and PKC3 Facility. Photo on the left shows ice in the bottom of a 3-inch diameter core sample collected from PKC3. On the left, photo shows frozen 2-inch diameter core collected from PKC2.

The depth to frost was measured at each location during the weeks of July 7, 2009 and September 22, 2009.

Samples of PK pore gas from the unsaturated zone were collected at locations PKC1 and PKCSW on September 29, 2009 and PKC1 was resamples on August 7, 2010, using a drive-point sampling tube. Pore gas was collected in 60 CC syringes at 0.10 m increments from ground surface to the depth of 1.0 m at PKC1 and at 0.20 m increments to a depth of 0.80 m at PKCSW. Gas-loaded syringes collected from each sampling interval were immediately injected into sterile vacuum-sealed Kendall 16x125 mm glass vials. Gas content from the vials was analyzed for O_2, CO_2, CH_4, and N_2 using a Varian CP-4900 Micro Gas Chromatograph at ARC in Calgary, AB. Gas samples were also analyzed at the University of Calgary for H_2S and isobutene, also using a Varian CP-4900 Micro Gas Chromatograph.

5.2 Piezometer Installation

During the week of September 22, 2009, a total of 14 drive point piezometers were installed into the PKC facility. All drive-point piezometers were driven through the PKC material by hand until refusal. At that point a Pionjar rock drill was used to drive the piezometer to the preferred depth or until refusal. Four piezometers were installed off the barge and ten piezometers were installed across the east shore of the PKC facility, ranging from one to three piezometers per location. Piezometers were surveyed for x-y-z coordinates by DDMI staff. A list of piezometer details can be found in Table 1.

When the piezometers were installed on September 27, 2009 the water column depth of the PKC facility adjacent to the barge was 1.8 m. Due to the extremely unconsolidated nature of the upper portion of the PK material, it was not possible to install a permanent piezometer above 2 m. A vertical Van Doren bottle sampler was used to collected sediment and water samples from a depth of 3 m (1.2 m below the surface water/sediment interface). No frost was encountered during the installation of piezometers off the end of the barge.

Between September 2009 and August 2010, the water level in the PKC pond had increased by ~2.4 m, completely submerging piezometers installed adjacent to the Barge and piezometers at locations PKC3, 4 and 5. Water samples could not be collected at PKC2 because they were frozen.

Figure 4: Installation of piezometers from the ConeTec barge. Photo on the right shows the completed piezometer nest.

In August 2010, five piezometers were re-installed off the Barge to similar depths as in 2009. In addition 6 piezometers (B2) were installed in the deepest area of the PKC facility using the ConeTech barge on September 11, 2010 (Figure 4).

Rising-head piezometer-response tests were performed in 2010 to estimate the hydraulic conductivity of the PKC material. Pressure transducers were installed in 1-¼-inch diameter piezometers at locations Barge-10,-25,-35, and PKC1-S. After installation of pressure transducers, piezometers were pumped dry and recovery was monitored at 1 minute intervals. A barrologger was deployed simultaneously with the pressured transducers to correct for changes in barometric pressure. Piezometers Barge-55 and -90 (¾-inch diameter) were pumped dry and recovery was monitored using an electric water level sounder. Hydraulic conductivities were calculated using the Hvorslev (1951) method.

Table 1: Piezometer details, elevations and ground elevations.

Location	Piezometer Type	Install. Date	Easting (m)	Northing (m)	Pipe Stick Up (m)	Tip Depth (m)	Ground Elev. (masl)	Elev. (TOP) (masl)	Tip Elev. (masl)
PKC1-S	1¼-inch PVC	2009	533702.781	7151946.75	1.08	1.46	450.65	451.73	450.28
PKC1-M	¾-inch PVC	2009	533702.526	7151946.78	1.75	1.45	450.62	452.50	451.05
PKC1-Deep	¾-inch SS	2009	533703.075	7151946.88	1.65	1.71	450.65	452.43	450.72
PKC2-S	1¼-inch PVC	2009	533602.193	7151944.957	0.85	1.72	448.54	449.39	447.67
PKC2-Deep	¾-inch SS	2009	533602.778	7151944.856	1.39	1.96	448.57	450.12	448.16
PKC5	¾-inch PVC	2009	533569.991	7151949.162	1.38	1.82	447.82	449.37	447.56
PKC4-S	1¼-inch PVC	2009	533539.871	7151951.458	1.77	1.46	447.07	448.84	447.38
PKC4-Deep	¾-inch SS	2009	533539.758	7151951.75	0.68	2.69	447.02	447.93	445.24
PKC3-S	¾-inch SS	2009	533514.698	7151948.758	0.80	2.55	446.50	447.44	444.89
PKC3-Deep	¾-inch SS	2009	533514.606	7151949.198	1.58	3.29	446.56	448.30	445.00
Barge-25	1¼-inch PVC	2009	n/a	n/a	1.47	7.62	n/a	n/a	n/a
Barge-35	1¼-inch PVC	2009	n/a	n/a	1.17	10.67	n/a	n/a	n/a
Barge-45	¾-inch PVC	2009	n/a	n/a	0.68	13.72	n/a	n/a	n/a
Barge-65	¾-inch SS	2009	n/a	n/a	0.46	19.81	n/a	n/a	n/a
Barge-25	1¼-inch PVC	2010	n/a	n/a	1.54	7.16	n/a	n/a	n/a
Barge-35	1¼-inch PVC	2010	n/a	n/a	1.58	9.82	n/a	n/a	n/a
Barge-45	1¼-inch PVC	2010	n/a	n/a	1.41	12.82	n/a	n/a	n/a
Barge-65	¾-inch PVC	2010	n/a	n/a	1.11	18.16	n/a	n/a	n/a
Barge-80	¾-inch SS	2010	n/a	n/a	1.67	25.73	n/a	n/a	n/a
B2-20	1¼-inch PVC	2010	n/a	n/a	1.6	6.1	n/a	n/a	n/a
B2-30	1¼-inch PVC	2010	n/a	n/a	1.23	9.15	n/a	n/a	n/a
B2-40	1¼-inch PVC	2010	n/a	n/a	1.71	12.2	n/a	n/a	n/a
B2-50	1¼-inch PVC	2010	n/a	n/a	1.17	15.24	n/a	n/a	n/a
B2-65	¾-inch PVC	2010	n/a	n/a	1.54	19.82	n/a	n/a	n/a
B2-90	¾-inch SS	2010	n/a	n/a	1.07	27.44	n/a	n/a	n/a

5.3 Porewater Sampling

Porewater from the vadose zone of the PKC facility was sampled using a squeezing technique. Porewater cores from PKC1, PKC2, PKC3, PKC4, PKC5 and PKCSW were immediately squeezed after collection in the DDMI Environmental Laboratory in 2009. In 2010 core was collected from locations PKC1 and PKC2 for porewater squeezing. The squeezing technique, as described by Patterson et al. (1978), and as later modified by Smyth (1981) and Moncur et al. (2005), involved adding a viscous immiscible liquid (Paraplex) to the top of each core, then applying light pressure with a sealed plunger to displace the Paraplex and porewater down through the core. The resulting water samples were collected in 60 mL syringes and passed through 0.45 µm cellulose-nitrate filters. This squeezing technique eliminates the contact between porewater samples and atmospheric O_2, limiting oxidation during sample collection. Eh and pH measurements of the extracted porewater were made one to three times during the collection of each unfiltered sample to obtain representative results. The Eh was measured using an Orion platinum redox electrode (model 96-78BN), calibrated in Zobell's solution (Nordstrom, 1977) and Light's solution (Light, 1972). The pH was measured using an Orion Ross combination electrode (model 815600) calibrated with standard buffer solutions at pH 4, 7, and 10. Measurements of alkalinity were made on filtered samples using a Hach digital titrator and bromcresol green / methyl red indicator and with 0.16 *N* H_2SO_4. Water samples were filtered with 0.45 µm cellulose-nitrate filters and split into two aliquots. One aliquot of water was acidified with 12 *N* trace-metal grade HNO_3 to a pH of <1 for cation analysis, and another aliquot was left unacidified to use for anion analysis. All samples were stored in pre-washed Nalgene bottles and immediately refrigerated until analysis at the University of Waterloo, Waterloo, ON.

5.4 Groundwater Sampling

Porewater from the saturated zone was collected from piezometers using a peristaltic pump and ¼-inch diameter polyethylene tubing. All piezometers were bailed dry and allowed to recover prior to sampling. Measurements of Eh and pH were made in the field using a sealed flow-through cell to prevent any alterations from atmospheric O_2. Calibration of the Eh and pH probes was checked before and after each sampling point. Temperature, conductivity and alkalinity were measured at each location. All water samples were collected and refrigerated until they were analyzed following the same methods as for samples collected from the vadose zone. Dissolved H_2S was determined on 25 mL aliquots using the methylene blue procedure (SMEWW, 1992). Dissolved NH_3, Fe(II), and PO_4 were measured in the field using a Hach DR2700 spectrometer. Samples for dissolved organic carbon (DOC) were collected in 60 ml glass vials and preserved with HCl and analyzed at the University of Calgary. Selected groundwater samples were also analyzed for the stable isotopes $\delta^{34}S_{SO4}$, $\delta^{18}O_{SO4}$, $\delta^{18}O$, $\delta^{2}H$, and $\delta^{13}C_{DIC}$. Sulfur isotope ratios of sulfate were analyzed at the University of Calgary. Isotope ratios of $\delta^{18}O$ and $\delta^{2}H$ on water, and $\delta^{13}C$ on dissolved inorganic carbon were analyzed at the AITF stable isotope lab in Victoria, BC.

5.5 Geochemical Modeling

Water chemistry was interpreted with the assistance of the equilibrium chemical-speciation/mass-transfer model MINTEQA2 (Allison et al., 1990). The MINTEQA2 data base was modified to make it consistent with that of WATEQ4F (Ball and Nordstrom, 1991), with additional solubility data incorporated for siderite (Ptacek, 1992) and Co (Papelis et al., 1991). MINTEQA2 was used to calculate the saturation indices for discrete minerals that may be controlling the concentrations of dissolved species in waters of the PKC facility.

5.6 Microbial Populations

Enumerations of sulfate reducing bacteria (SRB), iron related bacteria (IRB), heterotrophic bacteria (HAB), denitrifying bacteria (DN) and nitrifying bacteria (N) were performed using Biological Activity Reaction Tests (BART) following methods of Droycon Bioconcepts Inc. (2004). In 2010, Groundwater was collected from piezometers at locations PKC1, Barge and B2 and enumerated for populations of SRB, IRB, HAB, DN and N. A continuous core was collected at PKC1 from surface to 1.1 m, stored on ice and immediately shipped to the AITF laboratory in Calgary. Core was cut into 10 cm sections and enumerated for populations of SRB, IRB and HAB.

6.0 RESULTS AND DISCUSSION

6.1 PKC – East Beach

A transect of sampling locations on the east PKC beach extends from the East Dam to the edge of the PKC Pond (Figure 1). The exposed PKC material gently slopes from the toe of the rock dam to the PKC Pond edge with a 4.15 m change in elevation. Figure 4 shows a cross-section through the east beach from PKC1 to PKC3. On July 7, 2009, depth to frost was 1.13 m at PKC1 and 0.96 m at PKC3. By September 30, 2009, the active zone at had increased to 1.70 m at PKC1 and 1.23 m at PKC3, however there was minimal change in the depth to frost over the same time period at locations PKC2 and PKC5. At locations PKC4 and PKC3, a wedge of frost-free PK material was encountered below the frost layer (Figure 4). On August 9, 2010 depth to frost was 1.53 m at PKC1 and 1.38 m at PKC2.

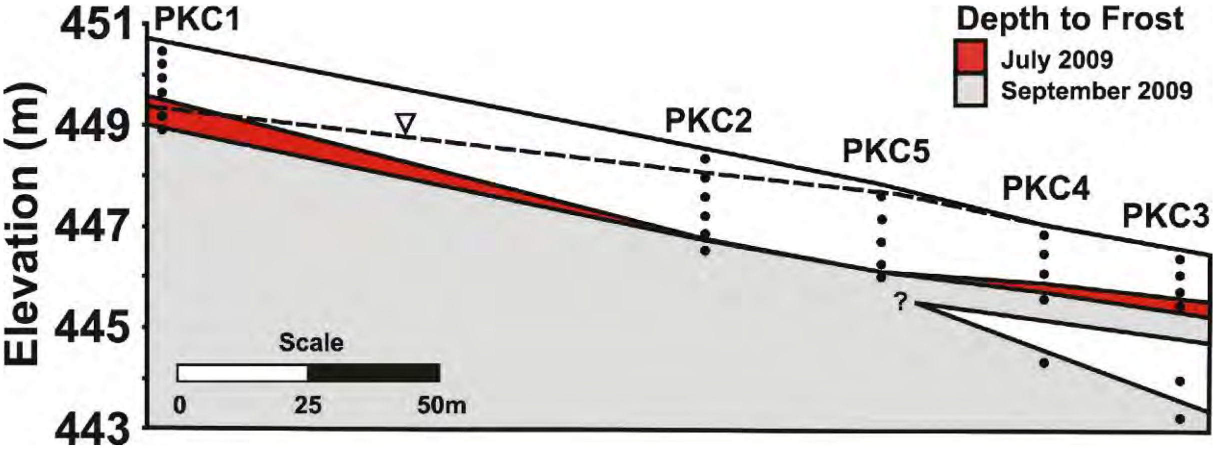


Figure 5: Transect across the PKC facility's east beach.
The upper red shading corresponds to the depth of frost within the PKC material in July 2009, and the grey area represents the depth to frost on September 2009. The unshaded wedge in the frost layer at PKC3 and PKC4 is frost-free PK material. Black dots represent discrete porewater sampling locations and the dashed line with inverted triangle corresponds to the water table elevation, measured on October 5, 2009.

On October 5, 2009, the depth to the water table in the PKC facility was 1.25 m below the PK surface at PKC1, and intersected the surface near PKC4 (Figure 5). Groundwater has a downward gradient at locations PKC1 and PKC2 and shows an upward gradient at location PKC4, indicating that groundwater flow is directed downwards from the toe of the east dam to the PKC Pond. The overall horizontal gradient between PKC1 and PKC3 is 0.016, following the topography of the ground surface.

Water levels at PKC1 measured on August 7, 2010, were 1.14 m below the ground surface in both the shallow and deep piezometers, showing no vertical gradient. This is likely due to the rapidly rising PKC Pond water causing the water table to mound at PKC1

Grain-size distributions were measured on 10 samples extracted from various depths across the PKC beach and 2 from PKC-SW (Table 2). The average d_{10} (the grain-size diameter at which 10% by weight of the particles are finer in mm) of the PK material varied between 0.01 mm to 0.12 mm. Hydraulic conductivities of the PKC material were estimated using the method developed by Beyer, which is suitable for sediments with a d_{10} within the range of 0.06 mm < d_{10} <0.6 mm (Vukovic and Soro, 1992). The arithmetic average hydraulic conductivity (K) calculated from the grain-size analysis was 2.54×10^{-5} m s^{-1}. The average calculated porosity of the PKC material was 0.30. These values were used with the water table gradient between PKCI and PKC3 measured in 2009 in the Darcy equation to estimate groundwater velocities of about 1.34×10^{-5} m s^{-1} (42 m a^{-1}).

Table 2: Grain size distributions of the PK material that were used to estimate porosity and K values.

Location	Units	PKC2	PKC2	PKC2	PKC3	PKC3	PKC3	PKC4	PKC4	PKC5	PKC5	PKC-SW	PKC-SW	Avg
Depth (interval)	cm	0-48	0-50	58-96	0-35	35-70	70-107	0-37	37-74	0-48	48-86	0-46	46-92	
Depth (average)	cm	24	25	77	18	53	89	19	56	22	67	23	69	45
D10 (mm)	mm	0.08	0.03	0.02	0.01	0.04	0.04	0.04	0.11	0.01	0.12	0.07	0.09	0.06
D17 (mm)	mm	0.13	0.09	0.04	0.02	0.14	0.13	0.13	0.17	0.02	0.18	0.14	0.18	0.11
D20 (mm)	mm	0.15	0.11	0.08	0.03	0.17	0.16	0.16	0.19	0.03	0.20	0.16	0.22	0.14
D60 (mm)	mm	0.42	0.38	0.49	0.31	0.44	0.47	0.48	0.53	0.36	0.48	0.44	0.66	0.46
Porosity	-	0.35	0.28	0.26	0.26	0.28	0.29	0.29	0.36	0.26	0.38	0.34	0.32	0.30
K	m/s	5.20E-05	2.89E-06	7.48E-06	1.04E-06	9.17E-08	1.25E-05	1.40E-05	1.01E-04	1.12E-06	1.47E-06	4.57E-05	6.51E-05	2.54E-05

The concentrations of selected major ions and metals versus depth across the unsaturated zone (Figure 6) show that the unsaturated zone is the most oxidized zone in the cross-section. This zone also has the lowest pH values and much higher concentrations of dissolved sulfate and metals than other waters sampled onsite (Moncur Groundwater, 2009). There are decreases in dissolved sulfate and metal concentrations and increases in pH as you approach the water table and within the frost zone.

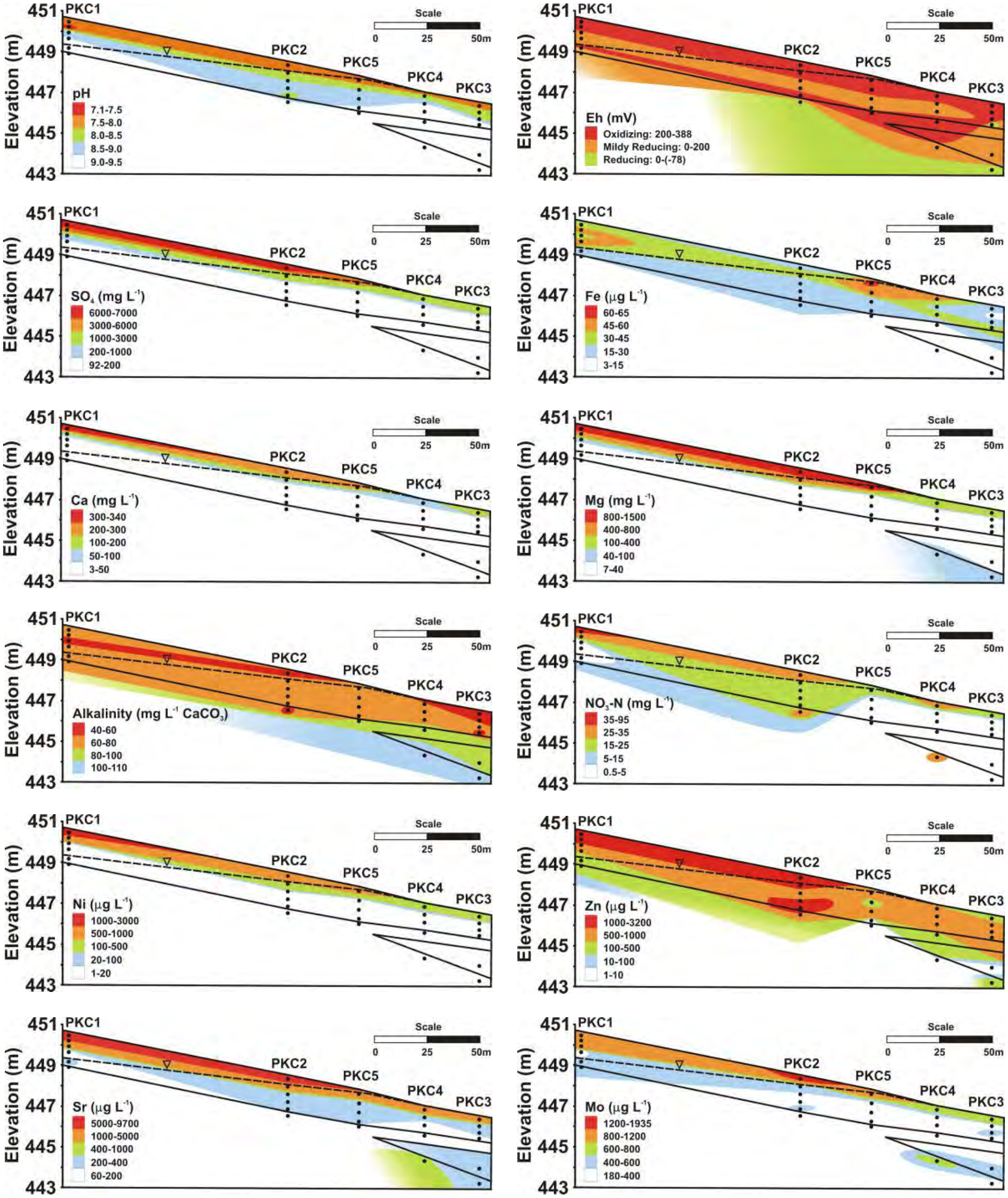


Figure 6: Water chemistry across the East Beach of the PKC facility. Black dots represent discrete porewater sampling locations and the dashed line with inverted triangle corresponds to the water table elevation, measured on October 5, 2009. The lower solid line represents the depth to frost and the wedge to the left is a frost-free zone.

There are distinct differences in the average concentration of pH, Eh and dissolved ions from the unsaturated zone, saturated zone and the frost zone (Table 3). Differences in Eh measurements indicate oxidizing conditions in the unsaturated zone that become progressively more reduced with depth into the frost zone. The shift towards more reduced conditions with depth corresponds with a shift towards increasing pH values. Average dissolved concentration of sulfate, most major cations and most metals decrease by almost an order of magnitude for as you move from the unsaturated zone to the saturated zone (e.g. SO_4: 3498 to 352 mg L^{-1}, Mg: 732 to 79 mg L^{-1}, Ni:819 to 38 µg L^{-1}). The concentrations of dissolved ions are significantly lower in the frost zone than in the saturated zone. Alkalinity concentration ranges (in mg L^{-1} of $CaCO_3$) are similar in the unsaturated and saturated zones, but increase in the frost zone. Ions that show little variation between the three zones include Cl, K, B and As.

Table 3: Maximum, minimum and average concentrations of dissolved ions from the unsaturated zone (UZ), saturated zone (SZ), frost zone (FZ) and the average of all zones based on the 2009 data. All concentrations in mg L^{-1} excepted where noted.

Location	*pH*	*Eh (mV)*	*Alkalinity (mg L^{-1})*	*NH_3 (mg L^{-1})*	*NO_2 (mg L^{-1})*	*NO_3 (mg L^{-1})*	*Cl (mg L^{-1})*	*SO_4 (mg L^{-1})*
Average UZ	**8.05**	**272**	**66**	**n/a**	**18.1**	**30.1**	**43**	**3498**
Max UZ	*9.06*	*388*	*85*	*n/a*	*56.1*	*93.3*	*63*	*6837*
Min UZ	7.01	191	52	n/a	4.5	2.0	27	99
Average SZ	**8.80**	**188**	**66**	**1.6**	**8.6**	**11.3**	**39**	**352**
Max SZ	*9.41*	*344*	*100*	*2.6*	*30.1*	*32.7*	*80*	*2412*
Min SZ	7.84	-46	47	0.6	1.1	0.6	16	87
Average FZ	**9.17**	**136**	**83**	**1.6**	**13.3**	**11.4**	**39**	**172**
Max FZ	*9.48*	*231*	*110*	*2.9*	*21.3*	*40.5*	*56*	*295*
Min FZ	8.95	-78	40	0.5	3.4	0.8	21	89
Average All	**8.72**	**193**	**70**	**1.6**	**11.7**	**15.3**	**40**	**1016**
Max All	*9.48*	*388*	*110*	*2.9*	*56.1*	*93.3*	*80*	*6837*
Min All	7.01	-78	40	0.5	1.1	0.6	16	87

Location	*Ca*	*Mg*	*Sr*	*Zn*	*Mn*	*Ni*	*Fe*	*Cu*	*Co*	*U*
Average UZ	**164**	**732**	**4910**	**1793**	**126.1**	**819**	**41**	**14.67**	**12.06**	**1.24**
Max UZ	*338*	*1489*	*9695*	*3162*	*394.5*	*2953*	*65*	*29.33*	*28.50*	*2.92*
Min UZ	5	7	148	538	4.5	2	26	7.21	4.71	0.45
Average SZ	**21**	**79**	**619**	**641**	**16.7**	**38**	**24**	**9.39**	**1.69**	**0.31**
Max SZ	*129*	*505*	*3723*	*3528*	*90.2*	*312*	*58*	*46.21*	*3.27*	*0.87*
Min SZ	4	15	148	2	0.02	1	3	0.95	0.13	0.002
Average FZ	**8**	**28**	**241**	**202**	**10.2**	**11**	**10**	**2.67**	**<DL**	**<DL**
Max FZ	*17*	*65*	*462*	*536*	*20.4*	*30*	*39*	*7.02*	*<DL*	*<DL*
Min FZ	2	8	60	1	0.03	1	3	0.46	<DL	<DL
Average All	**51**	**214**	**1490**	**788**	**49.4**	**207**	**24**	**8.85**	**8.17**	**0.67**
Max All	*338*	*1489*	*9695*	*3528*	*394.5*	*2953*	*65*	*46.21*	*28.50*	*2.92*
Min All	2	7	60	1	0.02	1	3	0.46	0.13	<DL

Elevated concentrations of dissolved ions within the unsaturated zone are likely the result of weathering reactions. Elevated concentrations of dissolved SO_4 and some metals may be due to microbially mediated oxidation of sulfide minerals within the PK material. Figure 6 shows a profile of pore gas concentrations measured from the PK surface to a one meter depth at location PKC1. Oxygen concentrations are at atmospheric (20.9%) from the surface to a depth of 0.5 m at which point the oxygen concentrations decreases to 3% at a 1 m depth. As discussed earlier, a number of sulfide minerals have been identified in the kimberlite and mudstone materials (Paktunc and Thibault, 2010). Consumption of oxygen by the oxidation of sulfide minerals is represented through (Nordstrom, 1982):

$$FeS_2 + \tfrac{15}{4} O_2 + \tfrac{7}{2} H_2O \rightarrow 2SO_4^{2-} + Fe(OH)_3 + 4H^+ \quad (1)$$

Where the oxidation of pyrite results in the release of 2 moles of sulfate, 4 moles of acid and a ferric (oxy)hydroxide precipitate. Speciation modeling results show that the porewater at locations PKC1 and PKC3 is supersaturated with respect to secondary ferric (oxy)hydroxide minerals, suggesting theses phases may be controlling dissolved Fe concentrations (Figure 8). Column experiments using the PK material have identified goethite as a secondary precipitate (Baker et al., 2003).

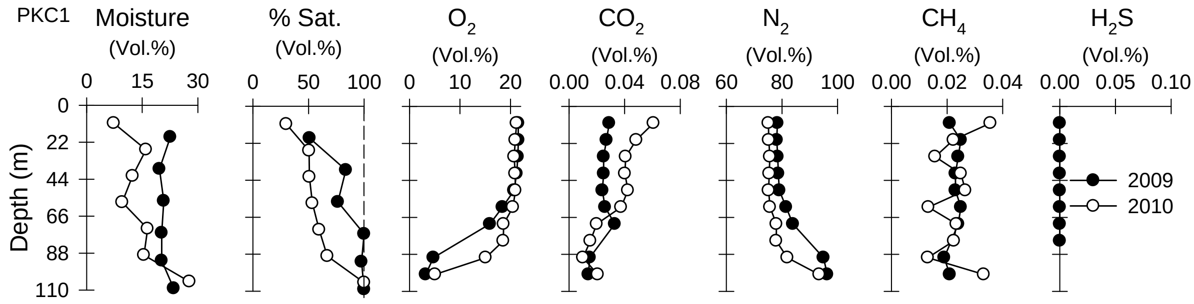


Figure 7: Depth profiles of soil moisture and pore gas measured at location PKC1.

Other sulfide minerals present in the oxidation zone may also react, releasing metals to the porewater. The oxidation of sphalerite, chalcopyrite, and galena, all of which have been identified in the PK material (Baker et al., 2003), can be represented through the equations:

$$ZnS + 2O_2 \rightarrow Zn^{2+} + SO_4^{2-} \quad (2)$$

$$CuFeS_2 + 4H^+ + O_2 \rightarrow Cu^{2+} + Fe^{2+} + 2S^0 + 2H_2O \quad (3)$$

$$PbS + 2O_2 \rightarrow Pb^{2+} + SO_4^{2-} \quad (4)$$

resulting in the release of Zn, Cu and Pb (equations (2), (3), and (4) respectively and SO_4. Sulfide oxidation of the PK material at DDMI was investigated using long-term kinetic column test conducted by Baker et al. (2003). This study found that sulfide oxidation could lead to the release of small amounts of Al, Fe, Ni, Co, Sr and Zn. These metals, along with others such as Pb, As, Cr and Cd are currently present in the porewater of the unsaturated zone of the PKC facility. The release of Cd is likely due to the weathering of sphalerite, Ni from the dissolution of olivine (Paktunc and Thibault, 2010) and oxidation of pentlandite

[$(Fe,Ni)_9S_8$], and millerite [NiS], and Cr from the dissolution of chromium diopside [Cr-$CaMgSi_2O_6$], garnet [$Ca_3(Al,Cr)_2(SiO_4)_3$] or possibly Cr-bearing magnetite [$Fe^{2+}Fe_2^{3+}O_4$].

Another cause for the decrease in O_2 gas concentration with depth is the increase in water content with depth in the PK material. In 2009 the O_2 content at PKC1 shows an abrupt decrease at 70 cm which coincides with almost complete saturation of the PK material at that depth (Figure 7). Gas measurements in 2010 at the same location show a decrease in O_2 gas concentration at 90 cm, again corresponding with saturation of the PK material. These results demonstrate that water content of the PK material controls the depth of O_2 diffusion.

The low dissolved concentrations of metals in the unsaturated zone are generally low due to the high neutralizing potential of the PK material. The pH of the porewater and groundwater remains neutral, limiting the solubility of most metals. The dissolution of calcite maintains the pH of the porewater near neutral through dissolution:

$$CaCO_3 + H^+ \leftrightarrow Ca^{2+} + HCO_3^- \qquad (5)$$

where one mol of acid is consumed and one mol of Ca and HCO_3 are released to the porewater. This reaction may account for the elevated concentrations of dissolved Ca in the unsaturated zone. Geochemical modeling results show that the porewater approaches or is at saturation with respect to calcite (Figure 8). Under neutral conditions, other minerals in the PKC facility, such as phlogopite, may undergo incongruent dissolution releasing dissolved K and Mg to the porewaters (Banfield and Eggelton, 1988; Murakami et al., 2003):

$$\begin{gathered}K(Mg_2Fe)(AlSi_3)O_{10}(OH)_2 + 5H^+ + 0.25O_2 + 3H_2O \rightarrow \qquad (6)\\ 0.5Al_2Si_2O_5(OH)_4 + Fe(OH)_3 + 2H_4SiO_4 + K^+ + 2Mg^{2+}\end{gathered}$$

Within the unsaturated zone, Ca and Mg concentrations are highest near the PK surface. Phlogopite was identified in the PK material (Baker et al., 2001; Paktunc and Thibault, 2010) and the porewater is the unsaturated zone is at satuation with respect to phlogopite (Figure 8). Low concentrations of K may be due to the precipitation of jarosite, removing K from solution:

$$K^+ + 3Fe^{3+} + 2SO_4^{2-} + 6H_2O \rightarrow KFe_3(SO_4)_2(OH)_6 + 6H^+ \qquad (7)$$

This is supported by MINTEQA2 calculations that suggest the porewaters near the surface at PKC1 and PKC3 are at saturation with respect to jarosite (Figures 8 and 9) potentially controlling the concentration of K, however this mineral phase was not identified by Paktunc and Thibault (2010) possibly due to low abundance.

In acid-neutralizing carbonate-mineral dissolution reactions the depletion of O_2 concentrations in pore gas is typically accompanied by an increase in CO_2 concentrations (Blowes et al., 1998). However, at PKC1 as O_2 concentrations decrease with depth the CO_2 concentrations also decrease to levels below atmospheric (0.036%) (Figure 7), suggesting that the CO_2 is being sequestered. This is consistent with previous work has shown that dissolution of silicate minerals within the PKC facility is sequestering CO_2 through the precipitation of carbonate mineral phases (Wilson et al., 2009). The possible dissolution of common silicate minerals like olivine and lizardite in the PKC facility can be represented by the equations:

olivine

$$(Mg,Fe)_2SiO_4 + 5/2O_2 + CO_2 + 5H_2O \rightarrow 2MgCO_3 + 2Fe(OH)_3 + Si(OH)_4 \quad (8)$$

lizardite

$$Mg_3Si_2O_5(OH)_4 + 3CO_2 \rightarrow MgCO_3 + 2SiO_2 + 2H_2O \qquad (9)$$

Speciation modeling suggests that porewater is undersaturated with respect to olivine. The dissolution of the minerals in equations (8) and (9) would result in the precipitation of magnesite [$MgCO_3$], which is consistent with equilibrium calculations that show the porewaters at locations PKC1 and PKC3 are at saturation with respect to magnesite (Figure 8 and 9). The dissolution of Ni-bearing olivine will also release dissolved Ni to the porewaters (Paktunc and Thibault, 2010).

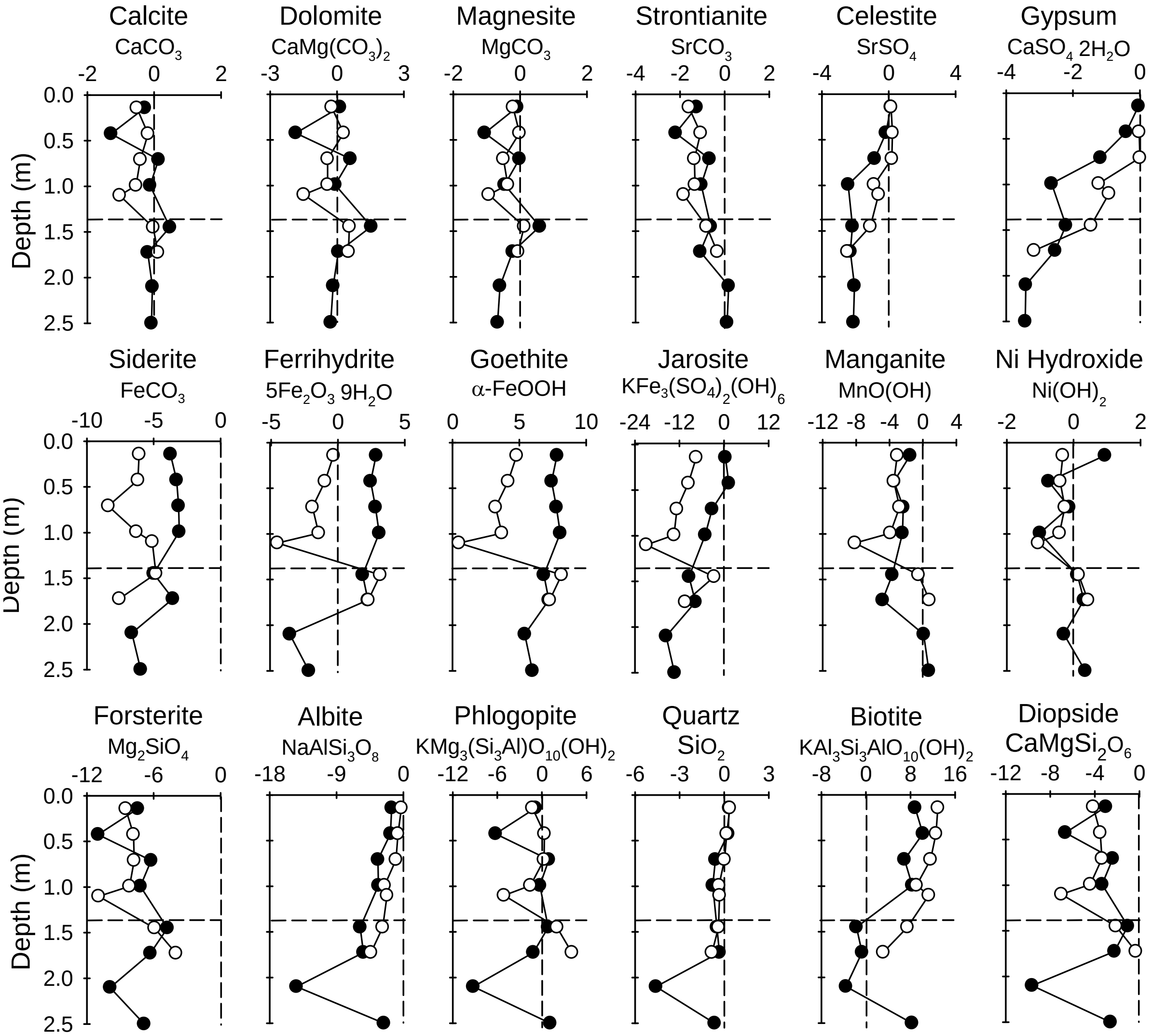


Figure 8: Depth profiles of saturation indices from PKC1 calculated using MINTEQA2.The horizontal dashed line with the inverted triangle represents the water table measured on October 5, 2009. Solid circles were measured in 2009 and open circles 2010.

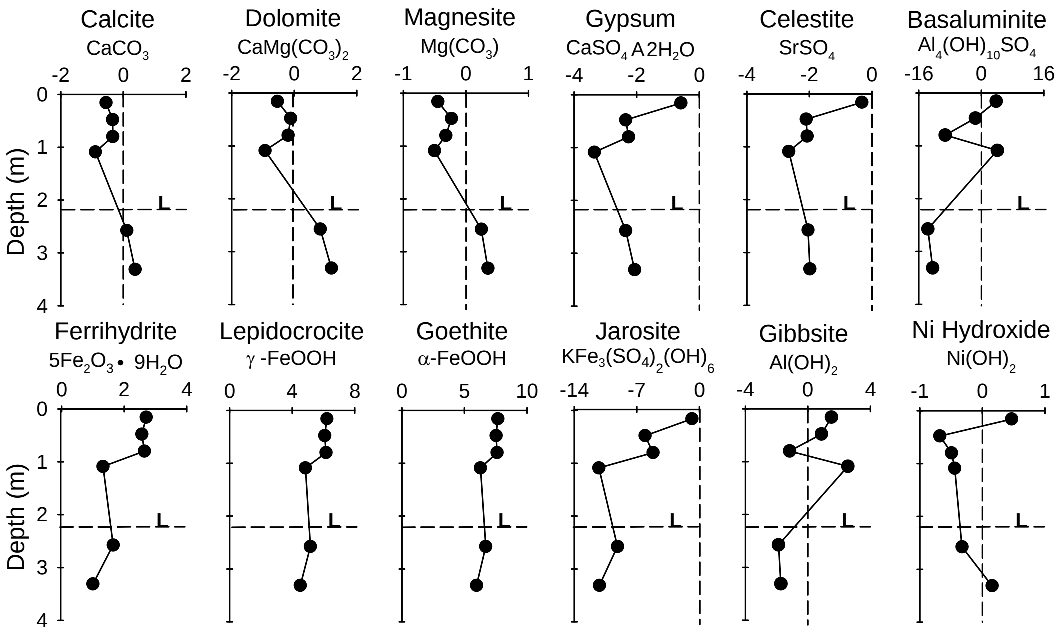


Figure 9: Depth profiles of saturation indices from PKC3 calculated using MINTEQA2.
The horizontal dashed line with the inverted triangle represents the water table measured on October 5, 2009.

6.2. Two Year Trend in Porewater Geochemistry

There were slight increases in the concentrations of SO_4, major cations and a number of metals in the unsaturated zone porewater 2009 and 2010 (Figure 10). For example, near the surface of PKC1 SO_4 and Mg increased from 6550 to 9650 mg L^{-1} and 1410 to 2140 mg L^{-1}, respectively, likely due to mineral dissolution. Alkalinity, pH, Eh and dissolved concentrations of Cl and Si exhibited minor variation between 2009 and 2010. In contrast, the concentration of some dissolved metals like Ni and Zn decreased between 2009 and 2010. During this time period dissolved concentrations of Ni decreased from 2950 to 590 µg L^{-1} and Zn from 3160 to 104 µg L^{-1} near the PKC1 surface. These decreases may be the result of precipitation or co-precipitation/adsorption reactions with secondary mineral phases. Speciation modeling shows that the porewater is at saturation with respect to $Ni(OH)_2$ and saturated to supersaturated with respect to Fe-oxyhydroxide minerals (Figure 8). The formation of secondary Fe-oxyhydroxide minerals may also account for the decrease of dissolved Fe in the unsaturated zone (Figure 10). The precipitation of Fe-oxyhydroxides at a pH above 4 leads to the co-precipitation or adsorption of metals, such as Zn, Cu, Ni, Co, and Cd (Thornber and Wildman, 1984; Bowell and Bruce, 1995; Holmström and Öhlander, 2001).

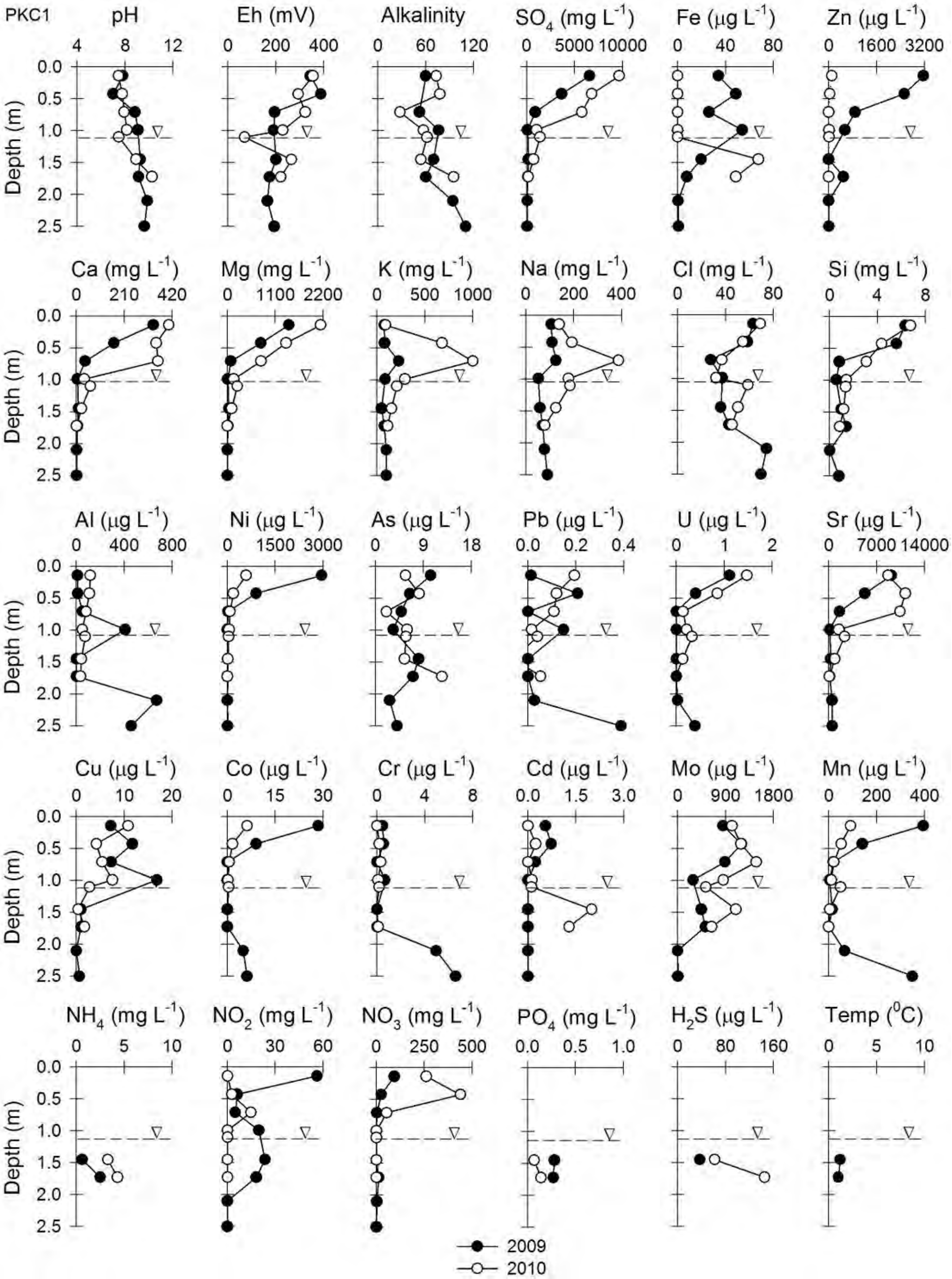


Figure 10: Depth profiles of porewater chemistry at location PKC1 measured in 2009 and 2010. The dashed line with inverted triangle represent the water table. Solid circles were measured in 2009 and open circles 2010.

In 2009, porewater and groundwater was sampled from PKC2. Porewater in the unsaturated zone contained elevated concentrations of dissolved SO_4, major cations and some metals, similar to concentrations measured from PKC1. There was ~2.4 m rise in the PKC Pond water level between 2009 and 2010, which resulted in a 0.30 m deep water column above the ground surface at PKC2 during sampling in 2010. Profiles of porewater chemistry measured at PKC2 in 2010 show the opposite trend as profiles measured in 2009 (Figure 11). The concentrations of dissolved ions increase with depth through the former unsaturated zone. Dissolved concentrations of ions near the surface of the profile are similar to concentrations measured in the PKC Pond water, then increase with depth. As water levels in the PKC Pond rise, water infiltrates into the unsaturated zone, displacing the porewater with elevated ion concentrations downward. This process is clearly demonstrated by comparison of the 2009 and 2010 profiles of dissolved SO_4, major cations and most metals (Figure 11). In 2010 concentrations of dissolved ions with depth are similar to dissolved ions measured near the surface in 2009. In a few cases, such as dissolved U and Cr, the concentrations are higher in the PKC Pond than the porewater, so the rising water level resulted in concentrations that increased near the groundwater/surface water interface.

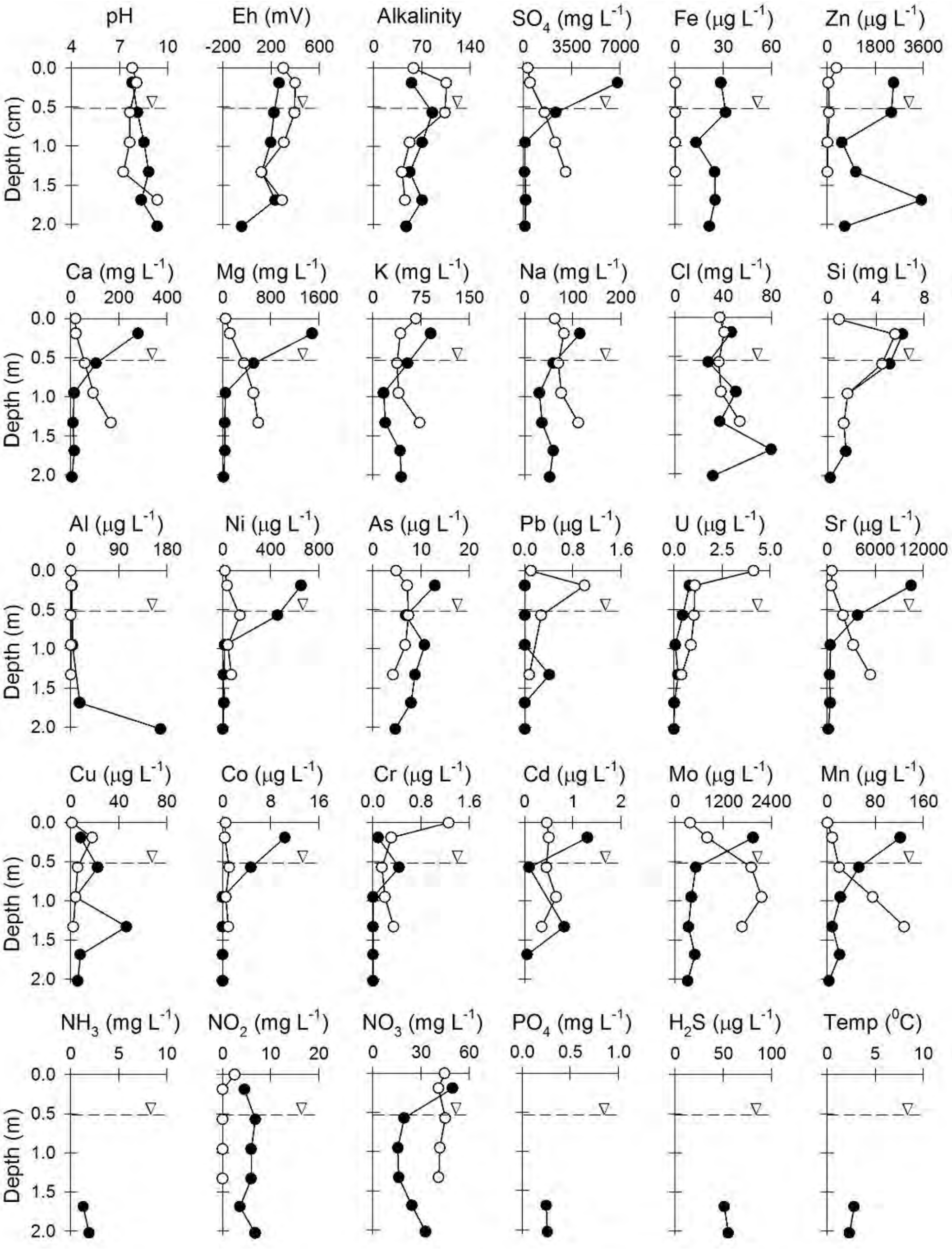


Figure 11: Depth profiles of porewater chemistry at location PKC2 measured in 2009 (closed circles) and 2010 (open circles). The dashed line with inverted triangle represents the water table measured in 2009. The top point in the 2010 data represent water chemistry of the PKC Pond.

6.3 PKCSW – South West Beach

Exposed PK material on the southwest beach of the PKC facility is thought to have undergone the longest weathering (PKCSW). Porewater was extracted from a core extending from surface to 1-m depth. Pore gas was also measured adjacent to the core location. Piezometers were not installed at this location, so measurements about depth to the water table are not available. We do know that the core hole remained dry for several days after the core was extracted indicating that the water table was greater than 1 m below the ground surface.

Pore gas was measured at 0.20 m intervals from surface to a depth of 0.80 m (Figure 9). The oxygen concentration at 0.80 m was 18.4 %, only slightly deviating from the atmospheric concentration indicating that O_2 has diffused much deeper into the PK material than at location PKC1. Nitrogen concentrations also remain near atmospheric (78 %) through the profile. CO_2 concentrations remain below atmospheric (0.036 %), suggesting that it is being sequestered (equations 8 and 9). Methane concentrations in the PK material far exceed atmospheric concentrations (0.00017 %) which may indicate product of microbial activity.

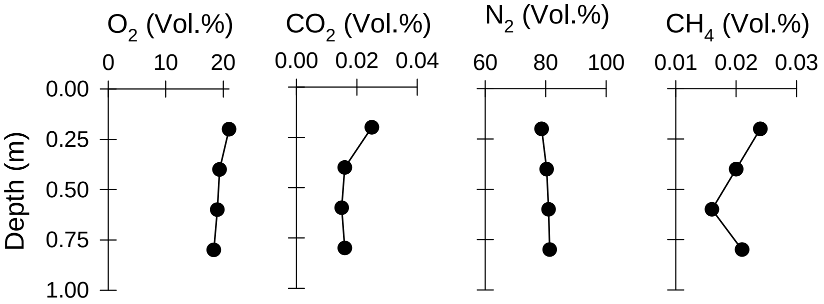


Figure 12: Depth profiles of pore gas measured at location PKC1 in 2009.

Porewater geochemistry profiles show that weathering of the PK material has led to the release of elevated concentrations of SO_4 and some metals to the porewater (Figure 13). Porewater extracted from a depth of 0.17 m has a pH of 7.3 and the highest concentrations of dissolved ions within the profile (eg. SO_4: 9100 mg L^{-1}, Ni: 0.75 mg L^{-1}, Sr: 9.5 mg L^{-1}, Zn: 2.7 mg L^{-1}). At a depth of 0.50 m, the porewater pH decreases to 4.02, the alkalinity is consumed and there is an abrupt spike in the concentration of some dissolved metals (Fe, Al, Pb, Cu, Cr). Speciation modeling shows that the porewater is undersaturated with respect to carbonate and some Al and Fe (oxy)hydroxide mineral phases (Figure 14). The low pH water could be causing the dissolution of these minerals and subsequent release of dissolved ions to the porewater. This low pH zone may represent an area of processed mudstone material. Column experiments indicated that the mudstone material is highly reactive, resulting in acidic effluent (e.g. pH=3) and elevated concentrations of SO_4, Fe, Al, Co, Cu, Ni and Zn in the mg L^{-1} range (Baker et al., 2003). At a depth of 0.8 m the pH increases to 7.7 and the concentrations of dissolved metals and SO_4 are generally similar or lower than concentrations measured at 0.17 m depth.

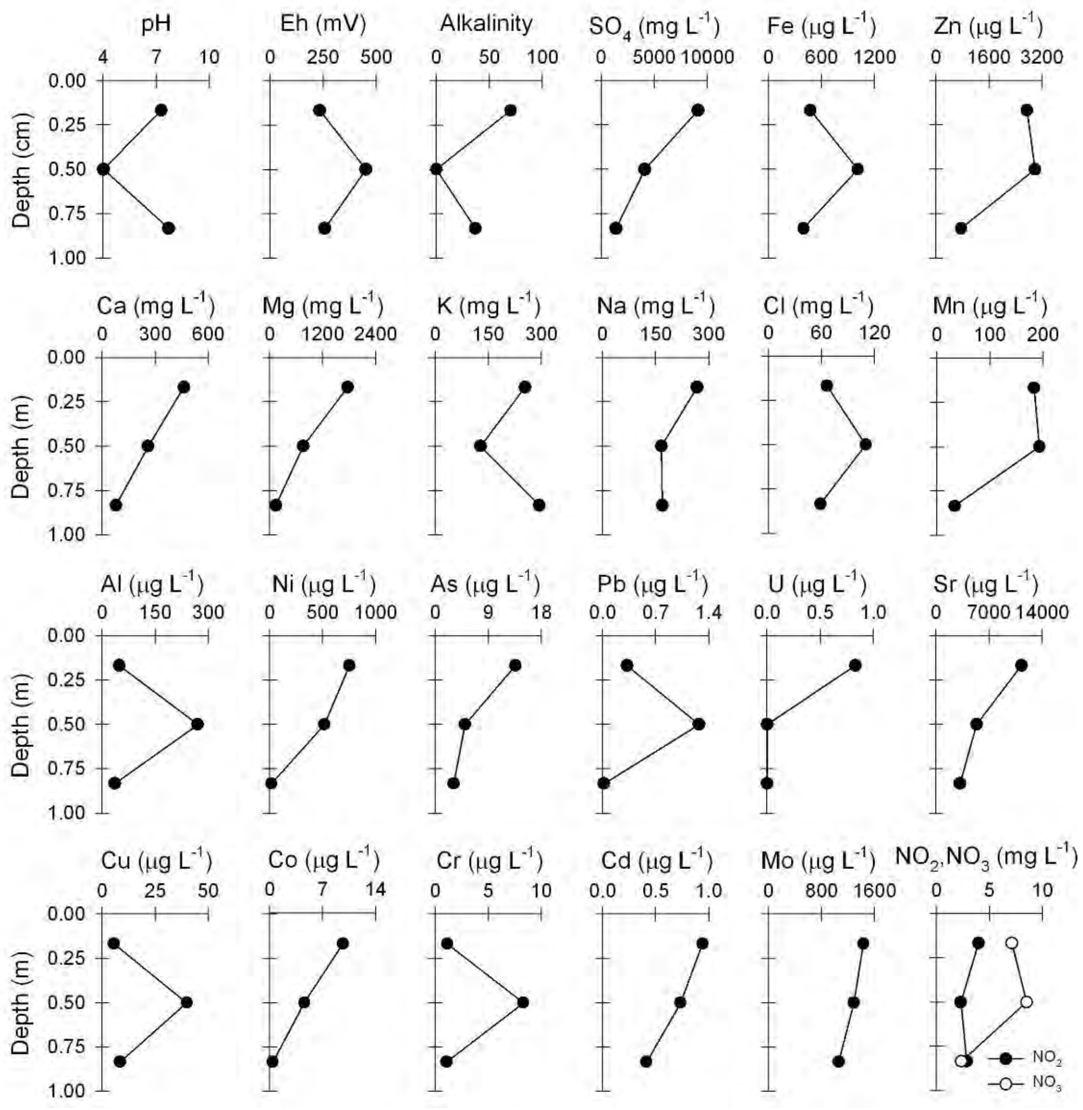


Figure 13: 2009 depth profiles of porewater chemistry at the PKCSW location.

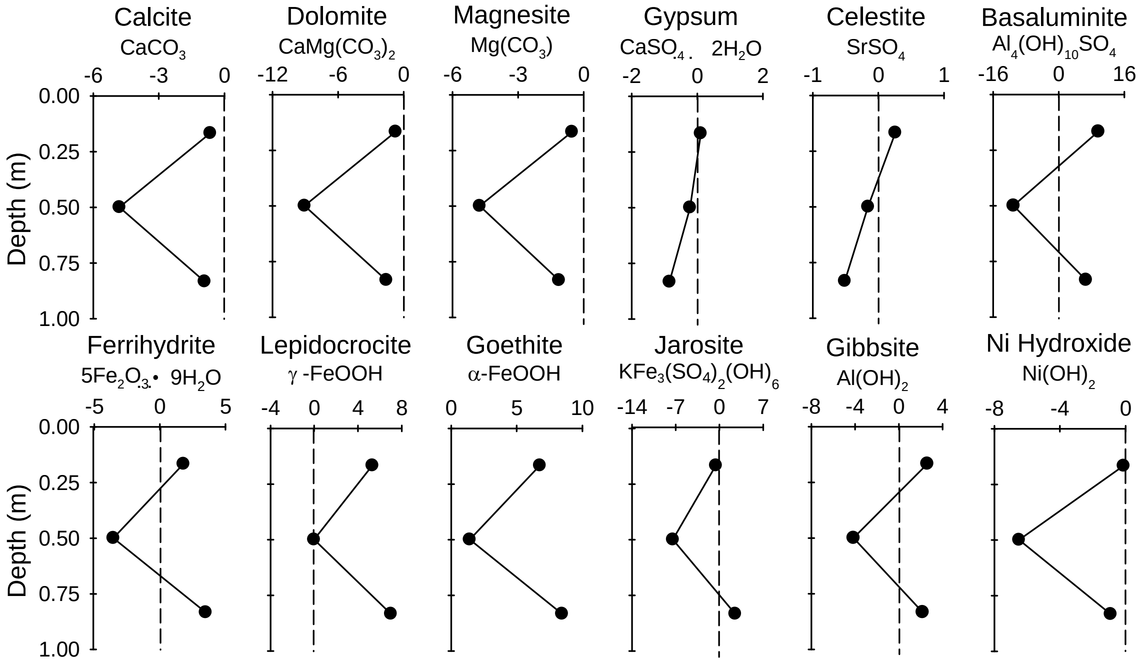


Figure 14: Depth profiles of saturation indices from PKCSW calculated using MINTEQA2.

6.4 PKC Barge and B2

Piezometers were installed into the pond bottom at the PKC pond in 2009 and 2010 at the Barge location and at B2 (Figure 1). The Barge location had to be re-instrumented each year because of rising water levels in the PKC pond. The water column at the barge was 1.8 m-deep when the piezometer was installed in 2009, unfortunately an accurate depth measurement could not be obtained in 2010. The PK material beneath the water column was extremely unconsolidated to the point where a vertical Van Doren bottle sampler was lowered to a depth of 1.2 m below the water/sediment interface to collect samples. Piezometers installed to a depth of 10 m were installed by hand, and piezometers deeper than this were installed using a Pionjar percussion drill. No frost was encountered during the installation of drive-point piezometers in 2009 and 2010.

Water levels in the four Barge piezometers were measured relative to the water level in the adjacent PKC pond on October 5, 2009 (Table 3). The water levels indicate a strong downward gradient between B-25 and B-35, but a strong upward gradient between B-45 and B-65. The B-35 piezometer had recently been sampled and we suspect that upward gradient between B-25 and B-35 is due to the water level at B-35 not having fully recovered when the water levels were measured.

Table 4: Water levels measured from the Barge piezometers. Water levels were measured on October 5, 2009, with respect to the water surface of the PKC pond. A negative value indicates piezometer water level above PKC pond water level.

Location	*Depth (m)*	*Water Level (m)*
Barge-25	7.2	0.99
Barge-35	10.7	5.26
Barge-45	13.7	-0.86 (flowing)
Barge-65	19.8	-0.74 (flowing)

Piezometers were re-installed off of the Barge on August 7, 2010. Water levels were measured in the piezometers on September 10, 2010 (Table 4) and rising-head tests were conducted to determine hydraulic conductivities. Deeper piezometers (Barge 55 and 80) show a strong upward gradient. Water levels in piezometers Barge 25 and 45 are near equilibrium with the PKC Pond, and the Barge 35 piezometer shows a downward gradient. As with the 2009 water level data, the anomalous gradient at Barge 35 could indicate that the water levels hadn't completely recovered.

The hydraulic conductivity (K), measured from the five 2010 Barge piezometers ranges from 7.8×10^{-8} m s^{-1} to 7.2×10^{-10} m s^{-1}, with an average of 3.5×10^{-8} m s^{-1}. The hydraulic conductivity of the PK material at the Barge is far lower than the hydraulic conductivity measured from the PKC East Beach material. The difference in K is due to differential settling during deposition of the PK material. The beach material is closer the spigot discharge point resulting in the deposition of a sand-size fraction of PK material whereas the Barge is more distal from the discharge point resulting in an accumulation of a clay-size fraction of PK material. The K estimate for the Barge-35 piezometer does not indicate any significant differences in hydraulic conductivity for this depth that would explain the unusual water levels.

Table 5: Water levels and hydraulic conductivities measured from the Barge piezometers. Water levels were measured on September 10, 2010, with respect to the water surface of the PKC pond. A negative value indicates piezometer water level above PKC pond water level.

Location	*Depth (m)*	*Water Level (m)*	*Hydraulic Conductivity (K) (m s^{-1})*
Barge-25	7.16	-0.02	2.9×10^{-9}
Barge-35	9.82	0.22	7.8×10^{-8}
Barge-45	12.82	0.01	9.2×10^{-8}
Barge-55	18.16	-1.04 (flowing)	1.6×10^{-9}
Barge-80	25.73	-1.67 (flowing	7.2×10^{-10}

Profiles of groundwater chemistry collected in 2009 and 2010 from the Barge piezometers show concentrations of dissolved ions, temperature and Eh are generally higher in the PKC pond water, and decrease with depth though the PK material (Figure 15). The distributions of SO_4 and major cations showed little change between 2009 and 2010. The trace metal concentration did show some differences between 2009 and 2010, however, these concentrations were near detection limits and likely within analytical uncertainties. In 2009 the average concentration of dissolved organic carbon (DOC) measured from the Barge piezometers and the PKC pond was 9.5 mg L^{-1}, however the concentrations measured in piezometers B-35 and B-45 was 109 and 257 mg L^{-1}, respectively. Concentrations of DOC were similar in 2010. The elevated DOC may indicate a period when raw sewage was discharged to the PKC facility. Normally sewage from the mining operations is treated prior to discharge to the PKC facility. Speciation modeling results show that carbonate minerals are a saturation near the surface and bottom of the profile and (oxy)hydroxide mineral phases are at saturation across the central portion of the profile (Figure 16). These secondary mineral phases may be controlling pH and the dissolved concentration of ions in the porewater.

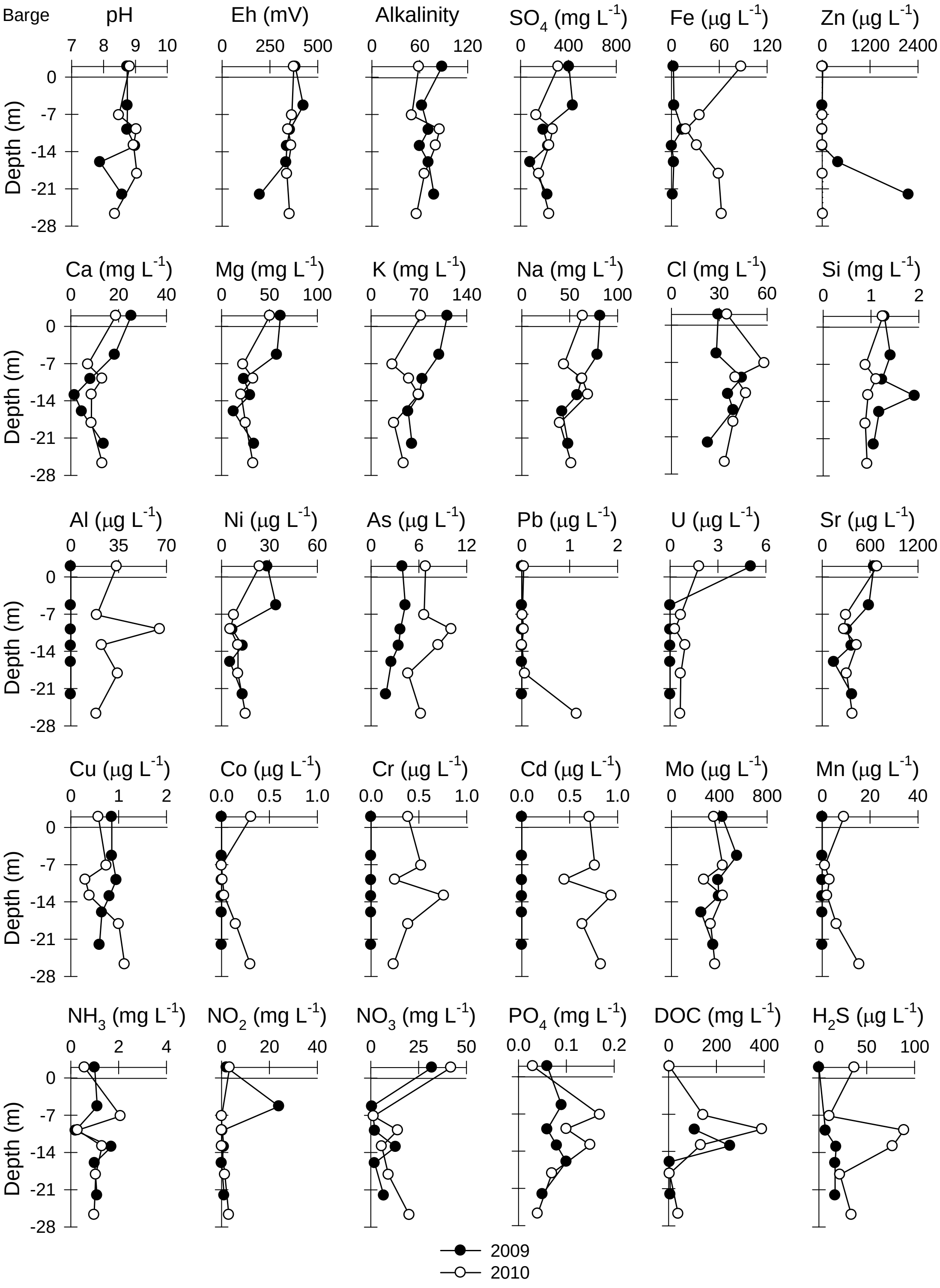


Figure 15: Depth profile of groundwater chemistry at the Barge location measure in 2009 and 2010.The top point represents PKC pond chemistry and the horizontal solid line is the boundary between the surface water column and PKC material.

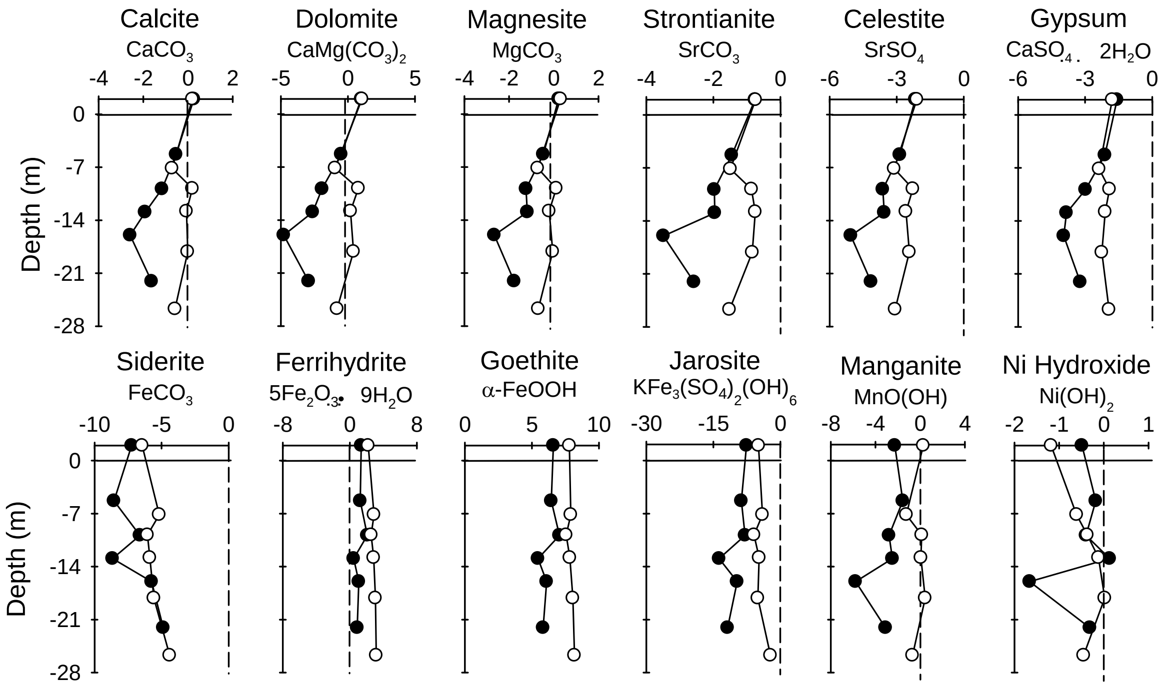


Figure 16: Depth profile of saturation indices from the Barge piezometers calculated using MINTEQA2. The upper point represents the PKC pond chemistry and the solid horizontal line is the boundary between the surface water column and PKC material. Closed circles represent 2009 and open circles are from 2010.

The B2 piezometer nest located at the center of the PKC Pond had similar geochemical profiles as the Barge piezometers (Figure 17). Most dissolved ions in the PK material are at or below the PKC Pond concentrations, with the exception of a spike of some dissolved trace metals at 9 m. Below 9 m dissolved metal concentrations are minimal. At a depth of 12 m there is a spike in DOC, similar to the increase and depth observed in the Barge piezometers suggesting that the elevated DOC layer extends across the PKC facility.

Concentrations of dissolved ions measured from both Barge and B2 piezometers are much lower than concentration from porewaters measured from the PKC East and PKC-SW beaches of the PKC facility. Even though the two sub-aqueous tailings sites (Barge and B2) received fairly similar materials as the two aerially exposed tailings sites (PKC East and PKC-SW) the difference between geochemical profiles indicates that the subaqueous disposal PK material has significantly limited weathering and the subsequent release of ions to the porewaters. The ability of a water cover to reduce the ingress of O_2 into tailings and the subsequent mineral weathering is well recognized and subaqueous disposal of mine tailings is a common practice in tailings management (eg. Pedersen et al., 1993; Vigneault et al., 2001; Jacob and Otte, 2004; Samad and Yanful, 2005). The O_2 ingress into the tailings is limited by the slow diffusion of O_2 through the water cover. For example, the diffusive flux of O_2 to water covered tailings is almost 10 000 times less than uncovered tailings (Robertson et al., 1997).

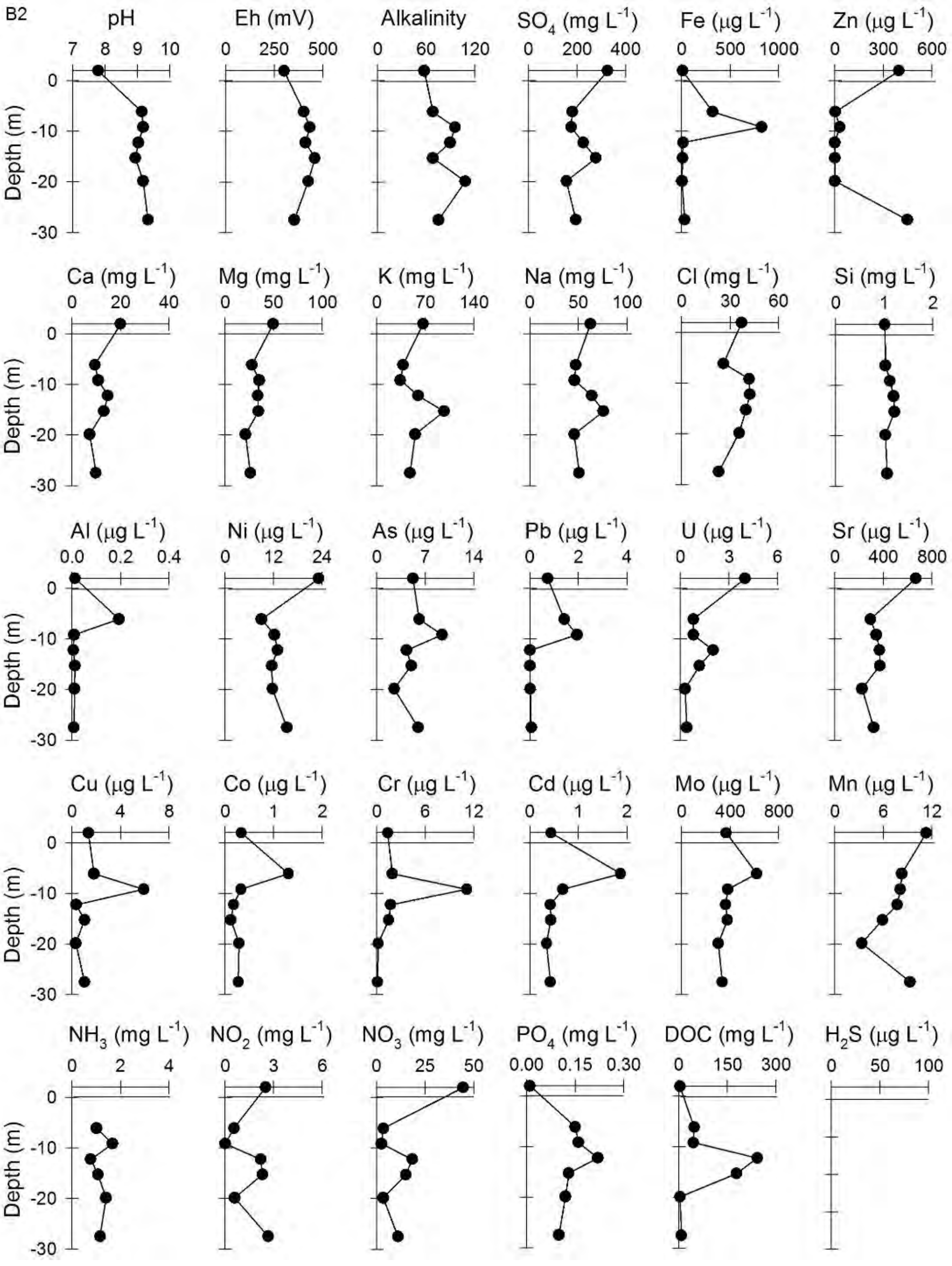


Figure 17: Depth profiles of groundwater chemistry at the B2 location measured in 2010.The top point represents PKC pond chemistry and the horizontal solid line is the boundary between the surface water column and PKC material.

7.0 BACTERIA POPULATIONS

The decrease in concentrations of dissolved metals and SO_4 observed at PKC1 with depth could be a result of bacterial mediated sulfate and iron reduction (Figure 18).

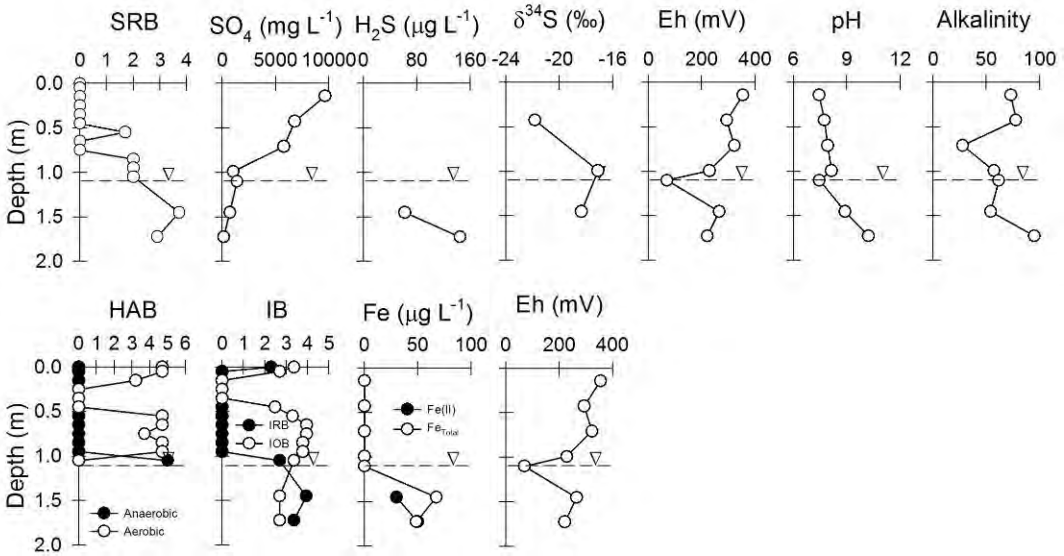


Figure 18: Depth profiles showing populations of sulfate reducing bacteria (SRB), iron-related bacteria (IB), and heterotrophic bacteria (HAB), including groundwater chemistry from location PKC1 measured in 2010.The dashed line with inverted triangle represents the water table.

As sulfate-reducing bacteria catalyze the oxidation of organic carbon, the reduction of SO_4 to H_2S (Berner, 1980) occurs through the reaction:

$$SO_4^{2-} + 2CH_2O \rightarrow H_2S + 2HCO_3^- \qquad (10)$$

where CH_2O represents a generic organic compound. The organic carbon source in the PKC facility likely originates from treated/untreated sewage and possibly Tertiary aged wood fragments found in the kimberlite. The release of H_2S in the presence of dissolved metal concentrations can result in the precipitation of sulfide minerals:

$$Me^{2+} + S^{2-} \rightarrow MeS \qquad (11)$$

where Me^{2+} denotes a divalent metal such as Fe and Ni; and MeS represents an amorphous or poorly crystalline metal sulfide.

Within the unsaturated zone at PKC, aerobic heterotrophic bacteria (HAB) and iron oxidizing bacteria (IOB) are the dominate populations. At the water table there is a redox boundary where Eh values show a shift from oxidizing to reducing conditions. The shift in redox condition corresponds to a change bacteria populations where sulfate reducing bacteria (SRB), anaerobic HAB and iron reducing bacteria (IRB) are the dominate populations. The sequence of reactions in equations (10) and (11) decreases the concentrations of dissolved SO_4, Fe, and other metals, and increases alkalinity and pH (Tuttle et al., 1969; Peine and Peiffer, 1998; Benner et al., 1999; Lindsay et al., 2009). The reduction of SO_4 described in reaction (10) is consistent with the increase of SRB populations through the unsaturated zone with H_2S production and the decrease of metals, SO_4, and Eh with depth (Figures 10 and 18). Alkalinity and pH also show an increase with depth providing further support that sulfate reduction is occurring. Below the water table there is an increase in dissolved ferrous iron which corresponds to the appearance of populations of IRB. The lack of HAB at a depth from 40 to 60 cm is likely a reflection of organic carbon availability. Heterotrophs require organic carbon as a growth substrate and the absence of HAB suggests that an organic carbon source is absent at the 40-60 cm depth interval.

The $\delta^{34}S_{SO4}$ values from PKC1 show little variation between the 0.4, 1.0 and 1.5 m depths (Figure 18). The isotopic fractionation that occurs as during microbial mediated sulfate reduction typically results in large positive shifts in the $\delta^{34}S_{SO4.}$ Hydrogen sulfide was measurable in groundwater from the two deepest piezometers but the concentrations were negligible when compared to dissolved SO_4 concentrations. For example, the concentration of dissolved SO_4 and H_2S measured from PKC1-S were 773 mg L^{-1} and 0.062 mg L^{-1}, respectively (Figure 18). Although there is small amount of H_2S produced from microbial mediated sulfate reduction, the concentration of SO_4 produced from possible sulfide oxidation reactions is more dominate, hence the sulfur isotopic ratios will maintain a sulfide oxidation signature. The negligible concentration of H_2S is not unique to the PK material, having been observed in other studies (e.g. Taylor et al., 1984 a,b; Edraki et al., 2005; Dold and Spangenberg, 2005; Balci et al., 2007; Moncur et al., 2009).

Bacteria populations from the Barge piezometers are presented in Figure 19. Profiles show that SRB and IRB populations increase between the PKC Pond and porewater from the PK material. There does not appear to be a strong correlation between microbial mediated SRB and IRB populations with pH, Eh, alkalinity and dissolved SO_4 concentrations, however the production of H_2S and increasing Fe(II) concentrations with depth indicates mild sulfate and iron reduction may be occurring. Values of $\delta^{34}S-SO_4$ and $\delta^{13}C$-DIC measured from Barge-25, Barge-65 and the PKC Pond waters are presented in Figure 19. The absence of a positive shift in $\delta^{34}S$ values typically associated with microbially mediated sulfate reduction could be the result of the high $SO_4:H_2S$ ratio.

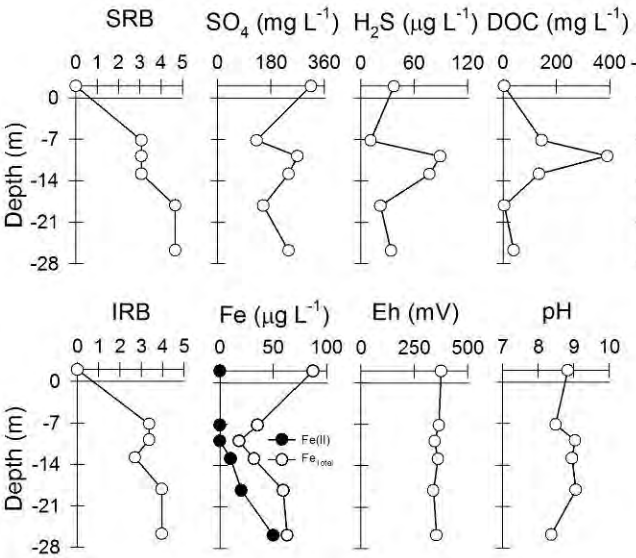


Figure 19: Depth profiles showing populations of sulfate reducing bacteria (SRB) and iron related bacteria (IRB), including groundwater chemistry from the Barge piezometers, measure in 2010.The solid horizontal line represents the sediment/water-column boundary.

Saturation indices calculated using MINTEQA2 indicate the groundwater in the Barge piezometers approaches saturation or becomes supersaturated with respect to some Fe, Ni and Zn secondary sulfide mineral phases at depth within the PK material (Figure 20). The precipitation of these secondary sulfide mineral phases could be controlling SO_4 and metal concentrations in the porewater of the PKC material as has been reported for other mine sites (e.g., Pedersen et al., 1993; Paktunc and Davé, 2002; Moncur et al., 2009).

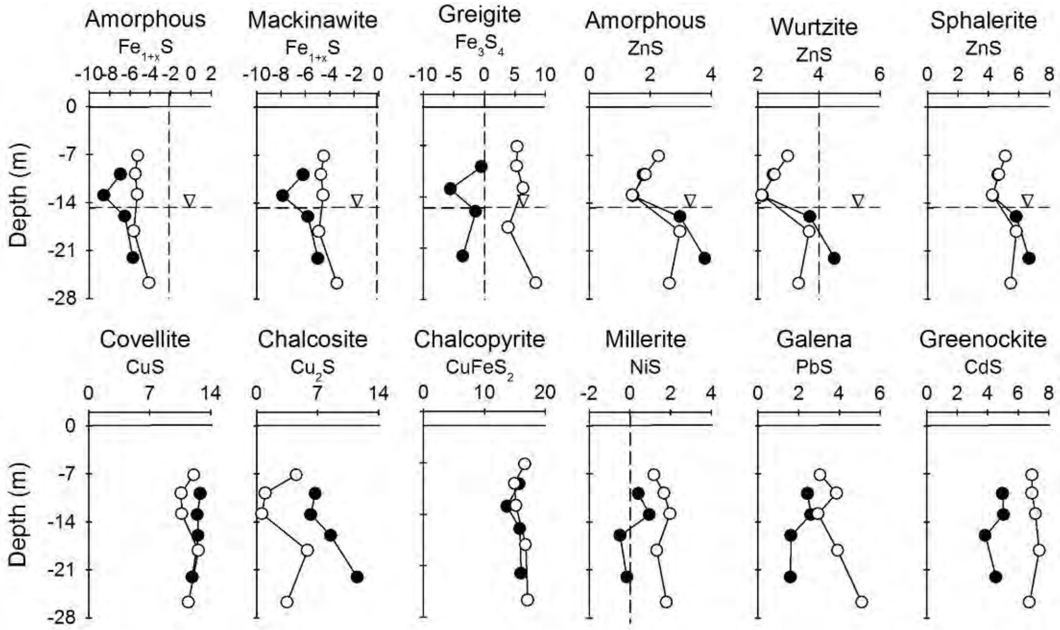


Figure 20: Saturation indices calculated using MINTEQA2, plotted versus depth at the Barge piezometer nest. The solid horizontal line is the boundary between the surface water column and PKC material. Closed circles represent 2009 data and open circles represent 2010 data.

The distributions of SRB and IRB populations in the porewater at B2 differ from those measured at the Barge site in that there does not appear to be a strong correlation with bacteria presence and porewater geochemistry (Figure 21). A positive detection of SRB at all of the depths sampled did not appear until after the 10 day monitoring period, indicating the presence of SRB, but at such low population sizes that it could not be quantified. The distribution of IRB are similar to the Barge location but there are not the same associated trends in dissolved SO_4 and metal concentrations.

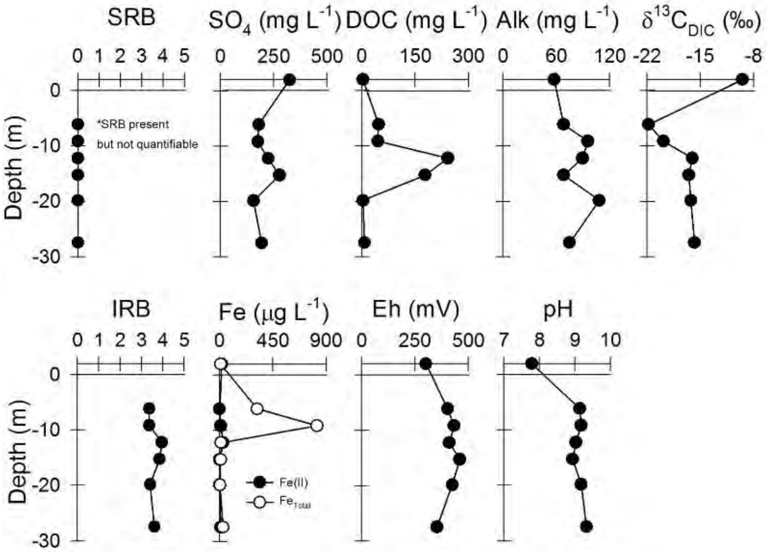


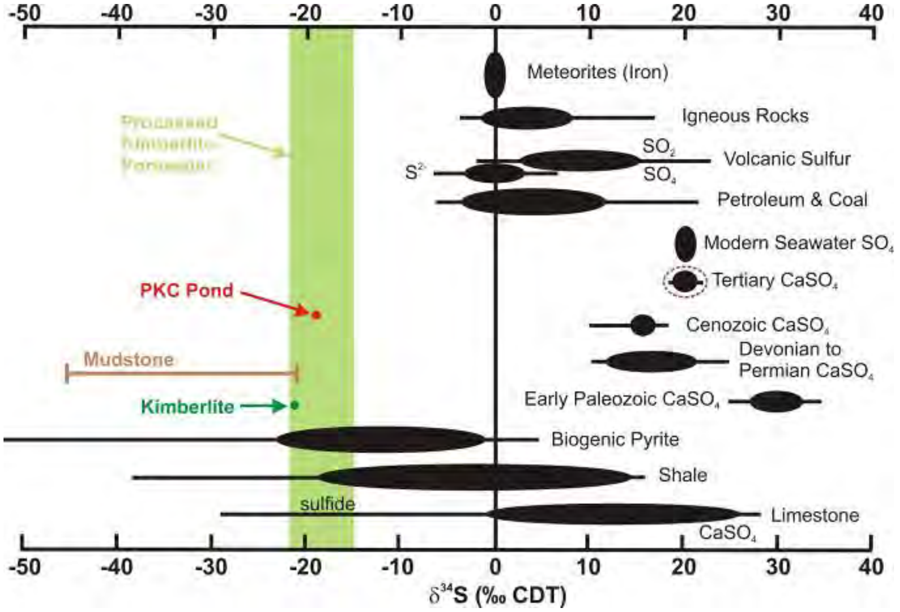
Figure 21: Depth profiles of groundwater chemistry at the B2 location measured in 2010.The top point represents PKC pond chemistry and the horizontal solid line is the boundary between the surface water column and PKC material.

8.0 ISOTOPIC TRENDS

8.1 $\delta^{34}S_{SO4}$ Isotopic Ratios

The $\delta^{34}S$-SO_4 values of the various rock types in the PK material and the $\delta^{34}S$-SO_4 and $\delta^{18}O$-SO_4 composition of the PKC waters collected at the East Beach, Barge and PKC Pond can be used to improve our understanding of the sources of SO_4 to in the PKC tailings and pond (Figure 22). The potential sources of SO_4 to the porewaters and pond include dissolution of sulfate minerals or oxidation of sulfides. Gypsum has been identified in the Diavik PK (Baker et al., 2003; Wilson et al., 2009) and previous work has suggested that elevated SO_4 concentrations in the PK porewater at the nearby Ekati Mine was due to dissolution of calcium sulfate mineral phase (Rollo and Jamieson, 2006). A number of sulfide minerals have been identified in the PK material including pyrite and pyrrhotite (Paktunc and Thibault, 2010). Samples of gypsum from the PK material were not available for $\delta^{34}S$ analysis, but the $\delta^{34}S$-SO_4 value of tertiary aged $CaSO_4$ is typically enriched, around +20‰ (Figure 22). The $\delta^{34}S$-SO_4 of the unprocessed kimberlite was -21.0 ‰ and the mudstone ranged from -20.4 to -46.4 ‰. Negative $\delta^{34}S$ values are typical of diagenetic environments where reduced sulfur compounds are formed, with the most common reaction product being pyrite (Clark and Fritz, 1997). The $\delta^{34}S\text{-}SO_4$ values of the PK porewater overlap the ranges for unprocessed kimberlite and mudstone with values -15.3 to -21.8‰. The similarity between the PK porewater and the unprocessed kimberlite and mudstone indicate minimal fractionation between the solid phase and dissolved phase which is consistent with previous studies (Taylor et al., 1984; Edraki et al., 2005). Gypsum identified in the Diavik PKC was identified as a secondary product from weathering of the PKC (Wilson et al., 2009). The $\delta^{34}S\text{-}SO_4$ values measured in the porewater of the Diavik PK material are strongly depleted (-19‰) suggesting that the primary source of SO_4 is sulfide oxidation. The dissolution of sulfate mineral phases cannot be excluded as a minor source of sulfate to the porewater, however only trace amounts of $BaSO_4$ were observed during mineralogical examination of the PK material (Paktunc and Thibault, 2010).

There was also very little variation in the PKC porewater $\delta^{34}S\text{-}SO_4$ signatures with depth, between the different redox zones and or between water with large differences SO_4 concentrations. The absence of a positive shift in $\delta^{34}S$ values typically associated with microbially mediated sulfate reduction could be the result of the high SO_4:H_2S ratio. The sample from the PKC pond and the PKC porewater samples all have $\delta^{34}S\text{-}SO_4$ and $\delta^{18}O\text{-}_{SO4}$ signatures consistent with the sulfate originating from the oxidation of sulfides.



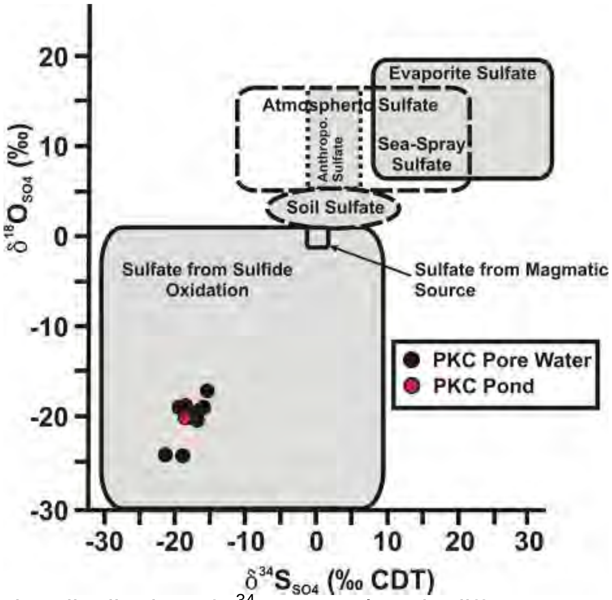


Figure 22: Top Plot showing distribution of δ^{34}S-SO$_4$ values in different materials and environments (modified from Clark and Fritz, 1997). The green shaded area represents the range of δ^{34}S-SO$_4$ values measured in groundwater samples collected from the East Beach and Barge sites. The red circled area represents typical values for tertiary age sulfate minerals. Bottom plot showing distribution of δ^{34}S-SO$_4$ values versus δ^{18}O-SO$_4$ from the PK porewater (revised after Mayer (2005)).

8.2 $\delta^{13}C_{DIC}$ Isotope Ratios

The δ^{13}C of dissolved inorganic carbon (DIC) in the PKC Pond and groundwaters have about the same range as the δ^{13}C values measured for the processed kimberlite (Figure 23). When DIC is formed in the soil zone from infiltrated water it typically acquires a δ^{13}C value close to –10 to -15 ‰ under open system conditions. Surface waters in direct contact with atmospheric concentrations of CO_2 typically acquire a slightly more positive δ^{13}C signatures of approximately -8 ‰. These initial δ^{13}C-DIC compositions can be further modified as processes like sulfate reduction or carbonate dissolution add HCO_3 to the water. Shifts towards more negative δ^{13}C-DIC values can occur during sulfate reduction. Carbonate dissolution can shift the δ^{13}C- DIC towards more negative or positive values depending on the δ^{13}C of the available carbonate minerals. If the mudstone and processed kimberlite are carbonate sources then the shift from more positive δ^{13}C-DIC values in the pond to more negative values may be the result of inputs of negative δ^{13}C-DIC from the dissolution of carbonates in the processed kimberlite material or mudstone. The PKC piezometer samples with the more positive δ^{13}C-DIC compositions also have lower alkalinity concentrations then the more negative δ^{13}C-DIC waters which are characterized by higher alkalinity concentrations. These trends are consistent with the differences in δ^{13}C-DIC being due to a combination of sulfate reduction and dissolution of mudstone and processed kimberlite.

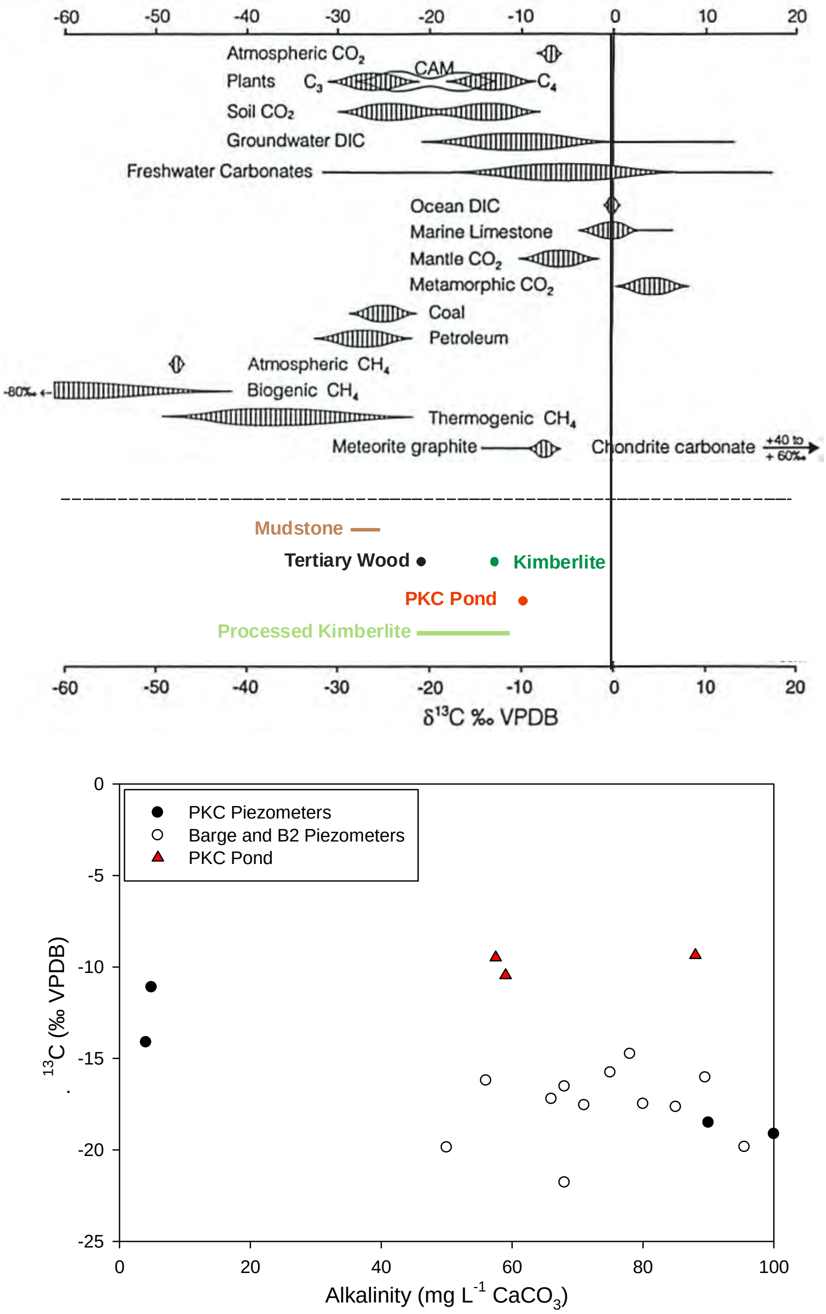


Figure 23: Top Plot shows the distribution of δ^{13}C-DIC values in different materials and environments (modified from Clark and Fritz, 1997). Lower plot shows distribution of δ^{13}C-DIC values versus alkalinity concentrations from the PK porewater.

8.3 δ^{18}O and δ^{2}H Isotope Ratios

Stable isotopes of δ^{18}O and δ^{2}H measured in water collected from the PKC Pond and groundwater collected from piezometers installed in the East Beach and Barge sites show systematic differences in the stable water isotope labeling of groundwaters and surface waters in the vicinity of the PKC pond (Figure 24). The global meteoric water line (GMWL; Craig

1961) and a local meteoric water line (LMWL) from Snare Rapids (based on data from 1997-2007) located 300 km west of Diavik (63.52°N, 116.00°W, 241 masl) (Canadian Network for Isotopes in Precipitation Station, 2007) are included for comparison. As expected the groundwater samples plot along the LMWL. Surface water having undergone evaporation typically plots along a LEL with a lower slope than the LMWL. In high latitude regions the slope of the LEL steepen and have been found to approach the LMWL, so the position of the surface waters from the PKC pond just below the LMWL is not unusual (Gibson and Birks, 2002). The groundwater samples sampled have more negative $\delta^{18}O$ and $\delta^{2}H$ compositions when compared to the more positive surface water values. Mixing of surface waters and groundwaters is indicated by the intermediate $\delta^{18}O$ and $\delta^{2}H$ composition found in some of the Barge PKC well samples. For example, Sample Barge-10, collected 1.2 m below the PKC Pond bottom, plots adjacent to the pond water indicating that this porewater is being actively exchanged with the overlying pond. Sample Barge-25, Barge-65 and PKC3-d all plot between the groundwater and surface water clusters suggesting that water from these piezometers is a mixture of pond water and deeper groundwater, the latter having an isotopic composition falling on a mixing line between pond water and mean annual precipitation at Snare Rapids ($\delta^{18}O$=-21.6‰, $\delta^{2}H$=-167.8‰). Enrichment in $\delta^{18}O$ and $\delta^{2}H$ in pond water at the time of sampling appears to be due to evaporation effects and/or a high content of summer rainfall in the pond.

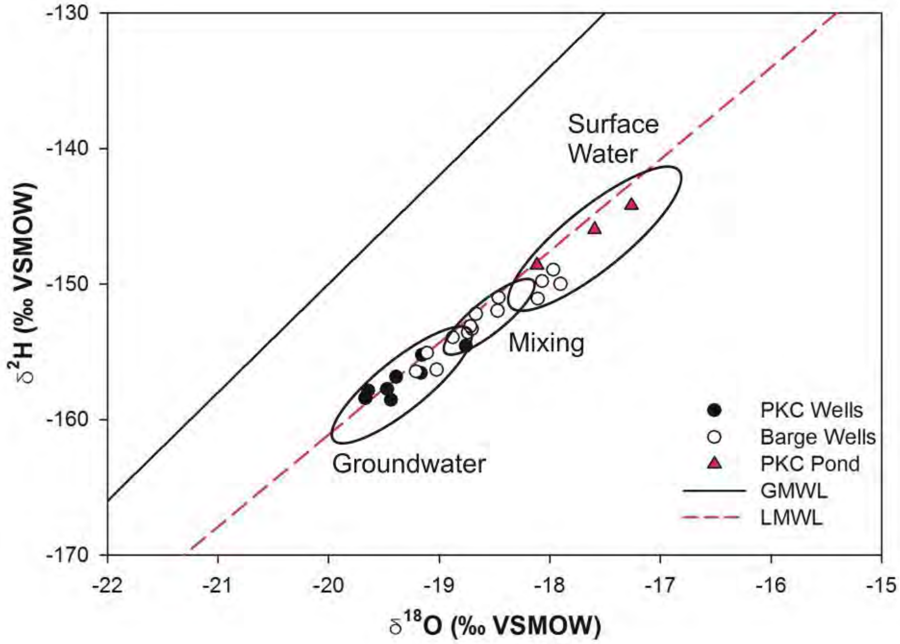


Figure 24: Plot showing stable isotopes $\delta^{18}O$ versus $\delta\,^{2}H$ of groundwater collected from the PKC East Beach, Barge, B2 and surface water from the PKC Pond. GMWL: Global Meteoric Waterline; LMWL: Local Meteoric Water Line)

9.0 CONCLUSIONS

The following conclusions were made:

- Frost Zone
    - The active, frost-free zone is below a depth of 1 m across the East Beach. Between July 7, 2009 and September 30, 2009, the active zone increased by 0.57 m and 0.27 m at locations PKC1 and PKC3, respectively.
    - During piezometer installation below the PKC Pond water column at the Barge in 2009 and 2010 and B2 in 2010, no frost was encountered from surface to a depth of 27 m.

- Groundwater Flow
    - In 2009, groundwater flow across the East Beach of the PKC facility is downward at toe of the dam and upward near the PKC Pond water.
    - The horizontal gradient between PKC1 and PKC3 is 0.016, following the topography of the ground surface.
    - The average hydraulic conductivity in the beach PK material is 2.54×10^{-5} m s^{-1} with an average groundwater velocity of 1.34×10^{-5} m s^{-1} (42 m a^{-1}) between piezometer nests PKC1 and PKC3.
    - At the Barge where PK material is submerged under a 1.8 m water cover, there is an upward gradient
    - The average hydraulic conductivity measured from the Barge piezometers is 3.5×10^{-8} m s^{-1}.

- Processed Kimberlite Groundwater Geochemistry
    - Moisture content in the PK material controls the depth of O_2 diffusion and is an important control on the depth of weathering.
    - Even though the two sub-aqueous tailings sites (Barge and B2) received fairly similar materials as the two aerially exposed tailings sites (PKC East and PKC-SW) the difference between geochemical profiles indicates that the subaqueous disposal PK material has significantly limited weathering and the subsequent release of ions to the porewaters.
    - The highest concentration of dissolved metals, major cations and sulfate were measured in the unsaturated zone of the PKC facility. The elevated ion concentrations are likely due to weathering processes. Weathering in the unsaturated zone of the PKC facility appears to be a significant source of metals and dissolved solids to the PKC Pond. However the concentrations of metals in the unsaturated zone at the PKC facility are relatively low due to the high neutralizing potential of the PK material, which keeps the pH of the porewater and groundwater near neutral and limits the solubility of most metals. Dissolution of carbonate minerals is consistent with the elevated concentrations of dissolved Ca in the unsaturated zone, saturation indices for carbonate minerals and the relationship between $\delta^{13}C$ and alkalinity.

  - Exposed PK material on the southwest portion on the PKC facility is thought to have undergone the longest weathering in the PKC facility and has elevated concentration of dissolved metals and SO_4. At a depth of 0.5, the porewater pH is 4 and some metals spike in concentration. The area may represent a zone of processed mudstone material.
  - Between 2009 and 2010, the concentration of dissolved SO_4, major ions and some metals increase in the unsaturated zone at PKC1. The increased concentration is likely a result of mineral dissolution and oxidation reactions.
  - In 2009, porewater sampled from the unsaturated zone at PKC2 contained elevated dissolved ions near the surface, decreasing with depth. By 2010, a 30 cm water column overlaid the PK surface at PKC2 due to rising water levels in the PKC Pond. Profiles of porewater chemistry measured at PKC2 in 2010 show the opposite trend as profiles measured in 2009 where dissolved ion concentrations increased with depth through the former unsaturated zone, due to piston displacement of infiltrating PKC pond water.
  - Groundwater collected from Barge and B2 piezometers and water extracted from the frost zone had the lowest concentration of dissolved ions.
  - The $\delta^{34}S\text{-}SO_4$ values measured in porewater from the PK material are strongly depleted (-19‰) and shows minimal fractions from unprocessed kimberlite (-21‰) suggesting that the source of SO_4 is most likely a product of sulfide oxidation.
  - Porewater samples collected from PKC1 show an overall decrease in SO_4, metals, Eh and increasing H_2S and populations of SRB and IRB with depth. This suggests that microbial mediated sulfate reduction is occurring and controlling SO_4 and metal concentrations.
  - $\delta^{18}O$ and $\delta^{2}H$ measured in water collected from the PKC Pond and groundwater collected from piezometers installed in the East Beach and Barge sites show that groundwater and surface water have two distinct isotopic signatures, with groundwater being depleted and surface water more enriched.
  - Speciation modeling shows that the main minerals controlling the pH and dissolved ions are secondary carbonate and (oxy) hydroxide minerals. Secondary sulfate minerals may control SO_4 and other metals at the near surface in unsaturated areas of the PKC facility.
  - The subaqueous disposal and freezing of the PK material limits the ingress of atmospheric O_2 subsequently limiting the release of dissolved concentrations of metals and SO_4 to the adjacent porewater.

10.0 RECOMMENDATIONS

- Water levels should be measured in all piezometers after spring freshet and on a regularly scheduled until freeze-up. The depth to frost should also be measured simultaneously at each piezometer location.
- Continual detailed sampling of piezometer locations to monitor the influence of rising water levels and fresh spigotted PK has on underlying pore waters

- Additional sulfur and carbon-DIC isotope ratios should be measured on unprocessed kimberlite to obtain a range of the isotopic signatures. Sequential extraction of the unprocessed PKC and mudstone material would also be beneficial to isolate the SO_4 and sulfide fraction of the $\delta^{34}S$.
- The distinct isotopic separation ($\delta^{18}O$ and $\delta^{2}H$) between the PKC pond water and PKC groundwater indicates that stable water isotopes would be a useful tracer to complete an isotopic mass balance and identify possible leakage of water from the PKC facility.
- It may be beneficial to investigate other locations within the PKC facility (unsaturated, saturated, submerged areas) determine the porewater concentration of dissolved ions in these areas.
- Additional porewater sampling from frost zones in the PKC would be useful to further understand freeze-out effects on the water chemistry

11.0 CLOSURE

Alberta Innovates-Technology Futures is pleased to present the findings of this investigation into the hydrogeology and hydrogeochemistry of the Processed Kimberlite Containment Facility at Diavik Diamond Mines Inc. We look forward to any comments regarding this report and future investigations.

Sincerely,

Michael Moncur, M.Sc.,
Research Hydrogeologist

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APPENDIX A

Tables of PKC Groundwater and Surface Water Chemistry (2009 and 2010)

Table of PKC Stable Isotopes (2009 and 2010)
$\delta^{18}O$, $\delta^{2}H$, $\delta^{34}S_{SO4}$, $\delta^{18}O_{SO4}$, $\delta^{13}C_{DIC}$

Location	Date	Depth$_{interval}$ (cm)	Depth (m)	pH 2009	Eh (mV) 2009	Eh$_{corrected}$ (mV) 2009	pe	Alkalinity (mg L^{-1} CaCO$_3$) 2009	Temp 2009	Cond (µS cm^{-1}) 2009	PO$_4$ (mg L^{-1}) 2009	DOC (mg L^{-1}) 2009	NH$_3$ (mg L^{-1}) 2009	H$_2$S (µg L^{-1}) 2009	Chloride (mg L^{-1}) 2009
PKC1-A	07/10/2009	0-28	14.2	7.79	94	345	6.37	60							62.9
PKC1-B	07/09/2009	28-57	42.5	7.01	137	388	7.16								58.4
PKC1-C	07/09/2009	57-85	70.8	8.82	-56	195	3.60	52							27.5
PKC1-D	07/09/2009	85-113	99.2	9.06	-60	191	3.52	76							37.1
PKC1-S	09/26/2009		1.45	9.33	-32	219	4.02	100	1.1	1301	0.15	32.17	1.9	91	38.85
PKC1-M	09/26/2009		1.47	9.25	-51	200	3.67	70	1.2	1282	0.28		0.6	37	36.0
PKC1-Deep	09/26/2009		1.72	9.12	-77	174	3.20	60	1.0	1357	0.27	7.53	2.5	-	42.81
PKC1-2.10	09/26/2009		2.10	9.85	-86	165	3.04	94							74.24
PKC1-2.5	09/26/2009		2.50	9.61	-57	194	3.58	110							69.55
PKC2-A	07/10/2009	0-38	0.19	7.78	15	266	4.91	55							46.6
PKC2-B	07/10/2009	38-76	0.57	8.09	-29	222	4.10	85							27.5
PKC2-C	07/10/2009	76-114	0.95	8.51	-56	195	3.60	70							50.3
PKC2-D	07/10/2009	114-152	1.33	8.80	-132	119	2.20	52							37.1
PKC2-E	07/10/2009	152-186	1.69	8.34	-18	233	4.30	70							79.6
PKC2-F	07/10/2009	186-219	2.02	9.34	-297	-46	-0.85	47							31.2
PKC2-S	09/26/2009		1.73	9.41	-12	239	4.36	80	2.8		0.25		1.3	51	40.20
PKC2-Deep	09/26/2009		1.96	9.19	-21	230	4.21	80	2.3		0.26		1.9	55	49.33
PKC5-A	07/12/2009	0-45	0.23	7.81	49	300	5.53	66			0.11		1.6		38.6
PKC5-B	07/12/2009	45-90	0.68	8.51	-16	235	4.33	52			0.12		1.3		39.6
PKC5-C	07/12/2009	90-136	1.13	8.87	-66	185	3.42	65			0.07		2.6		33.6
PKC5-D	07/12/2009	136-180	1.58	8.98	-209	42	0.77	69			0.13		1.8		25.3
PKC5	09/26/2009		1.83	9.10	-20	231	4.24	90	1.3	921	0.28		0.9	14	30.15
PKC4-A	07/13/2009	0-38	0.19	8.20	93	344	6.35	60							34.1
PKC4-B	07/13/2009	38-77	0.57	9.01	-89	163	3.00	64							32.9
PKC4-C	07/13/2009	77-115	0.96	9.09	-126	125	2.31	75							15.8
PKC4-S	09/26/2009		1.47	9.48	-35	216	3.97	90	1.2	924	0.30		1.8	20	23.12
PKC4-Deep	09/26/2009		2.72	8.95	-52	199	3.66	110	1.2	1832	0.29		2.9	39	56.00
PKC3-A	07/11/2009	0-32	0.16	7.84	34	285	5.26	48							35.67
PKC3-B	07/11/2009	32-64	0.48	8.74	7	258	4.75	59			0.12				37.51
PKC3-C	07/11/2009	64-96	0.8	8.54	-46	205	3.78	71							54.21
PKC3-D	07/11/2009	96-121	1.09	9.28	-329	-78	-1.44	40							20.90
PKC3-S	09/26/2009		2.57	9.13	-107	144	2.63	90	3.1	1165	0.17	4.30	0.9	23	39.29
PKC3-Deep	09/26/2009		3.31	9.09	-279	-28	-0.52	103			-	7.83	0.5	20	49.26
PKCSW-A	07/13/2009	0-33	0.17	7.28	-18	233	4.30	70							65.8
PKCSW-B	07/13/2009	33-67	0.50	4.02	199	450	8.30	0							110
PKCSW-C	07/13/2009	67-100	0.83	7.70	7	258	4.75	36.7							58.6
Barge-10	09/27/2009		5.32	8.75	174	425	7.66	62.8	6.4	1929	0.09		1.1		28.31
Barge-25	09/27/2009		9.89	8.74	103	354	6.51	71	0.7	1354	0.06	109.1	0.20	7	44.22
Barge-35	09/27/2009		12.94	8.99	87	338	6.20	60	1.6	1491	0.08	257.4	1.70	18	35.49
Barge-45	09/27/2009		15.99	7.89	84	335	6.12	71	2.5	890	0.1	4.281	1.00	17	38.85
Barge-65	09/27/2009		22.08	8.58	-54	197	3.63	78	0.5	1346	0.05	6.937	1.10	17	22.85
PKC-Pond	09/23/2009		0.0	8.74	132	383	6.88	88	7.3	2010	0.06	3.59	1.0	-	29.39

Location	Date	Nitrite (mg L^{-1}) 2009	Bromide (mg L^{-1}) 2009	Nitrate (mg L^{-1}) 2009	Sulfate (mg L^{-1}) 2009	Si (mg L^{-1}) 2009	Al (µg L^{-1}) 2009	Ca (mg L^{-1}) 2009	Na (mg L^{-1}) 2009	K (mg L^{-1}) 2009	Mg (mg L^{-1}) 2009	Be (µg L^{-1}) 2009	B (µg L^{-1}) 2009	P (µg L^{-1}) 2009	Ti (µg L^{-1}) 2009	V (µg L^{-1}) 2009
PKC1-A	07/10/2009	56.1		93.3	6554	6.32	9.297	337.6	106.9	76.87	1412	<0.039	71.84	<DL	1.525	3.511
PKC1-B	07/09/2009	6.21		26.4	3651	5.58	11.54	164.7	109.8	77.81	768.8	<0.039	80.02	<DL	0.539	2.813
PKC1-C	07/09/2009	5.03		2.90	895	0.81	51.57	38.77	126.1	227.1	77.83	<0.039	54.86	<DL	0.004	<0.014
PKC1-D	07/09/2009	19.8		1.95	98.6	0.56	406.8	4.946	53.32	85.73	6.501	<0.039	67.3	<DL	<0.003	0.305
PKC1-S	09/26/2009	30.12	0.71	3.08	148.59	0.97	<0.232	11.6	91.48	74.14	49.25	<0.039	<0.309	16.890	<0.003	<0.014
PKC1-M	09/26/2009	23.6	0.75	0.00	186.9	0.91	<0.232	9.07	59.10	48.45	33.35	<0.039	<0.309	60.970	<0.003	<0.014
PKC1-Deep	09/26/2009	18.22	0.85	12.51	119.64	1.38	<0.232	5.5	69.54	77.08	16.85	<0.039	99.000	37.840	<0.003	<0.014
PKC1-2.10	09/26/2009	< 0.2	0.64	2.86	69.70	0.00	669.9	1.30	78.20	99.51	1.11	<0.039	39.57	7.639	<0.003	0.793
PKC1-2.5	09/26/2009	< 0.2	1.00	< 0.2	57.19	0.78	459.7	1.46	90.55	99.29	1.16	0.383	52.8	3.318	<0.003	1.071
PKC2-A	07/10/2009	4.51		49.4	6837	6.18	2.017	279	114.5	89.74	1489	<0.039	87.36	<DL	0.409	2.916
PKC2-B	07/10/2009	6.78		19.4	2350	5.13	<0.232	105.4	59.26	53.95	516.5	<0.039	62.34	<DL	0.657	1.879
PKC2-C	07/10/2009	5.94		15.6	116	1.63	3.001	13.52	30.34	16.47	45.19	<0.039	65.45	<DL	0.04	1.502
PKC2-D	07/10/2009	5.94		16.0	87.3	1.31	<0.232	8.943	35.47	19.13	35.62	<0.039	57.87	<DL	<0.003	0.241
PKC2-E	07/10/2009	3.59		24.3	152.9	1.48	16.52	13.98	59.12	42.18	38.54	<0.039	92.03	<DL	<0.003	1.716
PKC2-F	07/10/2009	6.77		32.7	111.3	0.18	167.6	4.332	51.61	43.73	15.18	<0.039	53.12	<DL	<0.003	2.262
PKC2-S	09/26/2009	5.94	0.85	23.38	207.55	1.65	<0.232	23.6	50.60	37.92	39.18	<0.039	<0.309	23.590	<0.003	<0.014
PKC2-Deep	09/26/2009	10.29	1.16	40.51	294.98	1.58	<0.232	6.3	65.75	60.66	22.34	<0.039	128.400	43.860	<0.003	<0.014
PKC5-A	07/12/2009	27.9		17.6	4101	5.28	11.09	214.4	94.36	58.33	856.3	<0.039	77.51	<DL	0.231	2.373
PKC5-B	07/12/2009	1.14		0.56	119	1.09	59.55	8.92	38.27	24.8	32.23	<0.039	61.68	<DL	0.212	2.601
PKC5-C	07/12/2009	3.31		1.54	127	0.97	132	5.039	46.1	57.73	15.54	<0.039	51.42	<DL	<0.003	0.436
PKC5-D	07/12/2009	2.47		0.90	109	1.13	17.58	8.226	48.57	76.99	20.01	<0.039	51.96	<DL	0.041	1.063
PKC5	09/26/2009	n.a.	0.57	0.84	129.49	1.06	<0.232	6.6	44.36	25.39	29.78	<0.039	<0.309	24.610	<0.003	<0.014
PKC4-A	07/13/2009	18.4		29.5	1367	1.98	9.595	65.42	61.6	68.11	310.3	<0.039	40.33	<DL	<0.003	3.084
PKC4-B	07/13/2009	4.11		2.63	118	0.67	34.51	6.631	36.26	17.99	34.23	<0.039	64.65	<DL	0.128	0.32
PKC4-C	07/13/2009	2.60		1.58	110	0.95	31.37	5.516	39.39	35	18.91	<0.039	44.75	<DL	<0.003	0.927
PKC4-S	09/26/2009	n.a.	n.a.	n.a.	89.08	0.900	<0.232	1.7	48.84	61.93	7.65	<0.039	<0.309	38.600	<0.003	<0.014
PKC4-Deep	09/26/2009	3.38	1.13	16.01	282.97	1.750	<0.232	16.6	79.71	36.21	65.28	<0.039	<0.309	35.620	<0.003	<0.014
PKC3-A	07/11/2009	15.05		15.88	2412	3.19	11.11	128.9	74.42	50.31	504.8	<0.039	68.22	<DL	0.503	2.869
PKC3-B	07/11/2009	5.47		0.79	133.18	0.91	17.14	8.588	36.76	21.35	37.54	<0.039	58.42	<DL	<0.003	0.08
PKC3-C	07/11/2009	2.99		0.81	126.98	1.25	<0.232	11.53	40.06	25.62	40.58	<0.039	54.36	<DL	<0.003	0.778
PKC3-D	07/11/2009	21.32		4.23	91.87	0.11	2849	< 3.63	35.51	47.22	8.313	<0.039	23.13	<DL	0.19	0.057
PKC3-S	09/26/2009	n.a.	0.75	0.97	177.81	0.986	<0.232	7.0	58.68	54.06	29.53	<0.039	<0.309	28.750	<0.003	<0.014
PKC3-Deep	09/26/2009	n.a.	0.99	4.85	190.54	0.969	<0.232	13.6	53.14	50.56	43.08	<0.039	<0.309	30.300	<0.003	<0.014
PKCSW-A	07/13/2009	3.97		7.10	9117	5.49	48.12	462.2	266.7	253.5	1765	<0.039	64.7	<DL	0.4	3.751
PKCSW-B	07/13/2009	2.28		8.51	4092	4.22	269.7	259.8	166.1	127.7	764.4	<0.039	60.84	<DL	1.299	2.709
PKCSW-C	07/13/2009	2.83		2.34	1376	1.60	35.79	77.6	169	293.6	145.6	<0.039	39.4	<DL	0.026	0.596
Barge-10	09/27/2009	24.03	0.56	0.61	437	1.41	<0.232	18.4	78.98	99.71	57.74	<0.039	<0.309	<DL	<0.003	<0.014
Barge-25	09/27/2009	0.35	0.54	2.20	191	1.23	<0.232	8.2	62.44	75.10	23.39	<0.039	<0.309	21.150	<0.003	<0.014
Barge-35	09/27/2009	0.91	n.a.	13.06	230	1.91	<0.232	1.631	57.9	70.23	29.74	<0.039	<0.309	<DL	<0.003	<0.014
Barge-45	09/27/2009	n.a.	n.a.	2.05	80	1.17	<0.232	4.6	42.18	54.44	12.54	<0.039	<0.309	23.070	<0.003	<0.014
Barge-65	09/27/2009	1.10	n.a.	6.82	225	1.06	<0.232	13.8	48.46	60.07	33.96	<0.039	<0.309	19.920	<0.003	<0.014
PKC-Pond	09/23/2009	2.13	0.62	31.95	404.76	1.282	<0.232	25.3	81.74	111.70	61.69	<0.039	<0.309	<DL	<0.003	<0.014

Location	Date	Cr (µg L^{-1}) 2009	Mn (µg L^{-1}) 2009	Fe (µg L^{-1}) 2009	Co (µg L^{-1}) 2009	Ni (µg L^{-1}) 2009	Cu (µg L^{-1}) 2009	Zn (µg L^{-1}) 2009	As (µg L^{-1}) 2009	Se (µg L^{-1}) 2009	Sr (µg L^{-1}) 2009	Mo (µg L^{-1}) 2009	Ag (µg L^{-1}) 2009	Cd (µg L^{-1}) 2009	Sn (µg L^{-1}) 2009	Sb (µg L^{-1}) 2009
PKC1-A	07/10/2009	0.468	394.5	33.99	28.5	2953	7.213	3162	10.37	43.48	9134.3	853.2	<DL	0.55	<DL	6.02
PKC1-B	07/09/2009	0.549	139.9	48.5	9.026	897.8	11.69	2525	6.46	19.26	5280.7	1197.0	<DL	0.725	<DL	10.87
PKC1-C	07/09/2009	<0.045	19.23	26.22	<DL	17.46	7.285	879	4.855	0.955	1581.7	888.1	<DL	0.239	<DL	5.293
PKC1-D	07/09/2009	0.652	4.533	53.88	<DL	2.128	16.81	538	3.336	0.231	148.4	289.7	<DL	<DL	<DL	11.09
PKC1-S	09/26/2009	<0.045	<DL	4.109	<DL	7.857	3.5150	2.309	6.070	0.206	219.6	451.9	<DL	<DL	<DL	<DL
PKC1-M	09/26/2009	<0.045	0.015	19.578	<DL	7.260	0.9500	1.815	8.102	0.208	295.1	442.3	<DL	<DL	<DL	<DL
PKC1-Deep	09/26/2009	<0.045	<DL	7.718	<DL	11.940	1.0040	492.6	7.058	0.566	165.6	518.7	<DL	<DL	<DL	<DL
PKC1-2.10	09/26/2009	4.929	66.2	0.33	5.035	1.113	<DL	4.162	2.671	66.46	487.7	1.1	0.491	<DL	8.357	65.63
PKC1-2.5	09/26/2009	6.56	349.7	0.85	6.135	10.8	0.64	5.503	4.077	61.98	507.5	4.2	0.913	<DL	12.12	95.73
PKC2-A	07/10/2009	0.086	121.5	28.32	10.36	649.6	8.117	2489	12.86	62.72	9695.0	1935.0	<DL	1.297	<DL	6.367
PKC2-B	07/10/2009	0.433	53.1	31.43	4.712	456.3	22.23	2402	6.811	19.35	3549.3	514.1	<DL	0.092	<DL	7.106
PKC2-C	07/10/2009	<0.045	21.78	12.96	<DL	17.67	3.918	555.3	10.7	0.118	390.2	397.8	<DL	<DL	<DL	10.58
PKC2-D	07/10/2009	<0.045	8.67	24.62	<DL	7.835	46.21	1078	8.74	0.606	303.4	332.5	<DL	0.816	<DL	10.33
PKC2-E	07/10/2009	<0.045	20.78	24.85	<DL	9.823	7.938	3528	7.906	0.289	357.3	487.3	<DL	0.049	<DL	10.23
PKC2-F	07/10/2009	<0.045	3.119	21.16	<DL	2.703	5.657	660.7	4.659	0.024	148.4	307.2	<DL	<DL	<DL	3.548
PKC2-S	09/26/2009	<0.045	<DL	2.707	<DL	9.907	1.1540	439.6	7.586	0.5730	528.8	416.9	<DL	<DL	<DL	<DL
PKC2-Deep	09/26/2009	<0.045	<DL	6.328	<DL	29.800	1.0010	0.575	7.472	1.3480	363.0	636.0	<DL	<DL	<DL	<DL
PKC5-A	07/12/2009	<0.045	149.8	65.02	7.695	760	29.33	552.9	9.927	33.45	4979.0	1131.0	0.091	0.514	<DL	9.361
PKC5-B	07/12/2009	<0.045	11.96	57.51	<DL	5.199	10.5	481.6	9.823	0.606	292.4	344.4	29.19	<DL	<DL	11.39
PKC5-C	07/12/2009	<0.045	4.625	12.77	0.128	1.837	5.418	508.6	7.07	0.121	187.5	296.6	1.015	<DL	<DL	5.936
PKC5-D	07/12/2009	<0.045	5.357	24.25	<DL	2.91	10.71	2.71	6.044	0.373	213.0	300.1	<DL	<DL	<DL	8.629
PKC5	09/26/2009	<0.045	<DL	2.870	<DL	5.306	0.9090	2.530	6.421	0.4620	195.5	378.4	<DL	<DL	<DL	<DL
PKC4-A	07/13/2009	<0.045	26.94	48.32	1.658	200	6.033	504	5.373	12.47	2138.3	680.5	<DL	0.162	<DL	7.256
PKC4-B	07/13/2009	<0.045	8.81	21.92	<DL	1.868	7.09	520.9	6.531	0.141	270.9	378.0	<DL	<DL	<DL	7.581
PKC4-C	07/13/2009	<0.045	7.154	42.44	<DL	1.439	13.27	542.4	7.575	0.104	165.8	358.4	0.077	<DL	<DL	9.041
PKC4-S	09/26/2009	<0.045	<DL	4.166	<DL	4.883	1.5360	466.500	6.173	0.5310	59.8	203.2	<DL	<DL	<DL	<DL
PKC4-Deep	09/26/2009	<0.045	<DL	5.185	<DL	10.640	0.4580	0.813	13.430	0.5440	462.3	814.0	<DL	<DL	<DL	<DL
PKC3-A	07/11/2009	<0.045	90.17	27.9	3.271	312.4	13.69	391.8	7.384	12.15	3722.7	1215.0	<DL	0.585	<DL	9.496
PKC3-B	07/11/2009	<0.045	14.08	14	<DL	2.638	7.641	500.8	5.507	0.183	311.2	355.6	<DL	<DL	<DL	8.828
PKC3-C	07/11/2009	<0.045	10.88	17.05	<DL	8.815	6.468	540.9	7.409	0.018	356.4	401.0	<DL	<DL	<DL	11.35
PKC3-D	07/11/2009	<0.045	20.41	39.48	<DL	1.328	5.298	535.7	0.386	0.126	100.3	180.0	<DL	<DL	<DL	0.728
PKC3-S	09/26/2009	<0.045	<DL	3.125	<DL	7.004	4.1660	0.619	5.532	0.5460	267.5	404.0	<DL	<DL	<DL	<DL
PKC3-Deep	09/26/2009	<0.045	0.032	11.334	<DL	16.370	7.0180	115.000	4.515	0.5890	317.8	380.0	<DL	<DL	<DL	<DL
PKCSW-A	07/13/2009	1.112	182.7	472	9.67	751.2	5.517	2742	13.59	56.79	9503.7	1430.0	0.472	0.94	<DL	7.152
PKCSW-B	07/13/2009	8.291	193.1	1008	4.57	514.7	39.78	2986	5.027	9.339	4528.7	1284.0	<DL	0.732	<DL	7.72
PKCSW-C	07/13/2009	1.059	33.6	395	0.419	17.06	8.39	756.6	3.083	0.358	2677.3	1058.0	0.187	0.413	<DL	5.073
Barge-10	09/27/2009	<0.045	<DL	3.491	<DL	34.200	0.8590	0.783	4.314	0.3770	585.3	549.0	<DL	<DL	<DL	<DL
Barge-25	09/27/2009	<0.045	<DL	13.490	<DL	6.720	0.9520	2.483	3.689	0.1230	311.0	390.9	<DL	<DL	<DL	<DL
Barge-35	09/27/2009	<0.045	<DL	0.533	<DL	13.230	0.8090	1.272	3.457	0.5930	367.6	396.3	<DL	<DL	<DL	<DL
Barge-45	09/27/2009	<0.045	<DL	3.141	<DL	5.298	0.6530	398.600	2.551	0.1730	147.0	250.0	<DL	<DL	<DL	<DL
Barge-65	09/27/2009	<0.045	35.790	1.641	<DL	13.130	0.6010	2165.000	1.876	0.2350	373.3	349.5	<DL	<DL	<DL	<DL
PKC-Pond	09/23/2009	<0.045	<DL	2.618	<DL	28.640	0.8580	15.870	3.925	0.9520	648.1	425.8	<DL	<DL	<DL	<DL

Location	**Date**	**Depth$_{interval}$**	**Depth**	**pH**	**Eh**	**Eh$_{corrected}$**	**pe**	**Alkalinity**	**Temp**	**Cond**	**PO$_4$**
		(cm)	**(m)**		**(mV)**	**(mV)**		**(mg L^{-1} CaCO$_3$)**		**(µS cm^{-1})**	**(mg L^{-1})**
	2010	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**
PKC1-A	08/07/2010	0-28	14.2	7.45	151	355	6.55	73			
PKC1-B	08/07/2010	28-57	42.5	7.75	90	294	5.42	78			
PKC1-C	08/07/2010	57-85	70.8	7.92	119	323	5.96	28			
PKC1-D	08/07/2010	85-113	99.2	8.14	25	229	4.22	57			
PKC1-110	08/07/2010		110.0	7.47	-134	70	1.29	62			
PKC1-M	08/07/2010		1.47	8.9	62	266	4.88	54	1.8		0.07
PKC1-Deep	08/07/2010		1.72	10.23	17	221	4.05	95	2.0		0.14
PKC2-A	09/20/2010	0-22	0.19	8.05	148	399	7.36	105			
PKC2-B	09/20/2010	22-44	0.57	7.625	141.5	393	7.24	103			
PKC2-C	09/20/2010	44-66	0.95	7.62	54.5	306	5.64	52			
PKC2-D	09/20/2010	66-87	1.33	7.22	-134	117	2.16	41			
PKC-Pond	08/07/2010		0.0	8.82	124	375	6.52	59	16.7	986	0.03
Barge-10	08/07/2010		7.15	8.48	114	365	6.68	50	2.4		0.17
Barge-25	08/07/2010		9.82	9.03	94	345	6.32	85	1.9		0.1
Barge-35	08/07/2010		12.82	8.94	110.00	361	6.62	80	1.5		0.15
Barge-45	08/07/2010		18.16	9.05	88.00	339	6.21	66	2.0		0.07
Barge-65	08/07/2010		25.73	8.36	102.00	353	6.47	56	2.0		0.04
PKC-Pond	09/14/2010			7.78	50.00	301	5.45	57.5	5.0		0.01
B2-20	09/14/2010		6.1	9.13	151	402	7.42	68			0.15
B2-30	09/14/2010		9.15	9.17	182	433	7.99	96			0.16
B2-40	09/14/2010		12.2	9.02	159	410	7.56	90			0.22
B2-50	09/14/2010		15.24	8.93	208	459	8.47	68			0.13
B2-65	09/14/2010		19.82	9.17	174	425	7.84	108			0.12
B2-90	09/14/2010		27.44	9.32	102.2	353	6.52	75			0.1

Location	**Date**	**DOC (mg L^{-1})**	**NH_3 (mg L^{-1})**	**H_2S (µg L^{-1})**	**Fe(II) (mg L^{-1})**	**Chloride (mg L^{-1})**	**Nitrite (mg L^{-1})**	**Bromide (mg L^{-1})**	**Nitrate (mg L^{-1})**	**Sulfate (mg L^{-1})**	**Si (mg L^{-1})**
	2010	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**
PKC1-A	08/07/2010					68.94	< 1	0.79	260.62	9648.94	6.75
PKC1-B	08/07/2010					54.31	2.74	0.48	439.49	6791.52	4.34
PKC1-C	08/07/2010					36.84	14.83	0.37	53.95	5761.97	3.07
PKC1-D	08/07/2010					31.99	< 1	< 0.2	< 0.2	1028.00	1.39
PKC1-110	08/07/2010					58.74	< 1	< 0.2	< 0.2	1397.42	1.35
PKC1-M	08/07/2010		3.3	62	0.03	50.26	< 0.1	0.55	0.55	722.83	1.17
PKC1-Deep	08/07/2010	4.4	4.3	145	0.05	45.26	< 0.1	0.76	0.97	149.98	0.8513
PKC2-A	09/20/2010					40.60	< 0.2	< 0.2	40.81	471.18	5.58
PKC2-B	09/20/2010					36.33	< 0.2	< 0.2	44.98	1528.03	4.49
PKC2-C	09/20/2010					37.80	< 0.2	< 0.2	41.67	2306.64	1.63
PKC2-D	09/20/2010					53.44	< 0.2	< 0.2	40.95	3070.65	1.31
PKC-Pond	08/07/2010	4.0	0.6	37	0	34.93	3.41	0.46	41.99	314.78	1.246
Barge-10	08/07/2010	144.6	2.08	11	0	58.29	< 0.1	0.97	1.47	132	0.89
Barge-25	08/07/2010	390.9	0.29	89	0	40.15	< 0.1	0.66	14.15	269	1.11
Barge-35	08/07/2010	134.7	1.31	77	0.001	46.75	< 0.1	0.61	5.78	240	0.94
Barge-45	08/07/2010	4.7	1.05	22	0.02	38.85	1.43	0.55	9.33	154	0.89
Barge-65	08/07/2010	20.0	0.98	34	0.05	33.51	3.08	0.66	20.15	239	0.92
PKC-Pond	09/14/2010	3.3		12	0.02	37.01	2.50	0.39	44.60	325.06	1.01
B2-20	09/14/2010	47.2	1.01		0	25.77	0.54	0.33	3.47	180.16	1.02
B2-30	09/14/2010	45	1.66		0.01	41.60	< 0.2	0.55	2.53	175.35	1.12
B2-40	09/14/2010	242.2	0.77		0.03	42.08	2.20	< 0.2	18.43	224.90	1.19
B2-50	09/14/2010	178.2	1.07		0	39.64	2.31	< 0.2	15.12	277.09	1.21
B2-65	09/14/2010	3.3	1.4		0	35.49	0.59	< 0.2	3.35	155.99	1.02
B2-90	09/14/2010	7.9	1.16		0.01	22.81	2.65	< 0.2	11.10	193.97	1.06

Location	Date	Al	Ca	Na	K	Mg	Be	B	P	Ti	V
		(μg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(μg L^{-1})	(μg L^{-1})	(μg L^{-1})	(μg L^{-1})	(μg L^{-1})
	2010	2010	2010	2010	2010	2010	2010	2010	2010	2010	2010
PKC1-A	08/07/2010	115.5	405.70	138.80	90.34	2143	<0.03	48.14		<0.09	0.011
PKC1-B	08/07/2010	109.4	350.4	192.10	678.1	1350	<0.03	39.99		0.692	0.409
PKC1-C	08/07/2010	81.3	358.1	387	1000	771.7	<0.03	<0.22		3.554	0.424
PKC1-D	08/07/2010	49.7	35.06	178.20	291.4	147.60	<0.03	8.88		0.316	1.473
PKC1-110	08/07/2010	74.5	61.94	184.50	207.6	230.8	<0.03	18.07		0.281	0.738
PKC1-M	08/07/2010	42.2	22.43	126.1	152.9	98.35	<0.03	29.15	<DL	0.178	1.811
PKC1-Deep	08/07/2010	33.1	1.313	79.92	112.1	2.545	<0.03	62.73	<DL	0.352	3.473
PKC2-A	09/20/2010	1.18	20.52	81.34	42.80	121.60	<0.03	8.522		0.566	3.244
PKC2-B	09/20/2010	0.05	58.37	69.96	37.42	355.1	<0.03	-11.17		0.78	2.34
PKC2-C	09/20/2010	0.05	93.03	75.56	39.60	512.6	51.29	-0.13		1.262	1.518
PKC2-D	09/20/2010	0.06	165.90	111.20	72.76	594.2	<0.03	-0.613		0.8	0.412
PKC-Pond	08/07/2010	18.2	18.9	63.67	73.01	50.48	<0.03	54.18	<DL	2.389	2.589
Barge-10	08/07/2010	-0.635	7.247	44.095	31.275	22.45	<0.03	39.46	23.23	0.099	2.553
Barge-25	08/07/2010	0.0915	13.12	63.12	55.62	33.04	<0.03	46.455	89.14	0.312	1.577
Barge-35	08/07/2010	32.57	8.732	69.13	69.6	20.52	<0.03	42.37	29.01	0.102	0.929
Barge-45	08/07/2010	17.31	8.663	39.69	33.71	25.13	<0.03	38.55	138.3	1.9	1.573
Barge-65	08/07/2010	1.652	13.22	51.6	47.6	32.99	<0.03	129.4	182.1	3.078	1.755
PKC-Pond	09/14/2010	0.01	19.97	62.32	66.78	49.34	0.005	36.59	<DL	0.154	1.242
B2-20	09/14/2010	0.19	9.47	47.12	37.72	27.62	1.095	<0.22		<0.09	3.402
B2-30	09/14/2010	0.01	10.77	45.94	33.84	35.18	0.064	<0.22		<0.09	1.492
B2-40	09/14/2010	0.01	14.69	63.59	59.68	33.58	<0.03	5.43		<0.09	2.722
B2-50	09/14/2010	0.01	13.09	75.60	96.90	34.29	0.027	2.415		<0.09	2.761
B2-65	09/14/2010	0.01	7.21	45.59	55.12	20.92	0.089	<0.22		<0.09	2.78
B2-90	09/14/2010	0.01	9.85	50.65	47.94	25.90	72.44	68.31	<9	0.277	2.525

Location	**Date 2010**	**Cr (μg L^{-1}) 2010**	**Mn (μg L^{-1}) 2010**	**Fe (μg L^{-1}) 2010**	**Co (μg L^{-1}) 2010**	**Ni (μg L^{-1}) 2010**	**Cu (μg L^{-1}) 2010**	**Zn (μg L^{-1}) 2010**	**As (μg L^{-1}) 2010**	**Se (μg L^{-1}) 2010**	**Sr (μg L^{-1}) 2010**
PKC1-A	08/07/2010	<0.02	91.5	0.058	6.203	591.3	<0.03	103.6	5.668	128	8675
PKC1-B	08/07/2010	0.204	51.79	0.011	1.61	190.2	2.38	33.99	8.217	67.48	11210
PKC1-C	08/07/2010	0.308	20.89	<0.07	0.603	82.24	<0.03	1.031	2.082	2.353	10420
PKC1-D	08/07/2010	0.103	11.32	0.003	0.219	52.33	6.93	14.49	5.944	2.993	1485
PKC1-110	08/07/2010	0.189	49.89	0.031	0.423	43.07	0.483	11.44	5.745	0.792	2326
PKC1-M	08/07/2010	<0.02	4.584	67.46	<0.01	13.78	0.35	<0.05	5.486	<0.15	909.2
PKC1-Deep	08/07/2010	0.11	0.496	48.47	<0.01	2.149	1.733	1.184	12.52	0.023	99.56
PKC2-A	09/20/2010	0.305	8.524	0.018	0.379	37.08	17.83	47.23	7.082	1.675	542.6
PKC2-B	09/20/2010	0.148	20.1	<0.07	1.089	144.8	5.714	73.05	7.374	0.783	1984
PKC2-C	09/20/2010	0.197	75.81	<0.07	0.516	44.16	4.037	19.03	6.719	0.398	3246
PKC2-D	09/20/2010	0.343	127.9	<0.07	0.951	73.51	2.057	13.15	4.17	0.429	5384
PKC-Pond	08/07/2010	0.387	9.068	87.44	0.308	23.83	0.577	0.265	6.856	0.174	689.1
Barge-10	08/07/2010	0.524	1.158	35.44	<0.01	7.751	0.745	3.231	6.661	<0.15	299.1
Barge-25	08/07/2010	0.2505	3.042	18.12	0.0095	5.4825	0.3045	1.79	10.0665	<0.15	274.65
Barge-35	08/07/2010	0.762	2.073	31.89	0.027	10.37	0.393	0.802	8.442	<0.15	433
Barge-45	08/07/2010	0.389	5.981	59.33	0.148	10.39	1.003	9.254	4.665	0.04	306
Barge-65	08/07/2010	0.237	15.47	63.08	0.3	15.07	1.126	17.49	6.268	0.487	379.1
PKC-Pond	09/14/2010	0.029	11.29	8.94	0.332	23.12	1.356	396.7	5.209	1.482	666.1
B2-20	09/14/2010	1.909	8.267	318.2	1.302	8.982	1.795	1.874	6.11	1.609	292.9
B2-30	09/14/2010	11.09	8.083	821.4	0.324	12.15	5.906	30.79	9.405	0.129	341.8
B2-40	09/14/2010	1.688	7.697	12.42	0.171	12.96	0.347	<0.05	4.274	0.254	368.4
B2-50	09/14/2010	1.459	5.9	9.082	0.115	11.49	1.03	<0.05	4.999	1.009	371.8
B2-65	09/14/2010	0.17	3.312	2.564	0.286	11.65	0.315	<0.05	2.507	0.542	223.8
B2-90	09/14/2010	0.088	9.271	29.83	0.271	15.25	1.032	448.2	5.936	1.049	320.7

Location	**Date**	**Mo**	**Ag**	**Cd**	**Sn**	**Sb**	**Ba**	**Tl**	**Pb**	**U**
		(µg L^{-1})	**(µg L^{-1})**	**(µg L^{-1})**	**(µg L^{-1})**	**(µg L^{-1})**	**(µg L^{-1})**	**(µg L^{-1})**	**(µg L^{-1})**	**(µg L^{-1})**
	2010	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**	**2010**
PKC1-A	08/07/2010	1021	351.8	<0.01	<0.04	0.359	30.86	<DL	0.194	1.471
PKC1-B	08/07/2010	1190	1.561	0.242	6.619	2.724	32.38	0.065	0.119	0.854
PKC1-C	08/07/2010	1474	9.094	<0.01	<0.04	2.074	34.23	<DL	0.109	0.139
PKC1-D	08/07/2010	855.8	2.696	0.12	0.181	3.52	62.07	0.014	0.015	0.215
PKC1-110	08/07/2010	526.9	8.406	0.108	0.288	4.386	107.8	<DL	0.039	0.323
PKC1-M	08/07/2010	1090	23.63	1.994	0.014	4.769	32.42	0.012	<0.01	0.133
PKC1-Deep	08/07/2010	634.7	<0.01	1.286	0.056	5.459	35.45	0.008	0.053	<0.01
PKC2-A	09/20/2010	794.5	0.497	0.497	0.061	3.318	35.72	0.106	0.993	1.077
PKC2-B	09/20/2010	1892	0.448	0.448	0.06	3.671	43.49	0.204	0.269	1.028
PKC2-C	09/20/2010	2151	0.648	0.648	0.081	3.75	69.82	0.019	<DL	0.88
PKC2-D	09/20/2010	1661	0.351	0.351	<0.04	3.891	97.48	0.026	0.075	0.39
PKC-Pond	08/07/2010	355.3	10.96	0.707	<0.04	9.642	193	0.017	0.042	1.82
Barge-10	08/07/2010	429.5	17.92	0.763	0.975	2.517	44.21	0.025	0.011	0.674
Barge-25	08/07/2010	272.6	43.855	0.4455	4.2115	6.407	50.955	<DL	0.038	0.3045
Barge-35	08/07/2010	429.9	35.11	0.935	4.983	4.659	56.05	<DL	<0.01	0.95
Barge-45	08/07/2010	329.5	29.87	0.632	0.279	3.904	47.86	0.025	0.066	0.671
Barge-65	08/07/2010	365.2	44.85	0.826	0.267	6.63	27.55	0.027	1.144	0.636
PKC-Pond	09/14/2010	364.7	0	0.433	<0.04	8.752	127.2	0.05	0.733	3.987
B2-20	09/14/2010	616.9	17.75	1.866	0.415	4.04	47.34	1.183	1.417	0.806
B2-30	09/14/2010	379.1	8.35	0.675	6.706	3.261	60.12	0.465	1.946	0.799
B2-40	09/14/2010	360.9	6.738	0.421	2.668	5.177	61.3	0.026	0.004	2.018
B2-50	09/14/2010	376.4	30.86	0.428	1.517	5.022	56.36	0.032	<0.01	1.179
B2-65	09/14/2010	301.1	1.52	0.342	<0.04	2.067	55.86	0.069	0.006	0.283
B2-90	09/14/2010	333.6	<0.01	0.416	<0.04	4.617	39.52	0.023	0.069	0.391

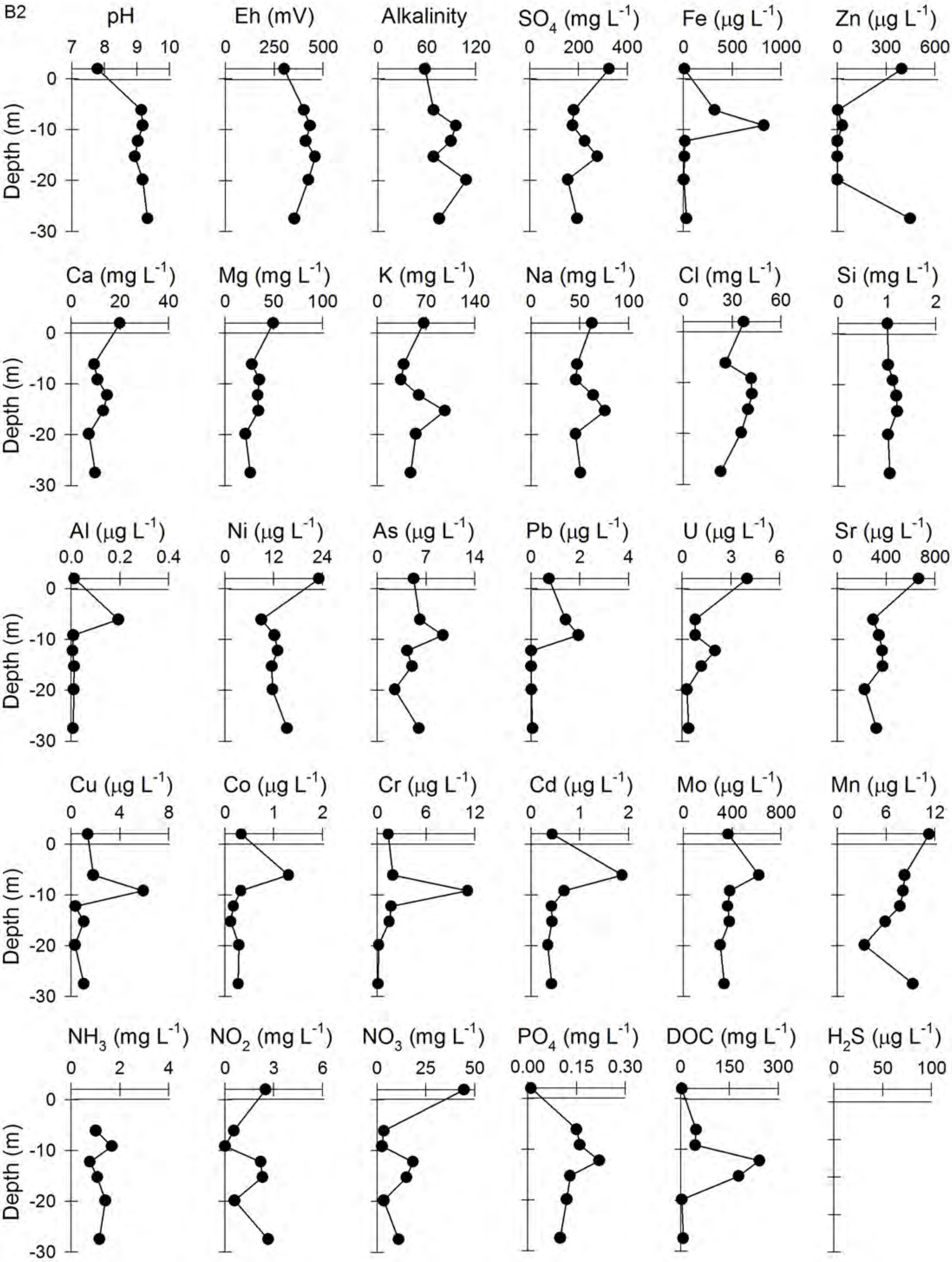
Location	Date	Ba (µg L^{-1}) 2009	Tl (µg L^{-1}) 2009	Pb (µg L^{-1}) 2009	U (µg L^{-1}) 2009
PKC1-A	07/10/2009	78.29	1.105	0.013	1.062
PKC1-B	07/09/2009	80.92	0.402	0.207	0.962
PKC1-C	07/09/2009	197.4	<DL	<DL	<DL
PKC1-D	07/09/2009	102.8	<DL	0.149	<DL
PKC1-S	09/26/2009	49.510	<DL	<DL	<DL
PKC1-M	09/26/2009	45.560	<DL	<DL	<DL
PKC1-Deep	09/26/2009	50.470	<DL	8.8	<DL
PKC1-2.10	09/26/2009	0.415	0.129	0.027	0.074
PKC1-2.5	09/26/2009	0.302	0.492	0.389	0.215
PKC2-A	07/10/2009	74.25	0.578	<DL	0.797
PKC2-B	07/10/2009	82.31	0.395	<DL	0.452
PKC2-C	07/10/2009	471.6	<DL	<DL	0.063
PKC2-D	07/10/2009	106.8	<DL	0.406	0.215
PKC2-E	07/10/2009	150.7	<DL	<DL	0.016
PKC2-F	07/10/2009	79.1	<DL	<DL	<DL
PKC2-S	09/26/2009	102.60	<DL	<DL	<DL
PKC2-Deep	09/26/2009	43.07	<DL	<DL	<DL
PKC5-A	07/12/2009	72.6	0.237	0.172	2.922
PKC5-B	07/12/2009	111.2	<DL	0.026	0.624
PKC5-C	07/12/2009	89.7	<DL	0.062	<DL
PKC5-D	07/12/2009	87.14	<DL	<DL	<DL
PKC5	09/26/2009	51.680	<DL	<DL	<DL
PKC4-A	07/13/2009	80.32	0.177	<DL	0.573
PKC4-B	07/13/2009	53.06	<DL	<DL	<DL
PKC4-C	07/13/2009	41.35	<DL	<DL	0.002
PKC4-S	09/26/2009	45.130	<DL	<DL	<DL
PKC4-Deep	09/26/2009	54.57	<DL	<DL	<DL
PKC3-A	07/11/2009	126.7	0.107	<DL	0.87
PKC3-B	07/11/2009	97.15	<DL	<DL	<DL
PKC3-C	07/11/2009	147.2	<DL	<DL	0.117
PKC3-D	07/11/2009	46.7	<DL	<DL	<DL
PKC3-S	09/26/2009	42.1	<DL	<DL	<DL
PKC3-Deep	09/26/2009	41.7	<DL	<DL	<DL
PKCSW-A	07/13/2009	108.6	0.422	0.321	0.831
PKCSW-B	07/13/2009	86.45	0.21	1.271	<DL
PKCSW-C	07/13/2009	39.4	<DL	0.018	<DL
Barge-10	09/27/2009	33.62	<DL	9.15	<DL
Barge-25	09/27/2009	41.61	<DL	8.8	<DL
Barge-35	09/27/2009	65.71	<DL	0	<DL
Barge-45	09/27/2009	69.39	<DL	1.7	<DL
Barge-65	09/27/2009	54.99	<DL	1.3	<DL
PKC-Pond	09/23/2009	121.60	<DL	3.2	5.06

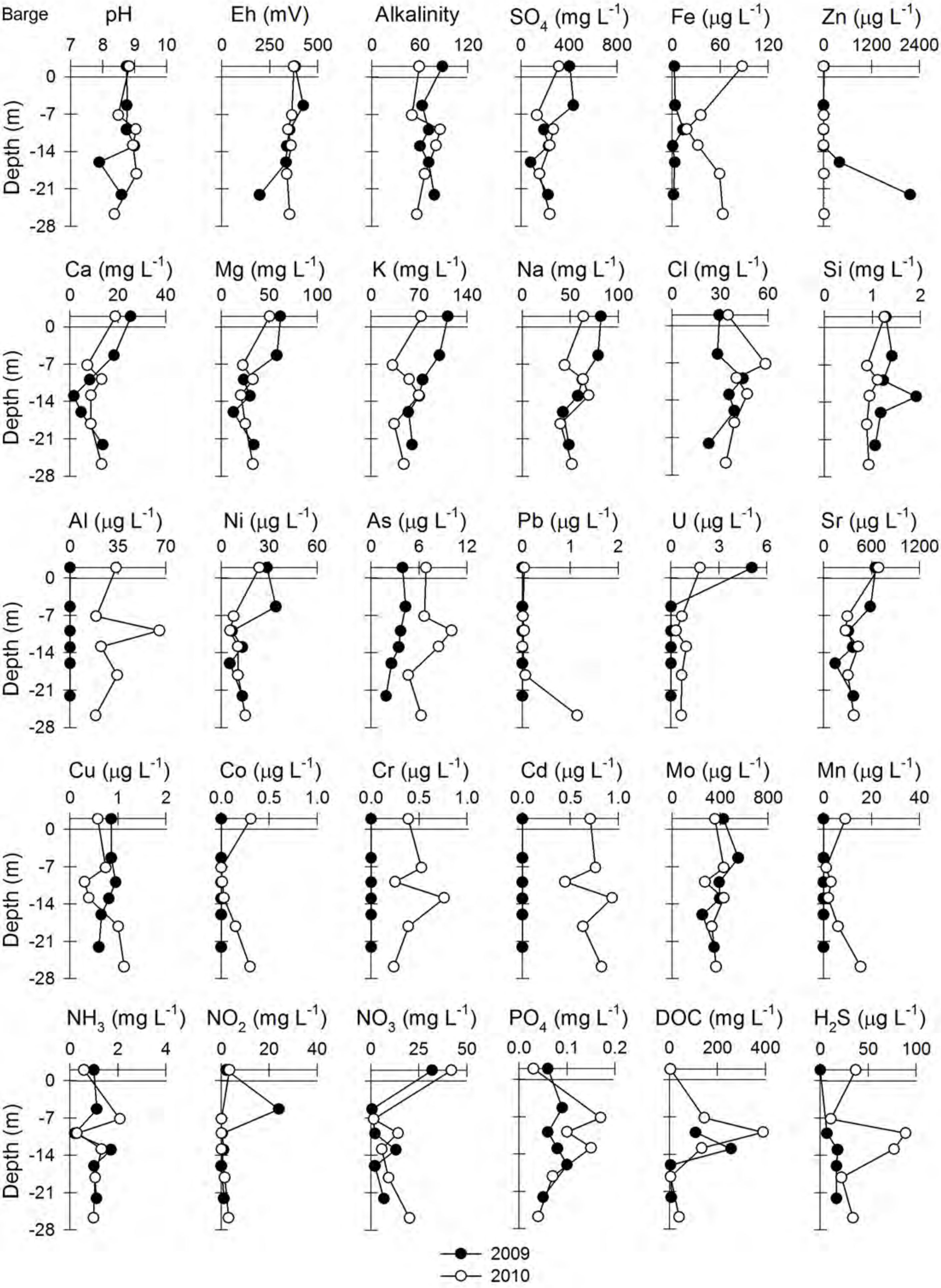
Location	Date	Depth (m)	$\delta^{18}O$ (‰)	$\delta^{2}H$ (‰)	d-excess (‰)	$\delta^{13}C_{DIC}$ (‰)	$\delta^{34}S$ (‰)	$\delta^{18}O\text{-}SO_4$ (‰)
Water Samples								
PKC1-A	07/10/2009	0.14					-21.8	-24.5
PKC1-D	07/09/2009	0.99	-19.39	-156.87	-1.77		-17.1	-19.6
PKC1-S	09/26/2009	1.45	-19.47	-157.76	-2.00	-19.13	-18.3	-17.9
PKC3-A	07/11/2009	0.16	-19.16	-156.58	-3.27		-19.2	-24.6
PKC3-C	07/11/2009	0.8	-19.44	-158.57	-3.08		-18.0	-18.7
PKC3-D	07/11/2009	1.09	-18.76	-154.59	-4.51			
PKC3-S	09/26/2009	2.57	-19.64	-157.87	-0.74	-18.51	-18.5	-19.6
PKC3-Deep	09/26/2009	3.31					-16.9	-19.1
PKC-Pond	09/23/2009	0	-18.12	-148.62	-3.68	-9.35	-17.8	-19.8
Barge-10	09/27/2009	5.3	-18.07	-149.80	-5.24			
Barge-25	09/27/2009	9.9	-18.74	-153.58	-3.66	-17.55	-15.3	-17.4
Barge-65	09/27/2009	22.1	-18.70	-153.32	-3.70	-14.75	-16.4	-19.0
PKC1-S	08/07/2010	1.47	-19.67	-158.42	-1.09	-11.11		
PKC1-Deep	08/07/2010	1.72	-19.16	-155.24	-2.00	-14.12		
PKC-Pond	08/07/2010	0	-17.60	-145.99	-5.21	-10.46		
Barge-10	08/07/2010	5.3	-19.11	-155.11	-2.23	-19.87		
Barge-25	08/07/2010	9.9	-18.67	-152.21	-2.86	-17.65		
Barge-35	08/07/2010	12.9	-18.88	-153.95	-2.94	-17.49		
Barge-45	08/07/2010	16.0	-18.72	-153.14	-3.40	-17.22		
Barge-65	08/07/2010	22.1	-18.46	-151.01	-3.31	-16.21		
PKC-Pond	09/14/2010	0.0	-17.2642	-144.205	-6.09	-9.49		
B2-20	09/14/2010	6.1	-19.2088	-156.466	-2.80	-21.78		
B2-30	09/14/2010	9.15	-19.0228	-156.327	-4.14	-19.84		
B2-40	09/14/2010	12.20	-17.9033	-150.007	-6.78	-16.04		
B2-50	09/14/2010	15.24	-17.967	-148.963	-5.23	-16.53		
B2-65	09/14/2010	19.82	-18.4706	-151.982	-4.22	-16.22		
B2-90	09/14/2010	27.44	-18.1088	-151.087	-6.22	-15.77		
Solid Samples								
Kimberlite	2010					-13.09	-21.96	
Mudstone 1	2010					-27.31	-23.87	
Mudstone 2	2010					-26.85	-46.36	
Mudstone 3	2010					-28.6	-20.35	
Tertery Wood	2010					-21.01		

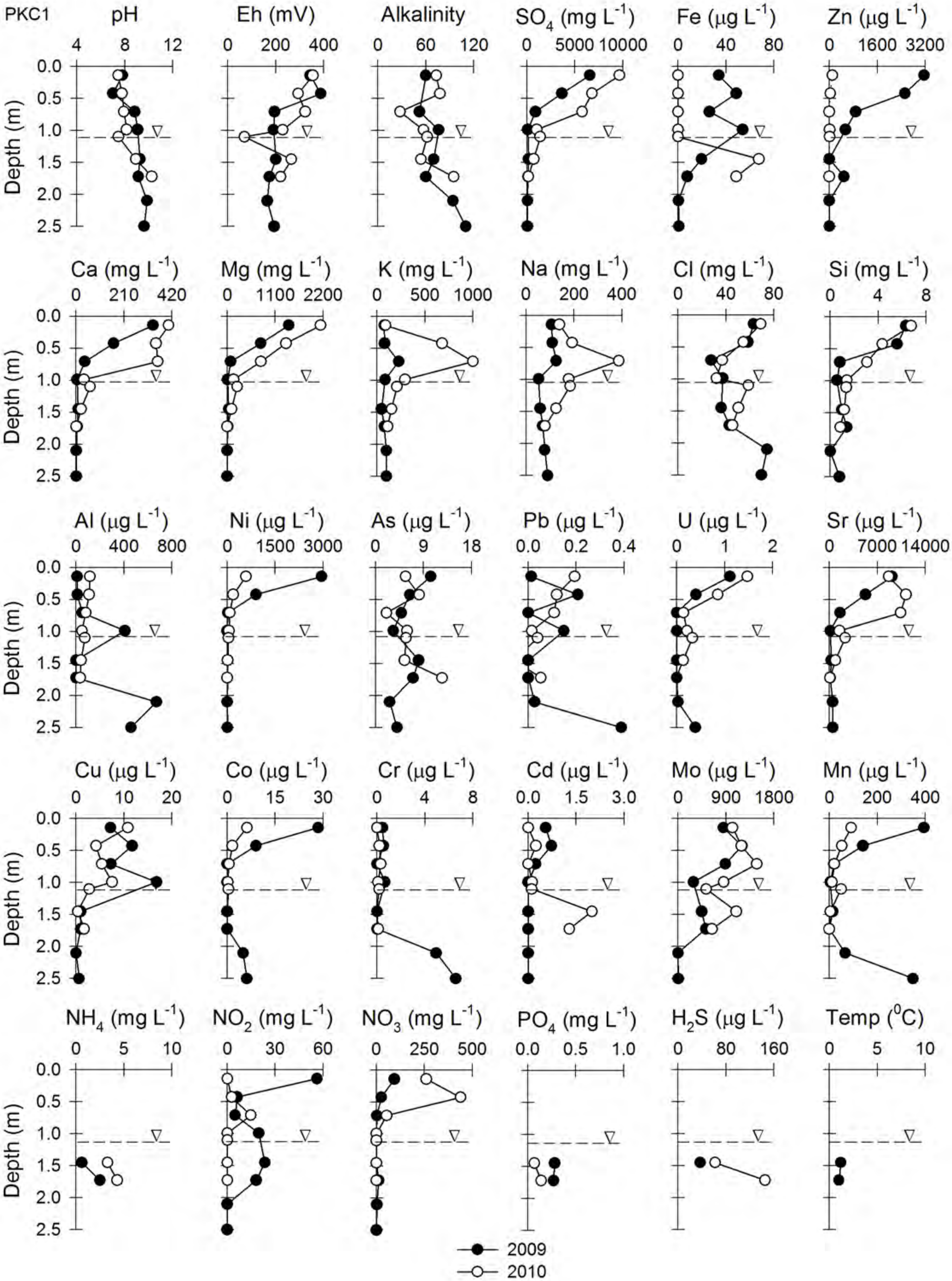
APPENDIX B

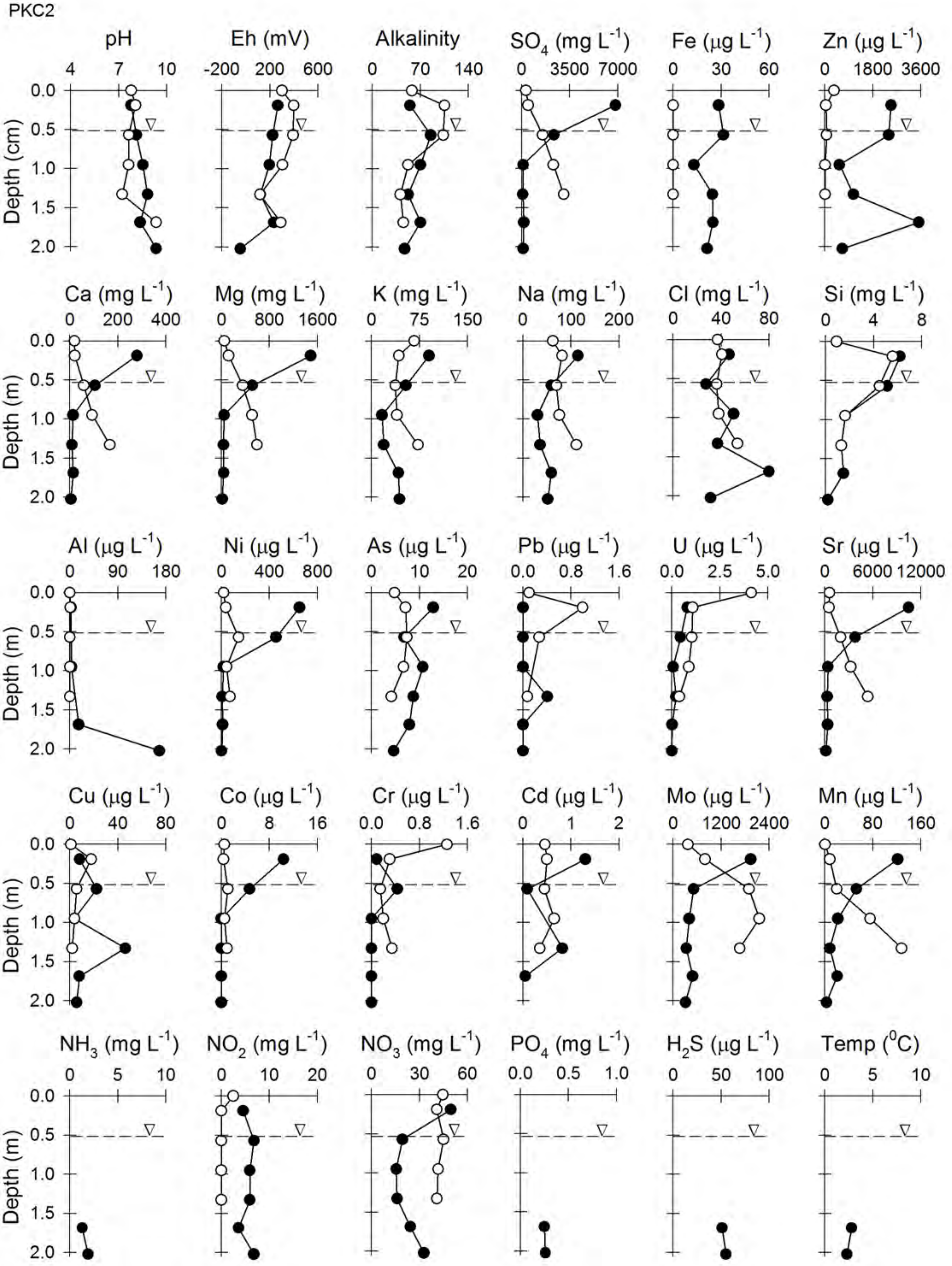
Plots of PKC groundwater and surface water chemistry (2009 and 2010) for locations:

PKC1, PKC2, PKC3, PKC4, PKC5, PKC-SW, PKC-Pond, Barge, B2

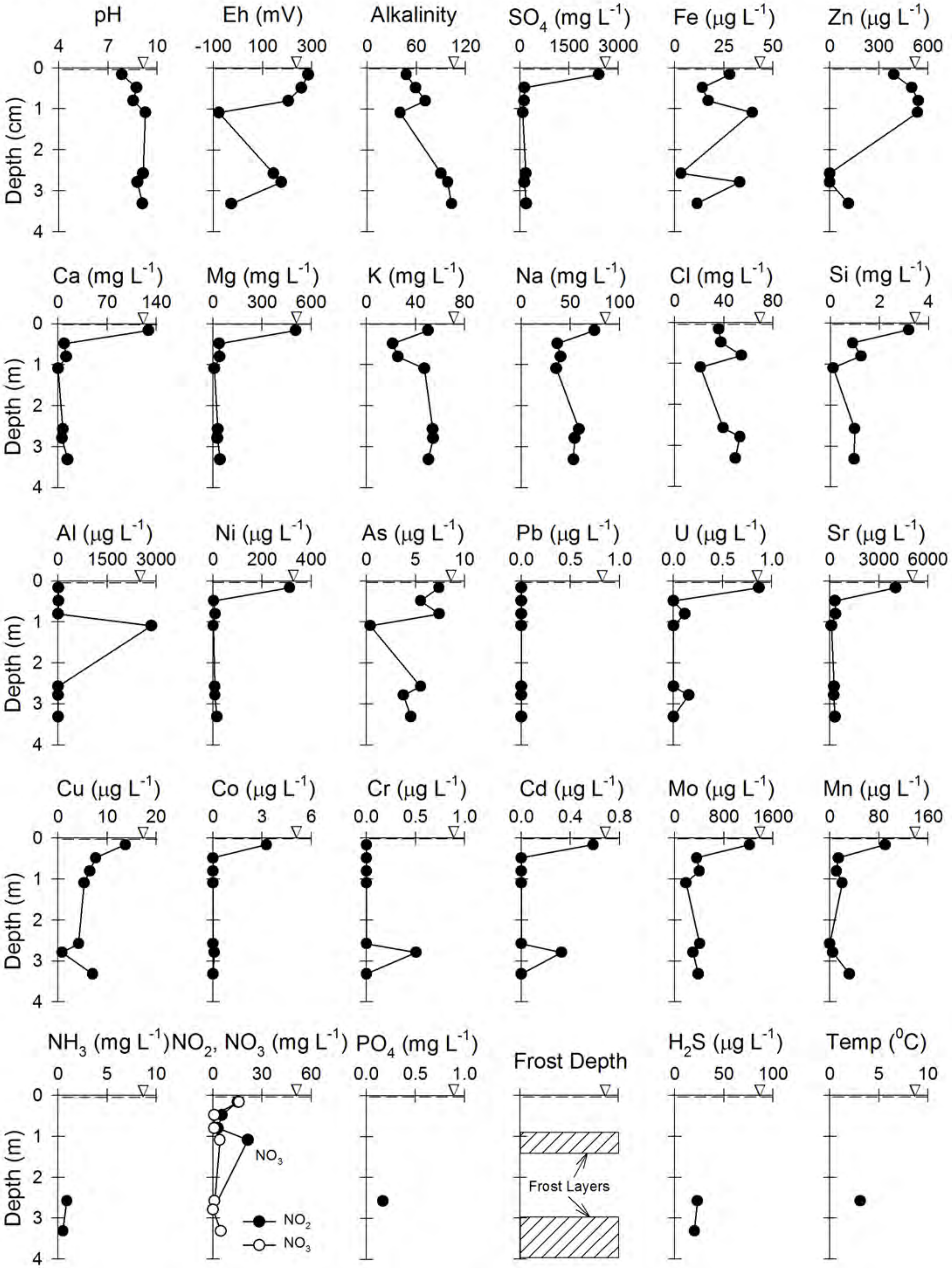

B2
pH
7
8
9
10
Eh (mV)
0
250
500
Alkalinity
0
60
120
SO4 (mg L-1)
0
200
400
Fe (μg L-1)
0
500
1000
Zn (μg L-1)
0
300
600
Ca (mg L-1)
0
20
40
Mg (mg L-1)
0
50
100
K (mg L-1)
0
70
140
Na (mg L-1)
0
50
100
Cl (mg L-1)
0
30
60
Si (mg L-1)
0
1
2
Al (μg L-1)
0.0
0.2
0.4
Ni (μg L-1)
0
12
24
As (μg L-1)
0
7
14
Pb (μg L-1)
0
2
4
U (μg L-1)
0
3
6
Sr (μg L-1)
0
400
800
Cu (μg L-1)
0
4
8
Co (μg L-1)
0
1
2
Cr (μg L-1)
0
6
12
Cd (μg L-1)
0
1
2
Mo (μg L-1)
0
400
800
Mn (μg L-1)
0
6
12
NH3 (mg L-1)
0
2
4
NO2 (mg L-1)
0
3
6
NO3 (mg L-1)
0
25
50
PO4 (mg L-1)
0.00
0.15
0.30
DOC (mg L-1)
0
150
300
H2S (μg L-1)
0
50
100
Depth (m)
0
-10
-20
-30


Barge
pH
7 8 9 10
Eh (mV)
0 250 500
Alkalinity
0 60 120
SO$_4$ (mg L^{-1})
0 400 800
Fe (µg L^{-1})
0 60 120
Zn (µg L^{-1})
0 1200 2400
Ca (mg L^{-1})
0 20 40
Mg (mg L^{-1})
0 50 100
K (mg L^{-1})
0 70 140
Na (mg L^{-1})
0 50 100
Cl (mg L^{-1})
0 30 60
Si (mg L^{-1})
0 1 2
Al (µg L^{-1})
0 35 70
Ni (µg L^{-1})
0 30 60
As (µg L^{-1})
0 6 12
Pb (µg L^{-1})
0 1 2
U (µg L^{-1})
0 3 6
Sr (µg L^{-1})
0 600 1200
Cu (µg L^{-1})
0 1 2
Co (µg L^{-1})
0.0 0.5 1.0
Cr (µg L^{-1})
0.0 0.5 1.0
Cd (µg L^{-1})
0.0 0.5 1.0
Mo (µg L^{-1})
0 400 800
Mn (µg L^{-1})
0 20 40
NH$_3$ (mg L^{-1})
0 2 4
NO$_2$ (mg L^{-1})
0 20 40
NO$_3$ (mg L^{-1})
0 25 50
PO$_4$ (mg L^{-1})
0.0 0.1 0.2
DOC (mg L^{-1})
0 200 400
H$_2$S (µg L^{-1})
0 50 100
Depth (m)
0
-7
-14
-21
-28
● 2009
○ 2010

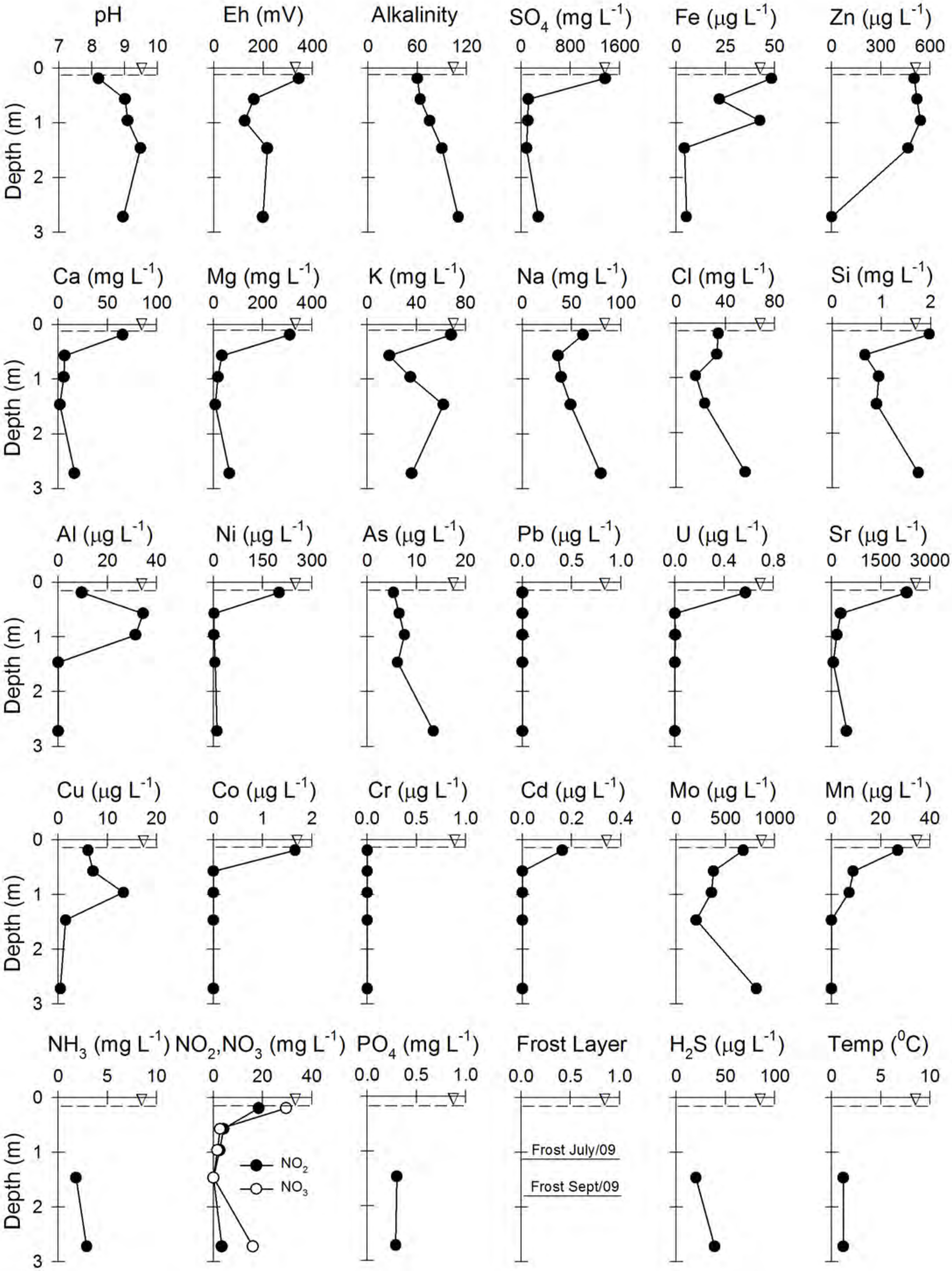

PKC1
pH
4 8 12
Eh (mV)
0 200 400
Alkalinity
0 60 120
SO$_4$ (mg L^{-1})
0 5000 10000
Fe (µg L^{-1})
0 40 80
Zn (µg L^{-1})
0 1600 3200
Ca (mg L^{-1})
0 210 420
Mg (mg L^{-1})
0 1100 2200
K (mg L^{-1})
0 500 1000
Na (mg L^{-1})
0 200 400
Cl (mg L^{-1})
0 40 80
Si (mg L^{-1})
0 4 8
Al (µg L^{-1})
0 400 800
Ni (µg L^{-1})
0 1500 3000
As (µg L^{-1})
0 9 18
Pb (µg L^{-1})
0.0 0.2 0.4
U (µg L^{-1})
0 1 2
Sr (µg L^{-1})
0 7000 14000
Cu (µg L^{-1})
0 10 20
Co (µg L^{-1})
0 15 30
Cr (µg L^{-1})
0 4 8
Cd (µg L^{-1})
0.0 1.5 3.0
Mo (µg L^{-1})
0 900 1800
Mn (µg L^{-1})
0 200 400
NH$_4$ (mg L^{-1})
0 5 10
NO$_2$ (mg L^{-1})
0 30 60
NO$_3$ (mg L^{-1})
0 250 500
PO$_4$ (mg L^{-1})
0.0 0.5 1.0
H$_2$S (µg L^{-1})
0 80 160
Temp (^{0}C)
0 5 10
Depth (m)
0.0 0.5 1.0 1.5 2.0 2.5
2009
2010

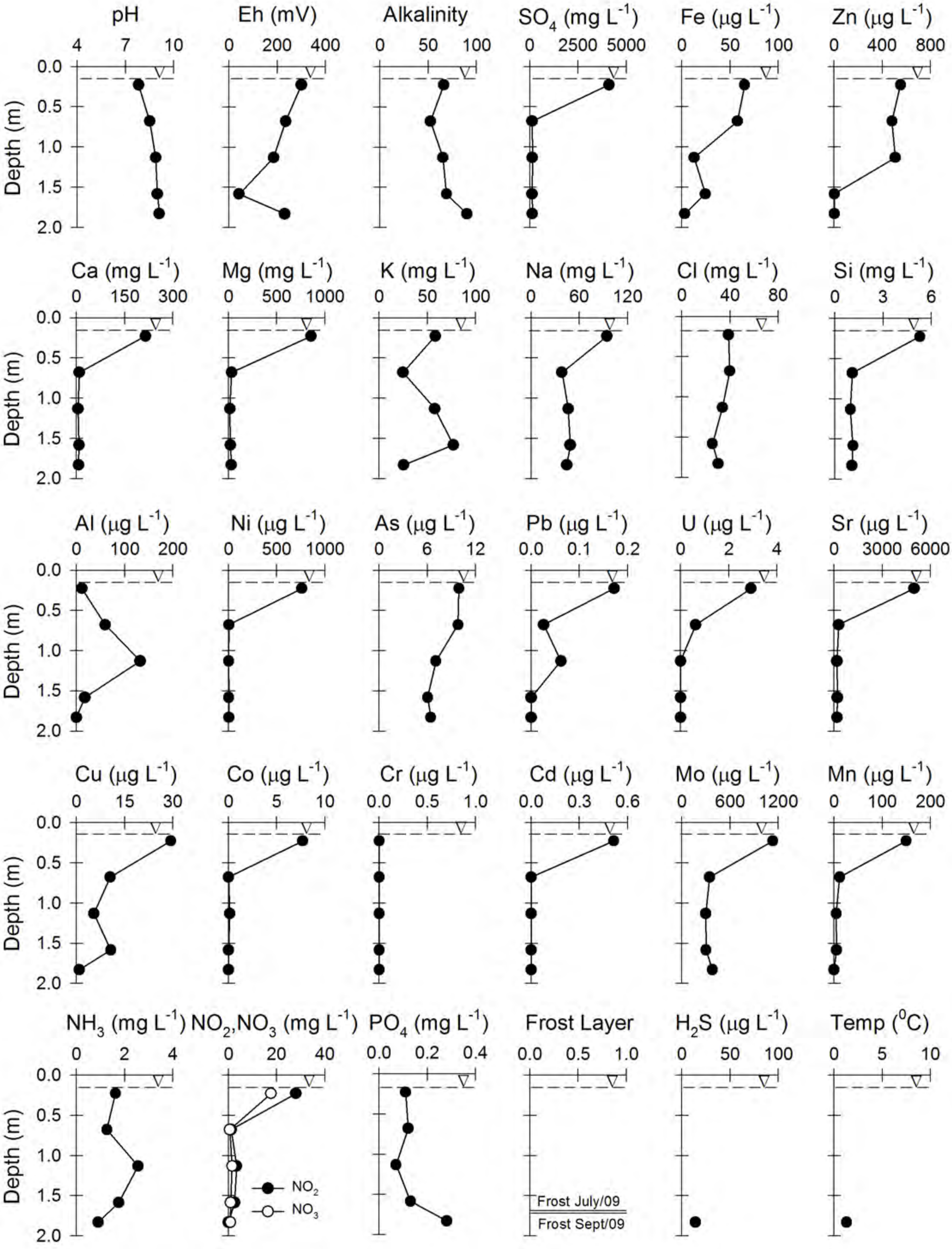

PKC2
pH
4
7
10
Eh (mV)
-200
200
600
Alkalinity
0
70
140
SO_4 (mg L^{-1})
0
3500
7000
Fe (μg L^{-1})
0
30
60
Zn (μg L^{-1})
0
1800
3600
Depth (cm)
0.0
0.5
1.0
1.5
2.0
Ca (mg L^{-1})
0
200
400
Mg (mg L^{-1})
0
800
1600
K (mg L^{-1})
0
75
150
Na (mg L^{-1})
0
100
200
Cl (mg L^{-1})
0
40
80
Si (mg L^{-1})
0
4
8
Depth (m)
Al (μg L^{-1})
0
90
180
Ni (μg L^{-1})
0
400
800
As (μg L^{-1})
0
10
20
Pb (μg L^{-1})
0.0
0.8
1.6
U (μg L^{-1})
0.0
2.5
5.0
Sr (μg L^{-1})
0
6000
12000
Cu (μg L^{-1})
0
40
80
Co (μg L^{-1})
0
8
16
Cr (μg L^{-1})
0.0
0.8
1.6
Cd (μg L^{-1})
0
1
2
Mo (μg L^{-1})
0
1200
2400
Mn (μg L^{-1})
0
80
160
NH_3 (mg L^{-1})
0
5
10
NO_2 (mg L^{-1})
0
10
20
NO_3 (mg L^{-1})
0
30
60
PO_4 (mg L^{-1})
0.0
0.5
1.0
H_2S (μg L^{-1})
0
50
100
Temp (^{0}C)
0
5
10
▽

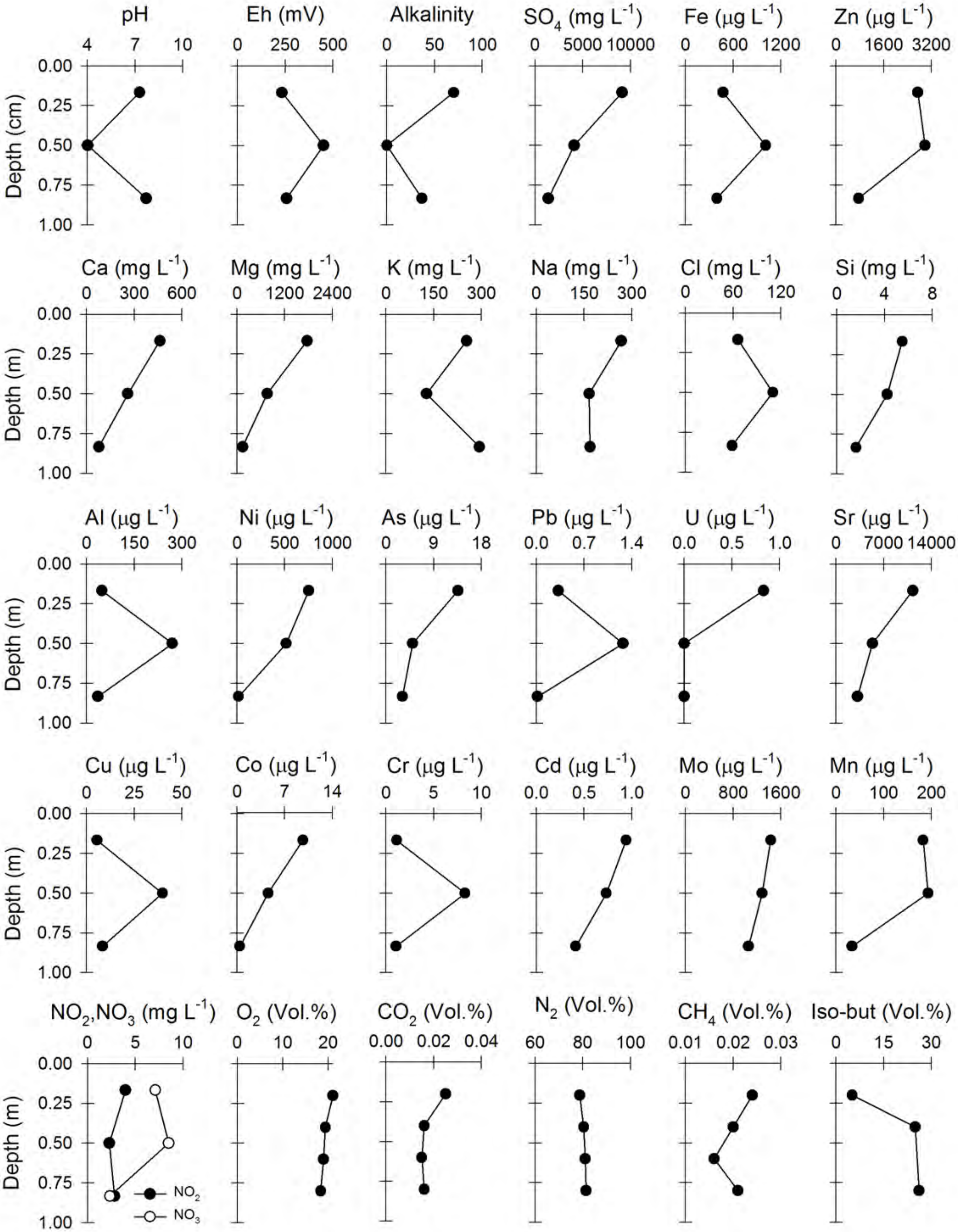
PKC3



pH
4 7 10
Eh (mV)
-100 100 300
Alkalinity
0 60 120
SO$_4$ (mg L^{-1})
0 1500 3000
Fe (μg L^{-1})
0 25 50
Zn (μg L^{-1})
0 300 600
Depth (cm)
0 1 2 3 4
Ca (mg L^{-1})
0 70 140
Mg (mg L^{-1})
0 300 600
K (mg L^{-1})
0 40 80
Na (mg L^{-1})
0 50 100
Cl (mg L^{-1})
0 40 80
Si (mg L^{-1})
0 2 4
Depth (m)
Al (μg L^{-1})
0 1500 3000
Ni (μg L^{-1})
0 200 400
As (μg L^{-1})
0 5 10
Pb (μg L^{-1})
0.0 0.5 1.0
U (μg L^{-1})
0.0 0.5 1.0
Sr (μg L^{-1})
0 3000 6000
Cu (μg L^{-1})
0 10 20
Co (μg L^{-1})
0 3 6
Cr (μg L^{-1})
0.0 0.5 1.0
Cd (μg L^{-1})
0.0 0.4 0.8
Mo (μg L^{-1})
0 800 1600
Mn (μg L^{-1})
0 80 160
NH$_3$ (mg L^{-1})
0 5 10
NO$_2$, NO$_3$ (mg L^{-1})
0 30 60
NO$_3$
NO$_2$
NO$_3$
PO$_4$ (mg L^{-1})
0.0 0.5 1.0
Frost Depth
Frost Layers
H$_2$S (μg L^{-1})
0 50 100
Temp (^{0}C)
0 5 10


pH
7 8 9 10
Eh (mV)
0 200 400
Alkalinity
0 60 120
SO_4 (mg L^{-1})
0 800 1600
Fe (µg L^{-1})
0 25 50
Zn (µg L^{-1})
0 300 600
Ca (mg L^{-1})
0 50 100
Mg (mg L^{-1})
0 200 400
K (mg L^{-1})
0 40 80
Na (mg L^{-1})
0 50 100
Cl (mg L^{-1})
0 40 80
Si (mg L^{-1})
0 1 2
Al (µg L^{-1})
0 20 40
Ni (µg L^{-1})
0 150 300
As (µg L^{-1})
0 10 20
Pb (µg L^{-1})
0.0 0.5 1.0
U (µg L^{-1})
0.0 0.4 0.8
Sr (µg L^{-1})
0 1500 3000
Cu (µg L^{-1})
0 10 20
Co (µg L^{-1})
0 1 2
Cr (µg L^{-1})
0.0 0.5 1.0
Cd (µg L^{-1})
0.0 0.2 0.4
Mo (µg L^{-1})
0 500 1000
Mn (µg L^{-1})
0 20 40
NH_3 (mg L^{-1})
0 5 10
NO_2,NO_3 (mg L^{-1})
0 20 40
NO_2
NO_3
PO_4 (mg L^{-1})
0.0 0.5 1.0
Frost Layer
0.0 0.5 1.0
Frost July/09
Frost Sept/09
H_2S (µg L^{-1})
0 50 100
Temp (^{0}C)
0 5 10
Depth (m)
0 1 2 3

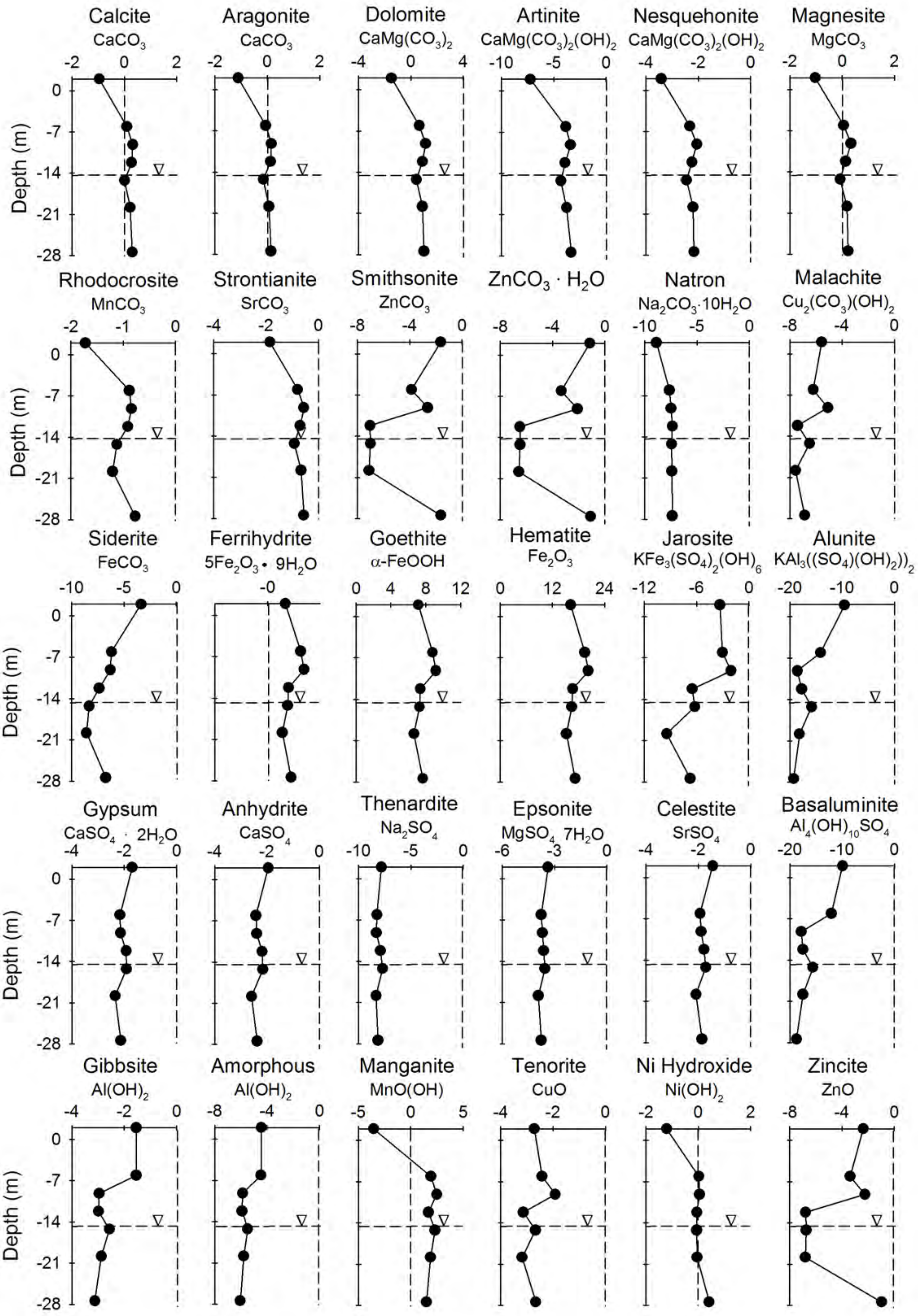

pH
4 7 10
Eh (mV)
0 200 400
Alkalinity
0 50 100
SO_4 (mg L^{-1})
0 2500 5000
Fe (µg L^{-1})
0 50 100
Zn (µg L^{-1})
0 400 800
Ca (mg L^{-1})
0 150 300
Mg (mg L^{-1})
0 500 1000
K (mg L^{-1})
0 50 100
Na (mg L^{-1})
0 60 120
Cl (mg L^{-1})
0 40 80
Si (mg L^{-1})
0 3 6
Al (µg L^{-1})
0 100 200
Ni (µg L^{-1})
0 500 1000
As (µg L^{-1})
0 6 12
Pb (µg L^{-1})
0.0 0.1 0.2
U (µg L^{-1})
0 2 4
Sr (µg L^{-1})
0 3000 6000
Cu (µg L^{-1})
0 15 30
Co (µg L^{-1})
0 5 10
Cr (µg L^{-1})
0.0 0.5 1.0
Cd (µg L^{-1})
0.0 0.3 0.6
Mo (µg L^{-1})
0 600 1200
Mn (µg L^{-1})
0 100 200
NH_3 (mg L^{-1})
0 2 4
NO_2,NO_3 (mg L^{-1})
0 20 40
NO_2
NO_3
PO_4 (mg L^{-1})
0.0 0.2 0.4
Frost Layer
0.0 0.5 1.0
Frost July/09
Frost Sept/09
H_2S (µg L^{-1})
0 50 100
Temp (°C)
0 5 10
Depth (m)
0.0 0.5 1.0 1.5 2.0


pH
4 7 10
Eh (mV)
0 250 500
Alkalinity
0 50 100
SO_4 (mg L^{-1})
0 5000 10000
Fe (µg L^{-1})
0 600 1200
Zn (µg L^{-1})
0 1600 3200
Depth (cm)
0.00 0.25 0.50 0.75 1.00
Ca (mg L^{-1})
0 300 600
Mg (mg L^{-1})
0 1200 2400
K (mg L^{-1})
0 150 300
Na (mg L^{-1})
0 150 300
Cl (mg L^{-1})
0 60 120
Si (mg L^{-1})
0 4 8
Depth (m)
0.00 0.25 0.50 0.75 1.00
Al (µg L^{-1})
0 150 300
Ni (µg L^{-1})
0 500 1000
As (µg L^{-1})
0 9 18
Pb (µg L^{-1})
0.0 0.7 1.4
U (µg L^{-1})
0.0 0.5 1.0
Sr (µg L^{-1})
0 7000 14000
Depth (m)
0.00 0.25 0.50 0.75 1.00
Cu (µg L^{-1})
0 25 50
Co (µg L^{-1})
0 7 14
Cr (µg L^{-1})
0 5 10
Cd (µg L^{-1})
0.0 0.5 1.0
Mo (µg L^{-1})
0 800 1600
Mn (µg L^{-1})
0 100 200
Depth (m)
0.00 0.25 0.50 0.75 1.00
NO_2,NO_3 (mg L^{-1})
0 5 10
O_2 (Vol.%)
0 10 20
CO_2 (Vol.%)
0.00 0.02 0.04
N_2 (Vol.%)
60 80 100
CH_4 (Vol.%)
0.01 0.02 0.03
Iso-but (Vol.%)
0 15 30
Depth (m)
0.00 0.25 0.50 0.75 1.00
● NO_2
○ NO_3

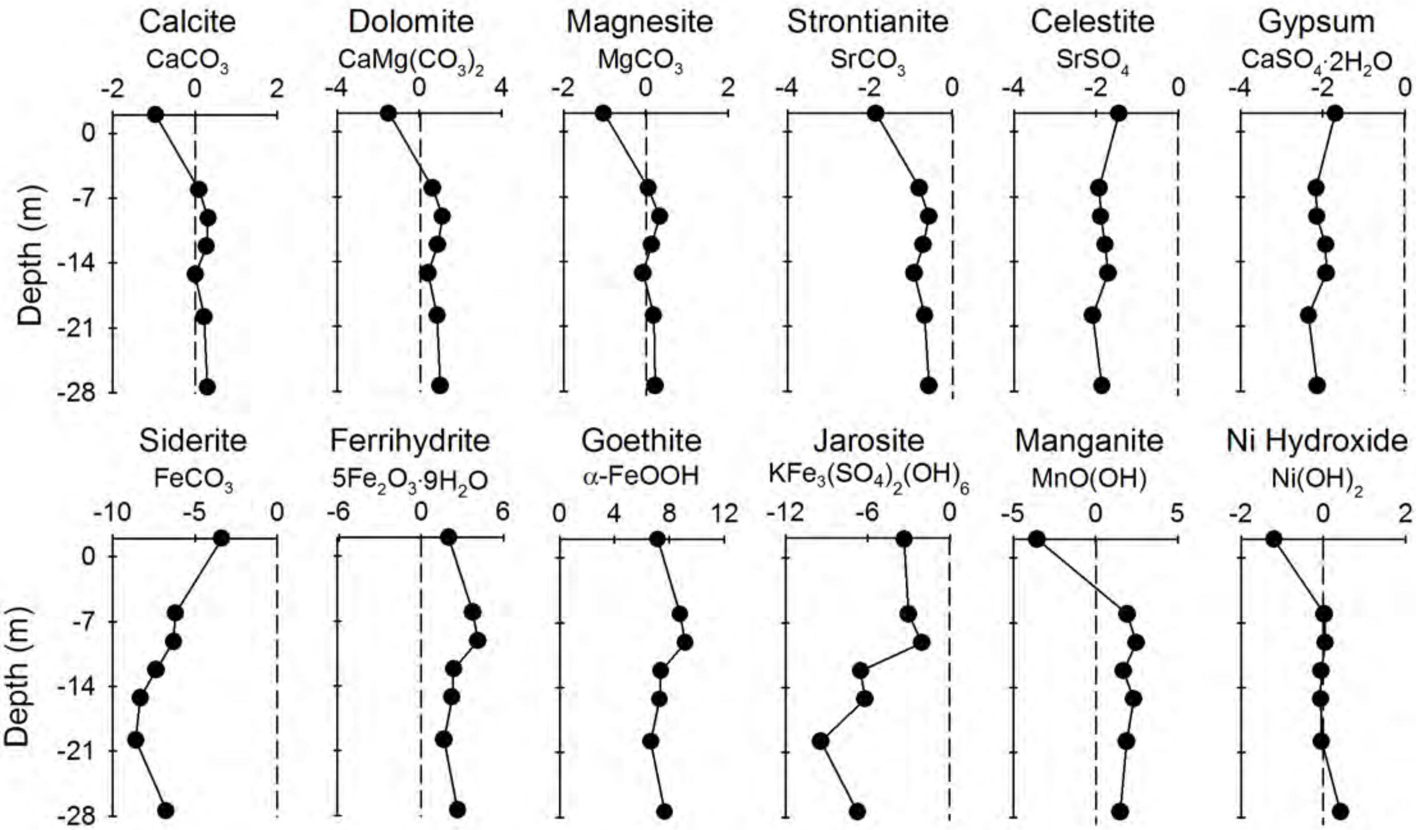
APPENDIX C

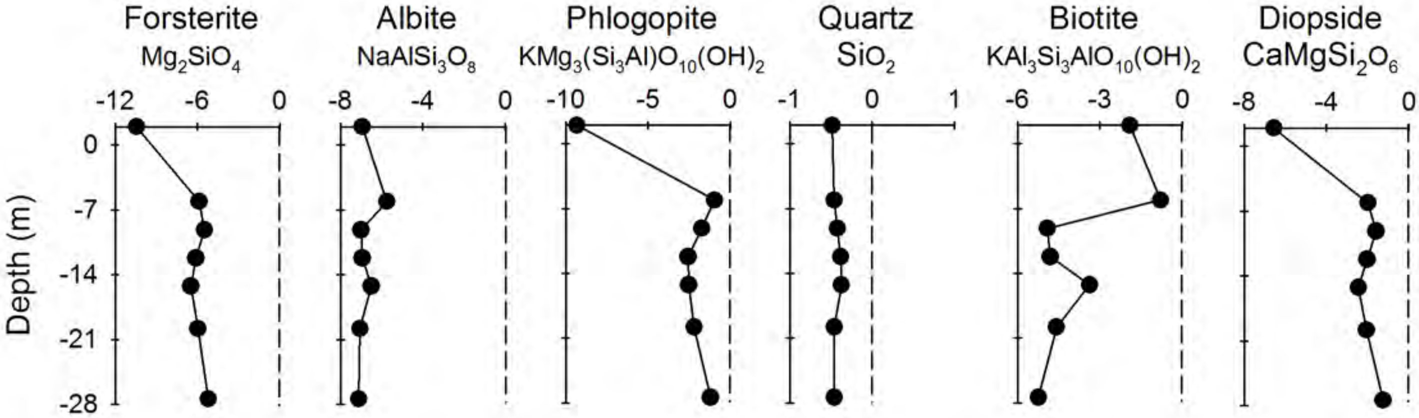
Plots of PKC groundwater and surface water saturation indices (2009 and 2010) for locations:

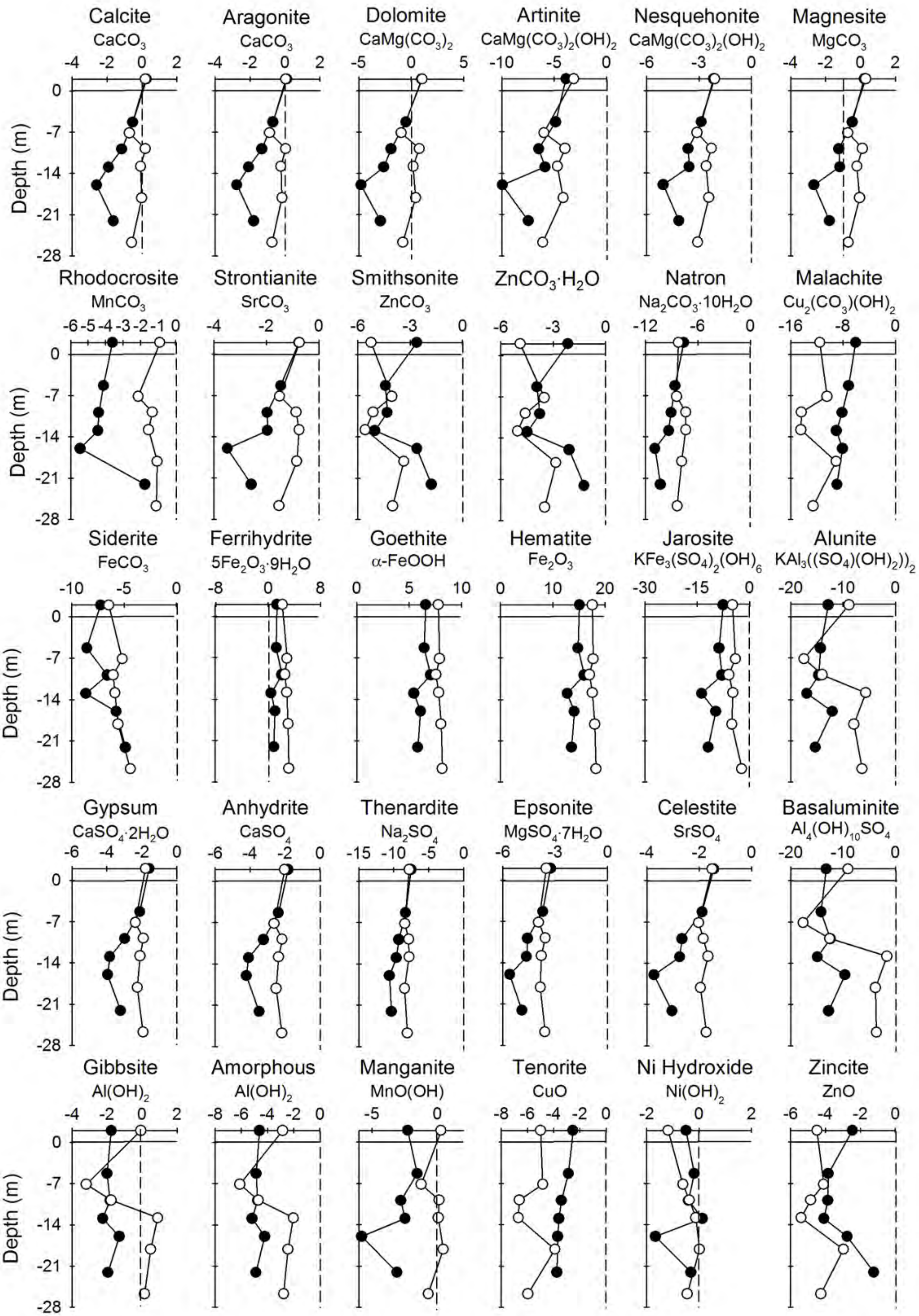
PKC1, PKC2, PKC3, PKC4, PKC5, PKC-SW, PKC-Pond, Barge, B2

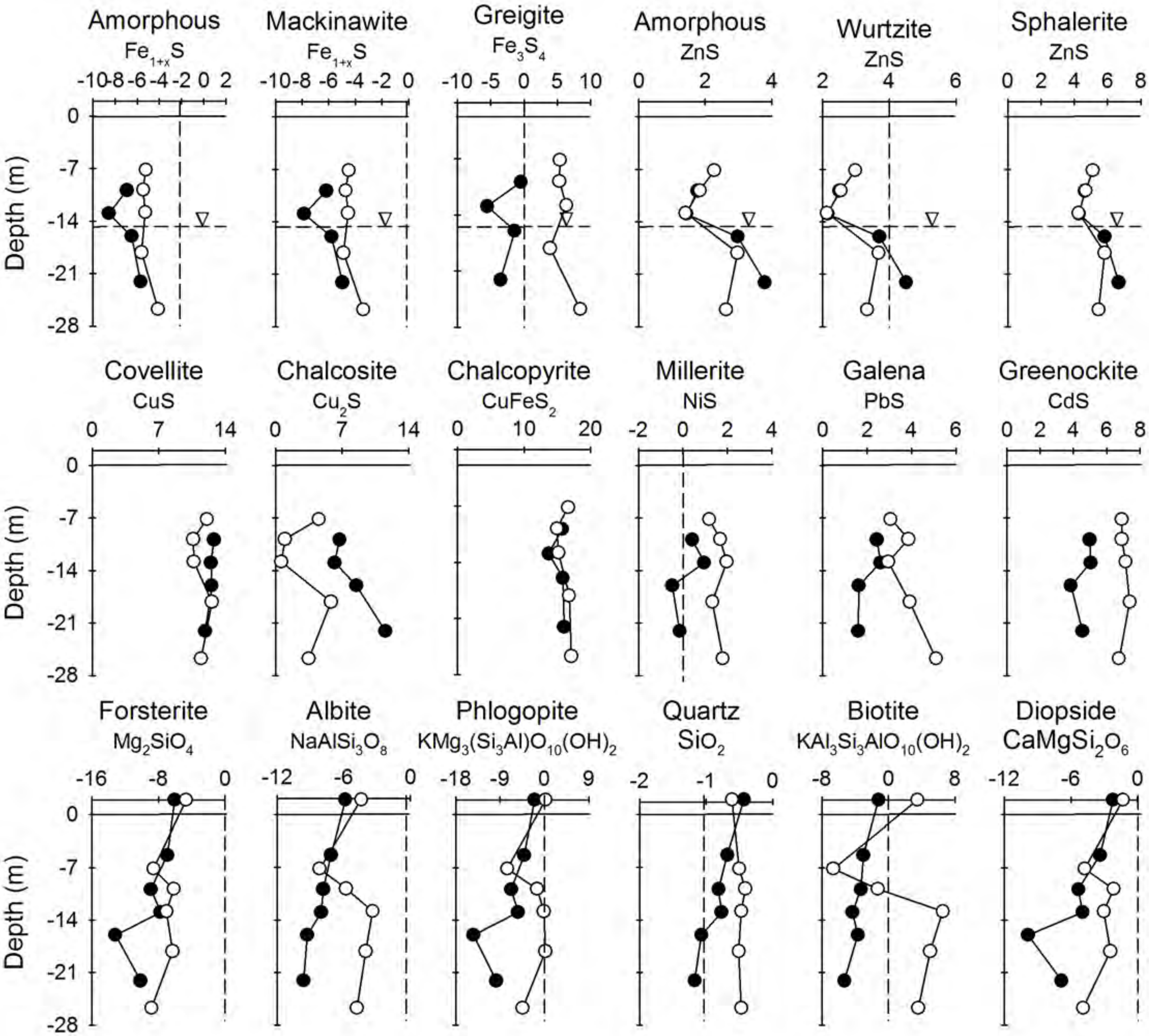


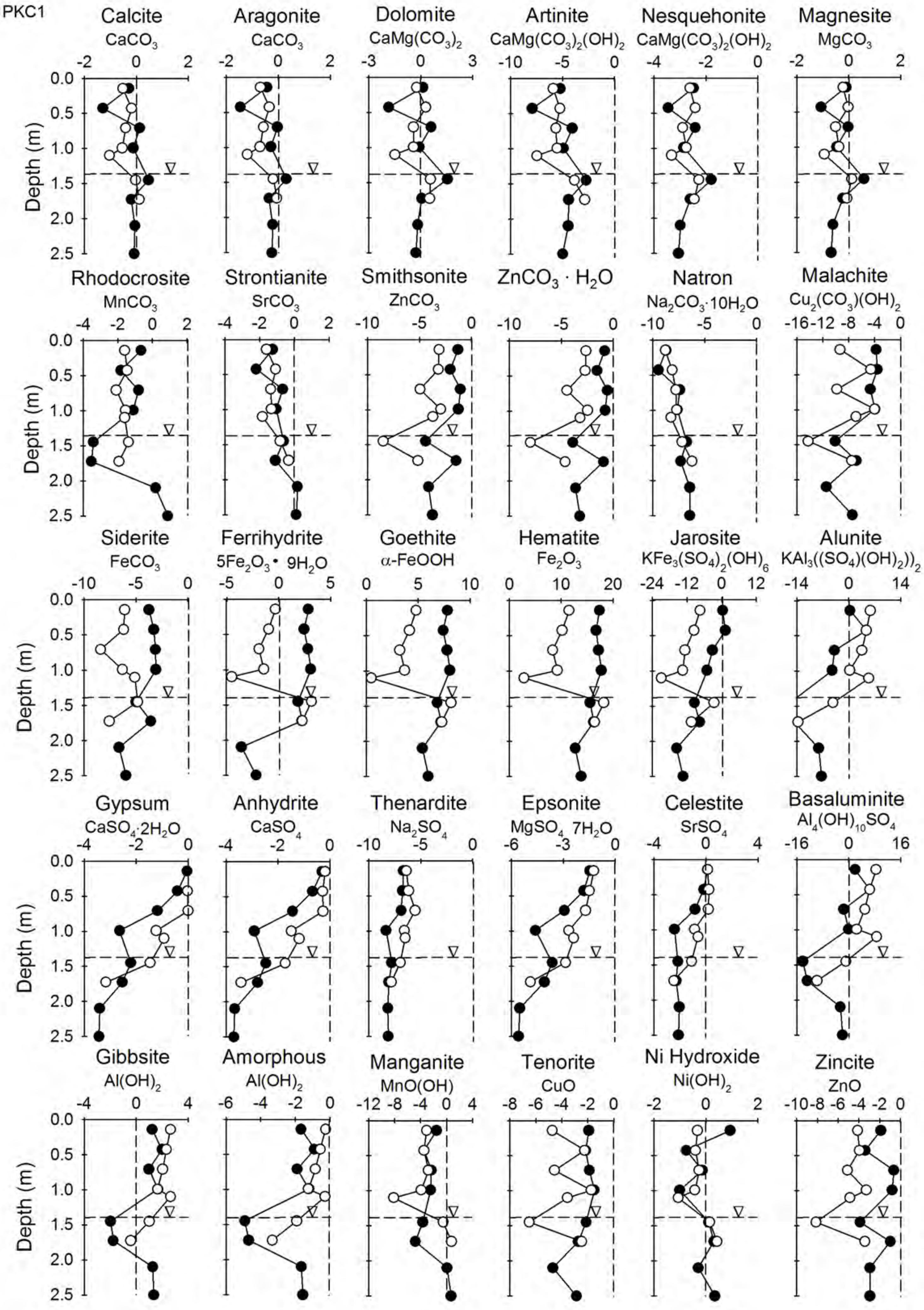
Calcite
$CaCO_3$
Aragonite
$CaCO_3$
Dolomite
$CaMg(CO_3)_2$
Artinite
$CaMg(CO_3)_2(OH)_2$
Nesquehonite
$CaMg(CO_3)_2(OH)_2$
Magnesite
$MgCO_3$
Rhodocrosite
$MnCO_3$
Strontianite
$SrCO_3$
Smithsonite
$ZnCO_3$
$ZnCO_3 \cdot H_2O$
Natron
$Na_2CO_3 \cdot 10H_2O$
Malachite
$Cu_2(CO_3)(OH)_2$
Siderite
$FeCO_3$
Ferrihydrite
$5Fe_2O_3 \cdot 9H_2O$
Goethite
α-FeOOH
Hematite
Fe_2O_3
Jarosite
$KFe_3(SO_4)_2(OH)_6$
Alunite
$KAl_3((SO_4)(OH)_2))_2$
Gypsum
$CaSO_4 \cdot 2H_2O$
Anhydrite
$CaSO_4$
Thenardite
Na_2SO_4
Epsonite
$MgSO_4$ $7H_2O$
Celestite
$SrSO_4$
Basaluminite
$Al_4(OH)_{10}SO_4$
Gibbsite
$Al(OH)_2$
Amorphous
$Al(OH)_2$
Manganite
MnO(OH)
Tenorite
CuO
Ni Hydroxide
$Ni(OH)_2$
Zincite
ZnO
Depth (m)
0
-7
-14
-21
-28
∇

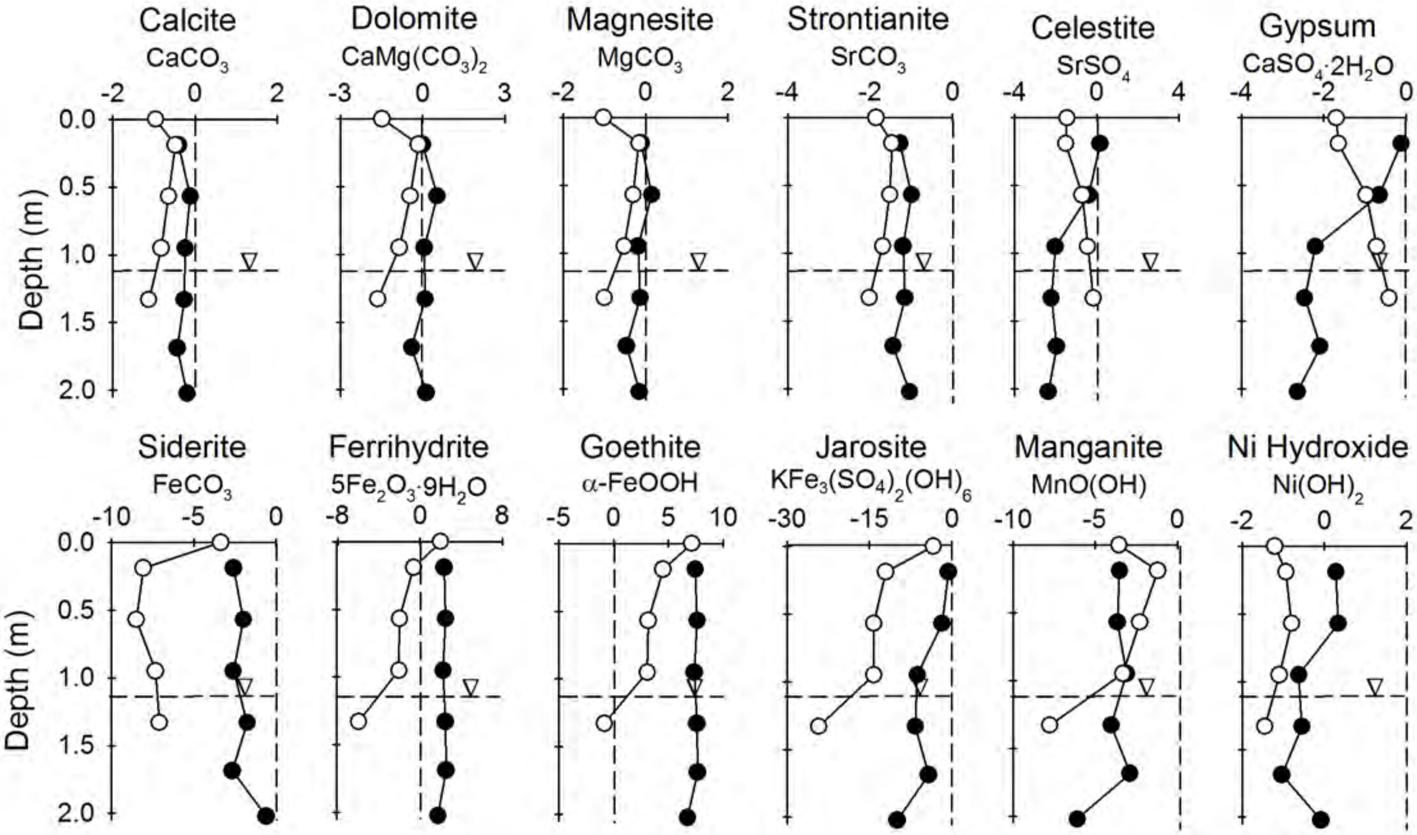

Calcite
CaCO3
Dolomite
CaMg(CO3)2
Magnesite
MgCO3
Strontianite
SrCO3
Celestite
SrSO4
Gypsum
CaSO4·2H2O
-2 0 2
-4 0 4
-2 0 2
-4 -2 0
-4 -2 0
-4 -2 0
Depth (m)
0
-7
-14
-21
-28
Siderite
FeCO3
Ferrihydrite
5Fe2O3·9H2O
Goethite
α-FeOOH
Jarosite
KFe3(SO4)2(OH)6
Manganite
MnO(OH)
Ni Hydroxide
Ni(OH)2
-10 -5 0
-6 0 6
0 4 8 12
-12 -6 0
-5 0 5
-2 0 2
Depth (m)
0
-7
-14
-21
-28


Forsterite
Mg2SiO4
Albite
NaAlSi3O8
Phlogopite
KMg3(Si3Al)O10(OH)2
Quartz
SiO2
Biotite
KAl3Si3AlO10(OH)2
Diopside
CaMgSi2O6
-12 -6 0
-8 -4 0
-10 -5 0
-1 0 1
-6 -3 0
-8 -4 0
Depth (m)
0
-7
-14
-21
-28

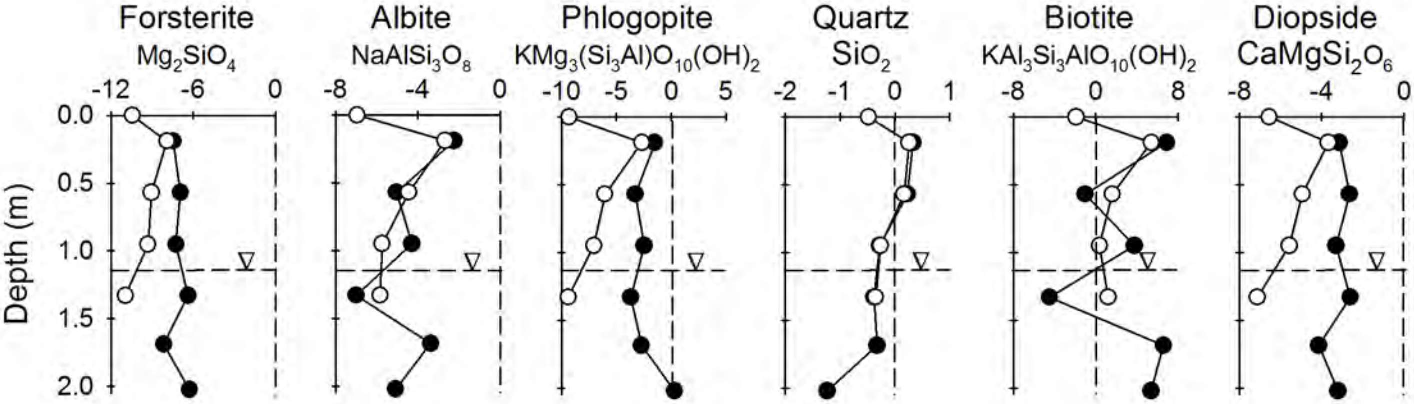

Calcite
$CaCO_3$
-4 -2 0 2
Aragonite
$CaCO_3$
-4 -2 0 2
Dolomite
$CaMg(CO_3)_2$
-5 0 5
Artinite
$CaMg(CO_3)_2(OH)_2$
-10 -5 0
Nesquehonite
$CaMg(CO_3)_2(OH)_2$
-6 -3 0
Magnesite
$MgCO_3$
-4 -2 0 2
Rhodocrosite
$MnCO_3$
-6 -5 -4 -3 -2 -1 0
Strontianite
$SrCO_3$
-4 -2 0
Smithsonite
$ZnCO_3$
-6 -3 0
$ZnCO_3 \cdot H_2O$
-6 -3 0
Natron
$Na_2CO_3 \cdot 10H_2O$
-12 -6 0
Malachite
$Cu_2(CO_3)(OH)_2$
-16 -8 0
Siderite
$FeCO_3$
-10 -5 0
Ferrihydrite
$5Fe_2O_3 \cdot 9H_2O$
-8 0 8
Goethite
α-FeOOH
0 5 10
Hematite
Fe_2O_3
0 10 20
Jarosite
$KFe_3(SO_4)_2(OH)_6$
-30 -15 0
Alunite
$KAl_3((SO_4)(OH)_2))_2$
-20 -10 0
Gypsum
$CaSO_4 \cdot 2H_2O$
-6 -4 -2 0
Anhydrite
$CaSO_4$
-6 -4 -2 0
Thenardite
Na_2SO_4
-15 -10 -5 0
Epsonite
$MgSO_4 \cdot 7H_2O$
-6 -3 0
Celestite
$SrSO_4$
-4 -2 0
Basaluminite
$Al_4(OH)_{10}SO_4$
-20 -10 0
Gibbsite
$Al(OH)_2$
-4 -2 0 2
Amorphous
$Al(OH)_2$
-8 -6 -4 -2 0
Manganite
MnO(OH)
-5 0
Tenorite
CuO
-8 -6 -4 -2 0
Ni Hydroxide
$Ni(OH)_2$
-2 0 2
Zincite
ZnO
-6 -4 -2 0
Depth (m)
0
-7
-14
-21
-28


Amorphous
$Fe_{1+x}S$
Mackinawite
$Fe_{1+x}S$
Greigite
Fe_3S_4
Amorphous
ZnS
Wurtzite
ZnS
Sphalerite
ZnS
Covellite
CuS
Chalcosite
Cu_2S
Chalcopyrite
$CuFeS_2$
Millerite
NiS
Galena
PbS
Greenockite
CdS
Forsterite
Mg_2SiO_4
Albite
$NaAlSi_3O_8$
Phlogopite
$KMg_3(Si_3Al)O_{10}(OH)_2$
Quartz
SiO_2
Biotite
$KAl_3Si_3AlO_{10}(OH)_2$
Diopside
$CaMgSi_2O_6$
Depth (m)
0
-7
-14
-21
-28
-10 -8 -6 -4 -2 0 2
-10 -8 -6 -4 -2 0
-10 -5 0 5 10
0 2 4
2 4 6
0 2 4 6 8
0 7 14
0 7 14
0 10 20
-2 0 2 4
0 2 4 6
0 2 4 6 8
-16 -8 0
-12 -6 0
-18 -9 0 9
-2 -1 0
-8 0 8
-12 -6 0
∇

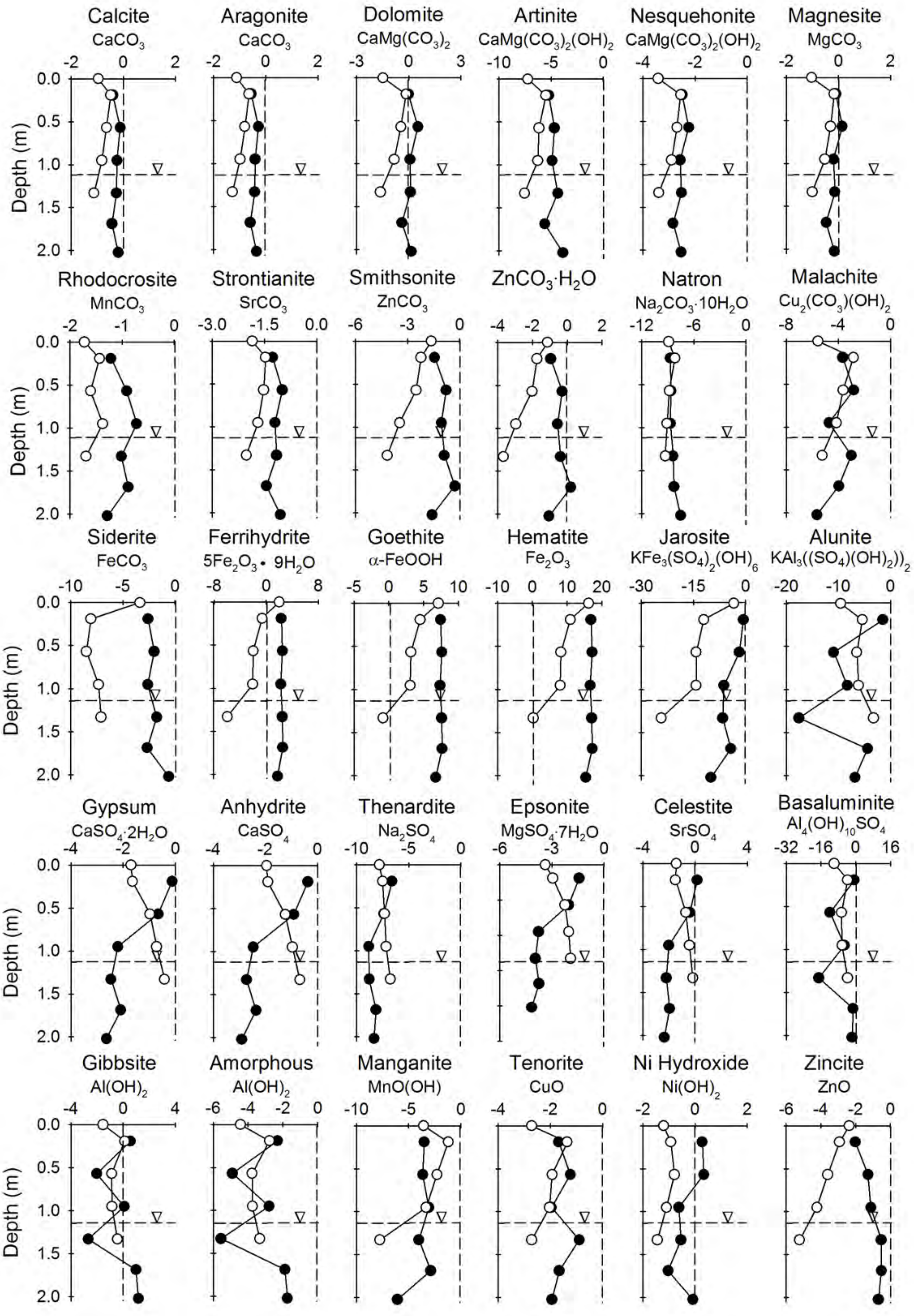

PKC1
Calcite
CaCO3
Aragonite
CaCO3
Dolomite
CaMg(CO3)2
Artinite
CaMg(CO3)2(OH)2
Nesquehonite
CaMg(CO3)2(OH)2
Magnesite
MgCO3
Rhodocrosite
MnCO3
Strontianite
SrCO3
Smithsonite
ZnCO3
ZnCO3 · H2O
Natron
Na2CO3·10H2O
Malachite
Cu2(CO3)(OH)2
Siderite
FeCO3
Ferrihydrite
5Fe2O3 • 9H2O
Goethite
α-FeOOH
Hematite
Fe2O3
Jarosite
KFe3(SO4)2(OH)6
Alunite
KAl3((SO4)(OH)2))2
Gypsum
CaSO4·2H2O
Anhydrite
CaSO4
Thenardite
Na2SO4
Epsonite
MgSO4 7H2O
Celestite
SrSO4
Basaluminite
Al4(OH)10SO4
Gibbsite
Al(OH)2
Amorphous
Al(OH)2
Manganite
MnO(OH)
Tenorite
CuO
Ni Hydroxide
Ni(OH)2
Zincite
ZnO
Depth (m)
0.0
0.5
1.0
1.5
2.0
2.5
∇

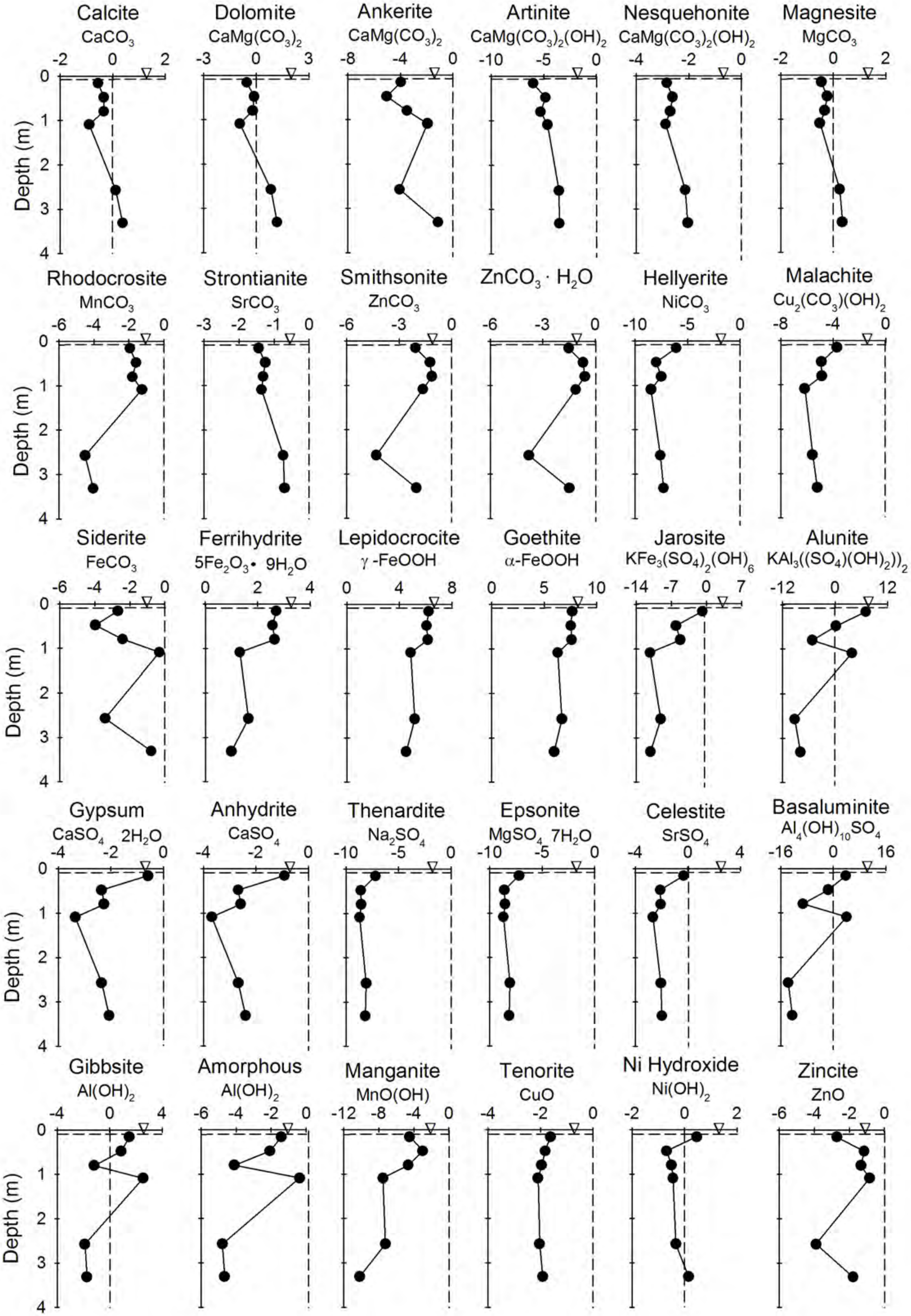


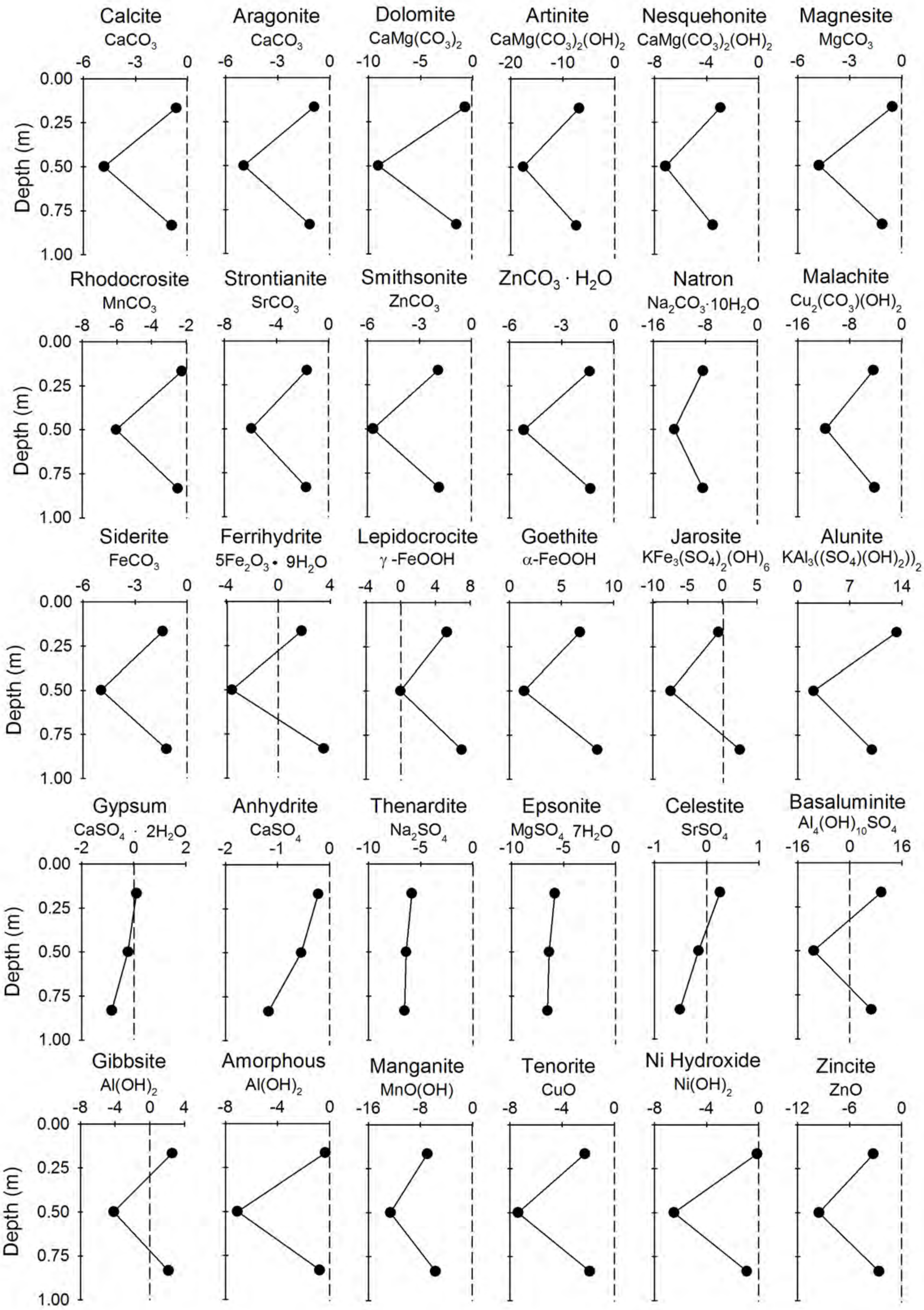
Calcite
CaCO$_3$
-2 0 2
Dolomite
CaMg(CO$_3$)$_2$
-3 0 3
Magnesite
MgCO$_3$
-2 0 2
Strontianite
SrCO$_3$
-4 -2 0
Celestite
SrSO$_4$
-4 0 4
Gypsum
CaSO$_4$·2H$_2$O
-4 -2 0
Siderite
FeCO$_3$
-10 -5 0
Ferrihydrite
5Fe$_2$O$_3$·9H$_2$O
-8 0 8
Goethite
α-FeOOH
-5 0 5 10
Jarosite
KFe$_3$(SO$_4$)$_2$(OH)$_6$
-30 -15 0
Manganite
MnO(OH)
-10 -5 0
Ni Hydroxide
Ni(OH)$_2$
-2 0 2
Depth (m)
0.0 0.5 1.0 1.5 2.0

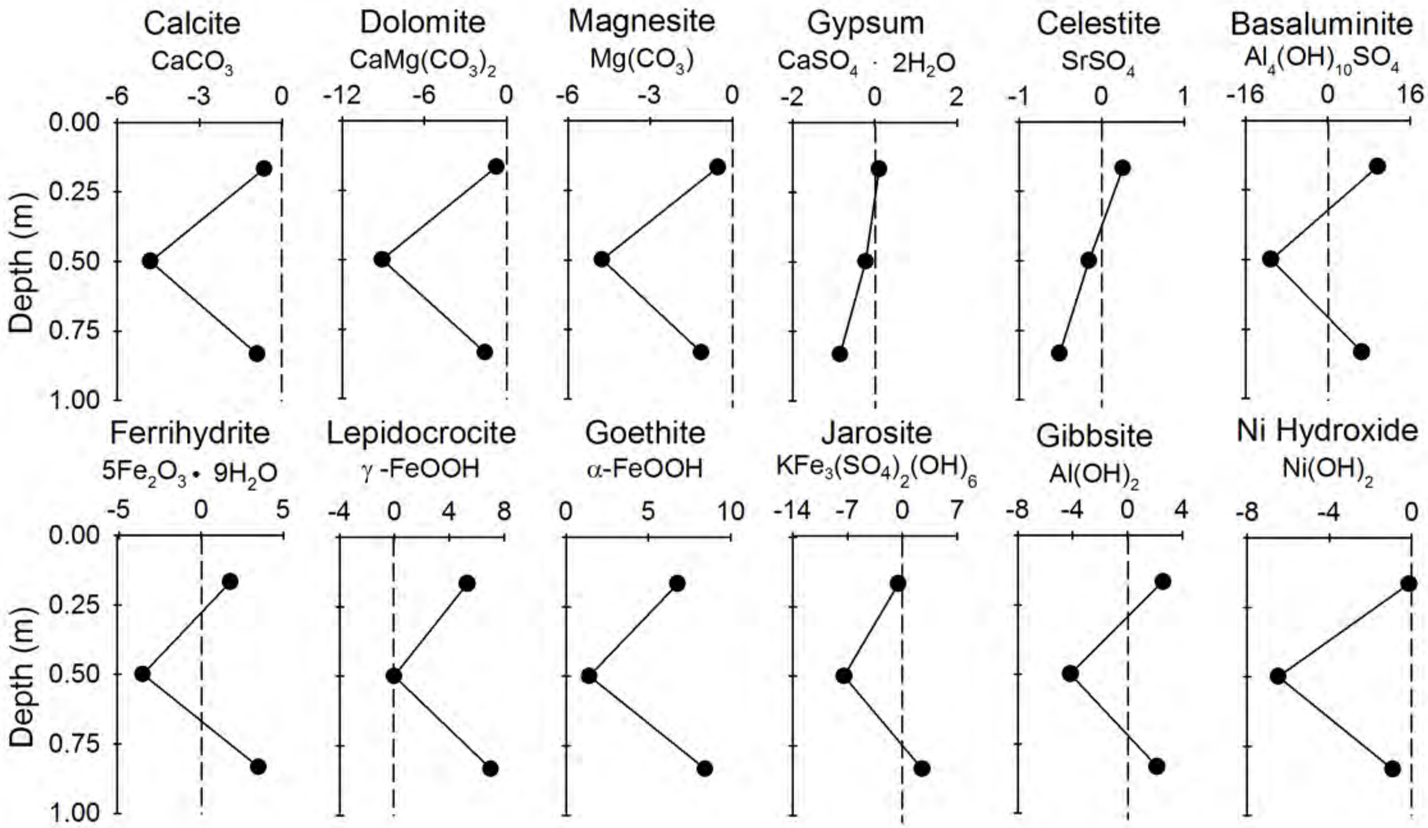


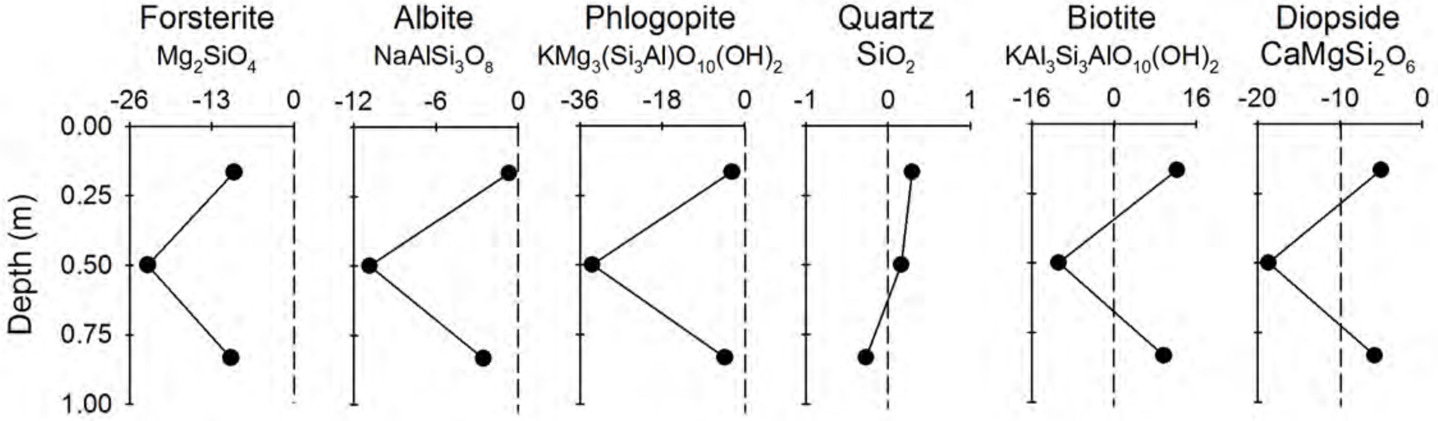
Forsterite
Mg$_2$SiO$_4$
-12 -6 0
Albite
NaAlSi$_3$O$_8$
-8 -4 0
Phlogopite
KMg$_3$(Si$_3$Al)O$_{10}$(OH)$_2$
-10 -5 0 5
Quartz
SiO$_2$
-2 -1 0 1
Biotite
KAl$_3$Si$_3$AlO$_{10}$(OH)$_2$
-8 0 8
Diopside
CaMgSi$_2$O$_6$
-8 -4 0
Depth (m)
0.0 0.5 1.0 1.5 2.0

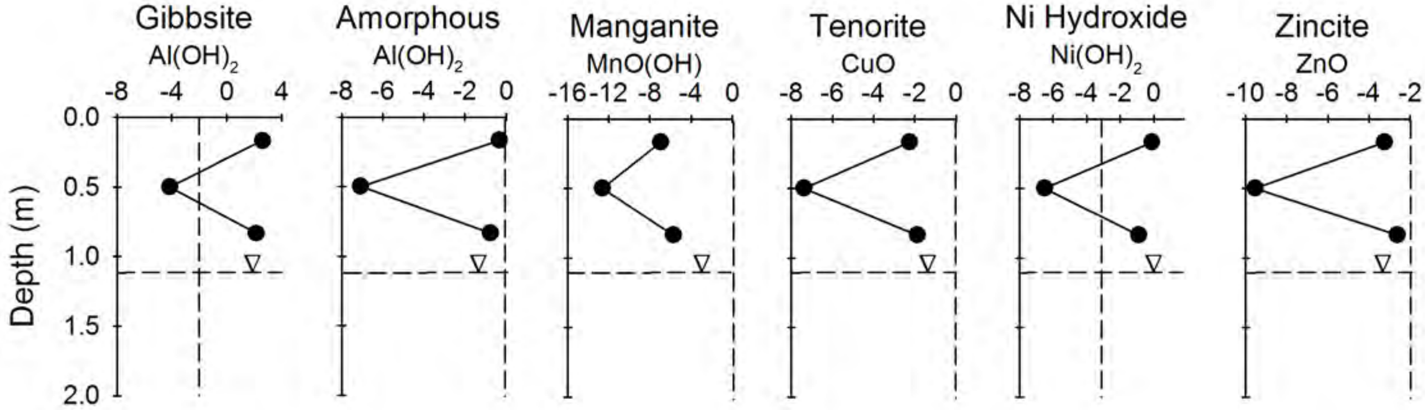

Calcite
$CaCO_3$
Aragonite
$CaCO_3$
Dolomite
$CaMg(CO_3)_2$
Artinite
$CaMg(CO_3)_2(OH)_2$
Nesquehonite
$CaMg(CO_3)_2(OH)_2$
Magnesite
$MgCO_3$
-2 0 2
-2 0 2
-3 0 3
-10 -5 0
-4 -2 0
-2 0 2
Depth (m)
0.0
0.5
1.0
1.5
2.0
Rhodocrosite
$MnCO_3$
Strontianite
$SrCO_3$
Smithsonite
$ZnCO_3$
$ZnCO_3 \cdot H_2O$
Natron
$Na_2CO_3 \cdot 10H_2O$
Malachite
$Cu_2(CO_3)(OH)_2$
-2 -1 0
-3.0 -1.5 0.0
-6 -3 0
-4 -2 0 2
-12 -6 0
-8 -4 0
Siderite
$FeCO_3$
Ferrihydrite
$5Fe_2O_3 \cdot 9H_2O$
Goethite
α-FeOOH
Hematite
Fe_2O_3
Jarosite
$KFe_3(SO_4)_2(OH)_6$
Alunite
$KAl_3((SO_4)(OH)_2))_2$
-10 -5 0
-8 0 8
-5 0 5 10
-10 0 10 20
-30 -15 0
-20 -10 0
Gypsum
$CaSO_4 \cdot 2H_2O$
Anhydrite
$CaSO_4$
Thenardite
Na_2SO_4
Epsonite
$MgSO_4 \cdot 7H_2O$
Celestite
$SrSO_4$
Basaluminite
$Al_4(OH)_{10}SO_4$
-4 -2 0
-4 -2 0
-10 -5 0
-6 -3 0
-4 0 4
-32 -16 0 16
Gibbsite
$Al(OH)_2$
Amorphous
$Al(OH)_2$
Manganite
MnO(OH)
Tenorite
CuO
Ni Hydroxide
$Ni(OH)_2$
Zincite
ZnO
-4 0 4
-6 -4 -2 0
-10 -5 0
-4 -2 0
-2 0 2
-6 -4 -2 0
∇


Calcite
CaCO3
Dolomite
CaMg(CO3)2
Ankerite
CaMg(CO3)2
Artinite
CaMg(CO3)2(OH)2
Nesquehonite
CaMg(CO3)2(OH)2
Magnesite
MgCO3
Rhodocrosite
MnCO3
Strontianite
SrCO3
Smithsonite
ZnCO3
ZnCO3 · H2O
Hellyerite
NiCO3
Malachite
Cu2(CO3)(OH)2
Siderite
FeCO3
Ferrihydrite
5Fe2O3• 9H2O
Lepidocrocite
γ -FeOOH
Goethite
α-FeOOH
Jarosite
KFe3(SO4)2(OH)6
Alunite
KAl3((SO4)(OH)2))2
Gypsum
CaSO4 2H2O
Anhydrite
CaSO4
Thenardite
Na2SO4
Epsonite
MgSO4 7H2O
Celestite
SrSO4
Basaluminite
Al4(OH)10SO4
Gibbsite
Al(OH)2
Amorphous
Al(OH)2
Manganite
MnO(OH)
Tenorite
CuO
Ni Hydroxide
Ni(OH)2
Zincite
ZnO
Depth (m)
0
1
2
3
4
-2 0 2
-3 0 3
-8 -4 0
-10 -5 0
-4 -2 0
-2 0 2
-6 -4 -2 0
-3 -2 -1 0
-6 -3 0
-6 -3 0
-10 -5 0
-8 -4 0
-6 -4 -2 0
0 2 4
0 4 8
0 5 10
-14 -7 0 7
-12 0 12
-4 -2 0
-4 -2 0
-10 -5 0
-10 -5 0
-4 0 4
-16 0 16
-4 0 4
-6 -4 -2 0
-12 -8 -4 0
-4 -2 0
-2 0 2
-6 -4 -2 0


Calcite
$CaCO_3$
-6 -3 0
Aragonite
$CaCO_3$
-6 -3 0
Dolomite
$CaMg(CO_3)_2$
-10 -5 0
Artinite
$CaMg(CO_3)_2(OH)_2$
-20 -10 0
Nesquehonite
$CaMg(CO_3)_2(OH)_2$
-8 -4 0
Magnesite
$MgCO_3$
-6 -3 0
Rhodocrosite
$MnCO_3$
-8 -6 -4 -2
Strontianite
$SrCO_3$
-8 -4 0
Smithsonite
$ZnCO_3$
-6 -3 0
$ZnCO_3 \cdot H_2O$
-6 -3 0
Natron
$Na_2CO_3 \cdot 10H_2O$
-16 -8 0
Malachite
$Cu_2(CO_3)(OH)_2$
-16 -8 0
Siderite
$FeCO_3$
-6 -3 0
Ferrihydrite
$5Fe_2O_3 \cdot 9H_2O$
-4 0 4
Lepidocrocite
γ -FeOOH
-4 0 4 8
Goethite
α-FeOOH
0 5 10
Jarosite
$KFe_3(SO_4)_2(OH)_6$
-10 -5 0 5
Alunite
$KAl_3((SO_4)(OH)_2))_2$
0 7 14
Gypsum
$CaSO_4 \cdot 2H_2O$
-2 0 2
Anhydrite
$CaSO_4$
-2 -1 0
Thenardite
Na_2SO_4
-10 -5 0
Epsonite
$MgSO_4\ 7H_2O$
-10 -5 0
Celestite
$SrSO_4$
-1 0 1
Basaluminite
$Al_4(OH)_{10}SO_4$
-16 0 16
Gibbsite
$Al(OH)_2$
-8 -4 0 4
Amorphous
$Al(OH)_2$
-8 -4 0
Manganite
MnO(OH)
-16 -8 0
Tenorite
CuO
-8 -4 0
Ni Hydroxide
$Ni(OH)_2$
-8 -4 0
Zincite
ZnO
-12 -6 0
Depth (m)
0.00
0.25
0.50
0.75
1.00


Calcite
$CaCO_3$
Dolomite
$CaMg(CO_3)_2$
Magnesite
$Mg(CO_3)$
Gypsum
$CaSO_4 \cdot 2H_2O$
Celestite
$SrSO_4$
Basaluminite
$Al_4(OH)_{10}SO_4$
-6 -3 0
-12 -6 0
-6 -3 0
-2 0 2
-1 0 1
-16 0 16
Depth (m)
0.00 0.25 0.50 0.75 1.00
Ferrihydrite
$5Fe_2O_3 \cdot 9H_2O$
Lepidocrocite
γ -FeOOH
Goethite
α-FeOOH
Jarosite
$KFe_3(SO_4)_2(OH)_6$
Gibbsite
$Al(OH)_2$
Ni Hydroxide
$Ni(OH)_2$
-5 0 5
-4 0 4 8
0 5 10
-14 -7 0 7
-8 -4 0 4
-8 -4 0
Depth (m)
0.00 0.25 0.50 0.75 1.00

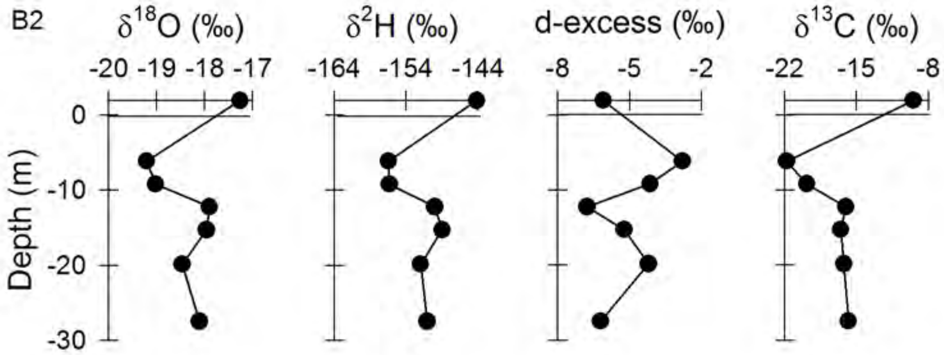

Forsterite
Mg_2SiO_4
Albite
$NaAlSi_3O_8$
Phlogopite
$KMg_3(Si_3Al)O_{10}(OH)_2$
Quartz
SiO_2
Biotite
$KAl_3Si_3AlO_{10}(OH)_2$
Diopside
$CaMgSi_2O_6$
-26 -13 0
-12 -6 0
-36 -18 0
-1 0 1
-16 0 16
-20 -10 0
Depth (m)
0.00 0.25 0.50 0.75 1.00

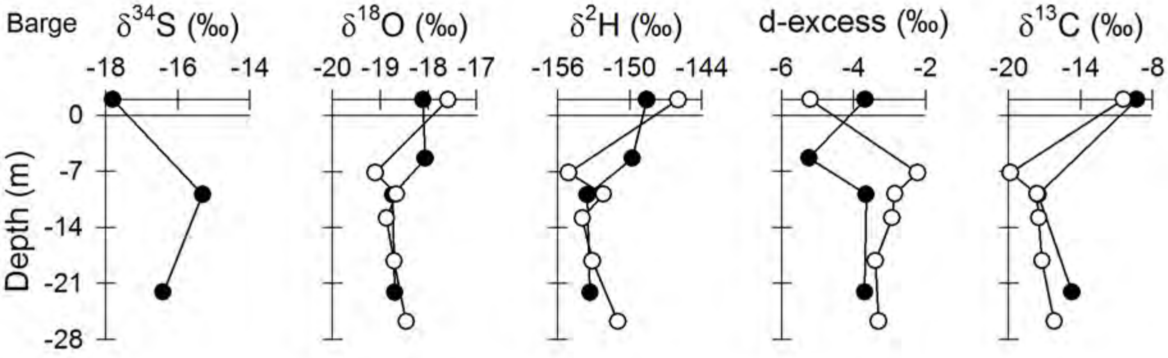

Gibbsite
$Al(OH)_2$
Amorphous
$Al(OH)_2$
Manganite
$MnO(OH)$
Tenorite
CuO
Ni Hydroxide
$Ni(OH)_2$
Zincite
ZnO
-8 -4 0 4
-8 -6 -4 -2 0
-16 -12 -8 -4 0
-8 -6 -4 -2 0
-8 -6 -4 -2 0
-10 -8 -6 -4 -2
Depth (m)
0.0 0.5 1.0 1.5 2.0

APPENDIX D

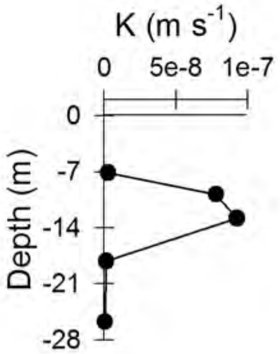
Plots of PKC stable isotopes (2010) for locations:

PKC1, PKC3, PKC-Pond, Barge, B2

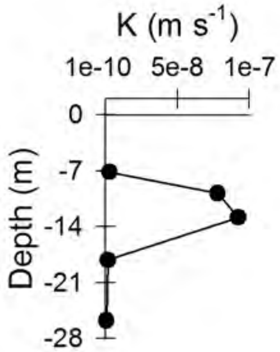

B2
δ18O (‰)
-20 -19 -18 -17
δ2H (‰)
-164 -154 -144
d-excess (‰)
-8 -5 -2
δ13C (‰)
-22 -15 -8
Depth (m)
0
-10
-20
-30



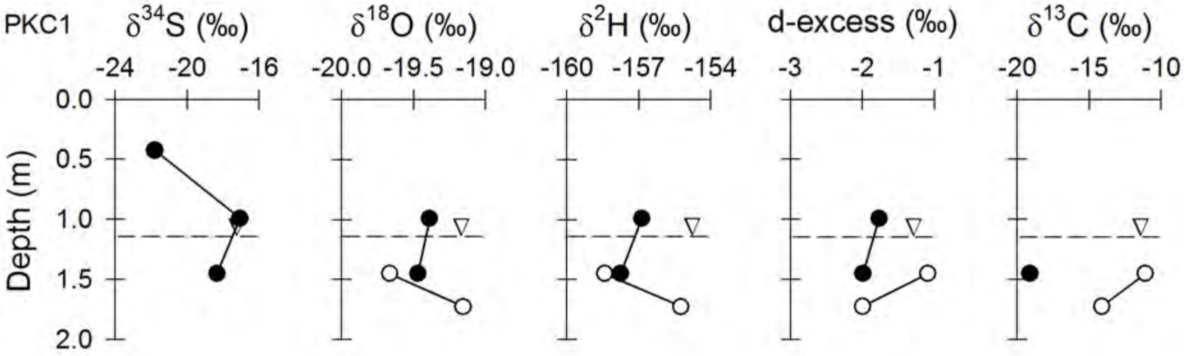
Barge
δ34S (‰)
-18
-16
-14
δ18O (‰)
-20
-19
-18
-17
δ2H (‰)
-156
-150
-144
d-excess (‰)
-6
-4
-2
δ13C (‰)
-20
-14
-8
Depth (m)
0
-7
-14
-21
-28

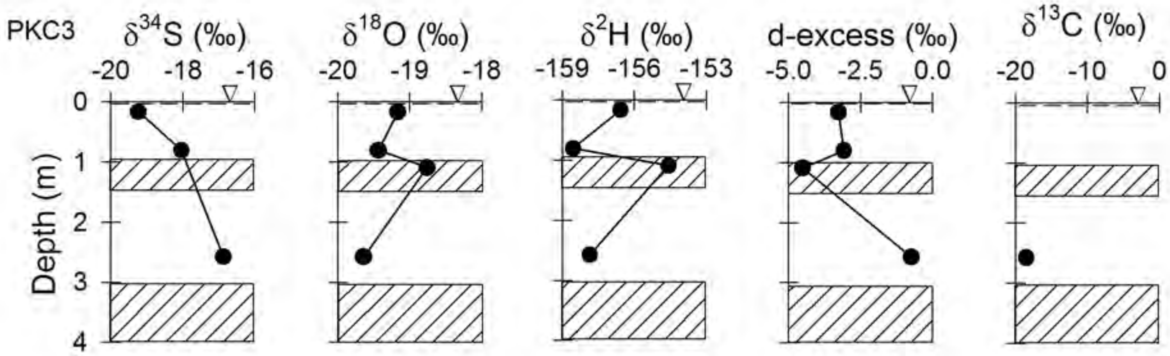


K (m s-1)
0
5e-8
1e-7
Depth (m)
0
-7
-14
-21
-28



K (m s-1)
1e-10
5e-8
1e-7
Depth (m)
0
-7
-14
-21
-28


PKC1
δ34S (‰)
-24
-20
-16
δ18O (‰)
-20.0
-19.5
-19.0
δ2H (‰)
-160
-157
-154
d-excess (‰)
-3
-2
-1
δ13C (‰)
-20
-15
-10
Depth (m)
0.0
0.5
1.0
1.5
2.0

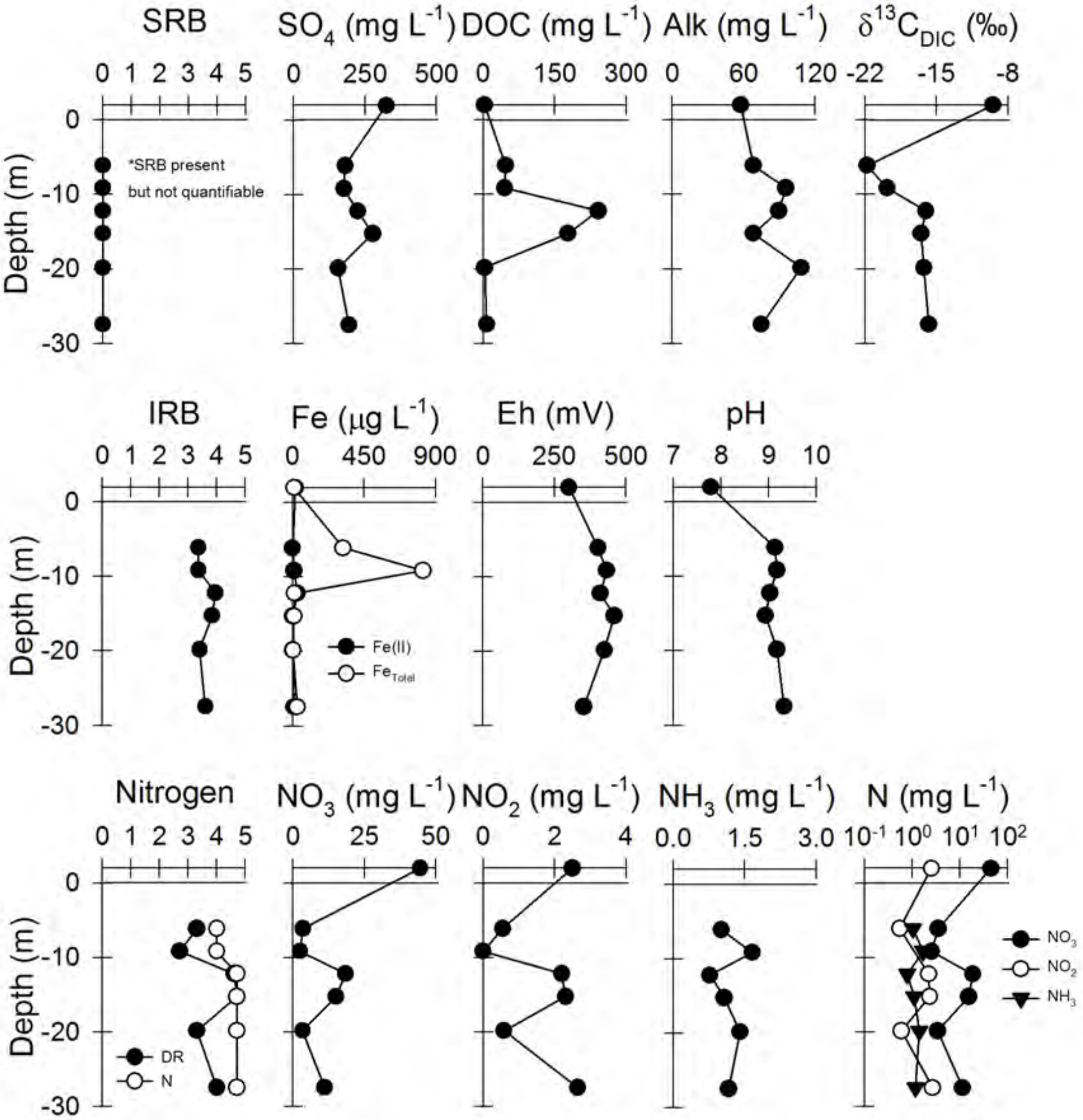

PKC3
δ34S (‰)
-20
-18
-16
δ18O (‰)
-20
-19
-18
δ2H (‰)
-159
-156
-153
d-excess (‰)
-5.0
-2.5
0.0
δ13C (‰)
-20
-10
0
0
1
2
3
4
Depth (m)

APPENDIX E

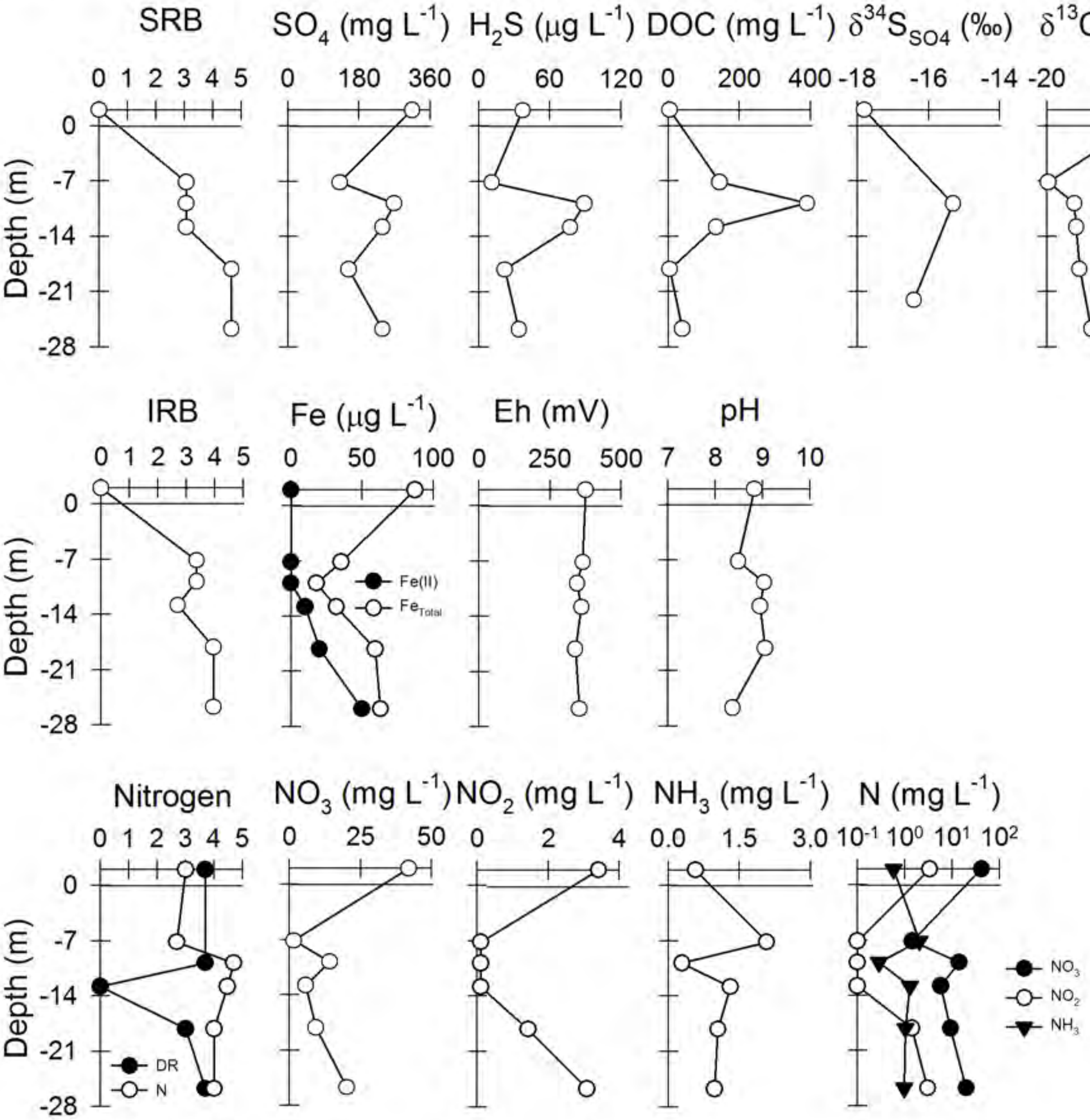
Plots of PKC microbiological populations (2010) for locations:

PKC1, PKC-Pond, Barge, B2

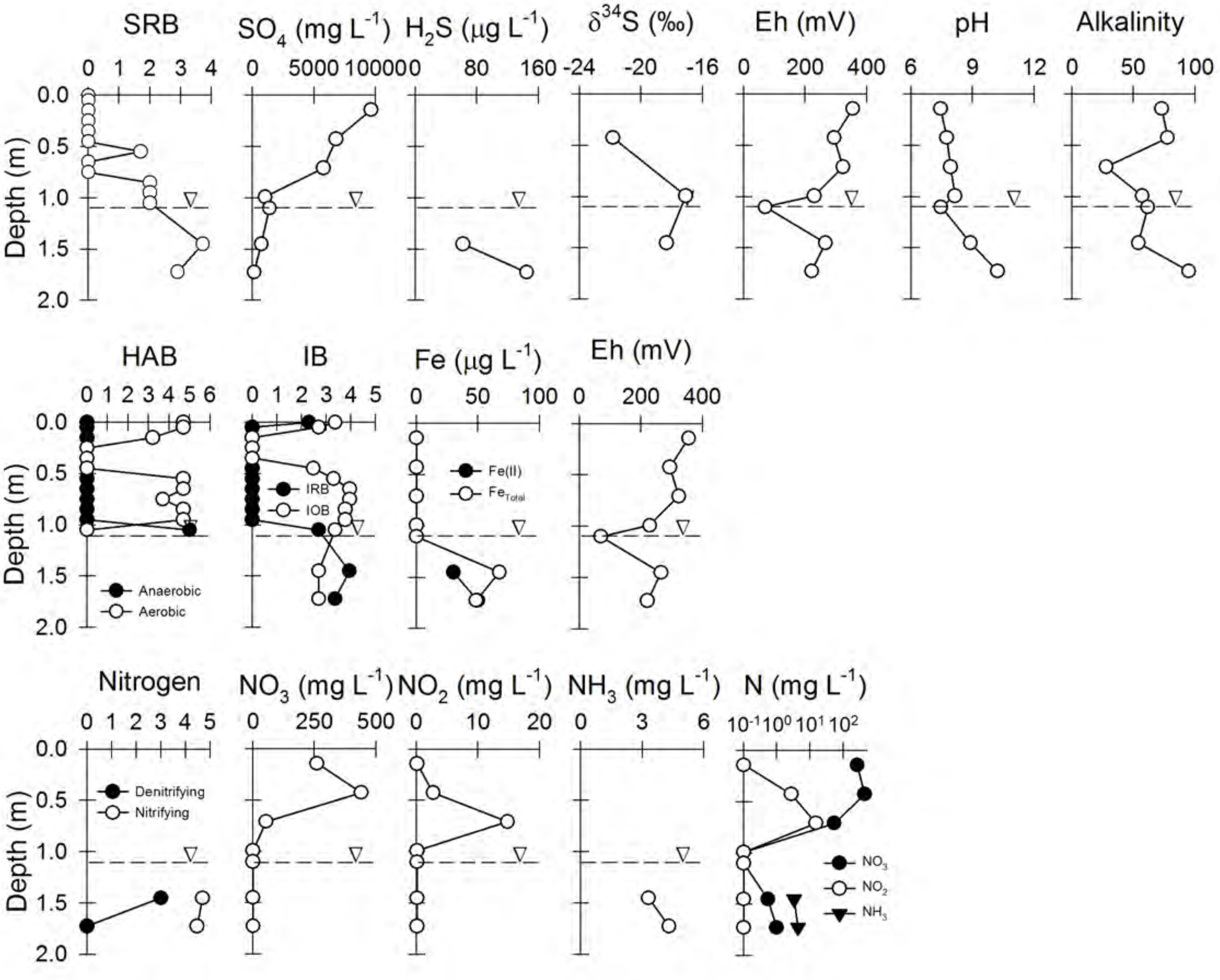
B2


SRB
SO4 (mg L-1)
DOC (mg L-1)
Alk (mg L-1)
δ13CDIC (‰)
0 1 2 3 4 5
0 250 500
0 150 300
0 60 120
-22 -15 -8
Depth (m)
0
-10
-20
-30
*SRB present
but not quantifiable
IRB
Fe (μg L-1)
Eh (mV)
pH
0 450 900
0 250 500
7 8 9 10
Fe(II)
FeTotal
Nitrogen
NO3 (mg L-1)
NO2 (mg L-1)
NH3 (mg L-1)
N (mg L-1)
0 25 50
0 2 4
0.0 1.5 3.0
10-1 100 101 102
DR
N
NO3
NO2
NH3

Off PKC Barge



PKC1


SRB
SO$_4$ (mg L^{-1})
H$_2$S (μg L^{-1})
δ^{34}S (‰)
Eh (mV)
pH
Alkalinity
HAB
IB
Fe (μg L^{-1})
Eh (mV)
Nitrogen
NO$_3$ (mg L^{-1})
NO$_2$ (mg L^{-1})
NH$_3$ (mg L^{-1})
N (mg L^{-1})
Depth (m)
0.0
0.5
1.0
1.5
2.0
0 1 2 3 4
0 5000 10000
0 80 160
-24 -20 -16
0 200 400
6 9 12
0 50 100
0 1 2 3 4 5 6
0 1 2 3 4 5
0 50 100
0 200 400
0 1 2 3 4 5
0 250 500
0 10 20
0 3 6
10^{-1} 10^{0} 10^{1} 10^{2}
Anaerobic
Aerobic
IRB
IOB
Fe(II)
Fe$_{Total}$
Denitrifying
Nitrifying
NO$_3$
NO$_2$
NH$_3$

Appendix II-8

Preliminary Assessment of Management Options for Hydrocarbon Contaminated Soils

January 18, 2011

DIAVIK - RISK-BASED APPROACH FOR MANAGING HYDROCARBON CONTAMINATED SOIL

Preliminary Assessment of Management Options for Hydrocarbon Contaminated Soils

Submitted to:
Diavik Diamond Mines Inc.
PO Box 2498
5007-50th Avenue
Yellowknife, NT
X1A 2P8

REPORT

Project Number: 10-1328-0028/6000
Doc. No.: 1021 Ver. 0
PO No.: D01487

Distribution:

2 Copies - Diavik Diamond Mines Inc.

2 Copies - Golder Associates Ltd.

A world of capabilities delivered locally

Golder Associates

Executive Summary

Golder Associates Ltd. (Golder) was retained by Diavik Diamond Mine Inc. (DDMI) to develop a strategy for risk-managing petroleum hydrocarbon (PHC) contaminated soil generated during operations at the Diavik Diamond Mine (the Site), located on East Island, a 17 square kilometre (km^2) island in Lac de Gras, NWT, approximately 300 kilometres (km) northeast of Yellowknife. This strategy was required in support of DDMI's Interim Closure and Reclamation Plan.

PHC-contaminated soils are generated during normal operations as a result of spills from heavy equipment and vehicles, primarily of diesel fuel and heavy hydraulic oils, and occasionally of antifreezes. DDMI's ongoing management of PHC contaminated materials includes land-farming[1] of the finer grained soils in the Waste Transfer Area and disposal of coarser materials (*e.g.,* blast rock, coarse gravel, and cobbles) in the Type III rock dump located in the country rock pile. It is our understanding that DDMI will continue with the land-farming of soils but wants to determine an appropriate long-term disposal option for the PHC-contaminated soils in one of three existing long-term waste disposal facilities: the Type III rock dump, the inert waste landfill, or the processed kimberlite containment facility. DDMI is also interested in optimizing the land-farming process.

The assessment focussed on the post-closure future land use of the Site, when it is expected that the Site will gradually recover to wildlands status and could be inhabited by wildlife and visited by humans.

The objectives of the study were to answer the following two questions:

1) Following mine closure, can PHC contaminated soil be left on Site in a manner that would be safe for human and ecological receptors?

2) Will some form of remediation/risk management be required to make this possible?

A risk-based approach was used to answer the above two questions. The first tier of the assessment, described herein, involved data gathering, development of a risk assessment problem formulation, and preliminary identification of risk management options for managing the contaminated soil.

The results of the problem formulation indicated that unrestricted disposal of PHC-contaminated soils may not be safe for people and ecological receptors following mine closure. Therefore, some form of remediation/risk management is required. The key exposure pathways driving potential risks included direct soil contact by plants and soil invertebrates; inhalation of soil vapour; sub-surface water[2] transport to Lac de Gras followed by consumption for drinking water (by humans); and, sub-surface water transport to Lac de Gras leading to direct exposure (by aquatic life). However, it was concluded that addressing these pathways through a combination of risk assessment and management could mitigate the potential for risk.

---

[1] Land-farming refers to the process where hydrocarbon contaminated soils are spread out over a surface layer of 0.3–1.0 m thick, nutrients are added, and the soils are mixed periodically, to stimulate volatilization and biodegradation and reduce petroleum hydrocarbon concentrations. Land-farming at the Site currently only includes soil spreading and mixing.

[2] In this report, "sub-surface water" refers to waters present seasonally in shallow, thermally active soils overlying permafrost. "Groundwater" is reserved for water present below permafrost or below Lac de Gras where permafrost is not present.

Preliminary management options were developed to address the key exposure pathways. The locations considered suitable for long-term management and disposal of the PHC-contaminated soils were: the Type III rock dump, the inert waste landfill, or the PKC. Following evaluation of these locations, it was determined that the driving exposure pathways for all three locations (*i.e.,* soil contact and vapour inhalation) could be mitigated through the depth of soil placement (*i.e.,* placement at surface vs depth). Therefore, the management options focused on evaluating three different depth placement scenarios:

- Option 1: Surface Placement (upper 1 m).
- Option 2: Subsurface/Active Zone Placement (depth >1 m but above permafrost).
- Option 3: Subsurface/Deep Placement (at depth where permafrost is expected to form and persist).

Overall, the evaluation indicated that Option 3 appeared to minimize exposure pathways and related uncertainty with respect to human health and ecological risks. Option 3 also represented current practices at the Site. With Options 1 and 2, operable exposure pathways remained, meaning that additional risk assessment and/or risk management would be necessary to determine the long-term safety of these options.

Best practices for spill response and land-farming of PHC-contaminated soil were also provided. Possible improvements to current land-farming practices for WTA soils include the addition of nutrients and moisture to the soils, and optimization of both the soil aeration frequency and nutrient addition ratios. It is recommended that the CWS-PHC management limits for free-phase formation be adopted as the upper limit treatment concentrations for land-farmed soil for CCME PHC fractions F1 through F4. If land-farming is highly successful (*i.e.,* greater reductions in concentration are achieved), then lower risk-based targets could be set to mitigate the risks associated with operable pathways under Options 1 or 2.

The current assessment is considered adequate for developing a preliminary understanding of potential management options for WTA soils. The need for further analysis, at this point, is dependent upon which options for long-term placement of WTA soils are deemed desirable for DDMI, taking into consideration potential risks associated with the pathways that are operable under each of the options.

Currently, Option 3 (subsurface-deep placement) appears to be the safest option for long-term disposal of PHC-soils. However, there may be other reasons (*e.g.,* economic or operational) why Options 1 or 2 might be more desirable. If these options are to be considered then one or more of the following issues may require further assessment:

- Review of uncertainties summarized in Section 5, and refinement of the risk assessment; and
- Effectiveness of best-practices for land-farming of WTA soils.

Study Limitations

This report was prepared for the exclusive use of Diavik Diamond Mine Inc. and is intended to provide a problem formulation and preliminary assessment of management options for petroleum hydrocarbon contaminated soils at Diavik Diamond Mine. These components are based on the available soil chemistry data and soil leachate chemistry data for petroleum contaminated soils from multiple locations at the Diavik Diamond Mine Site. Golder accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

The report is based on data and information collected and/or compiled by Golder Associates Ltd., as described in this report, as well as data collected and/or compiled by Diavik Diamond Mine Inc. It also relies on additional reports and information provided by Diavik Diamond Mine Inc. We have relied in good faith on information provided by Diavik Diamond Mine Inc. and by others, as noted. We assume that the information provided is factual and accurate. We accept no responsibility for any deficiency, misstatement or inaccuracy contained in this report as a result of omissions, misinterpretations or errors of the information sources consulted. Assessment has been made using the results of discrete chemical and analysis of samples from a limited number of locations. Additional study can reduce the inherent uncertainties associated with this type of study.

The services performed as described in this report were conducted in a manner consistent with the level of care and skill normally exercised by other members of the science professions currently practising under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

The content of this report is based on information collected during our investigation and Diavik Diamond Mine Inc.'s investigations, our present understanding of Site conditions, the assumptions stated in this report, and our professional judgement in light of such information at the time of this report. This report does not provide a legal opinion regarding compliance with applicable laws. With respect to regulatory compliance issues, it should be noted that regulatory statutes and the interpretation of regulatory statutes are subject to change.

The findings and conclusions of this report are valid only as of the date of the report. If new information is discovered in future work, or if the assumptions stated in this report are not met, Golder Associates Ltd. should be requested to re-evaluate the conclusions of this report, and to provide amendments as required.

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APPENDICES

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by Diavik Diamond Mine Inc. (DDMI) to develop a strategy for risk-managing petroleum hydrocarbon (PHC) contaminated soil generated during operations at the Diavik Diamond Mine (the Site), located on East Island, a 17 square kilometre (km^2) island in Lac de Gras, NWT, approximately 300 kilometres (km) northeast of Yellowknife. This strategy was required in support of DDMI's Interim Closure and Reclamation Plan (DDMI, 2009).

PHC-contaminated soils are generated during normal operations as a result of spills from heavy equipment and vehicles, primarily of diesel fuel and heavy hydraulic oils, and occasionally of antifreezes. DDMI's ongoing management of PHC contaminated materials includes land-farming[3] of the finer grained soils in the Waste Transfer Area (WTA) and disposal of coarser materials (*e.g.,* blast rock, coarse gravel, and cobbles) in the Type III rock dump located in the country rock pile. It is our understanding that DDMI will continue with the land-farming of soils but wants to determine an appropriate long-term disposal option for the PHC-contaminated soils in one of three existing long-term waste disposal facilities: the Type III rock dump, the inert waste landfill, or the processed kimberlite containment (PKC) facility. DDMI is also interested in optimizing the land-farming process. Hereafter, the PHC-contaminated soils are referred to as "WTA soils".

The assessment focussed on the post-closure future land use of the Site, when it is expected that the Site will gradually recover to wildlands status and could be inhabited by wildlife and visited by humans.

The objectives of the study are to answer the following two questions:

1) Following mine closure, can PHC contaminated soil be left on Site in a manner that would be safe for human and ecological receptors?

2) Will some form of remediation/risk management be required to make this possible?

A risk-based approach is being used to answer the above two questions. The first tier of the assessment, described herein, involved data gathering, development of a risk assessment problem formulation, and preliminary identification of risk management options for managing the contaminated soil. Depending on which risk management option is considered most appropriate by DDMI, further stages of risk assessment may be required to address operable exposure pathways for receptors under the future scenario. The preliminary identification of risk management options therefore includes an exposure pathway analysis to determine which exposure pathways would be operable under potential disposal options.

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[3] Land-farming refers to the process where hydrocarbon contaminated soils are spread out over a surface layer of 0.3–1.0 m thick, nutrients are added, and the soils are mixed periodically, to stimulate volatilization and biodegradation and reduce petroleum hydrocarbon concentrations. Land-farming at the Site currently only includes soil spreading and mixing.

2.0 BACKGROUND INFORMATION

This section provides a summary of the Site background information that is relevant to the problem formulation and potential management options for WTA soils. It includes consideration of Site operations, specific activities related to management of WTA soils, Site conditions (both abiotic and biotic), future land use, and applicable regulatory frameworks.

2.1 Review of Site Information

2.1.1 Information Sources

The following reports and data sources, provided by DDMI, were consulted for development of the problem formulation and preliminary evaluation of options:

- DDMI. 2010a. Hydrocarbon Impacted Soil at the Lower Type III Dump. Letter from Stephen Bourn of DDMI to Jennifer Potten, INAC. 31 August 2010.
- DDMI. 2010b. Closure of the Former Waste Transfer Area in the PKC, South Cell. Letter from Stephen Bourn of DDMI to Jennifer Potten, INAC. 28 August 2010.
- DDMI. 2009. Interim Closure and Reclamation Plan – Version 3.0. December 2009.
- DDMI. 1998. Integrated Environmental and Socio-Economic Baseline Report. Yellowknife, NWT. Diavik CD-ROM series.
- Rio Tinto. 2010. Diavik Diamond Mine - Aquatic Effects Monitoring Program 2009 Annual Report. Report prepared by Diavik Diamond Mine Health, Safety and Environment Department, Yellowknife, NT. March 31, 2010.
- Stephen Bourn, DDMI (personal communication).

Other sources have been cited where appropriate.

2.1.2 Overview of Mine Operations

The Diavik Project and Mine Plan are described in detail in DDMI (1998 and 2009). Only a brief overview is provided here. The Diavik Project is a diamond mine located on the East Island in Lac de Gras with open pits and their water retention dikes located just offshore in Lac de Gras. It is a large-scale mining/industrial facility that is almost entirely self-contained in terms of mining/processing, energy generation, waste management and water management. The facilities located on East Island include: a kimberlite processing and diamond recovery plant, accommodation building, mine maintenance shop, fuel storage, and mechanical and administration complex, hazardous wastes storage facility; waste transfer area (WTA) and inert landfill; and miscellaneous administration, storage, repair shops and laydown areas. Diesel-powered generators supply power for mine operations and an airstrip with helicopter pad and fuel storage are located on the northern portion of East Island. The project includes a water treatment plant for mine water as well as a sewage treatment plant with treated sewage outfall. Key features related to management of WTA soils are indicated on Figure 1 and described below.

Diamond mining at The Site involves the extraction of “country” rock[4] and kimberlite from two open pits with underground mining planned for the future. Kimberlite undergoes processing to extract diamonds and the processed kimberlite remaining after the diamonds have been removed is placed in an engineered containment structure in the centre of the island (the processed kimberlite containment, or PKC). Currently, the preferred option for long-term closure of the PKC is contouring of the PKC surface to facilitate water collection/drainage at the southeast corner, and covering of the stored processed kimberlite with waste rock (country rock of low acid generating potential).

Country rock (primarily granites) is classified as Type I, II or III based on the acid generating potential when it is mined (with Type III rock having the highest acid generating potential). It is then either used elsewhere at the Site (to build dykes, for road construction, as aggregate in underground backfill or concrete etc.) or directed to the appropriate location in the country rock pile, located in the central-west area of the Site. The Type III rock area of the country rock pile is located within specific underlying watersheds of East Island (to aid with seepage monitoring/control) and is designed such that the majority of the Type III rock will be frozen into the permafrost of the country rock pile.

An inert landfill[5] is located on the southwest corner of the country rock pile and receives domestic and facility wastes that are not contaminated and do not have dangerous or hazardous properties. The waste-transfer area (WTA) is west of the processing plant, accommodations and administration complex and includes a bermed and lined area where PHC-contaminated soils are undergoing land-farming (further detail is provided in the following section).

The open pit and underground mining, infrastructure construction, and extraction and hauling of kimberlite and country rock involves a wide range of diesel-powered heavy equipment, with associated maintenance activities and the potential hydraulic equipment failures and/or fuel spills. Fleet vehicles used across the mine site are also primarily powered by diesel fuel. Also, during the winter ice-road season, supplies and fuels are trucked to the Site.

2.1.3 Overview of Contaminated Soil Management

2.1.3.1 Sources of Contamination

The main source of PHC contamination in soils is spills and heavy equipment failures on the surface or in active mining areas. The types of PHC-containing materials that are used and stored at the Site include diesel fuel and heavy hydraulic oils with 90% of spills being hydraulic oil. Metals may also co-occur with PHCs in WTA soils (*i.e.,* from lubricating oils) and glycols, resulting from antifreeze spills may also be present in stockpiled soils.

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[4] Refers to the native granitic rock that must be excavated from the open pits and disposed of, in order to access the diamond-bearing kimberlite.

[5] Note that DDMI uses the term “inert waste landfill” to refer to the site where non-burnable wastes such as steel, concrete, wood, plastics and glass are placed for long-term disposal. This area does not receive domestic wastes.

2.1.3.2 *Current Management*

When spills or equipment failure occurs, efforts are made to prevent free-phase oil from entering soils and collect/remove visible oils from surface soils (*i.e.,* using drip pans and sorbents materials). In practice, when hydraulic equipment failures occur, hydraulic oils may be dispersed as a mist over wider areas, due to the pressurization in hydraulic equipment, making collection of free-phase oils challenging. Large boulders/rock that are coated with PHCs and too large to direct to the WTA are removed from the area and transferred directly to Type III rock area of the country rock pile. Surface soil and till with visible staining or other evidence of contamination is scraped from surface and transferred to the active WTA that is located in the southeast corner of the Site outside of the PKC Facility. The soil cell of the WTA is lined with geotextile overlain by coarse processed kimberlite (CPK) and surrounded by a berm. This cell in the WTA is used to landfarm (*i.e.,* spreading and turning during summer months) PHC contaminated soil that is generated across the Site. Land-farming is intended to facilitate volatilization of volatile PHCs and biodegradation of heavier PHCs that do not volatilize rapidly. Currently, approximately 400 m^3 of soils have been added to this area over the past 2 years and the area of active land-farming is approximately 30 m x 30 m with the depth of soil overlying CPK ranging from 0.13 to 0.75 m.

2.1.3.3 *Historical Management*

Prior to 2008, PHC-contaminated soils were directed to the former WTA that was located in the south cell of the PKC Facility. The former WTA was previously used to land-farm contaminated soil and also contained a burn pit, waste incinerator, waste oil storage, and hazardous waste storage. The portion of the former WTA used for land-farming was lined; however, the rest of the former WTA was not lined.

In preparation for closure of the former WTA, DDMI transferred the land-farmed material about 2 years ago to a temporary storage area located in the Type III country rock area. Prior to moving the land-farmed soils, samples of the land-farmed soil were collected and analyzed during summer 2008. Samples of the same material that was transferred from the former WTA to the Type III country rock area were again sampled in August 2010, although some of the soil had been inadvertently covered with country rock earlier that month. Based on the analytical results (refer to Appendix A), DDMI obtained approval to bury the material in the Type III rock pile.

2.1.4 Site Hydrogeology

The hydrogeology of the East Island and the surrounding tundra is governed to a large part by the dry climate (<400 mm annual precipitation in the Lac de Gras region) and the presence of permafrost at depths below 1-1.5 m that acts to reduce the movement of sub-surface water[6].

The hydraulic conductivity of the competent country rock is estimated to be approximately 5 x 10^{-8} m/s while weathered and fractured zones of the country rock are considerably more permeable, with hydraulic conductivities of approximately 1 x 10^{-5} m/s and 1 x 10^{-6} m/s, respectively. The hydraulic conductivity of the permafrost zone is very low (essentially zero). Some limited sub-surface flow occurs in warmer seasons through the thin (0.5 m to 1.5 m thick) active layer near the surface, but these flows are considered to be relatively small.

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[6] “Sub-surface water” refers to waters present seasonally in shallow, thermally active soils overlying permafrost. “Groundwater” is reserved for water present below permafrost or below Lac de Gras where permafrost is not present.

Waste rock at Diavik Mine consists of rock fragments ranging in size from silty sand to large boulders forming an unsaturated stockpile. Water may infiltrate this heterogeneous material and flow downward under thawed conditions at velocities of approximately <0.01 to 0.03 m/day in response to common rainfall and up to approximately 0.7 m/day in response to high-intensity rainfall, based on studies of test piles at Diavik (Neuner et al. 2009). Permafrost is assumed to have formed within central regions of the country rock pile (*i.e.,* where waste rock is disposed of) below a depth of approximately 5-10 m. Seepage collection ponds surround the country rock pile, which along with permafrost, provides a relatively impermeable barrier to seepage. Where seepage does occur, it is directed to the water management ponds on the Site (*i.e.,* Pond 3).

Processed kimberlite produced as a result of diamond extraction is primarily sandy material of varying grainsize. The permeability (k) is expected to be somewhere between that for the competent country rock (lowest k) and the waste rock pile (highest k). Permafrost is present in the PKC at depths of greater than 5 m. Similar to the waste rock pile, collection ponds surround the PKC, which along with permafrost, provides a relatively impermeable barrier to seepage. Where seepage does occur, it is directed to the water management ponds on the Site.

The development of permafrost in the material over time, as well as seepage containment measures limit the likelihood of sub-surface flow from country rock pile and the PKC to Lac de Gras.

2.1.5 Terrestrial Soils and Permafrost

Surface material in the vicinity of the Site consists of till and exposed bedrock with organic soils present only in depressions or crevices where organic material has accumulated. Maximum soil depths on the tundra are typically less than 0.5 m thick and up to 2.0 m where organic matter has accumulated. Glacial till is the dominant surficial material in undeveloped areas on the East Island, and overlies most of the bedrock. In developed areas within the mine footprint, the surface cover consists of till material, crushed waste rock and waste rock except in the PKC facility.

The seasonal active layer (*i.e.,* which thaws and freezes seasonally) in the vicinity of the mine site is about 1.5 m to 2.0 m deep in till deposits, 2.0 m to 3.0 m deep in well-drained granular deposits (eskers) and about 5 m in bedrock. In poorly drained areas including bogs, with thicker vegetation cover, the active layer is less than 1 m in depth. The depth of the seasonal thermal active zone in the country rock pile and the PKC is expected to be 5 m or greater.

2.1.6 Potential Future Human Use of Diavik Site

The Lac de Gras area falls within an area of overlapping Traditional Use between Dene/Metis and Inuit. Archaeological studies have found evidence of past human use of the area. In the Lac de Gras region, archaeologists have found quarries, artifact scatters and isolated artifact finds. On the East Island, primarily quarried veins of quartz and numerous quartz chip scatters were found. The area has and is currently used by the Tlicho, Yellowknives Dene First Nation, Lutsel K'e Dene First Nation, Inuit, North Slave Metis and others to hunt caribou, fish and trap for furs. Although not specifically documented, it is presumed that where fishing, hunting or trapping occurs in areas around Lac de Gras, collection/gathering of plant parts for food or other uses could also occur. Dene, Metis and Inuit are active participants and owners in the guiding and outfitting industry in and near the Lac de Gras and the level of participation might increase in the future.

Other human activity in the Lac de Gras area is largely confined to exploration, mining, outfitting and guiding related activities. Several outfitting operations conduct seasonal sport hunting, fishing and wildlife observation excursions within and around the Lac de Gras area. Sports hunting outfitters have camps located on the north east shore of Lac de Gras, and nearby on Contwoyto, Point, Courageous, Clinton-Colden, Desteffany, Jolly and MacKay lakes.

2.1.7 Terrestrial Ecology of Diavik Site

The Diavik Mine is located in the tundra biome of the central Canadian Arctic, in the transition zone between taiga and upper arctic tundra. The short growing season, with cool soil and subsoil temperatures limits soil development which in turn limits the establishment and productivity of plant communities. Vegetation cover is typical of the northern shrub tundra and includes dwarf birch, northern Labrador tea, blueberry and mountain cranberry species, with willow, sphagnum moss and sedge tussocks dominating wetter, low-lying areas.

Tundra ecosystems typically lack large-litter dwelling invertebrates which feed on fresh litter (*e.g.,* isopods, millipedes and earthworms) and dominant groups typically include Nematoda, Enchytraeidae (Annelida), Acari, Collembola and Diptera which feed on a combination of plant litter, humus and microbes (Bliss et al. 1981).

The presence of permafrost at depths as shallow as 1 m in natural tundra habitat and the small size of terrestrial vegetation (*e.g.,* primarily dwarf trees, shrubs and grasses) is expected to limit rooting depth. Studies of plant rooting depth in tundra ecosystems (as summarized in Canadell et al. 1996) indicate maximum rooting depths of 0.5 ± 0.1 m however, seasonal free thaw cycles could disturb surface soil layers resulting in biologically active depths that is somewhat deeper than 0.5 m. The 1 m depth is considered a conservative estimate of the depth of the biologically active zone.

The migratory range of the Bathurst caribou herd includes the Lac de Gras region and up to 100,000 caribou have been observed in the Lac de Gras region during spring migration, sometimes passing close to the Diavik Mine. Predators such as wolves follow the caribou migration and may den in the area in the summer. Mammals that reside in the area year-round are generally denning animals such as wolverines, grizzly bears, foxes (common near the Site), ground squirrels, lemmings, Arctic hare and ermine. Only two bird species (ptarmigan and raven) reside year round in the project area due to the scarcity of food during the long winter. However, many bird species migrate through the Lac de Gras area, seasonally.

2.1.8 Aquatic Ecology of Lac de Gras

Lac de Gras is the ultimate receiving environment for treated water (from the North Inlet Water Treatment Plant) sub-surface water, and seepage originating on the Site. Lac de Gras is an ultraoligotrophic lake (*i.e.,* very low productivity) as a result of relatively low concentrations of nutrients, low light levels during the winter months, extended periods of ice cover and low water temperatures. It supports an aquatic community typical of lakes in northern regions with only marginal growth of aquatic plants and most of the energy required by aquatic organisms in the lake coming from algal production. The broad functional groups that make up the ecological community include:

- Phytoplankton (predominantly green algae, golden algae and blue-green algae);

- Periphyton (broad organism assemblage composed of attached algae, bacteria, their secretions, detritus, and various species of microscopic invertebrates);
- Zooplankton (predominantly copepods, rotifers and cladocerans);
- Soft-bottom benthic invertebrate community (primarily chironomids, fingernail clams and infaunal worms);
- Demersal fish (such as burbot, longnose sucker and slimy sculpin); and
- Pelagic fish (such as lake trout, cisco, round whitefish, and arctic grayling).

No sentinel fish species have been observed in any of the streams originating from the East Island. This is likely due to the ephemeral nature of the streams on the island. Even during spring melt, the flow in streams of the East Island is dispersed through sedge meadows with no distinct channel.

2.2 Future Land Use

It is expected that, following closure of the Diavik Mine, the Site and surrounding lands will undergo reclamation and gradually revert to wildlands status. The Soil Guideline Derivation Protocol (CCME, 2007) does not include a wildlands land use category, but it does propose guidelines for agricultural land use that would be relevant to a wildlands ecosystem. In particular, the agricultural land use category "*includes agricultural land providing habitat for resident and transitory wildlife as well as native flora, as well as farm residences*" (CCME, 2007). Although the Site and surrounding lands would not support farming, they are likely to provide habitat for resident and migratory game, as well as native plant species, all of which could support hunting, trapping and gathering activities of local Aboriginal people. The use of the surrounding tundra as natural range-land by the Bathurst caribou herd is also consistent with an agricultural land use.

Although considered highly unlikely, it has been assumed that buildings and/or residences could be present on-site in the future, in the locations where WTA soils may have been placed for long term disposal. The rationale for including residences is based on the goal that long-term risk management of WTA soils post-closure should not place limits on the future land use of the Site. The most likely future use of the Site is assumed to be by Aboriginal people, who would visit the Site for hunting, trapping and gathering of country foods, as well as guiding tours.

2.3 Applicable Regulatory Frameworks

Closure criteria have been proposed as part of DDMI's Interim Closure and Reclamation Plan (DDMI, 2009). The closure criteria that are relevant to WTA soils include:

- CCME Guidelines for Contaminated Site Remediation (*i.e.,* Canadian Environmental Quality Guidelines [CEQGs] for Soil and Canada-Wide Standards for Petroleum Hydrocarbons [CWS-PHCs] in Soil), combined with risk-based criteria; and
- Closure water quality criteria for the protection of drinking water and the protection of aquatic life in Lac de Gras in the event of contaminants leaching from WTA soils and migrating into Lac de Gras.

The CEQGs and CWS-PHCs for soil have been developed according to the Summary of a Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines (CCME, 2007) and include distinct guidelines for a variety of human-health and ecological exposure pathways. The guidelines based on Agricultural land use have been applied at this preliminary stage. In addition, for screening purposes, it was assumed that all of the agricultural guidelines (*i.e.,* for all activities/pathways under Agricultural land use), could possibly apply for the future use of the Site.

Underlying these guidelines and standards are multiple conservative assumptions to make them protective for all sites in Canada under a range of plausible conditions. The Site represents unique conditions and receptors that were not considered explicitly in the guideline development process. Therefore there is some uncertainty as the applicability of the generic guidelines (*i.e.,* the local species the Site could be more sensitive than those used to derive the guidelines). However, given that the guidelines are based on several conservative assumptions to account for these types of uncertainty, they were considered appropriate to use a first preliminary screen to identify the operable exposure pathways for WTA soils.

In addition to standards for various human-health and ecological pathways, the CWS-PHCs also stipulates “management limits” for petroleum hydrocarbons, based on the following considerations: free phase formation; exposure of workers in trenches to PHC vapours; fire and explosive hazards; effects on buried infrastructure; technological factors - bioremediation effectiveness; and, aesthetic considerations (generally addressed by other management limits). Of these, free phase formation is the only management limit relevant to long-term risk management of WTA soils at the Site. Neither buried infrastructure nor underground utilities (applicable for fire and explosive hazards) will be present in the possible disposal areas for WTA soils, and future trenching in these areas is considered unlikely. Bioremediation effectiveness is not related to the potential risks of PHCs in soils, but could affect best practices for land-farming of WTA soils.

The closure water quality criteria for Lac de Gras for the protection of aquatic life are generally consistent with the CEQGs for Aquatic Life and the closure criteria for protection of drinking water are generally consistent with the Canadian Drinking Water Guidelines (CDWGs).

3.0 PROBLEM FORMULATION

The main objective of this study was to identify whether some form of remediation/risk management is required to manage PHC contaminated soil at the Site, following closure. Therefore, as a starting point, to assess whether management of PHC contaminated soils is necessary, the problem formulation focussed on assessing the unrestricted disposal (*i.e.,* disposal at surface) of WTA soils at any of the three long-term waste disposal facilities (*i.e.,* the Type III rock dump, the inert waste landfill, or the PKC) based on a future post closure scenario.

The problem formulation phase is a planning and screening process that defines the feasibility, scope, and objectives for the risk assessment. This process includes examination of the available data, considers site-specific factors that will influence how the risk assessment is implemented and helps focus any subsequent investigations and analysis on the key issues that require resolution. Problem formulations typically include the following standardized components:

- Review of the available site information;
- Selection of appropriate receptors;
- Exposure pathway pathways screening;
- Identification of contaminants of potential concern (COPCs);
- Articulation of assessment and measurement endpoints; and
- Development of a conceptual site model.

The review of available Site information has been conducted in the preceding section; the remaining components are discussed below. Note that problem formulation is an iterative, rather than linear process. Thus, specific steps have been conducted in concert with, and are reliant on one another (for example, identification of COPCs was reliant on pathway screening and vice versa).

3.1 Receptor Selection

This section describes the human and ecological receptors that are assumed to use the Site following closure.

3.1.1 Human Receptors

The Site falls within the traditional lands of the Dene, Metis and Inuit who may hunt caribou, fish, trap for furs and gather plants in the region. Several outfitting operations also conduct seasonal sport hunting, fishing and wildlife observation excursions in region. Thus, it is expected that both adults and children could be present at the Site in the future on a permanent or temporary basis.

As discussed in Section 2.2, this assessment also addresses the unlikely scenario where temporary or permanent buildings are established in areas where PHC-contaminated soil is placed. The rationale for including potential future occupied buildings is based on the principle that long-term risk management of WTA soils post-closure should not place limits on the future land use of the Site. Based on these considerations, the human receptors under future use of the Site include adults and children of all ages.

3.1.2 Ecological Receptors

3.1.2.1 Terrestrial

The tundra biome surrounding the Site supports a limited shrub plant community and soil invertebrate community. Productivity is limited by the low nutrient content of soils, short growing season and cool temperatures. Caribou (Bathurst herd) are a keystone species of the tundra biome that migrate close to the Site, and large predators such as wolves may be attracted by their presence. Grizzly bears, foxes, wolverines and smaller mammal species, such as ground squirrels, lemmings, Arctic hare and ermine, may be resident year-round as may be raven and ptarmigan. Many bird species migrate through the Lac de Gras area, seasonally. For this preliminary stage, this range of terrestrial organisms has been grouped into relatively simple terrestrial receptors groups including:

- Microbes responsible for nutrient cycling;
- Soil invertebrates and plants;
- Wildlife, including caribou; and
- Birds, such as ptarmigan and raven.

If necessary, these receptors groups may be refined at later stages to address specific exposure pathways and species sensitivities associated with specific management options for WTA soils.

3.1.2.2 Aquatic

Lac de Gras supports a relatively low productivity aquatic community which includes plankton (phytoplankton and zooplankton), periphyton and aquatic plants, aquatic benthic invertebrates, demersal fish, and pelagic fish. For this preliminary stage, these functional groups have been grouped into relatively simple aquatic receptors groups including:

- Lake productivity (phytoplankton, zooplankton, periphyton and plant populations);
- Aquatic invertebrates (aquatic insect larvae and resident benthic invertebrates); and
- Fish (both demersal and pelagic species).

If necessary, these receptors groups may be refined at later stages to address specific exposure pathways and species sensitivities associated with specific management options for WTA soils.

3.2 Contaminant and Exposure Pathway Screening

This section evaluates the available soil data for the former and active WTA to determine the contaminants of potential concern (COPCs). The evaluation of COPCs focuses on the WTA soils as it is our understanding that following a spill/leak, the finer grained PHC-contaminated soil is transferred here. Therefore, concentrations measured in soil from the former and active WTA are considered representative of PHC-contaminated soils that would be generated during mine operations.

As part of the screening process, it is also necessary to consider which possible exposure pathways are considered relevant to contaminants present in WTA soils. Thus, the COPC screening process also includes discussion of the exposure pathways relevant to receptors and describes the applicable pathway specific guidelines and standards which have been applied for each pathway.

A final section also describes the pathways that can be screened outdue to a lack of COPCs for this pathway, or a lack of concern for the pathway based on contaminant behaviour.

3.2.1 Soil Investigations

Three investigations have been conducted on WTA soils and include:

- An August 2008 investigation by DDMI in the former WTA land-farming area (described in DDMI 2010b);
- A July 2010 investigation by DDMI of soils from the former WTA land-farming area that had been transferred to the Type III area of the country rock pile (DDMI, 2010a); and
- An August 2010 investigation by Golder in the current WTA land-farming cell (refer to Appendix B for sampling methods and field notes/observations).

Table 1 provides an overview of the investigations that have been conducted for WTA soils, including the number of samples collected and the analyses conducted. Note that PCBs were not considered a concern for WTA soils because of the relatively young age of the Diavik Mine (*i.e.,* mine construction initiated in 2001), and ongoing phase-out of PCBs since the late 1970s; therefore, the hydraulic oils used for heavy equipment at the Site are unlikely to contain PCBs.

The available data include soil analytical results from all three of the above investigations, as well as leachate data for selected samples from the 2010 Golder investigation.

Table 1: Summary of WTA Soil Investigations

Date	Sampling by	Location	Number of Samples	Analyses
August 2008	DDMI	Former WTA	6	CCME F1-F4, metals, glycols, PAHs, and BTEX in bulk soil.
July 2010	DDMI	Type III Rock Dump	4	CCME F1-F4, metals, glycols, and BTEX in bulk soil.
September 2010	Golder	Active WTA	11	CCME F1-F4, metals, glycols, PAHs and VOCs (including BTEX) in bulk soil. CCME F2-F4, metals and PAHs in soil leachate.

3.2.2 Screening of Soil Sampling Results

3.2.2.1 Approach

The screening of soils data involved comparison of WTA soil contaminant concentrations to the CEQGs or CWS-PHCs that are most relevant to the potential exposure pathways that may be present for the soils. As an initial step, the soil data were compared to the lowest applicable CEQG or CWS-PHC, for a given contaminant, to identify which contaminants might be COPCs. These contaminants were then further evaluated by comparison to the remaining relevant guidelines/standards, as well as consideration of the leachate data, where applicable. As discussed in Section 2.3, it is acknowledged that there is some uncertainty as to the direct applicability of these guidelines and standards to a northern-latitude site. However, given the multiple conservative assumptions made for guideline/standard development, they were considered adequately protective for Site receptors.

The potential pathways and relevant soil guidelines and standards for human receptors include:

- Direct contact with, or ingestion of, soil (represented by guidelines/standards for *direct contact [ingestion/dermal]*);
- Inhalation of soil vapour in indoor or outdoor air (represented by guidelines/standards for *vapour inhalation [indoor, basement] and vapour inhalation [indoor, slab on grade]*);
- Consumption of Lac de Gras water as drinking water (represented by guidelines/standards for *protection of potable groundwater*); and
- Consumption of country foods including wild game and plants (represented by guidelines/standards for *produce, meat and milk*).

Note that CEQGs and CWS-PHCs for *produce, meat and milk* were adopted to represent the country foods pathway, which involves human consumption of local plants or wildlife that may have been impacted by contaminated soil. However, CEQGs and CWS-PHCs protective of this pathway have not been developed for the contaminants mostly likely to be of concern in WTA soils (*i.e.,* PHCs) and do not apply to metals. In general, the contaminants associated with diesel, hydraulic oils and antifreezes are not expected to be highly bioaccumulative. CCME (2008) indicates that PHC are not readily absorbed into or accumulated in plants and are readily metabolized in vertebrates and not anticipated to bioaccumulate. Given that the contaminants associated with WTA soils are not considered bioaccumulative, this pathway was considered a minor exposure pathway compared to the other exposure pathways.

At this stage, selection of vapour COPCs was based on the indoor exposure pathway, which, due to lesser attenuation between soil vapour and indoor air, is more conservative than the outdoor pathway (*i.e.,* substances are more likely to be of concern for indoor air than for outdoor air). It is recognized that the guidelines/standards for the indoor vapour pathway were generated based on typical building characteristics (slab on grade or basement) which allow for infiltration of soil vapours. However, this may not applicable to the potential residences/temporary housing options that may occur at the Site in the future, as buildings in permafrost areas often have special foundations to minimize impact on the permafrost in the underlying soil. However, as these guidelines were considered conservative, they were used for the problem formulation. If necessary, in later stages of the risk assessment the indoor inhalation pathway could be further examined (*e.g.,* through modelling). Given the greater attenuation available for vapours moving into outdoor air, the potential for unacceptable risk associated with the outdoor inhalation pathway is considered unlikely; and therefore, the outdoor inhalation of vapours is considered a minor exposure pathway.

For PAHs, screening for carcinogenic risks to humans and environmental health was conducted according to CCME (2010). Where the concentrations were below the detection limit, 0.5xMDL was used for the calculations. The current guidance (CCME, 2010) indicates that non-carcinogenic human health effects of PAHs in soil should be assessed using benchmarks from "other jurisdictions". Therefore, the US EPA Regional Screening Levels (residential sites; US EPA, 2010) were applied for this purpose.

The potential pathways and relevant soil guidelines and standards for terrestrial ecological receptors include:

- Ingestion of Lac de Gras water or other surface water by wildlife and birds that could have been impacted by contaminated sub-surface water (represented by guidelines/standards for *protection of groundwater for livestock watering)*;
- Incidental ingestion of soil by wildlife and birds (represented by guidelines/standards for *eco soil ingestion)*;
- Direct soil contact by plants and invertebrates (represented by guidelines/standards for *eco soil contact)*;
- Direct contact with soil by microbes responsible for nutrient cycling (represented by guidelines/standards for *nutrient cycling)*; and
- Ingestion of plants and prey by wildlife and birds (no direct guidelines/standards).

As indicated above, there are no CEQGs and CWS-PHCs protective of the potential food chain transfer of contaminants to higher trophic levels (*i.e.,* ingestion of plants and prey by wildlife and birds). However, the contaminants associated with diesel, hydraulic oils and antifreezes are not expected to be highly bioaccumulative in animals. CCME (2008) indicates that PHC are not readily absorbed into or accumulated in plants and are readily metabolized in vertebrates and not anticipated to bioaccumulate. Given that the contaminants associated with WTA soils are not considered bioaccumulative, this pathway was considered a minor exposure pathway compared to the other exposure pathways.

The guidelines and standards for *protection of groundwater for livestock* watering are intended to apply for groundwater or sub-surface water used directly for livestock watering rather than groundwater or sub-surface water flow to surface water consumed by livestock or wildlife (*i.e.,* where significant dilution would occur prior to consumption). Therefore, use of these standards and guidelines for the water ingestion pathway is considered highly conservative.

The potential pathways and relevant soil guidelines and standards for aquatic ecological receptors include:

- Sub-surface water transport to Lac de Gras, leading to direct exposure for aquatic life (represented by guidelines/standards for *protection of groundwater for aquatic life).*

Note that where soil contaminant concentrations exceeded a guideline relevant to possible leaching to groundwater or sub-surface water (primarily the aquatic life and drinking water pathways), then the leachate data were also considered, and generally took precedence (*e.g.,* fluorene and phenanthrene concentrations in soil exceeded soil guidelines/standards for aquatic life, but they were excluded as COPCs because they were not detected in leachate). Where soil guidelines for aquatic life and drinking water pathways were not available for a particular parameter, then screening for COPCs relied on the leachate data.

3.2.2.2 Results

The soil data from all three investigations were pooled to provide a representation of the possible range of conditions of WTA soils that are currently being land-farmed or may be in the future. Maximum concentrations observed in the pooled data were screened versus the CWS-PHCs and the CEQGs for soil to identify COPCs.

The results of the soil screening is presented in Appendix A. Table 2 lists the contaminants that exceeded and provides additional detail of the guidelines/standards that were exceeded, relevant to the specific pathways identified above. Contaminants that exceeded included F1, F2, F3, F4, chromium, copper, nickel, fluorene, phenanthrene, ethylbenzene, and xylenes (total).

The highest magnitude of exceedance of the guidelines and standards was observed for F1 (compared to the vapour inhalation standard), F2 (compared to vapour inhalation and eco soil contact standards), F3 (compared to the eco soil contact standards) and ethylbenzene (compared to the protection of potable groundwater guideline). The highest frequencies of exceedance of the guidelines and standards were observed for F2 (17 of 20 samples exceeding) and F3 (all samples exceeding).

CCME F1 to F4 petroleum hydrocarbon fractions were also compared to the management limits for free phase formation in Appendix A. For three samples in the pooled data set, the total of F1-F3 fractions exceeded the management limit (1% or 10,000 mg/kg) indicating that free phase formation could be a concern for WTA soils.

For CCME F3 fraction, the management limits for technological factors-bioremediation effectiveness (2,500 mg/kg in coarse soils) was exceeded in 4 samples indicating that the presence of these levels of F3 fraction might influence the land-farming effectiveness for WTA soils. The exceedance of this management limit only affects the management and treatment of WTA soils as opposed to potential risks associated with WTA soils. The management and treatment of WTA soils is considered further in Section 4.3.

The guideline for index of additive cancer risk (IACR) for protection of potable water was exceeded for one sample (B3). However, of the carcinogenic PAHs, only chrysene was detected in this sample (0.04 mg/kg) and the estimated IACR is determined primarily by the detection limits which were higher in this sample than for other samples of WTA soils. Carcinogenic PAHs are considered further using soil leachate testing results in the following section.

3.2.3 Screening of Soil Leachate Testing Results

3.2.3.1 Approach

The leachate data from the Golder 2010 investigation were evaluated to further examine potential exposure pathways related to sub-surface water mobilization and transport of soil contaminants. Screening and identification of COPCs in leachate involved a presence/absence approach based on whether analytes were detected in the leachate samples. There are no standards or guidelines that were considered appropriate for screening. The drinking water and aquatic life pathways are considered relevant for surface waters of Lac de Gras, but the degree of dilution as sub-surface water transitions to Lac de Gras surface water is currently unknown. Retention of detected parameters in leachate as COPCs, rather than screening with environmental quality guidelines, was considered a conservative approach because the presence of an organic or metal parameter in the leachate does not necessarily mean it would exceed toxicity thresholds for aquatic life or humans in drinking water or surface water.

3.2.3.2 Results

The leachate results are presented in Appendix A. Further evaluation of potential pathways relevant to leaching (aquatic life and drinking water) yielded the following conclusions:

- Fluorene and phenanthrene concentrations in soil exceeded guidelines/standards for aquatic life, but they were excluded as COPCs because they were not detected in leachate.
- None of the carcinogenic PAHs were detected in leachate, and were therefore, excluded as COPCs.
- Multiple metals were detected in leachate and these metals were conservatively retained as COPCs for the drinking water and aquatic life pathways.

Table 2: Summary of Soil Parameters that Exceeded Agricultural CCME Soil Quality Guidelines or Canada-Wide Standards for Petroleum Hydrocarbons

Contaminant	Range (mg/kg)	# Samples Exceeding Minimum Agricultural Guideline	Limiting Guideline	Other Guidelines Exceeded
F1 (C6-C10) (including or excluding BTEX)	<10 - 310	6[1] / 15	Vapour Inhalation (indoor, slab-on-grade; 30 mg/kg)	Vapour Inhalation (indoor, basement; 40 mg/kg), Protection of Potable GW (240 mg/kg), Eco Soil Contact (210 mg/kg)
F2 (C10-C16 Hydrocarbons)	59 - 3800	18 / 21	Vapour Inhalation (indoor, slab-on-grade; 150 mg/kg); Eco Soil Contact (150 mg/kg)	Vapour Inhalation (indoor, basement; 190 mg/kg)); Protection of Potable GW (320 mg/kg); Protection of GW for Aquatic Life (600 mg/kg [surface soils]; 380 mg/kg [subsurface soils])
F3 (C16-C34 Hydrocarbons)	810 - 42000	21 / 21	Eco Soil Contact (300 mg/kg)	Direct Contact (Ingestion/Dermal Contact)
F4 (C34-C50 Hydrocarbons)	150 - 9600	5 / 21	Eco Soil Contact (2800 mg/kg)	none
Chromium (Cr)	22 - 146	1 / 6	Nutrient Cycling (52 mg/kg)	Eco Soil Contact (64 mg/kg)
Copper (Cu)	10 - 66.5	1 / 6	Eco Soil Contact (63 mg/kg)	none
Nickel (Ni)	26.2 - 338	3 / 6	Eco Soil Contact (50 mg/kg)	Nutrient Cycling (146 mg/kg)
Fluorene	0.03 - 0.41	1 / 5	Protection of GW for Aquatic Life (0.25 mg/kg)	none
Phenanthrene	<0.01 - 0.53	1 / 5	Protection of GW for Aquatic Life (0.046 mg/kg)	none
Carcinogenic PAH (IACR)	0.1 – 1.48	1 / 5	Protection of Potable GW (1.0)	none
Ethylbenzene	<0.01 - 1.1	4 / 15	Protection of Potable GW (0.082 mg/kg)	none
Xylene (Total)	<0.02 - 22	1 / 15	Protection of Potable GW (11 mg/kg)	Vapour Inhalation (indoor, slab-on-grade; 14 mg/kg))

Note: 1 - one detection limit exceeded.

3.2.4 Identification of COPCs

Integration of the soil and leachate data screening yields the following COPCs for each of the receptor groups:

- Human Receptors
  - COPCs include:
    - CCME (petroleum hydrocarbon fractions) F1, F2, F3
    - Ethylbenzene, xylenes (total)
    - Leachable metals[7]
  - The driving pathways and associated COPCs for human health include: inhalation of soil vapour (F1 and F2), consumption of Lac de Gras water as drinking water (ethylbenzene, xylene (total), leachable metals), and direct contact with, or ingestion of, soil (F3).
- Terrestrial Receptors
  - COPCs include:
    - CCME (petroleum hydrocarbon fractions) F1, F2, F3, F4
    - Cr, Cu, Ni
  - The driving pathways and associated COPCs for terrestrial receptors include: direct soil contact by plants and invertebrates (F1, F2, F3, F4, Cu, and Ni) and direct soil contact by microbes responsible for nutrient cycling (Cr).
- Aquatic Life Receptors
  - COPCs include:
    - CCME (petroleum hydrocarbon fraction) F2
    - Leachable metals
  - The driving pathway for aquatic life receptors is sub-surface water transport to Lac de Gras, leading to direct exposure for aquatic life.

3.2.5 Identification of Exposure Pathways

Based on the COPCs retained and the receptors present at the Site, the following exposure pathways were retained:

- Human Receptors
  - Direct contact with, or ingestion of, soil.

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[7] Metals detected in leachate included Al, Sb, As, Cd, Cr, Co, Cu, Fe, Pb, Mn, Mo, Ni, U and Zn.

  - Inhalation of soil vapour.
  - Consumption of Lac de Gras water as drinking water.
- Terrestrial Receptors
  - Direct soil contact by plants and invertebrates.
  - Direct contact with soil by microbes responsible for nutrient cycling.
- Aquatic Receptors
  - Sub-surface water transport to Lac de Gras, leading to direct exposure for aquatic life.

Note that the pathways identified above represent the primary exposure pathways that might be operable, in the absence of risk management measures for WTA soils. Control/limitation of specific pathways under various risk management options is discussed later in Section 4.2.

The following pathways were considered minor pathways because the COPCs identified in WTA soils are not considered bioaccumulative (refer to discussion in Section 3.2.2):

- Consumption of country foods for human health; and
- Ingestion of plants and prey by birds and wildlife.

The following exposure pathways were not retained as concentrations of contaminants did not exceed the applicable pathway specific guidelines/standards:

- Incidental ingestion of soil by wildlife and birds; and
- Ingestion of Lac de Gras water or other surface water by caribou and other birds and wildlife.

3.3 Integration of Problem Formulation Findings

3.3.1 Conceptual Site Model

The conceptual site model (CSM) is depicted in tabular form in Table 4 and graphically in Figure 2. The CSM integrates receptors, COPCs and relevant exposure pathways that have been retained for WTA soils. At this stage, the CSM represents the potential exposure scenarios that would be operable post closure, assuming unrestricted disposal (*i.e.,* disposal at surface) of WTA soils at any of the three long-term waste disposal facilities.

Table 3: Summary of Receptors, Exposure Pathways and Contaminants of Potential Concern (COPCs)

Receptor Groups	Specific Receptors	Operable Exposure Pathways	COPCs
Human	Aboriginal and non-aboriginal users (including adults and children)	Inhalation of soil vapour	F1, F2, xylenes
		Consumption of Lac de Gras water as drinking water	F1, F2, xylenes, ethylbenzene, leachable metals
		Direct contact with, or ingestion of, soil	F3
		Consumption of country foods	None determined at this stage
Terrestrial	Microbes, soil invertebrates and plants	Direct contact	F1, F2, F3, F4, Cr, Cu, Ni
	Wildlife and birds	Ingestion of plants and prey items	None determined at this stage
Aquatic	Aquatic invertebrates and plants, and fish	Sub-surface water transport to Lac de Gras leading to direct exposure	F2, leachable metals

Based on the number of COPCs and the magnitude and frequency of the exceedances, the key exposure pathways that appears to be the driver in terms of exposure and potential for risk include

- Direct soil contact by plants and soil invertebrates (only considered operable if contamination is present in the upper biologically active zone (upper 1 m; refer to Section 2.1.7);
- Inhalation of soil vapour;
- Consumption of Lac de Gras water as drinking water (by humans); and
- Sub-surface water transport to Lac de Gras leading to direct exposure (by aquatic life).

Aside from the direct soil contact pathway, the above pathways are potentially operable regardless of depth with respect to the biologically active zone. However, there may be mitigating factors that limit the degree of exposure and resulting risk via these pathways, including:

- Freezing of WTA soils into permafrost (would limit all pathways);
- Distance from Lac de Gras and control management of seepage from disposal sites (may limit drinking water and aquatic life pathways); and
- Site-specific conditions such as permafrost and building design considerations (may limit soil vapour pathways).

Overall, the results of the problem formulation indicate that unrestricted disposal of PHC contaminated soils may not be safe for people and ecological receptors following mine closure. Therefore, some form of remediation/risk management is required. Addressing the key exposure pathways identified above, through a combination of risk assessment and management (especially considering the above mitigating factors), can mitigate the potential for risk and will also address the other exposure pathways shown in Table 4 and Figure 2.

4.0 PRELIMINARY DEVELOPMENT OF MANAGEMENT OPTIONS

This section is intended to support preliminary decision making regarding management and disposal of WTA soils. The proposed options are preliminary at this point and based on the findings of the problem formulation. Best practices for spill response and land-farming of PHC-contaminated soil are also provided.

As stated in Section 1, the preliminary assessment of management options focussed on the post-closure future land use of the Site, when it is expected that the Site will gradually recover to wildlands status and could be inhabited by wildlife and visited by humans. The two questions we set out to answer were:

1) Following mine closure, can PHC contaminated soil be left on Site in a manner that would be safe for human and ecological receptors?

2) Will some form of remediation/risk management be required to make this possible?

At this stage, Question 1 has been answered based on the problem formulation for the current condition of WTA soils; this current condition is expected to be representative of the ongoing condition of WTA soils as Diavik proceeds to closure, unless additional land-farming practices are adopted (as described in Section 4.3). The results of the problem formulation indicate that unrestricted disposal of PHC contaminated soils may not be safe for people and ecological receptors following mine closure. The main basis for this conclusion is as follows:

- COPC concentrations in WTA soils range well above the applicable guidelines and standards, and multiple pathways could be operable if WTA soils were to be disposed in an unrestricted fashion. Therefore, a combination of further risk assessment and risk management is necessary.
- Further risk assessment on its own may not address all contamination issues for WTA soils based on the currently observed conditions of WTA soils. Risk assessment on its own is typically a feasible option for soils with contaminant concentrations marginally exceeding the CEQGs or CWS-PHCs or where receptor sensitivity was expected to be lower than that assumed for guideline/standard development (allowing development of a site-specific benchmark), or where receptor groups assumed for specific guidelines/standards are not present. COPC concentrations in WTA soils range well above the applicable guidelines and standards (exceeding both the guidelines and management limits) and all receptor groups relevant to the guidelines and standards are potentially present at the Site and therefore do not fall into the "marginal exceedance" category. Also, there is no evidence suggesting that the receptors present at the Site would have lower sensitivity to contaminants (in fact, given their high degree of specialization, Arctic organisms are likely to be of equal if not higher sensitivity and protection goals could be higher for the relatively unique and pristine tundra ecosystem than for contaminated sites at lower latitudes. Based on these considerations, development of risk-based targets is considered unlikely to reduce potential risks to acceptable levels. It is possible that for the vapour or sub-surface water pathways, site-specific exposure assessment would indicate that likely exposure to COPCs for these pathways would not result in unacceptable risks.

Thus, the answer to Question 2 is that a combination of risk management (treatment, disposal in appropriate areas and disposal at appropriate depths) combined with risk assessment is considered necessary for long-term management of WTA soils.

4.1 Overview of Options

Long-term placement, following land-farming, in existing waste disposal infrastructure at the Site, at an optimal depth (considering potential risks and feasibility) is considered an appropriate approach for managing WTA soils. As a starting point, the options development assumes that the best practices described in Section 4.3 will be followed to achieve the limits described in Section 4.3.3. The implications of geographical locations and depth of placement of WTA soils are discussed below. The potential options are evaluated using an exposure pathway analysis to determine which exposure pathways would be operable under potential disposal options. Uncertainties and the need/feasibility of further risk assessment are highlighted.

4.1.1 Geographical Locations

Figure 1 shows the location of the three possible long-term placement locations for WTA soils that was considered. The infrastructure and geographic locations that may be appropriate for long-term placement of WTA soils include:

- Inert waste landfill – located in the SW corner of the country rock pile;
- Type III rock area – located in the NW corner of the country rock pile; and
- Processed kimberlite containment (PKC) - located in the approximate centre of the East Island, south of the country rock pile.

Based on discussions with DDMI, we understand that these locations are consistent with the current disposal practices (*i.e.,* WTA soils have been placed in the Type III rock area), and feasible for continued management of WTA soils. Although the materials and some conditions in each area may vary, there are features common to each which facilitates a common evaluation of possible placement practices (*i.e.,* by depth) among the geographical locations. The common features include:

- Material at depth (>5 m) will eventually freeze into permafrost, limiting leaching or contaminant transport potential. The depth of the active zone is expected to range from 0 to 5 m.
- It is expected that upon closure, the surface of these areas would be capped with non-acid generating rock that is “clean” with respect to PHCs (unless WTA soils are placed at surface).
- Sub-surface water permeability and conductivity in the thermally active zones of these locations may be relatively high given the coarse material present at each location (*i.e.,* waste rock and crushed waste rock, coarse processed kimberlite). However, the predominant flow direction would be downward toward permafrost, with only limited lateral movement during the summer season. In the permafrost, permeability and conductivity is negligible.

- The waste disposal facilities are located at least 200 m from Lac de Gras, in specific underlying drainage basins of the East Island. Seepage collection ponds surround the facilities, which along with permafrost provides a relatively impermeable barrier to seepage. Where seepage does occur it is directed to the water management ponds on the Site which are monitored regularly by DDMI. It is expected that monitoring will be ongoing during and after the mine life. Given the distance of the facilities from Lac de Gras and sub-surface water and seepage containment features it is considered unlikely[8] that significant contaminant transport to Lac de Gras would occur in the thermally active zone. The potential for transport of COPCs from permafrost to Lac de Gras is considered negligible.
- Each of these locations will be decommissioned and reclaimed following closure of the mine, and could possibly be accessed and used by wildlife or humans.

Thus, it is proposed that disposal of WTA soils in any one of these three areas would result in similar exposure scenarios from a risk assessment perspective, with these exposure scenarios being primarily dependent on the depth of soil placement.

4.1.2 Depth of Placement

Figure 3 depicts the possible placement depths for WTA soils. The exposure pathways described in the CSM vary with depth of placement, warranting a separate evaluation of pathways for each depth scenario:

- **Option 1: Surface Placement** – placement within the upper 1 m of surface soils which is within (i) the biological active zone (*i.e.,* depth stratum where soil invertebrates and plants would be present), and (ii) the active zone with respect to permafrost (*i.e.,* seasonal freeze-thaw occurs in the active zone).
- **Option 2: Subsurface/Active Zone Placement** – placement deeper than the biological active zone (*i.e.,* depth exceeding 1 m), but within the active zone with respect to permafrost, and capped with at least 1 m of non-contaminated material.
- **Option 3: Subsurface/Deep Placement -** Placement below the active zone in material that will eventually freeze into permafrost and overlain by at least 5 m of non-contaminated material.

Section 4.2 provides a preliminary evaluation of potential pathways and risks associated with each option.

4.2 Option-Based Pathway Analysis

The following sections describe the exposure pathways that are likely to be operable under each of the options described above and identifies the areas of uncertainty that would require further refinement if that option was selected.

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[8] Note that this has not been confirmed but could be if required.

To simplify the discussion, pathways have been grouped by common features according to the scheme on Figure 4. These groups include:

- Group 1: Direct contact, ingestion, and plant accumulation pathways relevant to ecological and human health for soils in the biologically active zone.
- Group 2: Soil vapour pathways relevant to human health for soils in the biologically active zone and thermally active zone.
- Group 3: Leaching/sub-surface water pathways relevant to ecological and human health for soils in the biologically active zone and thermally active zone.
- Group 4: (Lack of) pathways for soils in deep permafrost.

4.2.1 Option 1 – Surface Placement

With surface placement, the following pathway groups, as identified on Figure 4 could potentially be operable, based on COPCs identified in WTA soils and the assumptions described in the preceding section:

- *Group 1* including the key pathway of direct contact by plants and invertebrates.
- *Group 2* including the key pathway of soil vapour inhalation.

Comparison of COPC concentrations in WTA soils to the relevant guidelines and standards indicates that these pathways could potentially cause unacceptable risks to plants, invertebrates, microbes and humans. Therefore, if this Option were applied for management of WTA soils, further risk assessment would be necessary to refine the potential for risk for these pathways and determine if it results in conditions that are safe for humans and terrestrial receptors at the Site. As discussed above, with the current COPC concentration in WTA soils, risk assessment is unlikely to be successful at eliminating concerns with respect to long-term safety for these receptors. However, this could change if improvements to land-farming resulted in a significant reduction in COPC concentrations.

The *Group 3* pathways associated with leaching to Lac de Gras water and use by aquatic life and/or drinking water by humans is unlikely to be significant (*i.e.,* unacceptable risks are unlikely) because the design and monitoring of the waste facilities and distance from Lac de Gras would limit the migration of WTA soil contamination to Lac de Gras.

Assuming that the best practices described in Section 4.3 achieve PHC concentrations that are below the management limits for free phase formation, the presence and migration of free phase hydrocarbons from surface soils would not be expected.

At this stage, reasonable assumptions have been made regarding the operable pathways and potential risks associated with surface placement. Areas of uncertainty that would need to be refined if this Option was selected include:

- The actual magnitude of risks to soil invertebrates, plants, microbes and humans from soil direct contact (as described above, improved land-farming treatment would also likely be necessary).
- Degree of exposure to humans and resulting risks via soil vapour pathways.
- Confirmation that risks via the country-foods/plant and prey consumption pathways is minor.
- Confirmation of a lack of sub-surface water pathways.

4.2.2 Option 2 – Subsurface Active Zone Placement

With subsurface active zone placement, the following pathway group, as identified on Figure 4 could potentially be operable, based on COPCs identified in WTA soils and the assumptions described in the preceding section:

- *Group 2* including the key pathway of soil vapour inhalation.

Comparison of COPC concentrations in WTA soils to the relevant guidelines and standards indicates that the vapour pathways could potentially cause unacceptable risks to Aboriginal or non-aboriginal adults and children inhabiting the waste disposal areas in the future. Therefore, if this Option were applied for management of WTA soils, further risk assessment would be necessary to refine the risk estimates for these pathways and determine if it results in conditions that are safe for humans.

The subsurface placement at a depth exceeding 1 m removes the potential for exposure by ecological or human receptors via the *Group 1* pathways (direct contact, ingestion and country-foods).

The *Group 3* pathways associated with leaching to Lac de Gras water and use by aquatic life and/or drinking water by humans is unlikely to be significant (*i.e.,* unacceptable risks are unlikely) because the design and monitoring of the waste facilities and distance from Lac de Gras would limit the migration of WTA soil contamination to Lac de Gras.

Assuming that the best practices described in Section 4.3 achieve PHC concentrations that are below the management limits for free phase formation, the presence and migration of free phase hydrocarbons from subsurface soils would not be expected.

At this stage, reasonable assumptions have been made regarding the operable pathways and potential risks associated with subsurface active zone placement. Areas of uncertainty that would need to be refined if this Option was selected include:

- Degree of exposure to humans and resulting risks via soil vapour pathways.
- Confirmation of a lack of sub-surface water pathways.

4.2.3 Option 3 – Subsurface Deep Placement

With the subsurface deep placement, none of the pathways on Figure 4 would be operable (summarized as Pathway Group 4 on Figure 4).

The subsurface placement at a depth exceeding 5 m removes the potential for exposure by ecological or human receptors via the *Group 1* pathways (direct contact, ingestion and country-foods). Because the WTA soils would be frozen in permafrost neither dissolution of soil COPCs into a liquid-phase sub-surface water plume, or volatilisation of soil COPCs into soil vapour would be expected to occur, effectively eliminating the *Group 2* (soil vapour) and *Group 3* (leaching to sub-surface water and transport to Lac de Gras) pathways.

Assuming that the best practices described in Section 4.3 achieve PHC concentrations that are below the management limits for free phase formation, the presence and migration of free phase hydrocarbons from subsurface permafrost would not be expected.

At this stage, reasonable assumptions have been made regarding the depth and presence of permafrost in the existing Site waste disposal facilities. An area of uncertainty that would need to be refined if this Option was selected includes:

- Confirmation of the presence and depth of permafrost in the country rock pile, inert waste landfill and PKC.

4.3 Best Practices for PHC-Contaminated Soil Management

The following sections provide an overview of best-practices for PHC-contaminated soil management at the Diavik Mine.

4.3.1 Spill Response

Golder understands that the current practices for responding to spills/equipment failures are as follows:

- As much as possible, standing and/or dripping free-phase oils, fuels or antifreezes are captured and/or contained, and prevented from contaminating the soil surface. This is accomplished using a combination of drip pans, and sorbent materials.
- PHC-coated rocks or boulders (*i.e.,* resulting from sprays/mists of pressurized oil) that are too big to go to the WTA soil area are diverted directly to the Type III rock dump, and buried.
- Soil with visual staining is scraped from the surface and transferred to WTA soil area.

These practices are generally considered appropriate for spill response. The collection and containment measures are important for minimizing the amount of free-phase hydrocarbons that is ultimately transferred in soils, to the WTA soil area. The collected free-phase products and sorbents should be directed to the appropriate hazardous waste collection area on-site (*i.e.,* waste oil/antifreeze collection facility associated with maintenance shops) and then shipped off-site for disposal. Direction of the larger rocks and boulders to the Type III rock dump is considered appropriate because it is not possible to land-farm these larger substrates. These materials should be placed in the subsurface-deep zone of the Type III rock dump to eliminate possible exposure pathways and minimize the likelihood of migration of free phase hydrocarbons.

4.3.2 Land-farming

Golder understands that the current practices for land-farming of PHC-contaminated soils are as follows:

- Soils that are transferred to the WTA soil area undergo “land-farming” which involves spreading over an approximate 30x30 area to a depth up to ~0.75 m.
- Approximately 200 m^3 per year of PHC-contaminated soils are directed to the WTA soil area.
- The soil cell of the WTA is lined with geotextile overlain by coarse processed kimberlite (CPK) and surrounded by a berm.
- Soils from across the Site are combined in the same soil unit (*i.e.,* no separate stockpiling of materials from different sources).
- Soils are aerated (*i.e.,* turned and re-spread) regularly during the summer months to facilitate volatilization of the volatile petroleum hydrocarbon fractions and associated VOCs.

These practices are generally considered appropriate for land-farming. In addition, there are additional practices that may increase the treatment efficiency for WTA soils.

A preliminary literature scan was conducted to determine how the current practices could be augmented. It identified multiple studies which examined the factors affecting the land-farming success for petroleum hydrocarbons in Arctic and subarctic regions (*e.g.,* Braddock et al. 1997; Chang et al. 2010; Paudyn et al. 2008; Walworth et al. 2001; Walworth and Reynolds, 1995; Rike et al. 2003; Mohn et al. 2001; Thomassin-Lacroix et al. 2002). The reviewed studies confirm the presence of hydrocarbon-degrading bacteria in coarse Arctic and subarctic soils and have demonstrated success at land-farming PHC-contaminated soils through a combination of aeration to facilitate volatilization of lighter fractions, and bioremediation, even at relatively low temperatures (5-10 deg C). Based on a preliminary review, it is expected that the following factors could improve treatment efficiency for WTA soils:

- **Optimization of the frequency of aeration** – recent studies on Resolution Island, NU, achieved relatively high rates of volatilization (~1.5% per day) of petroleum hydrocarbons from coarse soils, with aeration every 4 days. Increasing aeration frequency to daily caused only a small additional increase in volatilization. While aeration is already conducted for WTA soils, further literature and/or pilot testing at the Site could be conducted to determine the optimal aeration frequency for WTA soils. Aeration is expected to remove primarily the smaller carbon fractions (F1 and F2) and associated contaminants such as BTEX and VOCs.
- **Amendment with moisture and nutrients** – Each of the studies reviewed also included biostimulation of bacteria responsible for PHC biodegradation by the addition of both water and nutrients, including organic carbon (OC), phosphorous (P) and nitrogen (N). For example, by also adding nutrients, combined rates of volatilization and biodegradation reached ~2.6% per day in the Resolution Island study. Analysis of WTA soils by Golder 2010, indicated very low concentrations of organic carbon, phosphorous and nitrogen, that are well below the concentrations found to stimulate biodegradation in studies of land-farming. There are three possible sources of nutrient amendments for WTA soils:

  - *Commercial/industrial fertilizers* – this would require purchase and maintenance of a stock of fertilizer, but would allow for fine-tuning of the precise amount of nutrient amendment.
  - *Sewage biosolids produced at Diavik Mine* – Sewage biosolids are stockpiled adjacent to the WTA soil area and would be a cost-effective and readily available source of moisture and nutrients. Amendment with biosolids would also add volume to the WTA soils resulting in a mild dilution effect. Prior to initiating use, some characterisation of moisture and nutrient contents, was well as contaminant concentrations, may be necessary. In addition, there would likely be occupational health requirements for the handling/use of the biosolids.
  - *Sludge from the North Inlet Water Treatment Plant* – Treatment plant sludge from North Inlet could also be a cost-effective and readily available source of moisture and nutrients, but given the high water content of the sludge, it is unlikely to add volume to the WTA soils. Prior to initiating use, some characterisation of moisture and nutrient contents, as well as contaminant concentrations, may be necessary. In addition, there would likely be occupational health requirements for the handling/use of the sludge.
- **Optimization of moisture, C, N and P ratios** – Some studies have determined optimal relative amendments with moisture, OC, N and P, and also demonstrate maximum nutrient additions above which bioremediation might be inhibited. Further literature and/or pilot testing at the Site could be conducted to determine the optimal moisture, C, N and P ratios for PHC biodegradation in WTA soils.
- **Optimization of land-farming depth** – Common land-farming depths range from 0.3 to 1 m thick to facilitate complete aeration and mixing. It is recommended that the depth of land-farmed soils not exceed 1 m in the WTA.

4.3.3 Upper Limit Treatment Concentrations

Regardless of the soil placement options identified in Section 4.2, the overarching objective of WTA soil management (spill response and land-farming) should be the minimization of free phase hydrocarbons in WTA soils that are placed in the Type III Rock Pile, Inert Waste Landfill or PKC. Free-phase hydrocarbons are known to migrate in soils and remain a long-term potential source of soil, sub-surface water or groundwater contamination and could potentially contaminate clean soils, waste rock or PK in these areas. Minimization of free-phase hydrocarbons in WTA soils would minimize this risk. Thus, it is recommended that the CWS-PHC management limits for free-phase formation be adopted as the upper limit treatment concentrations for land-farmed soil for CCME PHC fractions F1 through F4. The CWS-PHC management limits for free-phase formation are:

- 700 mg/kg for F1;
- 1% or 10,000 mg/kg for F1-F3 combined; and
- 1% of 10,000 mg/kg for F4.

Given the maximum observed concentrations of F1-F4 observed in WTA soils, it appears that these limits are already met for F1 and F4. For F1-F3, combined, a reduction from the maximum observed concentration (~46,000 mg/kg) to the management limit is likely to be attainable using the best-practices described above. For example, assuming 2.6% reduction per day[9] over 60 days (according to 1st order kinetics), and no addition of "new" contaminated soils, a reduction of approximately 80%, to ~10,000 mg/kg would be expected. Sixty days is consistent with one summer season at the Site and it is expected that WTA soils would be land-farmed for at least one season prior to long-term placement in one of the disposal areas. The ultimate treatment levels would depend on the rate of reduction relative to the rate of input of new contaminated soils to the WTA soil area.

If land-farming of WTA soils is highly successful (*i.e.,* greater reductions in concentration are achieved), then lower risk-based targets could be set to mitigate the risks associated with operable pathways under Options 1 or 2 in Section 4.2. In this case, the preliminary targets would be the limiting guidelines from Table 2 including the vapour guidelines/standards for F1-F2 (and other volatiles), and the eco soil contact guidelines/standards for F3-F4. If warranted, these lower targets could also be refined through follow up risk assessment work on the vapour and direct contact pathways.

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[9] Achieved by Paudyn et al. 2008.

5.0 UNCERTAINTY

At the problem formulation stage, uncertainty is often addressed by making conservative assumptions (*i.e.,* erring on the side of caution). By addressing key uncertainties, it is possible to refine the understanding of potential risks and resulting management decisions (in this case, management approaches for WTA soils). Key uncertainties that could influence the optimal management approach for WTA soils include:

- *The actual magnitude of risks to soil invertebrates, plants, microbes and humans from soil direct contact and ingestion.* For this stage, it has been assumed that COPCs which exceed their respective guidelines for these pathways would result in unacceptable risks to these receptors. Given the relatively high level of exceedance, especially for F2 and F3, especially with respect to direct contact by plants, invertebrates and microbes, there is reasonably strong evidence that risks would be unacceptable (*i.e.,* risk assessment unlikely to be successful at eliminating concerns with respect to long-term safety). However, if land-farming reduces COPC concentrations to levels near the guidelines, then the likelihood of unacceptable risks would become less certain. In this case, further examination of potential species sensitivity or site-specific toxicity might be warranted as there would be a higher probability of success at demonstrating that risks are acceptable over the long term.

- *The degree of exposure of humans and wildlife, and resulting risks, via the country-foods/plant and prey consumption pathways.* The magnitude of risk from these pathways is not quantified at this point, due to a lack of relevant guidelines and standards. However, considering that the types of COPCs identified in WTA soils, are not considered bioaccumulative, this pathway was considered a minor exposure pathway compared to other exposure pathways. If management of WTA soils includes surface placement (Option 1), then it may be necessary to examine these pathways further. The key gaps in knowledge include the degree of accumulation of COPCs in plants, wildlife and game meat.

- *Degree of exposure to humans and resulting risks via soil vapour pathways.* For this stage, it has been assumed that COPCs which exceed their respective guidelines for soil vapour pathways, would result in unacceptable risks to humans in indoor air. However, given that vapour intrusion into buildings is dependent on multiple factors (*e.g.,* temperature, soil grain size, ice/water saturation etc.), the actual likelihood of this occurring is uncertain. In addition, it is possible that building design for northern latitudes where permafrost occurs might limit this pathway. In particular, building design over permafrost often involves construction methods to prevent melting of permafrost; which could also limit vapour intrusion. If management of WTA soils includes surface or subsurface/active zone placement (Options 1 or 2), then this pathway should be examined further. This could be accomplished through modelling with application of site-specific conditions and attenuation factors and consideration of building design.

- *Confirmation of a lack of sub-surface water pathways.* It is considered unlikely that significant contaminant transport in the thermally active zone from the three possible disposal locations to Lac de Gras would occur (*i.e.,* contaminated sub-surface water originating from the water disposal locations is unlikely to reach Lac de Gras and pose unacceptable risk to aquatic life or humans). This is due to the distance from Lac de Gras (>200 m), generally low potential for lateral sub-surface water movement in the thermally active zone, and design features of the waste areas that direct sub-surface water flow and seepage to specific ponds. However, the actual degree of transport of COPCs (or lack of) in WTA soils disposed of in these areas to Lac de Gras has not been confirmed. If management of WTA soils includes surface or subsurface/active zone placement (Options 1 or 2), then further confirmation of this assumption may be warranted through modelling and or direct monitoring.

- *Confirmation of presence and depth of permafrost.* The lack of exposure pathways for Option 3 (subsurface-deep placement) is based on the assumption that permafrost will form and persist at a depth of about 5 m in the Type III rock dump, inert waste landfill or PKC. If the understanding of future permafrost conditions in these areas changes, then the evaluation of Option 3 should be updated accordingly.

- *Confirmation that carcinogenic PAHs are not COPCs*. At this stage, benzo(a)pyrene and carcinogenic PAHs have not been included as COPCs for drinking water because their inclusion would be based on detection limits rather than actual detected concentrations. It is possible, albeit unlikely, that the true concentrations of carcinogenic PAHs are right at or just below their detection limits, meaning that they are actually COPCs. If later stages of risk assessment determine that Lac de Gras drinking water is a key pathway, then this conclusion may need to be re-assessed, possibly through re-sampling and analysis of WTA soils.

6.0 CONCLUSION

6.1 Findings

The results of the problem formulation indicated that unrestricted disposal of WTA soils may not be safe for people and ecological receptors following mine closure. Therefore, some form of remediation/risk management is required. Based on the number of COPCs and the magnitude and frequency of the exceedances, the key exposure pathways driving risk included direct soil contact by plants and soil invertebrates; inhalation of soil vapour; sub-surface water transport to Lac de Gras followed by consumption for drinking water (by humans); and, sub-surface water transport to Lac de Gras leading to direct exposure (by aquatic life). However, it was concluded that addressing these pathways, through a combination of risk assessment and management could mitigate the potential for risk.

Preliminary management options were then developed to address the key exposure pathways. Based on discussions with DDMI, the locations considered suitable for long-term management and disposal of the PHC-contaminated soils were: the Type III rock dump, the inert waste landfill, or the PKC. Following our evaluation of these locations, it was determined that the driving exposure pathways for all three locations (*i.e.,* soil contact and vapour inhalation) could be mitigated through the depth of soil placement (*i.e.,* placement at surface vs depth). Therefore, the management options focused on evaluating three different depth placement scenarios:

- Option 1: Surface Placement (upper 1 m).
- Option 2: Subsurface/Active Zone Placement (depth >1 m but above permafrost).
- Option 3: Subsurface/Deep Placement (at depth where permafrost is expected to form and persist).

Overall, our evaluation indicated that Option 3 appeared to minimize exposure pathways and related uncertainty with respect to human health and ecological risks. Option 3 also represented current practices at the Site. With Options 1 and 2, operable exposure pathways remained, meaning that additional risk assessment and/or risk management would be necessary to determine the long-term safety of these options.

Best practices for spill response and land-farming of PHC-contaminated soil were also provided. Possible improvements to current land-farming practices for WTA soils include the addition of nutrients and moisture to the soils, and optimization of both the soil aeration frequency and nutrient addition ratios. It is recommended that the CWS-PHC management limits for free-phase formation be adopted as the upper limit treatment concentrations for land-farmed soil for CCME PHC fractions F1 through F4. If land-farming is highly successful (*i.e.,* greater reductions in concentration are achieved), then lower risk-based targets could be set to mitigate the risks associated with operable pathways under Options 1 or 2.

6.2 Next Steps

The current assessment is considered adequate for developing a preliminary understanding of potential management options for WTA soils. The need for further analysis, at this point, is dependent upon which options for long-term placement of WTA soils are deemed desirable for DDMI, taking into consideration potential risks associated with the pathways that are operable under each of the options.

Currently, Option 3 (subsurface-deep placement) appears to be the safest option for long-term disposal of PHC-soils. However, there may be other reasons (*e.g.,* economic or operational) why Options 1 or 2 might be more desirable. If these options are to be considered then one or more of the following issues may require further assessment:

- Review of uncertainties summarized in Section 5, and refinement of the risk assessment; and
- Effectiveness of best-practices for land-farming of WTA soils.

7.0 CLOSURE

We trust that this assessment meets your requirements at this time, should you have any questions please contact any of the undersigned at 604-296-4200.

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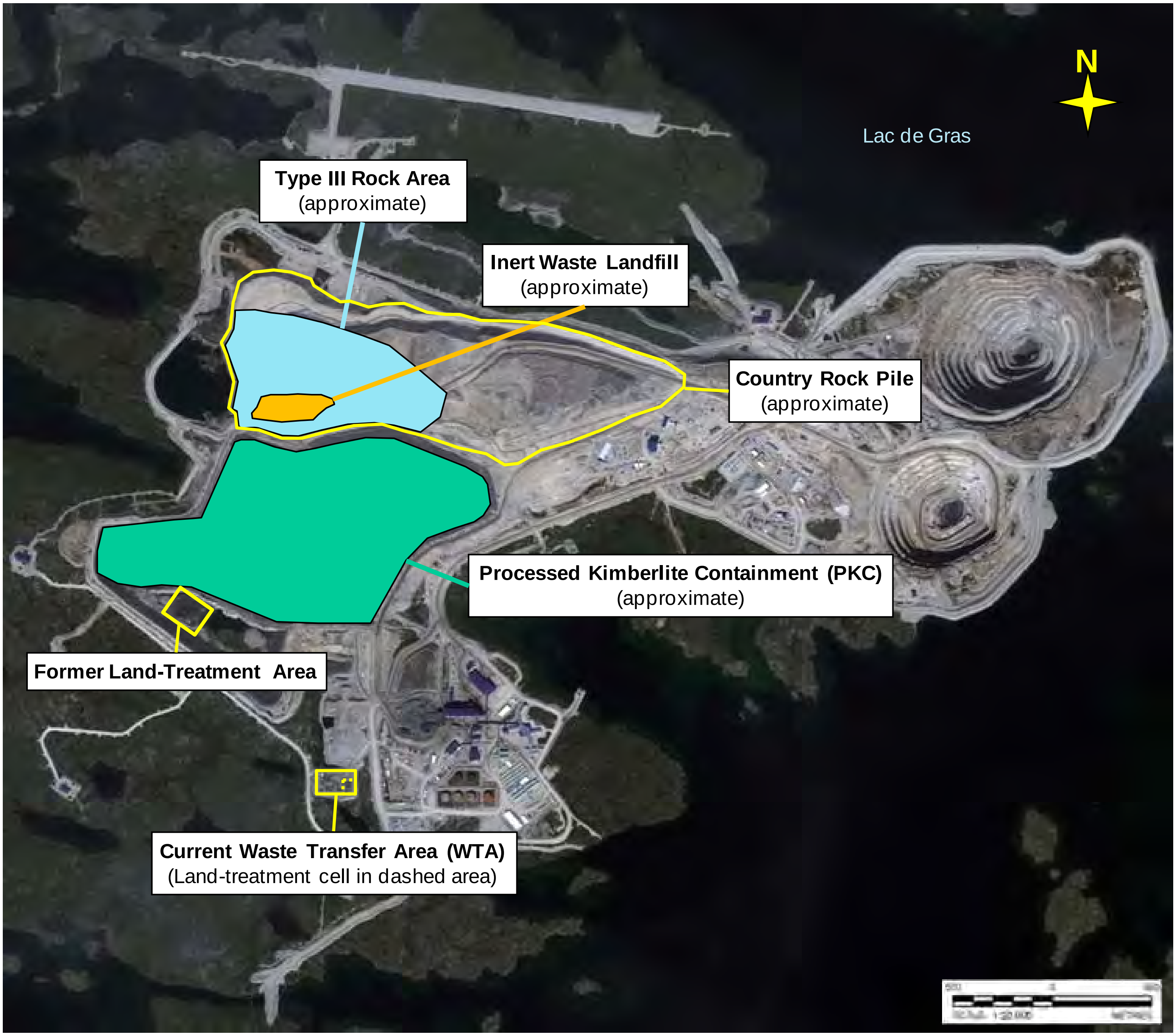

Scale is approximate

TITLE

Key Features of the Diavik Mine Site Related to Management of WTA Soils

Golder Associates

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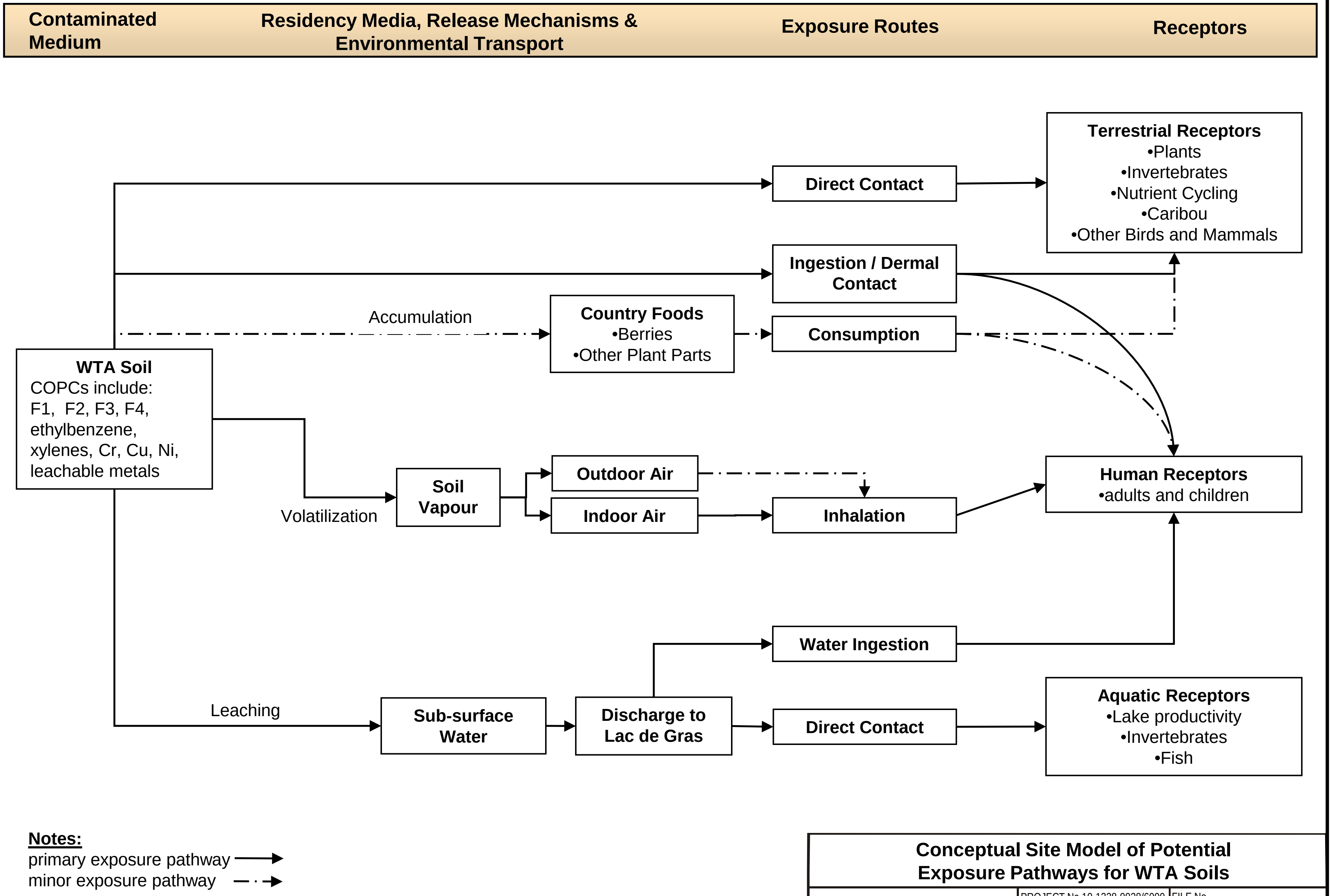
FIGURE 1



Conceptual Site Model of Potential Exposure Pathways for WTA Soils

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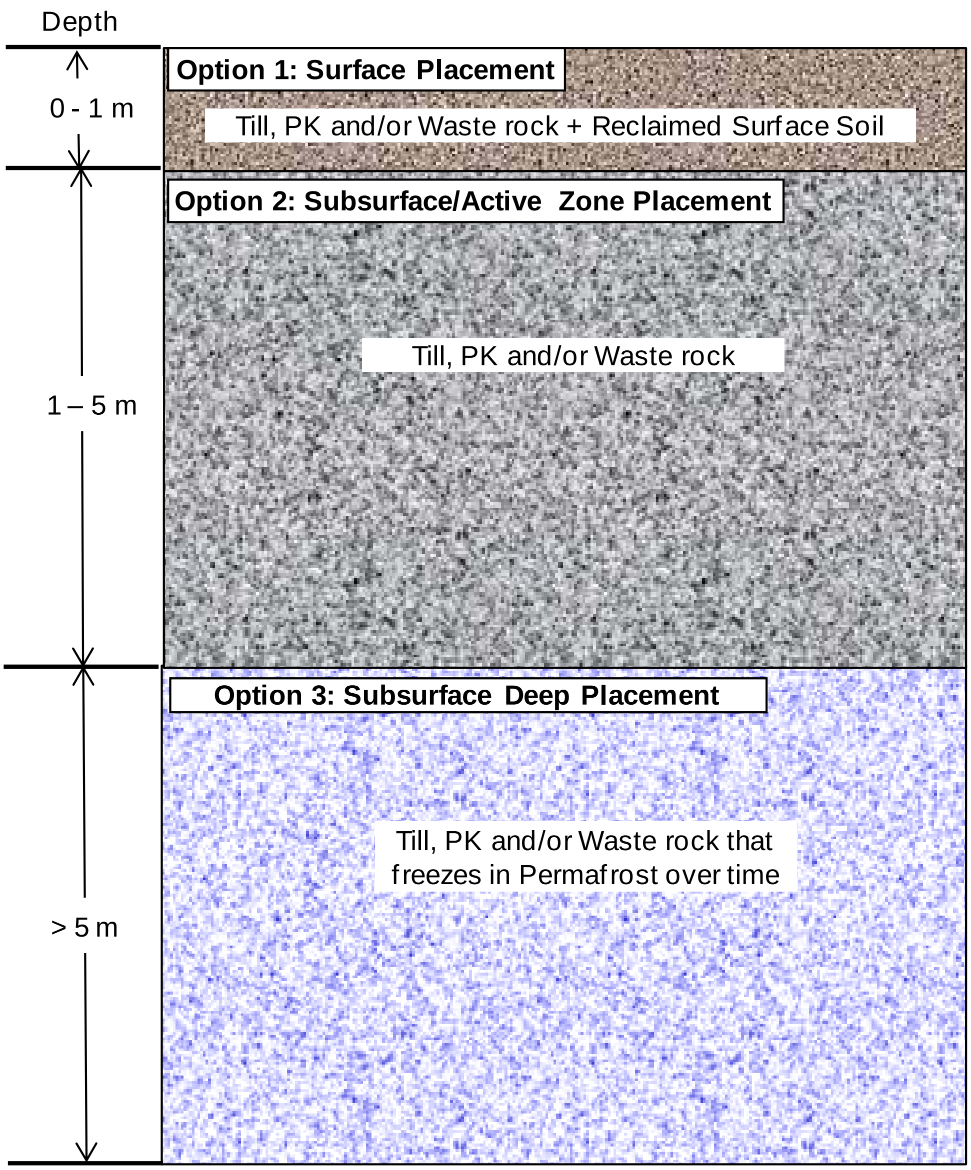

not to scale

<u>Pathway Summary for Each Option</u> (refer to Figure 4 for Groups)

Option 1: Surface pathways (Groups 1) and vapour pathways (Group 2) could potentially be operable. Sub-surface flow pathways (Group 3) are unlikely to be significant because design of the waste facilities and distance from Lac de Gras limits potential migration of COPCs to Lac de Gras.

Option 2: Vapour pathways (Group 2) could potentially be operable. Sub-surface flow pathways (Group 3) are unlikely to be significant because design of the waste facilities and distance from Lac de Gras limits potential migration of COPCs to Lac de Gras. Surface pathways (Group 2) are not operable.

Option 3: No pathways are operable because COPCs are located deeper than 1 m, preventing surface pathways (Group 1), and frozen in permafrost, preventing vapour pathways (Group 2) and sub-surface flow pathways (Group 3).

TITLE

Schematic of Potential Soil Placement
Depth Options for WTA Soils

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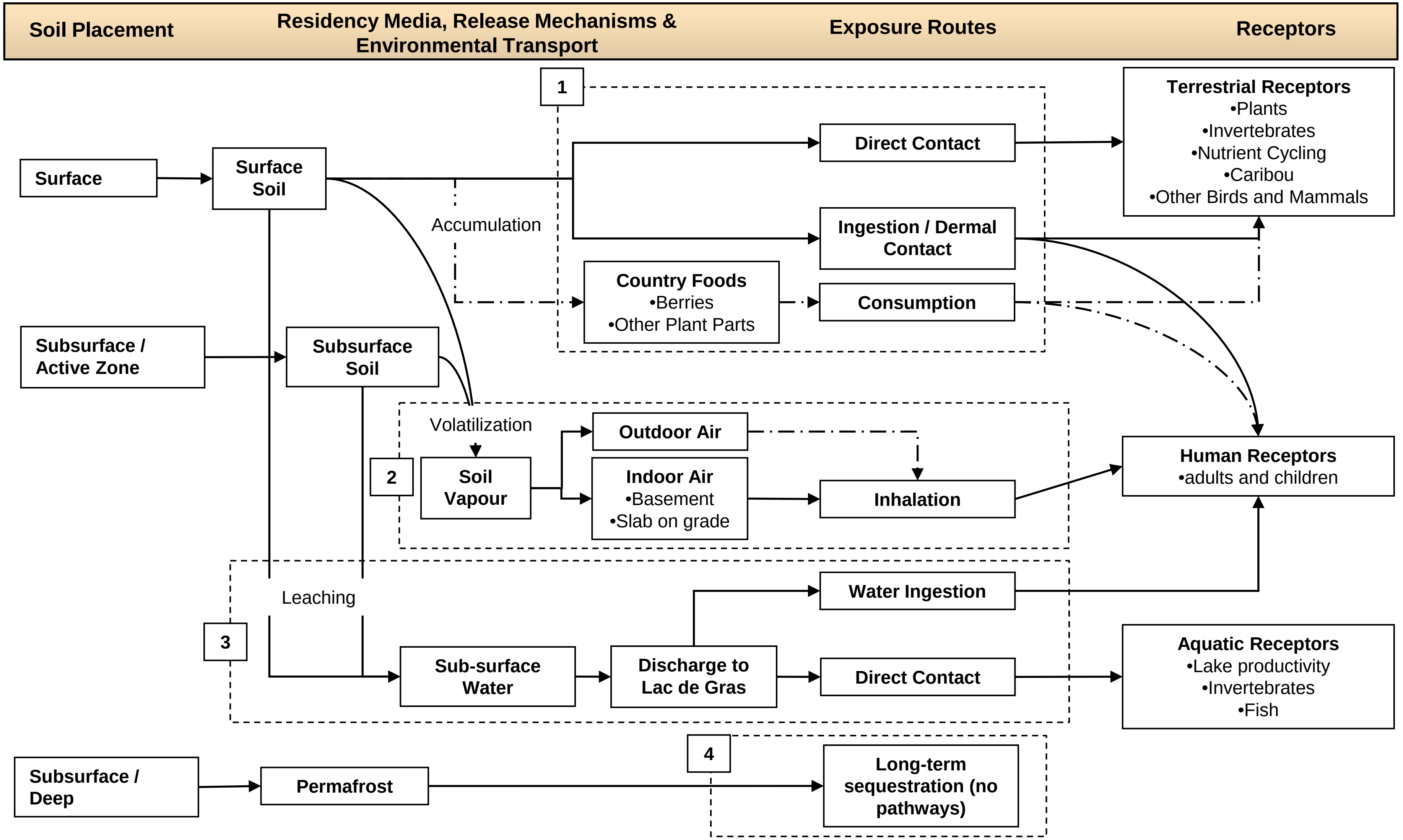

Pathway Groups

1. Direct contact, ingestion, and plant accumulation pathways for soils in the biologically active zone.
2. Soil vapour pathways for soils in the biologically active zone and thermally active zone.
3. Leaching/sub-surface water pathways for soils in the biologically active zone and thermally active zone.
4. (Lack of) pathways for soils in deep permafrost.

Pathway Groups Relevant to Varying Placement Depths for WTA Soils

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APPENDIX A

Comparison of Analytical Results for Soil and Leachate to Applicable Standards and Guidelines

APPENDIX A
Comparison of Analytical Results for Soil and Leachate to Applicable Standards and Guidelines

Table A-1: Screening of Bulk Soil Data

Sample ID	Canada-Wide Standard for Petroleum Hydrocarbons (CWS-PHC)		Canadian Environmental Quality Guidelines (CEQG)	US EPA Regional Screening Levels	A-1	A-2	A-3	B-1	B-2	B-2 DUPLICATE	B-3	C-1	C-2	C-3	C-3DEEP	TP1	TP2	TP3	TP4	TP1-SA1	TP2-SA1	TP3-SA1	TP4-SA1	TP5-SA1	TP6-SA1
Date Sampled					8/30/2010	8/31/2010	8/30/2010	8/30/2010	8/31/2010	8/31/2010	8/30/2010	8/30/2010	8/30/2010	8/30/2010	8/30/2010	7/31/2010	7/31/2010	7/31/2010	7/31/2010	8/18/2008	8/18/2008	8/18/2008	8/18/2008	8/18/2008	8/18/2008
Nature					SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL
Data Source	Agricultural - Coarse Grained[1]	Management Limit - Free Phase Formation	Agricultural - Coarse Grained[1]	Residential[1]	Golder-WTA August 2010	Golder-WTA August 2010	Golder-WTA August 2010	Golder-WTA August 2010	Golder-WTA August 2010	Golder-WTA August 2010	Golder-WTA August 2010	Golder-WTA August 2010	Golder-WTA August 2010	Golder-WTA August 2010	Golder-WTA August 2010	DDMI - Type III Rock Dump July 2010	DDMI - Type III Rock Dump July 2010	DDMI - Type III Rock Dump July 2010	DDMI - Type III Rock Dump July 2010	DDMI - Former WTA August 2008	DDMI - Former WTA August 2008	DDMI - Former WTA August 2008	DDMI - Former WTA August 2008	DDMI - Former WTA August 2008	DDMI - Former WTA August 2008
QA/QC									FD	FDA															
Physical Parameters																									
Moisture					8.7	8.6	9.5	5.9	8.3	10	15	8.9	6.7	3.6	7.2										
pH						8.60		8.18	7.96		8.30	8.59	8.77	7.30	8.78										
Total Organic Carbon (TOC)						0.35		0.60	0.46				0.27		0.74										
Volatile F1-BTEX																									
F1 (C6-C10) - BTEX	30	700						*<40*	<10		120		<10	39		<10	<10	<10	<10	<5	43	310	24	<5	190
CCME F1 (C6-C10)																									
F1 (C6-C10)	30	700						*<40*	<10		130		<10	39											
CCME Hydrocarbons (F2-F4)																									
F2 (C10-C16 Hydrocarbons)	150				110	59	210	220	160	230	3800	520	240	2700	600	220	213	138	238	270	990	3600	640	290	2800
F3 (C16-C34 Hydrocarbons)	300				3500	2000	3800	1100	1300	2400	42000	3800	810	2700	9400	1150	943	1050	2390	4400	10000	23000	5000	7000	13000
F4 (C34-C50 Hydrocarbons)	2800	10000			590	260	360	190	240	500	9600	520	150	240	670	1010	234	1080	2880	1500	4100	4400	1100	7500	2400
Total F1-F3 (screening for Free Phase Formation)		*10000*			*3610*	*2059*	*4010*	*1320*	*1460*	*2630*	*45930*	*4320*	*1050*	*5439*	*10000*	*1370*	*1156*	*1188*	*2628*	*4670*	*10990*	*26600*	*5640*	*7290*	*15800*
Glycols																									
Diethylene Glycol						<10		<10	<10				<10		<10			<10		<10			<10		
Ethylene Glycol			960			<10		<10	<10				13		37			<10		<10			<10		
Propylene Glycol						<10		<10	<10				<10		<10			<10		<10			<10		
Tetraethylene Glycol						<10		<10	<10				<10		<10										
Triethylene Glycol						<10		<10	<10				<10		<10			<10		<10			<10		
Metals																									
Aluminum (Al)											8960	6760		6070											
Antimony (Sb)											3.3	0.6		0.8		0.27					0.3		<0.2		
Arsenic (As)			12								9.2	2.5		1.2		3.93					3.6		1.4		
Barium (Ba)			750								234	98.2		53.5		36.1					46		70		
Beryllium (Be)											0.3	0.1		0.2											
Bismuth (Bi)											0.5	0.9		3.0											
Cadmium (Cd)			1.4								0.33	0.15		0.09		<0.5					<0.5		<0.5		
Calcium (Ca)											8750	3850		2150											
Chromium (Cr)			64								146	55		22		23.1					22.2		34.1		
Cobalt (Co)											22.9	11.2		4.7		3.7					4		7		
Copper (Cu)			63								66.5	13.4		10.0		53.7					14		12		
Iron (Fe)											47100	13800		10300											
Lead (Pb)			70								9.1	5.6		6.4		10					7		8		
Magnesium (Mg)											45200	21800		6780											
Manganese (Mn)											674	203		159											
Mercury (Hg)			6.6								<0.05	<0.05		<0.05		<0.05					<0.5		<0.5		
Molybdenum (Mo)											140	44.8		3.1		15.4					45		26		
Nickel (Ni)			50								338	143		34.7		26.2					28		67		
Phosphorus (P)						1000		1010	820		728	678	999	1050	946										
Potassium (K)											3000	3870		3370											
Selenium (Se)			1								0.7	<0.5		<0.5		<0.5					<0.5		<0.5		
Silver (Ag)											0.10	<0.05		<0.05		<1					<1		<1		
Sodium (Na)											373	273		<100											
Strontium (Sr)											96.2	39.3		10.0											
Thallium (Tl)			1								0.20	0.23		0.23		<0.5					<5		<5		
Tin (Sn)											2.3	0.5		0.6		<5					<1		<1		
Titanium (Ti)											657	593		377											
Vanadium (V)			130								36	18		13		9.9					12		15		
Zinc (Zn)			200								166	52		44		48					70		60		
Zirconium (Zr)											3.3	2.3		<0.5											
PAHs																									
2-Methylnaphthalene				310							0.99	<0.02		<0.05	<0.01				<0.06						
Acenaphthene			0.28	3400							0.18	<0.02		0.11	<0.01				<0.06						
Acenaphthylene			320								<0.1	<0.02		<0.04	<0.02				<0.06						
Anthracene			2.5	17000							<0.03	<0.01		<0.08	<0.01										
Benzo(a)anthracene			0.1								<0.01	<0.01		<0.01	<0.01				<0.06						
Benzo(a)pyrene			0.6								<0.2	<0.01		<0.01	<0.02				<0.06						
Benzo(b&j)fluoranthene			0.1								*<0.3*	<0.01		<0.02	<0.04				<0.06						
Benzo(g,h,i)perylene											<0.02	<0.02		<0.02	<0.02										
Benzo(k)fluoranthene			0.1								<0.06	<0.01		<0.01	<0.03				<0.06						
Chrysene			6.2								0.04	<0.01		0.02	<0.01				<0.06						
Dibenzo(a,h)anthracene			0.1								<0.02	<0.02		<0.02	<0.02				<0.06						
Fluoranthene			50	2300							<0.06	<0.01		0.02	<0.01				<0.06						
Fluorene			0.25	2300							0.41	0.03		0.17	0.03				<0.06						
Indeno(1,2,3-cd)pyrene			0.1								<0.02	<0.02		<0.02	<0.02				<0.06						
Naphthalene			0.013	140							*<0.4*	*<0.04*		*<0.2*	*<0.03*				*<0.06*						
Phenanthrene			0.046								0.53	0.01		<0.04	<0.01				*<0.06*						
Pyrene			7.7	1700							<0.2	<0.03		0.15	<0.02				0.064						
Benzo(a)pyrene-TPE [2]			0.6								0.13	0.02		0.02	0.03				ND						
PAH IACR (Drinking water protection) [2]			1								1.48[3]	0.14		0.18	0.31				0.70						

APPENDIX A
Comparison of Analytical Results for Soil and Leachate to Applicable Standards and Guidelines

Sample ID	Canada-Wide Standard for Petroleum Hydrocarbons (CWS-PHC)		Canadian Environmental Quality Guidelines (CEQG)	US EPA Regional Screening Levels	A-1	A-2	A-3	B-1	B-2	B-2 DUPLICATE	B-3	C-1	C-2	C-3	C-3DEEP	TP1	TP2	TP3	TP4	TP1-SA1	TP2-SA1	TP3-SA1	TP4-SA1	TP5-SA1	TP6-SA1
	Agricultural - Coarse Grained^1	Management Limit - Free Phase Formation	Agricultural - Coarse Grained^1	Residential^1																					
Date Sampled					8/30/2010	8/31/2010	8/30/2010	8/30/2010	8/31/2010	8/31/2010	8/30/2010	8/30/2010	8/30/2010	8/30/2010	8/30/2010	7/31/2010	7/31/2010	7/31/2010	7/31/2010	8/18/2008	8/18/2008	8/18/2008	8/18/2008	8/18/2008	8/18/2008
Nature					SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL
Data Source					Golder-WTA August 2010	Golder-WTA August 2010	Golder-WTA August 2010	Golder-WTA August 2010	Golder-WTA August 2010	Golder-WTA August 2010	Golder-WTA August 2010	Golder-WTA August 2010	Golder-WTA August 2010	Golder-WTA August 2010	Golder-WTA August 2010	DDMI - Type III Rock Dump July 2010	DDMI - Type III Rock Dump July 2010	DDMI - Type III Rock Dump July 2010	DDMI - Type III Rock Dump July 2010	DDMI - Former WTA August 2008	DDMI - Former WTA August 2008	DDMI - Former WTA August 2008	DDMI - Former WTA August 2008	DDMI - Former WTA August 2008	DDMI - Former WTA August 2008
QA/QC									FD	FDA															
VOCs																									
1,1,1,2-tetrachloroethane								<0.03	<0.03		<0.03		<0.03	<0.03											
1,1,1-trichloroethane								<0.03	<0.03		<0.03		<0.03	<0.03											
1,1,2,2-tetrachloroethane								<0.03	<0.03		<0.03		<0.03	<0.03											
1,1,2-trichloroethane								<0.03	<0.03		<0.03		<0.03	<0.03											
1,1-dichloroethane								<0.03	<0.03		<0.03		<0.03	<0.03											
1,1-dichloroethene								<0.03	<0.03		<0.03		<0.03	<0.03											
1,2-dichlorobenzene								<0.03	<0.03		<0.03		<0.03	<0.03											
1,2-dichloroethane								<0.03	<0.03		<0.03		<0.03	<0.03											
1,2-dichloropropane								<0.03	<0.03		<0.03		<0.03	<0.03											
1,3-dichlorobenzene								<0.03	<0.03		<0.03		<0.03	<0.03											
1,4-dichlorobenzene								<0.03	<0.03		<0.03		<0.03	<0.03											
Benzene			0.0095	0.0095				<0.005	<0.005		<0.008		<0.005	<0.005		<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Bromodichloromethane								<0.05	<0.05		<0.05		<0.05	<0.05											
Bromoform								<0.05	<0.05		<0.05		<0.05	<0.05											
Bromomethane								<0.3	<0.3		<0.3		<0.3	<0.3											
Carbon tetrachloride								<0.03	<0.03		<0.03		<0.03	<0.03											
Chlorobenzene								<0.03	<0.03		<0.03		<0.03	<0.03											
Chlorodibromomethane								<0.05	<0.05		<0.05		<0.05	<0.05											
Chloroethane								<0.1	<0.1		<0.1		<0.1	<0.1											
Chloroform								<0.05	<0.05		<0.05		<0.05	<0.05											
Chloromethane								<0.1	<0.1		<0.1		<0.1	<0.1											
cis-1,2-dichloroethene								<0.03	<0.03		<0.03		<0.03	<0.03											
cis-1,3-dichloropropene								<0.05	<0.05		<0.05		<0.05	<0.05											
Dibromoethane								<0.03	<0.03		<0.03		<0.03	<0.03											
Dichloromethane								<0.1	<0.1		<0.1		<0.1	<0.1											
Ethylbenzene			0.082	0.082				<0.01	<0.01		0.26		<0.01	<0.01		<0.015	<0.015	<0.015	<0.015	<0.01	0.100	1.100	<0.01	<0.01	0.160
m & p-Xylene								<0.1	<0.1		0.5		<0.1	<0.1											
Methyl-tert-butylether (MTBE)								<0.1	<0.1		<0.1		<0.1	<0.1											
o-Xylene								<0.1	<0.1		1.1		<0.1	<0.1											
Styrene								<0.1	<0.1		<0.2		<0.1	<0.1											
Tetrachloroethene			0.1	0.1				<0.03	<0.03		<0.03		<0.03	<0.03											
Toluene			0.37	0.37				<0.03	<0.03		0.06		<0.03	<0.03		<0.05	<0.05	<0.05	<0.05	<0.01	0.04	0.35	<0.01	<0.01	0.06
trans-1,2-dichloroethene								<0.03	<0.03		<0.03		<0.03	<0.03											
trans-1,3-dichloropropene								<0.05	<0.05		<0.05		<0.05	<0.05											
Trichloroethene			0.01	0.01				<0.01	<0.01		<0.01		<0.01	<0.01											
Trichlorofluoromethane								<0.2	<0.2		<0.2		<0.2	<0.2											
Vinyl chloride								<0.06	<0.06		<0.06		<0.06	<0.06											
Xylene (Total)			11	11				<0.1	<0.1		1.6		<0.1	<0.1		<0.02	<0.02	<0.02	<0.02	<0.02	0.99	22.00	0.11	<0.02	3.30

NOTES:
All units are reported in milligrams per kilograms (mg/kg), except Physical Parameters that were reported percentage (%; moisture and TOC) or unitless (pH).
When detection limits exceed guidelines or criteria, the values are italicized but not highlighted.
1 - lowest standards/guidelines were applied for initial screening purposes
2 - for non-detected values, estimates use 0.5xMDL.
3 - estimate is based almost entirely on MDLs rather than detected value for chrysene.

APPENDIX A
Comparison of Analytical Results for Soil and Leachate to Applicable Standards and Guidelines

Table A-2: Screening of Soil Leachate Data

Sample ID	**B-3**	**C-1**	**C-3**	**C-3DEEP**
Date Sampled	**8/30/2010**	**8/30/2010**	**8/30/2010**	**8/30/2010**
Nature	**Leachate**	**Leachate**	**Leachate**	**Leachate**
Data Source	**Golder-WTA August 2010**	**Golder-WTA August 2010**	**Golder-WTA August 2010**	**Golder-WTA August 2010**
CCME Hydrocarbons (F2-F4 in leachate)				
F2 (C10-C16 Hydrocarbons)	<100	<100	<100	<100
F3 (C16-C34 Hydrocarbons)	<80	<80	<80	<100
F4 (C34-C50 Hydrocarbons)	<5000	<5000	<5000	<5000
Metals in SPLP Leachate				
Aluminum (Al)	840	90	530	420
Antimony (Sb)	16	4	1	<1
Arsenic (As)	2	2	1	<1
Barium (Ba)	<100	<100	<100	<100
Beryllium (Be)	<1	<1	<1	<1
Boron (B)	<500	<500	<500	<500
Cadmium (Cd)	0.06	0.03	0.06	<0.02
Calcium (Ca)	8000	11000	5000	3000
Chromium (Cr)	2	<1	6	2
Cobalt (Co)	<1	<1	2	<1
Copper (Cu)	<2	<2	17	2
Iron (Fe)	610	60	2090	390
Lead (Pb)	1	<1	5	2
Magnesium (Mg)	5000	17000	3000	1000
Manganese (Mn)	8	<5	27	6
Mercury (Hg)	<0.1	<0.1	<0.1	<0.1
Molybdenum (Mo)	19	43	<5	5
Nickel (Ni)	10	<10	20	<10
Selenium (Se)	<1	<1	<1	<1
Silver (Ag)	<0.1	<0.1	<0.1	<0.1
Sodium (Na)	14000	12000	8000	8000
Thallium (Tl)	<0.1	<0.1	<0.1	<0.1
Titanium (Ti)	<100	<100	<100	<100
Uranium (U)	7	3	13	3
Vanadium (V)	<10	<10	<10	<10
Zinc (Zn)	10	<10	30	10
PAH on Leachate by GC/MS (SIM)				
2-Methylnaphthalene	<0.2	<0.2	<0.2	<0.2
Acenaphthene	<0.2	<0.2	<0.2	<0.2
Acenaphthylene	<0.2	<0.2	<0.2	<0.2
Acridine	<1	<1	<1	<1
Anthracene	<0.2	<0.2	<0.2	<0.2
Benzo(a)anthracene	<0.2	<0.2	<0.2	<0.2
Benzo(a)pyrene	<0.2	<0.2	<0.2	<0.2
Benzo(b&j)fluoranthene	<0.2	<0.2	<0.2	<0.2
Benzo(g,h,i)perylene	<0.4	<0.4	<0.4	<0.4
Benzo(k)fluoranthene	<0.2	<0.2	<0.2	<0.2
Chrysene	<0.2	<0.2	<0.2	<0.2
Dibenz(a,h)anthracene	<0.4	<0.4	<0.4	<0.4
Fluoranthene	<0.2	<0.2	<0.2	<0.2
Fluorene	<0.2	<0.2	<0.2	<0.2
Indeno(1,2,3-cd)pyrene	<0.4	<0.4	<0.4	<0.4
Naphthalene	<0.2	<0.2	<0.2	<0.2
Phenanthrene	<0.2	<0.2	<0.2	<0.2
Pyrene	<0.2	<0.2	<0.2	<0.2
Quinoline	<1	<1	<1	<1

NOTES:

All units are reported in micrograms per litre (ug/L).

APPENDIX B

Golder Investigation of WTA Soils – August 30 and 31, 2010

1.0 OVERVIEW

The following is a summary of field sampling activities conducted by Golder Associates Ltd. on August 30 and 31, 2010 at the soil cell of the current Waste Transfer Area (WTA) at Diavik Mine. Soil samples were collected from petroleum hydrocarbon (PHC)-contaminated soils that are current undergoing land-treatment at the WTA.

Characterization of the soils in the WTA generally followed the protocols described in the Draft Health Canada Guidance Manual for Environmental Site Characterization in Support of Human Health Risk Assessment[1]. A brief overview of the methods and results is provided below. The soil results are evaluated in detail in the main report.

2.0 METHODS

The soil cell of the WTA land-treatment area is a bermed square, measuring approximately 30 m x 30 m with an access road located along it's northern edge. For sampling purposes, the area was divided in to a 3 x 3 grid with each grid cell measuring approximately 10 m x 10 m. Within each grid cell, three shallow test pits were advanced to varying depths with the depth of each pit determined by the point at which coarse processed kimberlite (CPK), which overlies the geomembrane liner, was encountered.

Grid cells were identified by "vertical" columns (running north-south), labelled with A, B and C, west to east, and by "horizontal" rows (running west to east), labelled with 1, 2 or 3, north to south. Thus, the northwestern-most grid cell was labelled A1, while the southeastern-most grid cell was labelled C3. The grid scheme is summarized in the Figure B-1. Samples were collected from 0.5 m depth intervals, but given the shallow depth of the soils overlying CPK, most grid cells involved sampling of the surface 0.5 m only. At C3, both it was possible to sample both the 0 – 0.5 m interval, and the 0.5 – 1 m interval; these intervals were designated C3, and C3Deep, respectively.

Prior to sampling, field observations were made for each test pit, including:

- Test pit dimensions
- Depth to CPK
- Soil characteristics

Soil sampling for most analytes within each grid cell involved collection of a discrete sample of soil (approximately 250 ml) from a specific depth interval in each test pit (*i.e.,* 3 discretes for a given interval, per grid cell, one from each test pit). The three discrete samples were then combined in a composite to represent the particular depth interval for the entire grid cell. One field replicate sample was collected at grid cell B2. This involved collection of a separate composite sample from the grid cell according the method described above.

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[1] Golder Associates. 2007. Health Canada Guidance Manual for Environmental Site Characterization in Support of Human Health Risk Assessment: Volume 1 Technical Guidance. Report prepared for Health Canada. December 3, 2007.

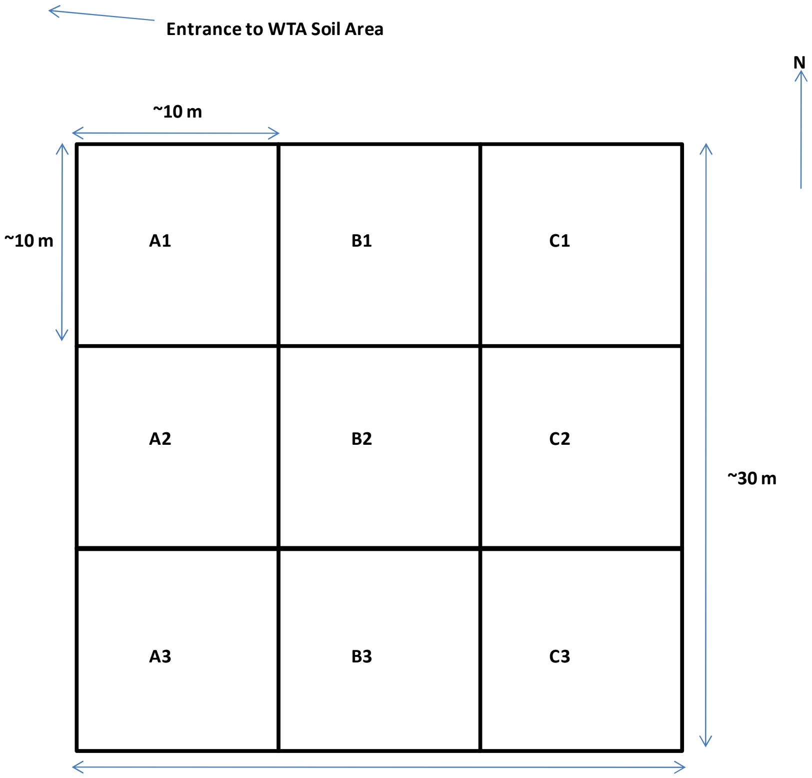

Figure B-1: Schematic of sampling design for the soil cell of the WTA

Composite samples from each grid cell/depth interval were submitted to Maxxam Analytical for the following analyses:

- CCME F2 – F4

In addition, a subset of the composite samples was also submitted to Maxxam Analytical for the following analyses:

- PAHs (B3, C1, C3, C3Deep).
- Metals (B3, C1, C3).
- Leachate procedure[2] and analysis of the leachate for CCME F2-F4, PAHs and metals (B3, C1, C3, C3Deep).
- Total organic carbon, total nitrogen, total phosphorous, and glycols (A2, B1, B2, C2, C3Deep).

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[2] USEPA's synthetic precipitation leaching procedure (SPLP), Method 1312.

Soil headspace testing was also conducted for each grid cell. This involved collection of a single half-full 125 ml jar from the depth interval of interest in two of the three test pits (randomly selected) in each grid cell. The lids of the retained samples were removed and the jar opening was sealed with aluminum foils. The samples were then agitated and allowed to site for approximately 15 minutes to allow headspace vapour to generate. The headspace vapour was then analyzed using a photo-ionization detector (PID), by piercing the aluminum foil with the PID probe. Soil samples were collected from the grid cells and test pits with the highest headspace readings (maximum of one test pit per grid cell). This involved transfer of soils from a given depth interval directly into a 125 ml jar. Each sample was submitted to Maxxam Analytical for the following analyses:

- CCME F1 (B1, B2, B3, C2, C3).
- Volatile organic chemicals, including BTEX (B1, B2, B3, C2, C3).

Method detection limits for all samples were sufficient to meet the CCME guidelines/standards for soils and surface waters.

3.0 RESULTS AND QA/QC

Field notes collected during the investigation are included in Attachment 1. Test pit sizes were approximately 1.3 m x 3-4 m. Table B-1 provides a summary of soil depths (overlying CPK) that were observed in each test pit. The depth of soil being land-treated ranged from 0.13 in A1 to 0.75 m in C3.

Table B-1: Summary of Observed Soil Depths Overlying CPK

	Depth to CPK (m)		
Cell	**TP 1**	**TP 2**	**Cell**
A1	0.44	0.43	A1
A2	0.44	0.4	A2
A3	0.44	0.36	A3
B1	0.32	0.3	B1
B2	0.48	0.35	B2
B3	0.58	0.5	B3
C1	0.25	0.27	C1
C2	0.6	0.52	C2
C3	0.75	0.75	C3

Observed soil texture was the same in each test pit, and consisted of a mix of sand and gravel, with low organic and water content. CPK consisted of coarse dark-colored sand. The depth to the water table varied depending on the location of the grid cell and this was due to sloping of the soil cell from southeast to northwest (*i.e.,* soil depth over CPK was higher in C3 than in A1).

The results of headspace testing are summarized in Table B-2.

Table B-2: Headspace Testing Results

Test Pit Number (Cell No - TP No)	Headspace Reading (ppm)	Sample Retained for Analysis?
C3-1	3.7	
C3-2	54	Yes
C3-1Deep	0.6	
C3-2Deep	4.7	
B3-1	27.2	Yes
B3-3	52	
A3-2	1.6	
A3-3	1	
C2-3	8.5	
C2-2	11.8	Yes
A2-1	1.4	
A2-2	2	
B2-1	9.5	Yes
B2-2	7.5	
Background (beginning of headspace testing)	0	
	0.3	
	0.9	
C1-1	3.1	
C1-2	4.4	
B1-1	7.9	Yes
B1-2	3.1	
A1-1	2.2	
A1-2	5.3	
Background (end of headspace testing)	0.3	
	0.8	
	1	

Headspace readings were highest for C3-2, B3-3, C2-2, B1-1, and B2-1 and samples were collected from these test pits for volatiles analysis.

The Maxxam laboratory report is included in Attachment 2 and the results are evaluated in detail in the main report (refer to Appendix A of the main report for a compilation of all of the data). Relative percent difference (RPD) was calculated for the replicate sample collected at B2 and the results are presented in Table 3. RPD ranged from 35.9% for CCME F2 to 70.3% for CCME F4. These values indicate the degree of variability in soil chemistry that might be expected within a given soil cell. Although the maximum RPD of 70.3% does indicate some variability, some degree of variability would be expected in a replicate sample due to the heterogeneous nature of soils, and the fact that the sample was a replicate (*i.e.,* separate sample) rather than a duplicate (split subsample from same homogenized soil sample). This degree of variability would not change the problem formulation conclusions or risk management approach for WTA soils and, therefore, characterization of soils in the WTA soil cell was considered adequate.

Table B-3: Estimates of RPD for Replicate Soil Samples

Sample ID	B-2	DUPLICATE	RPD
QA/QC	FD	FDA	
F2 (C10-C16 Hydrocarbons)	160	230	35.9%
F3 (C16-C34 Hydrocarbons)	1300	2400	59.5%
F4 (C34-C50 Hydrocarbons)	240	500	70.3%

Attachments: Attachment 1 - Field Notes
Attachment 2 - Maxxam Laboratory Report

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ATTACHMENT 1

Field Notes

Golder Associates

SUBJECT WTA SAMPLING GRID

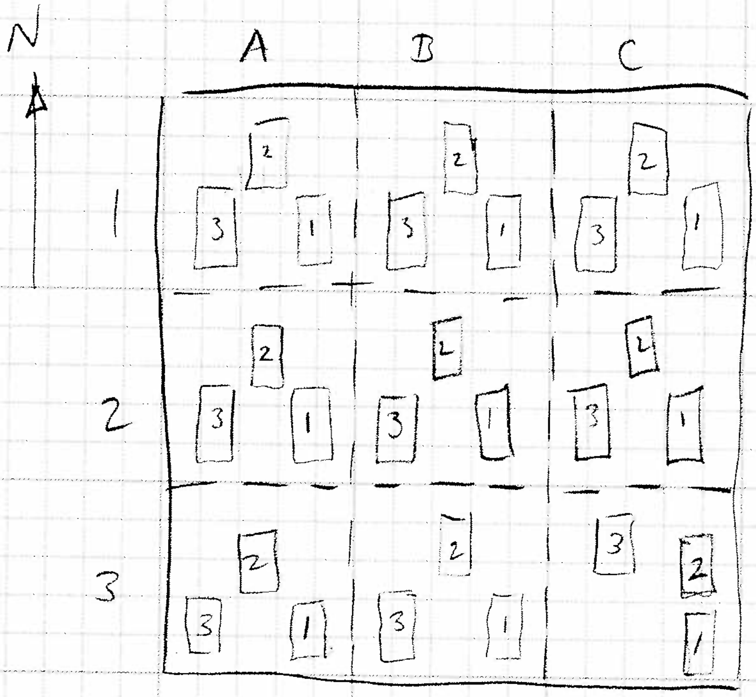
Job No. 10-1328-0023/6000

Made by

Reviewed

Date

Sheet of



FIELD TEST PIT LOG

Job No. 10-1328-0023/6000
Date AUG 30/2010 /2pm
Location C-3
Elev.
Reason for terminating hole ENCOUNTERED COARSE PK IN ALL (CPK)

Project DIAVIK WTA
Inspected by RWS
Excavation Method BACKHOE
Dimensions 1.3m WIDE × 3-4m

DEPTH	STRATUM DESCRIPTION	SAMPLE		REMARKS and TESTING
		No.	DEPTH	
	C3-1			
0	MIX OF SAND + GRAVEL			0.95m DEEP
↓				TP PHOTO 1
↓0.75				
↓0.95	CPK			
	WATER TABLE IN CPK LAYER			
	C3-2			TP [illegible] 2
0	MIX OF SAND + GRAVEL			TP PHOTO 2
↓				
0.75m				
↓0.9	CPK			TP PHOTO 3
	(WATER TABLE IN CPK)			
	C3-3			
0	MIX OF SAND + GRAVEL			TP PHOTO 3
|				
0.65				
↓0.95	CPK			

Depth to seepage

Rate of seepage

Depth to standing water

T.P. ______

FIELD TEST PIT LOG

Job No. 10~~B~~1328~~0~~0028

Project DIAVIK WTA

Date AUG 30/2010 / 245pm

Inspected by RWJ

Location B-3

Excavation Method BACKHOE

Elev.

Dimensions 1.3m × 3-4 m

Reason for terminating hole ENCOUNTERED CPK

DEPTH	STRATUM DESCRIPTION	SAMPLE		REMARKS and TESTING
		No.	DEPTH	
	B3			
	~~C~~-1			TP PHOTO 4
0	MIX OF SAND AND GRAVEL			0.85m DEEP.
	WATER TABLE AT ~0.8m			
0.58				
0.85	CPK			
	B3			
	~~C~~-2			
0	MIX OF SAND AND GRAVEL			TP PHOTO 5
	RAG IN FILL MATERIAL			
0.5				
0.65	CPK			
	B3			
	~~C~~-3			
0	MIX OF SAND + GRAVEL			TP PHOTO 6
				WATER TABLE AT
0.45				~0.7m
0.7	CPK			

Depth to seepage

Rate of seepage

Depth to standing water

T.P. ______

Golder Associates

FIELD TEST PIT LOG

Job No. 10-1328-0028
Date AUG 30/2010 / 3:08 pm
Location A3
Elev.
Reason for terminating hole ENCOUNTERED CPK

Project DIAVIK WTA
Inspected by TWS
Excavation Method BACKHOE
Dimensions 1.3 m x 3.4 m

DEPTH	STRATUM DESCRIPTION	SAMPLE		REMARKS and TESTING
		No.	DEPTH	
	SHALLOW TEST PITS (<0.5 m)			
	TP # TOTAL DEPTH DEPTH TO CPK			
	A3-1 0.55 m 0.44 m			
				PHOTO OF ALL
	A3-2 0.44 m 0.36 m			3 TEST PITS
	A3-3 0.42 m 0.34 m			
	TOOK 1 PHOTO OF ALL 3 TEST PITS			
	TOOK 1 PHOTO OF A3-1			
	(NO TAPE MEASURE IN SHOT)			
	(TP PHOTO 7)			
	MATERIAL IN TEST PITS IS			
	MIX OF SAND AND GRAVEL			
	OVERLYING COARSE PROCESSED			
	KIMBERLITE (CPK) = LINER MATERIAL			

Depth to seepage
Rate of seepage
Depth to standing water

T.P. ______

Golder Associates

FIELD TEST PIT LOG

Job No. 10-1328-0028/6000
Date AUG 30/2010 / 5pm
Location B-2
Elev.
Project DIAVIK WTA
Inspected by RWS
Excavation Method BACKHOE
Dimensions 1.3 × 8-9m
Reason for terminating hole ENCOUNTERED CPK

DEPTH	STRATUM DESCRIPTION	SAMPLE		REMARKS and TESTING
		No.	DEPTH	

SHALLOW TEST PITS (<0.5m)

TP#	TOTAL DEPTH	DEPTH TO CPK
B2-1	0.54m	0.48m
B2-2	44 0.[illegible]m	35 0.[illegible]m
B2-3	0.45m	0.40m

TOOK 1 PHOTO OF ALL 3 TEST PITS

SOIL MATERIAL IS MIX OF SAND + GRAVEL OVERLYING CPK

* TOOK DUPLICATE SAMPLE FROM COMPOSITE FOR B-2. LABELLED: "DUPLICATE"

Depth to seepage
Rate of seepage
Depth to standing water

T.P. ______

FIELD TEST PIT LOG

Job No. 10-1323-0028
Project DIAVIK WTA
Date AUG 30/2000 / 445pm
Inspected by RWS
Location C2
Excavation Method BACK HOE
Elev.
Dimensions 1.3m X 3-4m
Reason for terminating hole ENCOUNTERED CPK

DEPTH	STRATUM DESCRIPTION	SAMPLE		REMARKS and TESTING
		No.	DEPTH	
	C2-1			
0	MIX OF SAND + GRAVEL			TP PHOTO 8
↓ 0.6				
0.65	CPK			
	C2-2			
0	MIX OF SAND + GRAVEL			TP PHOTO 9
↓				
0.52				
	CPK RIGHT AT BOTTOM			
	C2-3			
0	MIX OF SAND + GRAVEL			TP PHOTO 10
↓ 0.48				
0.48	CPK			
↓ 0.6	↓			
	• SLIGHT HC ODOUR WHEN			
	MIXING COMPOSITE			

Depth to seepage
Rate of seepage
Depth to standing water

T.P. ______

Golder Associates

FIELD TEST PIT LOG

Job No. 10-1323-0023/6000
Project DIAVIK WTA
Date AUG 30/2010 / 515pm
Inspected by RWS
Location A2
Excavation Method BACKHOE
Elev.
Dimensions 1.3 × 3.4 m
Reason for terminating hole ENCOUNTERED PKD

DEPTH	STRATUM DESCRIPTION	SAMPLE		REMARKS and TESTING
		No.	DEPTH	
	SHALLOW TEST PITS (<0.5m)			
	TP TOTAL DEPTH DEPTH TO PKD			
	A2-1 0.5m 0.44m			
	A2-2 0.40m 0.40m			
	A2-3 0.28m 0.28m			
	SOIL MATERIAL IS MIX OF			
	SAND AND GRAVEL OVERLYING			
	CPK			

Depth to seepage
Rate of seepage
Depth to standing water

T.P. ______

Golder Associates

FIELD TEST PIT LOG

Job No. 10-1323-0028/6000
Project DIAVIK WTA
Date AUG 31/2010 / 833 am
Inspected by RWS
Location C1
Excavation Method BACKHOE
Elev.
Dimensions 1.3 m × 3-4 m
Reason for terminating hole ENCOUNTERED CPK

DEPTH	STRATUM DESCRIPTION	SAMPLE		REMARKS and TESTING
		No.	DEPTH	
	SHALLOW TEST PITS (<0.5m)			
	TP TOTAL DEPTH DEPTH TO CPK			
				TOOK PHOTO
	C1-1 0.33 m 0.25 m			OF WHOLE CORE
	C1-2 0.29 m 0.27 m			
	C1-3 0.43 m 0.32 m			
	SOIL MATERIAL IS MIX OF			
	SAND AND GRAVEL OVERLYING			
	CPK			
	CPK IS COARSE SAND (BLACK			
	COLOUR)			

Depth to seepage
Rate of seepage
Depth to standing water

T.P. ______

Golder Associates

FIELD TEST PIT LOG

Job No. 10-1328-0028/6000

Project DIAVIK WTA

Date AUG 31/2010 / 833am

Inspected by RWS

Location B-1

Excavation Method BACKHOE

Elev.

Dimensions 1.3 × 3-4m

Reason for terminating hole ENCOUNTERED CPK

DEPTH	STRATUM DESCRIPTION	SAMPLE		REMARKS and TESTING
		No.	DEPTH	
	SHALLOW TEST PITS (<0.5m)			
	TP TOTAL DEPTH DEPTH TO CPK			
	B1-1 0.42 m 0.32 m			
	B1-2 0.30 m 0.30 m			
	B1-3 0.36m 0.36m			
	SOIL MATERIAL IS MIX OF SAND			
	AND GRAVEL OVERLYING CPK			
	TOOK 3 PHOTOS - ONE FOR			
	EACH ROW (1, 2, 3)			

Depth to seepage

Rate of seepage

Depth to standing water

T.P. ______

FIELD TEST PIT LOG

Job No. 10 - 1328 - 0028/6000
Project DIAVIK WTA
Date AUG 31/2010/ 0835am
Inspected by RWS
Location A1
Excavation Method BACKHOE
Elev.
Dimensions 1.3 × 3-4 m
Reason for terminating hole ENCOUNTERED CPK

DEPTH	STRATUM DESCRIPTION	SAMPLE		REMARKS and TESTING
		No.	DEPTH	
	SHALLOW TEST PITS (<0.5m)			
	TP TOTAL DEPTH DEPTH TO CPK			
	A1-1 0.44m 0.44m			
	A1-2 0.43 m 0.43 m			
	A1-3 0.16 m 0.13 m			
	SURFACE MATERIAL IS MIX OF			
	SAND AND GRAVEL OVERLYING			
	CPK.			
	• LOWER 0.08m OF A1-1, A1-2			
	FILLED WITH SEEPAGE WATER			

Depth to seepage
Rate of seepage
Depth to standing water

T.P. ______

Golder Associates

HEADSPACE SCREENING DIAVIK WTA AUG 30/2010 10-1328-0028/6000

TP NUMBER	HS READING	TIME	SAMPLE RETAINED?	SUBMITTED FOR ANALYSIS?
C3-1S	3.7 ppm	~~473~~ 603 pm		
* C3-2S	54 ppm	~~436~~ 606 pm	YES	~~YES~~
C3-1D	0.6 ppm	64~~30~~ pm		
C3-2D	4.7 ppm	603 pm		
* B3-1	27.2 ppm	609 pm	YES	~~YES~~
B3-3	5.2 ppm	610 pm		
A3-2	1.6 ppm	612 pm		
A3-3	1.0 ppm	613 pm		
C2-3	8.5 ppm	614 pm		
* C2-2	11.8 ppm	615 pm	YES	~~YES~~
A2-1	1.4 ppm	617 pm		
A2-2	2.0 ppm	618 pm		
* B2-1	9.5 ppm	618 pm	YES	~~YES~~
B2-2	7.5 ppm	620 pm		
BACKGROUND	0.0 ppm 0.3 ppm 0.9 ppm	6 pm 603 pm 666 pm		
C1-1	3.1 ppm	648 pm		
C1-2	4.4 ppm	648 pm		
* B1-1	7.9 ppm	650 pm	YES	~~YES~~
B1-2	3.1 ppm	652 pm		
A1-1	2.2 ppm	654 pm		
A1-2	5.3 ppm	655 pm		
BACKGROUND	0.3 ppm ~~0.88 ppm~~ 0.8 ppm 1.0 ppm	645 pm 650 pm 655 pm		

ATTACHMENT 2

Maxxam Laboratory Report

Driven by service and Science
www.maxxamanalytics.com

Your C.O.C. #: 5454, 5453

Attention: Ryan Stevenson
GOLDER ASSOCIATES LTD
4260 STILL CREEK DRIVE
Suite 500
BURNABY, BC
Canada V5C 6C6

Report Date: 2010/09/17

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B081535
Received: 2010/09/07, 12:30

Sample Matrix: Soil
Samples Received: 11

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Volatile F1-BTEX	4	N/A	2010/09/09		
Volatile F1-BTEX	1	N/A	2010/09/10		
CCME Hydrocarbons (F2-F4 in soil)	11	2010/09/08	2010/09/09	BRN SOP-00342 R9.0	CCME Soil Tier 1
CCME Hydrocarbons (F2-F4 in water)	4	2010/09/15	2010/09/16	BRN SOP-00342 R9.0	CCME Soil Tier1
Ethylene, Di, Tri & Tetraethylene glycol	5	2010/09/08	2010/09/08	BRN SOP-00307R6	Based on EPA 8015B
Elements by ICPMS (total)	5	2010/09/09	2010/09/09	BRN SOP-00203 R5.0	Based on EPA 200.8
Elements by ICPMS (total)	3	2010/09/14	2010/09/14	BRN SOP-00203 R5.0	Based on EPA 200.8
Metals - SPLP	4	2010/09/16	2010/09/16	BRN SOP 00206 R7.0	Based on EPA 200.8
Moisture	11	N/A	2010/09/09	BRN SOP-00321 R5.0	Ont MOE -E 3139
PAH on Leachate by GC/MS (SIM)	4	2010/09/14	2010/09/17	BRN SOP-00331 R11.0	Based on EPA 8270D
PAH in Soil by GC/MS (SIM)	4	2010/09/13	2010/09/14	BRN SOP-00332 R9.0	Based on EPA 8270D
Total LMW, HMW, Total PAH Calc	4	N/A	2010/09/17		
Total LMW, HMW, Total PAH Calc	4	N/A	2010/09/16		PAHTOT-S
pH (2:1 DI Water Extract)	5	2010/09/09	2010/09/10	BRN SOP-00266 R6.0	Carter, SSMA 16.2
pH (2:1 DI Water Extract)	3	2010/09/14	2010/09/14	BRN SOP-00266 R6.0	Carter, SSMA 16.2
CCME F1 C6-C10 in Soil by GC/FID	4	2010/09/08	2010/09/08		Based on EPA SW8260B
CCME F1 C6-C10 in Soil by GC/FID	1	2010/09/08	2010/09/09		Based on EPA SW8260B
Total Organic Carbon LECO Method (1)	5	2010/09/12	2010/09/13	EENVSOP-00151	LECO# 203-821-170
VOCs in Soil by HS GC/MS	5	2010/09/08	2010/09/08	BRN SOP-00311 R8.0	Based on EPA 8260B

* Results relate only to the items tested.

(1) This test was performed by Maxxam Edmonton Environmental

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

VJ OCO, Burnaby Customer Service
Email: VJ.Oco@MaxxamAnalytics.com
Phone# (604) 639-8422

==
Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.
Total cover pages: 1

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		W78357	W78358	W78359	W78360	W78365		
Sampling Date		2010/08/31 08:30	2010/08/31 08:40	2010/08/30 16:00	2010/08/30 17:00	2010/08/30 19:00		
	Units	**B-2**	**A-2**	**C-2**	**C-3DEEP**	**B-1**	**RDL**	**QC Batch**
Misc. Inorganics								
Soluble (2:1) pH	pH Units	7.96	8.60	8.77	8.78	8.18	0.01	4245167

PETROLEUM HYDROCARBONS (CCME)

Maxxam ID		W78357	W78358	W78359	W78360		W78361		
Sampling Date		2010/08/31 08:30	2010/08/31 08:40	2010/08/30 16:00	2010/08/30 17:00		2010/08/30 14:00		
	Units	**B-2**	**A-2**	**C-2**	**C-3DEEP**	**RDL**	**C-3**	**RDL**	**QC Batch**
Extractable Hydrocarbons									
F2 (C10-C16 Hydrocarbons)	mg/L				<0.1(1)	0.1	<0.1(1)	0.1	4259524
F3 (C16-C34 Hydrocarbons)	mg/L				<0.1(1)	0.1	<0.08(1)	0.08	4259524
F4 (C34-C50 Hydrocarbons)	mg/L				<5(1)	5	<5(1)	5	4259524
Ext. Pet. Hydrocarbon									
F2 (C10-C16 Hydrocarbons)	mg/kg	160	59	240	600	10	2700	10	4245034
F3 (C16-C34 Hydrocarbons)	mg/kg	1300	2000	810	9400	10	2700	10	4245034
F4 (C34-C50 Hydrocarbons)	mg/kg	240	260	150	670	10	240	10	4245034
Reached Baseline at C50	mg/kg	YES	YES	YES	YES	N/A	YES	N/A	4245034
Surrogate Recovery (%)									
O-TERPHENYL (sur.)	%	93	104	87	85		100		4245034

N/A = Not Applicable
RDL = Reportable Detection Limit
(1) - RDL raised due to insufficient sample volume.

PETROLEUM HYDROCARBONS (CCME)

Maxxam ID		W78362	W78363	W78364	W78365	W78366		W78367		
Sampling Date		2010/08/31 08:45	2010/08/30 15:00	2010/08/30 19:00	2010/08/30 19:00	2010/08/30 19:00		2010/08/30 14:30		
	Units	**DUPLICATE**	**A-3**	**C-1**	**B-1**	**A-1**	**RDL**	**B-3**	**RDL**	**QC Batch**
Extractable Hydrocarbons										
F2 (C10-C16 Hydrocarbons)	mg/L			<0.1(1)			0.1	<0.1(1)	0.1	4259524
F3 (C16-C34 Hydrocarbons)	mg/L			<0.08(1)			0.08	<0.08(1)	0.08	4259524
F4 (C34-C50 Hydrocarbons)	mg/L			<5(1)			5	<5(1)	5	4259524
Ext. Pet. Hydrocarbon										
F2 (C10-C16 Hydrocarbons)	mg/kg	230	210	520	220	110	10	3800(2)	40	4245034
F3 (C16-C34 Hydrocarbons)	mg/kg	2400	3800	3800	1100	3500	10	42000(2)	40	4245034
F4 (C34-C50 Hydrocarbons)	mg/kg	500	360	520	190	590	10	9600(2)	40	4245034
Reached Baseline at C50	mg/kg	YES	YES	YES	YES	YES	N/A	YES	N/A	4245034
Surrogate Recovery (%)										
O-TERPHENYL (sur.)	%	93	90	92	89	93		76		4245034

GLYCOLS BY GC-FID (SOIL)

Maxxam ID		W78357	W78358	W78359	W78360	W78365		
Sampling Date		2010/08/31 08:30	2010/08/31 08:40	2010/08/30 16:00	2010/08/30 17:00	2010/08/30 19:00		
	Units	**B-2**	**A-2**	**C-2**	**C-3DEEP**	**B-1**	**RDL**	**QC Batch**
Glycols								
Extractable (Water) Ethylene Glycol	mg/kg	<10	<10	13	37	<10	10	4244123
Extractable (Water) Diethylene Glycol	mg/kg	<10	<10	<10	<10	<10	10	4244123
Extractable (Water) Triethylene Glycol	mg/kg	<10	<10	<10	<10	<10	10	4244123
Extractable (Water) Tetraethylene Glycol	mg/kg	<10	<10	<10	<10	<10	10	4244123
Extractable (Water) Propylene Glycol	mg/kg	<10	<10	<10	<10	<10	10	4244123
Surrogate Recovery (%)								
Extractable (Water) SULFOLANE (sur.)	%	103	97	93	99	105		4244123

N/A = Not Applicable
RDL = Reportable Detection Limit
(1) - RDL raised due to insufficient sample volume.
(2) - RDL raised due to dilution to bring analyte within the calibrated range.

PHYSICAL TESTING (SOIL)

Maxxam ID		W78357		W78358	W78359	W78360		W78361		W78362	W78363		
Sampling Date		2010/08/31 08:30		2010/08/31 08:40	2010/08/30 16:00	2010/08/30 17:00		2010/08/30 14:00		2010/08/31 08:45	2010/08/30 15:00		
	Units	**B-2**	**QC Batch**	**A-2**	**C-2**	**C-3DEEP**	**QC Batch**	**C-3**	**QC Batch**	**DUPLICATE**	**A-3**	**RDL**	**QC Batch**
Physical Properties													
Moisture	%	8.3	4241103	8.6	6.7	7.2	4241105	3.6	4241103	10	9.5	0.3	4241105

Maxxam ID		W78364		W78365		W78366		W78367		
Sampling Date		2010/08/30 19:00		2010/08/30 19:00		2010/08/30 19:00		2010/08/30 14:30		
	Units	**C-1**	**QC Batch**	**B-1**	**QC Batch**	**A-1**	**QC Batch**	**B-3**	**RDL**	**QC Batch**
Physical Properties										
Moisture	%	8.9	4241105	5.9	4241103	8.7	4241105	15	0.3	4241103

ELEMENTS BY ATOMIC SPECTROSCOPY (SOIL)

Maxxam ID		W78357	W78358	W78359	W78365		
Sampling Date		2010/08/31 08:30	2010/08/31 08:40	2010/08/30 16:00	2010/08/30 19:00		
	Units	**B-2**	**A-2**	**C-2**	**B-1**	**RDL**	**QC Batch**
Total Metals by ICPMS							
Total Phosphorus (P)	mg/kg	820	1000	999	1010	10	4245113

MISCELLANEOUS (SOIL)

Maxxam ID		W78357	W78358	W78359	W78360	W78365		
Sampling Date		2010/08/31 08:30	2010/08/31 08:40	2010/08/30 16:00	2010/08/30 17:00	2010/08/30 19:00		
	Units	**B-2**	**A-2**	**C-2**	**C-3DEEP**	**B-1**	**RDL**	**QC Batch**
Misc. Inorganics								
Total Organic Carbon (C)	%	0.46	0.35	0.27	0.74	0.60	0.02	4253100

RDL = Reportable Detection Limit

CSR/CCME METALS IN SOIL (SOIL)

Maxxam ID		W78360		W78361	W78364	W78367		
Sampling Date		2010/08/30 17:00		2010/08/30 14:00	2010/08/30 19:00	2010/08/30 14:30		
	Units	**C-3DEEP**	**QC Batch**	**C-3**	**C-1**	**B-3**	**RDL**	**QC Batch**
Misc. Inorganics								
Soluble (2:1) pH	pH Units			7.30	8.59	8.30	0.01	4257931
Total Metals by ICPMS								
Total Aluminum (Al)	mg/kg			6070	6760	8960	100	4257360
Total Antimony (Sb)	mg/kg			0.8	0.6	3.3	0.1	4257360
Total Arsenic (As)	mg/kg			1.2	2.5	9.2	0.2	4257360
Total Barium (Ba)	mg/kg			53.5	98.2	234	0.1	4257360
Total Beryllium (Be)	mg/kg			0.2	0.1	0.3	0.1	4257360
Total Bismuth (Bi)	mg/kg			3.0	0.9	0.5	0.1	4257360
Total Cadmium (Cd)	mg/kg			0.09	0.15	0.33	0.05	4257360
Total Calcium (Ca)	mg/kg			2150	3850	8750	100	4257360
Total Chromium (Cr)	mg/kg			22	55	146	1	4257360
Total Cobalt (Co)	mg/kg			4.7	11.2	22.9	0.3	4257360
Total Copper (Cu)	mg/kg			10.0	13.4	66.5	0.5	4257360
Total Iron (Fe)	mg/kg			10300	13800	47100	100	4257360
Total Lead (Pb)	mg/kg			6.4	5.6	9.1	0.1	4257360
Total Magnesium (Mg)	mg/kg			6780	21800	45200	100	4257360
Total Manganese (Mn)	mg/kg			159	203	674	0.2	4257360
Total Mercury (Hg)	mg/kg			<0.05	<0.05	<0.05	0.05	4257360
Total Molybdenum (Mo)	mg/kg			3.1	44.8	140	0.1	4257360
Total Nickel (Ni)	mg/kg			34.7	143	338	0.8	4257360
Total Phosphorus (P)	mg/kg	946	4245113	1050	678	728	10	4257360
Total Potassium (K)	mg/kg			3370	3870	3000	100	4257360
Total Selenium (Se)	mg/kg			<0.5	<0.5	0.7	0.5	4257360
Total Silver (Ag)	mg/kg			<0.05	<0.05	0.10	0.05	4257360
Total Sodium (Na)	mg/kg			<100	273	373	100	4257360
Total Strontium (Sr)	mg/kg			10.0	39.3	96.2	0.1	4257360
Total Thallium (Tl)	mg/kg			0.23	0.23	0.20	0.05	4257360
Total Tin (Sn)	mg/kg			0.6	0.5	2.3	0.1	4257360
Total Titanium (Ti)	mg/kg			377	593	657	1	4257360
Total Vanadium (V)	mg/kg			13	18	36	2	4257360
Total Zinc (Zn)	mg/kg			44	52	166	1	4257360
Total Zirconium (Zr)	mg/kg			<0.5	2.3	3.3	0.5	4257360

RDL = Reportable Detection Limit

SPLP METALS (SOIL)

Maxxam ID		W78360	W78361	W78364	W78367		
Sampling Date		2010/08/30 17:00	2010/08/30 14:00	2010/08/30 19:00	2010/08/30 14:30		
	Units	**C-3DEEP**	**C-3**	**C-1**	**B-3**	**RDL**	**QC Batch**
Metals							
Leachable Aluminum (Al)	mg/L	0.42	0.53	0.09	0.84	0.02	4265796
Leachable Antimony (Sb)	mg/L	<0.001	0.001	0.004	0.016	0.001	4265796
Leachable Arsenic (As)	mg/L	<0.001	0.001	0.002	0.002	0.001	4265796
Leachable Barium (Ba)	mg/L	<0.1	<0.1	<0.1	<0.1	0.1	4265796
Leachable Beryllium (Be)	mg/L	<0.001	<0.001	<0.001	<0.001	0.001	4265796
Leachable Boron (B)	mg/L	<0.5	<0.5	<0.5	<0.5	0.5	4265796
Leachable Cadmium (Cd)	mg/L	<0.00002	0.00006	0.00003	0.00006	0.00002	4265796
Leachable Calcium (Ca)	mg/L	3	5	11	8	1	4265796
Leachable Chromium (Cr)	mg/L	0.002	0.006	<0.001	0.002	0.001	4265796
Leachable Cobalt (Co)	mg/L	<0.001	0.002	<0.001	<0.001	0.001	4265796
Leachable Copper (Cu)	mg/L	0.002	0.017	<0.002	<0.002	0.002	4265796
Leachable Iron (Fe)	mg/L	0.39	2.09	0.06	0.61	0.05	4265796
Leachable Lead (Pb)	mg/L	0.002	0.005	<0.001	0.001	0.001	4265796
Leachable Magnesium (Mg)	mg/L	1	3	17	5	1	4265796
Leachable Manganese (Mn)	mg/L	0.006	0.027	<0.005	0.008	0.005	4265796
Leachable Mercury (Hg)	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	4265796
Leachable Molybdenum (Mo)	mg/L	0.005	<0.005	0.043	0.019	0.005	4265796
Leachable Nickel (Ni)	mg/L	<0.01	0.02	<0.01	0.01	0.01	4265796
Leachable Selenium (Se)	mg/L	<0.001	<0.001	<0.001	<0.001	0.001	4265796
Leachable Sodium (Na)	mg/L	8	8	12	14	1	4265796
Leachable Silver (Ag)	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	4265796
Leachable Thallium (Tl)	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	4265796
Leachable Titanium (Ti)	mg/L	<0.1	<0.1	<0.1	<0.1	0.1	4265796
Leachable Uranium (U)	mg/L	0.003	0.013	0.003	0.007	0.001	4265796
Leachable Vanadium (V)	mg/L	<0.01	<0.01	<0.01	<0.01	0.01	4265796
Leachable Zinc (Zn)	mg/L	0.01	0.03	<0.01	0.01	0.01	4265796

RDL = Reportable Detection Limit

PAH IN SOIL BY GC-MS (SOIL)

Maxxam ID		W78360		W78361		W78364		W78367		
Sampling Date		2010/08/30 17:00		2010/08/30 14:00		2010/08/30 19:00		2010/08/30 14:30		
	Units	**C-3DEEP**	**RDL**	**C-3**	**RDL**	**C-1**	**RDL**	**B-3**	**RDL**	**QC Batch**
Polycyclic Aromatics										
Naphthalene	mg/kg	<0.03(1)	0.03	<0.2(1)	0.2	<0.04(1)	0.04	<0.4(1)	0.4	4257238
2-Methylnaphthalene	mg/kg	<0.01	0.01	<0.05(1)	0.05	<0.02(1)	0.02	0.99	0.01	4257238
Acenaphthylene	mg/kg	<0.02(1)	0.02	<0.04(1)	0.04	<0.02(1)	0.02	<0.1(1)	0.1	4257238
Acenaphthene	mg/kg	<0.01	0.01	0.11	0.01	<0.02(1)	0.02	0.18	0.01	4257238
Fluorene	mg/kg	0.03	0.01	0.17	0.01	0.03	0.01	0.41	0.01	4257238
Phenanthrene	mg/kg	<0.01	0.01	<0.04(1)	0.04	0.01	0.01	0.53	0.01	4257238
Anthracene	mg/kg	<0.01	0.01	<0.08(1)	0.08	<0.01	0.01	<0.03(1)	0.03	4257238
Fluoranthene	mg/kg	<0.01	0.01	0.02	0.01	<0.01	0.01	<0.06(1)	0.06	4257238
Pyrene	mg/kg	<0.02(1)	0.02	0.15	0.01	<0.03(1)	0.03	<0.2(1)	0.2	4257238
Benzo(a)anthracene	mg/kg	<0.01	0.01	<0.01	0.01	<0.01	0.01	<0.01	0.01	4257238
Chrysene	mg/kg	<0.01	0.01	0.02	0.01	<0.01	0.01	0.04	0.01	4257238
Benzo(b&j)fluoranthene	mg/kg	<0.04(1)	0.04	<0.02(1)	0.02	<0.01	0.01	<0.3(1)	0.3	4257238
Benzo(k)fluoranthene	mg/kg	<0.03(1)	0.03	<0.01	0.01	<0.01	0.01	<0.06(1)	0.06	4257238
Benzo(a)pyrene	mg/kg	<0.02(1)	0.02	<0.01	0.01	<0.01	0.01	<0.2(1)	0.2	4257238
Indeno(1,2,3-cd)pyrene	mg/kg	<0.02	0.02	<0.02	0.02	<0.02	0.02	<0.02	0.02	4257238
Dibenz(a,h)anthracene	mg/kg	<0.02	0.02	<0.02	0.02	<0.02	0.02	<0.02	0.02	4257238
Benzo(g,h,i)perylene	mg/kg	<0.02	0.02	<0.02	0.02	<0.02	0.02	<0.02	0.02	4257238
Low Molecular Weight PAH`s	mg/kg	<0.03	0.03	0.3	0.2	0.04	0.04	2.1	0.4	4254000
High Molecular Weight PAH`s	mg/kg	<0.04	0.04	0.20	0.02	<0.03	0.03	<0.3	0.3	4254000
Total PAH	mg/kg	<0.04	0.04	0.5	0.2	0.04	0.04	2.1	0.4	4254000
Surrogate Recovery (%)										
D10-ANTHRACENE (sur.)	%	97		92		94		88		4257238
D12-BENZO(A)PYRENE (sur.)	%	102		99		98		117		4257238
D8-ACENAPHTHYLENE (sur.)	%	100		102		99		93		4257238
D8-NAPHTHALENE (sur.)	%	97		96		94		83		4257238
TERPHENYL-D14 (sur.)	%	103		99		98		94		4257238

RDL = Reportable Detection Limit
(1) - RDL raised due to sample matrix interference.

PAH IN LEACHATE BY GC-MS (SOIL)

Maxxam ID		W78360	W78361	W78364	W78367		
Sampling Date		2010/08/30 17:00	2010/08/30 14:00	2010/08/30 19:00	2010/08/30 14:30		
	Units	**C-3DEEP**	**C-3**	**C-1**	**B-3**	**RDL**	**QC Batch**
Polycyclic Aromatics							
Low Molecular Weight PAH`s	ug/L	<1	<1	<1	<1	1	4259000
High Molecular Weight PAH`s	ug/L	<0.4	<0.4	<0.4	<0.4	0.4	4259000
Total PAH	ug/L	<1	<1	<1	<1	1	4259000
Naphthalene	ug/L	<0.2(1)	<0.2(1)	<0.2(1)	<0.2(1)	0.2	4259375
2-Methylnaphthalene	ug/L	<0.2(1)	<0.2(1)	<0.2(1)	<0.2(1)	0.2	4259375
Quinoline	ug/L	<1(1)	<1(1)	<1(1)	<1(1)	1	4259375
Acenaphthylene	ug/L	<0.2(1)	<0.2(1)	<0.2(1)	<0.2(1)	0.2	4259375
Acenaphthene	ug/L	<0.2(1)	<0.2(1)	<0.2(1)	<0.2(1)	0.2	4259375
Fluorene	ug/L	<0.2(1)	<0.2(1)	<0.2(1)	<0.2(1)	0.2	4259375
Phenanthrene	ug/L	<0.2(1)	<0.2(1)	<0.2(1)	<0.2(1)	0.2	4259375
Anthracene	ug/L	<0.2(1)	<0.2(1)	<0.2(1)	<0.2(1)	0.2	4259375
Acridine	ug/L	<1(1)	<1(1)	<1(1)	<1(1)	1	4259375
Fluoranthene	ug/L	<0.2(1)	<0.2(1)	<0.2(1)	<0.2(1)	0.2	4259375
Pyrene	ug/L	<0.2(1)	<0.2(1)	<0.2(1)	<0.2(1)	0.2	4259375
Benzo(a)anthracene	ug/L	<0.2(1)	<0.2(1)	<0.2(1)	<0.2(1)	0.2	4259375
Chrysene	ug/L	<0.2(1)	<0.2(1)	<0.2(1)	<0.2(1)	0.2	4259375
Benzo(b&j)fluoranthene	ug/L	<0.2(1)	<0.2(1)	<0.2(1)	<0.2(1)	0.2	4259375
Benzo(k)fluoranthene	ug/L	<0.2(1)	<0.2(1)	<0.2(1)	<0.2(1)	0.2	4259375
Benzo(a)pyrene	ug/L	<0.2(1)	<0.2(1)	<0.2(1)	<0.2(1)	0.2	4259375
Indeno(1,2,3-cd)pyrene	ug/L	<0.4(1)	<0.4(1)	<0.4(1)	<0.4(1)	0.4	4259375
Dibenz(a,h)anthracene	ug/L	<0.4(1)	<0.4(1)	<0.4(1)	<0.4(1)	0.4	4259375
Benzo(g,h,i)perylene	ug/L	<0.4(1)	<0.4(1)	<0.4(1)	<0.4(1)	0.4	4259375
Surrogate Recovery (%)							
D10-ANTHRACENE (sur.)	%	83	77	78	78		4259375
D12-BENZO(A)PYRENE (sur.)	%	86	78	82	84		4259375
D8-ACENAPHTHYLENE (sur.)	%	75	65	68	62		4259375
D8-NAPHTHALENE (sur.)	%	74	64	67	60		4259375
TERPHENYL-D14 (sur.)	%	87	77	81	84		4259375

RDL = Reportable Detection Limit
(1) - RDL raised due to limited initial sample amount.

CCME VOC + F1 IN SOIL (SOIL)

Maxxam ID		W78357	W78359	W78361		W78365		W78367		
Sampling Date		2010/08/31 08:30	2010/08/30 16:00	2010/08/30 14:00		2010/08/30 19:00		2010/08/30 14:30		
	Units	**B-2**	**C-2**	**C-3**	**RDL**	**B-1**	**RDL**	**B-3**	**RDL**	**QC Batch**
Calculated Parameters										
F1 (C6-C10) - BTEX	mg/kg	<10	<10	39	10	<40	40	120	10	4239914
Chlorobenzenes										
1,2-dichlorobenzene	mg/kg	<0.03(1)	<0.03(2)	<0.03(2)	0.03	<0.03(2)	0.03	<0.03(2)	0.03	4241773
1,3-dichlorobenzene	mg/kg	<0.03(1)	<0.03(2)	<0.03(2)	0.03	<0.03(2)	0.03	<0.03(2)	0.03	4241773
1,4-dichlorobenzene	mg/kg	<0.03(1)	<0.03(2)	<0.03(2)	0.03	<0.03(2)	0.03	<0.03(2)	0.03	4241773
Chlorobenzene	mg/kg	<0.03(1)	<0.03(2)	<0.03(2)	0.03	<0.03(2)	0.03	<0.03(2)	0.03	4241773
Monocyclic Aromatics										
Benzene	mg/kg	<0.005(1)	<0.005(2)	<0.005(2)	0.005	<0.005(2)	0.005	<0.008(3)	0.008	4241773
Ethylbenzene	mg/kg	<0.01(1)	<0.01(2)	<0.01(2)	0.01	<0.01(2)	0.01	0.26(2)	0.01	4241773
m & p-Xylene	mg/kg	<0.1(1)	<0.1(2)	<0.1(2)	0.1	<0.1(2)	0.1	0.5(2)	0.1	4241773
o-Xylene	mg/kg	<0.1(1)	<0.1(2)	<0.1(2)	0.1	<0.1(2)	0.1	1.1(2)	0.1	4241773
Styrene	mg/kg	<0.1(1)	<0.1(2)	<0.1(2)	0.1	<0.1(2)	0.1	<0.2(3)	0.2	4241773
Toluene	mg/kg	<0.03(1)	<0.03(2)	<0.03(2)	0.03	<0.03(2)	0.03	0.06(2)	0.03	4241773
Xylenes (Total)	mg/kg	<0.1	<0.1	<0.1	0.1	<0.1	0.1	1.6	0.1	4241773

RDL = Reportable Detection Limit
(1) - Sample extracted past recommended hold time (7 days) - Pot. Low bias
(2) - Sample received past recommended hold time (7 days) - Pot. Low bias
(3) - Sample received past recommended hold time (7 days) - Pot. Low bias
RDL raised due to sample matrix interference.

CCME VOC + F1 IN SOIL (SOIL)

Maxxam ID		W78357	W78359	W78361		W78365		W78367		
Sampling Date		2010/08/31 08:30	2010/08/30 16:00	2010/08/30 14:00		2010/08/30 19:00		2010/08/30 14:30		
	Units	**B-2**	**C-2**	**C-3**	**RDL**	**B-1**	**RDL**	**B-3**	**RDL**	**QC Batch**
Volatiles										
1,1,1,2-tetrachloroethane	mg/kg	<0.03(1)	<0.03(2)	<0.03(2)	0.03	<0.03(2)	0.03	<0.03(2)	0.03	4241773
1,1,1-trichloroethane	mg/kg	<0.03(1)	<0.03(2)	<0.03(2)	0.03	<0.03(2)	0.03	<0.03(2)	0.03	4241773
1,1,2,2-tetrachloroethane	mg/kg	<0.03(1)	<0.03(2)	<0.03(2)	0.03	<0.03(2)	0.03	<0.03(2)	0.03	4241773
1,1,2-trichloroethane	mg/kg	<0.03(1)	<0.03(2)	<0.03(2)	0.03	<0.03(2)	0.03	<0.03(2)	0.03	4241773
1,1-dichloroethane	mg/kg	<0.03(1)	<0.03(2)	<0.03(2)	0.03	<0.03(2)	0.03	<0.03(2)	0.03	4241773
1,1-dichloroethene	mg/kg	<0.03(1)	<0.03(2)	<0.03(2)	0.03	<0.03(2)	0.03	<0.03(2)	0.03	4241773
1,2-dichloroethane	mg/kg	<0.03(1)	<0.03(2)	<0.03(2)	0.03	<0.03(2)	0.03	<0.03(2)	0.03	4241773
1,2-dichloropropane	mg/kg	<0.03(1)	<0.03(2)	<0.03(2)	0.03	<0.03(2)	0.03	<0.03(2)	0.03	4241773
Bromodichloromethane	mg/kg	<0.05(1)	<0.05(2)	<0.05(2)	0.05	<0.05(2)	0.05	<0.05(2)	0.05	4241773
Bromoform	mg/kg	<0.05(1)	<0.05(2)	<0.05(2)	0.05	<0.05(2)	0.05	<0.05(2)	0.05	4241773
Bromomethane	mg/kg	<0.3(1)	<0.3(2)	<0.3(2)	0.3	<0.3(2)	0.3	<0.3(2)	0.3	4241773
Carbon tetrachloride	mg/kg	<0.03(1)	<0.03(2)	<0.03(2)	0.03	<0.03(2)	0.03	<0.03(2)	0.03	4241773
Chlorodibromomethane	mg/kg	<0.05(1)	<0.05(2)	<0.05(2)	0.05	<0.05(2)	0.05	<0.05(2)	0.05	4241773
Chloroethane	mg/kg	<0.1(1)	<0.1(2)	<0.1(2)	0.1	<0.1(2)	0.1	<0.1(2)	0.1	4241773
Chloroform	mg/kg	<0.05(1)	<0.05(2)	<0.05(2)	0.05	<0.05(2)	0.05	<0.05(2)	0.05	4241773
Chloromethane	mg/kg	<0.1(1)	<0.1(2)	<0.1(2)	0.1	<0.1(2)	0.1	<0.1(2)	0.1	4241773
cis-1,2-dichloroethene	mg/kg	<0.03(1)	<0.03(2)	<0.03(2)	0.03	<0.03(2)	0.03	<0.03(2)	0.03	4241773
cis-1,3-dichloropropene	mg/kg	<0.05(1)	<0.05(2)	<0.05(2)	0.05	<0.05(2)	0.05	<0.05(2)	0.05	4241773
Dibromoethane	mg/kg	<0.03(1)	<0.03(2)	<0.03(2)	0.03	<0.03(2)	0.03	<0.03(3)	0.03	4241773
Dichloromethane	mg/kg	<0.1(1)	<0.1(2)	<0.1(2)	0.1	<0.1(2)	0.1	<0.1(2)	0.1	4241773
Methyl-tert-butylether (MTBE)	mg/kg	<0.1(1)	<0.1(2)	<0.1(2)	0.1	<0.1(2)	0.1	<0.1(2)	0.1	4241773
Tetrachloroethene	mg/kg	<0.03(1)	<0.03(2)	<0.03(2)	0.03	<0.03(2)	0.03	<0.03(2)	0.03	4241773
trans-1,2-dichloroethene	mg/kg	<0.03(1)	<0.03(2)	<0.03(2)	0.03	<0.03(2)	0.03	<0.03(2)	0.03	4241773
trans-1,3-dichloropropene	mg/kg	<0.05(1)	<0.05(2)	<0.05(2)	0.05	<0.05(2)	0.05	<0.05(2)	0.05	4241773
Trichloroethene	mg/kg	<0.01(1)	<0.01(2)	<0.01(2)	0.01	<0.01(2)	0.01	<0.01(2)	0.01	4241773
Trichlorofluoromethane	mg/kg	<0.2(1)	<0.2(2)	<0.2(2)	0.2	<0.2(2)	0.2	<0.2(2)	0.2	4241773
Vinyl chloride	mg/kg	<0.06(1)	<0.06(2)	<0.06(2)	0.06	<0.06(2)	0.06	<0.06(2)	0.06	4241773
Volatile Hydrocarbons										
(C6-C10)	mg/kg	<10(1)	<10(2)	39(2)	10	<40(4)	40	130(2)	10	4243203

RDL = Reportable Detection Limit

(1) - Sample extracted past recommended hold time (7 days) - Pot. Low bias

(2) - Sample received past recommended hold time (7 days) - Pot. Low bias

(3) - Sample received past recommended hold time (7 days) - Pot. Low bias
RDL raised due to sample matrix interference.

(4) - Sample received past recommended hold time (7 days) - Pot. Low bias
RDL raised due to background artifacts detected in analysis

CCME VOC + F1 IN SOIL (SOIL)

Maxxam ID		W78357	W78359	W78361		W78365		W78367		
Sampling Date		2010/08/31 08:30	2010/08/30 16:00	2010/08/30 14:00		2010/08/30 19:00		2010/08/30 14:30		
	Units	**B-2**	**C-2**	**C-3**	**RDL**	**B-1**	**RDL**	**B-3**	**RDL**	**QC Batch**
Surrogate Recovery (%)										
4-BROMOFLUOROBENZENE (sur.)	%	81	91	105		83		108		4241773
D10-ETHYLBENZENE (sur.)	%	78	83	88		74		88		4241773
D4-1,2-DICHLOROETHANE (sur.)	%	110	109	98		101		94		4241773
D8-TOLUENE (sur.)	%	91	92	95		85		99		4241773

RDL = Reportable Detection Limit

CCME VOC + F1 IN SOIL (SOIL) Comments

Sample W78359-01 VOCs in Soil by HS GC/MS: Samples submitted with excessive headspace for volatiles analysis (>2cm)

GOLDER ASSOCIATES LTD

Maxxam Job #: B081535
Report Date: 2010/09/17

QUALITY ASSURANCE REPORT

			Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
QC Batch	**Parameter**	**Date**	**% Recovery**	**QC Limits**	**% Recovery**	**QC Limits**	**Value**	**Units**	**Value (%)**	**QC Limits**	**% Recovery**	**QC Limits**
4241103	Moisture	2010/09/09					<0.3	%	6.3	20		
4241105	Moisture	2010/09/09					<0.3	%	8.6	20		
4241773	1,2-dichlorobenzene	2010/09/08	105	60 - 140	104	60 - 140	<0.03	mg/kg	NC	40		
4241773	1,3-dichlorobenzene	2010/09/08	113	60 - 140	106	60 - 140	<0.03	mg/kg	NC	40		
4241773	1,4-dichlorobenzene	2010/09/08	108	60 - 140	101	60 - 140	<0.03	mg/kg	NC	40		
4241773	Chlorobenzene	2010/09/08	99	60 - 140	93	60 - 140	<0.03	mg/kg	NC	40		
4241773	Benzene	2010/09/08	110	60 - 140	89	60 - 140	<0.005	mg/kg	NC	40		
4241773	Ethylbenzene	2010/09/08	113	60 - 140	100	60 - 140	<0.01	mg/kg	NC	40		
4241773	m & p-Xylene	2010/09/08	118	60 - 140	105	60 - 140	<0.1	mg/kg	NC	40		
4241773	o-Xylene	2010/09/08	109	60 - 140	96	60 - 140	<0.1	mg/kg	NC	40		
4241773	Styrene	2010/09/08	94	60 - 140	87	60 - 140	<0.1	mg/kg	NC	40		
4241773	Toluene	2010/09/08	98	60 - 140	89	60 - 140	<0.03	mg/kg	NC	40		
4241773	1,1,1,2-tetrachloroethane	2010/09/08	96	60 - 140	92	60 - 140	<0.03	mg/kg	NC	40		
4241773	1,1,1-trichloroethane	2010/09/08	103	60 - 140	87	60 - 140	<0.03	mg/kg	NC	40		
4241773	1,1,2,2-tetrachloroethane	2010/09/08	103	60 - 140	111	60 - 140	<0.03	mg/kg	NC	40		
4241773	1,1,2-trichloroethane	2010/09/08	91	60 - 140	97	60 - 140	<0.03	mg/kg	NC	40		
4241773	1,1-dichloroethane	2010/09/08	106	60 - 140	102	60 - 140	<0.03	mg/kg	NC	40		
4241773	1,1-dichloroethene	2010/09/08	98	60 - 140	88	60 - 140	<0.03	mg/kg	NC	40		
4241773	1,2-dichloroethane	2010/09/08	100	60 - 140	100	60 - 140	<0.03	mg/kg	NC	40		
4241773	1,2-dichloropropane	2010/09/08	93	60 - 140	90	60 - 140	<0.03	mg/kg	NC	40		
4241773	4-BROMOFLUOROBENZENE (sur.)	2010/09/08	102	70 - 130	110	70 - 130	85	%				
4241773	Bromodichloromethane	2010/09/08	91	60 - 140	89	60 - 140	<0.05	mg/kg	NC	40		
4241773	Bromoform	2010/09/08	92	60 - 140	99	60 - 140	<0.05	mg/kg	NC	40		
4241773	Bromomethane	2010/09/08	79	40 - 150	76	40 - 150	<0.3	mg/kg	NC	40		
4241773	Carbon tetrachloride	2010/09/08	105	60 - 140	87	60 - 140	<0.03	mg/kg	NC	40		
4241773	Chlorodibromomethane	2010/09/08	97	60 - 140	99	60 - 140	<0.05	mg/kg	NC	40		
4241773	Chloroethane	2010/09/08	88	40 - 150	78	40 - 150	<0.1	mg/kg	NC	40		
4241773	Chloroform	2010/09/08	107	60 - 140	92	60 - 140	<0.05	mg/kg	NC	40		
4241773	Chloromethane	2010/09/08	65	40 - 150	64	40 - 150	<0.1	mg/kg	NC	40		
4241773	cis-1,2-dichloroethene	2010/09/08	109	60 - 140	98	60 - 140	<0.03	mg/kg	NC	40		
4241773	cis-1,3-dichloropropene	2010/09/08	85	60 - 140	94	60 - 140	<0.05	mg/kg	NC	40		
4241773	D10-ETHYLBENZENE (sur.)	2010/09/08	91	50 - 130	81	50 - 130	87	%				
4241773	D4-1,2-DICHLOROETHANE (sur.)	2010/09/08	109	70 - 130	115	70 - 130	104	%				
4241773	D8-TOLUENE (sur.)	2010/09/08	91	70 - 130	95	70 - 130	96	%				
4241773	Dibromoethane	2010/09/08	96	60 - 140	105	60 - 140	<0.03	mg/kg	NC	40		
4241773	Dichloromethane	2010/09/08	110	60 - 140	109	60 - 140	<0.1	mg/kg	NC	40		
4241773	Tetrachloroethene	2010/09/08	84	60 - 140	75	60 - 140	<0.03	mg/kg	NC	40		
4241773	trans-1,2-dichloroethene	2010/09/08	107	60 - 140	88	60 - 140	<0.03	mg/kg	NC	40		
4241773	trans-1,3-dichloropropene	2010/09/08	86	60 - 140	106	60 - 140	<0.05	mg/kg	NC	40		
4241773	Trichloroethene	2010/09/08	95	60 - 140	85	60 - 140	<0.01	mg/kg	NC	40		

QUALITY ASSURANCE REPORT

			Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
QC Batch	**Parameter**	**Date**	**% Recovery**	**QC Limits**	**% Recovery**	**QC Limits**	**Value**	**Units**	**Value (%)**	**QC Limits**	**% Recovery**	**QC Limits**
4241773	Trichlorofluoromethane	2010/09/08	90	40 - 150	77	40 - 150	<0.2	mg/kg	NC	40		
4241773	Vinyl chloride	2010/09/08	76	40 - 150	65	40 - 150	<0.06	mg/kg	NC	40		
4241773	Xylenes (Total)	2010/09/08					<0.1	mg/kg	NC	40		
4241773	Methyl-tert-butylether(MTBE)	2010/09/08					<0.1	mg/kg	NC	40		
4243203	(C6-C10)	2010/09/08					<10	mg/kg			101	60 - 140
4244123	Extractable (Water) SULFOLANE (sur.)	2010/09/08	119	60 - 140	105	60 - 140	105	%				
4244123	Extractable (Water) Ethylene Glycol	2010/09/08	111	30 - 130	95	30 - 130	<10	mg/kg	NC	40		
4244123	Extractable (Water) Diethylene Glycol	2010/09/08	116	30 - 130	99	30 - 130	<10	mg/kg	NC	40		
4244123	Extractable (Water) Triethylene Glycol	2010/09/08	111	30 - 130	96	30 - 130	<10	mg/kg	NC	40		
4244123	Extractable (Water) Tetraethylene Glycol	2010/09/08	103	30 - 130	89	30 - 130	<10	mg/kg	NC	40		
4244123	Extractable (Water) Propylene Glycol	2010/09/08	120	30 - 130	104	30 - 130	<10	mg/kg	NC	40		
4245034	O-TERPHENYL (sur.)	2010/09/09	86	50 - 130	83	50 - 130	89	%				
4245034	F2 (C10-C16 Hydrocarbons)	2010/09/09	92	50 - 130	92	80 - 120	<10	mg/kg	NC	40		
4245034	F3 (C16-C34 Hydrocarbons)	2010/09/09	100	50 - 130	99	80 - 120	<10	mg/kg	NC	40		
4245034	F4 (C34-C50 Hydrocarbons)	2010/09/09	92	50 - 130	91	80 - 120	<10	mg/kg	NC	40		
4245034	Reached Baseline at C50	2010/09/09					YES, RDL=N/A	mg/kg	NC	50		
4245113	Total Phosphorus (P)	2010/09/09					<10	mg/kg	0.7	30	96	70 - 130
4245167	Soluble (2:1) pH	2010/09/10			102	96 - 104			1.3	20		
4253100	Total Organic Carbon (C)	2010/09/13			98	75 - 125	<0.02	%	4.3	50	121	75 - 125
4257238	D10-ANTHRACENE (sur.)	2010/09/14	100	60 - 130	97	60 - 130	101	%				
4257238	D12-BENZO(A)PYRENE (sur.)	2010/09/14	101	60 - 130	99	60 - 130	102	%				
4257238	D8-ACENAPHTHYLENE (sur.)	2010/09/14	98	50 - 130	98	50 - 130	101	%				
4257238	D8-NAPHTHALENE (sur.)	2010/09/14	95	50 - 130	95	50 - 130	101	%				
4257238	TERPHENYL-D14 (sur.)	2010/09/14	99	60 - 130	95	60 - 130	100	%				
4257238	Naphthalene	2010/09/14	77	50 - 130	95	50 - 130	<0.01	mg/kg	NC	50		
4257238	2-Methylnaphthalene	2010/09/14	79	50 - 130	94	50 - 130	<0.01	mg/kg	NC	50		
4257238	Acenaphthylene	2010/09/14	75	50 - 130	90	50 - 130	<0.01	mg/kg	NC	50		
4257238	Acenaphthene	2010/09/14	78	50 - 130	96	50 - 130	<0.01	mg/kg	NC	50		
4257238	Fluorene	2010/09/14	79	50 - 130	94	50 - 130	<0.01	mg/kg	NC	50		
4257238	Phenanthrene	2010/09/14	79	60 - 130	95	60 - 130	<0.01	mg/kg	NC	50		
4257238	Anthracene	2010/09/14	78	60 - 130	95	60 - 130	<0.01	mg/kg	NC	50		
4257238	Fluoranthene	2010/09/14	81	60 - 130	93	60 - 130	<0.01	mg/kg	NC	50		
4257238	Pyrene	2010/09/14	79	60 - 130	95	60 - 130	<0.01	mg/kg	NC	50		
4257238	Benzo(a)anthracene	2010/09/14	79	60 - 130	90	60 - 130	<0.01	mg/kg	NC	50		
4257238	Chrysene	2010/09/14	75	60 - 130	92	60 - 130	<0.01	mg/kg	NC	50		
4257238	Benzo(b&j)fluoranthene	2010/09/14	81	60 - 130	99	60 - 130	<0.01	mg/kg	NC	50		
4257238	Benzo(k)fluoranthene	2010/09/14	82	60 - 130	93	60 - 130	<0.01	mg/kg	NC	50		
4257238	Benzo(a)pyrene	2010/09/14	80	60 - 130	95	60 - 130	<0.01	mg/kg	NC	50		
4257238	Indeno(1,2,3-cd)pyrene	2010/09/14	84	60 - 130	93	60 - 130	<0.02	mg/kg	NC	50		
4257238	Dibenz(a,h)anthracene	2010/09/14	84	60 - 130	97	60 - 130	<0.02	mg/kg	NC	50		

QUALITY ASSURANCE REPORT

			Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	Units	Value (%)	QC Limits	% Recovery	QC Limits
4257238	Benzo(g,h,i)perylene	2010/09/14	79	60 - 130	92	60 - 130	<0.02	mg/kg	NC	50		
4257360	Total Arsenic (As)	2010/09/14	98	75 - 125	98	75 - 125	<0.2	mg/kg			94	70 - 130
4257360	Total Beryllium (Be)	2010/09/14	95	75 - 125	93	75 - 125	<0.1	mg/kg	NC	30		
4257360	Total Cadmium (Cd)	2010/09/14	99	75 - 125	97	75 - 125	<0.05	mg/kg			95	70 - 130
4257360	Total Chromium (Cr)	2010/09/14	99	75 - 125	98	75 - 125	<1	mg/kg			93	70 - 130
4257360	Total Cobalt (Co)	2010/09/14	99	75 - 125	99	75 - 125	<0.3	mg/kg			94	70 - 130
4257360	Total Copper (Cu)	2010/09/14	98	75 - 125	101	75 - 125	<0.5	mg/kg			90	70 - 130
4257360	Total Lead (Pb)	2010/09/14	96	75 - 125	101	75 - 125	<0.1	mg/kg			97	70 - 130
4257360	Total Mercury (Hg)	2010/09/14	90	75 - 125	96	75 - 125	<0.05	mg/kg				
4257360	Total Nickel (Ni)	2010/09/14	101	75 - 125	100	75 - 125	<0.8	mg/kg			99	70 - 130
4257360	Total Selenium (Se)	2010/09/14	101	75 - 125	101	75 - 125	<0.5	mg/kg				
4257360	Total Vanadium (V)	2010/09/14	101	75 - 125	99	75 - 125	<2	mg/kg			96	70 - 130
4257360	Total Zinc (Zn)	2010/09/14	NC	75 - 125	106	75 - 125	<1	mg/kg			90	70 - 130
4257360	Total Aluminum (Al)	2010/09/14					<100	mg/kg			95	70 - 130
4257360	Total Antimony (Sb)	2010/09/14					<0.1	mg/kg			87	70 - 130
4257360	Total Barium (Ba)	2010/09/14					<0.1	mg/kg			96	70 - 130
4257360	Total Calcium (Ca)	2010/09/14					<100	mg/kg			91	70 - 130
4257360	Total Iron (Fe)	2010/09/14					<100	mg/kg			93	70 - 130
4257360	Total Magnesium (Mg)	2010/09/14					<100	mg/kg			97	70 - 130
4257360	Total Manganese (Mn)	2010/09/14					<0.2	mg/kg			97	70 - 130
4257360	Total Molybdenum (Mo)	2010/09/14					<0.1	mg/kg			90	70 - 130
4257360	Total Phosphorus (P)	2010/09/14					<10	mg/kg			97	70 - 130
4257360	Total Silver (Ag)	2010/09/14					<0.05	mg/kg			75	70 - 130
4257360	Total Strontium (Sr)	2010/09/14					<0.1	mg/kg			91	70 - 130
4257360	Total Thallium (Tl)	2010/09/14					<0.05	mg/kg			86	70 - 130
4257360	Total Titanium (Ti)	2010/09/14					<1	mg/kg			94	70 - 130
4257360	Total Bismuth (Bi)	2010/09/14					<0.1	mg/kg				
4257360	Total Potassium (K)	2010/09/14					<100	mg/kg				
4257360	Total Sodium (Na)	2010/09/14					<100	mg/kg				
4257360	Total Tin (Sn)	2010/09/14					<0.1	mg/kg				
4257360	Total Zirconium (Zr)	2010/09/14					<0.5	mg/kg				
4257931	Soluble (2:1) pH	2010/09/14			102	96 - 104						
4259375	D10-ANTHRACENE (sur.)	2010/09/17			78	60 - 130	78	%				
4259375	D12-BENZO(A)PYRENE (sur.)	2010/09/17			83	60 - 130	89	%				
4259375	D8-ACENAPHTHYLENE (sur.)	2010/09/17			67	50 - 130	61	%				
4259375	D8-NAPHTHALENE (sur.)	2010/09/17			67	50 - 130	63	%				
4259375	TERPHENYL-D14 (sur.)	2010/09/17			80	60 - 130	88	%				
4259375	Naphthalene	2010/09/17			69	50 - 130	<0.1	ug/L				
4259375	2-Methylnaphthalene	2010/09/17			65	50 - 130	<0.1	ug/L				
4259375	Quinoline	2010/09/17			111	50 - 130	<0.5	ug/L				

QUALITY ASSURANCE REPORT

			Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
QC Batch	**Parameter**	**Date**	**% Recovery**	**QC Limits**	**% Recovery**	**QC Limits**	**Value**	**Units**	**Value (%)**	**QC Limits**	**% Recovery**	**QC Limits**
4259375	Acenaphthylene	2010/09/17			67	50 - 130	<0.1	ug/L				
4259375	Acenaphthene	2010/09/17			64	50 - 130	<0.1	ug/L				
4259375	Fluorene	2010/09/17			67	50 - 130	<0.1	ug/L				
4259375	Phenanthrene	2010/09/17			81	60 - 130	<0.1	ug/L				
4259375	Anthracene	2010/09/17			77	60 - 130	<0.1	ug/L				
4259375	Acridine	2010/09/17			81	50 - 130	<0.5	ug/L				
4259375	Fluoranthene	2010/09/17			82	60 - 130	<0.1	ug/L				
4259375	Pyrene	2010/09/17			82	60 - 130	<0.1	ug/L				
4259375	Benzo(a)anthracene	2010/09/17			77	60 - 130	<0.1	ug/L				
4259375	Chrysene	2010/09/17			82	60 - 130	<0.1	ug/L				
4259375	Benzo(b&j)fluoranthene	2010/09/17			79	60 - 130	<0.1	ug/L				
4259375	Benzo(k)fluoranthene	2010/09/17			85	60 - 130	<0.1	ug/L				
4259375	Benzo(a)pyrene	2010/09/17			84	60 - 130	<0.1	ug/L				
4259375	Indeno(1,2,3-cd)pyrene	2010/09/17			83	60 - 130	<0.2	ug/L				
4259375	Dibenz(a,h)anthracene	2010/09/17			77	60 - 130	<0.2	ug/L				
4259375	Benzo(g,h,i)perylene	2010/09/17			82	60 - 130	<0.2	ug/L				
4259524	F2 (C10-C16 Hydrocarbons)	2010/09/16			114	80 - 120	<0.08	mg/L				
4259524	O-TERPHENYL (sur.)	2010/09/16			103	50 - 130	98	%				
4259524	F3 (C16-C34 Hydrocarbons)	2010/09/16					<0.08	mg/L				
4259524	F4 (C34-C50 Hydrocarbons)	2010/09/16					<3	mg/L				
4265796	Leachable Arsenic (As)	2010/09/16	114	75 - 125	110	75 - 125	<0.001	mg/L	NC	35		
4265796	Leachable Beryllium (Be)	2010/09/16	110	75 - 125	123	75 - 125	<0.001	mg/L	NC	35		
4265796	Leachable Cadmium (Cd)	2010/09/16	116	75 - 125	118	75 - 125	<0.00002	mg/L	NC	35		
4265796	Leachable Chromium (Cr)	2010/09/16	108	75 - 125	104	75 - 125	<0.001	mg/L	NC	35		
4265796	Leachable Cobalt (Co)	2010/09/16	103	75 - 125	105	75 - 125	<0.001	mg/L	NC	35		
4265796	Leachable Copper (Cu)	2010/09/16	98	75 - 125	104	75 - 125	<0.002	mg/L	NC	35		
4265796	Leachable Lead (Pb)	2010/09/16	111	75 - 125	118	75 - 125	<0.001	mg/L	NC	35		
4265796	Leachable Nickel (Ni)	2010/09/16	102	75 - 125	118	75 - 125	<0.01	mg/L	NC	35		
4265796	Leachable Selenium (Se)	2010/09/16	113	75 - 125	118	75 - 125	<0.001	mg/L	NC	35		
4265796	Leachable Uranium (U)	2010/09/16	99	75 - 125	96	75 - 125	<0.001	mg/L	NC	35		
4265796	Leachable Vanadium (V)	2010/09/16	99	75 - 125	102	75 - 125	<0.01	mg/L	NC	35		
4265796	Leachable Zinc (Zn)	2010/09/16	99	75 - 125	109	75 - 125	<0.01	mg/L	NC	35		
4265796	Leachable Aluminum (Al)	2010/09/16					<0.02	mg/L	NC	35		
4265796	Leachable Antimony (Sb)	2010/09/16					<0.001	mg/L	NC	35		
4265796	Leachable Barium (Ba)	2010/09/16					<0.1	mg/L	NC	35		
4265796	Leachable Boron (B)	2010/09/16					<0.5	mg/L	NC	35		
4265796	Leachable Calcium (Ca)	2010/09/16					<1	mg/L	3.5	35		
4265796	Leachable Iron (Fe)	2010/09/16					<0.05	mg/L	NC	35		
4265796	Leachable Magnesium (Mg)	2010/09/16					<1	mg/L	1.6	35		
4265796	Leachable Manganese (Mn)	2010/09/16					<0.005	mg/L	NC	35		

QUALITY ASSURANCE REPORT

			Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
QC Batch	**Parameter**	**Date**	**% Recovery**	**QC Limits**	**% Recovery**	**QC Limits**	**Value**	**Units**	**Value (%)**	**QC Limits**	**% Recovery**	**QC Limits**
4265796	Leachable Mercury (Hg)	2010/09/16					<0.0001	mg/L	NC	35		
4265796	Leachable Molybdenum (Mo)	2010/09/16					<0.005	mg/L	0.7	35		
4265796	Leachable Sodium (Na)	2010/09/16					<1	mg/L	4.2	35		
4265796	Leachable Silver (Ag)	2010/09/16					<0.0001	mg/L	NC	35		
4265796	Leachable Thallium (Tl)	2010/09/16					<0.0001	mg/L	NC	35		
4265796	Leachable Titanium (Ti)	2010/09/16					<0.1	mg/L	NC	35		

N/A = Not Applicable
RDL = Reportable Detection Limit
RPD = Relative Percent Difference
Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.
Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.
QC Standard: A blank matrix to which a known amount of the analyte has been added. Used to evaluate analyte recovery.
Spiked Blank: A blank matrix to which a known amount of the analyte has been added. Used to evaluate analyte recovery.
Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.
Surrogate: A pure or isotopically labeled compound whose behavior mirrors the analytes of interest. Used to evaluate extraction efficiency.
NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spiked amount was not sufficiently significant to permit a reliable recovery calculation.
NC (RPD): The RPD was not calculated. The level of analyte detected in the parent sample and its duplicate was not sufficiently significant to permit a reliable calculation.

CHAIN-OF-CUSTODY / TEST REQUEST FORM

№ 5454

Golder Associates
500 - 4260 Still Creek Drive
Burnaby, B.C.
Canada V5C 6C6

Tel: 604-296-4200
Fax: 604-298-5253
www.golder.com

Client Name GOLDER ASSOCIATES
Address 500-4260 STILL CRK DRIVE
BURNABY-BC
CANADA V5C 6C6

Client Contact RYAN STEVENSON
Phone 604 297 2006
Fax 604 298 5253
Sampled by RWS

Ship to MAXXAM
4606 CANADA WAY
BURNABY V5G 1K5
Attn. VJOCO 604 639 8422

Shipping Date

Collection Date (DD/MMM/YYYY) 1	Time (24-h clock) 1	Sample Identification	Type of Each Sample 2	Material Safety Data Sheet Attached? (✓)	Sample Collection Method G=grab C=composite	Number of Sample Containers x Volume of Sample Containers (1 x 20L)	Sample Container Type by Code 3	Test(s) Requested: CCME F2-F4	F1 + VOCs	HOLD FOR PAH/METALS	HOLD FOR LEACHATE	GLYCOL, TOC, TOTAL N, TOTAL P	Sample Notes (preserved, saltwater, freshwater, may contain sewage...) 4
31-AUG/2010	0830	B-2	SOIL		C/G	5x125ml	GJ	✓	✓	✓	✓	✓	HOLD PAH/METALS + LEACHATE ANALYSES
31-AUG/2010	0840	A-2	SOIL		C/G	4x125ml	GJ	✓		✓	✓	✓	"
30-AUG/2010	1600	C-2	SOIL		"	5x125ml	"	✓	✓	✓	✓	✓	"
30-AUG/2010	1700	C-3 DEEP	SOIL		"	4x125ml	"	✓		✓	✓	✓	"
30-AUG/2010	1400	C-3	SOIL		"	4x125ml	"	✓	✓	✓	✓		"
31-AUG/2010	0845	DUPLICATE	SOIL		C/G	2x125ml	"	✓		✓			"
30-AUG/2010	1500	A-3	SOIL		C/G	3x125ml	"	✓		✓	✓		"
30-AUG/2010	1900	C-1	SOIL		C/G	3x125ml	"	✓		✓	✓		"
30-AUG/2010	1900	B-1	SOIL		C/G	5x125ml	"	✓	✓	✓	✓	✓	"
30-AUG/2010	1900	A-1	SOIL		C/G	3x125ml	"	✓		✓	✓		"

PO/Reference No. 10-1328-0028/6000
Project Title DIAVIK-WTA SOILS
Results Needed By

Comments/Instructions HOLD PAH/METALS/LEACHATE ANALYSES UNTIL NOTIFIED TO PROCEED (PENDING INITIAL RESULTS). TESTING TO MEET CCME + CWS-PHC GUIDELINES

1) Released by: Date: SEPT 2/2010
Company: Time:
Courier Name: G + G EXPEDITING

2) Released by: Date:
Company: Time:
Courier Name:

3) Released by: Date:
Company: Time:
Courier Name:

1) Received by: NICK SAMPAK Date: Sept 7/10
Company: TEMP 8/8/9 Time: 12:30

2) Received by: Date:
Company: Time:

3) Received by: Date:
Company: Time:

1 For composite effluent or water samples, the sample collection date/time is the **end** of the compositing period.
2 Receiving Water (RW): Effluent (E); Elutriate (ELU); Sediment (SED); Chemical (CHEM); Stormwater (SW); Other (Please Specify)
3 Collapsible Carboy (CC); glass jar (GJ); Jerry Can (JC); Plastic HDPE (P); Other (Please Specify)
4 Please note any conditions the lab should be aware of for safety and storage concerns

Distribution of copies:
White, Yellow—accompany the shipment
Pink—kept by consignor (e.g. shipper)
Yellow—kept by consignee (e.g. receiver)
White—returned to consignor by consignee

CHAIN-OF-CUSTODY / TEST REQUEST FORM

№ 5453

Golder Associates
500 - 4260 Still Creek Drive
Burnaby, B.C.
Canada V5C 6C6

Tel: 604-296-4200
Fax: 604-298-5253
www.golder.com

Client Name GOLDER ASSOCIATES
Address 500-4260 STILLCRK DRIVE
BURNABY, BC
V5C 6C6

Client Contact RYAN STEVENSON
Phone 604 297 2006
Fax 604 293 5253
Sampled by RWS

Ship to MAXXAM
4606 CANADA WAY
BURNABY V5G 1K5
Attn. VJ OCO 604 639 8422

Shipping Date

Collection Date (DD/MMM/YYYY) 1	Time (24-h clock) 1	Sample Identification	Type of Each Sample 2	Material Safety Data Sheet Attached? (✓)	Sample Collection Method G=grab C=composite	Number of Sample Containers x Volume of Sample Containers (1 x 20L)	Sample Container Type by Code 3	Test(s) Requested					Sample Notes (preserved, saltwater, freshwater, may contain sewage...) 4
								CCME F2-F4	F1 + VOCs	HOLD FOR PAHs/METALS	HOLD FOR LEACHATE		
30-AUG-2010	1430	B-3	SOIL		C/G	4x125ml	GJ	✓	✓	✓	✓		HOLD PAH/METALS + LEACHATE
													ANALYSES

PO/Reference No. 10-1328-0028/6000
Project Title DIAVIK - WTA SOILS
Results Needed By

Comments/Instructions HOLD PAH/METALS/LEACHATE ANALYSES UNTIL NOTIFIED TO PROCEED (PENDING INITIAL RESULTS); TESTING TO MEET CCME + CWS-PHC GUIDELINES

1) Released by: Date: SEPT 2/2010
Company: Time:
Courier Name: GTG EXPEDITING

2) Released by: Date:
Company: Time:
Courier Name:

3) Released by: Date:
Company: Time:
Courier Name:

1) Received by: NICK SANDER Date: Sept 7/10
Company: TEMP 8/8/9 Time: 12:30

2) Received by: Date:
Company: Time:

3) Received by: Date:
Company: Time:

1 For composite effluent or water samples, the sample collection date/time is the **end** of the compositing period.
2 Receiving Water (RW): Effluent (E); Elutriate (ELU); Sediment (SED); Chemical (CHEM); Stormwater (SW); Other (Please Specify)
3 Collapsible Carboy (CC); glass jar (GJ); Jerry Can (JC); Plastic HDPE (P); Other (Please Specify)
4 Please note any conditions the lab should be aware of for safety and storage concerns

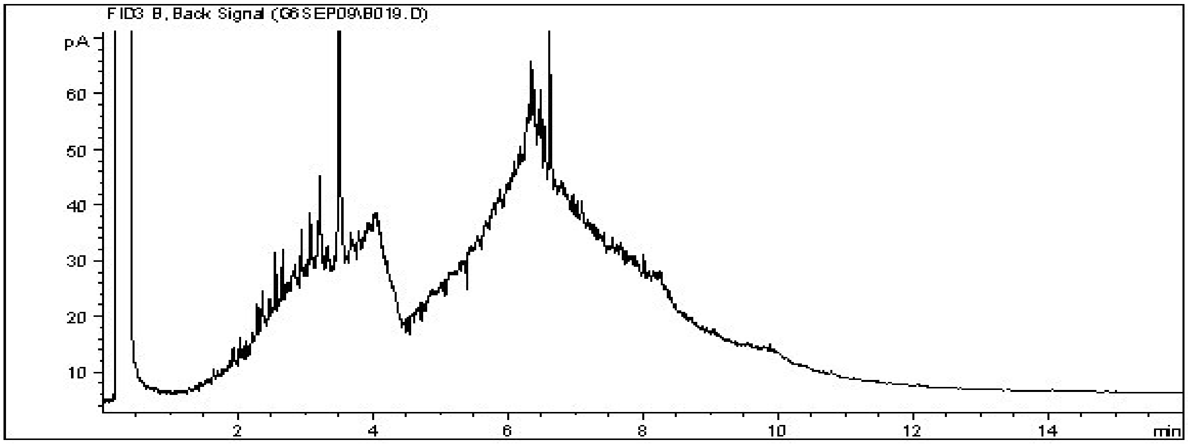
Distribution of copies:
White, Yellow—accompany the shipment
Pink—kept by consignor (e.g. shipper)
Yellow—kept by consignee (e.g. receiver)
White—returned to consignor by consignee

GOLDER ASSOCIATES LTD

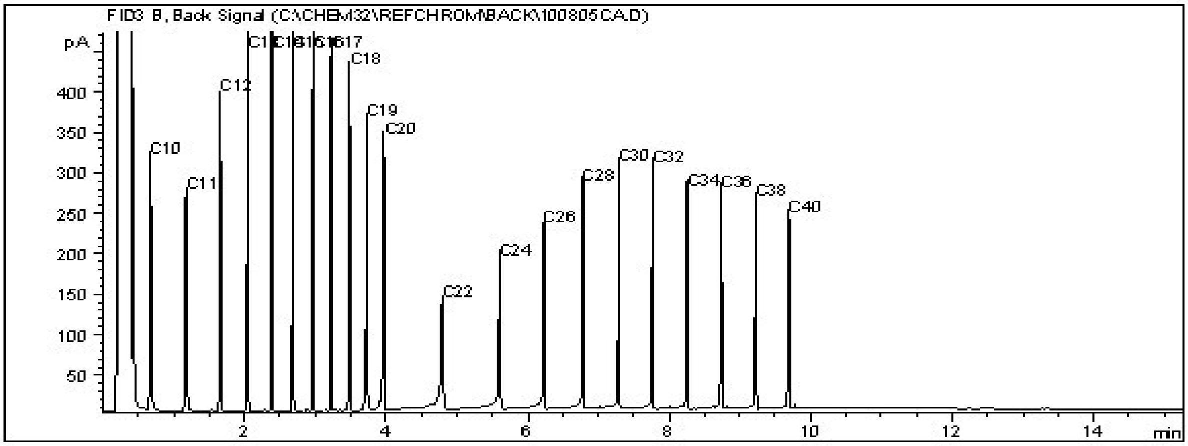
Report Date: 2010/09/17
Maxxam Job #: B081535
Maxxam Sample: W78357

Client ID: B-2

CCME Hydrocarbons (F2-F4 in soil) Chromatogram



Carbon Range Distribution - Reference Chromatogram



TYPICAL PRODUCT CARBON NUMBER RANGES

Gasoline:	C4 - C12	Diesel:	C8 - C22
Varsol:	C8 - C12	Lubricating Oils:	C20 - C40
Kerosene:	C7 - C16	Crude Oils:	C3 - C60+

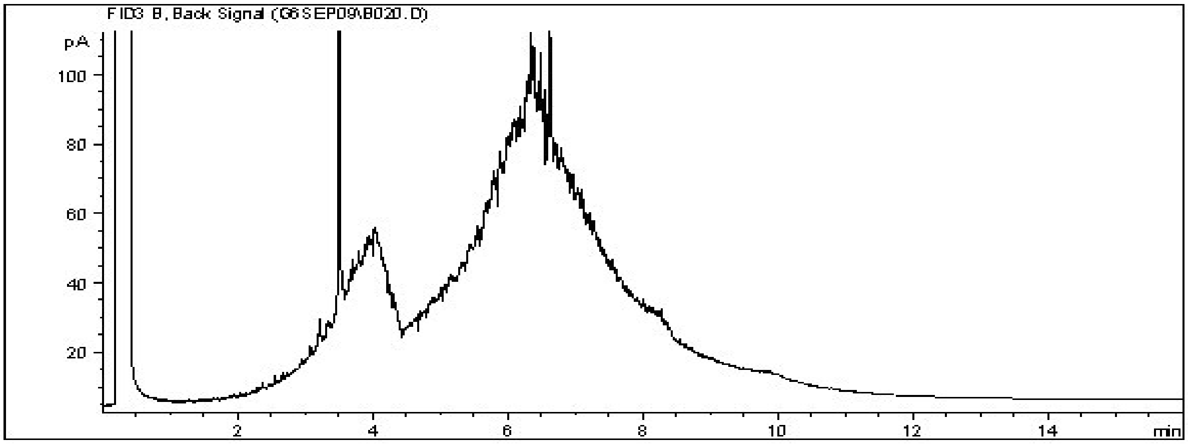
Note: This information is provided for reference purposes only. Should detailed chemist intrepretation or fingerprinting be required to please contact the laboratory.

GOLDER ASSOCIATES LTD

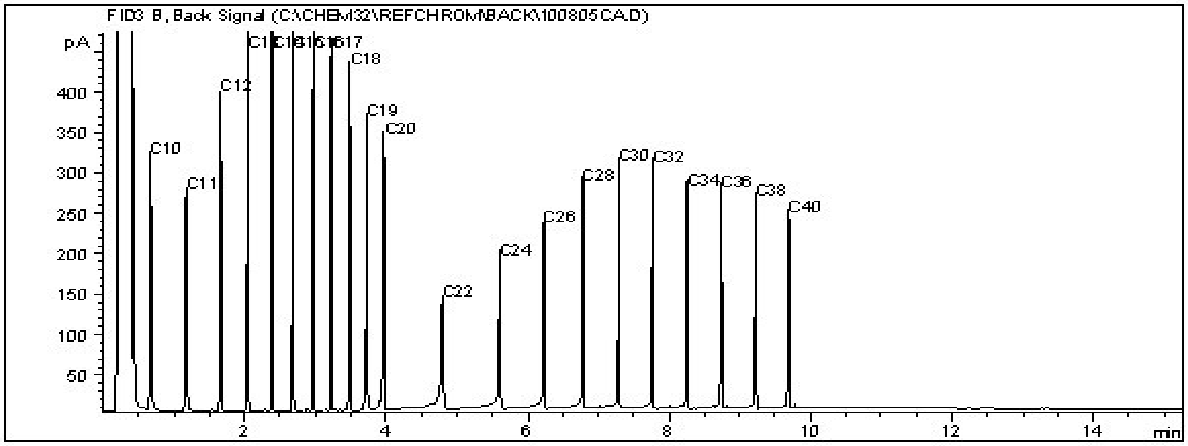
Report Date: 2010/09/17
Maxxam Job #: B081535
Maxxam Sample: W78358

Client ID: A-2

CCME Hydrocarbons (F2-F4 in soil) Chromatogram



Carbon Range Distribution - Reference Chromatogram



TYPICAL PRODUCT CARBON NUMBER RANGES

Gasoline:	C4 - C12	Diesel:	C8 - C22
Varsol:	C8 - C12	Lubricating Oils:	C20 - C40
Kerosene:	C7 - C16	Crude Oils:	C3 - C60+

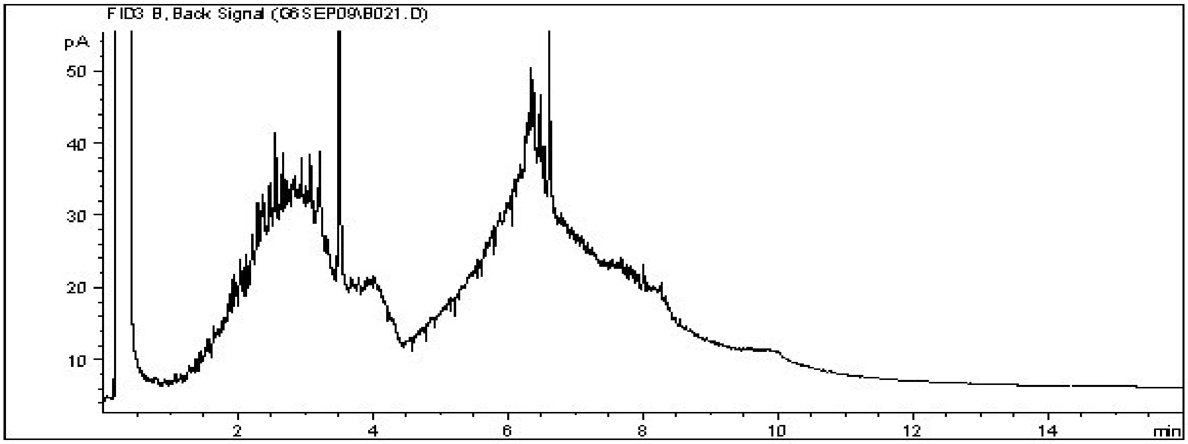
Note: This information is provided for reference purposes only. Should detailed chemist intrepretation or fingerprinting be required to please contact the laboratory.

GOLDER ASSOCIATES LTD

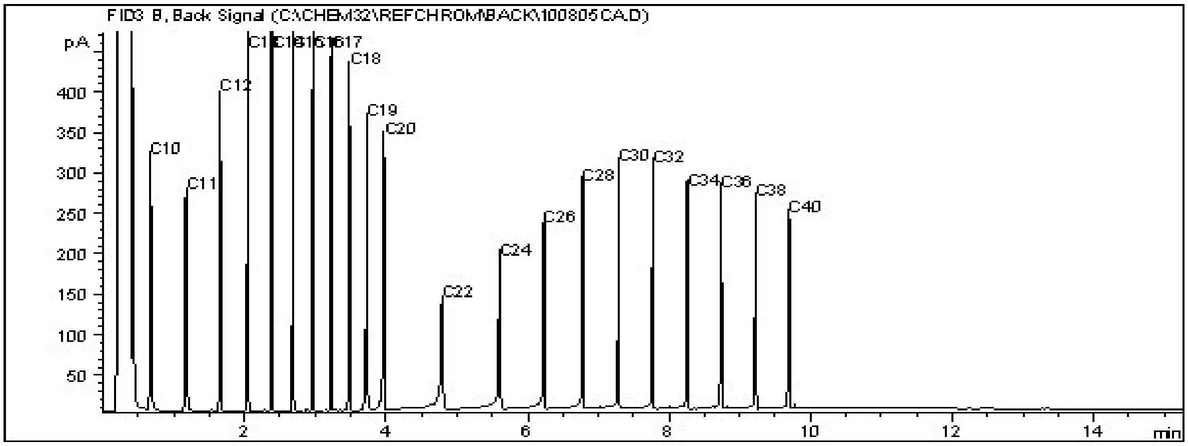
Report Date: 2010/09/17
Maxxam Job #: B081535
Maxxam Sample: W78359

Client ID: C-2

CCME Hydrocarbons (F2-F4 in soil) Chromatogram



Carbon Range Distribution - Reference Chromatogram



TYPICAL PRODUCT CARBON NUMBER RANGES

Gasoline:	C4 - C12	Diesel:	C8 - C22
Varsol:	C8 - C12	Lubricating Oils:	C20 - C40
Kerosene:	C7 - C16	Crude Oils:	C3 - C60+

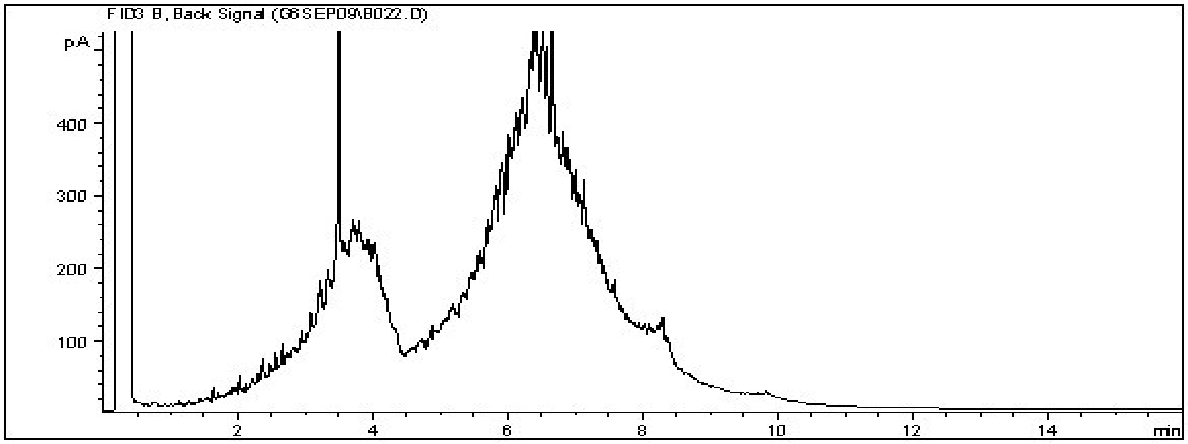
Note: This information is provided for reference purposes only. Should detailed chemist intrepretation or fingerprinting be required to please contact the laboratory.

GOLDER ASSOCIATES LTD

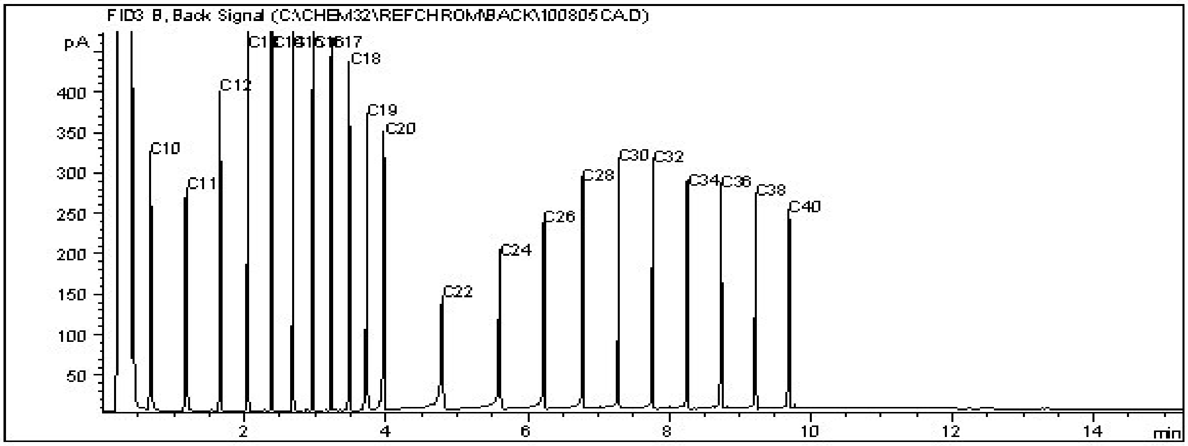
Report Date: 2010/09/17
Maxxam Job #: B081535
Maxxam Sample: W78360

Client ID: C-3DEEP

CCME Hydrocarbons (F2-F4 in soil) Chromatogram



Carbon Range Distribution - Reference Chromatogram



TYPICAL PRODUCT CARBON NUMBER RANGES

Gasoline:	C4 - C12	Diesel:	C8 - C22
Varsol:	C8 - C12	Lubricating Oils:	C20 - C40
Kerosene:	C7 - C16	Crude Oils:	C3 - C60+

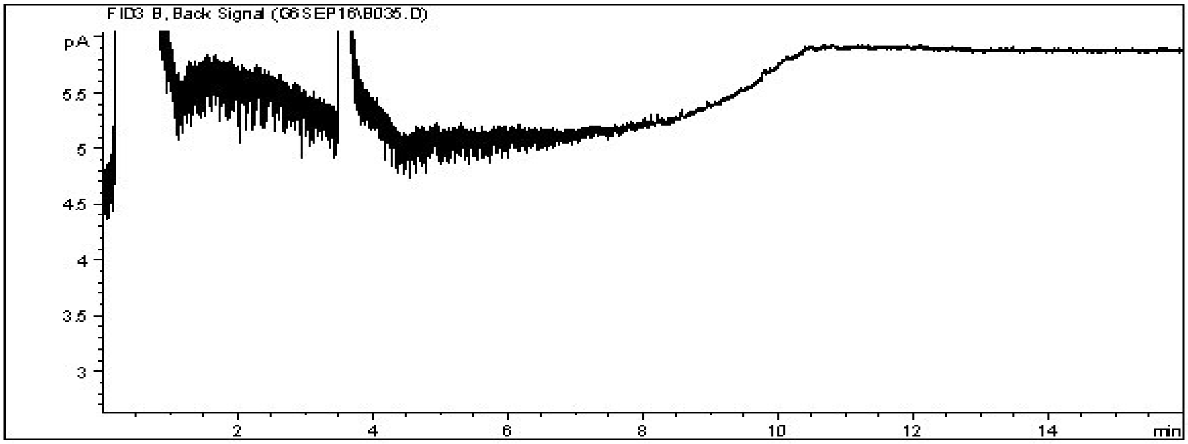
Note: This information is provided for reference purposes only. Should detailed chemist intrepretation or fingerprinting be required to please contact the laboratory.

GOLDER ASSOCIATES LTD

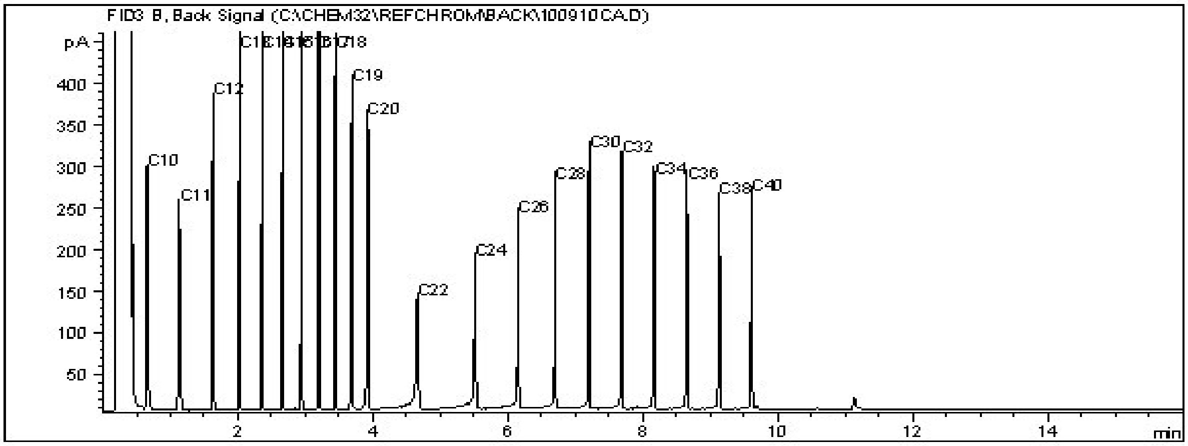
Report Date: 2010/09/17
Maxxam Job #: B081535
Maxxam Sample: W78360

Client ID: C-3DEEP

CCME Hydrocarbons (F2-F4 in water) Chromatogram



Carbon Range Distribution - Reference Chromatogram



TYPICAL PRODUCT CARBON NUMBER RANGES

Gasoline:	C4 - C12	Diesel:	C8 - C22
Varsol:	C8 - C12	Lubricating Oils:	C20 - C40
Kerosene:	C7 - C16	Crude Oils:	C3 - C60+

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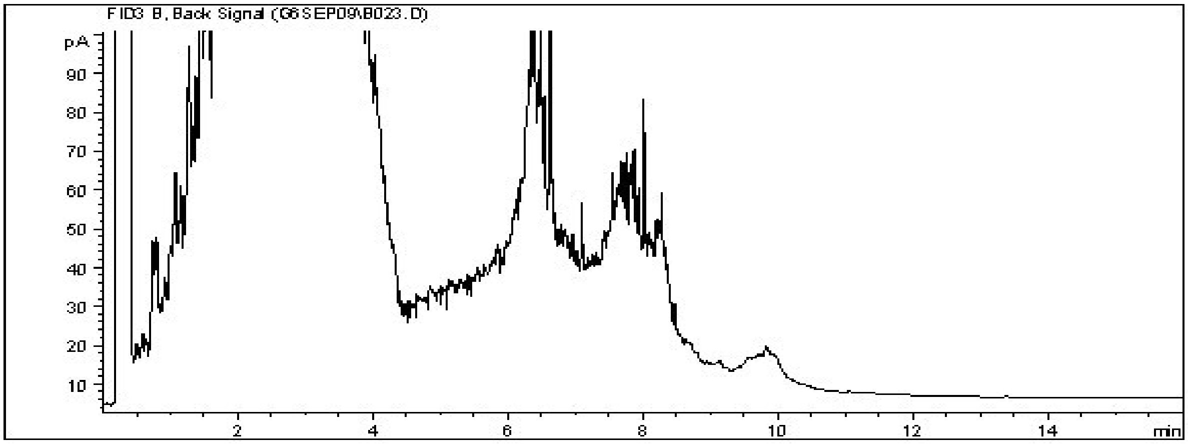
GOLDER ASSOCIATES LTD

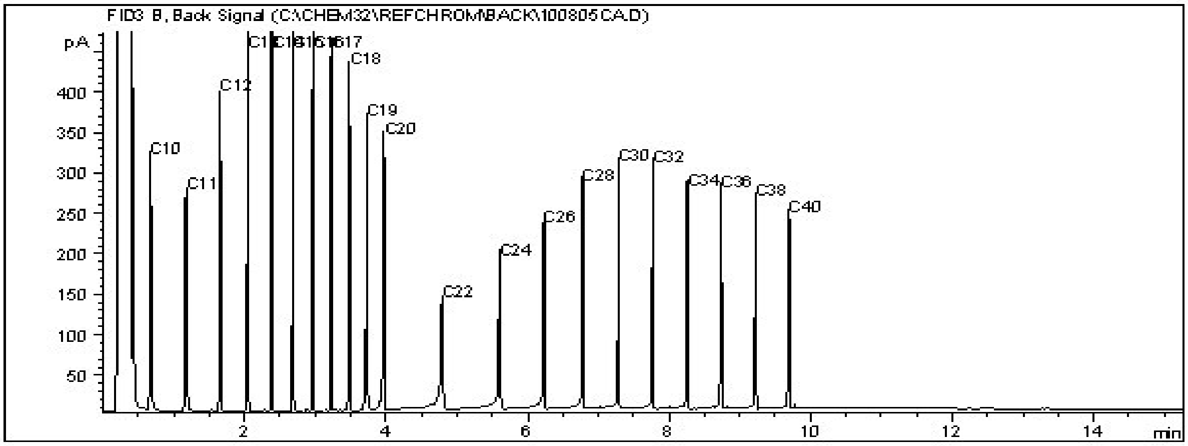
Report Date: 2010/09/17
Maxxam Job #: B081535
Maxxam Sample: W78361

Client ID: C-3

CCME Hydrocarbons (F2-F4 in soil) Chromatogram



Carbon Range Distribution - Reference Chromatogram



TYPICAL PRODUCT CARBON NUMBER RANGES

Gasoline:	C4 - C12	Diesel:	C8 - C22
Varsol:	C8 - C12	Lubricating Oils:	C20 - C40
Kerosene:	C7 - C16	Crude Oils:	C3 - C60+

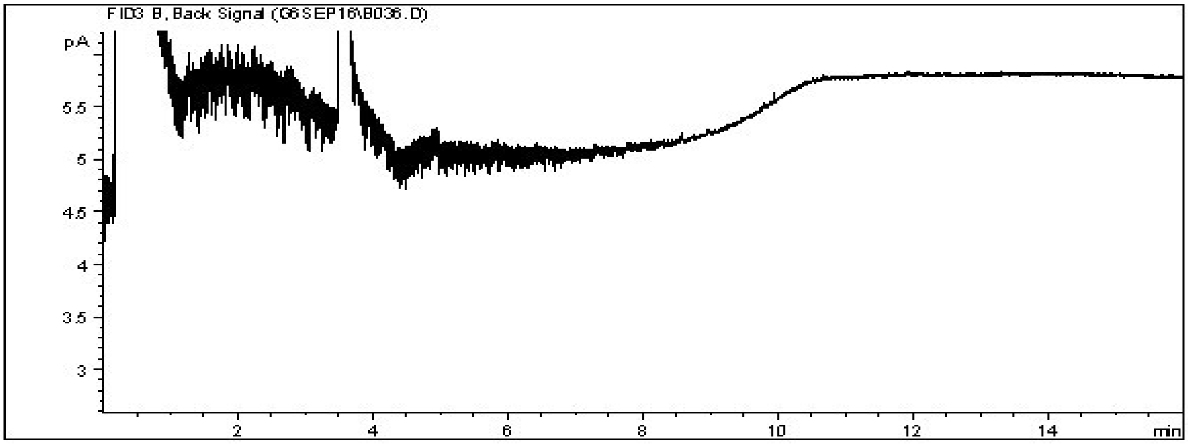
Note: This information is provided for reference purposes only. Should detailed chemist intrepretation or fingerprinting be required to please contact the laboratory.

Report Date: 2010/09/17
Maxxam Job #: B081535
Maxxam Sample: W78361

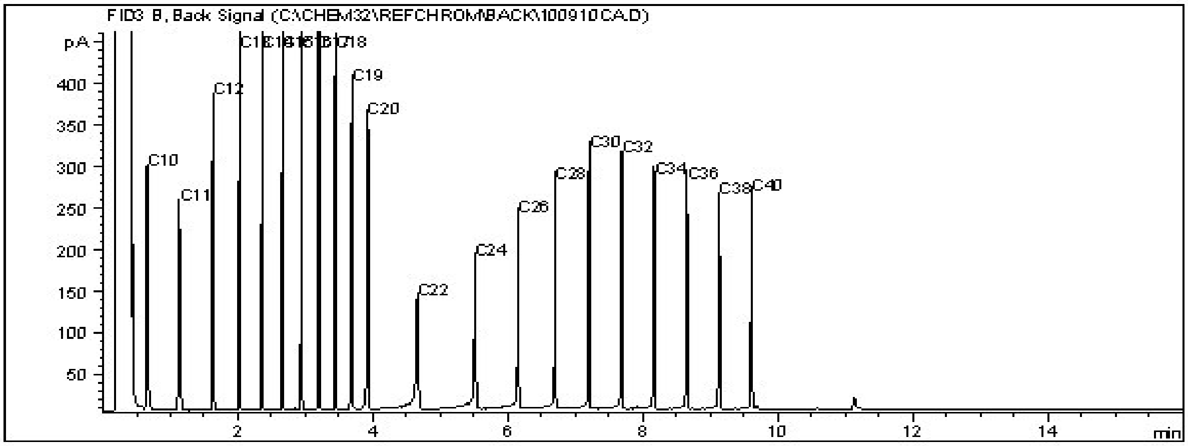
GOLDER ASSOCIATES LTD

Client ID: C-3

CCME Hydrocarbons (F2-F4 in water) Chromatogram



Carbon Range Distribution - Reference Chromatogram



TYPICAL PRODUCT CARBON NUMBER RANGES

Gasoline:	C4 - C12	Diesel:	C8 - C22
Varsol:	C8 - C12	Lubricating Oils:	C20 - C40
Kerosene:	C7 - C16	Crude Oils:	C3 - C60+

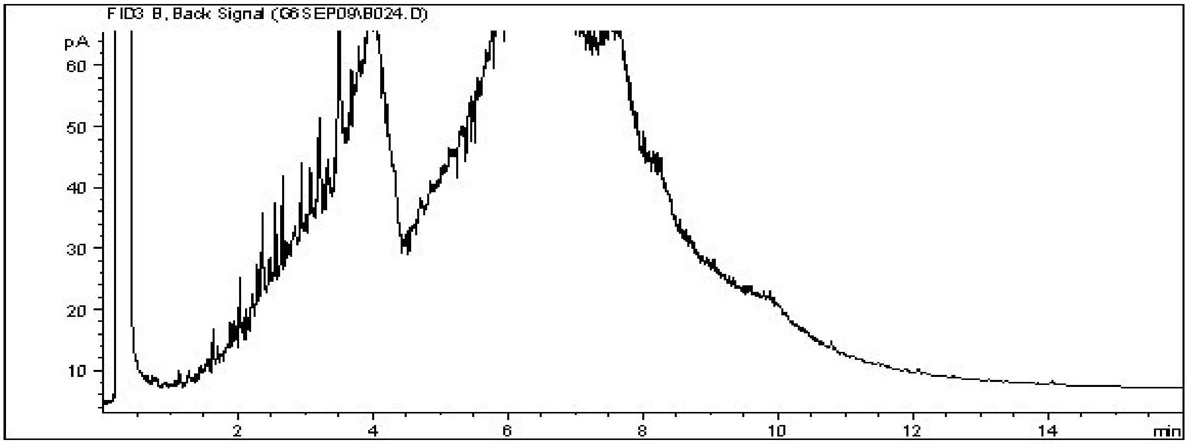
Note: This information is provided for reference purposes only. Should detailed chemist intrepretation or fingerprinting be required to please contact the laboratory.

GOLDER ASSOCIATES LTD

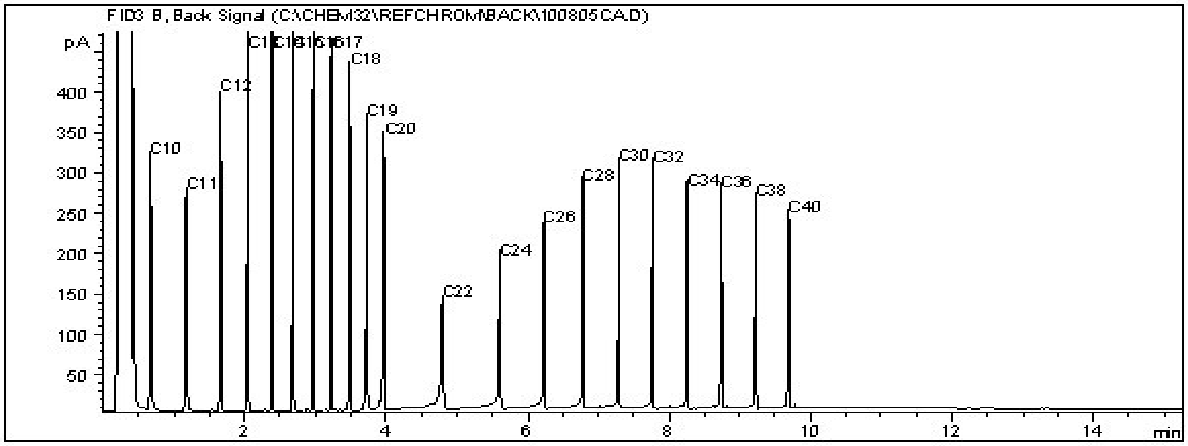
Report Date: 2010/09/17
Maxxam Job #: B081535
Maxxam Sample: W78362

Client ID: DUPLICATE

CCME Hydrocarbons (F2-F4 in soil) Chromatogram



Carbon Range Distribution - Reference Chromatogram



TYPICAL PRODUCT CARBON NUMBER RANGES

Gasoline:	C4 - C12	Diesel:	C8 - C22
Varsol:	C8 - C12	Lubricating Oils:	C20 - C40
Kerosene:	C7 - C16	Crude Oils:	C3 - C60+

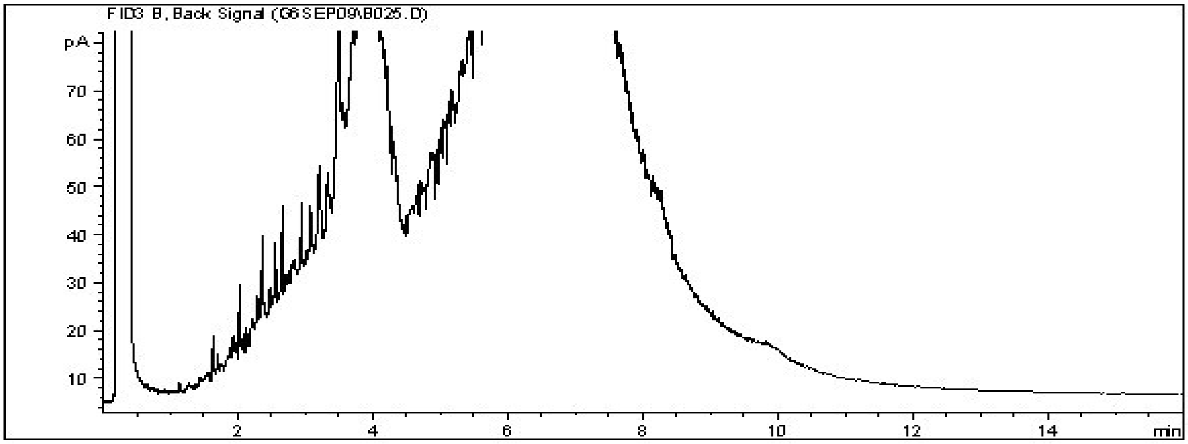
Note: This information is provided for reference purposes only. Should detailed chemist intrepretation or fingerprinting be required to please contact the laboratory.

GOLDER ASSOCIATES LTD

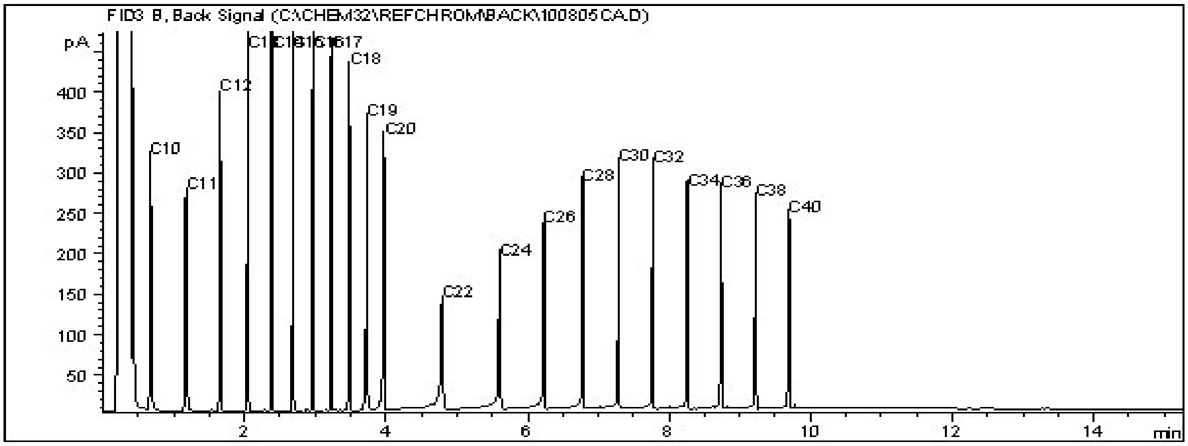
Report Date: 2010/09/17
Maxxam Job #: B081535
Maxxam Sample: W78363

Client ID: A-3

CCME Hydrocarbons (F2-F4 in soil) Chromatogram



Carbon Range Distribution - Reference Chromatogram



TYPICAL PRODUCT CARBON NUMBER RANGES

Gasoline:	C4 - C12	Diesel:	C8 - C22
Varsol:	C8 - C12	Lubricating Oils:	C20 - C40
Kerosene:	C7 - C16	Crude Oils:	C3 - C60+

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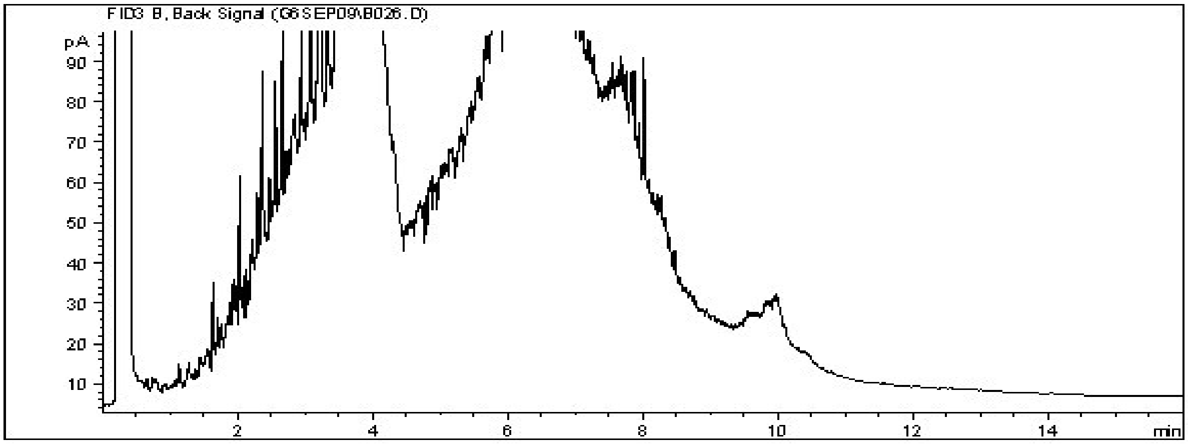
GOLDER ASSOCIATES LTD

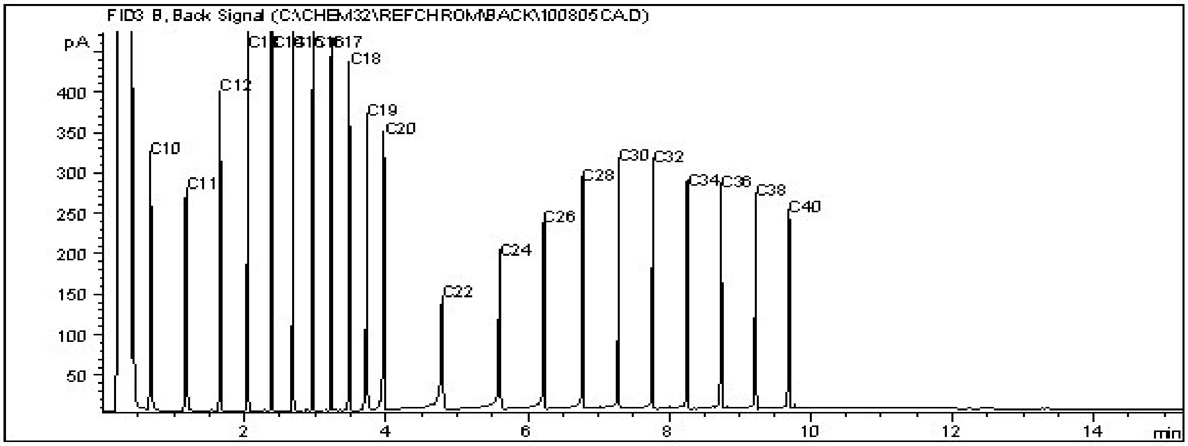
Report Date: 2010/09/17
Maxxam Job #: B081535
Maxxam Sample: W78364

Client ID: C-1

CCME Hydrocarbons (F2-F4 in soil) Chromatogram



Carbon Range Distribution - Reference Chromatogram



TYPICAL PRODUCT CARBON NUMBER RANGES

Gasoline:	C4 - C12	Diesel:	C8 - C22
Varsol:	C8 - C12	Lubricating Oils:	C20 - C40
Kerosene:	C7 - C16	Crude Oils:	C3 - C60+

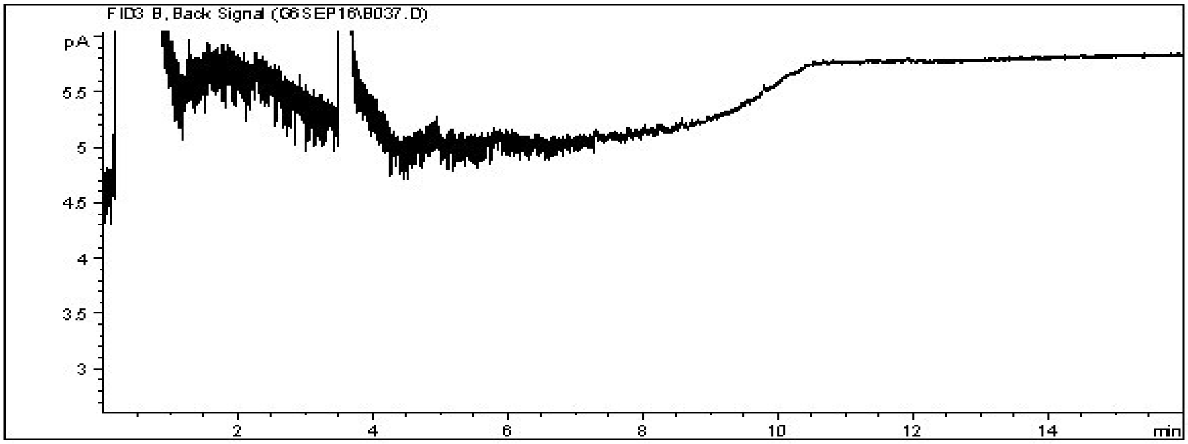
Note: This information is provided for reference purposes only. Should detailed chemist intrepretation or fingerprinting be required to please contact the laboratory.

GOLDER ASSOCIATES LTD

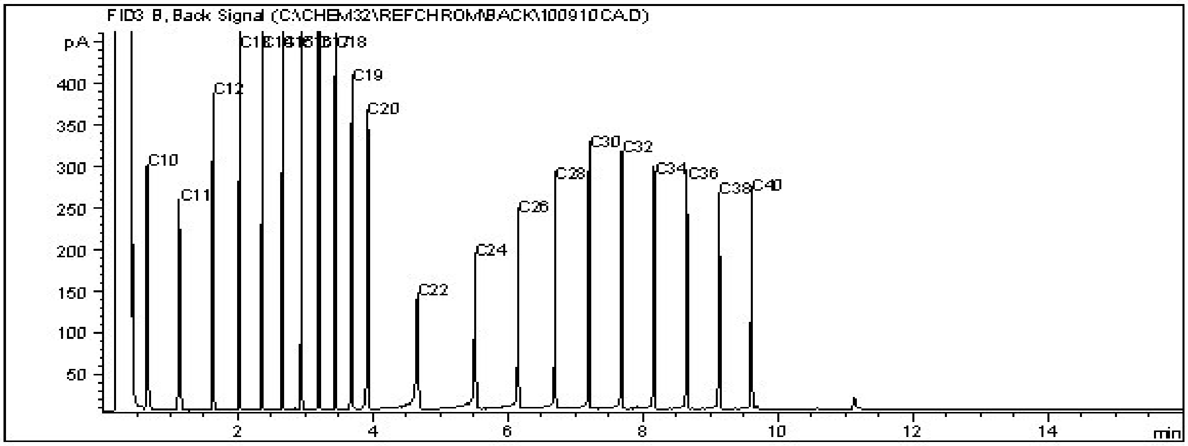
Report Date: 2010/09/17
Maxxam Job #: B081535
Maxxam Sample: W78364

Client ID: C-1

CCME Hydrocarbons (F2-F4 in water) Chromatogram



Carbon Range Distribution - Reference Chromatogram



TYPICAL PRODUCT CARBON NUMBER RANGES

Gasoline:	C4	-	C12	Diesel:	C8	-	C22
Varsol:	C8	-	C12	Lubricating Oils:	C20	-	C40
Kerosene:	C7	-	C16	Crude Oils:	C3	-	C60+

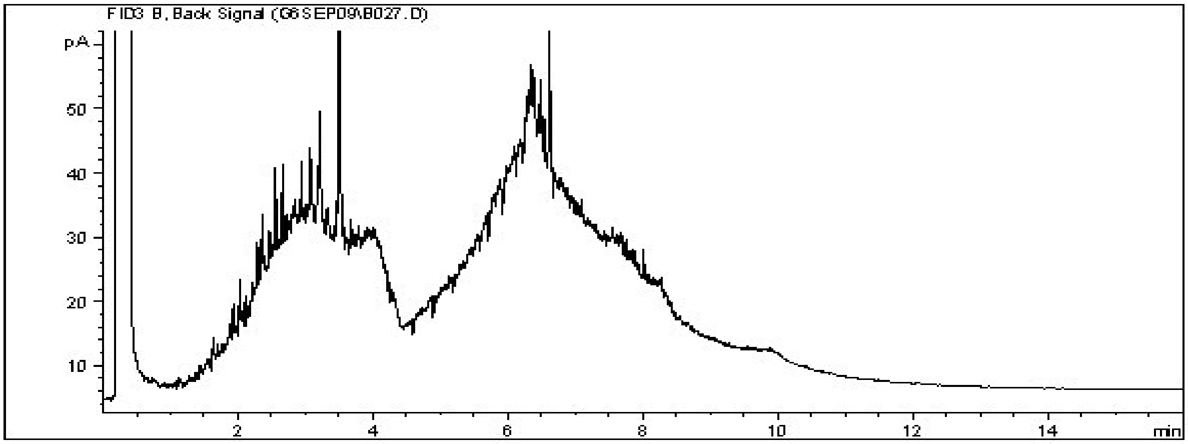
Note: This information is provided for reference purposes only. Should detailed chemist intrepretation or fingerprinting be required to please contact the laboratory.

GOLDER ASSOCIATES LTD

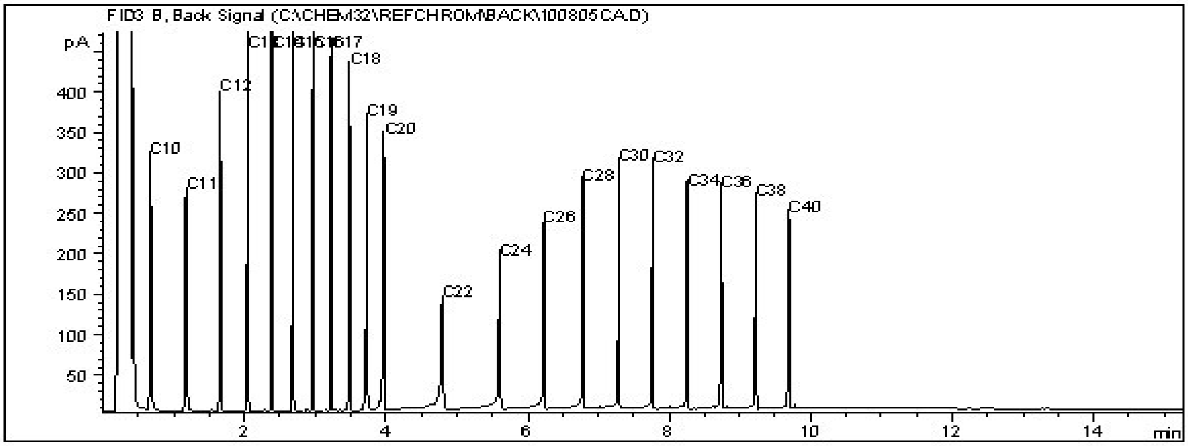
Report Date: 2010/09/17
Maxxam Job #: B081535
Maxxam Sample: W78365

Client ID: B-1

CCME Hydrocarbons (F2-F4 in soil) Chromatogram



Carbon Range Distribution - Reference Chromatogram



TYPICAL PRODUCT CARBON NUMBER RANGES

Gasoline:	C4	-	C12		Diesel:	C8	-	C22
Varsol:	C8	-	C12		Lubricating Oils:	C20	-	C40
Kerosene:	C7	-	C16		Crude Oils:	C3	-	C60+

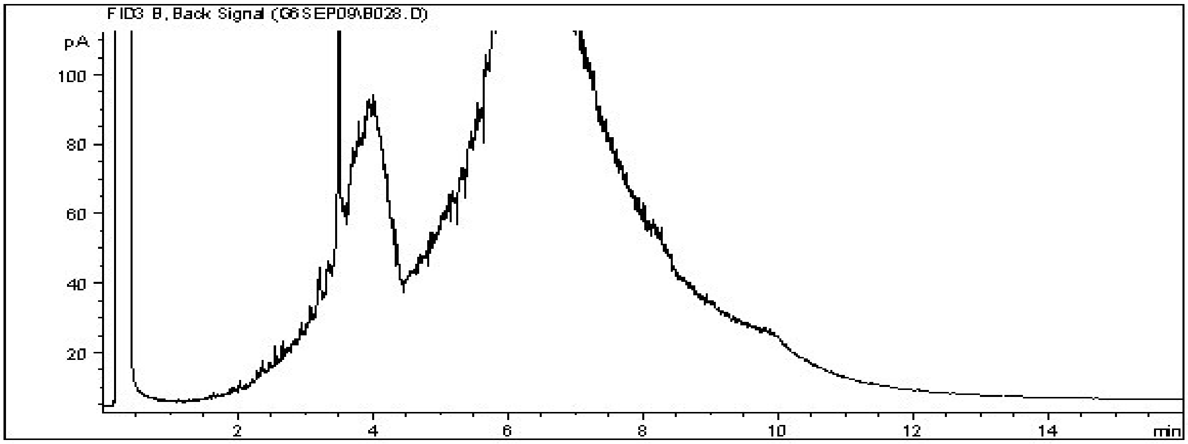
Note: This information is provided for reference purposes only. Should detailed chemist intrepretation or fingerprinting be required to please contact the laboratory.

GOLDER ASSOCIATES LTD

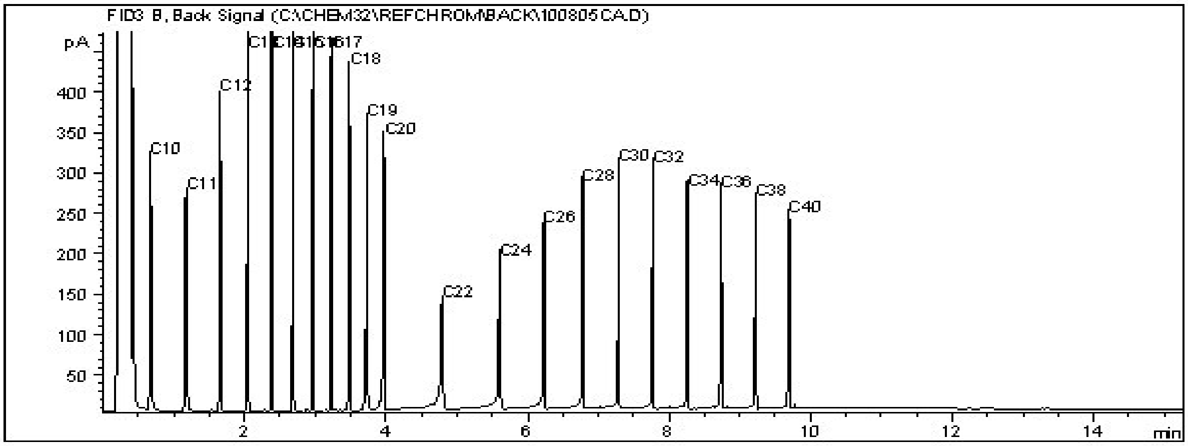
Report Date: 2010/09/17
Maxxam Job #: B081535
Maxxam Sample: W78366

Client ID: A-1

CCME Hydrocarbons (F2-F4 in soil) Chromatogram



Carbon Range Distribution - Reference Chromatogram



TYPICAL PRODUCT CARBON NUMBER RANGES

Gasoline:	C4 - C12	Diesel:	C8 - C22
Varsol:	C8 - C12	Lubricating Oils:	C20 - C40
Kerosene:	C7 - C16	Crude Oils:	C3 - C60+

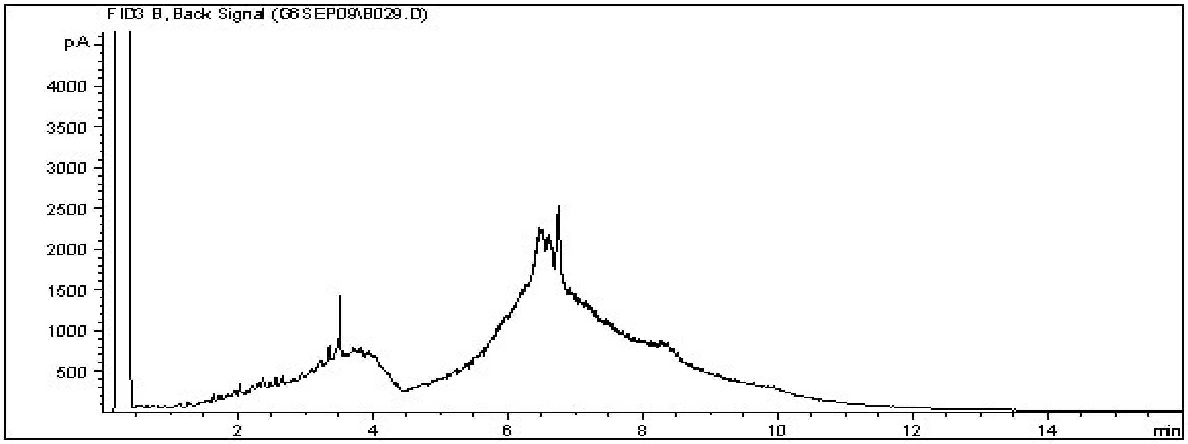
Note: This information is provided for reference purposes only. Should detailed chemist intrepretation or fingerprinting be required to please contact the laboratory.

GOLDER ASSOCIATES LTD

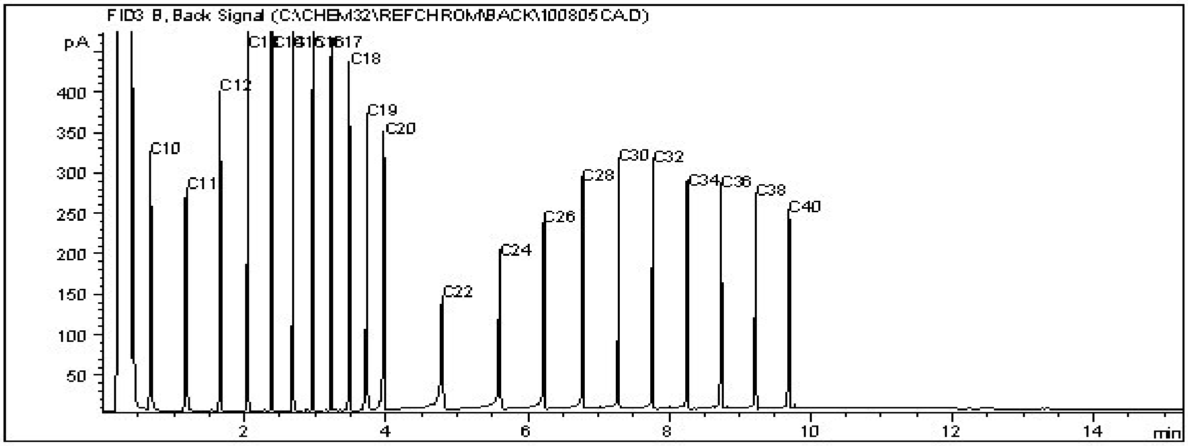
Report Date: 2010/09/17
Maxxam Job #: B081535
Maxxam Sample: W78367

Client ID: B-3

CCME Hydrocarbons (F2-F4 in soil) Chromatogram



Carbon Range Distribution - Reference Chromatogram



TYPICAL PRODUCT CARBON NUMBER RANGES

Gasoline:	C4 - C12	Diesel:	C8 - C22
Varsol:	C8 - C12	Lubricating Oils:	C20 - C40
Kerosene:	C7 - C16	Crude Oils:	C3 - C60+

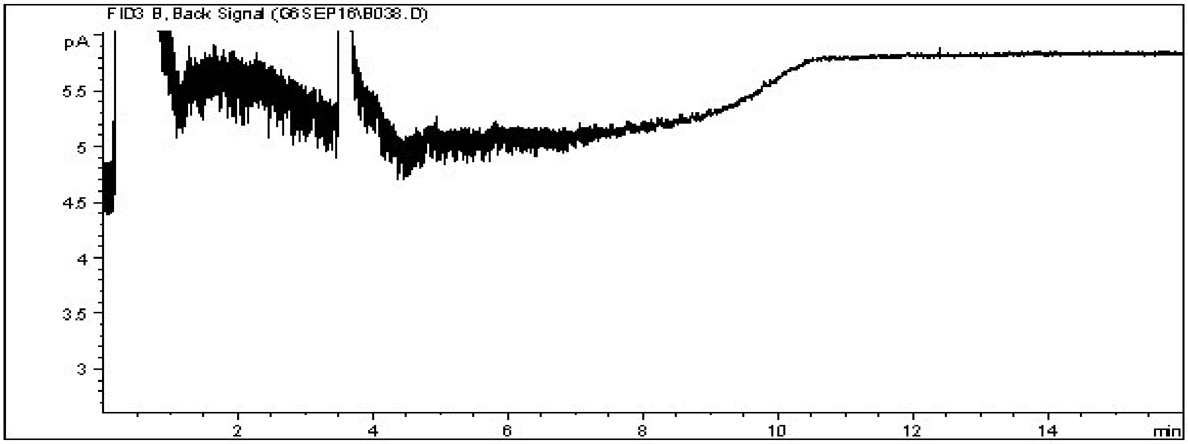
Note: This information is provided for reference purposes only. Should detailed chemist intrepretation or fingerprinting be required to please contact the laboratory.

GOLDER ASSOCIATES LTD

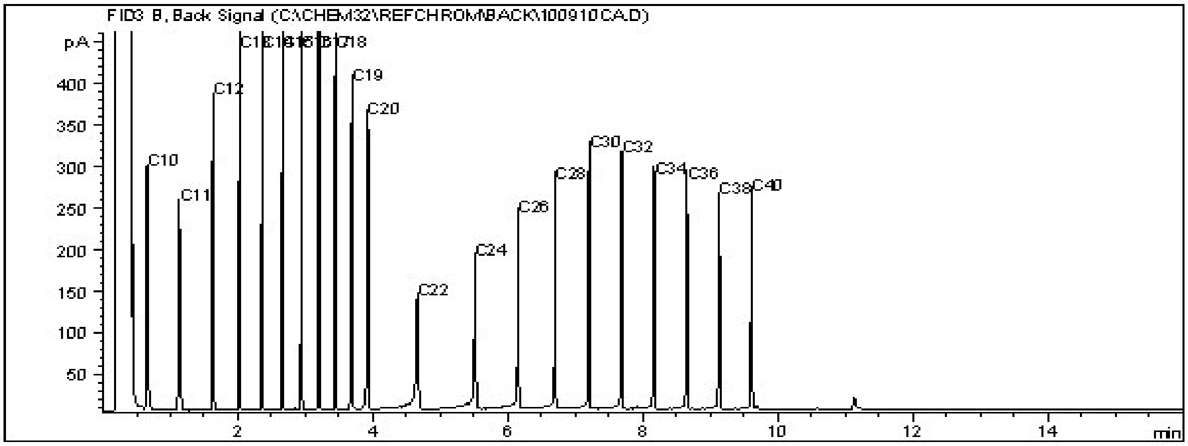
Report Date: 2010/09/17
Maxxam Job #: B081535
Maxxam Sample: W78367

Client ID: B-3

CCME Hydrocarbons (F2-F4 in water) Chromatogram



Carbon Range Distribution - Reference Chromatogram



TYPICAL PRODUCT CARBON NUMBER RANGES

Gasoline:	C4 - C12	Diesel:	C8 - C22
Varsol:	C8 - C12	Lubricating Oils:	C20 - C40
Kerosene:	C7 - C16	Crude Oils:	C3 - C60+

Note: This information is provided for reference purposes only. Should detailed chemist intrepretation or fingerprinting be required to please contact the laboratory.

Your Project #: B081535
Your C.O.C. #: N/A

Attention: Vj Oco
Maxxam Analytics
Burnaby to Bedford
4606 Canada Way
Burnaby, BC
V5G 1K5

Report Date: 2010/09/15

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B0C6727
Received: 2010/09/14, 9:03

Sample Matrix: Soil
Samples Received: 5

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Method Reference
CHN/Protein by Combustion	5	2010/09/15	2010/09/15	ATL SOP 00046	Based on AOAC990.03

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.
* Results relate only to the items tested.

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

KATIE COHOON, Bedford Client Services
Email: Katie.Cohoon@MaxxamAnalytics.com
Phone# (902) 420-0203

==
Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Total cover pages: 1

RESULTS OF ANALYSES OF SOIL

Maxxam ID		HD4179	HD4245	HD4246	HD4247	HD4248		
Sampling Date		2010/08/31	2010/08/31	2010/08/30	2010/08/30	2010/08/30		
	Units	**W78357-02R\B-2**	**W78358-02R\A-2**	**W78359-02R\C-2**	**W78360-02R\C-3DEEP**	**W78365-02R\B-1**	**RDL**	**QC Batch**
Inorganics								
Nitrogen	%	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	2265855

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

QUALITY ASSURANCE REPORT

			Method Blank		RPD		QC Standard	
QC Batch	**Parameter**	**Date**	**Value**	**Units**	**Value (%)**	**QC Limits**	**% Recovery**	**QC Limits**
2265855	Nitrogen	2010/09/15	<0.2	%	NC	25	99	80 - 120

N/A = Not Applicable

RPD = Relative Percent Difference

QC Standard: A blank matrix to which a known amount of the analyte has been added. Used to evaluate analyte recovery.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (RPD): The RPD was not calculated. The level of analyte detected in the parent sample and its duplicate was not sufficiently significant to permit a reliable calculation.

Validation Signature Page

Maxxam Job #: B0C6727

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Mike Mac Gill

MIKE MACGILLIVRAY, Bedford Inorg Spvsr

===

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Africa	+ 27 11 254 4800
Asia	+ 852 2562 3658
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

solutions@golder.com
www.golder.com

Golder Associates Ltd.
500 - 4260 Still Creek Drive
Burnaby, British Columbia, V5C 6C6
Canada
T: +1 (604) 296 4200

Appendix IV-1

Navigable Waters Permit August 2000

Fisheries and Oceans
Canada

Pêches et Océans
Canada

Coast Guard
Central & Arctic Region

Garde côtière
Région du Centre et de l'Arctique

201 N. Front Street, Suite 703
Samia, Ontario
N7T 8B1

REGISTERED

Your file Votre référence

Our file Notre référence
8200-97-6320

Diavik Diamond Mines
#205, 5007-50th Avenue
PO Box 2498
Yellowknife, Northwest Territories
X1A 2P9

Dear Sir/Madam:

RE: Application for approval of dykes, Lac De Gras, East Side of East Island, 320 km Northeast of Yellowknife, Northwest Territories

APPROVAL

Enclosed herewith is a formal document dated AUG 03 2000 signed on behalf of the Minister of Fisheries and Oceans.

Please acknowledge receipt of this documentation. In addition, kindly advise this office at the above address of the date of commencement and of completion of the work.

Yours truly,

Ken E. Brant
Superintendent
Navigation Protection Program
Canadian Coast Guard

RECEIVED
AUG 8 2000
DIAVIK - YK

Encl.

Canada

CANADA
DEPARTMENT OF FISHERIES AND OCEANS

FORM 1

NAVIGABLE WATERS PROTECTION ACT, PART 1
Section 5(1)

8200-97-6320

Approval

APPLICANT:
Diavik Diamond Mines
#205, 5007-50th Avenue
PO Box 2498
Yellowknife, Northwest Territories
X1A 2P9

WORK: Dykes

SITE - LOCATION:
Lac De Gras
Latitude: 64°29'0", Longitude: 110°16'0"
East Side of East Island
320 km Northeast of Yellowknife
Northwest Territories

IMPORTANT NOTE: This document authorizes the work in terms of its effect on marine navigation. It is the applicant's responsibility to obtain any other forms of approval, including building permits.

WHEREAS the above-named applicant has made application to the Minister of Fisheries and Oceans under the Navigable Waters Protection Act for approval of the above-described work at the above-referred to site in accordance with the attached plan(s):

WHEREAS it is considered advisable to approve the said work at the said site and plan(s) thereof for a period of 30 years, subject to the following term(s) and condition(s).

The owner(s) or person(s) in possession is required to ensure that:

1. Diavik will submit a plan to the Coast Guard Region Office showing the extent of dyke progress in April and September of each year until completion.
2. Upon completion of the project, all construction equipment and material, temporary structures and parts thereof are completely removed from the navigable waters at the worksite.
3. Any debris or other material accumulating on the bed or on the surface of the water attributed to the work is removed.

THEREFORE, the Minister of Fisheries and Oceans, pursuant to the provisions of the Navigable Waters Protection Act, Revised Statutes of Canada, 1985, chapter N-22, hereby approves the said work at the said site and plan(s) thereof for the period of time aforesaid providing:

(a) the construction of the work is commenced within six (6) months and completed within three (3) years of the date hereof;

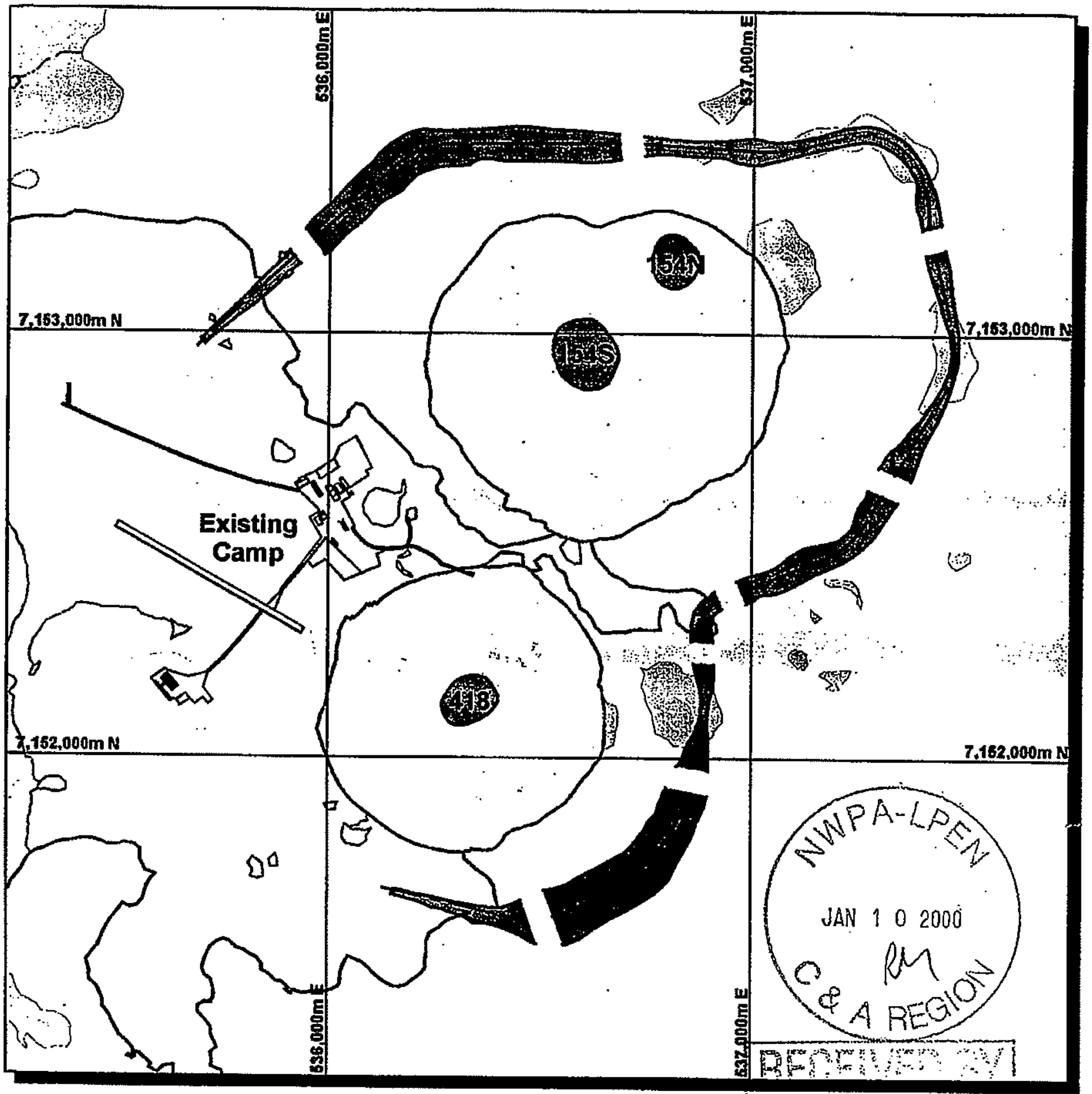
(b) the work is built, placed and maintained in accordance with the plan(s) and the Navigable Waters Works Regulations and the aforesaid term(s) and condition(s).

Sarnia, dated AUG 0 3 2000

Charles J. Gadula
Regional Director, Canadian Coast Guard
Central & Arctic Region

for Minister of Fisheries and Oceans.

73-0091 (08-92)



NOTE :

1. BREACHES ARE 30m WIDTH AND MINIMUM 2m DEPTH FROM LOW WATER.

2. ALL INTERNAL REEFS ARE MINIMUM 2m DEPTH FROM LOW WATER.

DIAVIK
DIAMOND MINES INC.

RECLAMATION

DIKE BREACH LOCATIONS

DRAWN WMF
AUTHOR R. LOCK
FILE CE-DIKE BREACH.cdr
DATE 24 AUGUST 99

Appendix V-1

Risk Assessment Workshop Presentation Material

RioTinto

Risk Assessment Workshop

December 6-7, 2011

RioTinto

Purpose

- Provide a working example of how risk assessment can be used in the development of closure criteria.

Closure Criteria - Definition

- Closure criteria are developed for each closure objective for approval by the Board that issued the water licence.
- They are used to determine if selected closure activities meet the closure objectives for each project component.
- Closure criteria can be site-specific or adopted from territorial/federal standards and can be narrative statements or numerical values.
- Closure criteria must be meaningful, measurable, and achievable over time to ensure successful reclamation of project components.
- Closure criteria may also have a temporal aspect to consider (e.g., testing will be done for two, five, ten years).

(**Source**: Land and Water Board DRAFT Guidelines for the Closure and Reclamation of Advanced Mineral Exploration and Mine Sites in the Northwest Territories. August 11, 2011)

An example

- Closure **goal :** Land and water that is physically and chemically stable and safe for people, wildlife and aquatic life.
- PKC specific closure **objective:** No adverse affects on people or wildlife.
- Closure **activities**:
  - Place rock covers over beaches
  - Remove free water, treat and discharge
- Closure **criteria**:
  - Wildlife: site-specific risk-based criteria met
  - Human: CCME or site-specific risk-based criteria met
- Closure **monitoring**: Post-closure sampling of runoff/seepage/vegetation/dust deposition at representative locations where human/wildlife consumption of water/vegetation/dust is likely.

Site-specific risk-based closure criteria

- Site-specific because the exposure pathways and wildlife receptor characteristics are for the Diavik area.
- Risk-based as they are calculated using the principles of risk assessment. Considers routes of exposure combined with relative toxicity of parameters of concern.
- Derived criteria are conservative exposure concentrations that would not pose an adverse risk to receptors. Meaning that they tend to over estimate the potential for health effect to wildlife.
- Exposure routes are biased to “reasonable maximum” exposure.
- They are initially screening criteria. If predicted or measured exposure concentrations exceed criteria then a detailed risk assessment may be undertaken using more realistic exposure scenarios to assess the risk.
- Closure criteria can evolve with more detailed assessment and/or new information

Example Wildlife Receptor Selection

Receptor	Rationale for Selection
Caribou:	* Mine site is located within an established caribou migration corridor * may spend up to 2 months per year on East Island * exposed to chemicals in the terrestrial food chain (soil, dust, water and plants) * a highly valued species in the area (hunting, conservation)
Northern Red-backed Vole:	* organism with high potential for exposure due to small home range and small body size (surrogate for other rodents) * common year-round resident in the area and may be a year-round resident on East Island * important as a food source for predators (e.g., red fox, raptors)
Red Fox:	* common year-round resident in the area (surrogate for other predators) * predator of voles and other small rodents, hare and ptarmigan which may inhabit the area * exposed to chemicals in the terrestrial food chain (soil, dust, water and prey) * valued species in the area (hunting/trapping)
Ptarmigan:	* common seasonal resident for six months of the year, and occasionally a year-round resident in the area (surrogate for other terrestrial avian species) * exposed to chemicals in the terrestrial food chain (soil, dust, water and plants) * valued species in the area (hunting)

Typical Site Specific Information

Parameter	Caribou[a]	Northern Red-backed Vole[a]	Red Fox	Ptarmigan[a]
Body Weight (kg)	90	0.02	4.5[bcd]	0.6
Longevity	4.5 years (max. 13 years)	9 months	12 years [d]	4 years
Dietary Preferences	100% vegetation	100% vegetation	100% mammals/birds[b]	100% vegetation
Food Ingestion Rates (kg dry weight/day)	2.7	0.0066	0.34[b] (wet wt) 0.1 (dry wt)	0.065
Water Ingestion Rates (L/day)	1.1	0.017	0.4 [b]	0.025
Soil/Dust Ingestion Rates (kg dry weight/day)	0.11	0.00016	0.0028 [e]	0.006
Lung Ventilation Rates (m^3/day)	24	0.042	2 [b]	0.44

Parameter	Caribou[a]	Northern Red-backed Vole[a]	Red Fox	Ptarmigan[a]
Duration of Exposure	2 months (60 days)	year round (365 days)	year round (365 days)	year round (365 days)
Key Habitats	Heath tundra, sedge meadows	Bouldery heath tundra	All habitat types during hunting, eskers for denning [a]	Heath tundra, tall shrub, bouldery tundra
Locations of Exposure: remaining natural habitat on east island	Residual heath tundra, sedge meadows, unvegetated areas like country rock storage	Residual bouldery heath tundra	All habitat types during hunting, eskers for denning [a]	Residual heath tundra, tall shrub, bouldery tundra

a Information compiled by Penner and Associates (Penner and Associates Ltd., 1998).
b EPA, 1993.
c Soper, 1973.
d Towers, 1980.
e Beyer et al., 1994.

Typical Toxicological Information

Chemicals	Test Species	Test[1] Species NOAEL (mg/kg-BW/day)	Toxicological Endpoint and Exposure Duration	Test Species Body Weight (kg)	Wildlife[2] Species Body Weight (kg)	Estimated[3] Chronic Wildlife NOAEL (mg/kg-BW/day)	References
Red Fox							
Arsenic	laboratory mice	0.126	reproduction; 3 generations (>1 year)	0.03	4.5	0.04	Perry et al. 1983.
Barium	laboratory rat	5.1	growth, hypertension; 16 months	0.435	4.5	2.8	Schroeder and Mitchener 1971
Beryllium	laboratory rat	0.7	longevity, weight loss	0.35	4.5	0.3	Schroeder and Mitchener 1975
Cadmium	laboratory rat	1.0	reproduction; 6 weeks during mating and gesta	0.303	4.5	0.5	Sutou et al. 1980b
Chromium (III)	laboratory rat	2737.0	reproduction; longevity; 2 years	0.35	4.5	1445.4	Ivankovic and Preussmann 1975
Cobalt	cattle	0.25	maximum tolerable level	318	4.5	0.7	NAS 1980.
Copper	mink	11.7	reproduction; 357 days during critical lifestage	1	4.5	8.0	Aulerich et al. 1982
Lead	laboratory rat	8.0	reproduction; 3 generations (>1 year)	0.35	4.5	4.2	Azar et al. 1973
Manganese	laboratory rat	88.0	reproduction; 244 days during critical lifestage	0.35	4.5	46.5	Laskey et al. 1982
Mercury	mink	1.0	reproduction; 6 months during critical lifestage	1	4.5	0.7	Aulerich et al. 1974
Molybdenum	laboratory mice	0.26	reproduction; 3 generations (>1 year)	0.03	4.5	0.1	Schroeder and Mitchener 1971
Nickel	laboratory rat	40.00	reproduction; 3 generations (>1 year)	0.35	4.5	21.1	Ambrose et al. 1976
Selenium	laboratory rat	0.20	reproduction; 2 generations (1 year)	0.35	4.5	0.1	Rosenfield and Beath 1954
Strontium	laboratory rat	263.00	body weight and bone changes	0.35	4.5	138.9	Skornya 1981
Uranium	laboratory mice	3.1	reproduction; during gestation, delivery and lacta	0.028	4.5	0.9	Paternain et al. 1989.
Vanadium	laboratory rat	0.21	reproduction; during gestation, delivery and lacta	0.26	4.5	0.10	Domingo et al. 1986.
Zinc	laboratory rat	160	reproduction; days 1-16 of gestation	0.35	4.5	84.5	Schlicker and Cox 1968

Typical Calculations

Water: $$\text{RBCC (mg/L)} = \frac{0.2 * \text{bw} * \text{NOAEL}}{\text{IR}_w * \text{EFR}}$$

Prey: $$\text{RBCC (mg/kg)} = \frac{0.2 * \text{bw} * \text{NOAEL}}{\text{IR}_{pr} * \text{EFR}}$$

Plant: $$\text{RBCC (mg/kg)} = \frac{0.2 * \text{bw} * \text{NOAEL}}{\text{IR}_{pl} * \text{EFR}}$$

Soil: $$\text{RBCC (mg/kg)} = \frac{0.2 * \text{bw} * \text{NOAEL}}{\text{IR}_s * \text{EFR}}$$

Dust: $$\text{RBCC } (\mu\text{g/m}^3) = \frac{0.2 * \text{bw} * \text{NOAEL} * \text{BAoral} * \text{CF}}{\text{LV} * \text{EFR} * \text{BAinhal}}$$

RBRC = risk-based closure criteria (in units specified)
bw = body weight (kg)
NOAEL = No-Observable-Adverse-Effect Level (mg/kg/d)
IR = ingestion rate (L/d) (kg dry weight/d)
LV = lung ventilation rate (m^3/d)
EFR = exposure frequency ratio; fraction of time spent on East Island (e.g., 20/365 d)
CF = conversion factor (1000 µg/mg)
BAoral = oral bioavailability; fraction of chemical absorbed via ingestion (chemical-specific)
BAinhal = inhalation bioavailability; fraction of chemical absorbed via inhalation (chemical-specific)

Example Results

Chemicals	Risk-Based Closure Criteria for Plants (mg/kg dry weight)	Risk-Based Closure Criteria for Prey (mg/kg dry weight)	Risk-Based Closure Criteria for Dust (ug/m^3)	Risk-Based Closure Criteria for Soil (mg/kg dry weight)	Risk-Based Closure Criteria for Water (mg/L)
Caribou					
Barium	170	n/a	2400	4000	130
Cadmium	8	n/a	370	200	20
Chromium (III)	28000	n/a	1000000	680000	68000
Cobalt	12	n/a	690	300	30
Copper	150	n/a	17000	3800	380
Lead	81	n/a	1300	2000	200
Molybdenum	1.6	n/a	180	40	4
Nickel	400	n/a	46000	10000	1000
Uranium	17	n/a	1900	410	41
Vanadium	2	n/a	230	50	5
Zinc	1600	n/a	180000	40000	4000
Red Fox					
Arsenic	n/a	0.4	n/a	n/a	n/a
Barium	n/a	80	500	2800	6
Beryllium	n/a	3	n/a	n/a	n/a
Cadmium	n/a	5	90	160	1
Chromium (III)	n/a	13000	216750	460000	3250
Cobalt	n/a	6	158	225	2
Copper	n/a	72	3600	2600	18
Lead	n/a	38	270	1350	9
Manganese	n/a	420	n/a	n/a	n/a
Mercury	n/a	6	n/a	n/a	n/a
Molybdenum	n/a	0.6	32	23	0.2
Nickel	n/a	190	9450	6750	47
Selenium	n/a	0.9	n/a	n/a	n/a
Strontium	n/a	1250	n/a	n/a	n/a
Uranium	n/a	8	387	280	2
Vanadium	n/a	0.9	45	32	0.2
Zinc	n/a	760	38025	27000	190

Acknowledgement

References:

Mucklow, L and S. Swanson 1998. Technical Memorandum: Risk-Based Reference Concentrations for Protection of Wildlife. Prepared for Diavik Diamond Mines Inc by Golder Associates. June 18,1998

Penner and Associates Ltd. 1998. Wildlife parameters to support risk based assessment for the Diavik Diamond Project. January 1998.

Appendix VIII-1

AANDC Table of Environmental Agreement Security

DDMI Environmental Agreement Security Requirements (Revised)

Purpose	Rationale	Detailed Rationale	Revised Estimate
1. Incre mental costs which Canada will incur if it has to undertake closure and reclamation (Article 15.1(d))	Incremental costs which the Crown may incur associated with the following:		$1.25M
	A. Retaining third party engineering/technical consultants to obtain regulatory approvals to conduct the reclamation work.	Costs associated with retaining technical experts during the acquisition of a water licence and land use permit required to conduct reclamation work. There are costs within RECLAIM^2 for reporting on reclamation monitoring but not for obtaining Water Licence and Land Use Permit, or any other regulatory instruments. Has not been specifically included in previous Board decision on reclamation security.	
	B. Upholding commitments under the Comprehensive Study Report.	Assume work conducted during 3 year interim care and maintenance and 7 year post-closure period (10 year total). Note all programs to involve representatives of local communities/signatories to the Environmental Agreement. - Air monitoring/dust monitoring and reporting; - Caribou monitoring and reporting; - Other carnivore monitoring (wolf, wolverine, bears) + raptor and prey monitoring; - Dike-Water interface monitoring of cadmium and bioavailability to fish Fish Palatability and Texture - Metal concentrations in fish tissue - East Island Lakes, and; - Fish consumption advisory plan - East Island Lakes	$3.4M
	C. Consultation and engagement in advance of and during the reclamation effort.	• Water Licence Acquisition (Years 0,1) – community meetings in Ndilo/Dettah; Gameti; Wekweti; Whati; Behchoko; Lutsel K'e; Kugluktuk; Yellowknife; • Site Visits during 7 year post closure period (Years 3, 7, and 10); and, • Bi-Annual Community Meetings (Years 2, 4, 6, 8) - community meetings in Ndilo/Dettah; Gameti; Wekweti; Whati; Behchoko; Lutsel K'e; Kugluktuk; Yellowknife.	$4.6M
2. Conting encies (Article 15.1(d))	Contingency is built into Purpose # 3.	Contingency is built into Purpose # 3.	$0M

3. Potential for increases in environmental liabilities related to Project configuration (Article 15.1(d))	Uncertainty remains in the *Interim Closure and Reclamation Plan* with respect to several elements on site, including closure approach for the North Country Rock Pile, Processed Kimberlite Containment, Open Pit and North Inlet. Costs are for alternative reclamation options.	• RECLAIM estimate is based upon the approved closure approach within the approved *Interim Closure and Reclamation Plan*. Contingencies within that estimate are allocated towards minor modifications to that approach, resolving difficulties in implementing the approach, need for additional or unique equipment to implement closure option, changes in unit costs, volumes, and time associated with the closure option. • The RECLAIM estimate and its built-in contingencies do not include potential liabilities at tha site due to uncertainty in closure approaches, and the need to re-design or develop a new closure approach. • It is clear that the Additional Security Deposit can include costs associated with Potential for increases in environmental liabilities related to Project configuration. • It is clear from the *Interim Closure and Reclamation Plan* that uncertainty remains in regards to the success of the proposed closure approach for the North Country Rock Pile, Processed Kimberlite Containment and North Inlat. Accordingly, the following potential liabilities have been identified and costs performed on a risk basis: - The North Inlet Dam cannot be removed as planned. - Water treatment to address water quality issues with waste rock piles. - Tailings cover is not effective at containing expelled water.	
	A. The North Inlet Dam cannot be removed as planned.	Water has to be pumped and treated and sediments dredged and placed in North Country Rock Pile.	$3.55M
	B. Water treatment to address water quality issues with waste rock piles.	10 years post-closure water treatment to deal with these potential liabilities:	$0.95M
	C. Tailings cover is not effective at containing expelled water.	Installation of liner over Processed Kimberlite Containment to prevent infiltration.	$7.63M
4. Non-reclamation related commitments under the Environmental Agreement (Article 15.1(d))	Canada continues to fulfill commitments under the Environmental Agreement during interim closure and maintenance (3 years) and during the 7 year post-closure period (10 years total).	Environmental Monitoring Advisory Board operation 10 years = $6M Note – EA Security Deposit ($3M) could also be used for this purpose	$3.00M

5. Serious and imminent threat to the environment (Article 15.3(b))	A period of cost cutting and declining site management preceding bankruptcy typically leads to events posing serious and imminent threat to the environment to which Canada must respond.	Catastrophic events which would result in a serious and imminent threat to the environment is not included within RECLAIM. Over-topping of a tailings pond would fall within this category. As a company approaches bankruptcy, it may be unable to maintain the site in a state of compliance with its licence. An indicative cost estimate is based on the cost of mitigating the imminent over-topping of the tailings pond where Aboriginal Affairs and Northern Development Canada would engage a contractor on an emergency basis to ensure the protection of water and the stability of structures.	$0.719M
6. Compliance with regulatory instruments (Article 5)	Outstanding substantial and material non-compliances at the time of bankruptcy could leave Canada with incrementel costs to return the site to compliance. These costs are included under "Serious and imminent threat to the environment" (see Purpose #5) and the interim care and maintenance amounts held under the Water Licence security.	This event is assumed to be either a serious and imminent threat to the environment (see above), or one involving less significant costs that are covered under the interim care and maintenance contract.	$0M
Subtotal			$25.10M
EA Security Deposit[3]			$3.0M
Total			$28.10M

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[2] RECLAIM is a methodology to estimate the amount of land use and water licence security required for a project. It supports security estimates for mine operations (e.g. management of rock piles, tailings, water, the pit, etc.)

[3] Article 15.1(k) provides for a fixed EA Security Deposit amount of $3 million.

DDMI TK Panel Recommendations and Response Tracking - Wildlife Monitoring & Management

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
Assigned by DDMI unless otherwise indicated in report	*Be as specific as you think is appropriate; for example a section or page of the document, a recommendation #, general comment, etc.*	*Recommendations should be as specific as possible and explain an action that you believe is necessary; supporting information or rationale should be explained in the "context" column.*	*Context should contain all the information needed to understand the rationale for the accompanying recommendation.*	*Distinct values/concepts that are contained in Traditional Knowledge and can help to guide decision process*	*Responses should be as specific as possible, relating the issues raised in the "recommendation".*	*Actions should be as specific as possible, relating the issues raised in the "recommendation"; where possible, a timeframe may be included.*
1.1	A Way of Life, 25 Oct 2012, pg. 19	During July/August, a regular training session should be planned for Diavik staff in ways of properly respecting caribou and other animals	Cross-cultural learning is important when there are two ways of knowing wildlife. Scientists and Environment staff have a different way of doing work and understanding wildlife compared to that of TK holders. Respect for wildlife by TK holders means following the traditional laws that govern the relationship between humans and individual species. A successful monitoring program requires good communication and this can be challenging in a cross-cultural setting. Strong relationships and a special effort to understand the differences are key to success.	Respect Reciprocity Traditional Laws	Diavik staff and community assitants participating in the monitoring program undergo onsite and field training prior to initiation of the program. In addition standard operating procedures are revisited in the field throughout the process. In 2012 and 2013, Diavik invited community Elders and youth to particpate in the monitoring program to observe staff performance and evaluate procedures. Minor changes were suggested and are currently being reviewed.	Involve community members in caribou monitoring and share knowledge of different practices relating to wildlife.
1.2	A Way of Life, 25 Oct 2012, pg. 19, 25	When elders are brought to site for staff training exercises, youth delegates should also be involved	The youth are living in a changing and complex world now. They have skills that the Elders don't, and they can help in the future. Everywhere that the Elders are called upon to share knowledge or observe changes, the youth should be with them to both learn and share. Teaching stewardship is the reponsibility of each generation of elders.	Stewardship Intergenerational Social	Due to the nature of remote field work, seating capacity may be limited. Adding a youth component to this program limits Elder participation but has generally been supported by the communities.	When possible, invite Elders and Youth to participate in Diavik activities.
1.3	A Way of Life, 25 Oct 2012, pg. 19	The TK-Science camp at the mine site is an important place for developing skills and capacity in cross-cultural caribou monitoring	Elders feel that they can be creative in collaborating with Diavik in a cross-cultural setting that includes observations and knowledge exchanges at the TK/IQ Camp.	Reciprocity	Recommendation is outside the scope of the Caribou Behavioural Monitoring SoP. Such opportunities may be considered for future camps, depending upon the focus of the camp.	N/A
1.4	A Way of Life, 25 Oct 2012, pg. 19	The TK-Science camp (known as the CBM Camp) should be moved to a location north of Diavik on Lac du Sauvage. The setup must be in the Aboriginal way, not in a square, so that it's not threatening to the caribou.	In keeping with traditional laws governing relatioship with caribou, the camp should be closer to the caribou migration route in order to develop skills and capacity in cross-cultural caribou monitoring. Aboriginal camps on the land have a specific way of being set up, and this should be respected for the set-up of the TK/IQ camp.	Traditional laws	The camp site has been established in consultation with community members under a land use permit with the WLWB and will not be relocated. The footprint of buildings and other infrastructure will not be changed significantly, in order to reduce further impacts on the environment.	N/A
1.5	A Way of Life, 25 Oct 2012, pg. 19	Monitoring results should be reported back to the communities on a consistent basis.	Participants expressed frustration at the lack of communication (and involvement) with community members relating to caribou monitoring at the mine site to date.	Reciprocity	Diavik prepares annual wildlife monitoring reports and an Environmental Agreement (EA) summary report. Additionally, EMAB produces an annual report that summarizes findings and recommendations. Wildlife monitoring updates are also included in annual presentations to communities. Diavik welcomes any further recommendations on how best to ensure that this information reaches individual community members.	Continue to distribute annual reports (which include executive summaries) to community organizations and visit communities as available. Investigate and request feedback on more appropriate methods for communication of monitoring programs & results.
1.6	A Way of Life, 25 Oct 2012, pg. 19	It will be valuable to "check nets" and synthesize what's already been done by Diavik to incorporate TK/IQ into its processes, and document/share lessons learned from these experiences in order to avoid repeating work already done.	Participants felt that they are often repeating themselves (to same and different companies) about many of these topics/concerns. A sign of being respected is 'being heard'; so to have to continually repeat themselves, TK holders feel disrespected. There is value in reviewing what Diavik has done to incorporate TK/IQ into their work.	Respect	Unclear if recommendation is addressed to the TK/IQ Panel or Diavik. Diavik is open to sharing information about current and upcoming TK/IQ plans and programs with the Panel for their review. Literature reviews have also been done to determine TK/IQ use for closure planning and vegetation.	Confirm if the recommendation is to Diavik or to TK Panel members/facilitators.
1.7	A Way of Life, 25 Oct 2012, pg. 20	Use pictures and/or other visual tools as part of the form for caribou behavioral scans.	Visual representation of the different behaviours of caribou is likely more accurate and would be helpful for people conducting the scans, especially new hires. People see things through a cultural lens and may interpret what is seen differently.	Reciprocity	An effort to take photos displaying various caribou behaviours was undertaken during the 2012 and 2013 monitoring seasons.	DDMI staff are evaluating opportunities to incorporate visual tools into the SoP.
1.8	A Way of Life, 25 Oct 2012, pg. 20	TK holders should be hired on a seasonal basis (i.e. spring through summer) to work with Diavik staff in caribou monitoring.	A TK holder on staff would be helpful in conducting cross-cultural training and monitoring considerations. Tradition requires TK holders to report their observations to each other and to discuss interpretation of those observations.	Reciprocity	Most caribou monitoring is completed from August - October. DDMI brings Elders to site to participate in these monitoring programs each year.	Investigate options for transitioning caribou behaviour monitoring to communities, while continuing to include Elders in current monitoring programs.

DDMI TK Panel Recommendations and Response Tracking - Wildlife Monitoring & Management

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
1.9	A Way of Life, 25 Oct 2012, pg. 20	Community meetings are a good way to gather more information on how caribou are doing	This can be a means of extending traditional monitoring practices to include scientists. Both parties are able to share their observations on caribou in a face-to-face meeting. Such an approach provides a good opportunity for community members to learn about what is happening at the mine in relation to caribou. And mine employees have a chance to learn what the communities are seeing in their areas.	Reciprocity	Recommendation is outside the scope of the Caribou Behavioural Monitoring SoP. Diavik hosts annual community meetings that include discussions on caribou and other wildlife. Diavik has also coordinated and participated in many wildlife forums to discuss caribou health and management with numerous stakeholders.	N/A
1.10	A Way of Life, 25 Oct 2012, pg. 20	Caribou observation logs can also be used by community members when they are on the land	TK holders adapt and are willing to use new tools to carry out their stewardship responsibilities. Harvesters in the community may find the Diavik forms useful, and it may be helpful information for ENR.	Social	Recommendation is outside the scope of the Caribou Behavioural Monitoring SoP. Diavik can supply the field sheets to communities, if requested.	N/A
1.11	A Way of Life, 25 Oct 2012, pg. 20	Include more behaviors in the list for observation	Participants felt that there were other common behaviours not captured in the list. Community members are more familiar with different caribou behaviours and could help to expand the list and capture more detailed information. The intricate TK about caribou and caribou behaviour is required to inform good decisions. For example, caribou that are scared will often put their nose in the air, sometimes jump and then gallop fast; they are threatened because they do not know what is going on.	Reciprocity	Elders from the YKDFN, NSMA and Tlicho participated in caribou behavior surveys in the fall of 2012 and 2013. One additional behavior has been recommended so far: curious (approached).	Consider changes to SoP based on feedback from community members.
1.12	A Way of Life, 25 Oct 2012, pg. 20; Closure Reclamation & Landscape History Interim Report, 19-22 February 2013, pg.6	Include more categories for herd composition and behaviour; involve two individuals nominated by the TK Panel to assist with updating the SOP.	Community members see caribou herds differently than scientists. For example, there are leaders and followers within a herd. Participants felt this would be helpful information to record because the relationship between herd members is important to understand in making decisions to reduce impacts on caribou.	Reciprocity	Elders from the YKDFN, NSMA and Tlicho participated in caribou behavior surveys in the fall of 2012 and 2013. No additional categories have been recommended to date.	Plans to review suggestions and improve the information in these categories is being considered by Diavik.
1.13	A Way of Life, 25 Oct 2012, pg. 20	Utilize Aboriginal terms/concepts as identifiers	Participants expressed that there are Aboriginal terms that capture caribou activity or behaviour, perhaps more accurately than English terminology for them. Specific terms and concepts contain unique understandings important in governing the way we treat or 'manage' caribou. Specific terms and concepts contain unique understandings important in governing the way we treat or 'manage' caribou Addition of such terms to the data form may be helpful for community members participating in surveys.	Symbolism	This may be beneficial in the future, if caribou behavioural monitoring were to transition to communities.	N/A
1.14	A Way of Life, 25 Oct 2012, pg. 20	Injured animals should be sent to ENR for assessment	It would be helpful to have as much information as possible about injured or dead caribou, so that community members are made aware of the cause. TK holders may have other ideas about how to safeguard caribou in the future.	Stewardship Capturing knowledge	Recommendation is outside the scope of the Caribou Behavioural Monitoring SoP. Diavik has a specific policy and procedures in place for reporting and handling of injured or deceased wildlife, and this involves ENR.	N/A
1.15	A Way of Life, 25 Oct 2012, pg. 20	Scientists and TK holders analyze dead caribou together	It would be helpful to have as much information as possible about injured or dead caribou, so that community members are made aware of the cause, can share information and learn the way that government analyzes caribou carcasses. TK holders and scientists can exchange ideas on causes and ways to prevent future deaths.	Stewardship Recording knowledge Reciprocity	Recommendation is outside the scope of the Caribou Behavioural Monitoring SoP. Diavik has a specific policy and procedures in place for reporting and handling of injured or deceased wildlife. Diavik staff do not analyze dead caribou themselves; it is done by ENR.	N/A
1.16	A Way of Life, 25 Oct 2012, pg. 20-23	Four key areas for monitoring: 1. Behaviours 2. Herd composition 3. Caribou health 4. Environmental conditions	These were identified as the key concerns of community members that are all factors considered in the traditional monitoring system; they should be monitored by Diavik. Indicators or signs of herd condition were identified within each of these areas.	Stewardship	Many of the indicators recommended that relate to herd composition, health and environment are more appropriate to be studied by government at a regional level. Behaviours and local conditions are included in the current SoP.	N/A

DDMI TK Panel Recommendations and Response Tracking - Wildlife Monitoring & Management

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
4.1.1	Checking Nets, 23-25 Oct 2012, pg.8; Closure/Reclamation and Landscape History Interim Report, 23-25 October 2012, pg.8	The TK/IQ Panel should develop a report that more fully represents our knowledge and practice for maintaining the well-being of the caribou. TK assumes that all who live on the land of the caribou have stewardship responsibilities and must take these responsibilities seriously.	Many planning and monitoring gaps exist in relation to caribou and Diavik that have yet to be addressed, such as: Aboriginal monitoring approach (harvest camp), stewardship (traditional caribou laws), movement & cumulative impacts (monitor migration with youth), behaviour and herd composition (response to environmental influences, not just to mining). Preference is to monitor the herds when they are moving, north of Diavik.	Stewardship	Recommendation is to the TK/IQ Panel, however Diavik does not view this as within the mandate of the Panel. The Panel could recommend considerations for planning and observing caribou well-being in relation to the development of closure plans & post-closure monitoring programs.	A future Panel session to discuss closure monitoring is expected and caribou will be a part of that discussion. COMPLETE
7.3	Re-vegetation Report, TK Panel Session #7, 14-18 August 2014	Use traditional techniques (e.g. flags, trees) to keep caribou away from areas that are unsafe (both near and far from site).	Caribou will find their old migration routes, but they also make their own trails that change over time. Some participants recognized that it is important to try to encourage caribou away from harmful areas far before they reach the mine site/East Island. Others felt that it would be impossible to prevent animals from coming to the mine site area. Consideration for guiding caribou on the mainland or around the island is a possible topic for future discussions.	Stewardship	DDMI proposes to hold a TK Panel session in the spring 2016 to discuss wildlife monitoring and management at closure. Further discussions to advance this concept would be well suited to this meeting.	Confirm TK Panel support for a 2016 spring session on wildlife monitoring and management at closure. If supported, DDMI to plan session for April/May 2016. COMPLETE
7.5	Re-vegetation Report, TK Panel Session #7, 14-18 August 2014	Create safe passage for caribou over the rock pile and through the site following their old migration routes on the north and south east sides (refer to map developed during session).	Panel members felt that it was not necessary to plan too much for the animals safe passage, as caribou will ultimately go where they want and will find the ramp, road or easy way. Preference was to align the path with the old migration route and to keep the slope similar to that of the test pile - as natural as possible. There are some big rocks at the bottom of the rock pile that would need to be covered. It was seen as important to think about the slope in the winter too - how wind will deposit snow - not just when it is snow free. The berms on top of the rock pile were viewed as a barrier to caribou movement, so it would be preferred to remove them and also to remove the berm around the top of the pile.	Stewardship Seasonality	This is very similar feedback to what community members said at a 2009 workshop relating to caribou at closure. Current closure plans, most notably for the rock pile, generally support this recommendation and the underlying reasons for the recommendation.	DDMI to consider design features that support this recommendation during the next major update to the ICRP (2016). COMPLETE
7.8	Re-vegetation Report, TK Panel Session #7, 14-18 August 2014	Allow more time for the TK Panel to discuss options for keeping animals away from certain areas (e.g. fencing).	Inuksuit are used to mark caribou crossings (nalluit) in Inuit culture. Other cultures use different techniques as well - e.g. flags, trees. More discussion on traditional and modern methods that can be used to prevent or deter animal presence in certain areas of concern may be useful. For example, some Panel members felt that a fence would be beneficial, while others felt it may be harmful and hard to maintain over time.	Stewardship Recording knowledge	DDMI proposes to hold a TK Panel session in the spring 2016 to discuss wildlife monitoring and management at closure. Further discussions to advance this concept would be well suited to this meeting.	Confirm TK Panel support for a 2016 spring session on wildlife monitoring and management at closure. If supported, DDMI to plan session for April/May 2016. COMPLETE
9.5	Focus on Caribou, TK Panel Session #9, 13-16 May 2016	Sponsor or co-sponsor a contest to gather ideas from communities on how to help the caribou get strong.	Many Elders felt that community youth, in particular, may have some good or new ideas on ways to improve caribou numbers, health, spirit, etc that are facing the population. They felt that a contest may encourage people to submit their ideas for consideration.	Intergenerational Stewardship	Diavik views this suggestion as better suited for communities themselves to undertake and then share relevant results with various stakeholders.	N/A
9.10	Focus on Caribou, TK Panel Session #9, 13-16 May 2016	Work with Ekati on developing monitoring plans for caribou after 2025.	Community members care for the caribou as a herd and across a vast landscape that is all connected. It can therefore be difficult to differentiate monitoring requirements as being specific to one company. The synergies and benefits of working together, as was done in the past among Aboriginal communities, is viewed as a preferred approach as compared with independent monitoring initiatives.	Reciprocity Stewardship	As recommended by the Panel, site-specific monitoring to confirm that the caribou are safe on and around the Diavik site in a post-closure landscape is priority. Diavik would consider exploring opportunities with other stakeholders to evaluate a potentially more regional approach to such monitoring, but are unable to commit to such an approach at this time. Diavik understands the desire to determine how and who will coordinate future monitoring on a regional basis and we are open to such discussions as closure planning progresses.	N/A

DDMI TK Panel Recommendations and Response Tracking - Wildlife Monitoring & Management

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
9.14	Focus on Caribou, TK Panel Session #9, 13-16 May 2016	Focus monitoring on wildlife health and safety and possible impacts of other mines in the Lac de Gras area.	Panel members recognized that the health and safety of caribou in the area of the closed mine was of utmost importance and were interested in ensuring that post-closure monitoring programs focused on these concerns. Additionally, it was recognized that other mines may start up in the Lac de Gras area, in addition to Ekati, so possible cumulative impacts to caribou should also be considered as part of the monitoring program.	Stewardship Safety Experiential learning	Diavik agrees that monitoring to confirm that caribou are safe on and around the site in a post-closure landscape is most important. Diavik has supported regional initiatives focused on possible cumulative impacts to caribou through their own monitoring programs and providing financial assistance and in-kind support to GNWT research and monitoring programs over the years, including the geofencing collars. DDMI is committed to on-going wildlife monitoring through the closure phase, both from scientific and Traditional Knowledge perspectives.	Diavik's post-closure wildlife monitoring programs to include methods to monitor animals safety when moving on and around the Diavik site, from both scientific and Traditional Knowledge perspectives.

DDMI TK Panel Recommendations and Response Tracking - Wildlife Monitoring & Management

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
9.18	Focus on Caribou, TK Panel Session #9, 13-16 May 2016	Focus monitoring to determine if steps taken/closure and reclamation actions are working the way they were intended, through the following measures: - Slopes for safe passage of wildlife, boulders for keeping wildlife out of areas, the use of natural water filtering systems, the use of video cameras to detect wildlife presence, the testing of water from the North Inlet and PKC area, understanding ecosystem dynamics and the linkages between components, cumulative effects - Include plant growth, plants dying, fur & antler condition, and presence/absence of injuries or spots on the side of caribou as some of the indicators of caribou well-being - Caribou presence identified on cameras, collars, and sightings would trigger monitoring - Other animals can be indicators that the land is not healthy (e.g. smaller rodents, birds, fish can tell of change happening in larger animals like caribou, bears, etc.)	TK Panel members worked hard to develop a list of measures that should be considered as part of a caribou monitoring program for closure. It was clear that scientific studies were important and appreciated, but that traditional knowledge should also contribute to the ways in which wildlife are monitored after closure. Elders and youth alike were interested in the possibilities of monitoring using technology such as wildlife cameras and collars.	Stewardship Seasonality Experiential learning Intergenerational Safety	DDMI is grateful for the Panel's work to identify measures and indicators that can potentially be incorporated into a wildlife monitoring program for closure, most notably those based on TK. Any such programs and plans are also shared through the WLWB regulatory review process for closure planning, which includes the opportunity for community organizations to provide their comments. DDMI encourages the TK Panel to work together to develop a site-specific Traditional Knowledge monitoring program for the Diavik mine.	DDMI and the TK Panel to evaluate and consider these recommendations when developing closure monitoring programs for wildlife.
9.19	Focus on Caribou, TK Panel Session #9, 13-16 May 2016	Ensure that all communities are involved in choosing where to establish locations for wildlife cameras, etc. Build on the locations and concepts identified by the TK Panel (i.e. refer to map). Train community members to operate monitoring technologies. Start using cameras now and continue to 2030.	Panel members felt that cameras placed in certain areas could be an effective and efficient way to monitor wildlife on and around the Diavik site, both during operations and at closure. Panel members themselves identified numerous areas where cameras could potentially be deployed but also noted the importance of involving community members in selecting appropriate locations. It was recognized that cameras may be best on a seasonal basis, due to challenges to keep them running in the cold; it was seen as most important that they be operational during the caribou migrations. They noted that community members would be interested in learning how to operate these types of monitoring technologies and that Diavik could start using cameras now.	Stewardship Intergenerational Social	Diavik has been using wildlife cameras for specific programs/purposes for the past few years, mostly on a seasonal or as-needed basis. Diavik is interested in exploring possible uses for technology in closure monitoring, provided that it is effective and economical. DDMI would seek the Panel's input to confirm locations for use.	DDMI to evaluate and consider this recommendation when developing closure monitoring programs for wildlife.
9.20	Focus on Caribou, TK Panel Session #9, 13-16 May 2016	Check to see if Ekati has a camera at the caribou crossing at the Narrows; if not, Diavik should install one there.	TK Panel members noted that this is a very important area that has historically been used by caribou migrating south from the calving grounds. Establishing a camera in this area was seen as a good way to determine the number of animals using the crossing and provide a visual of the condition of the animals. This was viewed as particularly important with the development of Ekati's Jay pipe.	Stewardship	Diavik has confirmed with DDEC that they operate a wildlife camera at the Narrows.	COMPLETE
10.9	Watching/Monitoring and the WRSA-SCRP, Session #10, 14-18 September 2017	Diavik must return East Island to a caribou-friendly state (as defined by the TK Panel and Elders), other than those areas identified as 'no-go' zones. Caribou pathways should follow caribou corridors identified through traditional knowledge.	Panel members have repeatedly said that planning for safe caribou movement will also ensure the health of other animals. The safe passage of caribou is paramount to this consideration. The Panel prefers that traditional caribou corridors be followed in areas where wildlife pathways are planned for closure.	Stewardship Respect Traditional Laws	Where infrastructure or land formations (e.g. rock pile) are placed in areas with traditional caribou trails, DDMI will work with the TK Panel and communities to identify preferred routing for trails at closure, as was done for the WRSA-NCRP. In other areas, such as roads and laydowns, Diavik plans to scarify/ rough up the surface but otherwise leave them as passable for wildlife.	Continue to work with the TK Panel and communities in planning caribou pathways and 'no-go zones' at closure, e.g. WRSA-SCRP.

DDMI TK Panel Recommendations and Response Tracking - Landscape & Vegetation (may include references to wildlife/wildlife habitat)

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/ CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
Assigned by DDMI unless otherwise indicated in report	*Be as specific as you think is appropriate; for example a section or page of the document, a recommendation #, general comment, etc.*	*Recommendations should be as specific as possible and explain an action that you believe is necessary; supporting information or rationale should be explained in the "context" column.*	*Context should contain all the information needed to understand the rationale for the accompanying recommendation.*	*Distinct values/c oncepts that are contained in Traditional Knowledge and can help to guide decision process*	*Responses should be as specific as possible, relating the issues raised in the "recommendation".*	*Actions should be as specific as possible, relating the issues raised in the "recommendation"; where possible, a timeframe may be included.*
1.0	A Way of Life, 25 October 2012, pg. 9	Ensure that any caribou trails are clean and clear of debris.	TK provides insights into caribou needs. Caribou are really sensitive about their feet and knowledge passed down over generations tells that it is important to make sure that any areas where caribou travel are clean so that their feet are well taken care of. From Renewing Our Landscape: Caribou feet are really soft so they prefer to travel on sand and eskers, and sometimes hills. Sand is really important. Soft sand can be used to cover jagged rock at water crossings so that caribou can get into and out of the water safely.	Respect Safety	Additional information on what is considered 'clean' is needed in order for Diavik to implement such a recommendation when designing caribou trails for post-closure use. e.g. TK Panel members have discussed the possibility of using fine PK as sand along wildlife access areas (Session 6), but Diavik would need to evaluate the properties of PK in relation to animal health before determining if its use is suitable for caribou trails.	Diavik plans to begin a toxicological study on PK material in 2015.
1.17	A Way of Life, 25 October 2012, pg. 17	A monitoring program that includes (western) science and TK/IQ is the most practical and preferred approach.	Provide an opportunity to continue practicing and integrating different ways of knowing and learning from each other. The mine's presence makes it necessary to develop cross-cultural ways of learning and sharing knowledge. Need to be creative in collaborating with Diavik. A successful program requires good communication and strong relationships.	Reciprocity Trust Shared learning	The TK/IQ Panel is Diavik's preferred method to consider and develop closure monitoring options that incorporate science and TK/IQ. Work to develop trust and communication protocols with the Panel and communities is a part of this approach.	Revise the document "Working Together" (previously created by the Panel under EMAB) to reflect the relationship of Diavik administering the Panel.
1.18	A Way of Life, 25 October 2012, pg. 24	Work with Aboriginal knowledge holders to investigate and experiment with the possible use of deflection zones (e.g. 20 miles away from the mine and another closer to the mine), based on knowledge of migration routes that may help to guide caribou movements away from the mine.	Humans do not control nature, but must take steps to provide for caribou needs when nature has been disrupted. There is no way that you can keep an animal out of its migrating route. Its either going north or south, and they follow different routes. They will go over anything in their path. Traditionally, spruce and other markers such as inuksuit have been used to direct caribou to certain areas. These could be used to try and reduce risks and stress on animals. If they are in a straight line, caribou will follow them and they won't go inbetween the markers, even if there is a large gap. From Renewing Our Landscape: East Island is a shelter for young and injured caribou; they get to it by swimming along the channel (on the north side of the island). South of the lake is jagged rock where caribou could get injured. The east side of the lake is better; there is a sandbar, muskeg and rocks and its good for caribou migration.	Respect Stewardship Reciprocity	Current mine activity levels appear to be sufficient to deter caribou from visiting East Island. Methods such as this may be effective as the mine transitions to closure and post-closure, depending on wildlife use preferences identified for mine site areas by community members.	Work with communities, regulators and potentially other industry representatives to determine wildlife use preferences for the area of the mine after closure.
1.19	A Way of Life, 25 Oct 2012, pg. 25; Closure Reclamation & Landscape History Interim Report, 19-22 February 2013, pg.6	Ensure that TK/IQ knowledge that has been shared in the past is incorporated into future planning, specifically in relation to caribou and vegetation.	Early work that was done for Diavik’s Environmental Impact Statement and other planning processes included knowledge about caribou that should be reviewed and used. Include a review of Elder site visits and best practices from the Golder Associates literature review.	Recording knowledge Respect	Diavik is interested in incorporating historical information on caribou and other areas of the environment from the companies documents, as well as external sources such as the West Kitikmeot Slave Study and community TK archives, particularly with respect to mine closure planning. The literature review that was completed by Golder Associates was a first step in identifying the type of information that is available to the public.	DDMI plans to review historical information for the LDG area in relation to caribou use and movement. Literature review of TK relating to plants in the Lac de Gras area was completed in October 2014.
2.5	Renewing Our Landscape, 7 December 2012, pg. 35	Seasonality of monitoring must be taken into consideration when planning for post-closure monitoring.	Land, water and air are the three key areas of concern for Aboriginal people. TK monitoring seasons are: winter for hare, foxes, wolverine, etc; spring for caribou; summer for fish and water; fall for berries in muskeg and plants.	Seasonality	Diavik is interested in further exploring ideas for closure monitoring with communities. Seasonality should be accounted for in these discussions.	Plan for a discussion on environmental monitoring at closure with the TK Panel.
3.4	Renewing Our Landscape, 7 December 2012, Appendix D, pg.14; Closure Reclamation & Landscape History Interim Report, 19-22 February 2013, pg.5	Leave the airstrip intact with one or two small buildings nearby; do not revegetate it.	Excellent infrastructure for the north as an emergency landing strip for aircraft. A small building can provide emergency shelter, or shelter for those using the area for hunting or fishing.	Reciprocity Safety	Maintenance and liability issues are the key challenges with leaving the airstrip and/or a small building after closure. Diavik would be open to Transport Canada or another party acquiring this airstrip. Alternatively, Diavik would consider leaving the airstrip intact (no reclamation, no on-going maintenance/liability), were this to be preferred by communities & approved by the Board.	Review such considerations prior to finalizing this aspect of the closure plan.
4.1.2	Checking Nets, 23-25 October 2012, pg.18; Closure/Reclamation and Landscape History Interim Report, 23-25 October 2012, pg.8	Diavik should carry out and make public a review of its use of TK/IQ in its environmental plans and programs. This review should document the successes and lessons learned from TK/IQ studies, and what changes or improvements in adaptive management can be attributed to TK/IQ.	Key concerns in relation to this recommendation are whether Diavik is doing what they said they would do, and community members are concerned with repeating themselves over the years without seeing any results from their suggestions. Community members feel that Diavik needs to demonstrate their use of TK, in respect to the Elders.	Respect Reciprocity	DDMI had a report prepared by Golder Associates titled "Literature Review of Traditional Knowledge Related to the Resource Sector - July 2011". Beyond this, DDMI does not feel that it is necessary to produce a separate report that documents where TK/IQ has been incorporated into its past processes. Many of these initiatives were established during the early years of the mine and it would be difficult to effectively represent the knowledge and provide lessons learned.	Looking forward, DDMI plans to use this response tracking system to document use of TK/IQ recommendations from the Panel. Past TK/IQ projects will be reviewed as necessary for individual topic discussions, e.g. re-vegetation.

DDMI TK Panel Recommendations and Response Tracking - Landscape & Vegetation (may include references to wildlife/wildlife habitat)

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/ CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
5.4	Closure Reclamation & Landscape History Interim Report, 19-22 February 2013, pg.5	Smooth slopes on the sides of roads and the airstrip so that they are less steep, and remove large boulders from these areas. Scarify engineered surfaces such as the camp areas, plant site, roads and laydowns. Revegetate to support biodiversity.	Consider revegetating the sides of the airstrip and roads so that they can filter runoff, but avoid revegetating the surfaces. Keep all roads to the pits and airstrip in tact to allow access for monitoring. Sides of old roads and the airstrip should be made less steep and revegetated to filter runoff. They should be relatively smooth and free of boulders so that wildlife can move over the areas safely.	Respect Safety	The current closure plan supports this recommendation and includes contouring of roads, restoration of drainage, surface scarification and revegetation. Some travel routes will be planned, connecting key areas of the old mine footprint for human and wildlife travel.	N/A
5.5	Closure Reclamation & Landscape History Interim Report, 19-22 February 2013, pg.5	Remove equipment, unused buildings, pipes, toxic materials and non-biodegradable items from the island.	Panel members refer to traditional practices of always leaving a clean campsite and respecting the land for your use. Buildings, equipment and materials no longer needed should be redistributed to Aboriginal communities if requested.	Stewardship Reciprocity	An approved landfill exists at Diavik (within the rock pile) and will continue to be used for non-hazardous waste materials. Hazardous materials are backhauled off site on the winter road. An evaluation of building or equipment condition would need to be conducted in advance of providing any materials to communities; if the materials were deemed suitable, Diavik would be interested in communities acquiring such items.	Determine salvage options for mine site materials on a case-by-case basis.
7.1	Re-vegetation Report, TK Panel Session #7, 14-18 August 2014	Do not disturb new areas and protect natural vegetation areas that exist on the Island (with the exception of planned development areas for A21, the rock pile for A21 and any future closure work that involves covering natural vegetation in order to flatten slopes for safe wildlife passage).	Panel members were able to visit areas of natural vegetation and most were happy with how these looked, and recognized the importance of preserving these, where possible. Comments: "I was looking for dust on berries and willows, but I saw that they were pretty clean; seeing it first hand helps." "The berries and leaves in the undisturbed areas look the same as before." "I feel peaceful and good after going out on site; I saw a fox and wolf and ground squirrels." " There were caribou trails at the south side of the airstrip; it looks good. Its good to see the land looks healthy." Panel members also recognized that it is important to balance preservation of natural vegetation with making sure that wildlife can pass through the site safely. For example, participants felt it more important to widen the base of any future rockpile associated with the A21 development, in order for the pile to be lower and less steep for wildlife movement.	Stewardship Natural condition Experiential learning Respect	DDMI understands and respects community interests in protecting areas of natural vegetation that remain on the mine site property while recognizing where it may be beneficial to lose some natural areas in order to promote the safe passage of wildlife through the mine property. The Panel has provided clear guidance on where and when it is appropriate to cover natural vegetation and this aligns well with DDMI's closure plan.	DDMI to consider design features that support this recommendation during the next major update to the ICRP (2016).

DDMI TK Panel Recommendations and Response Tracking - Landscape & Vegetation (may include references to wildlife/wildlife habitat)

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/ CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
7.2	Re-vegetation Report, TK Panel Session #7, 14-18 August 2014	Study vegetation east and north of the Island to understand good caribou habitat.	Participants felt that tundra vegetation is very powerful; like there is something underneath that is helping it. They noted the importance of moisture for growth. Many participants felt that the environment is powerful, that nature will heal itself and that vegetation at the mine site will grow again on its own. Others felt that what has happened on East Island is not natural, so it cannot be left to Nature alone to heal; Nature needs help in this case. Still others noted that climate change will result in differences; e.g. willows are taller now at places where Panel members used to camp and different species are coming to the north (which Elders predicted in the past). Some participants thought that vegetation on the East Island is different from the mainland (and that this could be from human activity, introduced species or climate change).	Experiential learning Natural condition	Since 2010, DDMI has incorporated a TK component to the lichen study that is conducted on East Island and the mainland. The main focus of the TK component of this study is to identify plants and habitat areas that are used by caribou in various locations on the tundra, up to 40 km (25 mi) away from the mine. This study is done every 3 years and is next planned for 2016.	DDMI to review questions posed to community members in the lichen TK study with the TK Panel and determine if any changes are needed to reflect the Panel's recommendation.
7.4	Re-vegetation Report, TK Panel Session #7, 14-18 August 2014	Test both natural vegetation and seeded plants (re-vegetation plots) for toxicity.	Vegetation itself was not seen as a concern; the worry is about hazards and concerns for caribou if they eat the plants. Panel members want to be sure that vegetation on the mine site is safe to eat and similar to that farther away on the mainland. Many participants noted that wildlife smell food before they eat it; they may roam around but not eat. Caribou are smart and this is is an indication that they know when plants are not healthy for them.	Reciprocity Natural condition Respect	This is planned as part of the re-vegetation study being conducted with the University of Alberta (U of A). Field samples to test for plant toxicity were planned for summer 2015, but the amount of plant material available to sample was too low. U of A plans to conduct greenhouse studies using the same materials and native plants to test for toxicity in the short term, as they can grow plants quicker under controlled conditions. They will then wait until the plants in the plots at the mine are large enough to sample and test as well, so that we have results from both the lab and field.	Communicate results of plant toxicity testing to Panel once obtained.
7.6	Re-vegetation Report, TK Panel Session #7, 14-18 August 2014	Use fine crushed rock on passage-ways to protect the feet of the caribou (similar to what is on the sides of the airstrip right now – August 2014).	Participants noted that caribou are the most important species to look after and that they must be respected. From 1.0 (above): Caribou are really sensitive about their feet and knowledge passed down over generations tells that it is important to make sure that any areas where caribou travel are clean so that their feet are well taken care of.	Respect	Diavik will evaluate options for crush size on caribou passage ways. A very fine crush, such as that at the airstrip, may not be possible. However, participants noted that the test pile slope material was also considered safe for passage. DDMI will use the surface of the test pile slope to guide final surface material design for caribou passage ways.	DDMI to consider design features that support this recommendation during the next major update to the ICRP (2016).
7.9	Re-vegetation Report, TK Panel Session #7, 14-18 August 2014	Create slopes on the sides of roads similar to that on the test pile to support safe travel for animals, and use crushed rock (like at the airstrip) on the surface.	All Panel members showed a clear preference for road reclamation that included a relatively flat top with downward sloping sides at a low angle. The material preferred for use in reclaiming such areas is crushed gravel. It was recognized that natural revegetation may be lost by pushing out the sides of roads in order to ease the slope, but this was seen as an overall positive because it allowed safe passage for wildlife.	Respect Experiential learning	The Panel's preferred design for roads at closure is supported. Preference for top surface is to be similar to test piles rather than placing additional crushed gravel.	DDMI to consider design features that support this recommendation during the next major update to the ICRP (2016).
7.10	Re-vegetation Report, TK Panel Session #7, 14-18 August 2014	Transplant a variety of natural 'tundra mats' and compare them to seeded test plots; this will help natural recovery by maintaining the biodiversity of the area.	The re-vegetation plots were visited and Panel members found it interesting to see the different plants that were growing there (e.g grasses) when compared to the tundra beside the plots. Many also felt that there seemed to be little vegetation given that it had been 10 years. Researchers explained that growing grass allows the soil to build (nutrients, moisture, etc.) and is the first phase in helping other natural tundra plants to then establish. Panel members felt that there could be benefit in taking natural 'tundra mats' from areas being impacted by mine development (e.g. future A21 rock pile area) and re-planting them in re-vegetation areas.	Natural condition Seasonality	Diavik initially planned to try this approach in the re-vegetation plots established in 2004. However, this approach requires access to an area planned to be distrubed (to take "tundra mats") while at the same time having areas available that require re-vegetation. This situation has not been identified. Currently DDMI does not see an opportunity for this approach.	N/A
7.11	Re-vegetation Report, TK Panel Session #7, 14-18 August 2014	Use the natural tundra mat to guide plant selection to ensure natural balance.	Similar to recommendation 7.2, it is seen as beneficial to "learn from Nature's quilt" and study the plants that grow together in various areas.	Natural condition Seasonality	The focus for re-vegetation studies to date is to utilize native plants from 'nature's quilt'. The goal for re-vegetation is to establish primary growth (such as grasses) that help to grow soil nutrients, which then allows plants from the surrounding tundra to move in and establish. In this way, Diavik helps to promote growth while allowing for natural processes and plants to occur over time.	N/A
7.12	Re-vegetation Report, TK Panel Session #7, 14-18 August 2014	When using fertilizers, use natural local fertilizers like droppings from local animals. The question of treated human sewage needs to be revisited.	Participants noted how caribou droppings have often resulted in better plant growth at traditional camp sites or other areas of the tundra. It was felt that use of such natural fertilizers may be beneficial in the re-vegetation work that Diavik will be doing. Participants were not sure how they felt about using treated human sewage as a fertilizer - a product that is readily available on site and has been used with some success in the re-vegetation test plots. Panel members would like to learn more about what is in the treated sewage before deciding on whether this is an acceptable fertilizer.	Natural condition	Diavik is interested in using treated human sewage waste as fertilizer, given that it is available on site and considered safe to use from a health perspective. The plan is only to use this material as fertlizer during the first couple of years after closure, as it promotes plant growth in the early stages of use and then loses its effectiveness over time. Local animal droppings would only be considered long-term, natural fertilizer and its use would not be a planned activity.	N/A

DDMI TK Panel Recommendations and Response Tracking - Landscape & Vegetation (may include references to wildlife/wildlife habitat)

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/ CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
7.15	Re-vegetation Report, TK Panel Session #7, 14-18 August 2014	The re-vegetation maps developed in this session are not yet complete and more time needs to be spent discussing and finalizing these.	Participants worked hard to classify various areas of the site in terms of zones for which they would prefer to 1) deter wildlife use, 2) encourage plant growth or 3) engineer areas of safe passage or use for wildlife. The map developed by the women during a break out session was the most supported approach to date, but Panel members felt that this requires more discussion at both the Panel and the community levels.	Intergenerational Stewardship Recording knowledge	Diavik is grateful for the maps developed at this session and views these as a useful tool for discussions with community members, community organizations, regulators and the TK Panel.	DDMI to use these maps as a basis for community engagement in relation to re-vegetation and wildlife use around the mine site at closure.
7.16	Re-vegetation Report, TK Panel Session #7, 14-18 August 2014	The TK Panel would like to use maps that show the TK of traditional caribou migration routes as the basis for evaluating the "big picture" and identifying areas for sloping (modification) on East Island at closure.	Panel members recognized that it would be helpful to have access to some of the early work produced prior to mine development that identified the traditional trails used by caribou and identified by Elders during the Environmental Assessment. Participants felt that it would be useful to compile that information onto a map that could then be marked up to show the 3 types of zones to be considered for animal use of the mine area after closure (deter wildlife use, encourage plant growth or engineer areas of safe passage or use for wildlife).	Recording knowledge Respect Natural condition	DDMI proposes to hold a TK Panel session in the spring of 2016 to discuss wildlife monitoring and management at closure. Further discussions to advance this concept would be well suited to this meeting.	Confirm TK Panel support for a 2016 spring session on wildlife monitoring and management at closure. If supported, DDMI to plan session for April/May 2016 and provide maps and TK shared on caribou trails during the Environmental Assessment.
8.1	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Maintain current TK camp site until at least 2018	Community members prefer a more traditional approach to spending time on the land. The connection to the land that can be felt at the camp is stronger than what people experience at the mine site, given all the rules and limited ability to be outside. The connection to the land supports each AEMP TK Study participant and lends to a feeling of family and a willingness to share knowledge, which contributes to the success of the program.	Respect Stewardship Recording knowledge Experiential learning	DDMI understands and respects community members' desire to continue to hold the AEMP TK Study at the TK camp site. DDMI agrees that the camp provides a more authentic experience and results in better information being shared. The current lease for the TK Camp area expires in May 2017. DDMI plans to renew the lease and currently supports holding the 2018 AEMP TK Study at the camp. DDMI would then re-evaluate plans for the TK camp after the 2018 session.	Renew land lease for the TK Camp property and budget to use the property for the 2018 AEMP TK Study.
8.2	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Consider options to donate camp facilities to people traveling to LdG after the mine closes.	TK Panel members are very interested in continuing to monitor the water and fish in the Lac de Gras area after the mine is closed. Leaving the camp in place would provide them with a base from which to do this. Communities would appreciate the camp facilities and supplies being "sold" ($1) or donated to a community organization or coordinating body that would oversee such work. Alternatively, if it is not possible to keep the camp intact, Daivik should consider leaving a tent frame in place for travellers that may need emergency shelter.	Experiential learning Reciprocity Safety	DDMI prefers not to leave the camp facilities in their current location, as the preference is to close the camp, reclaim the land and relinquish the lease. DDMI would consider 'selling' or donating the camp equipment to community organizations or a coordinating body, pending legal review, for their own use. The mine site itself is only a short distance away and is likely to have one or two buildings left behind after closure that could be used for emergency shelter.	Evaluate options to sell or donate TK camp equipment to communities after the camp is dismantled.
10.10	Watching/Monitoring and the WRSA-SCRP, Session #10, 14-18 September 2017	Consider alternative uses for A21 material: - Cover the Processed Kimberlite Containment (PKC) area after removing slimes. - Assuming the slimes are gone, slope the south face/wall between the NCRP and the north end of the PKC to allow for caribou movement. - Extend the west end of the NCRP and slope it for caribou. - Cover areas that may have been contaminated after clean-up like the hydro-carbon containment area. - Smooth edges of roads, airport and building areas	The Panel applies their traditional approach of respecting everything nature provides and being resourceful. The 'waste' rock supplied by mining activities in A21 should be used wherever possible, rather than simply being discarded into a pile on the tundra. In the Panel's view, if closure plans for the PKC area change (e.g. dry vs. pond), the suggestions relating to access to this area may also change.	Stewardship Traditional Laws	Diavik is planning to use A21 material for closure, including some of the items identified by the Panel. Details for each area have yet to be finalized, and we commit to continue updating and discussing this with the Panel as closure plans progress.	Continue discussions with the TK Panel and communities relating to closure plans for various areas of the mine, recognizing that these may change as plans evolve.

DDMI TK Panel Recommendations and Response Tracking - North Country Rock Pile (NCRP)

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/ CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
Assigned by DDMI unless otherwise indicated in report	*Be as specific as you think is appropriate; for example a section or page of the document, a recommendation #, general comment, etc.*	*Recommendations should be as specific as possible and explain an action that you believe is necessary; supporting information or rationale should be explained in the "context" column.*	*Context should contain all the information needed to understand the rationale for the accompanying recommendation.*	*Distinct values/ concepts that are contained in Traditional Knowledge and can help to guide decision process*	*Responses should be as specific as possible, relating the issues raised in the "recommendation".*	*Actions should be as specific as possible, relating the issues raised in the "recommendation"; where possible, a timeframe may be included.*
2.2	Renewing Our Landscape, 7 December 2012, pg. 22	Do not allow water to pool on top of the rock pile	Once a small pool of water forms, it gets bigger and becomes a lake that attracts animals. Animals then start to use it. Because the Panel is concerned with the quality of water within or flowing from the pile, there is concern for the health of caribou and other wildlife.	Stewardship	Diavik is not planning to have a water pond on top of the rock pile at closure.	N/A
2.3	Renewing Our Landscape, 7 December 2012, pg. 23	Have a 'moat' around the rock pile as a way of being able to contain and monitor the water that is coming out of the pile.	Relates back to the concern of water quality coming off/out of the pile. Eskers have cold water flowing out of them because of the permafrost within the esker. The same is likely to happen with the rock pile as permafrost builds up within the pile over the years.	Stewardship	The existing collection ponds surrounding the rock pile serve this purpose and current plans have the ponds remaining until adequate water quality has been demonstrated.	N/A
2.6	Renewing Our Landscape, 7 December 2012, pg. 45; Appendix D, pg. 8	Some revegetation should be planned for the rock pile. Consider use of good, black soil from the tundra or other eskers in the area. Plant native shrubs such as dwarf birch and willow in the soil near the bottom and allow the remainder to revegetate naturally.	Respect for the land includes respecting natural systems - there is a reason for each plant being there. Introduced species can be harmful and quickly take over; preference is to use naturally occurring plants. Using soil from elsewhere may be acceptable because the Diavik island is a traditional place for caribou to roam and is a good feeding/resting area; another option is to use till from A21. Revegetation will take time but it is the right thing to do. Consider visiting old archaeological sites or other esker sites to view re/growth; exposure will dictate what grows where (shade, leeward, side, top).	Respect Stewardship	The current closure plan does not account for revegetation on the rock pile. Harvesting soils from outside the mine footprint is not being considered. Re-vegetation priority for DDMi is still plant site, laydowns and roads.	N/A
3.1	Renewing Our Landscape, 7 December 2012, Appendix D, pg.6; Closure Reclamation & Landscape History Interim Report, 19-22 February 2013, pg.4	Simulate an esker when considering the final shape of the rock pile.	Traditional stewardship means leaving things as natural as possible. Make it look as natural as possible by imitating the effects of glaciers and prevailing easterly winds on the surrounding landscape. This includes sloping the top edges so they are rounded, sloping the sides so they are less steep (similar to the test pile) and have varying levels of steepness. Place rock from the pile back into the pit. The top should be flat with berms removed so that caribou can walk safely as there would be fewer places for predators to hide; they may want to use the hill to get away from bugs. Big boulders should be removed, particularly at the bottom of the pile and on the north slope, as wildlife will likely get injured trying to walk over them. The north side should be the most gradual slope, as this will be the area for wildlife and people to access the top.	Stewardship	Simulating a large esker is a preferred approach to re-shaping the rock pile. Closure plans do not include placing rock back in the pit. Diavik anticipates that re-shaping efforts would eliminate the need for large boulders to be removed.	N/A
3.2	Renewing Our Landscape, 7 December 2012, Appendix D, pg.7; Closure Reclamation & Landscape History Interim Report, 19-22 February 2013, pg.5	Safe wildlife access needs to be considered for all seasons when designing the final shape of the rock pile. There needs to be soft material in areas where caribou will be; consider the use of PK material for animal paths.	Prevailing winter winds (NE) will result in a smooth snow cover that drops straight down on the lee side of the pile so need to consider TK/IQ in relation to snow drifts. In summer, caribou will go on top of the pile to avoid flies; consider having something for them to eat up there. In fall, caribou will swim across to the island from the northwest, following their old migration path; consider having a caribou ramp across the pile that connects with this access point. Use waste rock to slope the pile and consider an esker 8 miles NE of Diavik as an example. Refer to comment 1.0, Landscape for further information on suitable materials for caribou feet.	Seasonality Stewardship Respect	A caribou 'ramp' (safe access on, off and across the pile) for the rock pile is included in the current version of the closure plan. Additional ideas on design options to provide safe access for wildlife are being discussed with communities, along with technical considerations for design and performance. Diavik would need to evaluate the properties of PK in relation to animal health before determining if its use is suitable for caribou trails.	Diavik plans to begin a toxicological study on PK material in 2015.

DDMI TK Panel Recommendations and Response Tracking - North Country Rock Pile (NCRP)

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/ CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
3.3	Renewing Our Landscape, 7 December 2012, Appendix D, pg.12 & 13	Channel water flow to prevent contaminants from reaching Lac de Gras.	Consider using geotextile to line drainage channels downstream of the pile and revegetate these areas. Snow drifts and areas of accumulation need to be considered when planning for drainage. The lake water needs to remain healthy as the people of Kugluktuk live downstream.	Stewardship Reciprocity	Closure plans for the mine consider the use of drainage paths that allow additional time for water to travel over the tundra before reaching Lac de Gras. Diavik's closure goals include land and water that is physically and chemically stable and safe for people, wildlife and aquatic life.	N/A
5.1	Closure Reclamation & Landscape History Interim Report, 19-22 February 2013, pg.4	Preference is to lower the height of the rock pile. However, if that is not possible, keep the rock pile height as low as possible while ensuring that contaminants within the Type II and III rock areas are contained.	The biggest concern that Panel members have is chemicals seeping from the pile into the lake or being injested by wildlife drinking the water. While the pile is considered an eyesore and Panel members would like to see it smaller (lower) on account of wildlife concerns, participants also recognize that it is most important for the pile to function well in containing chemicals from entering the environment.	Stewardship Respect	The rock pile has reached its maximum height and matches what was originally permitted for the mine, though capping materials will result in a slightly higher final elevation. Diavik's primary closure goal is to contain Type II and III rock and ensure that water quality from the rock pile seepage is safe for wildlife and humans.	N/A
5.2	Closure Reclamation & Landscape History Interim Report, 19-22 February 2013, pg.4	Cap the rock pile with the best materials for biodiversity based on TK and science, using nearby hills as a reference.	Many Panel members believe that nature needs a helping hand; it will heal itself, but conditions to allow re-growth need to be created. Everyone recognizes that things grow slowly in the north, but that over time the area should heal. Panel members desire to see the land as close as possible to how it looked before is the main factor in guiding recommendations. While it is acknowledged that the area will never be the same again, efforts to reclaim areas in a way that resemble natural features is preferred.	Nature is self-healing Stewardship	Material availability will be an important aspect of closure planning. Diavik's preference is to use materials available at the mine site, without having to disturb other areas. Mine rock and till will be the materials available in greatest supply and these are currently being considered for use in capping the rock pile.	Investigate areas that have naturally revegetated around the mine site; evaluate species and substrates.
5.3	Closure Reclamation & Landscape History Interim Report, 19-22 February 2013, pg.5	Experiment with different types of wetlands for filtering water that collects at the base of the rock pile.	Traditionally, people tried different things to solve problems and TK holders want to be involved in any new experiments. This method should be combined with current or alternate purification system(s) to treat remaining contaminants. There are opportunities for Aboriginal people to be trained to do this type of monitoring. Panel members recognize that it is not ideal to have a water treatment plant on site forever and that more natural treatment options, similar to many used in communities, are preferred in the long term.	Stewardship	Wetland drainage has been effective in this area in the past and that is what is currently planned for managing water from the rock pile.	Determine preferred drainage pathways, and possibly associated plant life, that would result in water that is safe for humans and wildlife.
EMAB-2	Environmental Monitoring Advisory Board TK/IQ Panel Recommendations from February 2013, Letter from EMAB, 8 Oct 2013, pg.2	EMAB recommends that Diavik incorporate into its ICRP research the following question: Will vegetation on the waste rock pile increase snow trap, which will increase run off and increase the chance of leaching?	TK/IQ Panel members have highlighted considerations for snow accumulation in relation to prevailing winds, but have not discussed this in relation to vegetation on the pile.	Stewardship	Not supported as current closure plans for the rock pile do not include revegetation.	N/A
EMAB-3	Environmental Monitoring Advisory Board TK/IQ Panel Recommendations from February 2013, Letter from EMAB, 8 Oct 2013, pg.2	EMAB recommends that Diavik shape rock piles in a way that directs freshet runoff away from Lac De Gras through natural wetlands in order to naturally filter the runoff.	Supports discussions of the TK/IQ Panel preferences of wetland treatment and diverting water away from Lac de Gras for as great a distance as possible.	Nature is self-healing Stewardship	Diavik supports this approach wherever possible but notes that runoff and seepage will eventually reach Lac de Gras. Suggest re-wording to: "...direct freshet runoff and seepage away from Lac de Gras and through seepage wetlands *for as long a distance as possible* ..." Diavik has also applied this recommendation to the proposed PKC closure option.	N/A

DDMI TK Panel Recommendations and Response Tracking - North Country Rock Pile (NCRP)

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/ CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
7.9	Re-vegetation Report, TK Panel Session #7, 14-18 August 2014	Create slopes on the rock pile similar to that on the test pile to support safe travel for animals.	Panel members felt that it was not necessary to plan too much for the animals safe passage, as caribou will ultimately go where they want and will find the ramp, road or easy way. Preference was to align the path with the old migration route and to keep the slope similar to that of the test pile - as natural as possible. Boulder size and angles were also a concern. Panel members noticed some big, sharp rocks at the bottom of the north country rock pile that would need to be covered. It was seen as important to think about the slope in the winter too - how wind will deposit snow - not just when it is snow free. The berms on top of the rock pile were viewed as a barrier to caribou movement, so it would be preferred to remove them and also to remove the berm around the top of the pile.	Stewardship Seasonality	This is very similar feedback to what community members said at a 2009 workshop relating to caribou at closure. Current closure plans, most notably for the rock pile, generally support this recommendation and the underlying reasons for the recommendation.	DDMI to consider design features that support this recommendation during the next major update to the ICRP (2016).
8.30	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Ensure long term scientific monitoring of NCRP to determine if it remains frozen and stable.	The NCRP has been identified as one of the main concerns of Panel members who feel that climate change may affect its integrity and release contaminated water into the environment. As such, Panel members want to make sure that pile remains frozen in the core, as it was designed to be.	Stewardship Intergenerational Seasonality	Many stakeholders are interested in the performance and integrity of the rock pile. As such, long-term monitoring plans would be incorporated into the development of the post-closure monitoring program.	Outline post-closure monitoring plans for the mine site, most notably those specific to the NCRP.
9.1	Focus on Caribou, TK Panel Session #9, 13-16 May 2016	Re-vegetate the base of the NCRP around the ponds.	While some members of the TK Panel initially hoped that the NCRP would be re-vegetated, others preferred to let nature take its course and heal itself over time. After much discussion, Panel members concluded that it would be beneficial to focus re-vegetation efforts to the areas where ponds are located at the base of the NCRP. This would help to both naturally filter water coming in to or flowing out of the ponds, as well as to possibly help the pile re-vegetate naturally over time.	Stewardship Nature is self-healing	Diavik has not yet finalized the closure plans for the ponds at the base of the NCRP, but the TK Panel's recommendation for these areas will be considered when developing these plans.	Update the TK Panel once Diavik has has determined a preferred closure plan for the ponds at the base of the NCRP.
9.2	Focus on Caribou, TK Panel Session #9, 13-16 May 2016	A limited number of large boulders (e.g. 3-4) should be placed on top of the NCRP to provide some shade for caribou, create habitat for small mammals and encourage natural re-vegetation	Panel members felt that a small number of large boulders could be beneficial for caribou, without harming the chemical stability of the pile. Many members think that caribou will go up the pile, primarily to get away from bugs, so it would be good to have some shade for them. If there were only a small number, it would be unlikely that they would be used by predators, but they could create habitat for smaller mammals as well as help with natural re-vegetation by sheltering seeds and water/snow to encourage growth.	Stewardship Seasonality Natural Condition	While there are no current plans to incorporate a small number of large boulders on top of the NCRP, Diavik would consider adding these if communities identified a need for these as a result of observations from a TK monitoring program, or discussions with Elders once the final landscape of the NCRP can be observed. The Final Closure Plan for the NCRP also identifies this option for future consideration.	N/A
9.3	Focus on Caribou, TK Panel Session #9, 13-16 May 2016	Study the wind and snow accumulation on caribou ramps/trails as well as the top of the NCRP before finishing/finalizing the sloping and grading of the NCRP.	The Panel wants to be sure that the caribou/wildlife pathway that was located along a route recommended by community members will allow safe access throughout the year, including during spring conditions when the caribou are heading north. It would be beneficial to study the wind and snow accumulation along the pathways to determine if the conditions are safe for caribou or other wildlife passage in all seasons. If this is done before the pile is completely finished, the Panel feels that Diavik should be able to fix any grading or sloping issues that communities may identify.	Stewardship Intergenerational Seasonality Safety	Diavik appreciates this suggestion and hopes that the TK Panel incorporates this monitoring into a site-specific, Traditional Knowledge wildlife monitoring program for the Diavik mine.	Support the process for the Panel to develop a TK Monitoring Program for the mine site.
9.4	Focus on Caribou, TK Panel Session #9, 13-16 May 2016	Ensure a gradual slope on the top of the NCRP so that there is a slight dome down the centre.	Panel members wanted to ensure that any water or snow that may fall or collect on the top of the pile would naturally drain off of the pile. This would minimize the amount of water that could seep into the pile. The Panel considers this another way to make sure that there is long-term protection for the land and water. Once there are no more people at the site, the water and snow must be able to drain safely off the pile.	Stewardship Intergenerational Seasonality Safety	Diavik appreciates this suggestion. The Final Closure Plan and design for the North Country Rock Pile includes this feature.	COMPLETE

DDMI TK Panel Recommendations and Response Tracking - North Country Rock Pile (NCRP)

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/ CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
10.1	Watching/Monitoring and the WRSA-SCRP, Session #10, 14-18 September 2017	Avoid disturbing new areas (e.g. tundra) with A21 material at the SCRP as much as possible. The proposed SCRP area is part of a major caribou migration and feeding corridor and should not be disturbed.	The TK Panel recognizes the importance of the SCRP area to caribou and would prefer that this area not be developed. However, recognizing that the SCRP location has already been approved and established, they are interested in minimizing the size (footprint and height) of the SCRP.	Stewardship Safety	Diavik shares the opinion of the Panel and prefers to utilize A21 material for other purposes (i.e. NCRP closure cover), thereby reducing the overall size of the SCRP. Diavik has now obtained regulatory and financial approvals to proceed with constructing the NCRP cover. This will begin in spring 2018, and A21 rock and till will be used for the cover. Other opportunities for the use of A21 materials for closure will continue to be evaluated as the CRP progresses.	COMPLETE
10.2	Watching/Monitoring and the WRSA-SCRP, Session #10, 14-18 September 2017	If this area must to be used, minimize the size (i.e. volume/amount) and height of the SCRP and slope all sides like an esker so that animals can easily walk over it. We recommend the slope should be at 3:1.	The TK Panel has evaluated the covered test pile and observed the re-sloping efforts undertaken on the NCRP. The 3:1 slope on these structures has been supported for the safe movement of wildlife and the Panel is interested in applying that same design to the SCRP at closure.	Stewardship Safety	While the SCRP is being constructed, side slopes will be at the angle of repose. As noted above, Diavik's preference is to minimize the size of the pile, however current closure plans do not provide for re-sloping the entire pile, as no closure cover is necessary for the SCRP. A wildlife pathway has been planned, and that would be re-sloped (3:1) and smoothed to facilitate safe movement across the pile.	N/A
10.3	Watching/Monitoring and the WRSA-SCRP, Session #10, 14-18 September 2017	If the SCRP is large, designated pathways become more important and must follow caribou routes known through TK.	Recognizing that there is a possibility that the SCRP could include all the rock from A21 (i.e., if the NCRP cover is not approved) and that the sides of the SCRP may not be re-sloped, the Panel notes that designated wildlife pathways would be very important, and that they must be safe and utilize known caribou routes across the pile.	Stewardship Safety	Diavik has currently planned for pathways over and across the SCRP at closure. We will work with the TK Panel and/or other community contacts as required to finalize their location prior to closure.	Work with the TK Panel and communities to confirm the recommended route for a wildlife pathway on the SCRP at closure.
10.4	Watching/Monitoring and the WRSA-SCRP, Session #10, 14-18 September 2017	We recommend that rock from A21 that could go to SCRP be used to cover the NCRP.	The Panel applies their traditional approach of respecting everything nature provides to mine closure planning. The 'waste' rock supplied by mining activities in A21 should be used wherever possible, rather than simply being discarded into a pile on the tundra.	Stewardship Traditional Laws	Diavik is in agreement with the TK Panel and was awaiting approval on the NCRP cover from the WLWB at the time of Session 10. DDMI has since received the necessary approvals for the cover and plans to begin progressive reclamation of the NCRP, that includes using rock from A21 that would otherwise go to the SCRP, in the spring of 2018.	COMPLETE
10.5	Watching/Monitoring and the WRSA-SCRP, Session #10, 14-18 September 2017	Drain the pond that would be covered by the SCRP before using the proposed area.	The Panel understands that the pond under the proposed SCRP is non-fish bearing and prefers to have this drained prior to filling it with rock. There were two reasons for this: one was to prevent that water flowing over the tundra to Lac de Gras and the second was to allow more room for rock to fill the area, because it would be covered anyway.	Stewardship	Diavik notes that this was not originally planned for the pond identified. This was a very helpful observation and recommendation that was completed during the fall of 2017.	COMPLETE
10.6	Watching/Monitoring and the WRSA-SCRP, Session #10, 14-18 September 2017	Have all SCRP water tested (both science and TK) before releasing into Lac De Gras.	As noted in past TK Panel sessions, Panel members see value in both scientific and TK monitoring of water on East Island at closure. Water that would flow from the mine area to Lac de Gras should be tested at closure, similar to what is done during operations.	Stewardship Safety	Diavik continues to work with the TK Panel to identify more specific locations for closure and post-closure monitoring and we agree that the drainage channel from the SCRP is important to sample. DDMI plans to establish a monitoring station in this location.	Plan for a water quality monitoring station for SCRP runoff at closure.
10.7	Watching/Monitoring and the WRSA-SCRP, Session #10, 14-18 September 2017	Use natural filtration methods in areas where water will run off the SCRP on site.	As noted in past TK Panel sessions, nature has the ability to heal and natural filtration to treat runoff water (e.g. rain, snow melt) at closure is encouraged. Runoff water from the site should be routed to travel across the tundra and naturally undergo some filtration before entering Lac de Gras.	Stewardship Traditional Laws Natural Condition Nature is self-healing	There are no plans for infrastructure in the area downstream of the SCRP where drainage water would flow at closure. As such, the water will flow over native tundra allowing natural filtration to occur before reaching Lac de Gras. While it is not a particularly long drainage path, it will exist.	Continue to identify areas where runoff water from the mine can travel across the tundra at closure, prior to entering Lac de Gras.
10.8	Watching/Monitoring and the WRSA-SCRP, Session #10, 14-18 September 2017	Diavik must plan for the same values, principles and goals held by the TK Panel for the NCRP, to the SCRP (e.g. maintain low height, 3:1 slope for caribou).	The TK Panel has evaluated the covered test pile and observed the re-sloping efforts undertaken on the NCRP. The 3:1 slope on these structures has been supported for the safe movement of wildlife and the Panel is interested in applying that same design to the SCRP at closure.	Stewardship Safety	Diavik has now obtained the necessary approvals to be able to use A21 rock to cover the NCRP. We are also evaluating other options for using A21 rock for reclamation material as closure planning for the site continues. This would help to reduce the overall size of the SCRP. Diavik is planning for a wildlife pathway across the SCRP, with reduced slope angles that we anticipate to be at 3:1. However, the remainder of the pile is not currently planned to be re-sloped. The reason for this is that there is no need for a cover on the SCRP as it contains no T3 rock.	Work with the TK Panel and communities to confirm the recommended route and design for a wildlife pathway on the SCRP at closure.

DDMI TK Panel Recommendations and Response Tracking - Processed Kimberlite Containment (PKC) Area

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
Assigned by DDMI unless otherwise indicated in report	*Be as specific as you think is appropriate; for example a section or page of the document, a recommendation #, general comment, etc.*	*Recommendations should be as specific as possible and explain an action that you believe is necessary; supporting information or rationale should be explained in the "context" column.*	*Context should contain all the information needed to understand the rationale for the accompanying recommendation.*	*Distinct values/concepts that are contained in Traditional Knowledge and can help to guide decision process*	*Responses should be as specific as possible, relating the issues raised in the "recommendation".*	*Actions should be as specific as possible, relating the issues raised in the "recommendation"; where possible, a timeframe may be included.*
6.1	Processed Kimberlite Containment Interim Report, 24-28 October 2013, pg. 5	Cover PKC area with a combination of natural sand and soil to ensure that the PKC is not over-heating the area (and melting permafrost) and to support natural re-vegetation	Concern was expressed that the dark colour of both the coarse PK and the liner would attract more sun (heat) that would result in permafrost melt. There was also a desire to see the area revegetated as Panel members expect that caribou and other wildlife will attempt to access the area after closure.	Stewardship Respect	The revised closure plan discussed in the October 2013 TK Panel session was approved by the WLWB in May 2014. The current plan includes a rock cover that would be lighter in colour and serve the same purpose as the sand and soil cover proposed by the TK/IQ Panel. The rock cover required to contain the Processed Kimberlite and protect it against wind & water could limit opportunities for revegetation.	Determine relative importance of overall function compared to specific material use with communities.
6.2	Processed Kimberlite Containment Interim Report, 24-28 October 2013, pg. 5	If there were eskers within the PKC area, reclaim these to their original state or as close as possible	A key goal expressed by the TK Panel was to return the landscape to a more natural state.	Natural condition	Need to consider technical requirements that would provide stability of the dam structure after closure. This is likely to limit the ability to re-design the PKC area with features such as an esker.	N/A
6.3	Processed Kimberlite Containment Interim Report, 24-28 October 2013, pg. 5	Re-vegetate the PKC area according to baseline traditional knowledge and science	A key goal expressed by the TK Panel was to return the landscape to a more natural state. Panel members thought that vegetation may help to stabilize the ground.	Natural condition Nature is self-healing	The current closure plan does not include revegetation of the PKC area. It is unlikely that vegetation would help to stabilize the ground in this area given the substrate, cover materials and permafrost development, and also in consideration of the limited root systems of sub-arctic plants. Lichen development on rock/ boulders may develop over time.	In consultation with communities, conduct further research and advance the plan for the PKC closure concept approved by the WLWB in May 2014.
6.4	Processed Kimberlite Containment Interim Report, 24-28 October 2013, pg. 5	Create wildlife habitat and stabilize ground with transplanted willow	TK/IQ Panel members first leaned toward deterring animals from using this area after closure, but the Panel came to realize through their discussions that caribou and other wildlife will attempt to access the area after closure. For this reason, the vision of the Panel for this area shifted to recreating habitat similar to what was present before the mine was constructed. A key concern that Diavik noted was the instability of the fine PK 'flatlands' or 'beaches' that are contained inside the PKC dam.	Natural condition	The current closure plan does not include revegetation of the PKC area. It is unlikely that vegetation would help to stabilize the ground in this area. Diavik would need to explore possible options and their associated risks if revegetation of the PKC was to be considered.	In consultation with communities, conduct further research and advance the plan for the PKC closure concept approved by the WLWB in May 2014.
6.5	Processed Kimberlite Containment Interim Report, 24-28 October 2013, pg. 5	Create marshy areas with moss, lichen and berries	This type of vegetation would provide a food source and safe travelways for animals. It would also resemble what the area looked like before the mine was built.	Natural condition	The main focus in closing the PKC is to direct PKC seepage and/or runoff water to marshy areas on the tundra that have moss cover and allow for natural filtration. It is currently preferred to keep the flatland area within the PKC dams dry and sloped toward a planned pond. This would help to stabilize the PK underneath the cover material.	N/A

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6.6	Processed Kimberlite Containment Interim Report, 24-28 October 2013, pg. 5	Removal of the slime from the mine site upon closure.	Traditional laws and stewardship of the land imply that you do not leave human-made materials behind as it is harmful to water, air or animals. The removal of slime provides a level of comfort and certainty to northern communities that is not otherwise available. This preference is based on the acknowledged problems created by leaving the slurry/slime onsite, in particular safety concerns for people and wildlife and the uncertainties associated with impacts from environmental change (e.g., a rise in temperature and associated drought, permafrost melting, earthquakes) long into the future. Further, it provides an opportunity to return the landscape to a more natural state which is a key goal expressed by the TK Panel throughout sessions to date.	Stewardship	Diavik understands the motivation to remove the slimes from site. However, should the material prove to be non-toxic to people and wildlife, Diavik plans to leave the slimes on site. Should the material be used or accessible to wildlife (directly or indirectly) at closure, it would be beneficial to conduct a toxicological study on the material.	Diavik plans to begin a toxicological study on PK material in 2015.
6.7	Processed Kimberlite Containment Interim Report, 24-28 October 2013, pg. 5	Removing the slime offsite remains the preferred option until Diavik can demonstrate through chemical and toxicological analysis that the slime is not harmful to the environment (i.e. plants, wildlife, fish, and humans).	Upon discussion, Panel members stated that should the slimes prove to be non-toxic, they would be more willing to assess on-site containment options for this material. TK holders need to see for themselves that something is not harmful to the environment. Participants would want to be confident in the results of the scientific testing.	Stewardship	Should the material prove to be non-toxic to people and wildlife, Diavik plans to leave the slimes on site and determine the preferred method for containment that allows for safe use or passage of wildlife in the PKC area.	Diavik plans to begin a toxicological study on PK material in 2015.
6.8	Processed Kimberlite Containment Interim Report, 24-28 October 2013, pg. 6	Return the lake and shoreline to their natural states, as much as possible (e.g. gradual slope)	This approach would create safe access for wildlife, as it is assumed that wildlife will try to use this area after closure.	Safety Respect	It is likely that the shoreline of any reclaimed pond will differ from a natural pond, but it may be possible to recreate some elements of interest to communities.	DDMI conducted a literature review to identify examples of re-vegetation efforts undertaken in northern climates. Completed in October 2014.
6.9	Processed Kimberlite Containment Interim Report, 24-28 October 2013, pg. 6	Ensure that the shoreline (of the PKC lake) is stable and that rocks are of the correct size to be safe for wildlife, especially caribou.	This approach would create safe access for wildlife, as it is assumed that wildlife will try to use this area after closure.	Safety	Another closure goal for Diavik is to have land areas that are physically stable and safe for people, wildlife and aquatic life.	In consultation with communities, conduct further research and advance the plan for the PKC closure concept approved by the WLWB in May 2014.
6.10	Processed Kimberlite Containment Interim Report, 24-28 October 2013, pg. 6	Line the lake bottom with granite, gravel and rocks and other natural materials that were there before	Create a more natural and stable lake bottom that would be safe for caribou use during the warm months.	Natural condition	One of Diavik's closure goals is to create a final landscape guided by pre-development conditions & TK. Consideration of materials available and suitable for use are evaluated as part of the closure planning process.	In consultation with communities, conduct further research and advance the plan for the PKC closure concept approved by the WLWB in May 2014.
6.11	Processed Kimberlite Containment Interim Report, 24-28 October 2013, pg. 6	Re-vegetate the lake with water plants of this area	Such plants contribute to biodiversity as they are a food source for other fish and animals. Plants feed fish but may also clean the water that wildlife may to drink and birds are likely to land on.	Natural condition	Current closure plans do not include revegetating lakes with water plants. Because the water pond within the PKC would not be stocked with fish (see below), efforts would also not be made to revegetate lakes with water plants. DDMI prefers to construct this lake in a manner that would not attract wildlife or promote its use.	N/A
6.12	Processed Kimberlite Containment Interim Report, 24-28 October 2013, pg. 6	Re-stock lake with fish and bugs	The desire of Panel members is to recreate pre-mine conditions. The limitations of water movement after closure were discussed in relation to elevation changes in this area; historic water flow patterns between Lac de Gras and the PKC area that would be necessary to support fish and bug life would be incredibly difficult to achieve.	Natural condition	Current closure plans do not include re-stocking fish and bugs in East Island lakes, and this includes the lake within the PKC area. Water flow patterns that would be similar to historic conditions and possibly allow for fish and bug life in the PKC pond are not planned for this area. As discussed, elevation changes from mine development would prevent this from occurring.	N/A
6.13	Processed Kimberlite Containment Interim Report, 24-28 October 2013, pg. 6	Recreate small ponds along the drainage route to encourage settling and healing of the water and fish habitat	There is a strong belief expressed by the Panel that nature heals itself and that it can be disrespectful to interfere with nature, but that humans can help to create the conditions to support healing. Encouraging longer drainage paths that utilize small ponds increases the chance of having cleaner water when it reaches Lac de Gras.	Nature is self-healing	Diavik agrees with this recommendation and the proposed drainage path for a pond within the PKC area flows across the tundra, and passes through 3 small ponds along the way.	In consultation with communities, conduct further research and advance the plan for the PKC closure concept approved by the WLWB in May 2014.

DDMI TK Panel Recommendations and Response Tracking - Processed Kimberlite Containment (PKC) Area

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
6.14	Processed Kimberlite Containment Interim Report, 24-28 October 2013, pg. 6	Support the drainage streams to encourage fish to migrate from Lac de Gras to the reclaimed lake	The desire of Panel members is to recreate pre-mine conditions. The limitations of water movement after closure were discussed in relation to elevation changes in this area; historic water flow patterns between Lac de Gras and the PKC area that would be necessary to support fish and bug life would be incredibly difficult to achieve.	Natural condition	The footprint of the PKC extends close to the shoreline of Lac de Gras which could make it very difficult to reduce the slope of the dam in some key areas. The elevation difference for the PKC area at closure will be significant when compared with the original lake in that area, making it very difficult to re-establish baseline conditions. Technical considerations also need to be taken into account; the dam walls still need to contain PK material that would remain after closure.	N/A
6.15	Processed Kimberlite Containment Interim Report, 24-28 October 2013, pg. 6	Make the closure lake as similar to the original lake, as much as possible	The desire of Panel members is to recreate pre-mine conditions and plan for safe usage of the area by wildlife.	Natural condition	Material availability will be limited and Diavik prefers to use material available at the site, without disturbing new areas. It is likely that the shoreline of any reclaimed pond will differ from a natural pond, but it may be possible to identify and recreate some elements of interest to communities.	In consultation with communities, conduct further research and advance the plan for the PKC closure concept approved by the WLWB in May 2014.
6.16	Processed Kimberlite Containment Interim Report, 24-28 October 2013, pg. 6	Provide sufficient travel-ways for caribou and muskox over the dam through re-sloping and topping with smaller material	This approach would create safe access for wildlife, as it is assumed that wildlife will try to use this area after closure.	Safety Respect Stewardship	The current closure plan does not include re-shaping of the PKC dams. Any proposed changes would need to be evaluated for possible risks and discussed with communities. The footprint of the PKC extends close to the shoreline of Lac de Gras which could make it very difficult to reduce the slope of the dam in some key areas. Technical considerations also need to be taken into account; the dam walls still need to safely contain PK material that would remain after closure.	In consultation with communities, conduct further research and advance the plan for the PKC closure concept approved by the WLWB in May 2014.
6.17	Processed Kimberlite Containment Interim Report, 24-28 October 2013, pg. 6	Recognizing that caribou may return, provide areas of soft materials that are good for caribou feet so that they may pass over the reclaimed site	TK holders care about the comfort of animals and want to avoid creating stress for them. This approach would create safe access for wildlife, as it is assumed that wildlife will try to use this area after closure.	Safety Respect Stewardship	The current closure plan does not include cover materials that would provide access over the PKC dams. Any proposed changes would need to be evaluated for possible risks and discussed with communities.	In consultation with communities, conduct further research and advance the plan for the PKC closure concept approved by the WLWB in May 2014.
6.18	Processed Kimberlite Containment Interim Report, 24-28 October 2013, pg. 6	Leave some areas steep to encourage snow accumulation for wolverine and other denning wildlife (e.g. wolf, bear, fox, ground squirrel, etc.)	This approach would create safe access for wildlife, as it is assumed that wildlife will try to use this area after closure.	Safety Respect Stewardship	This would be achieved with the current closure plan.	N/A
6.19	Processed Kimberlite Containment Interim Report, 24-28 October 2013, pg. 6	Open up sections of the dam to recreate natural water flow	The desire of Panel members is to recreate pre-mine conditions. The limitations of water movement after closure were discussed in relation to elevation changes in this area; historic water flow patterns between Lac de Gras and the PKC area would be incredibly difficult to achieve.	Natural condition	The footprint of the PKC extends close to the shoreline of Lac de Gras which would result in a very short pathway for water to travel and heal before entering Lac de Gras. This conflicts with previous guidance to route water overland for as long as possible, and DDMI's preference is the latter. Technical considerations also need to be taken into account; the dam walls still need to safely contain PK material that would remain after closure.	N/A
6.20	Processed Kimberlite Containment Interim Report, 24-28 October 2013, pg. 6	The TK Panel requests that DDMI starts to remove any new slime from site, effective immediately	The Panel felt it important to stop adding to the volume of slimes that has already accumulated on site.	Stewardship	DDMi is unable to immediately start removing slimes from site, as there is no alternative storage options available or permitted, nor is there an acceptable method of transport available.	N/A
6.21	Processed Kimberlite Containment Interim Report, 24-28 October 2013, pg. 6	The TK Panel requests that DDMI provide an overview of the sixteen closure options that have been considered and the preferred five options identified (including costs). Further, the TK Panel requests that DDMI provide an overview and cost estimate to remove the slime from the mine site.	The options, reasons and costs were important for the TK/IQ Panel to understand in consideration of their own assessment.	Reciprocity	The options were reviewed with Panel members, though cost information was not available at the time the information was presented.	Diavik provided the Panel with the additional information requested.

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6.22	Processed Kimberlite Containment Interim Report, 24-28 October 2013, pg. 6	The TK Panel recommends that DDMI explore ways of treating and removing slurry/slime with other diamond mines in the area to make it feasible	The assumption here is that costs will be reduced by working together.	Stewardship	Should such measures be necessary in the future, DDMI would be willing to explore such options in cooperation with other mines.	N/A
7.7	Re-vegetation Report, TK Panel Session #7, 14-18 August 2014	Create barriers and other means between the rock pile and PKC to discourage animals from going into the PKC area	Diavik provided feedback to the Panel at the start of Session 7 that a number of their recommendations from Session 6 (PKC) would not be possible, so Panel members had to re-evaluate their preferred approach to managing this area after closure. Participants realized that more discussion is required to develop alternate recommendations for the PKC. However, Panel members also noted that it is important to consider having a barrier between the rock pile and PKC that would prevent or deter animals from going into the PKC area. Keeping a steep slope on the side of the rock pile that is beside the PKC was recommended by the Panel.	Stewardship	The Panel's preferrance for design that prevents or deters caribou from travelling from the (north country) rock pile to the PKC is supported. The design approach to achieve this will need to be considered, as maximum slopes required for cover placement may not be sufficient in themselves to act as a barrier to movement.	DDMI to consider design features that support this recommendation during the next major update to the ICRP (2016).
8.11	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Monitor and filter two streams from the east and west sides of the PKC by Mother Nature through mosses, bogs; moss should be placed throughout the channel. In the short term, install an industrial filtering system. Monitor this water quality.	Another key concern for communities is the water quality of the PKC. Natural methods to filter water (e.g. moss) and planning for water to follow a long pathway to Lac de Gras are the Panel members preferred, long-term water treatment approaches. Recognizing that the development of moss may take time, it would be prudent to consider using an industrial filtering system to treat water flowing from the PKC once the mine closes and until such time as a natural filtering system has established. Water flowing from the PKC should be monitored scientifically for water quality.	Stewardship Nature is self healing Natural condition	Diavik currently monitors water quality in the PKC and this practice would be incorporated into a post-closure monitoring program. Routing options for water leaving the PKC after closure will be assessed, and DDMI agrees with the Panel that the distance it flows before entering Lac de Gras will be an important consideration. However, options may be limited in some areas, particularly on the west side. Should site-specific treatment of PKC water be required, relevant options (both industrial and natural) to achieve the required performance would be evaluated.	Outline post-closure monitoring plans for the mine site, including those specific to the PKC, and communicate the location and distance of drainage channels from the PKC.
9.8	Focus on Caribou, TK Panel Session #9, 13-16 May 2016	Place a circle of boulders around the PKC pond, in an area that is stable enough to support the weight and where they won't sink into the slimes, and around the shore of the North Inlet (refer to map).	Panel members prefer to find a way to deter caribou and other wildlife from accessing the PKC pond after closure. Panel members would prefer that the PKC pond not become a drinking water source for animals. Additionally, there is a risk of animals becoming trapped in the water, or stuck in the unstable slimes material at the edge of the pond. Man-made fences can sometimes injure wildlife or be used in predation, and require maintenance, so the preference is to use a natural way of deterring animals from accessing the pond.	Stewardship Natural condition Respect Safety	Diavik is still evaluating options for closing the PKC area. The current plan includes a pond in the centre of the PKC post-closure, but other options that could omit the need for a pond are being assessed in accordance with the recommendations recieved from past TK Panel sessions. The TK Panel's recommendation for the use of boulders around the pond has been noted for consideration, should the preferred closure plan result in the need for a pond in the PKC. Diavik is committed to arranging a future TK Panel session to re-visit the PKC closure plans, once further information on closure options have been further evaluated.	Update the TK Panel once Diavik has advanced closure research and evaluated additional closure options for the PKC area.

DDMI TK Panel Recommendations and Response Tracking - Open Pits

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Assigned by DDMI unless otherwise indicated in report	*Be as specific as you think is appropriate; for example a section or page of the document, a recommendation #, general comment, etc.*	*Recommendations should be as specific as possible and explain an action that you believe is necessary; supporting information or rationale should be explained in the "context" column.*	*Context should contain all the information needed to understand the rationale for the accompanying recommendation.*	*Distinct values/concepts that are contained in Traditional Knowledge and can help to guide decision process*	*Responses should be as specific as possible, relating the issues raised in the "recommendation".*	*Actions should be as specific as possible, relating the issues raised in the "recommendation"; where possible, a timeframe may be included.*
8.9	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Do not breach dikes until the TK Panel is satisfied with the water quality through visual inspection and reviewing results from scientific analysis.	Panel members have repeatedly expressed the importance of 'seeing with their own eyes'. It is important to continue to involve Panel members in key decisions during the closure phase of the mine. One of the most important phases to supporting this process will be prior to breaching the dikes. If Panel members are satisfied with what they see and learn, they can support reconnecting the dike areas to Lac de Gras.	Stewardship Experiential learning Consensus Respect	Continued engagement of the TK Panel through site visits during closure is Diavik's preferred approach to sharing plans and progress, and continuing to build the Panel's knowledge and expertise of closure activities.	Continue to engage the TK Panel through closure.
8.20	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Leave the land between the pits and the dikes as it is for natural regrowth when flooding.	Much of the natural lake beds that are exposed inside the dike have been undisturbed for many years and have had substantial growth of terrestrial (land) plants. Panel members felt that these plants should be left in place. While they will likely die once they are under water, they will help to establish other water plants and provide food for bugs that live in the water.	Nature is self-healing Natural condition	The plant growth that has occurred in these areas is something that was not anticipated during the environmental assessment. Diavik is in agreement with the Panel on their recommended approach, but recognizes that other stakeholders, such as DFO, will be interested in considering the best option for these areas at closure.	Engage stakeholders to determine the preferred approach for revegetated areas inside the dikes prior to filling the open pits with water.
8.21	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Leave dikes as they are (i.e. do not modify the slope or current construction).	Panel members had much discussion over the dikes. In the end, many felt that the dikes will act as islands and offer protection from wind and waves inside (good for small and resting fish). The outside of the dikes would be perfect for bigger fish and other fish to swim along, and many Panel members stated that this is where they would set nets.	Stewardship Social	This recommendation aligns with Diavik's current closure plans. The only changes to the dikes would be the areas that are breached to reconnect the pits back to Lac de Gras.	N/A
8.22	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Vary depths of built reefs.	Keeping some parts of the reef deeper and some shallow allows for current to run through the area. Keeping the reefs under water will allow the water to freeze and the ice to grow really thick for safe travel. Building islands that extend out of the water was considered by the Panel at one point, but they ultimately preferred keeping the reefs under water, given that the dikes will become islands once they are breached.	Stewardship Social	This recommendation aligns with Diavik's current closure plans.	N/A
8.23	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Don't build, or minimize building reefs on previous lake bottom areas inside the dike area (i.e. protect undisturbed and naturally vegetated areas).	Similar to the feedback received during the revegetation session (#7), Panel members were interested in preserving areas inside the dike that had not been disturbed by mining activities. Reef construction should be focussed on areas within the dike where disturbance has already occurred.	Stewardship Natural condition Nature is self healing	This recommendation aligns with Diavik's current closure plans.	N/A

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8.24	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Ensure good fish habitat for rearing, feeding and resting on reefs inside dike.	A combination of sand and gravel are the preferred materials to use for building reefs and new areas of lake bed, as this is what was there in the beginning (i.e. before mining). Fish that are just born like shallow areas with gravel and a bit of sand or till (original lake bottom sediments). Little fish don't like too much sand, though, and minnows will often die in these types of areas. There was alot of debate about what type of habitat to develop inside the dikes, but Panel members ultimately felt that there was enough good spawning habitat elsewhere in Lac de Gras, so the focus for this area should be shelter for feeding and resting.	Recording knowledge Stewardship Natural condition Experiential learning	This recommendation aligns with Diavik's current closure plans.	N/A
8.25	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Stock water in open pits with bugs to improve water quality.	Many Panel members identified that bugs in the water and on the lake bottom are beneficial to fish and the environment. Their continued presence is also an indicator of good water quality. Adding bugs to areas that were previously disturbed could help to reclaim those areas.	Recording knowledge Stewardship Natural condition Experiential learning	Diavik is interested in this idea and plans to explore the feasibility of incorporating this method into closure plans.??	Evaluate feasibility of aiding benthic invertebrate colonization.
8.26	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Provide opportunity for the TK Panel to view the present shoreline when snow-free to consider further recommendations (in spring).	Panel members have repeatedly expressed the importance of 'seeing with their own eyes'. This Panel session was held in December in Yellowknife, so many members were basing their discussions on memory and hadn't closely looked at the shoreline areas of the pits in the past. In order to confirm their preferences, Panel members would like to visit the shoreline areas within the dike when there is no snow on the ground.	Stewardship Experiential learning	A visit to these areas is planned for May 2016, during TK Panel Session 9.	Plan to visit the pit shorelines during the May 2016 TK Panel meeting at the Diavik site.
8.27	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Break-up the 1 km cliff on pit A418 with slopes (to make it safe for caribou).	There was a concern that a cliff feature at the edge of a lake could result in caribou or other animals being injured or killed, especially if it was used by predators as a hunting technique. Additionally, the length of the existing cliff would mean that caribou would have to swim up to 1 km to get out of the water. As such, it was felt that adding slopes at regular intervals would be helpful for animals to get in/out of the water safely.	Stewardship Experiential learning Sharing knowledge	Diavik plans to accommodate this request when finalizing closure designs for the A418 pit. A visit to this area is planned for May 2016, during TK Panel Session 9, and it would be helpful to have the TK Panel confirm that this recommendation still holds after seeing the area with their own eyes.	Plan to visit the pit shorelines during the May 2016 TK Panel meeting at the Diavik site and determine if the TK Panel reconfirms this recommendation.
8.28	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Leave current roads into the pits (e.g. A154).	Panel members found it acceptable to leave the ramps (that are currently used for vehicles to enter the pits) in place at closure,as they could provide safe access for wildlife into and out of the lake.	Stewardship	This recommendation aligns with Diavik's current closure plans.	N/A

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9.25	Focus on Caribou, TK Panel Session #9, 13-16 May 2016	Given that the pits are going to be refilled with water, that Diavik is considering putting processed kimberlite and 'slimes' into the pits and underground shafts and concerns about tremors and seismic activity, the TK Panel requests a tour of the pits and underground shafts to see the 'receiving environment' with their own eyes.	As with many other aspects of the site, TK Panel members find it helpful to see things with their own eyes in order to better understand an area and the related closure considerations for that area.	Experiential Learning Stewardship	DDMI understands the Panel's interest in viewing the open pits and underground to better understand the closure objectives for this area. A visit underground is very time consuming with many safety considerations and special equipment; not all Panel members may be comfortable going underground. DDMI suggests that a future TK Panel session focus on the option to store PK underground and that a tour of the open pit and underground areas would be arranged for those who wish to view them, in conjunction with that session.	DDMI to arrange for an open pit and underground tour, for those Panel members that wish to visit these areas, during a future Panel session.

DDMI TK Panel Recommendations and Response Tracking - North Inlet

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7.14	Re-vegetation Report, TK Panel Session #7, 14-18 August 2014	Relating to re-vegetation, the North Inlet requires further discussion in terms of it being a no go zone, replanting zone or encouraging zone for wildlife.	The men and women had separate break out sessions to develop their ideas on how best to manage various areas of the mine after closure. Many of their ideas were similar, but the suggestions for the North Inlet differed greatly. Panel members recognized that more information is needed from Diavik relating to the water quality and closure plan for the North Inlet pond, before a decision can be made on vegetation and wildlife access.	Stewardship Reciprocity	Diavik is grateful for the maps developed at this session and views these as a useful tool for discussions with community members, community organizations, regulators and the TK Panel. Further information relating to the North Inlet water quality and closure plan will be planned for a future TK Panel session.	DDMI to use these maps as a basis for community engagement in relation to re-vegetation and wildlife use around the mine site at closure. DDMI to plan a TK Panel session for the North Inlet once all relevant information is available.
9.24	Focus on Caribou, TK Panel Session #9, 13-16 May 2016	Do not reconnect the North Inlet, open pits and PKC area with the lake/land; keep dams and dikes intact unless the water and sediments in those areas is proven to be clean and the same as Lac de Gras.	The Panel members would prefer that areas with the potential for contaminating Lac de Gras waters or fish (e.g. North Inlet) remain separate from the rest of the lake. Similarly, the dam around the PKC should remain in tact unless the area would not pose a risk of contaminating the land or animals surrounding it. In order for the Panel to recommend or support plans to reconnect these areas back to Lac de Gras or East Island, Diavik would need to prove that the water, lake bottom and closure surface is clean and safe.	Stewardship Safety Natural condition	Diavik understands the Panel's concerns. Currently-approved closure plans would see the open pit/ underground areas and the North Inlet reconnected to Lac de Gras. Diavik has conducted several studies to determine if there are risks (potential for contamination) to the environment, should they be reconnected to LDG. Current plans also provide for multiple years of monitoring prior to possibly reconnecting these areas. Closure plans for the PKC include breaches in the dam in certain areas. It is Diavik's preference from a liability perspective to not retain regulated containment structures on the site.	Update the TK Panel as more information on these areas becomes available and a preferred closure plan is identified.

DDMI TK Panel Recommendations and Response Tracking - Water and Fish						
NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
Assigned by DDMI unless otherwise indicated in report	*Be as specific as you think is appropriate; for example a section or page of the document, a recommendation #, general comment, etc.*	*Recommendations should be as specific as possible and explain an action that you believe is necessary; supporting information or rationale should be explained in the "context" column.*	*Context should contain all the information needed to understand the rationale for the accompanying recommendation.*	*Distinct values/concepts that are contained in Traditional Knowledge and can help to guide decision process*	*Responses should be as specific as possible, relating the issues raised in the "recommendation".*	*Actions should be as specific as possible, relating the issues raised in the "recommendation"; where possible, a timeframe may be included.*
8.3	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	In future programs, document why certain fish are rejected by Elders.	It was noted that one of the participants in the 2015 AEMP TK Study rejected two fish for processing, but the reasons why were not well documented. It would be helpful to capture these reasons in future studies.	Experiential learning Sharing knowledge	Diavik agrees that the reasons why fish are selected or rejected should both be documented.	Communicate and incorporate this approach for the 2018 AEMP TK Study.
8.4	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Water testing should be done by tasting fresh water and by boiling the water, letting it set overnight and drinking it the following day (observe scum and clarity).	Panel members recognized that not all people may drink tea, and that it would be better to use plain water to taste the lake water quality. In this way, the water is natural and any impurities would be easier to identify. However, the benefit of also boiling the water allows people to see if anything with the water changes after being heated, e.g.has a layer of scum, or materials settle out. It was agreed that people could make tea with the lake water on their own, if that was important to them.	Experiential learning Sharing knowledge	Diavik supports the water quality testing method that is preferred by TK holders. Any change to methods used should be communicated and documented during the planning phase of the 2018 AEMP TK Study.	Communicate and incorporate this approach for the 2018 AEMP TK Study.
8.5	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Set fish nets on both sides of the island (north and south).	Panel members felt that it is important to capture fish on both sides of East Island and closer to the mine itself. They would like to plan ahead for this for the next AEMP TK Study in 2018.	Experiential learning Sharing knowledge	Nets can be set in a variety of locations, and Diavik supports the idea of determining where best to set nets during the planning phase of the 2018 AEMP TK Study. However, weather conditions may limit the ability to access certain areas as safety rules for site restrict boat travel if winds exceed 15 knots.	Communicate and incorporate this approach for the 2018 AEMP TK Study.
8.6	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Ensure two Elders and two youth from each group attend future camps and meetings.	Panel members expressed that having young people participate in the AEMP TK Study, meetings and monitoring is critical for effective monitoring in the future. Having two young people from each community present increases their comfort level, as many are shy, and helps to make sure that the Elders are properly cared for. Members recognized that they could help support this process by talking with their organizations and encouraging them to find youth to attend.	Respect Experiential learning Intergenerational Sharing knowledge Stewardship Traditional laws	It would be very beneficial to have TK Panel members assist in identifying and recruiting youth to participate in TK programs. The TK camp footprint is small and space is limited to what can be supported with existing beds/tents and cooking facilities. Most community organizations can send 4 people to the camp and this is usually 2 Elders, 1 youth and 1 interpreter. Should an interpreter not be required, Diavik would consider having 2 youth from the community attend.	Evaluate camp accommodations and participant needs in advance of the 2018 AEMP TK Study and advise community organizations and the TK Panel on options for attendees.
8.7	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Sample fish and water from the Narrows (In both LdG and LdS).	Concerns over future development of the Jay Pipe in Lac du Sauvage was a driver for Panel members to recommend sampling water and fish from the area around the Narrows (between LDS and LDG) as part of the AEMP TK Study.	Stewardship	The current area identified for fishing in LDG includes the area of the lake below the Narrows. For safety reasons, Diavik would like to avoid taking boats up the Narrows. Any concerns or interest in sampling LDS in relation to the Jay Pipe should be directed to Ekati.	N/A

DDMI TK Panel Recommendations and Response Tracking - Water and Fish

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
8.8	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Consider additional water sampling locations from different areas.	At closure, or with future development, community members may want to add water sample locations to the AEMP TK program.	Stewardship	Water samples can be taken in a variety of locations, and Diavik supports the idea of determining where best to obtain samples during the planning phase of the 2018 AEMP TK Study. However, weather conditions may limit the ability to access certain areas as safety rules for site restrict boat travel if winds exceed 15 knots.	Communicate and incorporate this approach for the 2018 AEMP TK Study.
8.10	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Focus water quality monitoring on the NCRP.	The NCRP has been identified as one of the main concerns of Panel members who feel that climate change may affect its integrity and release contaminated water into the environment. As such, Panel members want to make sure that water from the pile is monitored for quality.		Many stakeholders are interested in the performance and integrity of the rock pile, as well as the quality of water seeping from the pile. As such, long-term water monitoring plans would be incorporated into the development of the post-closure monitoring program.	Outline post-closure monitoring plans for the mine site, most notably those specific to the water quality from the NCRP.
8.12	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Monitor fish spawning areas closely, especially in the SE part of island (i.e. area just south of the pits).	Panel members are concerned about fish spawning in potentially contaminated areas, so they want to know if fish are using the areas close to the mine after closure.	Stewardship	Community members could monitor spawning areas at a variety of locations in LDG, and Diavik supports the idea of determining where best to monitor during the planning phase of post-closure TK studies.	Communicate and incorporate this approach for post-closure TK studies.
8.13	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Monitor and test water in pits and around East Island regularly.	Panel members were concerned with pit water quality once the pits were refilled with water because of potential contaminants. It is recommended to sample the water frequently and watch for wildlife using the water (drinking, swimming). If wildlife avoid water, there could be a concern about the water quality. Similarly, other areas around the mine site should also be monitored for water quality where water can run off into Lac de Gras.	Stewardship	Diavik currently monitors water quality around East Island and this practice would be incorporated into a post-closure monitoring program, along with open pit water quality. Incorporating a TK perspective of observing wildlife using the water is supported as part of a post-closure monitoring program.	Outline post-closure monitoring plans for the mine site, including various water quality monitoring methods.
8.14	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Regularly stock on-island pond water with bugs to improve water quality.	Many Panel members identified that bugs in the water and on the bottom of lakes are beneficial to fish and the environment. Their continued presence is also an indicator of good water quality. Adding bugs to areas that were previously disturbed could help to reclaim those areas.	Recording knowledge Stewardship Natural condition Experiential learning	Diavik is interested in this idea and plans to explore the feasibility of incorporating this method into closure plans.??	Evaluate feasibility of aiding benthic invertebrate colonization.

DDMI TK Panel Recommendations and Response Tracking - Water and Fish

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
8.15	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Test water scientifically and not by tasting.	Panel members are uncomfortable with the idea of tasting water, as a way to test water quality, for water that is on the mine site. Panel members noted that scientific sampling is important for water testing, as it tests for things that cannot be seen or tasted. They also noted that visual inspections of the water (in the same areas that science samples would be taken) would be important for community members after closure.	Stewardship Safety	Diavik currently monitors water quality around East Island and this practice would be incorporated into a post-closure monitoring program. Incorporating a TK perspective of visual observations of the water is supported as part of a post-closure monitoring program. It is Diavik's hope that community members will be the ones taking scientific samples and observing the water themselves, at the same time.	Outline post-closure monitoring plans for the mine site, including various water quality monitoring methods.
8.16	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Regularly measure heavy metals all around island.	Panel members were concerned with water quality around the island, largely in respect to animals consuming it and water from the island entering the lake. Metals can be a concern because of equipment and infrastructure that were used for the mine.	Stewardship	Diavik currently monitors metal concentrations in water quality around East Island and this practice would be incorporated into a post-closure monitoring program.	Outline post-closure monitoring plans for the mine site, including various water quality monitoring methods.
8.17	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Monitor water in late May and early June as these are critical times (i.e. melt).	Panel members know from experience that spring thaw produces the greatest amount of water that would runoff the island and into the lake over a short period of time. The volume can also pick up a lot of dirt and material from the ground and transport it to the lake. Therefore it is important to monitor water quality during this time, in addition to regular sampling.	Stewardship	Diavik currently monitors water quality around East Island, including during freshet, and this practice would be incorporated into a post-closure monitoring program. Incorporating a TK perspective of visual observations of the water is also supported during this time of year. It is Diavik's hope that community members will be the ones taking scientific samples and observing the water themselves.	Outline post-closure monitoring plans for the mine site, including various water quality monitoring methods and timing/frequency of samples.
8.18	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Regularly measure water quality in all bays, drainage and run-off.	Panel members know from experience that water runs off the island and into the lake, taking many materials from the land along with it. Therefore it is important to monitor water quality in runoff and in areas that receive the runoff.	Stewardship	Diavik currently monitors water quality around East Island and in Lac de Gras, and this practice would be incorporated into a post-closure monitoring program.	Outline post-closure monitoring plans for the mine site, including various water quality monitoring methods.
8.19	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Annually check for algae growth around shorelines as too much can be an indicator that there is less oxygen for the fish.	Panel members have experience with lakes in their home regions that have changed over the years. Many noted how algae and moss can be helpful in cleaning water, but too much build up of algae, especially along shorelines, may be an indicator that the water is not of good quality for fish. This is something that community members can help to identify through visual inspections of shoreline areas near the mine.	Stewardship Experiential learning	Diavik currently monitors water quality around East Island and in Lac de Gras, and this practice would be incorporated into a post-closure monitoring program. Incorporating a TK perspective of visual observations for algae in the water is also supported. It is Diavik's hope that community members will be the ones taking scientific samples and observing the water themselves.	Outline post-closure monitoring plans for the mine site, including various water quality monitoring methods.

DDMI TK Panel Recommendations and Response Tracking - Spiritual & Cultural Considerations

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/ CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
Assigned by DDMI unless otherwise indicated in report	*Be as specific as you think is appropriate; for example a section or page of the document, a recommendation #, general comment, etc.*	*Recommendations should be as specific as possible and explain an action that you believe is necessary; supporting information or rationale should be explained in the "context" column.*	*Context should contain all the information needed to understand the rationale for the accompanying recommendation.*	*Distinct values/concepts that are contained in Traditional Knowledge and can help to guide decision process*	*Responses should be as specific as possible, relating the issues raised in the "recommendation".*	*Actions should be as specific as possible, relating the issues raised in the "recommendation"; where possible, a timeframe may be included.*
2.4	Renewing Our Landscape, 7 Dec 2012, pg. 25	Renew relationship with the area after closure.	Spiritual ceremonies to invite the spirits to return to the mine site will be requiredresponsibilities require people to make amends to the spirits of the land for the damage created by the mine. It is important that current and future generations maintain their relationship with their homelands that surround the mine. Aboriginal harvesters will travel where the caribou go, and provided that the area is made safe and accessible for caribou, they will go there again. For this reason, Aboriginal people's connection with the land needs to be renewed and/or maintained after closure.	Traditional laws Stewardship	Diavik is open to recommendations on how best to approach this with each of the five Aboriginal Participation Agreement communities.	To be determined
4.3.1	Closure/Reclamation and Landscape History Interim Report, 23-25 October 2012, pg.6	Visit burial, archaeological and heritage resource areas close to the mine.	Provide comfort to community members that important sites have been preserved and that this historical connection still exists with the land in this area; important for youth to know the locations and stories behind these sites.	Intergenerational Stewardship Experiential learning	This type of activitiy could be incorporated into plans to renew the community's relationship with the land in this area after closure.	To be determined
4.3.2	Closure/Reclamation and Landscape History Interim Report, 23-25 October 2012, pg.6	Conduct a tobacco (or other) ceremony when the company is ready to leave the island.	Heal and reconciliate the relationship with the land once all work is complete. The type of ceremony may be different for different cultures.	Symbolism Stewardship	This type of activitiy could be incorporated into plans to renew the community's relationship with the area after closure.	To be determined
9.6	Focus on Caribou, TK Panel Session #9, 13-16 May 2016	Recognize and honour the importance of ceremony in healing the relationship to caribou and contribute to healing events that are currently being planned by communities.	N/A	Traditional laws Stewardship Symbolism Safety Respect	Diavik works through Implementation Committees that have been established with each of their Participation Agreement communities to determine priority areas for financial contributions. We recommend speaking with your community organizations to identify this request for their consideration.	N/A
9.22	Focus on Caribou, TK Panel Session #9, 13-16 May 2016	Respect spiritual beliefs and the importance of healing ceremonies of Aboriginal communities, work with the TK Panel to plan spiritual gatherings on site now through 2030: one would be held early to help people on site understand Aboriginal ceremonial ways, possibly timed with a TK Panel session (e.g. 2017-8), second would be to start healing the environment (e.g. 2020), third would be designed to seek guidance on the finalization of closure plans (e.g. 2023) and fourth would be large and involved to formally invite the spirits to return to the Island before Diavik leaves (all communities invited, e.g. 2030).	Building in the practice of healing and/or guidance ceremonies is important and can be of interest to workers at the mine, as well as the TK Panel members. It would be helpful to start this practice sooner rather than later.	Traditional laws Stewardship Symbolism Safety Respect	Diavik is open to further recommendations from the Panel as to when and how this could occur. If the Panel is comfortable with helping to define this, such practices could be incorporated into the TK monitoring program that Diavik is interested in having the Panel develop.	TK Panel members to consider including spiritual practices and/or considerations as part of the proposed TK Monitoring Program for the Diavik mine.
9.23	Focus on Caribou, TK Panel Session #9, 13-16 May 2016	Whenever the TK Panel and community members come on-site, allow opportunity, time, space, etc. for the TK Panel to practice ‘feeding the land or water’ by Panel members and others (visitors or workers) travel to/from the site and consider other ways to raise awareness (e.g. signage).	It is important to recognize and honor customs. While it is easy for the company to focus on their own safety, it is equally important for the Panel to have the opportunity to feed the land or water, as is traditionally done for safety on the land.	Traditional laws Stewardship Symbolism Safety Respect	Diavik recognizes the importance of this practice to community members and supports any practices that promote safety and wellbeing at the mine site. This practice will be incorporated into future TK Panel meetings, or other community visits to the site.	This opportunity will be provided to the Panel, or other community visitors to the site, upon their arrival.

DDMI TK Panel Recommendations and Response Tracking - Spiritual & Cultural Considerations

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/ CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
10.24	Watching/Monitoring and the WRSA-SCRP, Session #10, 14-18 September 2017	Research or monitoring methods that are offensive to elders (e.g. caribou collars) should lead to getting alternative method advice from elders. Diavik should check with the TK Panel as to whether any aspects of the current monitoring program is offensive and revise them accordingly.	The Panel focuses on closure planning and monitoring, but they are also interested in Diavik's operational monitoring and would like to learn more about monitoring programs, methods and results in order to determine if these are suitable and appropriate from a community perspective.	Respect Stewardship	Diavik can share details of each of the current (operational) monitoring programs with the Panel at a future session to determine if methods used are appropriate. This may also help to inform the Panel's recommendations relating to closure monitoring for wildlife.	Provide a presentation on Diavik's operational monitoring programs to the Panel at a future session.

DDMI TK Panel Recommendations and Response Tracking - Monitoring & General (including TK/IQ Panel Process)

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
Assigned by DDMI unless otherwise indicated in report	*Be as specific as you think is appropriate; for example a section or page of the document, a recommendation #, general comment, etc.*	*Recommendations should be as specific as possible and explain an action that you believe is necessary; supporting information or rationale should be explained in the "context" column.*	*Context should contain all the information needed to understand the rationale for the accompanying recommendation.*	*Distinct values/ concepts that are contained in Traditional Knowledge and can help to guide decision process*	*Responses should be as specific as possible, relating the issues raised in the "recommendation".*	*Actions should be as specific as possible, relating the issues raised in the "recommendation"; where possible, a timeframe may be included.*
1.20	A Way of Life, 25 October 2012, pg. 25	Youth should be involved with the TK/IQ Panel and included in discussions about closure.	Youth live in a changing and complex world and have skills that the Elders do not. They need to learn about their culture and history, as well as about the mines. They will be the future caretakers of the land and the ones speaking for their communities in the future, so they must be a part of the discussions and decisions.	Intergenerational Social Stewardship	Diavik sees value in having youth participate in TK/IQ Panel sessions, where possible.	Youth involvement was incorporated into the October 2013 Panel session, and also plans to include youth in future sessions.
2.1	Renewing Our Landscape, 7 December 2012, pg. 9; 19 July 2012 e-mail from EMAB	Arrange for a visit to the mine site to see some of the structures that are being discussed for closure, specifically the North Country (waste) Rock Pile. Preference is to stay at a camp on the land, rather than in mine site accommodations.	In order to provide effective and helpful advice, Panel participants need to see areas in person. A fundamental principle in TK/IQ is that "being knowledgable" requires an experiential context of what is being discussed, as TK comes to the forefront of peoples minds when they are on the land that they are discussing. This helps to understand the area as it was traditionally and to comprehend the change and scale of the current landscape.	Recording knowledge Experiential learning	Diavik sees value in having TK/IQ Panel members visit the mine site. For safety reasons, visitors stay at the mine site accommodations.	In response to this request, a site visit and follow up meeting in Yellowknife was arranged for 20 & 21 August 2012. Diavik also began to hold TK/IQ Panel meetings at the mine site in October 2013, when the Panel began to be administered by Diavik.
4.1.3	Checking Nets, 23-25 October 2012, pg.19; Closure/Reclamation and Landscape History Interim Report, 23-25 October 2012, pg.8	Diavik to develop and maintain a tracking sheet for documenting progress on recommendations and action items and present progress to the panel at the beginning of sessions.	Desire for Panel members to see the results of their work and obtain a response from Diavik. Shared learning and acknowledging contributions of others is an important tradition. There is an opportunity to learn from their experience and any recommendations that are implemented. There may be a need to revisit recommendations that are either ineffective, or are carried out or interpreted incorrectly. It is also an opportunity to celebrate successes achieved by the Panel and Diavik.	Recording knowledge Respect Reciprocity	Diavik is committed to providing a response to all Panel recommendations. Diavik also requested that EMAB provide past Panel recommendations to DDMI for response.	This Excel spreadsheet is the proposed tracking system and was reviewed and supported by the TK/IQ Panel. Updates to this spreadsheet are done over time and communicated in person to Panel members, and shared with the public as necessary.
4.1.4	Checking Nets, 23-25 October 2012, pg.20	Women to have opportunities to participate in TK/IQ Panel – especially for discussions on caribou and vegetation.	Women have specific roles in Aboriginal communities and the knowledge they can contribute is different from that of men. There needs to be respect for the distinct knowledge of women, as Elder women have special gifts and understandings that are important for carrying out stewardship responsibilities.	Respect Recording knowledge	Recommendation is to the TK/IQ Panel or their community organizations. DDMI does not select Panel participants but could request community organizations to include women participants, as recommended by the Panel.	A request to add women participants for the August 2014 re-vegetation Panel session was sent to communities, as this had been suggested by the Panel in the past.
4.1.5	Checking Nets, 23-25 October 2012, pg.20	Extend length of Panel sessions to 4 days.	Three days is not enough to review documents, learn about the context of the topic(s) and share new knowledge. The fourth day is key to completing the review and verification necessary to respectfully document knowledge and develop a complete document that all parties are happy with.	Recording knowledge Consensus Respect	A longer meeting is supported, provided that it results in an approved set of transcripts and recommendations by the end of the session.	Starting with the October 2013 TK/IQ Panel session, each Panel meeting is planned to be 4 days at the mine site. Transcripts are to be produced and presented to Panel members daily to be verified on-site, where possible.

DDMI TK Panel Recommendations and Response Tracking - Monitoring & General (including TK/IQ Panel Process)

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
4.1.6	Checking Nets, 23-25 October 2012, pg.21	Include Aboriginal words or terms in reports as appropriate. Keep wording in reports simple and make summary notes available soon after a meeting.	Some Aboriginal languages include concepts that are very precise and reflect a more complete understanding than what can be translated. Language contains distinct concepts unique to TK so the spiritual premise of certain terms contained within the language can often get lost in translation. Plain language should be used so that all people can understand it, regardless of their language or reading skills. It is important for participants to review their words and make sure they were recorded and/or interpreted correctly while the words are still fresh in participant's minds.	Symbolism Recording knowledge	TK/IQ Panel members should work with their interpreters and the facilitators to ensure that important Aboriginal words or terms are captured within transcripts and/or reports. Diavik makes efforts to report the results of their programs in different ways, for different audiences.	TK Panel reports are to use basic or plain language and efforts will be made to continue to make transcripts available daily for review.
4.1.7	Checking Nets, 23-25 October 2012, pg.21	An Aboriginal facilitator would be of benefit to the TK/IQ Panel.	Panel meetings should be organized in a way that fits with the Aboriginal way of knowing. This leads to improved communication, interpretation and understanding of the value of participants messages.	Respect	Diavik sees value in having an Aboriginal facilitator involved in the TK/IQ Panel sessions, provided that this approach continues to be supported by Panel members.	Joanne Barnaby has been contracted to co-facilitate TK Panel sessions.
4.2.1	Working Together, 23-25 October 2012, pg.8	Develop a TK/IQ Panel manual that would be regularly revised to reflect the Panel's process, topics and lessons learned over time.	There are few models for this type of organization or work so it is important to document the Panel's mandate, protocols and procedures. This approach should be recorded in an effort to develop best practices and learn from challenges. Panel facilitators would be responsible for updating the document, for review and verification by Panel members.	Recording knowledge Consensus Respect	Diavik supports the development of, and on-going updates to a TK/IQ Panel Manual. Discussions relating to Panel priorities and schedule should also be included in such a document.	Update the "Working Together" manual to reflect the change in administration of the Panel from EMAB to Diavik.
5.6	Closure Reclamation & Landscape History Interim Report, 19-22 February 2013, pg.6	Identify opportunities for Aboriginal participation in closure activities.	The TK/IQ Panel identified landscaping, planting, design and experiments as ideal for Aboriginal participation. Training youth to assist with site activities at closure will be important.	Stewardship Respect Recording knowledge Intergenerational	Diavik expects that the majority of closure activities will be completed by Aboriginal people and companies, and plans to work with communities over the next few years to identify and realize such opportunities.	N/A
5.7	Closure Reclamation & Landscape History Interim Report, 19-22 February 2013, pg.6	Engage the TK/IQ Panel in preparations for Elder programs at the mine site.	Panel members see an opportunity for them to assist with defining discussion topics, seeking input on how to prepare Elders and make full use of the visit and how to respectfully document their observations. The Panel can also advise on proper methods for Elder care during such site visits.	Respect Recording knowledge Reciprocity	Diavik is currently re-evaluating its approach to community engagement with communities. There may also be an opportunity for the TK/IQ Panel to assist with this process.	N/A
5.8	Closure Reclamation & Landscape History Interim Report, 19-22 February 2013, pg.6	Ensure experts are available to TK/IQ Panel members as needed, based on discussion topics.	It is important for Panel members to have access to technical and/or scientific experts for the topics being discussed, so that they can learn as much information as possible and therefore make informed recommendations. Such an approach supports the cross-cultural learning style that the Panel follows and allows for quicker progress.	Reciprocity	Diavik views this approach as beneficial as well, and has supported the Panel with such expertise in the past.	Continue to work with the TK/IQ Panel facilitators to identify the required resources and expertise needed for each Panel session.

DDMI TK Panel Recommendations and Response Tracking - Monitoring & General (including TK/IQ Panel Process)

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
EMAB-1	Environmental Monitoring Advisory Board TK/IQ Panel Recommendations from February 2013, Letter from EMAB, 8 Oct 2013, pg.2	EMAB feels that Diavik is proceeding in the right direction in working towards answers to these and other questions but recommends that DDMI conduct on-site workshops or community consultations or a combination of both. When this work is completed then EMAB will review the results and if necessary we will convene the TK/IQ Panel in order to review the process, methodology, and results.	References DDMI questions posed by DDMI at the February TK/IQ Panel session relating to NCRP shape, reclamation of roads & laydowns, and revegetation.	N/A	October 2013 TK/IQ Panel session was at the mine site. Diavik consults with communities through Closure Working Groups and public meetings held within the communities. In accordance with a letter received on 7 August 2013, EMAB gave Diavik permission to administer the TK Panel.	N/A
7.13	Re-vegetation Report, TK Panel Session #7, 14-18 August 2014	Complete the TK literature review report so that it can be used as a guide in the vegetation program and closure plan, and be available to communities.	As previously suggested by the Panel, there is value is compiling the existing TK that has been captured by community or company research in the past. Much of this information was compiled prior to Session 7, but a report was not completed. The Panel would like to see a complete report.	Recording knowledge	Diavik supports the completion of the literature review report that was initiated for TK Panel Session 7.	Literature review of the TK of plants in the Lac de Gras region was completed in October 2014.
7.17	Re-vegetation Report, TK Panel Session #7, 14-18 August 2014	Have a women's only session in the field next summer to address vegetation and other issues of interest to them.	Some Panel members felt that there would be a benefit to holding a 'womens only' session in the future, as this may create a more acceptable space for sharing the knowledge that is specific to women.	Traditional laws Respect Recording knowledge	Diavik's preferred approach, that has also been supported by Panel members, is to focus on creating an opportunity for women to participate in the TK Panel sessions on a regular basis, rather than holding specific women only sessions for certain topics. There is important knowledge that women have to share on all topics.	Diavik to request a woman participant from each community organization to attend each TK Panel session.
7.18	Re-vegetation Report, TK Panel Session #7, 14-18 August 2014	Diavik must meet its commitments to support a minimum of two TK Panel sessions a year.	Panel members felt that momentum is necessary to keep the Panel engaged and not have to start from scratch every time they meet. Participants recognize the number of topics and discussions that should occur prior to closure, and that this will take time.	Respect Reciprocity	Diavik is committed to the TK Panel and supports meeting on a regular basis. However, the number of meetings per year is not seen to be as important as making sure that we have the right information available to share and that session topics are relevant to the most current closure considerations. For example, during 2015, many TK Panel members were involved in multiple meetings for the AEMP TK Study, making it difficult to arrange a TK Panel session during the summer.	Diavik to provide suggested meeting topics and times for the following year at the last session in the previous year (e.g. plan for 2016 is provided at end of 2015), for discussion by Panel members.
7.19	Re-vegetation Report, TK Panel Session #7, 14-18 August 2014	TK panel members need to verify TK recommendations with elders back home.	Panel members feel that the results of each session are important to be shared with Elders in their respective communities. While Diavik has a role to play in doing this as well, Panel members felt that they also have a responsibility to discuss each session outcome with respected Elders on a more informal basis, and incorporate any feedback they recieve into future Panel sessions.	Traditional laws Respect Recording knowledge	Diavik encourages Panel members to informally share what they learned and recommended with their elders and organizations back home. Any feedback they receive can be shared with the Panel during the recommendations review in the next session.	N/A

DDMI TK Panel Recommendations and Response Tracking - Monitoring & General (including TK/IQ Panel Process)

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
7.20	Re-vegetation Report, TK Panel Session #7, 14-18 August 2014	Require one male and one female member from each community organization on the TK Panel (or formal alternates); where possible, members must know the LDG area (directed to Aboriginal governments).	Panel members recognize the different knowledge that males and females have, and that both types of knowledge must be recognized and incorporated into the TK Panel closure planning process. While there has been much success in keeping Panel members consistent over time (in an effort to build knowledge and familiarity with the mine and its closure plans), past participants have only been males. Incorporating females into the Panel will result in a change in Panel membership in the near future, but the value and depth of knowledge this change would bring is more important to Panel members than maintaining consistency of past membership.	Traditional laws Respect Recording knowledge	Diavik has incorporated this recommendation into the meeting notifications sent to the community organizations that arrange for their member participants. It is ultimately the community organization's decision of who to send, so we encourage TK Panel members to also relay their recommendation in person to their community's staff.	Diavik to include this request in future correspondence with community organizations that arrange meeting participants.
7.21	Re-vegetation Report, TK Panel Session #7, 14-18 August 2014	Formalize our recommendations to Aboriginal governments to have youth participate.	All participants recognize the important role that youth play as future custodians of the land. Because of this, it is important that they are included in the closure planning process now, so that they are educated, aware and able to contribute to decisions made that will impact future generations.	Intergenerational Social Stewardship	Diavik has incorporated this recommendation into the meeting notifications sent to the community organizations that arrange for their member participants. It is ultimately the community organization's decision of who to send, so we encourage TK Panel members to also relay their recommendation in person to their community's staff.	Diavik to include this request in future correspondence with community organizations that arrange meeting participants.
7.22	Re-vegetation Report, TK Panel Session #7, 14-18 August 2014	Celebrate our TK Panel as a model for other mining companies.	Panel members are happy with the work they are doing. They recognize how unique the Panel is, and the opportunity it provides to contribute to future planning. Seeing the importance of learning from what works, it is felt that the process and results the Panel has developed should be shared with others.	Stewardship Respect Recording knowledge Intergenerational Reciprocity	The results of the Panel's sessions are shared widely within the NWT. Panel session reports are provided as part of DDMI's annual closure updates to the WLWB, and this is shared more broadly with all reviewers on the WLWB distribution list. The process and results that you have produced to date are being noticed and celebrated.	N/A
8.29	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Explore long term monitoring options including how to coordinate and administer an ongoing post-2030 program that continues to integrate TK and science and involves both Elders and youth trained in science. (Consider funding, and if some of the bond can be used) .	TK Panel members are very interested in continuing to monitor the land and water in the Lac de Gras area after the mine is closed. Panel members are interested in exploring options for doing such work and determining how best to organize and fund such an initiative. There is a strong interest from the Elders to make sure that the youth of today are the future monitors for this work, which requires early involvement as well as capacity building in scientific and TK environmental monitoring.	Stewardship Intergenerational	While communities may be interested in monitoring past 2030, Diavik needs to plan for ultimate closure and relinquish ownership of the property back to the government. Once this is complete, monitoring would no longer be conducted or organized by Diavik. As such, any long-term monitoring plans past 2030 would need to be funded and coordinated by other parties. DDMI suggests that this recommendation is better directed to community organizations and/or governments.	N/A
8.31	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Continue to provide the TK Panel with teaching and communication 'tools' (i.e. videos, books, photos), to share progress and findings on closure planning with communities.	Panel members felt that information and materials that they can have and use to communicate with other Elders and people in their home communities are helpful to show the progress and importance of the work they are doing and knowledge they are sharing. Items like the AEMP TK Study videos and copies of reports are good.	Respect Reciprocity Social	Diavik continues to provide the Panel and their associated community organizations with reports, videos, maps, pictures or other materials that assist in sharing the work and success of the Panel. Further guidance as to what is helpful and effective for Panel members to use in communicating with others would be appreciated.	N/A

DDMI TK Panel Recommendations and Response Tracking - Monitoring & General (including TK/IQ Panel Process)

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
8.32	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Plan for climate change hundreds of years into the future.	There is concern that climate change will affect performance of some mine infrastructure and inadvertently impact the environment, for example by release of contaminated water. As such, Panel members want to make sure that climate change scenarios are considered in closure design and planning work in order to protect the environment long into the future.	Stewardship Social	Accepted climate change scenarios have been incorporated in to the planning models that guide design and construction decisions for site infrastructure. This includes planning for long-term performance after closure.	N/A
8.33	Reefs & Monitoring Water Report, TK Panel Session #8, 2-4 December 2015	Re-seed land and use dirt and *safe* sewage to facilitate re-growth.	As discussed in Session 7 on Revegetation, Panel members are interested in re-seeding the land around the mine to help plants grow back, but it should only be northern species that are used. A change from Session 7 is that Panel members are open to the idea of using human sewage from the on-site treatment plant as fertlizer, provided that Diavik can demonstrate that it is safe to do so (for animal and human health).	Stewardship Social Safety	Treated sewage is currently stored on site, with plans to use it as a soil amendment to aid in reclamation activities. Diavik is working to determine if the treated sewage is considered safe from an animal and human health perspective.	Test the treated sewage to determine if it is safe to use as a soil amendment (fertilizer) and communicate results back to the Panel.
9.9	Focus on Caribou, TK Panel Session #9, 13-16 May 2016	Contribute to training community monitors in using both traditional knowledge and western science so that common approaches across communities are used and results can be pulled together from many places.	The Panel felt that it is important to support capacity building for community members to actively participate in the closure process, particularly closure monitoring. They recognize that strength in monitoring can be achieved when western science (WS) and TK are conducted together. There is also value to ensuring that the similar techniques and methods are used across industry and communities so that this information is comparable.	Stewardship Intergenerational Social	Diavik provides site-based training to new hires and contributes to formal training programs through the Mine Training Society and support for the Aurora College BEAHR environmental monitor training program, as well as the College's Environmental Monitor Certification program. If it is necessary to revise or expand existing training programs to meet the needs of closure monitoring, Diavik suggests that this is best coordinated through these professional training institutes. DDMI also provides scholarship funding to community members through their PA's. Diavik suggests that the communities themselves are best suited to provide training in monitoring using Traditional Knowledge.	N/A
9.11	Focus on Caribou, TK Panel Session #9, 13-16 May 2016	Recognizing that Aboriginal communities are committed to their traditional responsibility to take care of the environment, participate with Diavik and other partners (e.g. Dominion Diamonds) to explore ideas and develop capacity to establish a Cumulative Effects Monitoring and Management Station (CEMMS) using the TK camp as a base that has program links to the GNWT Daring Lake Research Station.	The Panel viewed the TK camp as an ideal base for studying the Lac de Gras area after the mine was closed. The GNWT's Daring Lake Research Station is also in a good position to further support such research and the Panel saw value in coordinating efforts with the Government's programs at Daring Lake. In order to achieve this, the Panel identified the need for mines, government and other regulators to work together to determine how best to coordinate and implement a CEMMS (or similarly structured) program.	Stewardship Intergenerational Social	Diavik intends to continue its scientific monitoring programs through the closure phase. Diavik also encourages the Panel to develop a TK Monitoring Program for the Diavik site. While there are no formal plans for how or who would coordinate regional monitoring in the future, or where to base such monitoring initiatives, Diavik expects that any such regional program would build upon the existing site-specific programs to ensure that similar information is collected to evaluate trends over time.	Diavik to conduct site-specific WS and TK monitoring programs through the closure phase and work with communities, regulators and industry to determine a suitable regional approach for long-term, post-closure monitoring.

DDMI TK Panel Recommendations and Response Tracking - Monitoring & General (including TK/IQ Panel Process)

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
9.12	Focus on Caribou, TK Panel Session #9, 13-16 May 2016	In partnership with communities and the GNWT, begin planning a joint TK and WS monitoring program that would begin in 2023 to be ready for implementation in 2025 by building on and expanding the current Diavik monitoring program.	Panel members consider intergenerational plans and programs, recognizing that there is a need for long-term monitoring in the Lac de Gras region long after the mining companies are gone. Given that it can take time to coordinate these types of programs, the Panel sees value in starting these discussions now so that plans are in place for when the Diavik mine is closed.	Stewardship Intergenerational Social	Diavik intends to continue its scientific monitoring programs through the closure phase. Diavik also encourages the Panel to develop a TK Monitoring Program for the Diavik site. While there are no formal plans for how or who would coordinate regional monitoring in the future, Diavik expects that any such regional program would build upon the existing site-specific programs to ensure that similar information is collected to evaluate trends over time.	Diavik to conduct site-specific WS and TK monitoring programs through the closure phase and work with communities, regulators and industry to determine a suitable regional approach for long-term, post-closure monitoring.
9.13	Focus on Caribou, TK Panel Session #9, 13-16 May 2016	Offer monitor training to provide traditional land users with new skills and techniques to monitor from mine closure through to when Diavik completely leaves the site (expected to be 2030) and beyond for long term monitoring.	The Panel felt that it is important to support capacity building for community members to actively participate in the closure process, particularly closure monitoring. They recognize that strength in monitoring can be achieved when western science (WS) and TK are conducted together.	Stewardship Intergenerational Social	Diavik provides site-based training to new hires and contributes to formal training programs through the Mine Training Society and support for the Aurora College BEAHR environmental monitor training program, as well as the College's Environmental Monitor Certification program. If it is necessary to revise or expand existing training programs to meet the needs of closure monitoring, Diavik suggests that this is best coordinated through these professional training institutes. DDMI also provides scholarship funding to community members through their PA's.	N/A
9.15	Focus on Caribou, TK Panel Session #9, 13-16 May 2016	Design monitoring training with the objective of understanding what is happening in the eco-system with cumulative effects.	Communities are most concerned about cumulative impacts to the Lac de Gras region. For this reason, monitoring should focus on cumulative effects.	Stewardship Intergenerational Social	Existing scientific monitoring training programs focus on techniques that evaluate the state of the environment and contribute to understanding cumulative effects through the analysis of the data collected.	N/A
9.16	Focus on Caribou, TK Panel Session #9, 13-16 May 2016	Employ community monitor trainees and ensure they have a meaningful role in the design of various aspects of closure work, including the building of wildlife ramps; the reclamation of the PKC, the North Inlet and contaminated sites; and any re-vegetation work on site.	It is important to the Panel to have community members employed on site and participating in healing the land and ensuring a safe environment for future use by wildlife and humans.	Stewardship Intergenerational Social	Diavik has and will continue to focus on employing people from the PA communities at the mine site. This includes the closure work identified by the Panel. We also see value in incorporating community members in inspecting and evaluating reclamation work in relation to the objectives and plans for each area, whether this be the TK Panel or other community representatives and we are hopeful this will form a part of the site-specific TK monitoring plan.	Diavik to continue to focus on employing PA community members, particularly to assist with closure work.
9.17	Focus on Caribou, TK Panel Session #9, 13-16 May 2016	Employ and ensure opportunities for high level employment/career advancement of trained community monitors (graduates of the training program) funded by Diavik and/or others. In addition to community members, a minimum of one Elder and one youth from each community should participate in the training program.	It is important that community members have meaningful jobs at the mine, throughout the closure process.	Stewardship Intergenerational Social	Diavik has and will continue to focus on employing people from the PA communities at the mine site. This includes closure monitoring identified by the Panel. We also see value in incorporating community members in inspecting and evaluating reclamation work in relation to the objectives and plans for each area, whether this be the TK Panel or other community representatives and we are hopeful this will form a part of the site-specific TK monitoring plan.	Diavik to continue to focus on employing PA community members, particularly to assist with closure monitoring.

DDMI TK Panel Recommendations and Response Tracking - Monitoring & General (including TK/IQ Panel Process)

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
9.21	Focus on Caribou, TK Panel Session #9, 13-16 May 2016	Support the focus of long term monitoring goals for cumulative effects (CEMMS) on natural re-vegetation, return of caribou and other wildlife, and water quality in the Lac de Gras area.	The Panel is hopeful that Diavik recognizes the importance of contributing to long-term, regional monitoring that will continue after the mine is closed.	Stewardship Intergenerational Social	Diavik intends to continue its scientific monitoring programs through the closure phase. Diavik also encourages the Panel to develop a TK Monitoring Program for the Diavik site. While there are no formal plans for how or who would coordinate regional monitoring in the future, Diavik expects that any such regional program would build upon the existing site-specific programs to ensure that similar information is collected to evaluate trends over time.	Diavik to conduct site-specific WS and TK monitoring programs through the closure phase and work with communities, regulators and industry to determine a suitable regional approach for long-term, post-closure monitoring.
10.11	Watching/Monitoring and the WRSA-SCRP, Session #10, 14-18 September 2017	Some start-up watching projects might look at: - what plants are growing on disturbed ground and why/why not; - presence of grounds squirrels on the East Island; - health of the shorebirds on the water (as an indicators for health of water); - snow accumulation and natural revegetation around boulders atop the test pile; - watch and monitor dust impacts on water and plants as an important part of the food chain; - animal scat, this should be part of a TK Watching program; - look at possible impacts on plants, with special consideration for those used for medicine.	The TK Panel is interested in starting to identify the types of things that are of interest to elders and youth to monitor. They recognize that more time and discussion is needed to build on these ideas and confirm what and how to watch the area, but that it is but that it is important to start documenting what has been shared to date.	Stewardship Intergenerational Recording Knowledge	Diavik is interested in further discussions for TK/community-based monitoring programs that can support or enhance other (western) scientific monitoring programs that will be conducted at the site.	Plan for another TK Panel session to focus on closure and post- closure monitoring at the Diavik site.
10.12	Watching/Monitoring and the WRSA-SCRP, Session #10, 14-18 September 2017	Pair every adult with a youth monitor. Scientists should also be involved. Consider the TK camp as a good model, bringing elders and youth together with scientists.	The TK Panel members see great value in mentoring youth and advocate for including youth in TK prorams wherever possible. The TK Panel recoginzes that people learn from one another and respect the different kinds of knowledge that each person contributes. They view this as a good model to carry forward for closure monitoring.	Stewardship Intergenerational Recording Knowledge Respect	Recognizing that there are still many details to work out in relation to closure planning and monitoring, Diavik is generally supportive of an approach that involves Elders, youth and scientists working together.	Plan for another TK Panel session to focus on closure and post- closure monitoring at the Diavik site.
10.13	Watching/Monitoring and the WRSA-SCRP, Session #10, 14-18 September 2017	Ideally, watching would occur all year round. At a minimum, watching must occur in all seasons.	The land and animals behave differently depending on the season. There are important indicators to watch throughout the seasons and year to make sure that the land and animals are healthy. Panel members are interested in watching programs that would occur across all seasons.	Stewardship Intergenerational Recording Knowledge Seasonality	Recognizing that there are still many details to work out in relation to closure planning and monitoring, Diavik is generally supportive of this approach.	Plan for another TK Panel session to focus on closure and post- closure monitoring at the Diavik site.
10.14	Watching/Monitoring and the WRSA-SCRP, Session #10, 14-18 September 2017	Watchers should be trained by trained monitors from existing guardianship programs (e.g. Ni Hat'ni Dene, Tlicho, Dehcho). From there, trained watchers will train new watchers through a pay-it-forward model.	Existing guardianship programs are celebrated as good models from which to learn. The next step will be to determine how best to apply their practices, resources, and support systems. Collaboration and sharing are keys to success.	Stewardship Intergenerational Recording Knowledge Respect	Diavik's understanding of existing Guardianship programs is that they are largely organized and operated by community organizations. It is important to continue discussing this model to determine what role Diavik and others may play in such an approach; e.g. funding agreement for Guardianship program, in-kind donations, program coordination, etc.	Plan for another TK Panel session to focus on closure and post- closure monitoring at the Diavik site.

DDMI TK Panel Recommendations and Response Tracking - Monitoring & General (including TK/IQ Panel Process)

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
10.15	Watching/Monitoring and the WRSA-SCRP, Session #10, 14-18 September 2017	Be designed for long term watching/monitoring as impacts may take a long time to show up (i.e. a plant may look healthy now but in the future it may not be strong if dust or contaminated water affect it).	Community members understand that nature has great power to heal, but that this can take a long time. The TK Panel wants to be sure that there are plans in place for long term watching and monitoring so that they can be confident that closure was successful and the land is healthy again.	Stewardship Intergenerational Recording Knowledge	Recognizing that there are still many details to work out in relation to closure planning and monitoring, Diavik is generally supportive of this approach and is interested in continuing discussions with communities and regulators to determine a suitable approach for this type of work.	Plan for another TK Panel session to focus on closure and post- closure monitoring at the Diavik site.
10.16	Watching/Monitoring and the WRSA-SCRP, Session #10, 14-18 September 2017	Watch and check everything (water, wildlife, birds, bugs, small mammals, plants, weather, etc.).	The TK Panel is interested in starting to identify the types of things that are of interest to elders and youth to monitor. They recognize that more time and discussion is needed to build on these ideas and confirm what and how to watch the area, but that it is but that it is important to start documenting what has been shared to date.	Stewardship Intergenerational Recording Knowledge	Diavik is interested in further discussions for TK monitoring programs that can support or enhance other (western) scientific monitoring programs that will be conducted at the site.	Plan for another TK Panel session to focus on closure and post- closure monitoring at the Diavik site.
10.17	Watching/Monitoring and the WRSA-SCRP, Session #10, 14-18 September 2017	Ensure long-term, ongoing and significant funding.	Funding and resources are important to secure when planning for long-term watching programs. The Panel recognizes that more discussions are required to determine how best to secure and maintain funding for this type of work.	Stewardship Intergenerational Recording Knowledge	Recognizing that there are still many details to work out in relation to closure planning and monitoring, Diavik is generally supportive of this approach and is interested in continuing discussions with communities and regulators to determine a suitable framework to support this type of work.	Plan for another TK Panel session to focus on closure and post- closure monitoring at the Diavik site.
10.18	Watching/Monitoring and the WRSA-SCRP, Session #10, 14-18 September 2017	Be grounded in strong communication and traditional laws around sharing, exchanging and stories.	Collaboration and sharing are the keys to success. Watching programs should be structured to include opportunities for sharing the rich stories that tell the history of the land and enrich monitoring outcomes. Scenarios that encourage sharing should be strongly supported.	Traditional laws Respect Recording knowledge	Recognizing that there are still many details to work out in relation to closure planning and monitoring, Diavik is generally supportive of this approach and is interested in continuing discussions with communities and regulators to determine a suitable framework for this type of work.	Plan for another TK Panel session to focus on closure and post- closure monitoring at the Diavik site.
10.19	Watching/Monitoring and the WRSA-SCRP, Session #10, 14-18 September 2017	Start training for watching programs during mine operations by inviting community members to site, i.e. train-the-trainer program. For example, bring up people to work with Environment dept, starting with one weekend a month and scaling up over time	The Panel recognizes the benefit of training monitors now in order to carry forward those skills for closure and post- closure monitoring at Diavik and other sites. The Panel is supportive of community monitors that are able to work in both worlds of knowledge - traditional and western scientific.	Stewardship Intergenerational Recording Knowledge	Diavik currently invites and involves community members in some of their on-site monitoring however, it is largely program-specific. Additionally, we have had community members as employees throughout operations. Diavik will evaluate options for community assistants on some weekends. We also continue to support and encourage participation in the BEAHRS Environmental Monitoring program and the Environment and Natural Resources Technology Program offered through Aurora College.	Evaluate options for some weekend community assistants.
10.20	Watching/Monitoring and the WRSA-SCRP, Session #10, 14-18 September 2017	Diavik should support and encourage the TK Panel to assess and review existing monitoring methods and results to help us determine what and how we should monitor in the future	The Panel focuses on closure planning and monitoring, but they are also interested in Diavik's operational monitoring and would like to learn more about monitoring programs, methods and results in order to determine if they are suitable for closure monitoring and, if so, how best to apply these to closure.	Stewardship	Diavik supports the TK Panel in this work. We have previously engaged the Facilitators for the TK Panel to compile some examples of TK and other monitoring to assist the Panel in developing ideas for monitoring at Diavik. We have also dedicated some of the past TK Panel sessions to monitoring and continue to plan for future sessions on this as well.	Provide a presentation on Diavik's operational monitoring programs to the Panel at a future session.

DDMI TK Panel Recommendations and Response Tracking - Monitoring & General (including TK/IQ Panel Process)

NUMBER	REFERENCE	RECOMMENDATION	CONTEXT	TK VALUE/CONCEPT	DDMI RESPONSE	DDMI ACTION ITEMS
10.21	Watching/Monitoring and the WRSA-SCRP, Session #10, 14-18 September 2017	Encouraging all of the communities working together and supporting each other long into the future will give us strength. Diavik has helped us do this and we must continue into the future.	The collaborative approach that the TK Panel has developed has been effective for all parties to learn and understand everyone's interests, views, ideas and limitations in relation to Traditional Knowledge, the mine and planning for the future.	Stewardship	Diavik views this as a recommendation to the TK Panel members and community organizations. We are pleased that the Panel recognizes the efforts we have undertaken to encourage collaborative work.	N/A
10.22	Watching/Monitoring and the WRSA-SCRP, Session #10, 14-18 September 2017	Diavik should plan to leave some buildings (and possibly the airstrip) to support Watching Programs for this and other mines in the surrounding area.	In order to conduct a watching program in the mine area long after closure, it would be helpful to have some buildings present that could be used for accommodation and monitoring activities. Communities will be interested in visiting and observing the area long after the mines are gone.	Stewardship Safety Reciprocity Intergenerational	Diavik is aware of the Panel's interest in having some buildings or infrastructure remain. Options for this will continue to be discussed with communities and regulators. Liability concerns and maintenance requirements may preclude some areas/buildings from being left but we understand that this is important in the North.	Determine possibility of leaving some infrastructure at site post- closure.
10.23	Watching/Monitoring and the WRSA-SCRP, Session #10, 14-18 September 2017	Diavik should support the development of a 'best practices' document that explains the Panel's approach to integrating TK into mine closure planning.	The TK Panel is proud of their cooperative efforts to ensure that TK informs mine closure planning in a meaningful and transparent way. The TK Panel is interested in summarizing and sharing their knowledge and approach with others, in hopes that others considering projects in the north of elsewhere can benefit either now or in the future.	Stewardship Intergenerational Recording Knowledge	Diavik is generally supportive of this idea, though we also think that the Panel's presentations and reports do a good job of summarizing the process and principles that underly the Panel's recommendations and guidance. Something like this may be more valuable further in the future, once closure plans advance and more is learned about how to practically apply these reccommendations and guidance.	N/A

ENVIRONMENTAL AGREEMENT

This Agreement made as of the 8th day of March, 2000.

BETWEEN:

HER MAJESTY THE QUEEN IN RIGHT OF CANADA
as represented by the
Minister of Indian Affairs and Northern Development

(hereinafter referred to as "Canada")

AND

THE GOVERNMENT OF THE NORTHWEST TERRITORIES
as represented by the
Minister of Resources, Wildlife and Economic Development

(hereinafter referred to as the "GNWT")

AND

DIAVIK DIAMOND MINES INC.

(hereinafter referred to as "DDMI")

AND

DOGRIB TREATY 11 COUNCIL

AND

LUTSEL K'E DENE BAND

AND

YELLOWKNIVES DENE FIRST NATION

AND

NORTH SLAVE MÉTIS ALLIANCE

AND

KITIKMEOT INUIT ASSOCIATION

RECITALS

A. WHEREAS DDMI as manager of an unincorporated Joint Venture with Aber Diamond Mines Ltd.("Aber") proposes to establish the Project to be located at the East Island in Lac de Gras, Northwest Territories for the production of rough diamonds;

B. AND WHEREAS the Responsible Authorities conducted a comprehensive study of the Project pursuant to the *Canadian Environmental Assessment Act* and issued the Comprehensive Study Report wherein the Responsible Authorities concluded that, taking into account the implementation of appropriate mitigation measures, the Project is not likely to cause significant adverse environmental effects;

C. AND WHEREAS the Minister of the Environment and the Responsible Authorities have determined that the Project, taking into account the implementation of appropriate mitigation measures, is not likely to cause significant adverse environmental effects;

D. AND WHEREAS the CSR includes a requirement for the Minister, as the lead Responsible Authority, to develop an environmental agreement to provide a formal mechanism to ensure that the mitigation measures outlined in DDMI's Commitments, in addition to the mitigation measures and follow-up requirements which will be specified as terms and conditions by Regulatory Instruments, are appropriately implemented and monitored;

E. AND WHEREAS the air, land, water, aquatic resources, and wildlife are essential to the lives and well-being of the Aboriginal Peoples;

F. AND WHEREAS DDMI proposes to conduct adaptive environmental management to minimize the environmental impact of the Project;

G. AND WHEREAS DDMI and the Aboriginal Peoples have entered into or are in the process of negotiating and settling Participation Agreements in connection with the Project;

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H. AND WHEREAS, DDMI and the GNWT have entered into a Socio-economic Monitoring Agreement which is intended to meet the requirement of the CSR and provides for the involvement of Aboriginal Peoples.

NOW THEREFORE, in consideration of the premises and the covenants herein contained and other good and valuable consideration, the receipt and sufficiency of which is hereby acknowledged by the Parties hereto, the Parties covenant and agree as follows:

ARTICLE I

STATEMENT OF PURPOSE AND GUIDING PRINCIPLES

1.1 PURPOSE

This Agreement is intended to be a legally binding agreement for the achievement of the following purposes:

(a) To ensure that the mitigation measures outlined in DDMI's Commitments and in the Responsible Authorities' conclusions as documented in the CSR are appropriately implemented;

(b) To provide for additional monitoring which, in conjunction with the monitoring requirements of Regulatory Instruments, will serve to verify the accuracy of the environmental assessment of the Project and the effectiveness of mitigation measures, and whether Commitments are being fulfilled;

(c) To facilitate the use of holistic and ecosystem-based approaches for the monitoring, management and regulation of the Project;

(d) To respect and protect air, land, water, aquatic resources, wildlife, archaeological and cultural resources, and the land-based economy that are essential to the way of life and well-being of the Aboriginal Peoples;

(e) To create opportunities for community and public input and participation;

(f) To provide advice and direction to DDMI in order to assist DDMI in managing the Project consistent with these purposes;

(g) To maximize the effectiveness and co-ordination of environmental monitoring and regulation of the Project; and

(h) To facilitate effective communication about the Project with Affected Communities and effective participation of the Aboriginal Peoples and the general public in the achievement of the above purposes.

1.2 GUIDING PRINCIPLES

The Parties agree to carry out their responsibilities under this Agreement and the Regulatory Instruments consistently with the purposes in Article 1.1 and guided by the following principles:

(a) Adaptive environmental management;

(b) Sustainable development;

(c) Design and implementation of Environmental Protection Measures to minimize adverse effects on Environmental Quality to the extent technically and economically feasible;

(d) Precautionary Principle;

(e) Promotion of capacity-building for the Aboriginal Peoples respecting Project-related environmental matters;

(f) Recognition of the particular environmental values of the Lac de Gras region;

(g) Full consideration and use of both traditional knowledge and other scientific information where appropriate; and

(h) Promotion of a co-operative approach among the Parties respecting Project-related environmental matters.

ARTICLE II

NO PREJUDICE

2.1 NO PREJUDICE

This Agreement is without prejudice to the positions of the Parties respecting any:

(a) existing Aboriginal or treaty rights of the Aboriginal Peoples;

(b) on-going or future land claims or self-government negotiations affecting Aboriginal Peoples;

(c) constitutional changes which may occur in the Northwest Territories;

(d) changes to legislation or regulations resulting from the settlement of land claims and self-government negotiations, or resulting from constitutional changes or devolution; or

(e) existing or future Participation Agreements.

2.2 TRANSITIONAL

In the event that jurisdiction or regulatory authority relating to the Project or any aspect of the Project, is transferred or devolved as a result of constitutional change, treaty, self-government or land claim agreement, or otherwise, the Parties shall negotiate, in good faith, to amend this Agreement to reflect such transfer or devolution, while maintaining the purposes and principles of this Agreement.

ARTICLE III

INTERPRETATION

3.1 DEFINITIONS

In this Agreement, unless the context otherwise indicates, the following terms shall have the meanings ascribed to them below:

"Aboriginal Peoples" means the Dogrib Treaty 11 Council, the Lutsel K'e Dene Band, the Yellowknives Dene First Nation, the North Slave Métis Alliance and the Kitikmeot Inuit Association.

"Affected Communities" means the communities identified in the CSR which are affected in relation to the subject matter within which they are referenced in the CSR.

"Annual Report" has the meaning attributed thereto in Article 12.1.

"Arbitrator(s)" means the arbitrator or arbitrators selected pursuant to Article 16.3 in respect of any particular dispute.

"Archaeological Site" means a site or work of archaeological, ethnological or historical importance, interest, or significance or a place where an archaeological specimen is found and includes explorers' cairns.

"Commercial Production" means production at the rate of 80% of design capacity for the Project processing plant for 30 consecutive days.

"Commitment" means:

(a) any commitment to a mitigation measure or a follow-up program made by DDMI, whether

  (i) given to a Responsible Authority in the course of seeking or securing any recommendation or decision under the *Canadian Environmental Assessment Act* with respect to the Project, or

  (ii) given to the governmental agency responsible for issuing any Regulatory Instrument, in the course of seeking or securing the issuance of the Regulatory Instrument,

 provided that

  (iii) where the commitment as originally given by DDMI was modified by DDMI and where the modification was accepted by the Responsible Authority (in the case of a commitment referred to in paragraph (a)(i) of this definition) or the responsible governmental authority (in the case of a commitment referred to in paragraph (a)(ii) of this definition) in the recommendation, decision or Regulatory Instrument, or prior to the making or issuance thereof, "Commitment" means the commitment as so modified, and

  (iv) where the commitment as originally given by DDMI is departed from in order to comply with the requirements of the principle of adaptive environmental management, "Commitment" means the commitment modified to comply with those requirements; and

(b) any obligation imposed upon DDMI by or pursuant to the terms of any such recommendation, decision, or Regulatory Instrument.

"Consult" or **"Consultation"** shall mean, at a minimum:

(a) the provision, to the party to be consulted, of notice of a matter to be decided in sufficient form and detail to allow that party to prepare its views on the matter;

(b) the provision of a reasonable period of time in which the party to be consulted may prepare its views on the matter, and provision of an opportunity to present such views to the party obliged to consult; and

(c) full and fair consideration by the party obliged to consult of any views presented.

"CSR" means the report entitled "Comprehensive Study Report - Diavik Diamonds Project" dated June 1999 and includes the Responsible Authorities' Response to Public Comments dated September 1999.

"$" means Canadian dollars.

"Effective Date" has the meaning assigned to it in Article 18.1 (a).

"Environment" means the components of the Earth, and includes:

(a) land, water, and air, including all layers of the atmosphere,
(b) all organic and inorganic matter and living organisms, and
(c) the interacting natural systems that include components referred to in paragraphs (a) and (b)

"Environmental Management Plans" has the meaning attributed thereto in Article VI.

"Environmental Monitoring Advisory Board" means the Advisory Board referred to in Article IV.

"Environmental Monitoring Programs" has the meaning attributed thereto in Article VII.

"Environmental Plans and Programs" means the Environmental Management Plans, Environmental Monitoring Programs, the Reclamation and Abandonment Plan and any other environmental management plans or environmental monitoring programs carried out or conducted in connection with the Project.

"Environmental Protection Measures" means all measures taken to effect Environmental Quality, including but not limited to, assessment and prediction of impacts, monitoring, measures to avoid or mitigate impacts, setting of limits for environmental degradation, and measures for construction, operations, closure, reclamation and abandonment of the Project.

"Environmental Quality" means the state of the environment at any time as compared to natural, unaltered characteristics of the area with respect to biological diversity and ecosystem structures and processes. Environmental Quality is maximized when measured indicators show that ecological processes are functioning naturally, ecosystem structure and reproductive capacity of animal and plant populations is unimpaired, and human interference has negligible impacts.

"Joint Venture" means the unincorporated joint venture established by the parties to the Joint Venture Agreement.

"Joint Venture Agreement" means the agreement between DDMI and Aber.

"Land Leases" means the following leases under the *Territorial Lands Act*: 76D/8-5-2 (Water Lot B A154/418), 76D/8-6-2 (Quarry/PKC/North Inlet), 76D/8-7-2 (Infrastructure), 76D/9-5-2 (Airstrip), and 76D/9-9-2 (Water Lot E A21), which as of the date of this Agreement, have not yet been fully executed; and includes any renewal, amendment or replacement thereof.

"Minister" means the Minister of Indian Affairs and Northern Development.

"Minister's Report" means a report that may be provided by the Minister to DDMI in the event that any Annual Report, Environmental Management Plan, or Environmental Monitoring Program provided to the Minister by DDMI is determined by the Minister to be deficient.

"Notice of Default" means a notice which may be issued by the Minister upon the occurrence of any non-compliance by DDMI with any provisions of this Agreement describing the specific default or defaults including a requirement to rectify such default or defaults.

"NWT" means the Northwest Territories.

"Nunavut" means the Territory of Nunavut.

"Participation Agreements" means those participation agreements, also known as impact benefit agreements or other similar agreements, entered into between DDMI and the Aboriginal Peoples with respect to the Project and as same may be supplemented, revised, restated or replaced from time to time during the term of this Agreement.

"Parties" means those parties listed on the face page and second page of this Agreement who actually sign this Agreement in accordance with the provisions of Article 18, and "Party" shall mean any one of them.

"Precautionary Principle" means, where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing reasonable measures to prevent environmental degradation.

"Project" means the Project described in the Project Description Submission submitted by DDMI in March 1998 for the purpose of providing the Responsible Authorities with sufficient information to initiate the Federal Environmental Assessment Process, with such refinements or alterations as have been submitted since the Project Description Submission and considered in the CSR or which are required by Responsible Authorities or regulatory authorities.

"Reclamation and Abandonment Plan(s)" has the meaning attributed thereto in Article X.

"Regulatory Instrument(s)" means any authorization, licence, lease, or permit required under any legislation required for the carrying out of the Project and includes without limitation, the Water Licence, the Fisheries Authorization(s) issued under s.35 of the *Fisheries Act*, the Land Use Permits, the Land Leases, the Explosives Factory Licences, and the Navigable Waters Permits.

"Responsible Authorities" means those departments identified as such in the CSR.

"Socio-economic Monitoring Agreement" means the agreement made the 2nd day of October, 1999 between the GNWT and DDMI pursuant to the requirements of the CSR.

"Water Licence" means the Type A Water Licence #N7L2-1645 for which original application was made by DDMI on March 4, 1998, revised September 10, 1999, and which as of the date of this Agreement, has not yet been issued by the Northwest Territories Water Board pursuant to the *Northwest Territories Waters Act* and *Northwest Territories Waters Regulations* and includes any renewal, amendment or replacement under that or any successor or other applicable legislation.

3.2 EXTENDED MEANINGS

Words importing the singular number include the plural and vice versa; words importing gender include the masculine, feminine and neuter genders; words importing persons include firms and corporations.

3.3 TIME OF ESSENCE

Time shall be of the essence in all respects of this Agreement.

3.4 BUSINESS DAY

Whenever a payment to be made or action to be taken under this Agreement is required to be made or taken on a day which is a Saturday, Sunday or statutory holiday in the NWT, then such payment shall be made or action taken on the next succeeding day that is not a Saturday, Sunday or statutory holiday in the NWT.

3.5 REFERENCES

References to an article, section, subsection, paragraph or schedule shall be construed as references to an article, section, subsection, paragraph or schedule to this Agreement unless the context otherwise requires and all references to this Agreement mean this Environmental Agreement dated as of March 8, 2000.

3.6 HEADINGS

The division of this Agreement into articles and subsections and the insertion of headings are for convenience of reference only and shall not alter the construction or interpretation of this Agreement.

3.7 LEGISLATION

A reference to any statute shall be construed as including any regulations promulgated thereunder, any amendments thereto, and any successor legislation.

ARTICLE IV

ENVIRONMENTAL MONITORING ADVISORY BOARD

4.1 ENVIRONMENTAL MONITORING ADVISORY BOARD

(a) The Environmental Monitoring Advisory Board (the "Advisory Board") for the Project shall be established as a non-profit organization under the *Societies Act*, R.S.N.W.T 1988, c. S-11. Canada shall arrange to have the Advisory Board established within sixty (60) days of the coming into effect of Article IV.

(b) The costs incurred by Canada in establishing the Advisory Board shall be credited against Canada's contribution to the first year's budget under Article 4.8(d).

4.2 MANDATE OF THE ADVISORY BOARD

The Advisory Board shall operate at arm's length and independent from the Parties, and shall perform its functions consistently with the purposes and guiding principles in Article I. The mandate of the Advisory Board shall be, in respect of the Project, to:

(a) provide an integrated approach to achieving the purposes in Article I;

(b) assist the Parties to implement a co-operative approach to achieving the purposes and implementing the guiding principles in Article I;

(c) serve as a public watchdog of the regulatory process and the implementation of this Agreement;

(d) review Environmental Plans and Programs, Annual Reports, Environmental Protection Measures, compliance or monitoring reports and other reports and data bearing on Environmental Quality that are produced by any of the Parties or regulatory authorities pursuant to this Agreement, Regulatory Instruments and laws of general application;

(e) in respect of a matter reviewed pursuant to (d), make recommendations for the achievement of the purposes and guiding principles in Article I, to DDMI, the Minister and any other Party or body having regulatory or management responsibility for the matter;

(f) make recommendations on issues relating to access for purposes of wildlife harvesting;

(g) make recommendations respecting the participation of each of the Aboriginal Peoples and Affected Communities in training initiatives and monitoring programs bearing on Environmental Quality;

NOT IMPLEMENTATION

(h) make recommendations concerning the need for and design of traditional knowledge and other studies, and, where appropriate, facilitate the management and implementation of these studies;

NO RESEARCH FUNDING

(i) facilitate programs to provide information to Affected Communities and the general public on matters bearing on Environmental Quality;

(j) report to the Parties and the public on the Advisory Board's activities and the achievement of its mandate;

(k) provide an accessible and public repository of environmental data, studies and reports relevant to the Advisory Board's mandate;

(l) participate as an intervenor, as appropriate for the achievement of its mandate, in regulatory processes, the dispute resolution process under this Agreement and other legal processes; and

(m) provide a meaningful role for each of the Aboriginal Peoples in the review and implementation of environmental monitoring plans in respect of the Project.

4.3 The Minister, DDMI, or any other Party, shall within sixty (60) days of receipt of any written recommendation of the Advisory Board directed to it, give full and serious consideration to the written recommendation; and either:

(a) accept for implementation a written recommendation of the Advisory Board that is determined by the recipient to be appropriate and report to the Advisory Board to that effect; or

(b) provide the Advisory Board with written reasons where it has been determined by the recipient that the recommendation is not appropriate and will not be implemented.

4.4 The Minister shall encourage any regulatory authority to which a written recommendation is provided by the Advisory Board to comply with the requirements in Article 4.3.

4.5 COMPOSITION OF THE ADVISORY BOARD

(a) Subject to Article 4.6 (a), the Parties may appoint their respective members to the Advisory Board as follows:

Dogrib Treaty 11 Council	1 representative
Yellowknives Dene First Nation	1 representative
Lutsel K'e Dene Band	1 representative
Kitikmeot Inuit Association	1 representative
North Slave Métis Alliance	1 representative
GNWT	1 representative
Government of Canada	1 representative
DDMI	1 representative

(b) Subject to Article 4.6 (b), the Government of Nunavut may appoint one representative to the Advisory Board.

(c) The Parties may jointly appoint two public representatives to the Advisory Board.

(d) Subject to Article 4.6 (a) and (b), each of the Parties and the Government of Nunavut may appoint one alternate representative.

(e) Either or both of the representative and the alternate representative appointed to the Advisory Board by the Parties and the Government of Nunavut shall be resident in the Northwest Territories or Nunavut.

4.6 FUNCTIONING OF THE ADVISORY BOARD

Each Party to this Agreement and the Government of Nunavut shall be entitled to appoint representatives to the Advisory Board as follows:

(a) A representative and an alternate shall be appointed by each Party within sixty (60) days, or as soon as practicable, following the later of the signing of this Agreement by that particular Party or the conditions in Article 18.1(c) being satisfied or waived;

(b) The Government of Nunavut shall appoint its representative and alternate within sixty (60) days, or as soon as practicable, following the conditions in Article 18.1(c) being satisfied or waived;

(c) Notice of appointments shall be given in writing to the Minister, and to the Chair of the Advisory Board once a Chair has been appointed;

(d) Each of the Parties and the Government of Nunavut may, from time to time, change the representatives on the Advisory Board appointed by it, upon notice in accordance with Article 4.6(c);

(e) The Parties may, from time to time, jointly change or remove either or both of the public representatives on the Advisory Board, upon notice in accordance with Article 4.6(c);

(f) In the event of any vacancy or vacancies, the Advisory Board may conduct its business with such members as have been appointed;

(g) The Advisory Board shall establish procedural rules and by-laws that are not inconsistent with the purposes and principles of this Agreement;

(h) Terms of appointment and selection of officials and similar matters such as remuneration and conflict of interest shall be governed by the Advisory Board's by-laws;

(i) No representative shall be deemed to be in a conflict of interest in representing the general interest of the Party or government that appointed that representative;

(j) The Advisory Board shall have an annual audit of its accounts done and shall provide a copy of the audit report to the Parties and to the Government of Nunavut. The Advisory Board shall maintain its financial records in accordance with generally accepted accounting principles; and

(k) The Advisory Board may coordinate its activities with the activities of the board established pursuant to the Socio-economic Monitoring Agreement.

4.7 ANNUAL ADVISORY BOARD REPORT

The Advisory Board shall provide an annual report of its activities and recommendations to the Parties and the Government of Nunavut. The annual report shall be made available to the public.

4.8 FUNDING

(a) During the term of this Agreement, DDMI shall provide funding, in accordance with the Advisory Board's budget, to the Advisory Board to carry out its mandate.

(b) DDMI will pay to the Advisory Board the full amount of its contribution to the budget for a 12-month period sixty (60) days prior to the commencement of the period or, in the case of the first budget, within thirty (30) days following the establishment of the Advisory Board.

(c) The Advisory Board shall manage and conduct its affairs in a fiscally prudent, reasonable and cost-effective manner and shall to that end endeavour wherever possible to reduce the cost of fulfilling its responsibilities hereunder including by: making full use of information, data and resources that may be available from DDMI or public sources; avoiding the duplication of monitoring and other activities being conducted by DDMI or governmental agencies or departments; and co-ordinating its activities with those of the board established pursuant to the Socio-economic Monitoring Agreement, including sharing office space and administrative and secretarial functions where practicable.

(d) The Advisory Board's annual budget for each of the first two years after its establishment shall be $800,000. DDMI, Canada, and the GNWT shall contribute respectively, $600,000, $150,000, and $50,000 of that amount. The first two years' budget contains start-up costs that are non-recurring and accordingly shall not be considered a base amount for future years. Thereafter, Canada and the GNWT shall have no obligation to provide funding for future years to the Advisory Board.

(e) After the first two years, the Advisory Board's budget will be for two year periods, unless the Advisory Board and DDMI agree on a shorter or longer period. The Advisory Board's budget for a period shall be determined as follows:

(i) At least 180 days before the expiry of the then current budget period, the Advisory Board shall prepare a recommended budget for the next budget period, based on a plan of anticipated work for that period and a review of past work and financial experience;

(ii) The Advisory Board shall make best efforts to ensure that the amount of DDMI's contribution to the budget for any two year period shall not, without the agreement of DDMI, exceed DDMI's contribution to the budget for the preceding two year period by a percentage which is greater than the percentage change in the Consumer Price Index published by Statistics Canada over that two year period. For this purpose, the budget for the second year shall be considered $600,000.

(iii) DDMI and the Advisory Board shall jointly review the plan of anticipated work and the recommended budget, and shall attempt to agree on a budget for the period;

(iv) In the event that DDMI and the Advisory Board cannot agree on the budget within sixty (60) days following the initiation of the joint review under Article 4.8 (e)(iii), they shall forthwith confer with the Minister and each of them will submit to the Minister a proposed budget; and

(v) If DDMI, the Minister, and the Advisory Board cannot within thirty (30) days following the initiation of the process under Article 4.8(e)(iv), agree on a budget for a period, the Minister shall forthwith select either the budget submitted by DDMI or, provided the Minister is reasonably satisfied that the Advisory Board has complied with Article 4.8(e)(ii), the budget submitted by the Advisory Board, and the budget so selected by the Minister shall be the budget for the next two year period.

(f) In addition to the budget, DDMI may provide additional funding to the Advisory Board for research and monitoring activities or unforeseen circumstances, based on proposals submitted to DDMI by the Advisory Board for which funding is not available in the budget. DDMI shall in good faith review and consider proposals submitted by the Advisory Board for additional funding and shall provide written reasons to the Advisory Board and Canada if any request for funding is not accepted by DDMI. If requested by the Advisory Board or DDMI, the Minister shall review the matter and provide the Advisory Board and DDMI with his/her views on how this matter might be resolved and shall make public those views.

(g) Any funds provided by DDMI, Canada, or GNWT in a budget period that are not expended in that period shall be applied to fund the costs of the Advisory Board in accordance with the budget for the succeeding budget period, provided that funds that are designated for a program that continues into a new budget period may be used for that program.

4.9 ADMINISTRATION, TRADITIONAL KNOWLEDGE AND SCIENTIFIC SUPPORT

(a) The Advisory Board may establish a secretariat to support it in its activities.

(b) The Advisory Board may from time to time establish two panels of experts as follows:

  (i) One panel to assist in the application and consideration of traditional knowledge; and

  (ii) One panel to assist in the application and consideration of other types of scientific knowledge.

(c) Each panel shall act on specific instruction from the Advisory Board to assist it in carrying out the Advisory Board's mandate.

(d) The panels of experts may, both separately and jointly, meet, prepare reports and meet with the Advisory Board from time to time.

(d) Scientific and traditional knowledge obtained through the operation or activities of the Advisory Board shall be considered public information. In the case of traditional knowledge, the agreement of the Aboriginal Peoples providing the traditional knowledge shall be necessary before the information is made public.

4.10 INFORMATION AND CO-OPERATION

Each of the Parties shall co-operate with the Advisory Board and provide the Advisory Board in a timely fashion with such information and assistance requested by the Advisory Board that such Parties are reasonably able to provide and which is required for the Advisory Board to carry out its mandate.

4.11 TRANSITIONAL

The Parties shall review this Article IV two years after the Effective Date of this Agreement. Taking into account the results of the regional cumulative effects assessment and management framework initiative referred to in Article IX and the experience of other advisory environmental boards, including the BHP Independent Environmental Monitoring Agency, the Parties may negotiate to amend the provisions of this Article IV. DDMI shall not, as a result of such negotiations, be required to provide, in relation to the Project, any funding in excess of its funding obligations specified in Article 4.8.

ARTICLE V

ENVIRONMENTAL COMPLIANCE

5.1 COMPLIANCE

DDMI shall carry out the Project in compliance with all environmental laws and regulations and Regulatory Instruments applicable to the Project including, without limitation, the following:

(a) the Water Licence;

(b) Authorization(s) issued under Section 35 of the *Fisheries Act*;

(c) Explosives Factory Licences issued under the *Explosives Act*;

(d) the Land Leases;

(e) Navigable Waters Permits issued under the *Navigable Waters Protection Act*; and

(f) Any and all additional Regulatory Instruments applicable to the Project at any time.

5.2 In carrying out the Project, DDMI shall comply with this Agreement and all Environmental Plans and Programs submitted and reviewed in accordance with this Agreement.

5.3 DDMI shall take prompt and appropriate corrective action to remedy any non-compliance with Article 5.1 or Article 5.2.

5.4 CONFIRMING COMPLIANCE

(a) The Minister may direct, on his or her own initiative or at the request of the Advisory Board, any qualified person to conduct investigations to confirm compliance with Article 5.2 of this Agreement.

(b) DDMI shall admit the qualified person to the Project and shall provide the qualified person with all reasonable assistance.

(c) The Minister will take all reasonable efforts to co-ordinate investigations under this Agreement with inspections under the Regulatory Instruments.

(d) The qualified person shall prepare a report of his or her investigations for the Minister and the Advisory Board.

ARTICLE VI

ENVIRONMENTAL MANAGEMENT PLANS

6.1 PROVISION OF ENVIRONMENTAL MANAGEMENT PLANS

Construction Phase(s)

DDMI has provided the Parties and the Government of Nunavut, and will provide the Advisory Board (when established), with copies of its Environmental Management Plans for the Construction Phase(s) of the Project. The Environmental Management Plans contain specific and comprehensive plans to deal with environmental matters of particular concern during construction of the Project. DDMI shall provide the Parties, the Government of Nunavut, and the Advisory Board with any and all amendments and revisions to the Environmental Management Plans as and when such amendments or revisions are made.

Operating Phase

Not later than six months before the commencement of Commercial Production from the Project, DDMI shall provide the Parties, the Government of Nunavut, and the Advisory Board with updated copies of its Environmental Management Plans for the operating phase of the Project. The Environmental Management Plans shall contain specific and comprehensive plans to deal with environmental matters of particular concern during operation of the Project. Thereafter DDMI shall provide the Parties, the Government of Nunavut, and the Advisory Board with any and all amendments and revisions to the Environmental Management Plans as and when such amendments or revisions are made. DDMI shall consider technological advances as factors in the development of Environmental Management Plans during operations. In order to effectively incorporate the traditional knowledge of Aboriginal Peoples in its Environmental Plans and Programs, DDMI shall undertake or fund such traditional knowledge studies as a Party can reasonably demonstrate are necessary and relevant, do not duplicate existing studies, and can be carried out at reasonable cost. Where applicable, traditional knowledge shall be considered fully along with scientific knowledge in developing, reviewing and amending the Environmental Management Plans.

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Closure Phase

Not later than three years before planned closure activities are scheduled to occur, DDMI shall provide the Parties, the Government of Nunavut, and the Advisory Board with current copies of its Environmental Management Plans for the Closure and Post Closure phase(s) of the Project. Thereafter DDMI shall provide the Parties, the Government of Nunavut, and the Advisory Board with any and all amendments and revisions to the Environmental Management Plans as and when such amendments or revisions are made.

6.2 ENVIRONMENTAL MANAGEMENT PLANS

DDMI shall undertake environmental management of the Project through the implementation of Environmental Management Plans. The Environmental Management Plans shall, where applicable, include the following specific and comprehensive plans designed as part of a program of adaptive environmental management:

(a) Waste Management Plan;
(b) Water Management Plan;
(c) Hazardous Materials Management Plan;
(d) Blasting/Explosives Management Plan;
(e) Quarry Management Plan;
(f) Emergency Response Plan;
(g) Processed Kimberlite Containment Management Plan;
(h) Country Rock and Till Storage Management Plan;
(i) Dredged Lakebed Sediment Management Plan;
(j) Reclamation and Abandonment Plan(s) (including Initial, Interim and Final Plans);
(k) Biotite Schist Management Plan;
(l) Exploration Environmental Management Plan;

(m) Traffic Management Procedures;
(n) Fish Habitat Management Plan;
(o) Construction Area and Activity Management Plan;
(p) Operations Area and Activity Management Plan; and
(q) Wildlife Management Related Extracts from above noted plans.

The Environmental Management Plans shall include the mitigation measures outlined in DDMI's Commitments and in the conclusions of the Responsible Authorities documented in the CSR. DDMI shall adapt or revise these mitigation measures in accordance with the principles of adaptive environmental management.

DDMI shall, in the development and implementation of Environmental Plans and Programs include, where appropriate, the following:

(a) quality control and assurance programs;

(b) environmental awareness training for employees and contractors;

(c) regular briefings on environmental matters to on-site supervisors; and

(d) detailed adaptive environmental mitigation measures.

6.3 REVIEW OF ENVIRONMENTAL MANAGEMENT PLANS

(a) In the event that, at any time, the Minister on his/her own initiative, or in response to a request from any Party or the Advisory Board and after Consultation with DDMI, determines that an Environmental Management Plan is inadequate or incomplete, the Minister may provide DDMI with a Minister's Report and DDMI shall forthwith, but in any event within sixty (60) days of receipt of the Minister's Report, provide:

(i) the Minister with revisions to the Environmental Management Plan which address to the Minister's satisfaction the deficiencies described in the Minister's Report;

(ii) a replacement Environmental Management Plan which addresses to the Minister's satisfaction the deficiencies described in the Minister's Report; or

(iii) specific replies to the deficiencies described in the Minister's Report and DDMI's detailed explanation, to the Minister's satisfaction, as to why, in DDMI's view, the Environmental Management Plan need not be revised or replaced to deal with the deficiencies outlined in the Minister's Report.

(b) In relation to matters substantially within the jurisdiction of the GNWT, the Minister shall provide DDMI with a Minister's Report pursuant to Article 6.3 (a) when the Minister receives a request from the GNWT pursuant to that Article and the GNWT's request shall be included in the Minister's Report.

(c) The Minister may provide DDMI with an extension of time where DDMI is bona fide delayed in complying with this Article.

ARTICLE VII

ENVIRONMENTAL MONITORING PROGRAMS

7.1 PROVISION OF ENVIRONMENTAL MONITORING PROGRAMS

DDMI shall undertake compliance and environmental effects monitoring of the Project through the Environmental Monitoring Programs. DDMI shall provide the Parties, the Government of Nunavut, and the Advisory Board (when established) with copies of its Environmental Monitoring Programs. The Environmental Monitoring Programs contemplated by this Article shall be reviewed in accordance with Article 7.5 of this Agreement. The Environmental Monitoring Programs shall be revised on an ongoing basis as necessary and where appropriate in response to changing circumstances and additional information.

The Environmental Monitoring Programs shall include activities designed to:
(a) meet the monitoring requirements of all Regulatory Instruments;
(b) verify the accuracy of the environmental assessment of the Project;
(c) determine the effectiveness of measures taken to mitigate any adverse environmental effects of the Project;
(d) consider traditional knowledge;
(e) establish or confirm thresholds or early warning signs;
(f) trigger action by adaptive mitigation measures where appropriate;
(g) provide opportunities for the involvement or active participation of each of the Aboriginal Peoples in the implementation of the monitoring programs; and
(h) provide training opportunities for each of the Aboriginal Peoples.

7.2 ENVIRONMENTAL MONITORING COMPONENTS

The Environmental Monitoring Programs shall include, but not necessarily be limited to, the following programs:

(a) An Environmental Air Quality Monitoring Program;
(b) A Wildlife/Vegetation Monitoring Program;
(c) An Aquatic Effects Monitoring Program;
(d) A Geotechnical Monitoring Program;
(e) An Operational Health and Safety Program (limited to effects on human health resulting from environmental changes); and
(f) Other specific environmental monitoring programs as required under territorial or federal legislation or as required in the CSR.

7.3 The Environmental Monitoring Programs will include the identification of monitoring objectives and the monitoring programs outlined in DDMI's Commitments and in the conclusions of the Responsible Authorities documented in the CSR. DDMI shall adapt or revise the Environmental Monitoring Programs in accordance with the principles of adaptive environmental management.

7.4 MONITORING DATA AND RESULTS

(a) DDMI shall deliver monitoring data and information to the Parties, the Government of Nunavut, and the Advisory Board in time-frames and in formats developed in Consultation with the Advisory Board.

(b) The formats for submission of monitoring program results and analysis shall not be inconsistent with reporting requirements established under legislation, regulations and Regulatory Instruments and the requirements of such legislation, regulations and Regulatory Instruments shall apply to the extent of any inconsistency.

(c) Reporting dates will be established to conform with the requirements of the appropriate Regulatory Instruments.

(d) DDMI shall carry out the monitoring in a manner which will provide data consistent with any cumulative effects monitoring programs and shall Consult and co-operate with the regulatory agencies undertaking such programs, as appropriate.

7.5 REVIEW OF ENVIRONMENTAL MONITORING PROGRAMS

(a) In the event that, at any time, the Minister, on his/her own initiative, or in response to a request of any Party or the Advisory Board, and after Consultation with DDMI, determines that an Environmental Monitoring Program is inadequate or incomplete, including with respect to a matter under Article 7.4, the Minister may provide DDMI with a Minister's Report and DDMI shall forthwith, but in any event within sixty (60) days of receipt of the Minister's Report, provide:

  (i) the Minister with revisions to the Environmental Monitoring Program which address to the Minister's satisfaction the deficiencies described in the Minister's Report;

  (ii) a replacement Environmental Monitoring Program which addresses to the Minister's satisfaction the deficiencies described in the Minister's Report; or

  (iii) specific replies to the deficiencies described in the Minister's Report and DDMI's detailed explanation, to the Minister's satisfaction, as to why, in DDMI's view, the Environmental Monitoring Program need not be revised or replaced to deal with the deficiencies outlined in the Minister's Report.

(b) In relation to matters substantially within the jurisdiction of the GNWT, the Minister shall provide DDMI with a Minister's Report pursuant to Article 7.5(a) when the Minister receives a request from the GNWT pursuant to that Article and the GNWT's request shall be included in the Minister's Report.

(c) The Minister may provide DDMI with an extension of time where DDMI is bona fide delayed in complying with this section.

7.6 ABORIGINAL COMMUNITY INVOLVEMENT

In addition to the participation of Aboriginal Peoples in the review of Environmental Management Plans and Environmental Monitoring Programs through participation on the Advisory Board and its activities, and the resulting capacity building, DDMI shall use its best efforts to:

(a) provide for the involvement of members of each of the Aboriginal Peoples in Environmental Monitoring Program design and implementation;

(b) give priority to members of each of the Aboriginal Peoples in the provision of training and employment in relation to environmental monitoring in accordance with the provisions of the Socio-economic Monitoring Agreement; and

(c) provide technical training opportunities for youth of each of the Aboriginal Peoples.

ARTICLE VIII

SOCIO-ECONOMIC EFFECTS RESULTING FROM ENVIRONMENTAL CHANGE

8.1 DDMI shall comply with all requirements of the CSR relating to monitoring and mitigation of potential socio-economic effects resulting from environmental changes.

ARTICLE IX

REGIONAL CUMULATIVE EFFECTS ASSESSMENT & MANAGEMENT FRAMEWORK

9.1 DDMI will participate in the initiative announced by the Minister of the Environment on November 3, 1999 to develop a regional cumulative effects assessment and management framework. This framework is to consider both scientific and traditional knowledge, and be used in conjunction with adaptive management to ensure sustainable development.

ARTICLE X

RECLAMATION AND ABANDONMENT

10.1 RECLAMATION AND ABANDONMENT

(a) DDMI shall submit Reclamation and Abandonment Plan(s) as and when required pursuant to the *Northwest Territories Waters Act*, the *Mackenzie Valley Resource Management Act*, and the *Territorial Lands Act;*

(b) The Parties acknowledge that the Reclamation and Abandonment Plan(s) will evolve over time during the life of the Project as part of the process of adaptive environmental management and through the incorporation of new and emerging technologies;

(c) The final Project will be abandoned using the most current technology reasonably practicable; and

(d) DDMI will implement progressive reclamation and abandonment of the Project in a manner consistent with sustainable development.

ARTICLE XI

ARCHAEOLOGICAL SITES

11.1 PROTECTION OF KNOWN SITES

DDMI shall establish, after Consultation with the Aboriginal Peoples and the appropriate government agencies, including the Prince of Wales Northern Heritage Centre, appropriate protection of the Archaeological Sites in the vicinity of the Project, in accordance with applicable laws and regulations, to minimize the impacts on Archaeological Sites.

11.2 ARCHAEOLOGICAL SURVEYS

(a) In the continuing exploration and development of the Project, DDMI shall conduct Archaeological surveys to meet the prevailing standards of the day and respecting places of significance to Aboriginal Peoples.

(b) Archaeological surveys shall to the greatest extent possible, be designed and, where possible, implemented in partnership with the Aboriginal Peoples and Affected Communities or if not possible, in Consultation with the Aboriginal Peoples and Affected Communities.

(c) DDMI shall Consult with Aboriginal Peoples and Affected Communities to ensure that traditional knowledge is incorporated into the archaeological surveys and to ensure that burial sites are identified.

(d) In the event that an Archaeological Site is discovered in carrying out the Project, DDMI shall immediately notify the Minister, the GNWT and Aboriginal Peoples of the presence of the Archaeological Site and, subject to Article 11.2(e), DDMI shall take all reasonable steps necessary to protect the Archaeological Site.

(e) In conducting archaeological surveys and in the event that it becomes necessary to disturb the Archaeological Site and collect the artifacts, DDMI shall Consult with Aboriginal Peoples and obtain all necessary authorizations and comply with all applicable laws.

ARTICLE XII

ANNUAL REPORTS

12.1 ANNUAL REPORT

(a) DDMI shall prepare and submit an annual report (the "Annual Report") to the Parties, the Government of Nunavut, and the Advisory Board on March 31, (or on such other date as prescribed by the Minister from time to time), for each calendar year during the term of this Agreement, commencing March 31, 2001.

(b) Each Annual Report shall include the results of Environmental Monitoring Programs, and a rolling summary and analysis of environmental effects data over the life of the Project to illustrate any trends. The actual performance of the Project shall be compared to the results predicted in the environmental assessment and the CSR and an evaluation provided as to how DDMI's adaptive environmental management has performed to the date of each Annual Report.

(c) Each Annual Report shall include, but not be limited to, the following:

(i) a comprehensive summary of all supporting information, data and results from the Environmental Monitoring Programs and all studies and research;
(ii) a comprehensive summary of all compliance reports required by the Regulatory Instruments;
(iii) a comprehensive summary of operational activities during the preceding year;
(iv) actions taken or planned to address effects or compliance problems which are set out in the Annual Report;
(v) a comprehensive summary of operational activities for the next year;
(vi) lists and abstracts of all Environmental Plans and Programs;
(vii) verification of accuracy of environmental assessments;
(viii) determination of effectiveness of mitigative measures;
(ix) a comprehensive summary of all adaptive management measures taken;
(x) a comprehensive summary of public concerns and responses to public concerns;

(xi) a comprehensive summary of the new technologies investigated;

(xii) the Minister's comments, including any Minister's Report, on the previous Annual Report; and

(xiii) a plain English executive summary and translations into Dogrib, Chipewyan, and Innuinaqtun using appropriate media.

(d) In order to prepare each Annual Report and with a view to both ensuring that an opportunity is provided for early disclosure and discussion of problems and that each Annual Report meets with the requirements of this Agreement, DDMI shall Consult with the Minister and the Advisory Board as DDMI compiles the information and data to be included in such Annual Report.

(e) Within forty-five (45) days of the receipt of the Annual Report, any Party or the Advisory Board may advise the Minister whether such Annual Report is satisfactory or unsatisfactory.

(f) Within ninety (90) days of the receipt by the Minister of the Annual Report, the Minister shall advise DDMI whether such Annual Report is satisfactory or whether the Minister has determined that such Annual Report is deficient. In the event that the Minister has determined the Annual Report to be deficient, the Minister shall provide DDMI with a Minister's Report.

(g) In relation to matters substantially within the jurisdiction of the GNWT, the Minister shall provide DDMI with a Minister's Report pursuant to Article 12.1(f) when the Minister receives advice from the GNWT that the Annual Report is unsatisfactory and the GNWT's advice shall be included in the Minister's Report.

(h) Within sixty (60) days of the receipt by DDMI of a Minister's Report, DDMI shall reply to the Minister's Report and provide the Minister with a revised Annual Report or an addendum which addresses satisfactorily the deficiencies described in the Minister's Report.

(i) The Minister may provide DDMI with an extension of time where DDMI is bona fide delayed in completing an Annual Report or providing a reply to a Minister's Report.

ARTICLE XIII

REGULATORY AUTHORITY

13.1 PARAMOUNTCY

In the event that any provisions of this Agreement are in conflict with or inconsistent with any legislation or Regulatory Instrument with respect to the Project, the terms of such legislation or Regulatory Instrument shall prevail over any of the terms of this Agreement to the extent of the conflict or inconsistency.

13.2 NON-DUPLICATION

The Parties to this Agreement acknowledge that it is not the intention of this Agreement to cause any duplication with the requirements of any Regulatory Instrument. In the event that any provisions of this Agreement duplicate the requirements of any Regulatory Instrument, satisfaction of the requirements of the Regulatory Instrument shall be accepted as compliance with the requirements of this Agreement.

13.3 EXERCISE OF STATUTORY DUTIES

Nothing in this Agreement shall be construed as limiting the Minister or any other regulatory authority in the exercise of statutory powers and duties.

ARTICLE XIV

COMMUNICATION AND PUBLIC ACCESS TO INFORMATION

14.1 GENERAL COMMUNICATIONS PRINCIPLES

(a) The Advisory Board shall ensure that a timely, responsive, pro-active and cooperative approach to communication and exchange of information among the Parties, between the Advisory Board and the Parties, and between the Advisory Board and the Affected Communities is in place at all times.

(b) The Parties shall remain respectful of the functions and responsibilities of each other in the conduct of their duties.

(c) The Parties shall provide to the Advisory Board adequate copies of all information (including data, studies, reports and other material) they generate for another body, or the public, which relates to this Agreement and is non-proprietary.

(d) The Parties shall take reasonable steps to provide access for the public and Affected Communities to all plans, programs, reports and other documents referred to in this Agreement.

(e) DDMI in Consultation with the Advisory Board shall make each Annual Report available to the public and shall arrange for public meetings to review and discuss each Annual Report.

(f) The Parties' obligations under this Agreement to collect or provide information and documentary materials are subject to any applicable legislation regarding access to information or privacy.

14.2 COMMUNICATION PLAN

The Advisory Board shall develop a Communication Plan. The Communication Plan shall ensure timely, effective, efficient and consistent communication of information related to the environmental management of the Project.

14.3 PUBLIC REGISTRY

The Advisory Board shall maintain a public registry and a listing of all materials placed on the public registry. All written correspondence, reports, or other materials received by the Advisory Board that relate to this Agreement shall be placed on the public registry in the Advisory Board's office and shall be made available to the public.

ARTICLE XV

SECURITY AND ENFORCEMENT

15.1 SECURITY

The Security Deposit, the ~~EA Security Deposit~~ and the Additional Security Deposit shall be held by the Minister as security for the performance by DDMI of its reclamation and abandonment obligations under the Water Licence and Land Leases, any other obligations of DDMI under environmental laws and regulations or under any other Regulatory Instruments for which the Minister is responsible, and any other obligations of DDMI under this Agreement, on and subject to the terms and conditions of this Article XV.

include description of what each is

30 ← no immediate liability

(a) Within ~~20~~ days of the Effective Date of this Agreement, DDMI shall provide to the Minister a security deposit, in the amount of ~~$15,000,000.~~

(b) On March 31, 2001 and annually on March 31 thereafter, DDMI shall provide the Minister with additional security so that the amount of security deposited with the Minister shall equal the amount specified for that particular year in Column A in Schedule 1 as adjusted pursuant to Articles 15.1(g),15.1(h) and 15.1(i). The $15,000,000 amount deposited pursuant to Article 15.1(a) together with such additional amounts deposited under this Article 15.1(b) shall hereinafter be referred to as the "Security Deposit".

(c) Column A of Schedule 1 is the estimated cost of DDMI undertaking the reclamation and abandonment of the Project should abandonment take place in any particular year. As of the Effective Date, Column A of Schedule I is the estimated projected cost of restoration and abandonment for the Project as prepared for DDMI by an independent professional engineer with recognized expertise in this area.

(d) In addition to the Security Deposit, on March 31, 2003 and annually on March 31 thereafter, DDMI shall provide to the Minister additional security so that the aggregate amount of additional security deposited with the Minister shall equal the amount specified for that particular year in Column B of Schedule 1. Such aggregate amount of additional security is hereinafter referred to as the "Additional Security Deposit". Where the Additional Security Deposit held by the Minister on March 31 of any year exceeds the amount specified in Column B of Schedule 1 for that year, the Minister shall refund to DDMI any excess. The Additional Security Deposit includes security for the incremental costs which Canada will incur if it has to conduct reclamation and abandonment of the Project due to a default by DDMI, contingencies, potential for increases in environmental liabilities related to variations in Project configuration and operations which may occur over the life of the Project, and defaults under this Agreement not related to reclamation and abandonment. At the fifth anniversary of the Effective Date and at five-year intervals thereafter, the Minister at his or her sole discretion may adjust the Additional Security Deposit by an amount not to exceed the average change in the Consumer Price Index over the five-year interval. DDMI may at any time request that the Minister review the amount of the Additional Security Deposit. Upon receiving such a request the Minister shall review the amount of the Additional Security Deposit and may, in his/her sole discretion, acting in a commercially reasonable manner and in the public interest, reduce the amount of the Additional Security Deposit that DDMI is required to provide to the Minister. In making determinations under this Article 15.1(d), the Minister will take into account the extent to which the development and operations of the Project have reduced the need for the Minister to hold additional security for contingencies and for the

Exclude

potential for increases in environmental liabilities related to variations in Project configuration and operations, as well as the principle that there should be no duplication between the security for costs and contingencies which DDMI provides by way of the Security Deposit and the security which it provides for costs and contingencies by way of the Additional Security Deposit. The Minister will provide DDMI and the Advisory Board with reasons for all his/her decisions made pursuant to this Article 15.1(d).

(e) The Security Deposit and the Additional Security Deposit shall be maintained throughout the term of this Agreement. In the event that all or any portion of the Security Deposit or the Additional Security Deposit is used by the Minister pursuant to Article 15.3 of this Agreement, DDMI shall, unless otherwise directed by the Minister, within thirty days of demand by the Minister showing particulars of use reimburse to the Minister the amount so used so that the amounts of the Security Deposit and the Additional Security Deposit are at all times equal, respectively, to the amounts required to be maintained pursuant to Article 15.1(b), subject to adjustment as provided in Articles 15.1(g), 15.1(h) and 15.1(i), and Article 15.1(d).

OK/

(f) The amount of each security deposit which DDMI posts with the Minister pursuant to the Land Leases or the Water Licence shall be credited first against the Security Deposit and then against the Additional Security Deposit, provided that any credit against the Additional Security Deposit shall not exceed 67% of the Additional Security Deposit. For greater certainty, a credit will not reduce either the quantum of the Security Deposit required by Article 15.1(b) or the quantum of the Additional Security Deposit required by Article 15.1(d), but rather will be an amount that is deemed to have been provided as required. Also for greater certainty, if the security posted under the Water Licence or the Land Leases is reduced, then: the credit given under this Article 15.1(f) shall decrease by an amount which corresponds to the reduction; and DDMI shall provide without delay an addition to the Security Deposit, and/or an addition to the Additional Security Deposit, to fully offset the decrease in the credit.

Credits to Land & water will not affect additional security

(g) As provided for in Article X of this Agreement, DDMI is required to undertake progressive reclamation and abandonment of the Project in accordance with the principles of sustainable development.

Not requir!

(i) Column C of Schedule 1 sets out DDMI's projected cumulative expenditures on progressive reclamation work that it will undertake over the life of the Project.

(ii) Prior to January 31, 2005 and prior to January 31 of each year thereafter, DDMI may deliver to the Minister and the Advisory Board a report detailing the progressive reclamation work undertaken by or for DDMI during the previous calendar year(s), the costs incurred in undertaking this progressive reclamation work and a revised estimate of the cost of DDMI undertaking the reclamation and abandonment over the remaining life of the Project, taking into account this progressive reclamation, certified by an independent professional engineer with recognized expertise in this area. By March 31 of the same year, the Minister will review the report and determine the extent to which the progressive reclamation work has reduced the estimated cost of DDMI undertaking the reclamation and abandonment over the remaining life of the Project and the extent to which the estimate contained in the report accurately reflects the revised costs of DDMI undertaking the remaining reclamation and abandonment of the Project. To the extent the Minister is satisfied that the progressive reclamation work undertaken by DDMI has reduced the estimated costs of reclamation and abandonment remaining over the life of the Project, the Minister shall make a determination to that effect and provide a copy to DDMI and the Advisory Board. The amount of the Security Deposit which DDMI must provide to the Minister on March 31 of that year and subsequent years shall be reduced so that it is equal to the revised estimated costs of DDMI undertaking the reclamation and abandonment over the remaining life of the Project, as accepted by the Minister and Column A of Schedule I shall be adjusted accordingly. Where the amount of the Security Deposit which DDMI has provided to the Minister exceeds the estimated cost of DDMI undertaking reclamation and abandonment over the life of the Project on any March 31 date, as accepted by the Minister, the Minister shall refund to DDMI any such excess, subject to applicable legislation.

Not. required!

(h) At any time after the second anniversary of the Effective Date of this Agreement, DDMI may deliver to the Minister and the Advisory Board a report detailing a revised estimate of the cost of DDMI undertaking the reclamation and abandonment over the remaining life of the Project, taking into account changes to the Project~~, and any other relevant factors not considered in Article 15.1(g) above,~~ prepared by an independent professional engineer with recognized expertise in this area. Within ninety days of receipt of the report, the Minister will review the report and determine the extent to which this revised estimate accurately reflects the costs of DDMI undertaking the remaining reclamation and abandonment of the Project. To the extent the Minister is satisfied that this estimate accurately reflects the costs of DDMI undertaking the remaining reclamation and abandonment of the Project, the Minister shall make a determination to that effect and will provide a copy to

Change to consider [illegible] as well

Drafts around concepts of (h) + (i)
Co. will see if there is any timeline for doing a reclamation
preparing report

DDMI and the Advisory Board. The amount of the Security Deposit which DDMI must provide to the Minister on the next March 31, and March 31 of subsequent years shall be reduced so that it is equal to the revised estimated costs of DDMI undertaking the reclamation and abandonment over the remaining life of the Project, as accepted by the Minister and Column A of Schedule I will be amended to reflect the Minister's determination. Where the amount the Security Deposit which DDMI has provided to the Minister exceeds the estimated cost of DDMI undertaking reclamation and abandonment over the life of the Project on any March 31 date, as accepted by the Minister, the Minister shall refund to DDMI any such excess subject to applicable legislation.

(i) At any time after the second anniversary date of the Effective Date of this Agreement, the Minister may notify DDMI and the Advisory Board that he/she intends to seek a report containing an updated estimate of the cost of reclamation and abandonment for the Project prepared by an independent professional engineer with recognized expertise in this area. ~~DDMI shall be offered a reasonable opportunity to provide comments to the Minister on the scope of such a report.~~ When any such report is then available, the Minister shall provide a copy to DDMI and the Advisory Board and will again provide to DDMI a reasonable opportunity to provide comments on the report. To the extent that the Minister determines that he/she does accept the updated estimates of the costs of reclamation and abandonment over the remaining life of the Project, and should such estimated costs of reclamation and abandonment to the extent accepted by the Minister as at that time be greater than the amount of the Security Deposit, DDMI shall provide the Minister with an additional amount of security so that the amount of the Security Deposit required as at that time is equal to the estimated costs of reclamation and abandonment as at that time, such additional security to be provided to the Minister within 60 days of a demand by the Minister to do so, and Column A of Schedule I will be amended to reflect the Minister's determination.

(j) The reviews of the Security Deposit contemplated in Articles 15.1(g), 15.1(h) and 15.1(i) shall, to the extent practicable, be co-ordinated with the reviews of security posted pursuant to the Land Leases and/or the Water Licences. In addition, where there has been a reduction in the amount of the security under either the Water Licence or the Land Leases, the Minister shall, at the request of DDMI, review the amount of the Security Deposit to determine if the Security Deposit should be adjusted, giving serious consideration to the rationale for any such reduction in the amount of security posted under the Water Licence and Land Leases.

Intégrale

(k) In addition to the Security Deposit and the Additional Security Deposit, as security for the performance of its obligations under this Agreement, DDMI shall provide to the Minister within 90 days of the signing of this Agreement, and shall at all times maintain with the Minister, a security deposit (the "EA Security Deposit") in a form satisfactory to the Minister and on terms satisfactory to the Minister in the amount of $3,000,000. At the fifth anniversary of the Effective Date and at five-year intervals thereafter, the Minister at his or her sole discretion may adjust the EA Security by an amount not to exceed the average change in the Consumer Price Index over the five-year interval. In the event that all or any portion of the EA Security Deposit is used by the Minister pursuant to Article 15.3 to cure a default under this Agreement, DDMI shall within thirty days of demand by the Minister showing particulars of use reimburse to the Minister the amount so used so that the aggregate amount of the EA Security Deposit shall at all times equal $3,000,000 subject to adjustment as herein provided.

(l) The Security Deposit, the EA Security Deposit and at least sixty-seven percent (67%) of the Additional Security Deposit shall be provided in the form of: cash; an irrevocable unconditional letter of credit; an amount held in a Qualifying Environmental Trust established through an indenture that has been approved by the Minister; any other form of security proposed by DDMI and satisfactory to the Minister; or any combination of the foregoing. Up to thirty-three percent (33%) of the Additional Security Deposit need not be provided in the form of: cash; an irrevocable unconditional letter of credit; an amount held in a Qualifying Environmental Trust established through an indenture that has been approved by the Minister; or any combination of the foregoing, but may be provided in the form of: an irrevocable guarantee; insurance; or any other form of security proposed by DDMI; or any combination of the foregoing, provided that the Additional Security Deposit is in a form(s) satisfactory to the Minister.

(m) If the Security Deposit, the Additional Security Deposit or the EA Security Deposit is composed in whole or in part of cash, how it is invested and how interest which may be earned thereon will be allocated, shall be determined by the Minister and DDMI in the terms of the applicable security instrument(s). The terms on which the Security Deposit, the Additional Security Deposit or the EA Security Deposit will be delivered to and held by the Minister, if the Security Deposit, the Additional Security Deposit or the EA Security Deposit is not wholly in the form of cash, shall be consistent with the terms of this Agreement and be determined by the Minister and DDMI in the applicable security instrument(s).

and obligation under this agreem

(n) Once DDMI has completed the reclamation and abandonment of the project to the satisfaction of the Minister, the Minister shall return to DDMI any unused portion of the Security Deposit, the EA Security Deposit and of the Additional Security Deposit less any amounts related to ongoing monitoring and maintenance of the Project, if and to the extent required by this Agreement. The Minister's obligation to return any unused portion of the Additional Security Deposit shall include taking appropriate steps to terminate, cancel or release guarantees, insurance or like assurances comprised in the Additional Security Deposit.

(o) Schedule 1 shall form part of this Agreement and shall be deemed to be amended from time to time to incorporate changes made to it pursuant to this Article 15.1.

15.2 GNWT JURISDICTION

(a) The Minister shall provide DDMI with a Notice of Default, in accordance and compliance with the process in Article 15.3, when the Minister is notified in writing by the GNWT that, in the opinion of the GNWT DDMI has not performed an ~~any of its~~ obligation~~s~~ under this Agreement with respect to a matter substantially within the jurisdiction of the GNWT.

(b) In relation to matters substantially within the jurisdiction of the GNWT, the Minister shall, within 30 days after the Minister has drawn funds on the Security Deposit, the EA Security Deposit or the Additional Security Deposit in accordance with Article 15.3(a)(iii) or Article 15.3(a)(iv), pay to the GNWT from the funds so drawn reimbursement of all reasonable costs expended by the GNWT in rectifying non-compliance by DDMI under Article V.

15.3 EVENTS OF DEFAULT AND REMEDIES

(a) (i) Subject to Articles 15.3(b) and 15.3(d), in the event that in the opinion of the Minister DDMI has not performed any of its obligations under this Agreement, the Minister will advise DDMI, specifying the failure, and DDMI will have a reasonable period determined by the Minister in his/her discretion in which to either explain to the Minister's satisfaction why such failure has not occurred, or commence to carry out, and thereafter diligently continue to carry out, all required steps to remedy the failure and to prevent its recurrence.

(ii) If, within the determined period, DDMI fails to explain to the Minister's satisfaction and fails to commence carrying out to the Minister's satisfaction all required steps to remedy the failure and to prevent its recurrence, or if DDMI, having commenced to carry out all required steps, thereafter fails to continue carrying out to the Minister's satisfaction any required step, then the Minister shall be entitled to give Notice of Default to DDMI.

(iii) Subject to Article 15.3(iv) below, if the default has arisen as a result of DDMI's failure to comply with any of its obligations under this Agreement, and if within 30 days, or such longer period as the Minister will grant if reasonable in his/her opinion, of receipt of such Notice of Default DDMI does not commence to carry out, and thereafter diligently continue to carry out, all required steps to remedy the failure and to prevent its recurrence, the Minister shall be entitled to draw down and use the Security Deposit, the Additional Security Deposit and the EA Security Deposit as and when required to carry out any work reasonably required to cure such default, provided that the Minister shall draw down and use the portion of the Additional Security Deposit that is described in the second sentence of Article 15.1(l) only after utilizing the security posted under the Water Licence, the Land Leases, the Security Deposit, the remainder of the Additional Security Deposit and the EA Security Deposit, to the extent available. In addition, if such default has arisen as a result of DDMI's failure to comply with its obligations under Article V or X of this Agreement, and if such default is substantial and material, and if DDMI does not commence to carry out, and thereafter diligently continue to carry out, all required steps to remedy the failure and to prevent its recurrence, the Minister shall, in addition to the right to use the Security Deposit, the Additional Security Deposit and the EA Security Deposit, be entitled to suspend the operations of the Project and/or terminate the Land Leases.

(iv) The Minister shall be entitled to draw down and use the EA Security Deposit, as and when required, only to remedy defaults under this Agreement except for defaults under Article 5.1.

(b) In the case of a serious and imminent threat to the environment for which DDMI is responsible under this Agreement and in respect of which DDMI has been informed and is not taking measures satisfactory to the Minister, the Minister shall be immediately entitled to use the Security Deposit (unless the security deposit under the Water Licence or the security deposits under the Land Leases are available for that purpose) and the Additional Security Deposit without the requirement for any demand, notice or other formality whatsoever.

(c) In the event that DDMI fails to provide the Minister with the Security Deposit, the EA Security Deposit or the Additional Security Deposit as required by Article 15.1, fails to increase the Security Deposit or the Additional Security Deposit as required by Article 15.1 or fails to reimburse any amounts drawn on the Security Deposit, the Additional Security Deposit or the EA Security Deposit as required by this Agreement, within 30 days of the delivery to DDMI of a Notice of Default, or any such longer period as the Minister in his/her sole discretion may decide, the Minister shall be entitled to suspend the operations of the Project and/or terminate the Land Leases.

(d) In the event that DDMI is adjudged or declared bankrupt or adjudged or declared insolvent or makes an assignment for the benefit of its creditors or petitions or makes a proposal in bankruptcy or applies to any tribunal for the appointment of a receiver or trustee for DDMI or for any substantial part of its property, or commences any proceedings, other than a Permitted Arrangement, relating to it under any reorganization, arrangement or re-adjustment of debt, dissolution or liquidation law, law enabling corporate reorganizations or statute of any jurisdiction whether now or hereafter in effect relating to or governing debtors, or by any act indicates its consent to, approval of, or acquiescence in, any such proceeding for DDMI or any part of its property, or suffers the appointment of any receiver or trustee or administrative receiver, DDMI shall, absent a declaration to the contrary by the Minister, be immediately deemed to be in default under this Agreement and the Minister shall immediately be entitled to the full amount of the Security Deposit, the Additional Security Deposit and the EA Security Deposit without the requirement for any notice or demand or other formality whatsoever provided, however, that as long as DDMI is otherwise in compliance with its obligations under this Agreement, the Water Licence, the Land Leases and any other applicable Regulatory Instruments, the Minister shall not withdraw any amounts from the Security Deposit, the EA Security Deposit and the Additional Security Deposit, it being acknowledged and agreed that the Security Deposit, the EA Security Deposit and the Additional Security Deposit shall only be used to fund performance, by or on behalf of the Minister, of said obligations in the event DDMI defaults in the performance of such obligations and, except in the case of a serious and imminent threat to the environment resulting from such default of which DDMI has been informed and in respect of which DDMI is not taking measures satisfactory to the Minister, in which case the Minister shall be immediately entitled to use the Security Deposit, EA Security Deposit and the Additional Security Deposit as provided in Article 15.3(b), DDMI does not cure such default to the Minister's satisfaction within thirty (30) days, or such longer period as the Minister may grant if reasonable in his/her opinion, of the Minister providing DDMI with notice of such default. DDMI shall no longer be deemed to be in default under this Article 15.3(d) in the event that a plan, proposal or arrangement under the *Bankruptcy and Insolvency Act* or *Companies' Creditors Arrangement Act* or similar or analogous proceedings are approved and implemented.

'Permitted Arrangement' means an arrangement, amalgamation or winding-up under the *Canada Business Corporations Act* or any similar legislation which the Minister has consented to, such consent not to be unreasonably withheld, or which (a) would not in any way compromise, adversely affect or adversely modify the rights, ranking and priority of the claims of Her Majesty arising under this Agreement, the Water Licence, the Land Leases or any other applicable Regulatory Instruments or any security provided in connection herewith or therewith against DDMI or its assets or property it being acknowledged that a substitution, in accordance with the provisions of Article 17.6, of a new or successor corporation for DDMI that would not itself be deemed to be in default pursuant to this Article 15.3(d), will not in and of itself be an adverse modification of Her Majesty's rights, (b) would not convert or create any entitlement (whether conditional or otherwise) to conversion of any equity into indebtedness, other than indebtedness which by its terms is subordinated to the claims of Her Majesty under this Agreement and (c) would not result in the holder of any claim which, prior to such arrangement taking effect, ranked subordinate to or *pari passu* with the claims of Her Majesty arising under this Agreement, the Water Licence, the Land Leases or any other applicable Regulatory Instruments or any security provided in connection herewith or therewith acquiring a priority (or prior right or claim) over such claims of Her Majesty.

(e) The remedies provided for hereunder are not exclusive and are not intended to replace remedial measures which are given effect pursuant to environmental legislation, regulations or under the Regulatory Instruments. For greater certainty, notwithstanding Article 15.3(a) and (b); any security taken pursuant to the Water Licence shall be used in accordance with the Northwest Territories Waters Act.

(f) Any costs which are incurred by Canada in connection with default by DDMI under the terms of this Agreement, and which exceed the amount available under any of the security deposits, shall be recoverable from DDMI as a debt due to Her Majesty.

(g) In using the Security Deposit, EA Security Deposit and the Additional Security Deposit to remedy defaults under this Agreement, the Minister shall be required to act in a commercially reasonable manner, and shall not remedy any default to a higher standard than would be required of DDMI.

(h) To the extent not prohibited by law, DDMI shall have the right to audit, from time to time on reasonable notice to the Minister and at DDMI's expense, any expenditure of funds withdrawn by the Minister from the Security Deposit, EA Security Deposit or the Additional Security Deposit.

15.4 DISPUTE SETTLEMENT

Any determination by the Minister under Articles 15.1(g), 15.1(h) or 15.1(i) shall be subject to arbitration by DDMI and the Minister in accordance with the provisions of Article XVI in the event that such determination is disputed by DDMI. Any other dispute or matter arising under or with reference to this Article XV shall not be dealt with pursuant to Article XVI but shall instead be within the jurisdiction of the courts.

ARTICLE XVI

RESOLUTION OF DISPUTES

16.1 DISPUTE RESOLUTION

Subject to Article 15.4, where there is a dispute between any Parties (the "disputing parties") arising out of or in connection with this Agreement, then the disputing parties shall submit the matter to binding arbitration subject to the dispute resolution provisions set out below.

16.2 In the event a dispute arises, the disputing parties shall use all reasonable efforts, including mediation if the disputing parties agree, to amicably resolve the dispute within sixty (60) days, or such extended time as the disputing parties may agree, within delivery of notice in writing of a dispute from one disputing party to another.

16.3 SELECTION OF THE ARBITRATOR(S)

If the dispute is not resolved pursuant to Article 16.2, then the disputing parties shall refer the dispute to binding arbitration and the following provisions shall apply:

(a) the dispute shall be referred to a single arbitrator if the disputing parties agree; otherwise it shall be referred to three arbitrators, one of whom shall be chosen by the Party or Parties bringing the dispute, one by the Party or Parties responding to the dispute, and the third by the two so chosen. The third arbitrator shall be the chairperson. Arbitrators shall be independent, disinterested, knowledgeable and experienced in the issue in dispute. A decision may be made by a majority of the arbitrators;

(b) if, within sixty (60) days of being notified that a dispute has been referred to arbitration, or such extended time as the disputing parties may agree upon, a Party or Parties who have been so notified fail to appoint an arbitrator, then an application may be made to the Supreme Court of the Northwest Territories for the appointment of an arbitrator; and

(c) if within thirty (30) days or such extended time as the disputing parties may agree upon, the first two arbitrators appointed under Article 16.3 (a) or (b) above do not agree upon the third arbitrator, then an application may be made to the Supreme Court of the Northwest Territories for the appointment of the third arbitrator.

16.4 Except as to matters otherwise provided herein, the provisions of the *Commercial Arbitration Act* (Canada) and *Commercial Arbitration Code* annexed thereto, shall apply.

16.5 The Advisory Board shall be entitled to intervene, as appropriate, in the resolution of disputes under this Agreement.

16.6 COSTS OF DISPUTE RESOLUTION

Unless the parties agree otherwise, the Parties shall bear their own costs of dispute resolution, and the costs of a mediator or an Arbitrator(s) shall be paid in equal shares by the parties to the dispute.

16.7 JURISDICTION OF THE ARBITRATOR(S)

The jurisdiction of the Arbitrator(s) is limited to issuing awards resolving disputes respecting interpretation, application or alleged breach of the terms of this Agreement, awards requiring compliance with this Agreement and awards requiring the performance of work in accordance with this Agreement. An Arbitrator(s) shall not have jurisdiction to issue any monetary awards or damages, penalties, accounting, costs or equitable remedies, except for the issuance of orders requiring the performance of work in accordance with this Agreement.

16.8 INTERLOCUTORY RELIEF

(a) Nothing in this Article prevents a Party from commencing judicial proceedings at any time:

- (i) to prevent a loss of a right to commence proceedings due to the expiration of a limitation period; or
- (ii) to obtain an interim order for the protection or preservation of property that is the subject matter of the dispute;

where, for any reason, it is impossible or impractical for an Arbitrator(s) to promptly resolve the matter in dispute.

(b) Neither the resolution of such court application nor the participation therein by any Party shall operate as a bar to arbitration, or as a waiver of any of the rights and obligations of any Party with respect to dispute resolution in accordance with the terms of this Agreement.

ARTICLE XVII

GENERAL PROVISIONS

17.1 REMEDIES NOT EXCLUSIVE

The rights and remedies of any Party under this Agreement are cumulative and in addition to, and not in substitution for, any rights, powers or remedies provided at law or in equity including, without limitation, pursuant to applicable environmental legislation. Any single or partial exercise by any Party of any right or remedy for a default or breach of any term, covenant, condition or agreement in this Agreement does not affect that Party's rights and does not waive, alter, affect or prejudice any other right or remedy to which that Party may be entitled for the same default or breach. Any waiver by any Party of the strict observance of, performance of, or compliance with, any term, covenant, condition or agreement of this Agreement must be in writing to be effective and any waiver or indulgence by any Party shall not constitute a waiver of any other provisions, a continuing waiver or a waiver of any subsequent default.

17.2 REVIEW AND AMENDMENT OF AGREEMENT

(a) After the fifth anniversary of the Effective Date of this Agreement and thereafter at five-year intervals, the Parties may conduct an assessment of this Agreement in Consultation with the Advisory Board.

(b) This Agreement may be amended at any time by written agreement among the Parties.

17.3 GOVERNING LAW

This Agreement is governed by and is to be construed in accordance with the laws of the Northwest Territories, and the laws of Canada applicable therein.

17.4 FURTHER ASSURANCES

The Parties shall with reasonable diligence do all things and provide such further documents or instruments as may be reasonably necessary or desirable to give effect to this Agreement and to carry out its provisions.

17.5 SUCCESSORS AND ASSIGNS

This Agreement shall enure to the benefit of and be binding upon the Parties and their respective successors and permitted assigns.

17.6 ASSIGNMENT

DDMI shall not assign this Agreement or any part of it, nor be released from its obligations or covenants under this Agreement, unless:

(a) it is determined by Canada and the GNWT that the proposed assignee has the financial capacity and qualifications, and such other capacity and qualifications as may be required, to carry out DDMI's obligations under this Agreement;

(b) the proposed assignee enters into an agreement in writing with Canada and the GNWT in which the assignee assumes all of DDMI's obligations and liabilities under this Agreement; and

(c) the proposed assignee is also the assignee of DDMI's obligations under the Regulatory Instruments and the Participation Agreements.

Provided, however, that if the requirements of Articles 17.6 (a) to (c) above are satisfied, DDMI shall be released from all and any obligations under this Agreement and the Parties shall execute and deliver to DDMI documents of release reasonably requested by DDMI.

17.7 SEVERABILITY

Any provision of this Agreement which is or becomes prohibited or unenforceable in any jurisdiction shall not invalidate or impair the remaining provisions hereof, which shall be deemed severable from any such prohibited or unenforceable provision, and any such prohibition or unenforceability in any jurisdiction shall not invalidate or render unenforceable such provision in any other jurisdiction.

17.8 MEMBER OF HOUSE OF COMMONS NOT TO BENEFIT

As required by the *Parliament of Canada Act*, it is an express condition of this Agreement that no member of the House of Commons shall be admitted to any share or part of this Agreement or to any benefit arising therefrom.

17.9 NOT A PARTNERSHIP OR JOINT VENTURE

Nothing contained in this Agreement shall be deemed to constitute the Parties or any of them partners, joint venturers or principal and agent.

17.10 LIABILITY

This Agreement in no way limits the obligations of DDMI with respect to any environmental matter relating to the Project including, without limitation, the legal obligation to undertake full mine site reclamation and post closure water treatment in respect of the Project and any other potential development within the bounds of the Project.

17.11 DDMI COMMITMENTS

For greater certainty, nothing in this Agreement shall lessen or otherwise remove any of DDMI's Commitments.

17.12 REVIEW OF AGREEMENT

The Parties agree to review, and amend if necessary, this Agreement when the Land Leases are fully executed and the Water Licence is issued to DDMI, to address any conflicts or inconsistencies.

17.13 DDMI AS MANAGER

DDMI represents and warrants that it is the manager of the Project in accordance with the terms of the Joint Venture Agreement and that the terms of the Joint Venture Agreement entitle DDMI to enter into this Agreement and carry out its obligations hereunder.

17.14 FORCE MAJEURE

Except in respect of matters of a serious and imminent threat to the environment in which case this Article 17.14 will not apply, in the event that DDMI is delayed or hindered in or prevented from the performance of its obligations under this Agreement by reason of an event beyond the reasonable control of DDMI, including, without limitation, strikes, inability to procure materials or services, civil commotion, sabotage or act of God, then obligations under this Agreement that are not fulfilled by DDMI as a direct result of such delay or hindrance shall not constitute a default under this Agreement during the period of such delay or hindrance.

17.15 SUSPENSION OF OPERATIONS

DDMI may curtail, suspend or interrupt operations as it sees fit, and during such period of curtailment, suspension or interruption, DDMI shall be excused from the performance of its obligations hereunder to the extent considered reasonable by the Minister in Consultation with the Advisory Board.

17.16 NOTICES

Any notices or communications required or permitted to be given pursuant to this Agreement shall be in writing and shall be delivered, during normal business hours, to, or sent by prepaid registered or certified mail, or confirmed facsimile addressed as follows:

1) In the case of a notice or communication to the Minister:

Department of Indian Affairs and Northern Development
P.O. Box 1500
Yellowknife, NT
X1A 2R3
Attention: Regional Director General
Telephone: (867) 669-2501
Facsimile: (867) 669-2703

2) In the case of a notice or communication to the GNWT:

Government of the Northwest Territories
P.O. Box 1320
Yellowknife, NT
X1A 2L9
Attention: Deputy Minister
Resources, Wildlife and Economic Development
Telephone: (867) 920-8691
Facsimile: (867) 873-0563

3) In the case of a notice or communication to the Government of Nunavut:

Government of Nunavut
P.O. Box 1340
Iqaluit, NU
X0A 0H0
Attention: Deputy Minister
Sustainable Development
Telephone: (867) 979-5900
Facsimile: (867) 975-5982

4) In the case of a notice or communication to DDMI:

Diavik Diamond Mines Inc.
P.O. Box 2498
Yellowknife, NT
X1A 2P8
Attention: Vice President - Environmental Affairs
Telephone: (867) 669-6500
Facsimile: (867) 669-9058

5) In the case of a notice or communication to Dogrib Treaty 11 Council:

Dogrib Treaty 11 Council
P.O. Box 412
Rae-Edzo, NT
X0E 0Y0
Attention: Grand Chief
Telephone: (867) 392-6381
Facsimile: (867) 392-6389

6) In the case of a notice or communication to Lutsel K'e DeneBand:

Lutsel K'e Dene Band
P.O. Box 28
Lutsel K'e, NT
X0E 1A0
Attention: Chief
Telephone: (867) 370-3051
Facsimile: (867) 370-3010

7) In the case of a notice or communication to Yellowknives Dene First Nation:

Yellowknives Dene First Nation
P.O. Box 2514
Yellowknife, NT
X1A 2P8
Attention: Chiefs
Telephone: (867) 873-4307
Facsimile: (867) 873-5969

8) In the case of a notice or communication to North Slave Métis Alliance:

North Slave Métis Alliance
P.O. Box 340
Yellowknife, NT
X1A 2N3
Attention: President
Telephone: (867) 873-9176
Facsimile: (867) 669-7442

9) In the case of a notice or communication to Kitikmeot Inuit Association:

Kitikmeot Inuit Association
P.O. Box 18
Cambridge Bay, NU
X0E 0C0
Attention: President
Telephone: (867) 983-2458
Facsimile: (867) 983-2701

10) In the case of a notice or communication with the Advisory Board:

> The Advisory Board shall give notice of its address to the Parties and the Government of Nunavut as soon as is practicable.

or at such other address as any Party or the Government of Nunavut may from time to time advise the other Parties, the Government of Nunavut, and the Advisory Board by notice in writing. Any notice given by personal delivery shall be deemed to be received on the date of delivery. Any notice sent by fax shall be deemed to have been received on the next day following receipt by the sender of confirmation of completion or transmission that is not a Saturday, Sunday or statutory holiday in the NWT.

17.17 COUNTERPARTS

This Agreement may be executed in counterparts each of which shall be considered an original and all of which taken together shall constitute a single agreement. The Parties may rely upon copies of this Agreement which are delivered by facsimile as if such copies were originals.

ARTICLE XVIII

TERM

18.1 TERM

(a) Subject to Article 18.1 (c), this Agreement shall come into effect upon signing by at least DDMI, GNWT and Canada (the date upon which such a signing occurs being called the "Effective Date").

(b) This Agreement shall become binding upon and shall enure to the benefit of each of the other Parties if, as and when they sign this Agreement.

(c) Subject to Article 18.1 (d), the provisions of Articles IV, VI, VII, VIII, XII and XIV shall not come into effect unless and until the Land Leases have been fully executed and the Water Licence and all other Regulatory Instruments to commence construction of the Project have been issued to DDMI and DDMI has given written notice to the Minister of its intention to proceed to construct and operate the Project.

(d) DDMI may unilaterally waive the condition in Article 18.1 (c).

18.2 This Agreement shall terminate upon full and final reclamation and abandonment of the Project site, in accordance with the requirements of all Regulatory Instruments and the terms of this Agreement and completion of any and all post-closure monitoring and maintenance required in connection with the Project.

18. 3 Once DDMI has ceased Commercial Production at the Project, the Minister may, in his/her discretion, and following Consultation with the Parties and the Advisory Board, do either or both of the following:

(a) relieve DDMI of its responsibilities and obligations arising from this Agreement to the extent deemed by the Minister to be reasonable in the circumstances; and

(b) set a schedule for winding down and concluding the operation of the Advisory Board.

IN WITNESS WHEREOF the Parties have caused this Agreement to be executed in their respective names by their duly authorized representatives

DIAVIK DIAMOND MINES INC.

By: ______________________ c/s

By: ______________________

Robert D Nault

Minister of Indian Affairs and Northern Development, on behalf of Her Majesty The Queen in right of Canada

Clint Davis

Witness

for

Minister of Resources, Wildlife and Economic Development on behalf of the Government of the Northwest Territories

Witness

Grand Chief
Dogrib Treaty 11 Council

Witness

Sept 24/2001

Chief
Lutsel K'e Dene Band

J B R Pierre Catholique

Witness

Dec 11/00

Chief
Yellowknives Dene First Nation

Rachel Ann Crapeau

Witness

President
Kitikmeot Inuit Association

Witness

President
North Slave Metis Alliance

Kathy Arden

Witness

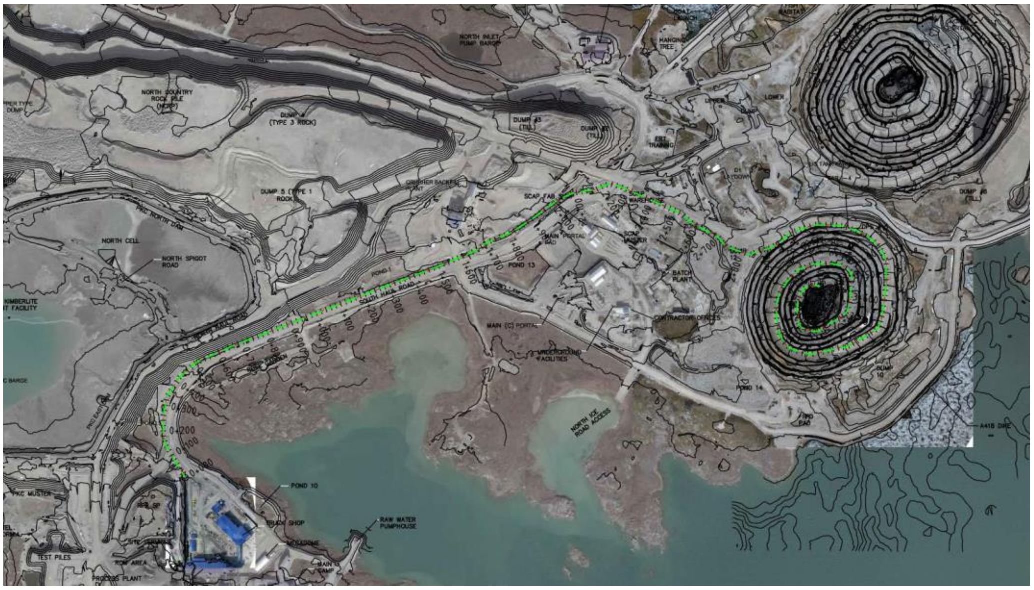
SCHEDULE 1

(millions)

	(A)	(B)	(C)
	Life of Project Closure Costs	Amount of Additional Security Deposit	DDMI Projected Cumulative Progressive R&A Expenditures
2000	C$15	C$0	C$0
2001	C$20	C$0	C$0
2002	C$25	C$0	C$0
2003	C$40	C$10	C$0
2004	C$48	C$26	C$2
2005	C$56	C$43	C$4
2006	C$65	C$59	C$6
2007	C$74	C$75	C$8
2008	C$80	C$103	C$12
2009	C$86	C$102	C$18
2010	C$92	C$101	C$21
2011	C$98	C$98	C$23
2012	C$103	C$95	C$26
2013	C$105	C$95	C$28
2014	C$107	C$105	C$37
→ 2015	C$109	C$103	C$39
2016	C$111	C$101	C$41
2017	C$113	C$99	C$43
2018	C$115	C$97	C$45
2019	C$117	C$95	C$47
2020	C$119	C$93	C$49
2021	C$121	C$91	C$53
2022	C$123	C$89	C$57
2023	C$123	C$79	C$87
2024	C$123	C$59	C$111
2025	C$123	C$39	C$116
2026	C$123	C$19	C$117
2027	C$123	C$10	C$118
2028	C$123	C$10	C$119
2029	C$123	C$10	C$120
2030	C$123	C$10	C$121
2031	C$123	C$10	C$122
2032	C$123	C$10	C$123

Review of Diavik's Water Licence Amendment

DDMI Responses to WLWB Information Request re: Water License W2015L2-0001 Amendment Request



Final Report to

Environmental Monitoring Advisory Board (EMAB)

By

Randy Knapp

Original Report-December 2018

Updated February 25, 2019

EXECUTIVE SUMMARY

Diavik has applied to the Wek'èezhìi Land and Water Board (WLWB) to amend their operating licence. The key aspects of the amendment include the provision for placement of processed kimberlite into the mine voids and to extend the licence by 2 years to 2025 coinciding with the end of commercial operations. Following review of the Application, the Wek'èezhìi Land and Water Board (WLWB) on 31 August 2018, the Board determined that there was insufficient information available on the record to inform a preliminary screening and requested additional information. This additional information has been reviewed and the key findings from this review are summarized in the report originally issued in December 2018.

Since the December 2018 report, Technical Meetings have been held and Diavik has responded to numerous IRs. This revised report reflects changes that arise from the information provided at the Technical sessions and IR responses by Diavik.

In general terms, Diavik has provided a response to all issues and requests raised by the WLWB. However, the initial responses did not adequately address all issues and concerns. The key findings from this review include:

1. The ICRP has stated that all of pits once flooded would remain stratified (meromictic) with a stable layer of dense salty water at depth. Modelling has indicated this will not be the case and will need to be clarified in the updated Closure and Reclamation Plan (CRP). *This is a significant finding and this change was addressed by Diavik (see response to IRs on meromixis).*
2. Modelling was used to assess the effects of the PK disposal in all three pits at Diavik mine on the water quality in Lac de Gras. The model predicts that the depth of water cover is important with greater depths of water cover having less mixing and producing more stable stratification. In all cases, some contamination from depth enters Lac de Gras and over the very long term (more than 100 years), it is expected (although not stated) that the stratification will eventually break down. *Diavik is now only considering PK disposal from ongoing operations and is no longer including the potential for the relocation of slimes from the surface PKC facility. It is my opinion that relocation of the slimes should be considered.*
3. There is limited site-specific data for calibration of the model. The User Manual (Cole and Scott 2015) states "*Results will be suspect at best and will not withstand scrutiny at worst if the model is applied with insufficient and/or inadequate calibration data*". Although this model is an excellent tool, given the warning by the authors of the user manual, one need to cautious when placing great emphasis on the results when calibration data are inadequate/insufficient. *Diavik has undertaken a number of sensitivity analyses based upon EMAB concerns regarding model calibration. The results indicate that model predictions from the sensitivity analysis were not materially different but accept additional data will be collected and more detailed assessment completed as the project advances.*
4. Given the concern with calibration, one need to assured that if the model is wrong and the lake mixes, that the results will not be catastrophic. This could be the case if metal levels were much greater than projected in the PK porewater, or if reducing conditions at depth lead to oxygen depletion. Mixing under these conditions, even if only persisting for a short period, could have significant impacts on water quality and fish. *Diavik has now completed assessments of unplanned mixing of the pit lake including the potential effects of low oxygen levels on fish. The overall*

conclusions are that impacts will be minimal and no significant environmental effects are likely to occur. We have no basis to disagree with the Diavik assessment.

5. It is unclear how the pit will be filled with water and this could have a material effect on the initial water quality in the pit. One would expect in order to not disturb the PK upon flooding that a layer of several meters of PK slurry water would need to be present over the PK. This process water would be similar to PK porewater and would mix with the Lac de Gras water used to flood the pit. The model assumes that Lac de Gras water is placed and does not mix in any way with the PK or PK process water. This is not a rational assumption as used in the model. *Diavik in the responses have addressed the effect of various depths of PK porewater at the start of flooding on the water quality in the pit Lakes. Diavik has demonstrated the effects are not significant*.
6. The model assumes that there is an ongoing displacement of porewater as the PK settles. The rate of consolidation has not been measured but was estimated based upon the properties of the PK. Consolidation testing would have been useful to confirm the rate of porewater release to the stratified layer over time, however, this is likely not a significant deficiency. *Diavik is proposing to complete some consolidation testing. It is our opinion the model, as it currently used, is conservative and likely overestimates the loading of porewater to the pit lake.*

Having stated the above, the primary concern from the December 2018 review was how Lac de Gras water quality would be affected if the model is not accurate and the pit lakes turn over. Diavik has subsequently addressed this issue and we are satisfied that environmental effects will not be significant and will be of a relatively short duration.

1.0 INTRODUCTION

1.1 Overview

Diavik has applied to amend their Water Licence (W2015L2-0001) to allow Processed Kimberlite (PK) to be placed into former mine workings at the Diavik Mine. Diavik is also asking to extend the Water Licence term from 2023 to 2025 and to make administrative changes. The Wek'èezhìi Land and Water Board (WLWB) distributed the application on June 15, 2018. Proponent responses were received by the WLWB August 23. On August 31, 2018 the WLWB determined insufficient information was available on the record to inform a preliminary screening decision and they issued an Information Request (IR) to Diavik. Diavik responded to the IR on November 6, 2018 and the WLWB distributed the item for review.

In this regard, EMAB is conducting a review of the application and has requested that Randy Knapp to prepare a report to address specific aspects of the Diavik licence amendment.

1.2 Scope of Work

The scope of work was to complete a technical review of Diavik's Responses to the IR and comment on:

- How well did the IR response address issues identified during the review of the original application?
- Have any additional information gaps been identified?
- Water quality predictions for each pit under the scenarios examined.
- The assessment of meromixis under the model scenarios examined.
- Other potential environmental impacts of the project that require further investigation, and a description of information needed to allow assessment of the environmental effects.

This revised report also addresses how our concerns were addressed by Diavik in their responses and whether the responses are considered adequate. Key changes to the December report are noted in italics.

2.0 FINDINGS

The findings from this review are organised under the following headings.

- Meromixis and its Long Term Stability
- CE-QUAL-W2 Model and Calibration
- Model Inputs
- Fatal Flaws

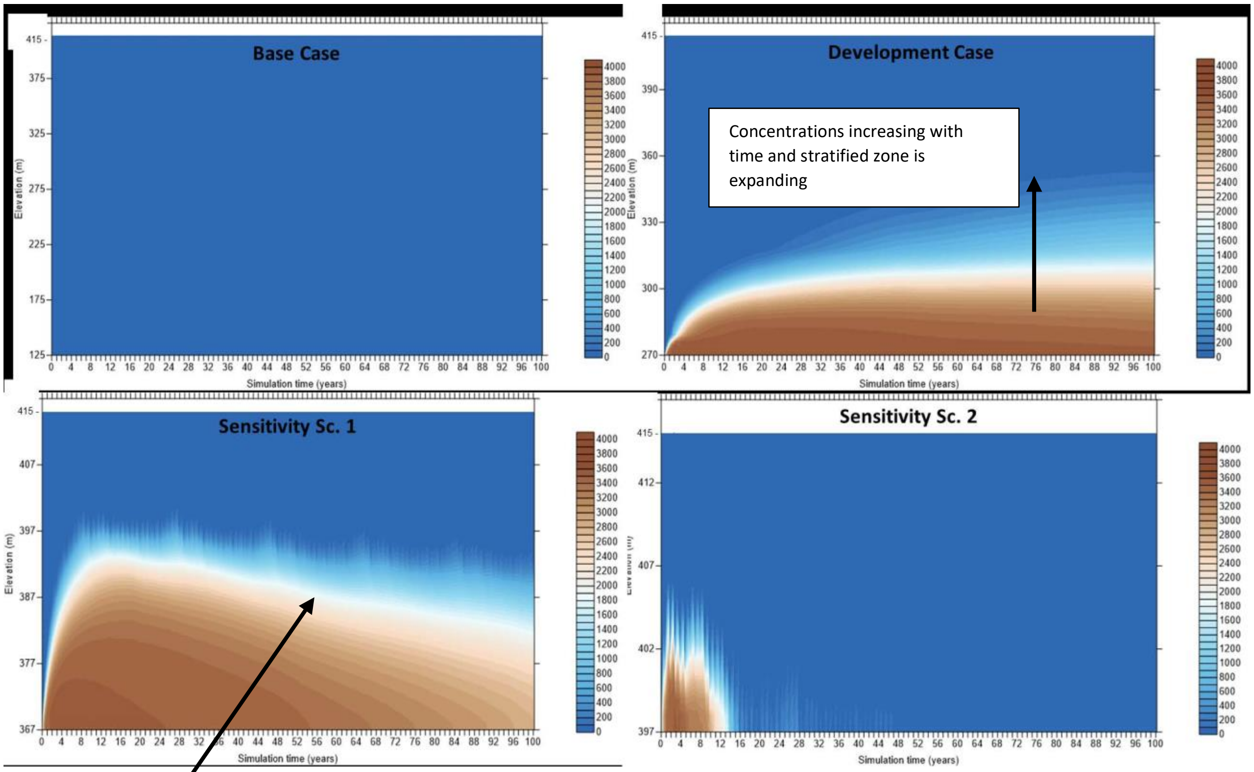
2.1 Meromixis and Long Term Stability

The ICRP has maintained for many years now that the pit lakes will be stratified at closure. Specifically, Diavik has stated on page 104 CRP V4 "For these reasons, DDMI continues to prefer a closure design that enhances a meromixis condition instead of one that weakens the meromixis condition. There does not appear to be sufficient rationale for further consideration or research related to options that weaken meromixis, as such none is planned."

The recent modelling completed by Golders has indicated that the none of the flooded pits are projected to be stratified and will be fully mixed. This is a major divergence from all previous comments yet is never acknowledged in the responses. Diavik need to address this material change.

Diavik responded that the contributions of saline groundwater for the base case with no PK added assumed the pits would be rapid filled and under these conditions, meromixis would not form. The ground water inflows over the long term would not be a material source of salinity once the pit lakes are flooded given there will be no hydraulic head to transport saline groundwater into the pit. The Diavik response is satisfactory.

Model results have shown that the meromixis is stable in the short term for water covers of 50m and 150m. However, overtime the high salinity layer at depth is diluted and mixes with overlying waters. For example, as shown in Figure 10 (reproduced on the following page), with the 20 m water cover over PK in the breakdown in complete in about 12 years with the lake fully mixed. For the 50 m water cover, the stratified layer expands rapidly over the first 8-12 years followed by a slow but steady dilution of the layer with Lac de Gras surface water. Based upon the trend shown, it is likely full mixing will occur in the next 50 to 100 years after the initial 100 years shown on the Figure 10. With the 150 m deep water cover, the stratification is much stronger however, stratified layer continues to mix with overlying waters and it is anticipated that in the future, this layer will eventually mix with Lac de Gras.



Concentrations increasing with time and stratified zone is expanding

Figure 10: Contour Plots of Predicted Total Dissolved Solids Concentrations in the A154 Pit Lake over the Simulation Period (100 years Post-Closure)

Note that the concentrations in the stratified layer are continuously reducing indicating dilution with Lac de Gras surface water.

The quality of the water in the stratified layer is of major concern if this layer was to mix with surface water in Lac de Gras. The layer will contain essentially all of the porewater released from PK consolidation and could also be anoxic (no oxygen). Mixing of this mass of porewater with the surface water could have a material impact on water quality and fish in the pit lake. The mixing of the stratified water with Lac de Gras was modelled and indicated some elevated levels of several contaminants. The report suggests this will be a short- term issue however this has not been demonstrated. The base case suggested mixing is most likely to occur in October just prior to freeze up. It will therefore be important to model water quality for this period to assess how long elevated conditions exist and whether this will have any impact on fisheries.

Since the December 2018 report, Diavik has undertaken assessments of the unplanned mixing of the pit lake. The results suggest that there will no significant impacts and we have no basis to doubt these findings. The greatest concern originally raised was the impact of mixing anoxic water and this aspect was specifically addressed by Diavik. The key point identified by Diavik is that that although dissolved oxygen levels would be reduced, the levels once blended with surface water would not be zero such that major impacts are not predicted. Fish would tend to avoid areas with lower DO and likely would leave the immediate areas where low DO occurs. The Diavik response is satisfactory.

2.2 CE-QUAL-W2 Model and Calibration

Golders have used the CE-QUAL-W2 Model to assess the effects of PK placement in the Diavik pits. This model is well known and is used extensively. With all models, results are often highly dependent upon the quality of data available used in the model.

The User Manual (Cole and Scott 2015) states “Results will be suspect at best and will not withstand scrutiny at worst if the model is applied with insufficient and/or inadequate calibration data.” As noted by Golder in the modelling report, “*because the pit lake is not yet constructed, model calibration is not possible*”. In lieu of calibration data for the pit lake, Golder used data from other regional modelling studies. The most recent of the of the studies referred to was Vandenberg et al. 2015. It is noteworthy that the authors of this study note for “the calibration was considered to be approximate because the true values of a large proportion of the measured data were not known. All of these inputs and assumptions carry inherent variability and uncertainty, which impose and propagate uncertainty on model predictions.*”*

Although we have a useful tool, it is clear that calibration is essential for reliability of the predictions. **Given the caution expressed by both the Users Manual and Vandenberg et al. 2015 regarding model calibration, one needs to treat the model results with a bit of skepticism and adopt a cautious approach. Diavik should complete sensitivity analyses for a range of potential inputs to the model (e.g. meteorological conditions, lake temperature, porewater quality, dissolved oxygen content, etc.).**

In this regard, Diavik has completed a sensitivity analysis and the results indicate there was no material changes in the sensitivity model runs. Should the amendment be approved, additional more detailed modelling is proposed. The Diavik response is satisfactory.

2.3 Model Inputs

2.3.1 Consolidation Model

The model assumes that there is an ongoing displacement of porewater as the PK settles. The rate of consolidation has not been measured but was estimated based upon the properties of the PK. Consolidation testing would have been useful to confirm the rate of porewater release to the stratified layer over time. It is uncertain how this would affect the model results; however, this is likely not a significant deficiency.

2.3.2 Initial Conditions

The initial conditions for the modelling exclude groundwater inputs or contributions of source contaminants from wall rock. Saline groundwater inputs were understood to be the primary source of high salinity water that would result in the stratification of the pits. Previous modelling was completed to assess the impacts of wall rock on pit water quality. It is not clear why one would exclude these sources of contamination into the model. **Certainly, for the cases where PK is placed into the pits, pit wall rock contributions are likely insignificant. However, groundwater will continue to be a material source of TDS until such time as the pits are flooded and hydraulic gradients to the pit are diminished. Diavik should defend why groundwater was not included as a source of salinity to the pits for all cases modelled. (***see previous comments related to saline groundwater inputs***)**

It is unclear how the pit will be filled with water and this could have a material effect on the initial water quality in the pit. The model assumes the start conditions is a pit lake filled uncontaminated Lac de Gras water. **One would expect in order to not disturb the PK upon flooding that a layer of several meters of PK slurry water would need to be present over the PK. This process water would be similar to PK porewater and would mix with the Lac de Gras water used to flood the pit. The model assumes that somehow, Lac de Gras water is placed and does not mix in any way with the PK or PK process water. This is not a rational assumption as used in the model. Diavik should rerun the model with the start conditions including an initial of a layer of process water mixed with Lac de Gras water.**

Since the December report, Diavik has run the model with various depths of porewater present over the PK at the time of flooding. The results confirm there is no material impact of having a layer of porewater over the PK at the time of flooding. The Diavik response is satisfactory.

2.4 Fatal Flaw Assessment

It is not known at this time whether there are any fatal flaws. The primary concern remains how Lac de Gras water quality would be affected if the model is not accurate and the pit lake turns over. Diavik need to address this to assure everyone that a major impact will not occur the water quality and fish in Lace de Gras.

Diavik has now completed the assessment of the what if scenario where it is assumed that the pit lake will turn over and will become mixed with the PK porewater. The results demonstrate there is no significant environmental impact. Most effects are of relatively short duration as the pit lake is flushed with Lac de Gras water. The Diavik response is satisfactory.

3.0 ADDITIONAL COMMENTS REGARDING 11 FEBRUARY IR RESPONSES BY DIAVIK

Diavik has withdrawn from the current amendment the remining of 5 Mm^3 of slime tailings from the PKC. Although the option for relocation may occur in future, it is my opinion that the real benefit to PK disposal in the pits is the relocation of the slime tailings. This allows for a dry closure concept for the PKC and eliminates the long-term concern over care and maintenance of the surface pond and spillway.

As requested, Diavik completed model runs with the placement of and additional 5Mm^3 of slimes. The predicted surface water quality remains below AEMP benchmarks for all parameters at both surface and 40 m depth suggesting that the slimes could be placed into pit A418 after PK placement with no material effects to water quality in the pit or Lac de Gras. ***It is suggested that Diavik be required to evaluate the relocation of the slimes to the pit as a condition of licence and provide justification as to why re-mining of the slimes for disposal in the pit should not be undertaken.***

It is also unclear why Diavik have requested the flexibility to use any of the three pits. Does this suggest that in future Diavik will retain the option of using more that one of the pits for PK disposal? ***It would not be unreasonable to approve PK disposal in the A418 pit and require an amendment to allow for PK disposal in other pits.***

4.0 RECOMMENDATIONS FOR LICENCE CHANGES/REQUIREMENTS

Diavik has outlined the studies and plans they proposed being included in Water Licence W2015L2-0001. The list as outlined appears reasonable. Diavik has also proposed a post-closure monitoring program. It is our opinion that the program is in general acceptable. ***The one potential deficiency relates to how Diavik will demonstrate and confirm the stability of meromixis and the location/stability of the chemocline.***

5.0 CLOSURE

We trust this draft report addresses your requirements. It is my opinion that the information provided by Diavik is essentially complete and adequate to support the use of the Mine openings for PK disposal.

Should you require clarification or additional information please contact the writer at your convenience.

Yours truly

Randy Knapp

R. A. Knapp P. Eng.

Environmental Consultant, Mining

REFERENCES

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Photo reproduced from Diavik ICRP V4

Review DIAVIK Version 4 Closure and Reclamation Plan

FINAL REPORT TO
ENVIRONMENTAL MONITORING AND ADVISORY BOARD
AUGUST 2017

By Randy Knapp

SIMPLE LANGUAGE SUMMARY

Diavik has submitted Version 4 of the Interim Closure and Reclamation Plan for the Diavik Diamond Mine. The closure plan is similar to previous versions and has been updated to reflect more recent information and revisions to the closure concepts. Details of meetings held with the communities and TK Panel are also included.

The Interim Closure and Reclamation Plan includes some new information. This includes:

- A preliminary plan for revegetation of the site. The vegetation plan as discussed with the TK Panel will focus on target areas disturbed by infrastructure (for example roads). The plan is to smooth these areas to eliminate animal barriers and hazards, roughen the soil and vegetate as appropriate. Caribou trails are to be left with smooth surfaces for safe migration across the site.
- The PK closure plan has been updated but the plan contains many uncertainties. These include: the quality of the pond water and seepage; the stability of the cover and pond shoreline; and whether the plan can be implemented as proposed.
- The plan includes an estimate for the long term monitoring, care and maintenance of the site after closure. The current plan calls for Diavik to leave the site in 2032 however there will remain a long term need for care and maintenance of the site. Diavik's preliminary estimate is that the costs could exceed half a million dollars per year. Who pays these costs remains to be clarified?
- The North Inlet sediment is contaminated with hydrocarbons which appear to originate from the underground mine. The sediment is currently toxic and as a result the plan is to retain the dam that isolates the North Inlet and include a porous section in the dam that allows water to flow through the structure but blocks fish access.
- Diavik also indicated they are investigating options for management of the processed kimberlite. Options include disposal in the open pits or underground mines and possible removal of the fine processed kimberlite from the existing containment. The results of this review will be used to update the final design for closure of the Processed Kimberlite Containment.
- Information was also provided on the fate of potentially acidic waste rock (Type III) that was misclassified and placed in several areas outside the approved locations. The result suggests that the majority of the material is unlikely to be of issue but one area with about 6000 m^3 was identified and will be the subject of additional study. Given the small quantity it makes more sense to simply pick up this material and dispose of it in the North Waste Rock Pile.

Contents

1.0 INTRODUCTION

1.1 Overview

Diavik submitted Version 4.0 of its Closure and Reclamation Plan (CRP) on April 20, 2017. The Wek'èezhìi Land and Water Board (WLWB) completed their conformity check with the Water Licence and distributed the CRP for review on May 19, 2017. This revised Interim CRP contains material changes to a number of sections.

1.2 Scope of Work

Randy Knapp was requested to undertake a technical review of the Diavik Version 4 CRP. The review of the CRP Version 4.0 and Appendices I – XIII will consider Diavik's Type A Water Licence, outstanding requirements from the WLWB, and any EA requirements. Mr. Knapp will use knowledge of current best practices for mine closure and reclamation, including use of Traditional Knowledge and community participation, and comment on the following:

Item 1- Significant changes from ICRP Version 3.2 to CRP Version 4.0

Item 2- Practicality and achievability of the closure plan for the five different mine components with attention to:

- o Appendix X-5 PKC Closure Design Concept
- o Appendix X-6 North Inlet Closure Options

Item 3- Adequacy and achievability of closure objectives and criteria

Item 4 Flaws, risks, uncertainties

Item 5- Long-term issues that could arise

Item 6- Areas that require further research

Item 7- Appropriateness of expected closure and reclamation costs

Section 2 addresses items 1 to 7. Section 3 of the report includes miscellaneous comments. Appendix 1 includes details of the current issues and concerns associated with the Processed Kimberlite Containment Facility (PKC).

2.0 TECHNICAL REVIEW VERSION 4- DIAVIK ICRP

The following section reviews key aspects of the Diavik Closure plan. The report addresses the specific items as outlined in the scope of work.

2.1 ITEM 1- SIGNIFICANT CHANGES FROM ICRP VERSION 3.2 ICRP VERSION 4.0

The following are some of the key changes that are included in the Version 4 ICRP.

- A general approach to re-vegetation at the mine site has been presented. The plan includes an identification of the target areas and a listing of the potential vegetation methods. The plan also includes for the first time a budget vegetation allowance in the RECLAIM model.
- A preliminary budget for post closure care and maintenance of the site. This has been requested by EMAB and is believed to be the first time a mining proponent has provided an estimate of the potential costs for long term care and maintenance of a mine site post closure. Who will pay for these costs remains a material issue. Diavik has not assumed responsibility for long term care.
- Revised closure plan for the North Inlet (NI). The original plan was to breach the main dam to allow fish access. Given the current issue with hydrocarbon contaminated sediments, this option no longer appears to be acceptable and as such a permeable barrier which blocks fish access and allows water to flow in and out of the NI is proposed.
- Potential changes to the closure of the Processed Kimberlite Containment Facility (PKC). The PKC closure plan remains a concern (see Item 2a).
- Updated predictions of post closure water quality.
- Presentation of preliminary results of metals uptake in vegetation. Initial results suggest this is not a material issue however some additional R&D programs are underway.
- Updates to Section 3 -Project Environment to bring the tables and figures up to date (e.g. climate data).
- Provided some 3-dimensional figures of how the mine site will look at closure.

The ICRP continues to develop and is improved over previous versions. Uncertainty remains and these aspects are being addressed in the Reclamation Research Plans.

2.2 ITEM 2- PRACTICALITY AND ACHIEVABILITY OF THE CLOSURE PLAN

2.2.1 The Processed Kimberlite Containment Facility

The PKC closure will involve the placement of 2m of waste rock over the surface of the exposed PK. The PKC will retain a central pond and drainage ditch to a spillway located in the dam. The pond will overflow to Lac de Gras. There remains uncertainty in the long term success and performance of the plan (see Appendix 1-PKC Closure). The uncertainties include:

- Water quality in the pond post closure. Preliminary modelling was completed but the results remain uncertain.
- Long term stability of the cover. Issues include:
    - Potential for piping of fine PK through the cover.
    - Differential settlement of the cover.
    - Stability of the cover under earthquake loading
    - Future thawing and settling of the cover due to climate change
    - Long term care and maintenance of surface ditches and spillway
    - Long term repair and maintenance of the rock cover.
    - Uncertainty in water balance

Appendix 1 includes more detail on the issues related to the closure of the PKC. It is noteworthy that Diavik is considering modifications to the PKC closure concept. These modifications include but are not limited to placing FPK/CPK in a completed open-pit/underground mine and/or not leaving a pond at closure.

2.2.2 North Inlet

The North Inlet served as the central collection point for site drainage and the sludge disposal from the NI treatment facility. The original closure plan was to breach the Main dyke and allow fish passage into the inlet. Monitoring and toxicity testing has indicated that the bottom sediments are contaminated with hydrocarbons. The primary source appears to be from spillages in the underground mines. The monitoring data suggest the sludge is toxic to some benthic species and as such is currently not suitable fish habitat.

A detailed alternatives analysis was completed to assess the options for cleanup of the bottom sediments. Options ranged from removal to cover to do nothing. Given the high cost of alternatives, Diavik recommended that sediments remain in place in the NI and that the closure plan be revised. The revision would be to keep the NI isolated from fish passage but to provide a pervious section in the NI dam that allows water to pass into and out of the NI. The potential to breach the dam remains an option should sediment quality improve. The final decision would be made after completion of a post closure sediment survey.

The issues at present include:

- No information was provided on the stability of the sediment and the potential or time period for natural degradation of the hydrocarbon. (is there a potential that the sediment quality will improve over time?).

2.2.3 North Waste Rock Pile (NWRP)

A review of the NWRP was previously completed. For detailed comments refer to R. Knapp Technical Memorandum of June 6, 2017.

Development of the South Country Rock Pile (SCRP) WRSA will commence with the pre-stripping of the A21 pit late in 2017. Closure plans for the SCRP-WRSA are not available for ICRP V4.

One of the outstanding issues remains the future handling of the Type III rock from the A-Portal. Diavik recently provided a report on 3 July 2017 "Portal Waste Rock Misclassification" which provides their proposed action plan to deal with the rock. In general seepage monitoring will be used to identify if any areas produce contaminated drainage. The report identified about 6,100 m^3 of potential Type III waste rock that was deposited East of the Waste Transfer. This was the only area visually identified as potentially having material quantities of Type III waste rock. Diavik propose to drill and sample this area to assess the ARD potential. Our recommendation would be to excavate and dispose of this material as the cost is unlikely to be greater than drilling and sampling.

2.3.4 Open Pits and Underground Mines

Open Pits

The open pits are proposed to be flooded with Lac de Gras water and monitored. When water quality is acceptable, small breaches of the dykes will be made to allow for navigation and fish passage. The pits will include fisheries habitat enhancement per agreements with Fisheries and Oceans Canada.

The closure concepts for the pits are reasonable and likely to perform as expected. The one issue that remains is the stability of the stratified pit (meromixis). The bottom layer of the pit will be salty and more contaminated and as such could impact surface water quality if the pit lake was to mix. Modelling suggests that the meromixis will be stable however this remains to be demonstrated at closure.

The TK panel raised concerns regarding wildlife access and egress from pit A418. Diavik have included an additional ramp in pit A418 shoreline to facilitate wildlife movement.

The open pits are also under study as a potential receptor for PK. The primary advantage would be to allow early closure and monitoring of the surface PK pile.

Overall, the proposed closure plans for the open pits is rational and supported by the information provided.

Underground Mines

The underground mines will be decontaminated and salvageable equipment removed then flooded. Surface openings will be sealed to prevent access. The flooded mines are not expected to be a long term source of contamination. As with the open pits, Diavik is considering the potential for the disposal of PK in the underground mines. This is likely to be far more costly and difficult as compared with surface disposal in the existing facility or in open pits however is worthy of investigation.

The proposed closure concept is rational and supported by the available information.

2.3.5 Surface Infrastructure

The removal of all equipment, buildings, pipelines, power lines and other items for resale/reuse where practical;

• removal of all hazardous materials- The plan is to haul materials off-site for disposal. Hydrocarbon contaminated soils will be managed on-site although a final management plan for hydrocarbon treated soils has not been finalized. The current proposal is disposal within the permafrost zone of the landfill or PKC.

• salvageable materials recycled where practical.

• materials that are not reused or recycled safely disposed of on-site. The mine currently has an approved landfill in the NWRP. Diavik is also considering the option of disposal of inert waste (e.g. building rubble) in the open pits. A final landfill strategy is not in place.

• materials that cannot be safely disposed of on site would be hauled to approved off-site facilities.

• foundations and concrete slabs covered with rock. There are no plans to vegetate these areas.

• fuel tanks removed;

• roads, laydowns, plant sites, airstrip scarified and targeted re-vegetation.

Diavik has had extensive discussions with the TK panel and communities on the final vegetation strategy. Key actions arising from these discussions include:

- Use of amendments to enhance vegetation is accepted as a potential necessary requirement for the disturbed areas.
- Vegetation efforts for the NWRP should focus on the collection ponds.
- Re-sloping of the road berms over natural ground to facilitate wildlife movement and safety.
- Retaining areas where surfaces are smooth and not scarified to facilitate wildlife movement.

Overall the proposed plans for closure of the mine infrastructure are rational. The current plan to scarify the airport runway at closure should be reviewed. The runway is an asset to the area and the TK panel has suggested it should be retained.

The primary issue is the extent of the proposed vegetation as compared with the total disturbed area. Based upon Table 9-3, as of 2018 a total of 1157 ha of area will be disturbed by the mine. Total vegetated area as indicated in the RECLAIM estimate is 131 ha or 11% of the disturbed area.

2.3 ITEM 3-ADEQUACY AND ACHIEVABILITY OF CLOSURE OBJECTIVES AND CRITERIA

The closure objectives and criteria are the focus of other reviewers. A detailed report by Slater "Closure Criteria Recommendations Diavik Mine" March 21, 2017 provides an excellent review.

The proposed change to eliminate closure objective N-1-Reconnection of the North Inlet with Lac de Gras is not accepted. Although the current belief is this may not be possible due to the presence of hydrocarbon in the sediment, this remains the overall objective.

2.4 ITEM 4-FLAWS, RISKS, UNCERTAINTIES

No fatal flaws have been identified. The greatest risks and uncertainty are associated with the closure of the Processed Kimberlite Containment facility. Concerns include:

- Uncertainty in pond and seepage water quality. The primary source of metals in porewater is believed to be associated with the oxidation of sulphides in the unsaturated PK. The unsaturated zone may well be much deeper than modelled increasing metal loadings in seepage and to the pond.
- AMEC Appendix X-5 identified a number of uncertainties including:
    - *Post-closure thermal conditions, particularly as they relate to long-term seepage control. This uncertainty impacts on the post-closure hydrology of the facility, the ability to retain a pond and the location of any releases of pond water to Lac de Gras.* Based upon this statement, there is no guarantee that the pond can be maintained. If not, the fine PK will be exposed.
    - *Closure thermal conditions of beaches and semi-fluid FPK material. This uncertainty relates to the ability to place materials for beach erosion protection and shoreline stability protection over areas with high semi-fluid FPK content.*
- Stability of the cover placed on unconsolidated PK during seismic events. Implications for long term maintenance and the potential for loss of PK to the environment.

There is a Reclamation and Research plan in place to address some of these issues but the work has been delayed to 2020. This work would appear to be critical to confirm the concept and needs to proceed.

2.5 ITEM 5-LONG-TERM ISSUES THAT COULD ARISE

The current schedule for closure assumes that the mine will close in 2025 and final closure works implemented post 2025 with all work and monitoring completed by 2032. Financial assurance is allotted for completion of the work and monitoring to 2032. Diavik has assumed that their responsibility for the site ends in 2032. Beyond 2032 there are a myriad of issues that could arise and a number of care, maintenance and monitoring requirements. These will include:

- Geotechnical Inspection of Dams (e.g. PKC) per Canadian Dam Safety Guidelines.
- Care and maintenance of PKC ditches and spillway.
- Care and maintenance of the rock covers on the NWRP and PKC
- Environmental Monitoring
- Repair/replacement of instrumentation (e.g. thermistors, inclinometers)

There is also the potential that predictions for seepage quality and pond water quality in the PKC and possibly seepage quality from the waste piles is not protective of the aquatic ecosystem. Should this occur, treatment could be required and this could occur well into the future especially as the climate warms.

Accessibility to the site may also become problematic. Currently there are ice roads that service multiple mines. As mines close, and if others do not open, the costs for mine access will increase and thus greatly increase the costs for long term care and maintenance. Furthermore, as the climate warms, the availability for ice roads will decrease, making ice road access in future more difficult and possibly not practical.

2.6 ITEM 6-AREAS THAT REQUIRE FURTHER RESEARCH

Diavik has a well-developed Research and Reclamation program that has been in place since the mine was developed. The plan has effectively addressed a number of issues and is ongoing. The greatest uncertainty is related to the PKC. A research plan is in place but much of the work associated with effects of climate change and predictions of future water quality (pond and seepage) has been deferred.

Additional work should also be completed related to:

1) The potential effects of a probable magnitude earthquake on the stability of the PKC.
2) Improved modelling of the water balance with explicit emphasis on the impacts of extended drought. The question to answer here is what are the effects of extended drought on pond water levels and exposure of fine PK.

2.7 ITEM 7- APPROPRIATENESS OF EXPECTED CLOSURE AND RECLAMATION COSTS

Diavik has applied the RECLAIM model to develop costs for closure and reclamation of the site. The RECLAIM summary is provided in Appendix VII of the ICRP. The text to support the summary tables is not provided although there is a footnote on the Summary of Costs Table that the complete report can be found at (blank). It would be worthwhile for Diavik to update and file the text so that reviewers better understand the current basis for the estimate.

Overall, the cost estimate is well done and there are no material issues. The costs are reasonable and well documented. The primary issue is that there is no financial assurance for long term monitoring, care and maintenance.

Diavik provided a preliminary estimate of what potential cost for long term care of the mine could be in Attachment #3 to the North Waste Rock Pile Final Closure plan. Although the costs are not detailed, they provide a good first cut at the potential order of magnitude costs that will be required to assure pong term care and maintenance of the site. The estimated annual costs for maintenance of the site is about $570,000. This is a material cost and needs to be financed. As noted previously, these costs could increase significantly if ice road access was not available.

3.0 MISCELLANEOUS OBSERVATIONS AND COMMENTS

The following are miscellaneous comments on the Version 4 ICRP.

Page 103 – Open Pit Closure- *No reviewer has identified a benefit to mitigating meromixis. For these reasons, DDMI continues to prefer a closure design that enhances a meromixis condition instead of one that weakens the meromixis condition.* Can Diavik outline measures other than minimizing the size of the dyke breach, that they propose to enhance meromixis?

Page 106- Open Pit Closure- *Over time the deep water in the pit will equilibrate with the natural groundwater chemistry. This meromictic condition will provide better aquatic habitat conditions than if the entire water column regularly mixed as this would introduce more groundwater constituents into the surface waters.*

The statement that meromixis provides better aquatic habitat is misleading. Much of the pit lake below the surface zone will become anoxic and unsuitable habitat.

Page 109-Open Pit Closure- *Specific engineering design items to be addressed include: …*

• *evaluation of pit wall stability after flooding with specific emphasis on risk of a wall failure causing mixing of deep water with surface water.*

Has this work been initiated and is there a scope of work?

Page 110- Pit Closure-Contingency Planning- *Possible contingency actions have been developed based on our current understanding of uncertainties and risks (see Section 5.2.4.6):*

• *aerial application of lime, alum or a synthetic polymer to assist in clarifying mine area pool water to achieve acceptable water quality before dike breaching;*

Can Diavik provide examples of where aerial application of chemicals has been applied to open pits?

• possibility of not breaching dikes if breaches would put Lac de Gras at significant risk.

Can Diavik explain what is meant by significant risk? Does the water quality not have to meet closure criteria before the dykes are breached?

Page 119- PKC Closure- *Removal of the semi-fluid FPK material is a contingency measure.*

Can Diavik explain how the FPK material would be removed and where the material would be disposed?

Page 120-PKC Closure- *Minimizing the post-closure pond size will enable the greatest extent of permafrost development within the PKC Facility, enhancing seepage control.*

Although a reduced pond level will reduce seepage, will pond water quality be impacted? The source of metals leaching appears to be oxidation of sulphides in the unsaturated zone. One would expect that lowering of the pond would reduce the water table and expose more PK to oxidation. Golder's preliminary modelling suggests that the unfrozen zone could extend up to 5 m with climate change. Does Diavik plan to investigate the option of retaining a larger pond and assess how pond levels may impact upon the amount of PK that would be unsaturated and how this may impact discharge water quality?

Page 120-PKC Closure- *The advantages of this revised closure concept design are: …*

• Allows for progressive reclamation opportunities with cover placement starting during operations. Progressive reclamation allows construction procedures to be confirmed during operations when all available resources are on site.

Based upon the conceptual plan, it would appear that the final surface will be shaped by placing PK from the perimeter in preparation for rock cover. What waste rock cover placement is proposed during operations and how much rock cover would be progressively applied?

Figure 5-14 shows the closure concept. The concept shows run of mine rock will be applied to the surface of the exposed PK to a point below the water. Golder (Figure 3 in Appendix X-5 in their Technical Memorandum to AMEC on 21 November 2013) show a small area of geogrid would also be used to support rock fill in portions of the cover below water. At this point in time there does not appear to be any attempt to provide a filter zone to prevent migration of slimes at other locations. At several other sites where rock cover has been applied over fine tailings, piping of tailings to surface has occurred as pore pressures are dissipated. How will Diavik avoid piping of the fine PK to surface?

Page 164- Integrated Schedule-*Decommissioning North Inlet Dams – When NI water and sediment quality have been confirmed, the east and west dams will be decommissioned.*

The decommissioning of the NI dams is confusing. A dam can only be decommissioned if it is no longer required which suggests the dams will be breached (Diavik has clarified that the dam will include a pervious zone constructed to below the frost depth to assure that the zone will not freeze and impound water). Objective N-1 which is to reconnect for the North Inlet with Lac de Gras was dropped. It is recommended that Diavik reinstate Closure Objective N-1 as this is the preferred option.

Appendix VI-1 Post Closure Monitoring and Reporting - Open Pit, Underground and Dike Areas

Twice per year deep water quality samples will be collected from approximately 25 m above the pit bottom, if feasible.

Why would it not be feasible to sample 25 m above the pit bottom?

Appendix VI-3 Post Closure Monitoring and Reporting – Processed Kimberlite Containment Area

Observation wells, collection wells, thermistors and slope inclinometers have been installed in the PKC area to monitor operational performance. Much of this instrumentation is expected to remain post-closure, however the final determination of post-closure instrumentation will not be made until the final closure plan is prepared.

Are there any provisions for maintenance/replacement of instruments given most of these have a limited life span?

Appendix VI-3 Post Closure Monitoring and Reporting – Processed Kimberlite Containment Area- Section 1.2

if the estimated flow volume from 1645-42, 69 or 44 is greater than 10 L/s following breaching of the collection ponds then a sample will also be collected quarterly and assessed for acute lethality to rainbow trout

What is the basis for the 10 L/s cutoff for monitoring acute lethality. It is probable that lower flows would have less dilution and as such more likely to be lethal.

Appendix VI-4 Post Closure Monitoring and Reporting - North Inlet Area. Section 1.3 Sediment Quality

A sediment quality investigation will be conducted at the end of commercial operations to evaluate the sediment conditions in the NI. The investigation will follow the scope and procedures used in 2015.

Would it not be prudent to also complete a sediment survey in 2031 and if the sediment quality is acceptable then the preferred option of reconnection could potentially be implemented at that time?

Appendix VI-5 Post Closure Monitoring and Reporting – Mine Infrastructure Areas Section 3.5 Re-Vegetation

Additional re-vegetation monitoring items may include shoreline vegetation surveys around collection pond areas, PKC outlet, A154, A418, A21 and the North Inlet as well as documentation of areas of natural recovery, plant ingress/egress or identified invasive species.

Why does it say monitoring may include? Is it or is it not proposed?

Re-vegetated areas will be inspected annually for two years following initial planting.

Inspection for 2 years seems to be minimal as vegetation growth is slow and may take many years to be successful. Also, vegetation is proposed for 2031 but all monitoring stops in 2032. This is only one year. Please explain.

Appendix VII- Reclaim Estimate

The Reclaim estimate still shows that allowances have been made for till application to the caribou ramps yet there is no mention of till application in the NCRP closure plan. It is Diavik's position that till addition will not be required but continues to carry this allowance in the Reclaim estimate.

Appendix VIII Research task 4.4.1, 4.4.2 and 4.4.3

These tasks are critical to confirm the viability of the conceptual design and have been deferred. Why is this work being delayed to a later date? It is understood that Diavik are investigating alternatives for PK disposal but the uncertainties associated with the current design need to be addressed such that the design can proceed if the alternatives are not implemented.

DDMI Seepage Survey Annual Report

The 2016 annual seepage survey discussed the issue of ice damming in the downstream shell of the PKC shell and the resultant storage of large quantities of seepage. Diavik has installed seepage collection wells to intercept the seepage and reduce water levels in the upstream shell to control seepage and prevent further ice damming. It is unclear whether the seepage ice dams present an issue for closure. Diavik should provide a discussion of the significance of ice damming and implications for closure of the PKC.

APPENDIX 1- REVIEW OF THE PKC CLOSURE DESIGN

A.1 Overview

The proposed closure design for the Processed Kimberlite Containment is provided in Appendix X-5 of the Version 4 ICRP. The concept for the design was revised and included in 2011 ICRP. AMEC in their report (Diavik Diamond Mine PKC Facility Revised Closure Concept-28 November 2013) provided additional review and details on the design and made suggestions for minor revisions. AMEC concluded the original concept of creating a domed cap over the PKC was not constructible and concluded the revised plan was constructible and should meet closure objectives. The revised design, approved by the Water Board, includes a concave surface sloping down to a central pond which has a drainage ditch with an overflow spillway to Lac de Gras. The surface is to be covered with 2 m of waste rock. The waste rock will extend into the pond.

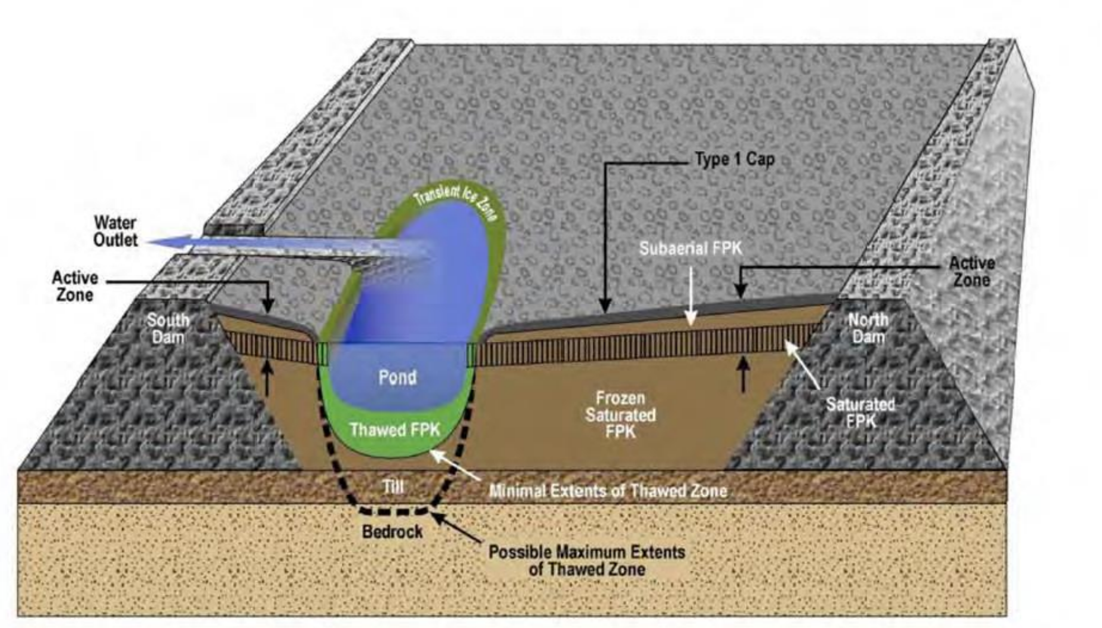

Figure from Diavik 2011 ICRP.

The AMEC review includes information on the water balance for the pond, predictions of future water quality and preliminary thermal modelling by Golder (November 13, 2013).

What is clear from the work is the concept may be valid, however there is a high degree of uncertainty. The uncertainties are raised by AMEC and acknowledged by Diavik.

The primary uncertainties identified by AMEC were:

- Post-closure thermal conditions, particularly as they relate to long-term seepage control.

- Post-closure pond water quality.

- Post-closure shoreline stability along the residual water pond.
- Closure thermal conditions of beaches and the transition to semi-fluid FPK material.
- Community preferences and concerns around closure landscape.

The following are comments and concerns regarding the concept.

A-2 Technical Issues and Concerns with the PKC Closure Concept

A.2.1 SEEPAGE QUANTITY AND QUALITY

Seepage Quantity

There is a substantial degree of uncertainty with regard to the quantity of seepage that will occur in the long term. When conducting the geochemical predictions of pond and seepage water quality, 2 scenarios were considered: one where 100 % of the net precipitation occurs as seepage, and a second where 50% of the net precipitation occurs as seepage. However, when the water balance modelling was completed to assess the impact of wet and dry periods, zero seepage was assumed.

The quantity of seepage is critical because it will determine how much water is stored in the pond and whether or not a pond can be maintained. AMEC indicated in 2013 that the current seepage rates are in the order of about 40 L/s. This level of seepage would not allow a permanent pond to form and would expose the fine PK. Seepage levels are anticipated to decline as freezing progresses. If seepage occurs in future, it is likely there will be conditions (drought) when the pond levels will drop with the potential to expose the fine PK. This exposure represents a potential hazard.

Seepage Quality

Seepage quality predictions are based upon the assumption that metals are formed from the oxidation of sulphide minerals in the PK and the amount of oxidation is based upon the depth of unsaturated/unfrozen PK. AMEC assumed that the active layer for oxidation was .25 to 1 m deep. Golder (Appendix B -Thermal and seepage Analysis) states on age 12 “With the rockfill cover in place, the active layer depth after 100 years in the FPK beach area is estimated to be 2 to 2.2 m for the scenario without the climate change effect; and 3 to 5 m for the scenario with the climate change effect. This suggests that the potential unfrozen zone would be 1-3 m deep as compared with the AMEC assumption of .25 to 1 m. This would greatly increase the amount of PK exposed to oxidation.

Other assumptions include porosity which was set at 0.3 (note this is not typical). One would expect a porosity of closer to .5 for consolidated coarse tailings. Golder in Table 3 of Appendix B show porosity of .44 for coarse PK and 0.6 to 0.75 for fine PK.

This is a simplistic model with highly uncertain inputs some of which are likely invalid and as such the predictions are highly suspect.

A.2.2 DYNAMIC STABILITY

It is unclear what work has been completed to assess the static and dynamic stability of the PK tailings. Failure analysis does not appear to have been completed and will be essential for assessing the viability of the concept. Potential issues and concerns include:

- Liquefaction of the tailings and the fate of pond and FPK during extreme seismic events
- Failure mechanisms for the cover including piping, thawing differential settlement, etc.)
- Dewatering of the pond and exposure of the FPK

A.2.3 PK RECLAMATION RESEARCH SCHEDULE

The additional work for tasks PK research Tasks 4.4 have been delayed to 2020. This is a material concern as this must address key uncertainties in the conceptual design. The final closure plan and engineering for the closure concept is to be completed in 2020 yet the work required to address the uncertainties in the design will not have been completed.

Subject: **Diavik Diamonds Mines Inc. EA1819-01 Processed Kimberlite in Pits and Underground Environmental Assessment: Support to EMAB for MVEIRB hearing preparation**

To: John McCullum
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Date: July 26, 2019 **DRAFT**

1.0 INTRODUCTION

DDMI produced a Summary Impact Statement (SIS) for the Processed Kimberlite to Mine Workings Project (MVEIRB File No.: EA1819-01) on May 17, 2019. NSC was retained by EMAB to review the aquatic environment components of the SIS, and to provide comments and identify any IRs (final memo submitted to EMAB June 19, 2019). DDMI provided responses to the IRs on July 4; NSC was retained to review these responses and provide any further comment (comments provided on July 18). As follow-up to this review and to obtain input on key questions for EMAB's intervention for the MVEIRB hearings in fall 2019, NSC was asked to provide comments and input to several topics (email from J. McCullem July 19 and subsequent discussion). This technical memorandum provides responses to the topics raised by EMAB.

2.0 EVAULATION OF SIGNIFICANT EFFECTS

DDMI through its assessment, including modeling of water quality in the pit lakes and information related to existing pit lakes presented in the IR responses, has demonstrated that significant adverse effects due to storage of PK in the pits and subsequent reconnection of the pits to Lac de Gras, are unlikely. As noted below in Section 5.0, key to this conclusion is the anticipated quality of pore water; there is some uncertainty with respect to the quality of the pore water and this is being addressed through on-going studies and a commitment from DDMI to reassess potential effects to water quality when this information is available. Furthermore, potential risks can be managed through the implementation of a monitoring plan prior to and after breaching of the dikes; recommendations for monitoring are provided in Section 7.0.

3.0 DISSOLVED OXYGEN

DDMI presented the results of a mass-balance model, as recommended in an earlier EMAB comment, in their responses to Information Requests (EMAB IR#18).

DDMI Response:

"(vi) It must be re-iterated that this response requires that we assume hypothetical conditions that are in opposition to all available evidence. This response provides an answer to the information request, but it should not be interpreted to imply that such conditions are likely to occur. Assuming the worst-case conditions of a full pit overturn at the point of maximum volume of anoxia, again using Scenario 3A and pit A418, a simple mass balance would assume the following conditions in late summer with a shallow epilimnion:

- *Anoxic below 350 m; volume = 6.2 Mm3*

- *DO = 10 mg/L at surface, with 5-m deep thermocline; volume = 2.0 Mm3*

- *DO = 9 mg/L in intermediate zone; volume = 15.1 Mm3.*

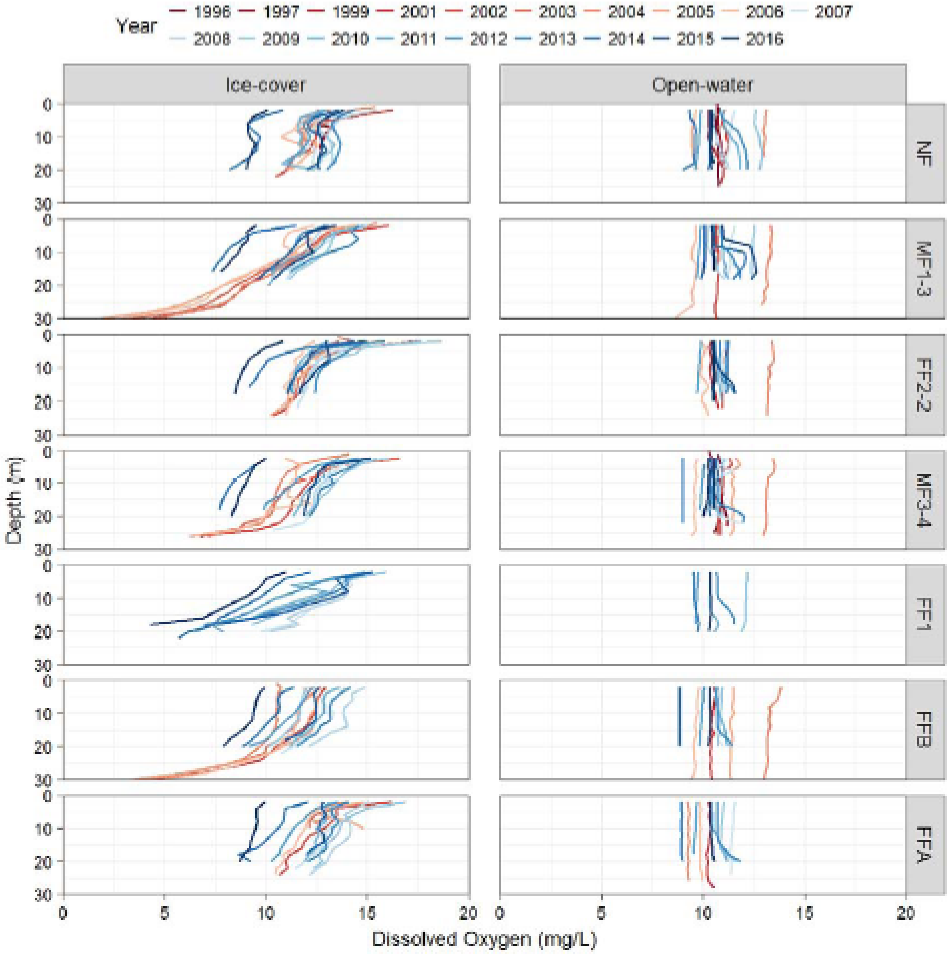
An unanticipated turnover during these conditions would yield a whole-pit-lake DO concentration of 6.9 mg/L. DO in the surface waters would rapidly be replenished, with nearly instantaneous re-aeration at the air-water interface are replenishment in the mixed zone within hours or days, depending on prevailing conditions and the amount of turbulence in the pit lake generated by the hypothetical mixing event. If the mixing is wind-driven, the same process would entrain dissolved oxygen throughout the water column as part of the mixing process. Although the duration of the hypothetical period of low DO is unknown at this time, changes in DO concentrations may be within the range of natural fluctuations in DO that occur in Lac Gras and other natural lakes. Whether from an oxygen demand in the PK slurry at the bottom of the pit or from decomposition of long-term deposition of detrital matter in natural areas of the lake, fish are expected to move elsewhere to avoid the volumes to remain well stratified at the lake bed as oxygen is depleted over time. The diked area has been designed to provide suitable conditions for fish upon closure of the A418 pit including water quality conditions within the pit to support healthy populations of fish. As discussed in a previous response to the second round of IRs from the Environmental Monitoring Advisory Board (please see EMAB #30), we do not expect increased productivity as a result of nutrient enrichment in the surface waters of the pit (as per Attachment 1 to the original report, Figure A-1, A-4 and A-7; e.g., phosphorus); therefore, we also do not anticipate DO depletion in the surface water of the pit under normal conditions."

The response provided by DDMI indicates that the estimated DO after unanticipated mixing, even with anoxic bottom waters, would not result in a fish kill in surface waters. Based on other pit lake examples provided by DDMI, DO concentrations should be relatively high above the chemocline even under ice, providing that no mixing with waters below the chemocline occurred. The primary sources of oxygen demand are associated with substrates where organic matter may accumulate (this is also observed in natural lakes) and the PK deposited at depth in the pit. Assuming that there is limited biological productivity in the lakes, the amount of organic material available to support bacterial consumption of DO is low. DDMI's response provides examples of existing pit lakes which demonstrate a lack of an oxygen demand from the chemocline itself and, therefore, open-water areas should not experience notable DO depletion - including under ice cover. Provided there is limited biological productivity in the pit lakes and therefore limited amounts of organic materials that would consume oxygen deposited in the substrates (including the ramps and other shallower areas of the lakes that may be used by biota), DO should remain relatively high. However, these areas could experience lower DO as is observed in some areas of Lac de Gras currently (i.e., independent of deposition of PK into the pits) (see Figure 4-35 below).

If Diavik's model inputs are incorrect, effects on DO could differ from those predicted. Specifically, the mass balance model DDMI ran for DO in pit A418 under a mixing event may overestimate DO concentrations if the assumed DO concentrations in the upper waters (above the monimolimnion) were lower prior to mixing and if the size of the monimolimnion were larger than modeling predicts (the mass balance model assumed the monimolimnion was 40 m deep). Having said that, the DO concentrations in the upper layers would have to be relatively low prior to mixing for DO concentrations to drop to relatively critical levels. The intermediate layer (which DDMI assumed to contain 9 mg/L of DO) would have to be <5 mg/L in order to result in a fully mixed DO concentration of <4 mg/L.

The mass-balance model was based on assumed DO concentrations in the upper water column (10 mg/L in the upper 5 m and 9 mg/L in the “intermediate zone”). While it is acknowledged that DO concentrations have frequently been at or above 10 mg/L at the surface in the open-water season in Lac de Gras, concentrations have been below this level in some years in both the open-water and ice-cover seasons (see Figure 4-35 from the 2014 to 2016 Aquatic Effects Re-evaluation Report (Golder 2018) excised below for illustration). In its ongoing assessment of the effects of PK deposition in the pits, DDMI should estimate the fully mixed concentration of DO if the upper water column had a DO equivalent to the minimum surface DO concentration measured in Lac de Gras (or a similar statistic such as a 5th percentile). In addition, the model was run for pit A418 only. The potential for DO to decrease to potentially harmful levels may be greater for pit A21 due to the differences in morphometries and volume of water above and below the chemocline. DDMI should also address the predicted effects on DO in the other two pit lakes, notably for pit A21 which is characterized by a notably different shape, volume, and depth, and a shallower water cap using a mass-balance model.

Figure 4-35 Dissolved Oxygen Depth Profiles in Lac de Gras, 1996 to 2016



Note: Depth profiles prior to 2007 were measured at historical locations that were deeper than station locations after 2007 (see Table 4-1 for the pairing of historical and contemporary AEMP stations).

4.0 FISH CONSUMPTION

Due to potential concerns respecting contamination of fish and effects on human consumers, it is recommended that a metals (including mercury) in fish survey be undertaken following breaching of the dikes. The scope of a metals in fish survey should consider the results of the water quality monitoring acquired up to and following breaching of the dikes, as well as fish use (i.e., species and sizes) of the pits. From a human consumption perspective, the survey would ideally be conducted on a large-bodied fish species that is or may be harvested in the study area (e.g., Lake Trout) and metals would be measured in the tissues that are consumed (e.g., muscle).

5.0 POREWATER STUDIES/MODELING

The chemical constituents of the porewater are the most critical input to the water quality models and, given the wide range of concentrations observed in the beach porewater vs the fresh PK slurry, exhibit a wide range of chemistry depending on conditions. DDMI has committed to reviewing results of on-going studies, including work currently being conducted at the University of Alberta, and will revisit the models if future results indicate chemistry that is different from the fresh PK used in the current models.

6.0 CLOSURE OBJECTIVES/CRITERIA FOR FISH

Closure objective M3. Enhanced lakewide fish habitat to off-set fish habitat temporarily lost during operations.

DDMI in V4 of the Closure Plan proposed to address this criterion by demonstrating that the as-built fish habitat conforms adequately with designs. Demonstrating adherence to this objective should provide documented use by fish of the offsetting habitat, in addition to meeting the as-built specifications. We are not familiar with the monitoring requirements with respect to the offsetting set out in the *Fisheries Act* Authorization, however we anticipate that it would include demonstrating fish use of the newly constructed habitat. Moreover, the intent of breaching the pit lakes is to return them to usable fish habitat, therefore monitoring should demonstrate fish use of the lakes as a whole. Recommendations for monitoring are provided in Section 7.0 below.

7.0 MONITORING

The monitoring plan for the pit lakes should address the closure objectives specific to the aquatic environment as set out in the Closure Plan – Version 4.0, as well as any unanswered questions or information gaps. The closure plan objectives are:

- **M1.** Water quality in the flooded pit and dike area that is similar to Lac de Gras or at a minimum protective of aquatic life.
- **M2.** Pit and dike closure do not have adverse effects on aquatic life or water uses in Lac de Gras, the Coppermine River or on groundwater use.
- **M3.** Enhanced lakewide fish habitat to off-set fish habitat temporarily lost during operations.

The closure criteria to determine whether these objectives have been met is currently under discussion; however, DDMI has proposed that comparison to the AEMP benchmarks and/or a risk assessment would be used to determine whether M1 and M2 are met and comparison to the plans for compensatory works would be used to determine whether M3 is met.

The intent of this document is to provide key points that should be considered in the development of a monitoring plan to address the aquatic environment in the pit lakes. Monitoring will comprise two phases:

- <u>Prior to Breaching</u>: prior to breaching of the dikes determining whether conditions are suitable for breaching the dikes is the primary emphasis; and
- <u>Following Breaching</u>: after breaching the dikes determining whether the closure objectives are met, and whether water quality is posing a risk to aquatic life, both within the pit lakes and in Lac de Gras, is the focus.

DDMI has provided information on proposed monitoring, most recently in the IR response issued on July 4. Proposed monitoring is consistent with some but not all of the key points listed below; the intent of this document is not to provide a critical review of monitoring proposed by DDMI but rather highlight key points that should be considered for inclusion in a final monitoring plan. As noted below, a key component of the monitoring plan should be an adaptive approach, i.e., that monitoring activities are adjusted based on monitoring results.

7.1 CLOSURE OBJECTIVE M1

Closure Objective M1. Water quality in the flooded pit and dike area that is similar to Lac de Gras or at a minimum protective of aquatic life.

7.1.1 Part 1: Monitoring prior to breaching of the dikes

The following are recommendations for monitoring prior to breaching of the dikes:

- Complete a profile in the centre of the pit lake from surface to bottom to monitor development of a chemocline. Initial sampling should focus on conductivity profiles to determine when meromixis is established and obtain information on the rate of establishment. The frequency of sampling should be based on the anticipated rate of gradient formation (e.g., quarterly if a gradient is expected to form within a few years).
- Initial conditions should also be recorded for the suite of parameters included in the AEMP to provide a starting point for the development of meromixis and an indication of conditions for organisms that are introduced when water is pumped from Lac de Gras to form the closure cap.
- After a stable gradient has formed and until such time as water quality has improved to the point that dikes may be breached, monitoring should be conducted at a station in the centre of the lake in late winter, after the spring turnover, during late summer and after the fall turnover. The intent would be to obtain information when stratification in the epilimnion and hypolimnion (both above the chemocline) has been established for much of the season and after the water column above the chemocline has been mixed. Lac de Gras is ice free from approximately mid-June to mid-October and sampling during the open water season should be spaced out over this period, while considering conditions in the lake (i.e., timing of turnover) listed above.
- Profiles of pH, dissolved oxygen, temperature , turbidity, and conductivity should be obtained for the entire water column above and immediately below the chemocline during each sampling period.
- Sample collection for laboratory analysis should be conducted at different depths within the epilimnion and hypolimnion up to and including immediately below the chemocline. Depth stratification of samples would depend on results of the *in situ* profile.
- Parameters should include those monitoring in the AEMP (including mercury), and comparisons would be to both the AEMP benchmarks and water quality in Lac de Gras.
- During each sampling episode, a sample for analysis of laboratory parameters should be collected from near the bottom. Water quality from below the chemocline could be used to support risk assessments to address the effect of unanticipated mixing.
- When water quality at the sampling location in the centre of the pit lake is considered suitable for breaching of the dikes, an expanded water quality sampling program should be conducted to address potential spatial and temporal variability.
- It is recommended that sampling be conducted for two years to ensure that there are not seasonal or interannual variations in conditions that result in adverse effects to water quality in the pit lakes above the chemocline.
- Prior to considering breaching of the dikes, water quality should be sampled at additional stations for a two year period to determine whether there is marked spatial variation in water quality between the open pelagic area of the lake and shallow areas, in particular where fish habitat has been constructed.
- The criteria for breaching of the dikes should consider sampling over the two years, in different areas of the lake. If there is marked temporal or spatial heterogeneity, then the criteria should be adjusted accordingly.

- A dissolved oxygen survey should also be completed at additional sites, including shallow sites over substrate, to confirm the predictions that dissolved oxygen concentrations will be high above the chemocline in all seasons.
- Prior to breaching of the dikes, sampling of biota (fish and benthic invertebrates) that may have been introduced when water from Lac de Gras was pumped in to form the closure cap should be conducted. These biota would have been exposed to higher concentrations of contaminants in water prior to the formation of a stable chemocline. If significant numbers of organisms are present, the need to assess them for concentrations of metals and mercury to avoid potential risk to fish that will be introduced after breaching of the dikes should be considered.

7.1.2 Part 2: Monitoring after breaching of the dikes

The following are recommendations for monitoring after breaching of the dikes:

- Monitoring for the first year(s) after breaching of the dikes should confirm that the meromictic gradient remains stable.
- Sampling should include vertical profiles of pH, dissolved oxygen, temperature and conductivity above and immediately below the chemocline. Sampling should be conducted in late winter, after the spring turnover, in late summer and after the fall turnover. Parameters sampled for laboratory analysis should include those monitored in the AEMP, and comparisons would be to both the AEMP benchmarks and water quality in Lac de Gras.
- Initial monitoring after breaching of the dikes should include various locations in the pit lake to determine which areas are more affected by direct water exchange with Lac de Gras and which are more affected by water quality within the pit lake. If spatial heterogeneity is observed then the locations of sample collection should be adjusted.
- The frequency of water quality sampling can be reduced if conditions are observed to be stable. An assessment of the risk of an unanticipated mixing event would need to be completed to determine what frequency of sampling is required to support implementation of the contingency plan (i.e., closing the breaches in the dike). Monitoring data available at the time will assist in informing this assessment.

7.2 CLOSURE OBJECTIVE M2

Closure objective M2. Pit and dike closure do not have adverse effects on aquatic life or water uses in Lac de Gras, the Coppermine River or on groundwater use

Sampling in Lac de Gras related to breaching of the dikes would occur after opening of the dikes. However, it is anticipated that sufficient information at sampling locations would have been collected prior to breaching of the dikes to provide the basis for analyzing effects. Monitoring in Lac de Gras after breaching of the dikes should consider the following:

- If water quality in the pit lakes is markedly different from that in Lac de Gras, then initial sampling of conductivity, or some other parameter suitable for tracing the plumes from mixing with the pit lakes, should be conducted to determine the spatial extent of effects. It is anticipated that sampling at multiple times during the open water season would be required to address seasonal variation in mixing as well as stabilization after initial breaching of the dikes.
- After the spatial extent of the effect of the pit lakes has been established, sampling sites should be located close to and further from the breaches to determine the extent to which water quality in Lac de Gras is affected by the pit lakes.
- Parameters should include those included in the AEMP and compared to AEMP benchmarks and background conditions in the Lac de Gras.

7.3 CLOSURE OBJECTIVE M3

Closure objective M3. Enhanced lakewide fish habitat to off-set fish habitat temporarily lost during operations.

For the purposes of this document, addressing this objective will focus on fish use of the pit lakes. Fish are anticipated to use both shallow areas, including constructed compensatory habitat, and the pelagic zones of the pit lakes. DDMI in V4 of the Closure Plan proposed to address this criterion by demonstrating that the as-built fish habitat conforms adequately with designs. We are not aware of the commitments to demonstrated fish usage set out in the offsetting plan, which would need to be consistent with the monitoring plan. However, we suggest that monitoring of fish use in the pit lakes should address two objectives:

- Demonstrate that fish use in the pit lakes meets objectives set out in the compensation plan; and
- Fish use of the pit lakes does not pose a risk to fish populations in Lac de Gras.

Monitoring the fish use of pit lakes should to the extent feasible rely on non-lethal techniques such as trap nets, minnow traps, and hydro acoustic surveys to avoid adversely affecting local fish populations as they become established. It is understood that a certain amount of lethal sampling may be required, but the need for this type of information should be considered in context of the number of fish present.

Monitoring should demonstrate that fish are using the offsetting habitats as predicted, including, if applicable, use as spawning and juvenile rearing habitat. Given that colonization of newly constructed habitats and the pit lakes may require several years, monitoring could be initiated several years after breaching of the dikes.

The risk to fish in Lac de Gras from use of habitat in the pit lakes could arise if (i) fish use habitat where they are exposed to potentially harmful concentrations of contaminants; and (ii) dissolved oxygen concentrations in the pit lakes decline to critical levels and they are not able to escape. DDMI has provided evidence that fish will not be exposed to potentially harmful concentrations of contaminants due to the formation of a meromictic gradient, the depletion of dissolved oxygen below the chemocline which will make deep waters unsuitable for aquatic life, and the observation that fish in arctic lakes generally occupy waters less than 40 m in depth. However, it is recommended that fish use of the upper waters of the pelagic zone and their absence in deep waters be confirmed through monitoring conducted after breaching of the dikes. The need for monitoring the ability of fish to escape from areas of low dissolved oxygen would need to be determined based on observed water quality results. If surface waters of the pit lakes exhibit oxygen depletion under ice, then a monitoring plan to demonstrate that fish are able to escape and not be subject to a fish kill would need to be developed.

If fish that use the pit lakes may be harvested for human consumption, it is recommended that a sample be analyzed for contaminants, including mercury, several years after breaching of the dikes. It is recommended that this sampling be conducted even if water quality sampling indicates low concentrations of contaminants to address the potential for transfer of contaminants via the food web.

8.0 LITERATURE CITED

Golder Associates Ltd. (Golder). 2018. Diavik Diamond Mines (2012) Inc. 2014 to 2016 Aquatic Effects Re-evaluation Report Version 1.0. Submitted to Diavik Diamond Mines (2012) Inc. Yellowknife, NT, March 2018.

Executive Summary

Slater Environmental Consulting has reviewed information related to DDMI's proposed Processed Kimberlite to Mine Workings (PKMW) Project. The review focused on issues and concerns related to the environmental assessment. It is intended to support EMAB's development of an intervention for the Mackenzie Valley Environmental Impact Review Board's environmental assessment.

For assessing the significance of effects, DDMI relies on thresholds and definitions that are the same as or "consistent with" the 1999 CEAA Comprehensive Study. Reliance on these significance thresholds and definitions does not consider changes that have occurred since the original assessment was conducted. For example, conditions and context for the Bathurst caribou herd are much different now than they were in 1999.

DDMI has not addressed effects that could occur during the operational phase, for example the creation of a large open water body in the pit that could attract waterfowl at some times.

DDMI has conducted preliminary modelling to predict potential effects of various scenarios for deposit of Processed Kimberlite (PK) in pits. There are uncertainties in the modelling. More detailed modelling of a selected scenario should be done to address uncertainties and improve accuracy of predictions.

Because there are multiple projects that affect Lac de Gras, the environmental assessment needs to consider the combined effects (cumulative effects). DDMI has done a cumulative effects assessment for water quality, but the methods and results are not described in adequate detail.

A decision to place PK in pits will influence closure plans for both pits and the Processed Kimberlite Containment (PKC) Facility. Closure plans, objectives and criteria need to be updated to address these changes.

DDMI has proposed monitoring and follow-up related to the storage of PK in pits. This includes monitoring and water quality criteria that will help define when the pit lakes can be safely reconnected with Lac de Gras. Some components of the monitoring and follow-up program should be refined to provide a better understanding of environmental conditions in the pit lakes.

Memorandum

To: John McCullum, Janyne Matthiessen – Environmental Monitoring Advisory Board

From: Bill Slater, Rasheeda Slater – Slater Environmental Consulting

Date: July 28, 2019

Re: Diavik Diamond Mine – Processed Kimberlite to Mine Workings Project

1.0 Introduction

Slater Environmental Consulting (SEC) has reviewed information related to the environmental assessment of Diavik Diamond Mines (2012) Inc.'s (DDMI's) proposed Processed Kimberlite to Mine Workings (PKMW) Project. SEC has previously reviewed DDMI's application for amendment of its water licence including information provided in the following documents:

1. DDMI Amendment Request dated June 1, 2018 (the "June 2018 Amendment Application").
2. DDMI Response to Information Request dated November 6, 2018 (the "November 2018 Response").
3. DDMI Response to Reviewer Comments and Recommendations dated January 8, 2019 (the "January 2019 Response").
4. DDMI Response to WLWB Information Requests dated February 11, 2019 (the "February 2019 Response").

The current review was completed to support EMAB's development of an intervention for the Mackenzie Valley Environmental Impact Review Board's (MVEIRB) environmental assessment of the PKMW Project. The review focuses on potential effects of the project on Valued Components (VCs), the methods that DDMI has used to assess potential effects, and proposed mitigation and monitoring.

2.0 Assessment Methods - Thresholds for Significance

For four of the five VCs[1] considered in the SIS, DDMI defines thresholds for significance and describes the factors and quantitative measures used to characterize the significance of effects. For most VCs (i.e., Water Quality, Fish and Fish Habitat and Wildlife and Wildlife Habitat), DDMI relies on thresholds and definitions that are the same as or "consistent with" the 1998 Comprehensive Study, with a few noted minor modifications. DDMI argues that applying the previously developed

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[1] DDMI's VCs are Water Quality, Surface Water Quantity, Fish and Fish Habitat, Wildlife and Wildlife Habitat and Cultural Use.

thresholds and definitions provides consistency with the original mine assessment, but does not provide any additional rationale for why the thresholds and definitions are still relevant and applicable. The definition of significance from the 1999 Comprehensive Study Report, completed under the *Canadian Environmental Assessment Act* (CEAA), is applied directly for Water Quality, and Wildlife and Wildlife Habitat:

> "*The definition of a significant adverse effect is an effect that has a high probability of a permanent or long-term effect of high magnitude, within the regional area,that cannot be technically or economically mitigated.*"

For Water Quality for example, Table 4-2 in the SIS describes the factors and quantitative measures used to characterize effects. High magnitude effects are those where contaminant concentrations exceed the Aquatic Effects Monitoring Program (AEMP) Benchmarks by more than 20%. Long-term effects are those that last more than 30 years. The Regional Area is defined as anything more than 1 km from East Island. With DDMI's definitions and threshold, modelling would have to confidently predict contaminant concentration(s) more than 20% higher than AEMP Benchmarks for more than 30 years at distances more than 1 km from East Island before an effect would be considered significant.

For the water quality assessment for zinc, DDMI proposes to rely on the AEMP benchmark of 30 μg/L as a basis for calculating significance thresholds. However, the context for this threshold has changed. DDMI acknowledges that the Canadian Water Quality Guideline for the Protection of Aquatic Life has been decreased to 7 μg/L, but proposes to use the outdated guideline for consistency.

DDMI developed an updated definition of significance for Cultural Use to reflect the complexity of assessing effects on cultural use and meet the requirements of the *Mackenzie Valley Resource Management Act*. While the significance thresholds and definitions for Cultural Use are not drawn from the 1999 CEAA Comprehensive Study Report, they apply similar methods and set thresholds of similar magnitude. Based on the definition of significance developed to evaluate effects on Cultural Use, effects will only be considered significant if the residual effects extend beyond decommissioning and abandonment and cause critical reduction or elimination of Cultural Use within the Regional Assessment Area (RAA). The RAA is a 13,865 km^2 area, shown in Figure 8-1 in the Summary Impact Statement. DDMI does not provide a definition for critical reduction of Cultural Use.

In the July 4 response to EMAB's review comment #4, DDMI outlined that the environmental assessment methods used to develop the SIS are consistent with current practices. While the methods for conducting environmental assessments remain similar to those used under CEAA in 1999, this does not mean that the specific thresholds for significance are still applicable and appropriate. DDMI's response does not provide up-to-date rationale for the applying the threshold and significance definitions developed during the initial mine assessment.

The decision to rely on significance thresholds and definitions from the 1999 CEAA Comprehensive Study Report does not adequately consider the changes in conditions and context that have occurred since that assessment was conducted. Environmental conditions and contexts have changed and need to be considered for the current assessment. The issue needs to be addressed for all VCs, but the wildlife and wildlife habitat VC provides an obvious example. The conditions and context for the Bathurst caribou herd have changed dramatically since 1998, and the significance threshold has likely also changed. When the 1998 Comprehensive Study was completed the Bathurst caribou herd had a population over 42 times the current population. The significance thresholds developed at that time may have provided sufficient protection for the herd in that context. In the April 2019 "*Scope of the Environmental Assessment and Reasons for Decision*" document, the Review Board emphasizes the precarious state of the Bathurst caribou herd and states that any potential impact of the proposed activities on the herd should be carefully considered and mitigated. This careful consideration should extend to the thresholds for significance and the definitions used to characterize effects.

The recalibration of the assessment that arises from updated definitions and thresholds could lead to identification of important effects that are not currently considered in the assessment. For example, the current assessment for Wildlife and Wildlife Habitat focuses on changes in wildlife health due to water quality effects during the closure and post-closure periods. Revisions of thresholds for wildlife may mean that other potential effects become relevant.

The cultural and legislative/policy context has also changed since the completion of the 1998 Comprehensive Study. CEAA no longer applies and has been replaced by the *Mackenzie Valley Resource Management Act*, with its foundation in land claim agreements with Indigenous groups. People's understanding of mining and its effects has also changed. Governments and citizens have much more experience with diamond mining. Reconciliation with Indigenous groups has become an important Canadian policy initiative. Although these changes have led to an adjustment in the definition of significance for Cultural Use from the 1999 Comprehensive Study Report, the SIS does not address how perspectives and values have been considered in establishing the definitions and thresholds for significance for all VCs. The people who will be most affected by the project are those who use the area for their life sustaining activities. Consideration of these people's perspectives should be a fundamental part of both defining and determining the significance of effects for all VCs.

Recommendation: When conducting its assessment, the MVEIRB should give careful consideration to the definitions and thresholds for significance. It should rely on definitions and thresholds that reflect the current conditions and context for the environmental assessment and incorporate the perspectives and values of the people who will be most affected.

3.0 Scope of Assessment – Operational Effects on Wildlife

The operation of pits as PK disposal facilities will create large open water areas during operations. The pits will have supernatant water overlying the PK that likely will not meet AEMP benchmarks during operations, and may have concentrations that exceed safe levels for wildlife and/or birds. In the north, it is common for active mine waste storage facilities to have open water earlier in the season than surrounding lakes. In the July 4 response to EMAB Comment No. 14, DDMI refers to modelling that predicts longer open water seasons for this type of facility:

> *The predicted time for ice melting in the pit lakes leads to an open-water season which is longer than that observed at Lac de Gras, where ice melt generally occurs in mid-July.*

This is likely to occur at Diavik during disposal of PK to the pit. If open water occurs early in the season, waterfowl may be attracted to the open water, leading to exposure to the pit water. Exposure to water overlying the PK could affect waterfowl health during operations.

The SIS indicated that the PK disposal project would have no interactions with wildlife habitat or health during the operational period. This is not consistent with the potential for open water conditions to attract waterfowl.

In response to EMAB Comment #5, DDMI acknowledged the potential for wildlife to be attracted to open water in pits/mine workings during operation. In order to address concerns, they outlined the following existing wildlife, monitoring and management procedures for Diavik:

1. Monitoring/tracking of wildlife presence and/or proximity to the mine workings.
2. Training all site personnel to record and/or report incidental sittings of wildlife, including birds, in the general area of the mine workings during operations.
3. Use of wildlife deterrence techniques such as truck horns, bear bangers, 12Ga cracker shells, 12Ga bean bags, scarecrows, decoy foxes and falcons, noise makers (Wetland Wailer Mk IV), and hanging screens down the high walls of the pits.

Effective application of the proposed monitoring and response actions can likely mitigate effects of the PK disposal project during the operational period. But, DDMI's response does not specify the changes that would be required to management plans and actions to address the specific concerns in the pit.

Recommendation: When conducting the environmental assessment, the MVEIRB should acknowledge the potential for the PK disposal to affect wildlife habitat and health during the operational period, and consider these effects in the assessment. To mitigate potential effectds, MVEIRB should require development/refinement of management plans to incorporate specific requirements for monitoring and responses related to waterfowl and wildlife use of pits during the operational period.

4.0 Water Quality Modelling and Prediction

The characterization and evaluation of effects on water quality rely on predictions of water quality in the pits once PK placement is complete and pits have been filled with water from Lac de Gras. Appendix B of the SIS provides a very short summary of the modelling with references to other memos prepared by Golder. Golder describes the modelling as preliminary:

> "*The modelling was intended to answer these questions for preliminary planning purposes, and as such, simplifying assumptions were employed….*" (May 9, 2019 Response to IRs, Appendix 2, Diavik Mine – Water Quality Modelling of A418, A154 and A21 Mined Out Pits)

DDMI proposes that more detailed modelling will be completed before it proceeds with the PKMW Project:

> "*The modelling work was designed to be phased with the initial preliminary modelling being conducted with the best available model input information at this time, including information from Ekati. A second phase of water quality modelling would be conducted prior to any deposition and submitted for final Water License approvals with updated model input information*." (May 9, 2019 Response to MVEIRB IR No. 5)

There are several areas where model assumptions, inputs and methods create uncertainty about the accuracy of model predictions. As a result, the models may under-predict effects of the proposed PKMW Project. Details of some areas of concern are provided in the subsections below, and form the basis for the following recommendation.

Recommendation: In conducting its assessment of potential effects on water quality, the MVEIRB should acknowledge the preliminary nature of the current modelling. To address the uncertainty about model results, the MVEIRB should require completion of more detailed, site-specific modelling to confirm the accuracy of predictions. This refined modelling should be provided for review/approval prior to deposition of PK into pits.

Loading Sources to Pits

Water quality modelling results provided in the June 2018 Amendment Application did not incorporate potential loading from pit walls or groundwater inflow. In the January 2019 Response, DDMI provided a sensitivity analysis that considered impacts of additional sources on long-term water quality conditions. It also considered a potential pool of water remaining on top of the PK at the initiation of pit filling. These scenarios were considered as separate events. There was no prediction of conditions of combined events, even though this is the most likely scenario.

The sensitivity analysis also considered different rates of pore water release from the PK, but only considered slower rates of release, making the optimistic assumption that conditions would not be worse than the initial predictions, but they could be better.

With respect to groundwater inflows, DDMI's sensitivity analysis considered a groundwater input of 177,647 m^3 during pit filling. This number seems small in comparison to the previous modelling that used the following approach:

> *"The groundwater inflow rate was estimated based on a linear relationship developed from historical pit dewatering rates and pit depths. ... the groundwater inflow rate at the start of filling was set to 28,300 m^3/day. It was then assumed to decline over the filling period as water levels in the pit increased, ultimately reaching a value of zero when the pit was full of water."* (Golder Associates. 2010. *Preliminary Pit Lake Mixing Study*. Appendix -3 of Interim Closure and Reclamation Plan, Version 3.2)

All of these load sources are likely to contribute to water quality in the pit and should be directly included in the modelling. They do not represent "sensitivity" conditions because they are expected sources, not uncertain contributors.

In its July 4, 2019 response to EMAB Comment No. 10, DDMI does not address the issue of groundwater volume considered in modelling. With respect to contribution of groundwater to the assumed pool of water in the pit at the start of filling, DDMI refers to Scenario 4a that includes a 15m deep pool of water overlying PK at the beginning of pit backfilling with freshwater. DDMI states:

> *"Scenario 4a was defined at the WLWB Technical Session and assumes there would be 15m of decant water above the settled PK at the time the mine workings were to be filled with water from Lac de Gras. The 15m of decant water was assumed to have developed through the final years of operations through an accumulation of PK slurry/pore water and groundwater inflow."*

The SIS and modelling documents do not provide information about the methods used for estimating the quality of the supernatant water pool for Scenario 4a, including how groundwater is incorporated in the estimate. For scenarios 2a and 3a however, there is no consideration of groundwater inflows. Instead the water quality is assumed to be represented by pore water quality only. (DDMI Response to IR #5, Erratum May 9, 2019).

PK Pore Water Quality

Water quality and hydrodynamic modelling for deposit of PK in mine workings relies on an understanding of pore water quality from PK. The pore water expelled from PK as it consolidates is expected to be an important source of high Total Dissolved Solids (TDS) water at the pit bottom, supporting establishment of permanent stratification (layering) in the pit lakes. The PK pore water is also the main source of contaminant loading in the pit lakes, with modelling indicating that this load will gradually diffuse upward and disperse into Lac de Gras over a period of many decades.

The information provided in the June 2018 Amendment Application was not sufficient to understand the basis for DDMI's input assumptions about pore water quality. Each of the subsequent submissions provided additional information, with the January 2019 Response providing summary statistics for "*in situ PKC beach sampling.*" Unfortunately, the response did not clarify if this was surface or subsurface sampling from the beach, leaving outstanding uncertainty about the adequacy of the data supporting water quality input assumptions.

The February 2019 Response provides additional clarification about the sampling, with the Table in Attachment 1 referring to "PKC Beach Pore Water" samples and citing data from Moncur and Smith (2014) in the table notes. The Moncur and Smith paper titled "*Four-Year Hydrogeochemical Field Investigation of Processed Kimberlite Weathering at Diavik Diamond Mines Inc.*[2]" was submitted to the Wek'èezhìi Land and Water Board as part of the Diavik 2014 ICRP Annual Progress Report. The report appears to confirm that the samples are of pore water in PK material and the February 2019 information helps to support the modelling inputs that DDMI applied up to January 2019. One challenge with these inputs is that DDMI relied on average values so it is possible that more adverse conditions could occur. Nonetheless, DDMI continues to assert that its models represent a "*worst-case rather than being representative of the conditions that could be expected at Diavik*" (Responses in Review Comments Table, January 2019).

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[2] Moncur, Michael and Lianna Smith. 2014. *Four-Year Hydrogeochemical Field Investigation of Processed Kimberlite Weathering at Diavik Diamond Mines Inc*. Submitted to Gord MacDonald, Diavik Diamond Mines Inc.

In the February 2019 Response based on discussions at the WLWB Technical Session, DDMI revised its model inputs and now relies on data from 3 samples of water collected from fresh PK slurry to represent pore water quality for PK disposed from the processing plant. Contaminant concentrations for this assumption are much lower than in previous modelling and therefore the models predict lower effects on water quality in the pit and Lac de Gras. However, the results presented in Moncur and Smith (2014) appear to indicate that relying on water from fresh PK is likely to underestimate the pore water concentrations in deposited PK, for example:

- "*Although the exposed FPK had only been weathering for about one month, porewater extracted from the upper 0.25 m of the FPK had elevated dissolved concentrations of cations and SO_4, much higher than the PKC Pond water or water from the End of Pipe*." (Moncur and Smith [2014], Section 6.4)
- "*Within 1 month of fresh slurried FPK deposited over the East Beach of the PKC facility, elevated concentrations of dissolved SO_4 and major cations were observed in the upper 0.25 m of the FPK, suggesting rapid oxidation/dissolution of FPK minerals*." (Moncur and Smith [2014], Section 9.0)

DDMI's May 9, 2019 response to Review Board Information Request #19 confirms that the model relies on data from fresh PK slurry and also acknowledges that this may underestimate the concentrations in PK porewater.

> "*… the sample size for the "Fresh PK" is small and because the PK has not been in solution for very long, the constituent concentrations may be slightly underestimated*." (Response to MVEIRB IR No. 19, May 9, 2019)

DDMI argues that its sensitivity analyses indicate that the model results for Lac de Gras are not sensitive to changes in porewater chemistry. This does not consider the potential characteristics of the water in the pit during operations. Also, the porewater is likely the largest source of contaminant loading in the pit lakes so models need to incorporate reasonably conservative estimates of loading. The revised modelling in the February 2019 Response predicts that water quality in the pit will remain below the AEMP benchmarks even with full mixing of the pit. This may be an optimistic prediction given the revised input assumptions about pore water quality.

Attachment 7 of the January 2019 Response describes comparisons of laboratory and field scale predictions of PK effluent, but results are described as preliminary and no information is provided about how this information has or could inform model inputs and predictions.

Table B-2 in the SIS provides data for five different characterizations of porewater. Of these five, DDMI has optimistically selected the two characterizations that have the lowest concentrations to support its predictions of porewater quality for PK deposited from the processing facility, and EFPK deposited from the PKC facility. Given the available data, and the interpretation provided in Moncur and Smith (2014), it appears likely that the predictions may underestimate the contributions of porewater to contaminant loading.

PK Density

The consolidation and density of PK material once placed in the pits has implications on the final depth of the water cover over the PK, the capacity of the pits for PK storage, the release of pore water from the PK during consolidation, and the volume of excess water that may require treatment during operations. The consolidation and water quality models rely on assumptions of density for making predictions of effects. The adequacy of operational water treatment capacity also relies on an understanding of consolidation and density.

The June 2018 Amendment Application stated assumptions about PK density and provided some information about existing data and measurements. However, there was still uncertainty about how PK may perform in pits. For example,

- Section 3.2 of the Amendment Overview referred to dry densities of various types of PK based on results of field trials (grit-rich Coarse PK 1.8 t/m^3, grit-poor Coarse PK 1.35 t/m^3, Fine PK 0.75 t/m^3). Tables 7 and 8 in Section 3.3.2 of the Amendment Overview provided estimates of pit filling levels and excess water volumes based on dry density of placed PK of 0.8 t/m^3
- In Section 3.3.6 the Amendment Overview identified the slimes (Extra Fine PK) density in the PKC facility as 0.4 t/m^3 but proposed that density in the pit will be 25% higher at 0.5 t/m^3.

Following the January 2019 technical session, the WLWB requested an update of Table 8 in the June 2018 Amendment Application, "*based on a lower dry density of fine PK (based on a range of dry density estimates that is foreseeable in the future)*." The February 2019 Response provided a revised table of "Potential Decant Volumes" considering an assumed FPK dry density of 0.6 t/m^3. The table indicated that excess water volume would be greater for the lower dry density (i.e., less consolidated material). This was counterintuitive and indicated a potential error in the calculations.

Tables 2-2a through 2-2i provide updated information about volumes of settled PK and excess slurry water and appear to correct the previous error. However, there is no information about assumed densities for PK slurry or settled PK, or the basis for any of the calculations. The calculation of "*Supernatant Water Overlying PK Surface*" is not clear – it seems like it should be the difference between the "*Slurry Water Plus Groundwater*" and "*Total Decanted Water*" but the numbers do not reflect this result.

DDMI's July 4, 2019 response to EMAB Comment No. 13 fails to provide any additional information about the assumed densities or the basis for the calculations.

Model Calibration

DDMI states (SIS Section 4.4.1) that it was unable to calibrate its model because the pit lake is not yet established. Instead it states that its model relied on rates and constants from previous model calibrations in the region, and refers to the Jay Project at the Ekati Mine and the Gahcho Kue Project. DDMI's July 4, 2019 response to EMAB Comment No. 14 confirms that most components of the model have not been calibrated. Only the ice module of the hydrodynamic model has been calibrated at other nearby locations. The lack of calibration leaves uncertainty about the accuracy of predictions for future conditions.

Extra Fine Processed Kimberlite

The scope of the assessment includes the placement of extra fine PK (EFPK) from the PK Containment (PKC) Facility in pits. Because the material in the PKC Facility has segregated during the placement and settling processes, the material coming from re-mining at certain times may have very high content of fine or extra fine PK. This could lead to elevated Total Suspended Solids (TSS) concentrations or turbidity in the water in pits during periods of re-mining. EFPK could settle very slowly, especially with water depths that may be substantially larger than those in the PK Containment Facility. Slow settling of EFPK could lead to challenges for achieving AEMP benchmarks before reconnection of pits to Lac de Gras.

The ongoing deposit of PK from the processing plant will also include a component of EFPK. Laboratory consolidation testing conducted in 2011 and presented in the 2012 ICRP Annual Progress Report found that the EFPK resulted in a layer of clayey PK between the clear water and the underlying settled solids. This material could influence water quality (e.g., turbidity and/or TSS) in the pit, especially during any unanticipated mixing event.

DDMI's modelling included predictions for a "settleable constituent" (SIS Section 4.4.1), but there is no information to demonstrate that this modelling would represent behaviour of EFPK which would contribute to turbidity in the water column, but is so fine that it may not behave like a settleable constituent.

5.0 Assessment of Effects on Water Quality

Table 4-2 in Section 4.1.5 in the SIS describes the characterization for effects on water quality. For magnitude, effects are considered negligible if there is "*no measurable change or the concentration of the parameter is less than 5% above the AEMP benchmarks*." AEMP benchmarks are established based on use-protection for aquatic life, and can be much higher than natural conditions in a waterbody. As such, for some parameters a change that reaches an AEMP benchmark may constitute a substantial change in contaminant concentration in water. Nonetheless, DDMI considers these as negligible changes.

The use of AEMP Benchmarks to define negligible magnitude relies on an underlying assumption that water quality has value only in the context of protecting some specific water use, in this case primarily for protection of the aquatic ecosystem. This assumption is appropriate when assessing how water quality may affect aquatic ecosystem VCs, for example fish and fish habitat. However, the identification of water quality as a VC assigns an inherent value to water quality. The definitions of magnitude of changes for an assessment of effects on water quality as a VC should consider the extent of change from baseline conditions, not just the extent of excursion above use-protection based guidelines or benchmarks. When developing definitions of magnitude of change, it is likely appropriate to assign lower ratings to changes that fall within use-protection guidelines or benchmarks, but these changes should not be considered negligible.

Recommendation: When developing definitions and thresholds for significance for water quality, the MVEIRB should consider the magnitude of change from baseline conditions. For water quality, negligible magnitude should be consistent with changes from baseline that are not detectable with a reasonable monitoring program. Changes that are within use-protection guidelines or benchmarks may be appropriate for defining other categories of magnitude.

6.0 Cumulative Effects on Water Quality

Section 4.5 of the SIS describes the cumulative effects assessment for water quality with additional clarification provided in DDMI's July 4, 2019 response to EMAB Comment #19. SIS Table 4-11 indicates that DDMI considered existing Diavik operations and Ekati Mine operations (including the Jay Project) in the cumulative effects assessment for water quality. SIS Section 4.5.2.3 refers to a semi-quantitative approach used to predict cumulative effects. Tables B-7 through B-9 in Appendix B of the SIS provide predicted results in the Diavik pits for cumulative effects modelling. These results are different than those in Tables B10 through B12, the predictions for the PKMW Project on its own. The results in these tables appear to confirm use of modelling predictions, but no details are provided about how the modelling was done, or what inputs were used to predict effects. As a result, it is not possible to understand how the effects of existing Diavik operations and Ekati mine operations were incorporated.

The discussion of significance of cumulative effects in SIS Section 4.6.2.1 states that modelling was completed for nitrate, cadmium and molybdenum in the pit lakes. DDMI does not provide any rationale for the selection of these parameters for consideration, or why other parameters of concern are not considered.

Overall, DDMI has not provided sufficient information to understand the basis for the cumulative effects assessment for water quality. Section 4.5.2.3 of the SIS does not provide a clear explanation of how the effects of the existing Diavik operations and Ekati operations are considered in combination with the effects of the PKMW Project.

Recommendation: To support its assessment of cumulative effects, the MVEIRB should seek additional clarification about the methods used to predict cumulative effects on water quality.

7.0 Criteria for Reconnection of Pit Lakes to Lac de Gras

DDMI proposes that the decision to reconnect pit lakes to Lac de Gras can be based on water quality, specifically that pit lakes will not be reconnected with Lac de Gras until the monitoring program shows that water quality in the pit lakes meets the AEMP benchmarks.

Water quality is an important consideration when deciding whether conditions are acceptable for connecting pit lakes with Lac de Gras. However, sediment quality and safety/physical stability also warrant consideration when assessing whether the proposed PKMW Project may adversely affect VCs.

Sediment Quality

Sediment quality is an important consideration for defining acceptable fish habitat and assessing effects on the fish and fish habitat VC. DDMI has recognized this in its criteria for reconnecting the North Inlet with Lac de Gras. In that case, deteriorated sediment quality has led DDMI to argue that reconnection of the North Inlet to Lac de Gras may not be possible, because the current sediment quality may adversely affect fish. In the absence of sediment quality criteria for the pit lakes, it is difficult to reach assessment conclusions about potential effects on fish and fish habitat.

Recommendation: The MVEIRB should recognize sediment quality as an important indicator for the fish and fish habitat VC, and require DDMI to define appropriate sediment quality criteria that it will apply before reconnecting pit lakes with Lac de Gras. These criteria should be developed to support licensing for the PKMW Project and should be protective of the aquatic ecosystem. The application of the criteria should be limited to areas that may affect fish, i.e., where fish are likely to be present.

Safety/Physical Stability

Closure objectives M4 and M5 in the Closure and Reclamation Plan respectively address safety for small craft navigation, and physical stability of pit walls and shorelines. For small craft navigation, the closure criterion is specific to the size of the dike breach. However, safe navigation is not limited to the size of the dike breach. Safe navigation could also be affected by the physical stability of pit walls and physical conditions of pit walls. For example, physical failures could directly affect boats or navigation, steep pit walls at the shoreline could limit boaters' abilities to access shore in emergency circumstances, or access to pit walls could be a direct safety hazard for people. Establishing connection between the pit lakes and Lac de Gras will lead to improved access to the pit lakes by local users. As a result, the reconnection should not take place until physical conditions and stability of pit walls has been confirmed to be safe.

Recommendation: To address potential effects on public safety, the MVEIRB should require establishment of criteria for defining acceptable pit wall stability (e.g., return periods, factors of safety, etc.) before reconnection of pit lakes with Lac de Gras. These criteria should be developed to support licensing for the PKMW Project. They should be consistent with the expected post-closure land use, specifically increased recreational and subsistence use of the pit lake areas.

8.0 Closure Planning and Closure Objectives/Criteria

Current versions of the ICRP do not describe closure measures for pit lakes containing PK. The closure objectives and criteria for mine workings, listed in the ICRP, do not currently contemplate effects associated with PK in the workings.

Similarly, a decision to place PK in pits could influence the closure plan, objectives and criteria for the PKC Facility. The current closure plan for the PKC Facility relies on careful placement of PK beaches to establish a surface that will support placement of rock cover over most areas, and establishment of a small, permanent closure pond over the slimes. The closure plan relies on the pond to address concerns about the safety of PK slimes. At the January 2019 WLWB technical session, DDMI estimated that discontinuing placement of PK in the PKC Facility would cause the current pond to drain within one year. As a result, the decision to place PK in pits may affect achievement of closure objectives for the PKC Facility. The draining of the pond would also offer an opportunity for DDMI to explore closure options for PK slimes, including potential measures for covering these materials.

As mine plans change, closure planning and the associated objectives and criteria need to be refined to ensure that closure plans are always relevant to the actual site conditions and activities. The closure plan is a key mitigation measure for addressing long-term effects of mining activities, and the closure objectives and criteria define the expected outcomes that the closure plan should produce. As a result, a positive conclusion for an environmental assessment relies on the assumption that an effective closure plan will be implemented once mining activities are completed. Because DDMI is now proposing that those mining activities will include the storage of PK in pits and discontinuation of PK placement in the PKC Facility, these need to be incorporated in closure planning, including objectives and criteria that address potential effects of the revised PK management on VCs.

For example, the ICRP would benefit from objectives that address potential for resuspension of PK material (both during pit filling and for post-closure conditions) and interaction of PK material with the aquatic ecosystem. Criteria will be required to define acceptable outcomes for these objectives. These may include criteria that prescribe minimum depth of closure water cap and depth of water needed to avoid potential direct contact of fish with PK. Criteria related to stratification of the closure pit lakes may also be relevant because stratification is likely to remain important for maintaining suitable water quality at the pit lake surface where it interacts with Lac de Gras.

Establishing criteria related to interaction of PK with the aquatic environment will likely need to consider the perspectives of the TK Panel including the following:

> "*One panel member said that they have set nets 12–14 metres deep on an extremely hot day. One suggestion was to make sure PK was at least 30 metres below the surface of the water, as this is deep enough and fish will not go that deep without a food source to attract them. However, the Inuit contingent suggested that fish can go much deeper, up to roughly 100 metres, which may be a regional difference.*" (DDMI Traditional Knowledge Panel Session #11, Options for Processed Kimberlite, Section 2)

There would also be benefit from the development and implementation of a reclamation research plan focused on addressing slimes in the PKC Facility. DDMI is proposing further feasibility research related to relocating EFPK to the pits, which offers a potential long-term solution for storage of these materials. Research scope should be expanded to take advantage of the expected draining of the pond and include investigation of other closure methods, for example covering in place. Methods used for covering of mature fine tailings at oil sands facilities may provide examples.

Recommendation: The MVEIRB should identify an effective closure and reclamation plan as a key mitigation measure for addressing long-term effects of the PKMW Project. To ensure that this mitigation will be effective, the MVEIRB should establish requirements for timely updating of the closure and reclamation plan to incorporate the PKMW Project. Updated closure planning should include updates of closure objectives and criteria to address potential interactions between VCs and PK stored in pits, as well as changes in conditions at the PKC Facility. MVEIRB should also require a comprehensive reclamation research project to investigate methods for closure and reclamation of PK slimes.

9.0 Follow-up and Monitoring

Section 4.8 of the SIS, and Section 4.4 and Appendix 1 of the May 9 Response to IRs describe the proposed follow-up and monitoring activities aimed at verifying environmental effects predictions, and effectiveness of mitigation.[3]

DDMI proposes to primarily rely on a single sampling location with sampling in the pit to characterize conditions. The plan includes sampling at various depths and frequencies at this location. Section 4.4 of the May 9 Response to IRs also describes a single sampling event with multiple locations that would occur before the pits are reconnected to Lac de Gras, but this sampling is not included in the monitoring appendix.

Recommendation: There are several issues that should be considered and addressed for the proposed monitoring program.

1. DDMI proposes monitoring of decant water from the pipeline, but the monitoring plan does not appear to include monitoring of the water stored in the pit during operations. The decant water likely will not be representative of the water stored in the pit due to aging of the process water and the influence of other sources like groundwater, porewater release and local runoff. The quality of the supernatant water is a key component of the model and monitoring should be conducted to verify model assumptions.
2. The primary reliance on a single station to characterize water quality in each pit after the pits are full may not provide a representative characterization of water quality conditions. Water quality may be variable due to influences from pit walls, local runoff, winds, or internal pit currents. Similarly, a single sampling event with one transect prior to pit reconnection may not accurately characterize variability in pit water quality over time. A more comprehensive water quality monitoring program is needed to confirm the model predictions and the suitability of water quality for reconnection with Lac de Gras. The program should aim to understand spatial (in three dimensions) and temporal variability of water quality conditions to support validation of modelling and decision-making about pit

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[3] There are several inconsistencies between the text in the SIS and the Appendix in the May 9 Response document. Some are noted in the comments, but there may be additional inconsistencies.

lake reconnection. Pit lake reconnection should only occur once monitoring confirms that water quality is suitable in all relevant locations in the pit, and through all seasons.

3. DDMI proposes a monthly “bioprofile.” According to Table 2 in the May 9 Response to IRs, this is to include pH, Turbidity, Temperature, Dissolved Oxygen and Conductivity. The monitoring appendix does not refer to “bioprofiles” but proposes profiles for temperature, turbidity, conductivity and dissolved oxygen. pH is not included.
4. According to the May 9 Response appendix, the proposed profiles are to be recorded over the first 30 m of depth. Profiles of this type would usually be the basis for identifying different layers in a meromictic pit, but the proposed monitoring only to depths of 30m would be well above the predicted depths of the chemoclines predicted in most model scenarios. Profiles should be taken throughout the pit depths.
5. Section 4.4 of the May 9 Response to IRs proposes quarterly sampling of water quality at 2m below surface, 2m above the chemocline, 2m below the chemocline and 2m above the bottom. This approach will require a good understanding of the location of the chemocline – which is not possible without profiles that extend throughout the depth of the pit. The monitoring appendix does not describe the same program, instead referring to monthly sampling at surface, 15m and 30m, and twice-per-year sampling 25m above the pit bottom.
6. The list of water quality parameters should include dissolved metals and TSS. These parameters will be important for data interpretation and understanding the conditions in the pits. If monitoring results confirm that TSS and dissolved metals are not relevant because of clear water conditions, then these parameters could be removed later.
7. DDMI proposes that monitoring in the pits can be reduced to two times per year once the dikes are breached. This reduced frequency may be appropriate once monitoring confirms temporal variability (e.g., seasonal) of conditions after reconnection. More frequent sampling should continue for a period of at least two years to confirm temporal variability.
8. Porewater quality is an important input for modelling predictions. The monitoring program should include a program to collect porewater quality from the PK placed in pits, to verify assumptions in the modelling. A program to monitor PK consolidation would also provide valuable input for model verification.
9. The monitoring program should include monitoring of sediment quality in areas that may be accessible to fish once the pit lakes are reconnected to Lac de Gras. Monitoring should be conducted to support decision-making about reconnection, and also after reconnection to confirm continuation of suitable conditions.
10. The modelling currently relies on temperature data from Snap Lake. Temperature monitoring in Lac de Gras should be initiated to support model updates.
11. The monitoring program should include monitoring of quantity and quality of groundwater inflows into the pits where possible.

10.0 Closing

If you have any questions about the review comments or recommendations, I would be happy to discuss them with you. Thank you for the opportunity to continue working with the EMAB on this project.

Sincerely,

Bill Slater