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Via Email: dswisher@centurymining.com

Attention: Mr. David Swisher
Senior Project Manager

Subject: Desktop Evaluation of Natural Groundwater Flow Velocities
Pine Point Mine Ground Freezing Project

1.0 INTRODUCTION

Tamerlane Ventures Inc. (Tamerlane) is planning a pilot project to mine the R-190 ore deposit from the Pine Point mine located approximately 100 km east of Hay River, NT. The ore deposit is located at a depth of between 90 to 170 m below ground surface and within a permeable dolomite formation. As part of this pilot project, Tamerlane plans to evaluate the applicability of artificial ground freezing for managing seepage during mining. The design intent is to use ground freezing technology to develop a frozen wall of ice-saturated soil or rock around the perimeter of the ore deposit and tie it to the underlying lower-permeability formation such that it creates an impermeable barrier to seepage so that water inside of the frozen wall can be drawn down and the ore deposit mined safely. EBA Engineering Consultants Ltd. (EBA) conducted a feasibility study of the ground freezing option and found that it was technically feasible at this site, as long as natural groundwater seepage rates were sufficiently low (EBA, 2006). Flowing groundwater transports convective heat; if seepage rates are sufficiently high, a continuous frozen wall between two parallel freeze pipes may never develop.

EBA was retained by Tamerlane to conduct a desktop evaluation of natural groundwater conditions at the site. The work was authorized via e-mail by Mr. David Swisher, Senior Project Manager, to EBA on September 7, 2006.

2.0 WORK SCOPE

The work scope, as outlined in an e-mail from EBA dated September 7, 2006, is as follows:

- Review historical hydrogeology reports from the Pine Point Mine, as provided by Tamerlane;
- Develop a conceptual lithological section for the area around the R-190 deposit;

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- Conduct seepage analyses, including sensitivity analyses, to estimate the maximum expected groundwater flow velocities; and
- Summarize the findings in a report.

This review is not intended to be a comprehensive review and analysis of the local and regional hydrogeology around the R-190 deposit. It is intended to be an evaluation of anticipated natural groundwater conditions that may affect the feasibility of artificial ground freezing for this application and is based on a review of selected technical reports provided to EBA by Tamerlane. No site investigation was carried out specifically for this evaluation.

3.0 AVAILABLE HYDROGEOLOGY REPORTS

The following reports (listed in chronological order) were obtained by Tamerlane and provided to EBA:

(1) "Some Practical Aspects of Open-Pit Dewatering at Pine Point", by R.I.J. Vogwill, 1976.

(2) "Report on Pre-Feasibility Groundwater/Geotechnical Assessment, Great Slave Reef Project, N.W.T.," by Dames & Moore, 1976.

(3) "Open Pit Dewatering at the Pine Points Operations of Cominco Limited," by K.J. Durston, 1979.

(4) "Preliminary Environmental Evaluation of the Great Slave Reef Project, NWT," by Beak Consultants Limited, 1980.

(5) "R-190 Zone Aquifer Test Analysis and Preliminary Dewatering Design," by Brown, Erdman & Associates Ltd., 1981.

(6) "Hydrogeologic Evaluation of the Pine Point – Great Slave Lake Region," by GTC Geologic Testing Consultants Ltd., 1983.

(7) "Hydrogeology of R190 Mineralized Region, Great Slave Reef Project, Westmin Resources Limited," by Stevenson International Groundwater Consultants Ltd., 1983.

These reports refer to additional local and regional geology/dewatering study reports that have not been reviewed as part of this desktop evaluation. However, they are believed to provide sufficient information for the purpose of understanding natural groundwater flows and controls at this site.

4.0 SUMMARY OF SITE CONDITIONS

This section summarizes the site climate, topography and drainage, geology, and physical hydrogeology, based on a review of the above reports. Where the information has been described in only one or two reports, reference is made in form of the document number listed in Section 3 (e.g., [1] denotes the Vogwill, 1976 report). Where the information has been covered in more than two reports, no specific reference is made.

4.1 SITE CLIMATE

Hay River, located approximately 100 km west of Pine Point, is the closest meteorological station to Pine Point with a long-term historical record. According to Environment Canada's website, Hay River has a mean annual air temperature of -2.9°C and receives approximately 320 mm of precipitation annually (based on the 1971 to 2000 climate normal period). This compares to a mean annual air temperature of -3.4°C and approximately 340 mm of annual precipitation based on the 1961 to 1990 climate normal period, which is more representative of the time when the mine was operational and all the historical groundwater/dewatering studies were conducted. The climate is classed as semi-arid.

4.2 TOPOGRAPHY AND DRAINAGE

The project area lies across the central parts of Birch Creek and Twin Creek catchments, which are tributary to Great Slave Lake, and on the west side of Buffalo River catchment, north of Highway No. 5. The land is low-lying and poorly-drained, with a gentle northwesterly slope toward the southern shore of Great Slave Lake. Elevations in the region range from approximately 175 m in the northwest to 232 m in the southeast. Swamp, muskeg, and low gravel ridges are the main topographic features. Surface expressions of karstic features include intermittent creeks, natural springs, and sinkholes. Some of the sinkholes have been filled with fine sand. Others are generally filled with granite, limestone, and dolomite boulders in sand, gravel and clay[2].

4.3 GEOLOGY

Surface outcrops are rare in the region[2]. Overburden consists of clayey glacial till with occasional gravel beds and areas of varved clays and cemented fine sands, and varies in thickness from 3 m to 45 m[3]. The overburden generally becomes finer with depth[7]. The glacial till forms an effective confining layer and has a shallow water table established in it. This material is often overlain by an organic, peaty layer of muskeg that is up to 3 m thick. Lacustrine deposits and beach ridges have also been reported in the area. Permafrost has been reported in localized areas within the overburden, but is not common.

Bedrock in the vicinity of the project site consists of a sequence of gently-folded, west-dipping, stratified rocks, associated with a Devonian reef complex. The main stratigraphic units (from top to bottom) are as follows:

1. The limey Hay River Shale formation forms the subcrop westward from its eastern erosional edge, which lies just east of the R190 ore deposit.
2. Slave Point limestone, which has pitted and scattered vuggy zones toward the base, approximately 60 m thick in the R-190 area;

3. Amco Shale-Watt Mountain argillaceous, micritic limestone sequence with green, waxy shale, approximately 15 m thick;
4. Pine Point unit of medium-grained sandstone, dolomite, and limestone that contain scattered vugs and pitted zones. This includes the Presquile subunit, formed of medium to coarse-grained, moderate to extreme vuggy dolomite, approximately 60 m thick in the R-190 area;
5. Keg River Formation, consisting of dense to sucrosic dolostone with varying amounts of argillaceous and carbonaceous material and chert nodules; and
6. Chinchaga Formation, consisting predominantly of anhydrite with minor amounts of dense, finely crystalline dolomite.

The main geological structures, other than the gentle western dip of the strata, are the minor folds and major amount of fracturing that have occurred. Folding is generally associated with differential compaction, gentle flexing, and differences in rates of subsidence in the original sediments. Faulting and fracturing in the Devonian are related to tectonic movements in the basement and follow two main directions: northeast to southwest and east to west.

Generally, the Slave Point unit is massive, with low RQD (Rock Quality Designation) values associated with a vuggy zone located near the base of the rock unit. There is a fractured, apparent weak zone located at the base of the shaly Amco Shale-Watt Mountain unit, and at the apparent disconformity at the top of the underlying Presquile unit.

The Presquile unit generally has low RQD values and is structurally weak. Parts of the vugs are infilled with calcite and sulphur crystals, some of which are bitumen coated in the upper part of the rock unit.

The basal Pine Point unit appears stronger than the Presquile unit. Some pitted zones with weak vug development are present in the basal unit.

Around the R-190 ore deposit, the Presquile zone occurs between approximately 122 m and 183 m depths below ground surface(7).

There have been no piezometric, permeability, or other direct measurements on which to firmly establish the extent of interformational hydraulic interconnection caused by deep-seated, karstification or solution channelling(6). The main karstification in the area is limited to the Hay River and Upper Slave Point formations(6).

5.0 HYDROGEOLOGY

Based on over 15 years of open pit dewatering operations at Pine Point, the hydrogeology of the Pine Point district is considered reasonably well-understood(5). Groundwater occurs as both a shallow phreatic water table associated with the overburden and also under confined pressure conditions in the bedrock. The natural groundwater table in the Pine Point area varies in depth below surface from approximately 1 m to 18 m depth[3]. Perched water is common within the overburden[3]. Regional groundwater movement in the bedrock is towards the northeast and may be locally modified by changes in geological features. Groundwater flow systems developed in the bedrock are a result of large-scale topographic features to the south and west of the R-190 area. The movement of shallow groundwater associated with the overburden depends more on very local topographic relief, but is believed to have an overall direction of movement to the northeast[5]. Vertical hydraulic gradients indicate that groundwater movement is downward from the overburden into the bedrock. Linked porosity in the limestones and dolomites is considered very low and groundwater flows mainly through solution channels, bedding planes, and fracture zones. The glacial till and shales form a relatively impervious confining layer over the underlying aquifers.

The Presquile formation is by far the most porous local stratigraphic unit. Laboratory measurements of intact core recovered from this formation indicated porosities ranging from 2.1 to 18.5 percent and hydraulic conductivities ranging from 1.7×10^{-10} m/s to 1.2×10^{-4} m/s [6]. These measurements do not include fracture conductivity, which may be high.

The main aquifers in the area occur in the bedrock and are mostly present because of fracture permeability, although the Presquile zone is thought to have both vuggy and fracture components in permeability. Bedrock aquifers are under confined conditions and groundwater occurring in them are therefore under a pressure head[5]. Confined conditions have been reported to be the effects of topography, low-permeability clayey overburden and shale units, and elevated recharge areas to the south (Caribou Mountains and, to a lesser extent, Cameron Hills). As the elevation of the land surface drops towards Lesser Slave Lake, flowing artesian conditions and springs are common. The results of a modelling study indicated that flow in the deeper sediments, particularly the barrier reef, was not dominated by the recharge from the Caribou Mountains[6].

Aquifer tests at the Pine Point Mine have shown that the hydraulic conductivity of the bedrock can be anisotropic, meaning that there is a preferred direction of groundwater movement along these features as compared to across them.[5]

Natural groundwater movement within the bedrock aquifer is reported to be towards the northeast at an average gradient of one foot to 2200 feet[5]. Northward groundwater flow under a hydraulic gradient of 1.5 m per km has also been reported[7].

Springs discharging mineralized groundwater have been observed along the south shore of Great Slave Lake[6,7]. Sulphurous springs as well as artesian boreholes along the banks of the Buffalo River have also been reported[6].

While many of the reviewed reports discuss the results of pumping tests, only one report, (6), has described a groundwater model developed to estimate steady-state conditions prior to dewatering. The calculated hydraulic conductivity for the Presquile unit ranges from 10^{-4} m/s [6] to 10^{-3} m/s [7]. The upper-bound hydraulic conductivity is comparable to a clean sand or clean sand and gravel[7].

6.0 GROUNDWATER MODELLING

Groundwater modelling was carried out to understanding the regional controls on groundwater flow, as well as to estimate natural, steady-state groundwater flow velocities. Analyses were carried out using SEEP/W, a two-dimensional finite element seepage model program developed by Geo-Slope International Ltd. A two-dimensional model was used as opposed to a three-dimensional one because the absence of recent piezometric data and analysis of current groundwater recharge meant that the results of any comprehensive groundwater model would be questionable for current conditions. A simple two-dimensional section would also allow model parameters (e.g., hydraulic conductivity) and boundary conditions (e.g., hydraulic gradient) to be varied and the sensitivity of groundwater flow to these parameters be evaluated.

6.1 STRATIGRAPHIC PROFILE

The north-south stratigraphic section developed by (6) formed the basis of the groundwater model. This section was originally for a profile located east of the R-190 deposit and was thus modified to include the stratigraphic layers around the R-190 deposit. Figure 1 shows the modeled section. The modeled section is 200 km wide by just over 300 m high.

6.2 INPUT PARAMETERS AND BOUNDARY CONDITIONS

The hydraulic parameters used for each stratigraphic unit are summarized in Table 1. These parameters were based on the results of three-dimensional groundwater modelling of steady-state conditions[6].

TABLE 1: MAJOR STRATIGRAPHIC UNITS AND THEIR HYDRAULIC CONDUCTIVITIES[6]

Unit	Hydraulic Conductivity (m/s)
Hay River Shales	10^{-9}
Slave Point Limestones, Shales	10^{-9}
Presquile Dolomite	10^{-4}
Keg River Dolomite	10^{-6}
Chinchaga Anhydrite	10^{-9}

Great Slave Lake was modeled with the lake elevation at 156 m. The left hand side of the boundary was modeled with a pressure head of 210 m.

6.3 RESULTS AND DISCUSSION

Figure 2 shows the results of the steady-state seepage analysis. All groundwater flow is channeled within the relatively high-permeability Keg River and Presquile units. The maximum calculated velocity through these units is 5 x 10^{-10} m/s (4 x 10^{-5} m/day). Sensitivity analyses were conducted, varying the hydraulic conductivities of the Keg River and Presquile units, in addition to the head on the southern (upslope) boundary of the model section. The results indicated that increasing the hydraulic conductivity of the Keg River unit from 10^{-6} m/s to 10^{-4} m/s raised the calculated maximum velocity to 6 x 10^{-8} m/s (5 x 10^{-3} m/day).

The above calculated velocities represent average water flowing through a cross-sectional area normal to the macroscopic direction of flow. The actual seepage velocity (v') relates the average velocity (v) with porosity (n):

$$v' = \frac{v}{n} \quad [1]$$

Equation [1] indicates that the seepage velocity increases with decreasing porosity. For example, for a given average velocity, the seepage velocity will be greater for a low-porosity rock where water flows through a relatively small-aperture fracture than it would for a more porous rock. As described in Section 5, measured porosities of intact rock core recovered from the Presquile unit ranged from 2.1 percent to 18.5 percent. If we assume 2 percent porosity, then the maximum seepage velocity due to natural groundwater seepage is estimated to be 6 x 10^{-8}/2 x 10^{-2} = 3 x 10^{-6} m/s or 0.26 m/day. However, this estimate is very conservative, as it is more representative of a low-permeability, unfractured rock. Since groundwater flow through the Presquile unit is mainly through fractures, faults, and solution channels, the porosity is likely much higher than 2 percent and seepage velocities will be less than 0.26 m/day.

7.0 LIMITATIONS

The results presented in this letter report are based on a review of documents provided to EBA by Tamerlane. It is not considered a comprehensive evaluation of local and regional hydrogeology, as not all published reports (some which may no longer exist in the public domain) relevant to the hydrogeologic conditions in the vicinity of the R-190 ore deposit at Pine Point were reviewed.

The subsurface conditions described in this report are considered to be reasonably representative of the area around the R-190 site. They are, however, based on studies that were done twenty to thirty years ago. Current groundwater conditions may be different due to development and changing climate, among other reasons.

This report has been prepared for the exclusive use of Tamerlane Ventures Inc., for specific application to the R-190 site. It has been prepared in accordance with generally-accepted geotechnical engineering practices. No other warranty is made, either expressed or implied.

8.0 CLOSURE

We trust that this letter report meets your current requirements. We would be pleased to provide additional information, if required. Please contact the undersigned if you have any questions.

Respectfully submitted,
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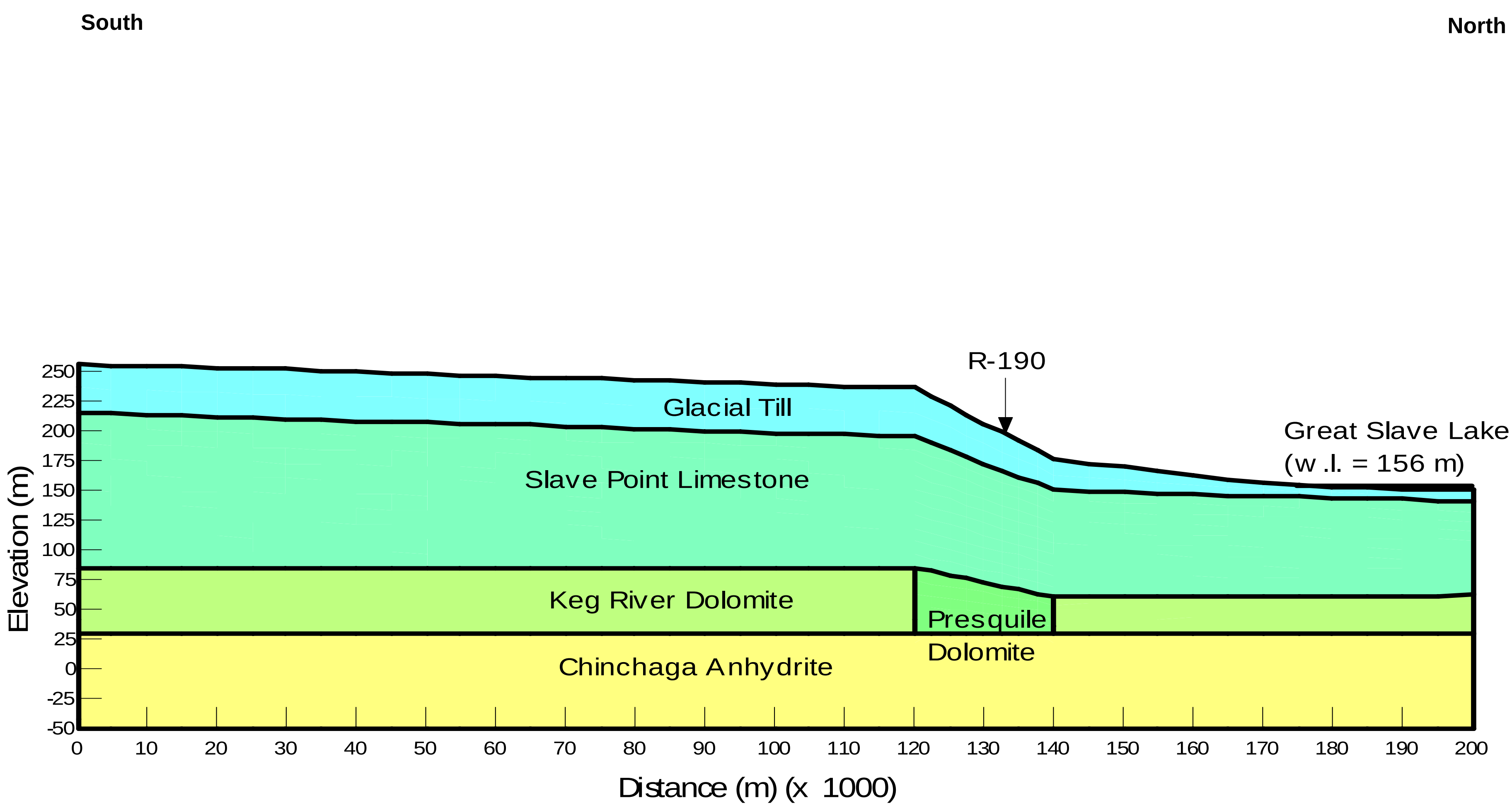

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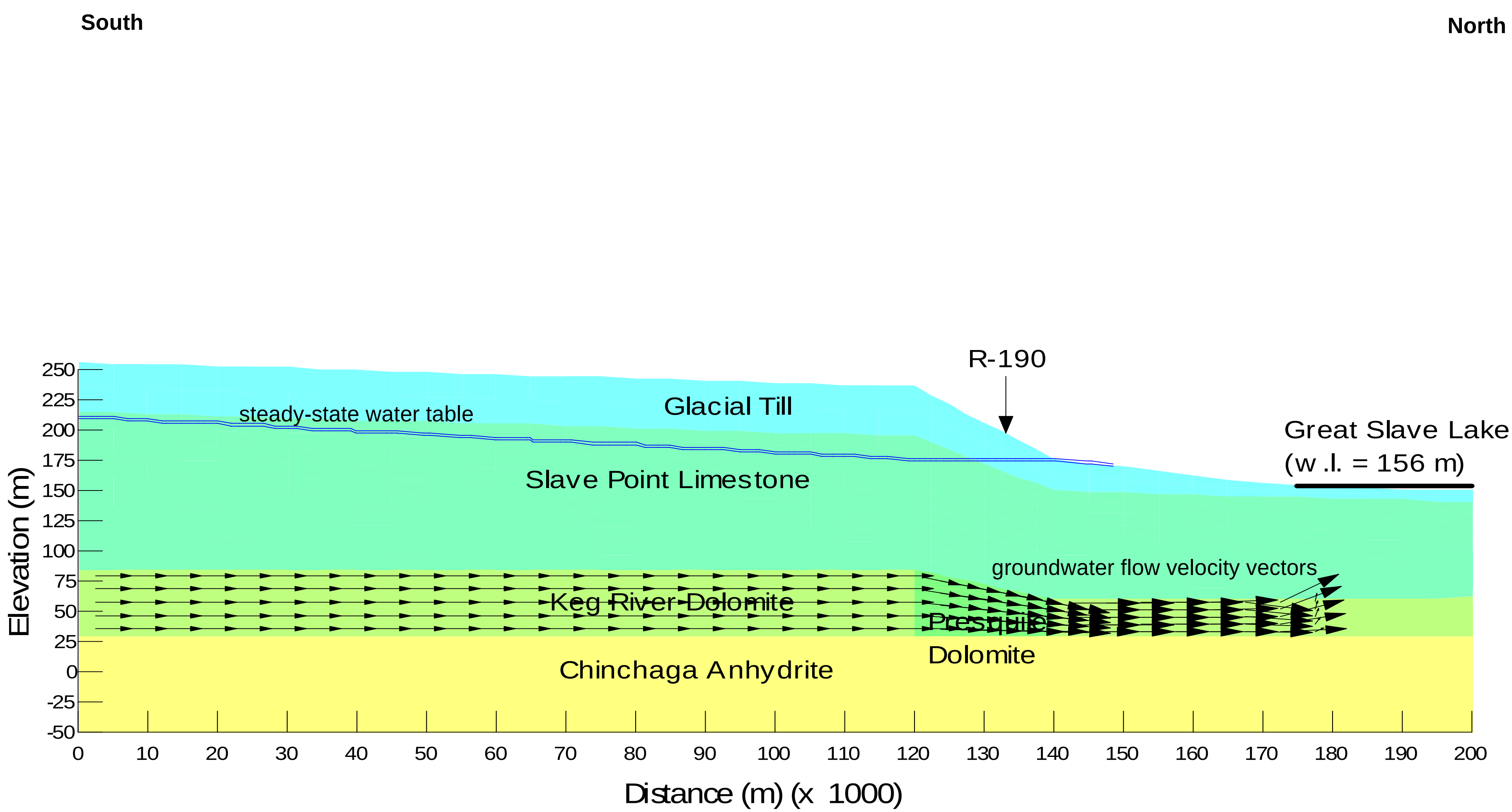

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DWN. JTCS / CHKD. JTCS		TITLE Results of Seepage Analyses, Base Case	
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