TECHNICAL MEMORANDUM

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DATE: May 19, 2008 Proj. No. 071-3340052

TO: Rob McLean, Josh Harvey

CC: K. Conroy, K. DeVos, M. Digel, L. Young, S. House

FROM: Paul Pigeon, Peter Lemke

RE: Snap Lake Water Management Treatment Alternatives Report

This Technical Memorandum presents the results of the De Beers Snap Lake Diamond Mine Water Management Alternatives Study. The work plan dated November 2, 2007 included the following:

1. Identifying what treatment systems for removal of total dissolved solids (TDS) appear to be the most economically feasible for treatment of the water originating from the waste rock mine workings (haulage drifts).

2. Developing order-of-magnitude costs to design, construct, install, operate and maintain a TDS removal treatment system at flow rates of:

   - An initial capacity of 3,000 cubic meters (m^3) per day that can be expanded to 10,000 m^3/day;
   - An initial capacity of 3,000 m^3/day that can be expanded to 20,000 m^3/day; and
   - An initial capacity of 3,000 m^3/day that can be expanded to 30,000 m^3/day.
   - (After the site visit for project kickoff, on November 27, 2007, it was noted that the haulage drift water flow rate had already at times exceeded 3,000 m^3/day. For purposes of this study, the initial flow rate was changed from 3,000 m^3/day to 5,000 m^3/day).

To complete these objectives, the project work was divided into four tasks including the Kick-off and Site Visit, Characterization and Design Basis, Alternatives Development, and Evaluation and Recommendations. The Work Plan and the Site Visit and Project Kickoff Report are provided as attachments to this report. The balance of this report addresses the influent water quality characterization (or design basis influent), treatment alternatives and evaluation, and a recommended treatment system

WATER QUALITY CHARACTERIZATION

Key to the development of viable treatment alternatives is the understanding of the influent water quality characterization. De Beers provided fifteen data sets from routine sampling and analysis events covering the time period from March through October 2007, for several monitoring points. The monitoring points that are most representative of the water to be treated were drift water sampling points 10 and 11 (DW10 and DW11). These two sampling points were later combined into a single sample for analysis and the location was designated as DW1011. These data are summarized in Table 1.

Based upon review of the available data, Golder requested performance of additional sampling and analyses to generate an adequate design basis influent data set for development of treatment alternatives. The list of additional analyses requested is provided as an attachment to this report. This list also provides justification and comments on the utility of the data. Of primary importance to the identification and screening of potential treatment technologies for TDS removal were the concentrations of trace metals in dissolved form, as opposed to "total" (dissolved and particulate) form as previously reported.

Sampling to obtain the additional data was conducted on February 25, 2008, and samples were submitted to ALS with a request for expedited analysis. Results were provided on March 4, and a revised design basis influent water quality characterization was developed. This design basis influent is presented in Table 2.

Table 1. Water Quality Characterization (2007 data available at project kickoff)

	Avg	Min	Max
Alkalinity	49	11	93
Bicarbonate	59	ND	114
Carbonate	16	ND	20
Hardness (mg/l as CaCO3)	2,124	214	3,070
Hydroxide	10	ND	17
Acidity	<5	ND	ND

	Avg	Min	Max
Ammonia	3.22	0.36	8.71
Total Kjeldahl Nitrogen	3.44	0.35	8.71
Nitrate	9.05	ND	30.1
Nitrite	0.34	ND	0.97
Nitrate + Nitrite	6.26	ND	31.8

	Avg	Min	Max
pH	8.1	6.9	10.8
Conductivity (uS/cm)	4,800	901	8,380
Turbidity (NTU)	1,491	4	5,700

	Avg	Min	Max
Total Dissolved Solids	3,178	596	5,090
TDS (calculated)	2,748	418	4,890
Total Suspended Solids	1,967	ND	6,250
Total Organic Carbon	6	ND	12

	Avg	Min	Max
Fluoride	0.94	0.66	1.09
Chloride	1,561	191	2,820
Sulphate	154	32	252
Orthophosphate	<0.001	ND	ND
Phosphorus Total	0.48	0.008	1.63
Phosphorus, Total Diss.	0.03	ND	0.04
Calcium	631	85	1,210
Magnesium	33	0.7	46.7
Potassium	23	ND	436
Sodium	306	69	543
Silica, Reactive Soluble	13.13	9.6	15.4

TOTAL METALS	Avg	Min	Max
Aluminum (ug/l)	21,300	11,200	31,400
Antimony (ug/l)	6	ND	6
Arsenic (ug/l)	24	5	42
Barium (ug/l)	365	60.7	669
Beryllium (ug/l)	0.50	1	-
Bismuth (ug/l)	0.60	0.2	1
Boron (ug/l)	370	190	550
Cadmium (ug/l)	1.2	ND	1.2
Cesium Total	<50	ND	ND
Chromium (ug/l)	97	24.8	169
Cobalt (ug/l)	7	5.2	9.6
Copper (ug/l)	17	6	27
Iron (ug/l)	23,150	13,000	33,300
Lead (ug/l)	124	15.4	233
Lithium (ug/l)	84	47	121
Manganese (ug/l)	208	97	318
Mercury (ug/l)	2	0.5	4
Molybdenum (ug/l)	10	9.2	11.2
Nickel (ug/l)	54	19.2	89
Rubidium (ug/l)	80	ND	80
Selenium (ug/l)	<0.4	ND	ND
Silver (ug/l)	<0.4	ND	ND
Strontium (ug/l)	5,365	1,420	9,310
Thallium (ug/l)	2	1.3	1.80
Tin (ug/l)	9	2.9	15.80
Titanium (ug/l)	929	507	1,350
Uranium (ug/l)	4	3.4	4.5
Vanadium (ug/l)	50	31.2	68.1
Zinc (ug/l)	197	54	340

Ion Balance	97.96%

Table 1 Note. All values are milligrams per litre (mg/l) except as noted. ND = non-detect. Avg = average of all reported values for DW-10 and DW11. Min and Max are minimum and maximum reported values.

Table 2. Water Quality Characterization (Supplemental sampling and analysis, February 2008)

	Avg	Max	Min
Alkalinity	32	49	14
Bicarbonate	35	58	11
Carbonate	<5	<5	<5
Hardness (mg/l as CaCO3)	2,124	3,070	214
Hydroxide	<5	<5	<5
Acidity	<5	<5	<5

	Avg	Max	Min
Ammonia	3.22	8.71	0.36
Total Kjeldahl Nitrogen	3.44	8.71	0.35
Nitrate	8.5	8.5	8.5
Nitrite	0.394	0.394	0.394
Nitrate + Nitrite	8.8	8.8	8.8

	Avg	Max	Min
pH	8	8.5	8.4
Conductivity (uS/cm)	3191	6090	292
Turbidity (NTU)	340	340	340
Total Dissolved Solids	3,178	5,090	596
TDS (calculated)	2,748	4,890	418
Total Suspended Solids	795	795	795
Total Organic Carbon	6	12	ND
Fluoride	0.94	1.09	0.66
Chloride	1016	1980	52
Sulphate	154	252	32
Orthophosphate	<0.001	<0.001	<0.001
Phosphorus Total	0.48	1.63	0.008
Phosphorus, Total Diss.	0.03	0.04	ND
Calcium	631	1,210	85
Magnesium	33	46.7	0.7
Potassium	23	436	ND
Sodium	306	543	69
Silica Reactive Soluble	13.13	15.4	9.6

	Dissolved metals - 5 samples			Total metals
TRACE METALS	Avg	Max	Min	L609513-5
Aluminum (ug/l)	<10	<10	<10	7180
Antimony (ug/l)	<0.8	<0.8	<0.8	<5
Arsenic (ug/l)	2.7	5.7	<0.4	<1
Barium (ug/l)	57	61.6	54	132
Beryllium (ug/l)	<0.5	<0.5	<0.5	<1
Bismuth (ug/l)	0.09	0.1	0.06	0.3
Boron (ug/l)	405	556	341	450
Cadmium (ug/l)	0.1	0.1	<0.1	<0.2
Cesium (ug/L)	0.2	0.2	0.2	<50
Chromium (ug/l)	<5	<5	<5	41
Cobalt (ug/l)	0.8	0.9	0.7	8.6
Copper (ug/l)	2.2	2.8	1.7	17
Iron (ug/l)	12	30	<5	11100
Lead (ug/l)	0.2	0.3	0.1	17
Lithium (ug/l)	113	115	109	156
Manganese (ug/l)	21	27	14	132
Mercury (ug/l)	<0.1	<0.1	<0.1	<0.2
Molybdenum (ug/l)	6.4	7.8	5.7	7.2
Nickel (ug/l)	35.1	107	16	69.4
Rubidium (ug/l)	<50	<50	<50	<50
Selenium (ug/l)	0.6	0.7	0.4	0.5
Silver (ug/l)	<0.2	<0.2	<0.2	<0.4
Strontium (ug/l)	10492	11200	9860	12200
Thallium (ug/l)	0.09	0.1	0.08	0.2
Tin (ug/l)	<0.2	<0.2	<0.2	0.6
Titanium (ug/l)	1.2	1.5	1	399
Uranium (ug/l)	2	2.8	1.6	3.4
Vanadium (ug/l)	1.4	2	<1	24.1
Zinc (ug/l)	21.4	83	<2	60

Table 2 Notes. All values are milligrams per litre (mg/l) except as noted. ND = non-detect. Avg = average of all reported values for DW-10 and DW11. Min and Max are minimum and maximum reported values. The following analyses were not performed for the Feb 25 sampling event, and values for these parameters are copied from the 2007 historical data: hardness, ammonia, total kjeldahl nitrogen, TDS, TDS (calculated), total organic carbon, fluoride, phosphorus total, phosphorus dissolved, calcium, magnesium, potassium, sodium and silica.

The water quality characterization as presented in Table 2 along with the flow rate requirements over the project life, the treated effluent requirements, and general guidance as to acceptable forms and quantities of secondary waste were used to identify and pre-screen the field of potentially applicable treatment technologies. Technology pre-screening is described below.

POTENTIALLY APPLICABLE TREATMENT TECHNOLOGIES

Typical TDS removal technologies

Potentially applicable treatment technologies for removal of TDS include evaporation, reverse osmosis, ion exchange, electrodialysis reversal, and chemical precipitation. Development of treatment alternatives may require implementation of a single primary technology from the candidate list (with minimal pre- or post-treatment steps) or may involve a combination of technologies (e.g., reverse osmosis and chemical precipitation). Minimization of secondary waste is an important aspect of the Snap Lake Water Management project. While any of the above technologies can produce an effluent of acceptable quality, additional processing steps may be necessary to produce a secondary waste stream of manageable quality and volume.

Each of the candidate technologies is briefly described. Table 3 presents a summary and comparative screening evaluation for the treatment of De Beers Snap Lake drift water.

Evaporation – Mechanical Process Equipment

Evaporative techniques produce a treated effluent by vaporizing and then condensing pure water. In cases where "zero liquid discharge" is preferred or required, the vaporized water is released to atmosphere rather than condensed. The evaporation waste byproduct (or "bottoms") is a concentrated brine stream, which may in turn be processed to a dry residue.

Mechanical methods

Mechanical evaporation involves boiling off the water phase of the waste stream leaving a concentrated brine stream. The vapor can either be discharged to atmosphere as a steam plume or condensed to produce an essentially distilled water effluent stream. Evaporation is broadly applicable to removal of non-volatile contaminants in wastewater including TDS. A mechanical vapor recompression (MVR) brine concentrator is a commonly used process for this type of application. The brine concentrator typically evaporates approximately 95 to 98 percent of water and produces a small volume slurry stream that must be disposed of or managed. Typical management methods for evaporative slurry include crystallization to near dryness, deep well disposal, and off-site disposal. On-site disposal with waste rock is also a possibility for the Snap Lake site. The total volume of crystallized waste and potential for reintroduction of TDS to ground water or surface water (if leached from waste rock storage) would have to be evaluated to assess the viability of on-site disposal.

Reverse Osmosis

Reverse osmosis (RO) treatment is essentially an extremely fine filtration technique that utilizes a series of fine pore membranes. Water and extremely low levels of some contaminants pass through the membranes while the majority of the contaminants are retained on the brine side of the membrane. The system is relatively simple, consisting primarily of membranes in a series flow configuration and a high pressure pump. Some pretreatment to protect the membranes is typically required, and may include filtration for suspended solids removal, antiscalent addition, and preheating of the waste stream. The osmotic pressure required for RO treatment is inversely related to the temperature of influent water. Thus preheating can increase treatment efficiency while reducing the pumping power requirement. The RO-treated effluent is termed the "permeate". The RO waste stream is referred to as brine or reject. Based on experience with similar water sources the TDS of the permeate produced at Snap Lake could be in the 50 to 100 mg/l range. TDS in the RO brine stream could be in the range of 10,000 and 15,000 mg/l. The brine stream volume is typically in the range of 20 to 50 percent of the influent stream. Like the evaporation process an RO is broadly applicable to TDS contaminants and can provide a 95 to 99 percent reduction in the contaminant concentrations.

Ancillary equipment requirements for a fully functional RO treatment system may include prefiltration, antiscalent addition, preheating, and a membrane cleaning system.

Electrodialysis Reversal

Electrodialysis reversal (EDR) is an electrochemical separation process that removes ions and other charged species from water and other fluids. EDR uses small quantities of electricity to transport these species through membranes composed of ion exchange material to create separate purified and concentrated streams. The ion exchange membranes are configured in an alternating series of anionic and cationic membranes. Ions are transferred through the membranes by means of direct current (DC) voltage and are removed from the feed water as the current drives the ions through the membranes to desalinate the process stream. When membranes become saturated, the DC current is reversed, effectively cleaning the membranes for continued use.

EDR presents an advantage over RO in that it typically requires less pretreatment. Control of influent pH and addition of antiscalent are usually not necessary with EDR. EDR has been demonstrated effective on groundwaters containing up to 5,000 mg/l TDS, recovering clean water at a 94% rate. Polarity reversal allows for concentrating brine beyond saturation. Through this electrically driven process the product water quality can essentially be "turned up" or "turned down" by adjusting the DC current flow.

Ion Exchange

Ion exchange is the reversible exchange of ions between the stream to be treated and an insoluble solid ion exchange resin. It is a well-developed process for extraction of cations (such as calcium or magnesium) or anions (such as sulphate or nitrate) from contaminated wastewater. Ions present in the wastewater are exchanged with ions on the resin, without producing any permanent change to the resin structure. The most commonly used exchange ions (present on fresh resin) are sodium for cation exchange and chloride for anion exchange. Thus, the treated water stream will contain elevated levels of sodium and chloride. When the active sites on the resin are exhausted, the resin is regenerated by contacting it with a concentrated solution of the exchange ions originally associated with the resin. The contaminant ions are carried off the resin with the regeneration liquor. The regeneration liquor is the secondary waste stream resulting from primary treatment by ion exchange.

Ion exchange treatment efficiency can be in the range of 90 to 99 percent for common anions and metals. Suspended solids and organics must be removed from the wastewater prior to treatment by ion exchange to prevent fouling of the resin.

The ion exchange media is contained in a column or series of two to three columns and the water flows by gravity or is pumped through the system. Support systems include tanks for the regeneration fresh and used regeneration chemicals.

Chemical Precipitation

Chemical precipitation is a pH adjustment process that involves the addition of a chemical to adjust the pH to the point of minimum solubility for target compounds. For the primary constituents of the TDS in the leachate, addition of lime to pH values in the 10 to 11 range could reduce the sulphate, alkalinity, and metals levels and provide an overall TDS reduction in the 40 to 60 percent range on the raw leachate. Sodium will not be affected by lime treatment and it is unlikely that nitrate or selenium will be removed. The solid precipitate must be removed by filtration or settling and then managed and disposed. Typically the sludge volume is reduced by a sludge dewatering step such as a filter press. Since the sludge is expected to be primarily gypsum (calcium sulphate) and calcite (calcium carbonate) it is likely that the sludge can be disposed in a municipal-type landfill. Disposal with mine tailings could be a satisfactory repository.

Support systems include the chemical storage and feed system, and solids separation which is typically accomplished by a clarifier and polishing filter. Final pH adjustment to reduce the pH from the elevated treatment pH to a more neutral pH is typically required. The sludge can be further treated by dewatering in a filter press or other mechanical dewatering device. Some mines utilize pond systems for treatment and solids separation.

TECHNOLOGY SCREENING

In most water management alternatives studies, there are two or three viable process trains that can be developed with equivalent capabilities to meet the treatment goals, which can then be evaluated against criteria such as capital and operating costs, labour requirements, ancillary equipment, utilities consumption, etc. However, the Snap Lake Diamond Mine site presents unique conditions which severely restrict the range of viable treatment technologies. These conditions include the influent water quality characterization and treatment goals, site location, and limited secondary waste storage/disposal options. These conditions and their bearing on the technology identification and screening process are described below.

Influent Water Quality Characterization and Treatment Goals

Water chemistry. The influent water quality characterization includes the chemistry summarized in tables 1 and 2 above, and other parameters affecting treatment technology identification. The design basis influent water chemistry is not well-suited to treatment by EDR, ion exchange or chemical precipitation. EDR is best-suited to a relatively “clean” influent of about 500 mg/l TDS concentration which is lower than the minimum reported TDS value for 2007. Ion exchange is not viable for TDS reduction due to its contaminant removal mechanism of replacing the resin-absorbed contaminant ions from the treated flow with ions released from the resin which are considered to be innocuous. In the case of Snap Lake’s discharge requirement to remove TDS, ion exchange is not viable. Chemical precipitation for metals and sulphate removal is generally performed by addition of hydrated lime (calcium hydroxide). The hydroxide ions bond with dissolved metals and form insoluble metal-hydroxides. Calcium ions bond primarily with the sulphate in the influent stream, forming an insoluble solid. The metal-hydroxides and calcium sulphate are removed from the influent stream as a sludge. As noted above, the TDS removal efficiency for chemical precipitation is limited to approximately 40 to 60%, which is inadequate for the worst case design basis influent. The sludge would also require additional handling to minimize volume.

The water quality characterization has process impacts on an RO- or evaporation-based treatment system but can be handled with pretreatment steps, primarily filtration to remove suspended solids.

Temperature. Influent water temperature is another prime consideration for viability of treatment technologies. The operational efficiency of an evaporation system is relatively unaffected by influent temperature, although additional energy consumption is required for lower temperature influents. RO operates more efficiently on an influent stream with a moderate temperature of approximately 20°C to 30°C.

Flow rates. The initial flow rate of 5,000 m^3/day, and future expansions to 10,000, 20,000 and 30,000 m^3/day can also be handled by either evaporation or RO as the main treatment operation. These technologies are constructed in modules which will facilitate capacity expansion as mine dewatering flows increase.

Site Location

The primary issue with location is the inaccessibility of the site by surface transportation except during the limited time period of winter road operation. This presents problems for treatment processes that are dependent on routine use and replacement of chemical reagents or resins in bulk quantities. Requirements for chemical or resin storage or shipment are prohibitive for ion exchange and for chemical precipitation treatment systems.

Again, RO and evaporation will require some pretreatment steps but are more viable than ion exchange or chemical precipitation treatment systems with regard to storage or delivery of bulk materials required for continuous operation.

Secondary Waste

Similar to the constraints of bulk deliveries to the site for process operations, location is also a constraint relative to storage or disposal of secondary wastes generated by treatment processes. The options for final disposition of secondary waste are limited to storage in the North Pile or use in paste backfill returned to the mine workings.

The waste stream generated by a chemical precipitation system would be a sludge, consisting of calcium sulphate and metal hydroxides. By adding a dewatering step, the volume could be somewhat reduced but is still anticipated to be prohibitively large, especially at the increased treatment flow rates in the out-years of production. The characteristics of the sludge may or may not be suitable for use in paste backfill. The planned volume and rate of paste backfill in relation to mine development may also be a limiting factor in disposal of chemical precipitation sludge.

Ion exchange will produce a concentrated waste stream when the resins are regenerated. The regenerant stream will require additional treatment for volume reduction and stabilization. Untreated ion exchange regenerant will not be suitable for use as a paste backfill additive, nor can it be disposed in an uncontained waste pile. Disposal would require an isolation cell, and the volume of untreated backwash over the life of the project would make isolation infeasible.

Similar to ion exchange regenerant, EDR and RO will both produce a concentrated liquid waste stream. This reject (or brine) stream will also require additional treatment for volume reduction and stabilization.

Brine is not suitable for addition to paste backfill, and cannot be disposed in an uncontained waste pile. Disposal of RO or EDR waste without additional treatment is infeasible.

Evaporation will produce the lowest volume of secondary waste. If a crystallizer is utilized, evaporation will produce only dry solids as a waste stream. This dry solid waste is unlikely to be useful as a paste backfill additive, but will require the smallest volume of isolated disposal of any of the technology options. As such, evaporation is a viable option as the main treatment process and is also viable as an additional treatment step, for volume reduction of the secondary waste streams from other processes.

The advantages and disadvantages of each technology are summarized in Table 3. As noted in the comments column, EDR, ion exchange, and chemical precipitation have been deemed infeasible due to failing the screening criteria described above. The development of viable treatment processes will consider evaporation and RO with a supplemental evaporation process.

Table 3. Comparative Evaluation of Treatment Technologies for De Beers Snap Lake Drift Haulage Water

Technology	Advantages	Disadvantages	Comments
Evaporation	Zero liquid discharge treatment is an option, or a condenser can be utilized to recover a treated effluent in liquid form. Treated water quality with condenser is essentially contaminant free. Residual stream requiring management or disposal is extremely low volume. Can be operated continuously or batch-wise.	Distilled water can be corrosive and aggressive. Reuse and/or discharge may require post-treatment. Most costly capital and operating costs of all technologies screened. Lead time on equipment may be up to one year. Requires significant energy input.	Probably not cost effective as the primary treatment unit for the full stream. Treating a split stream and blending back with untreated water to maintain TDS effluent goal may be viable. May also be appropriate as a secondary treatment unit, to manage a smaller volume brine or concentrate stream.
Reverse Osmosis (RO)	Produces an extremely low TDS, high quality treated water stream. Proven technology for TDS treatment. Can be operated continuously or batch-wise, but best operated in continuous mode.	Brine stream flow rate may be as high as 25-50% of the influent flow, and would likely require further treatment. Higher capital and operating costs than other technologies with the exception of mechanical evaporation. May require several months of equipment order lead time. Operations become problematic if system is shut down. Membranes must be properly cleaned and stored when not used for more than 1-2 days. Requires relatively skilled operations personnel.	Treatment of RO brine for volume reduction could be accomplished by series RO treatment or by mechanical evaporation. Similar to evaporation a split stream could be treated and recombined with untreated flow while maintaining effluent quality at the required TDS effluent discharge limit.
Electrodialysis Reversal (EDR)	Produces an extremely low TDS, high quality treated water stream. Proven technology for TDS treatment. Can be operated continuously or batch-wise.	Brine stream flow rate may be as high as 25-50% of the influent flow, and would likely require further treatment. Generally used on TDS influent of 500 mg/l or less. Same pretreatment requirements as RO. Requires more power than RO and is more sensitive to influent temperature.	Technically infeasible for this site.

Technology	Advantages	Disadvantages	Comments
Ion Exchange	Simple “flow-through” technology. Could be implemented extremely quickly. Can be operated continuously or batch-wise.	Ineffective for TDS reduction at levels projected for Snap Lake’s design basis influent. Typically used to remove specific contaminant ions when replacement of the removed contaminant with an innocuous ion is acceptable. Produces a concentrated waste stream when resin is regenerated that would have to be treated or disposed.	Technically infeasible for this site.
Chemical Precipitation	Simple technology can be implemented relatively quickly. Equipment is relatively inexpensive. Provides gross TDS reduction when primary constituents are sulphate and metals.	Produces sludge stream that must be managed. May not provide enough TDS reduction for discharge or reuse, given the relatively low sulphate and metals concentrations in the design basis influent. Calcium is a significant contributor to the TDS load, and will not be removed by this process. Onsite lime storage is needed, and storage capacity could be prohibitive.	Technically infeasible for this site.

TREATMENT ALTERNATIVES

Based on the technology screening, the viable treatment technologies for the Snap Lake Diamond Mine are RO and evaporation. In the development of treatment alternatives, these technologies are used as the main treatment step, along with the likely pre-treatment and post-treatment steps that will be required. Influent water quality characterization, effluent treatment requirements and flow rates were provided to commercial providers of RO and evaporation equipment. These vendors included GE Infrastructure Water & Process Technologies, Siemens Water Technologies Corporation, and Aquatech International Corporation. GE and Siemens provided equipment descriptions and budgetary cost estimates for RO-based treatment systems, while Aquatech provided estimates for an evaporator-based system as well as an RO-based system. GE and Siemens provided considerably different pre-treatment equipment, which is discussed in the later sections of this report. The RO treatment alternative described below is based on GE's estimate. The evaporative treatment alternative is based on Aquatech's estimate.

ALTERNATIVE 1 – REVERSE OSMOSIS BASED TREATMENT

Pretreatment

The efficiency of RO operation is dependent on several factors in the influent stream. These factors include temperature, presence of suspended solids, and presence of dissolved species which are considered to be membrane "foulants". Based on review of available water quality characterization data, pretreatment will be required for RO.

In some cases foulant species must be removed from the RO influent stream, while others can be controlled by addition of antiscalant. GE modeling based on the maximum constituent concentrations (Table 2) indicated that scaling of RO membranes will not be a problem in treatment of the Snap Lake drift water. Species which tend to scale in RO include calcium carbonate, calcium sulphate, barium sulphate, strontium sulphate calcium fluoride, iron, manganese, aluminum, silica dioxide and calcium phosphate. None of these species, even in the "worst case" are present in concentrations which would require removal prior to RO treatment and can be controlled by addition of antiscalant.

The presence of total suspended solids (TSS) in the influent at concentrations as high as 6,250 mg/l, will require a pretreatment step. TSS removal could be accomplished with treatment equipment similar to the existing multi-media pressure filters. Alternatively, ultrafiltration units could be utilized. Vendor information on ultrafiltration is provided as an attachment. It is also important to note that the method of pumping water from the drift haulage tunnel has significantly reduced the TSS load observed at the existing treatment plant. However, due to the uncertainties of increased flows and quality, it is prudent in the pre-feasibility phase of study to carry forward with a "worst case" approach. GE's ultrafiltration recommendation is carried forward as the preferred pretreatment step for RO.

As noted above, the efficiency of RO treatment will be optimal if the influent water temperature can be raised to 20° to 30°C. Preheating, either by a dedicated heat exchanger or through re-use of waste heat should also be considered for RO pretreatment steps.

Reverse Osmosis Treatment

The RO unit is capable of producing treated water at an efficiency of 75 percent. That is, 75 percent of the influent flow becomes RO permeate, while 25 percent becomes RO brine. Total dissolved solids (TDS) in the RO permeate is projected at approximately 20 mg/l based on an RO membrane efficiency of 99.6 percent. High quality permeate production will allow for some bypass and blending of untreated water with treated RO permeate while maintaining the effluent discharge limit for TDS of 350 mg/L. Assuming an initial influent flow rate of 5,000 m^3/day, RO treatment would produce a treated effluent flow of 3,750 m^3/day. A bypass flow of 250 m^3/day could be blended in to the RO permeate without reaching the TDS limit, effectively increasing the influent flow to 5,250 m^3/day. RO reject flow, requiring further treatment for volume reduction, would be 1,250 m^3/day.

GE's ultrafiltration/RO systems are available in a range of throughput capacities from 50 to 450 gallons per minute (190 l/min to 1,700 l/min). Two of the largest units would very nearly provide the initial treatment requirement (5,000 m^3/day), if installed in parallel. A break tank and transfer pump would also be required to receive ultrafiltration outflow and provide equalization for RO inflow. The floorspace requirement would be approximately 3,200 square feet (300 m^2) in a 40-ft by 80-ft (12.2-m by 24.4-m) arrangement. The system capacity could be expanded in any flow increment with skid-mounted "stock" units. Capacity expansion increments of 1,700 l/min would require additional floorspace of 150 m^2. Additional specifications and drawings for this equipment are provided as an attachment.

Post-treatment of Secondary Waste

Two secondary waste streams will result from ultrafiltration and RO unit processes. Ultrafiltration will produce a solids-laden filter backwash and RO will produce a contaminant-concentrated brine stream. Both of these streams can be treated for volume reduction by evaporation. The RO brine stream will contribute the majority of flow to the evaporation process.

An evaporative process, capable of initially treating approximately 900 l/min of RO brine will be required to minimize the volume of secondary waste.

Evaporation of RO brine should achieve a volume reduction of approximately 95 percent, resulting in a secondary waste slurry volume of 62.5 m^3/day. Additional volume reduction could be achieved with a crystallizer, if isolation cell volume is inadequate for this volume of waste generation.

ALTERNATIVE TWO – EVAPORATION-BASED TREATMENT

Pretreatment

Bicarbonate must be removed to prevent scale accumulation in the brine concentrator tubes in the form of calcium carbonate. Aquatech's pretreatment stage will include feed water acidification to pH 5.5 with sulphuric acid to convert bicarbonate to dissolved carbon dioxide. Dissolved carbon dioxide will then be removed in the de-aerator. A small amount of anti-scalant will also be added to avoid scaling in the feed/distillate plate heat exchanger.

The feed will be preheated through a plate-and-frame type heat exchanger with feed running counter-current to the evaporator distillate stream. The feed stream then flows to the deaerator for removal of oxygen and dissolved carbon dioxide. A flashing deaerator is utilized with spray feed into a pressurized chamber, heated with evaporator vent vapour followed by a low pressure chamber in which the carbon dioxide and oxygen flash out of solution.

Evaporative Treatment

The pretreated feed flows to a brine concentrator vessel. The brine concentrator is a seeded slurry vessel, with calcium sulphate solids homogenously dispersed in the slurry. The solids in suspension provide surface area for additional crystal growth while ensuring that the calcium sulphate does not form a hard scale on the heat transfer surface. Seed crystals are added as gypsum to the seed makeup tank at startup to establish the circulating slurry. As the brine is concentrated and transferred to the crystallizer, seed crystals are replenished by generation from calcium and sulphate ions in the feed water. Calcium chloride can be added if the feed concentration of calcium is too low to maintain the seeded slurry.

The overhead product from the brine concentrator next contacts a vapour separator with mist eliminators to remove entrained droplets of brine from the pure vapour stream before it flows to the compressor. Mist eliminators are periodically sprayed with hot distillate to dissolve any accumulated solids.

Vapour generated in the brine concentrator flows to a mechanical compressor which increases its saturation temperature and pressure. From the compressor the vapour flows to the feed pre-heat heat exchanger as described above. The pressurized vapour condenses in the heat exchanger, giving up its heat to the feed stream and condensate is pumped out of the system. The condensate is the "treated effluent", ready for blending and discharge. (Similar to the discussion of RO bypass and blending above, the highly purified condensate stream may be blended with untreated water and still meet the effluent target for TDS concentration of 350 mg/l).

The evaporator brine is concentrated to approximately 25 percent solids. Brine is continuously removed as feed water enters to maintain the brine in the concentrator. Removed brine flows to the forced circulation crystallizer.

Post-treatment

Brine is pumped to a forced circulation heat exchanger where it is heated with steam from the brine concentrator to a temperature higher than its normal boiling point. Boiling is suppressed by the static head pressure in the unit. The superheated brine then passes to a flash tank operating at a slightly lower pressure resulting in flash evaporation of water and formation of salt crystals in the brine. High recirculation rates are used to minimize the contact time on the heat transfer surface, again to avoid scale formation.

Slurry is discharged from the crystallizer batchwise to a filter press feed tank. The slurry is fed to the belt filter press which removes salt-saturated liquid, and produces a "cake" of salt crystals. The salt-saturated liquid is returned to the forced circulation crystallizer.

Vendor flow sheets depicting the two treatment alternatives are provided in Attachment 3.

ALTERNATIVES TECHNICAL EVALUATION

Technical factors for evaluation of the two treatment alternatives include the following:

- Capacity expansion – the initial treatment system for evaluation must be capable of treating 5,000 m3/day, with increasing capacity to 10,000 m3/day, 20,000 m3/day, or 30,000 m3/day over the 20-year life of the mine. Technical issues associated with adding treatment capacity are evaluated.

- Flexibility – the treatment system must have flexibility to treat a range of flow rates that will vary with mining and grouting activities. The known water quality also shows a range of concentrations of individual constituents as well as TDS. Current data shows a minimum TDS value of about 600 mg/l and a maximum of about 5,000 mg/l. The treatment system must produce a license-compliant treated effluent regardless of changes in the influent water quality.

- Secondary waste generation – both the quantity and the physical form are evaluated. Brine slurry wastes will be much more costly to dispose due primarily to volume when compared with wastes in solid form. Removing secondary wastes from the site for disposal can only be accomplished during winter road operations. Both liquid and solid form wastes could require development of waste isolation cells to prevent mobilization and migration of contaminants into either ground water or surface water. The viability of incorporating secondary waste into paste backfill for placement in the mine is unknown at this time.

Technical evaluation of Alternative 1 – RO based treatment.

Capacity expansion. The RO treatment process can be expanded for increased treatment capacity by adding new banks of RO units in parallel to the base treatment system. RO units can be stacked and would not necessarily require continuous expansion of the treatment facility footprint through the life of the project. An initially oversized building could be provided as a long-term cost benefit. GE's maximum sized RO unit is 450 gallons per minute (approximately 2,450 m^3/day). The initial requirement to treat 5,000 m^3/day could be met through installation of two units, followed by addition of two units to reach a capacity of 10,000 m^3/day. The 20,000 m^3/day capacity would require addition of four units, and finally reaching 30,000 m^3/day would require addition of four units for a total of twelve to reach the full capacity. The initial footprint of a three-unit system including feed tanks, pumps, and cleaning skid would be approximately 140 square meters. Assuming no economy of floor space design during expansion, the final treatment system would have a footprint of approximately 600 square meters.

RO units can be added to a treatment system with a relatively short lead time of approximately 3 to 4 months. RO units of "standard design" can be relatively quickly fabricated upon order. Use of a vendor's standard unit presents some capacity expansion advantage to RO. In fact, assuming that long-term storage space is available, the units required for capacity expansion could be ordered and delivered to storage as early as economically advantageous in the life of the mine. Units could be brought out of storage and installed into the treatment system as needed. Advanced procurement for future expansion could also be unnecessarily costly if mine dewatering flow rates over time do not require increased treatment capacity.

As noted in the process alternative description, the secondary waste treatment step (evaporation) would initially be sized for an RO reject stream of 900 liters per minute. Expansions over the life of the mine would likely require the evaporator capacity to increase to 1,800 liters per minute, 3,600 liters per minute and finally 5,400 liters per minute if the system must be expanded to treat 20,000 m^3/day or 30,000 m^3/day.

Flexibility. RO operates optimally when there is little change in influent flow rate and water quality characterization. An RO-based treatment system could require a relatively large equalization basin to ensure that influent flow and quality are consistent and the treated effluent can continually meet the discharge requirements. RO treatment efficiency can also vary based on influent quality with permeate recovery varying from 50 to 80 percent. While the permeate would still be of “high quality” the reject stream volume could increase by a factor of 2.5, which would carry through the secondary waste treatment process. Flow equalization or oversizing the secondary treatment unit could be required.

Secondary waste. RO will produce a brine stream that is assumed to be 20 percent of the influent flow, and at worst 50 percent of the influent flow. RO brine must be further volume-reduced for process viability. The RO brine evaporator should provide an additional volume reduction on the RO brine stream of 95 to 99 percent. A final product of brine slurry or crystallized waste in a solid form will require isolated disposal if kept on site. At an RO efficiency of 80 percent and a secondary evaporator efficiency of 95 percent, the initial 5,000 m3/day treatment system will produce 50 m^3/day or approximately 18,250 m^3/year. Evaporator bottoms produced over the 20-year life of the mine could reach a total volume of almost 1.6-million cubic meters if mine dewatering flows increase to 30,000 m3/day. Annual production of RO brine and evaporator concentrate are shown in Table 3. Onsite disposal is assumed, if adequate volume of isolated storage can be developed.

Table 3. Projection of Alternative 1 RO-based treatment system treated effluent and waste generation over the life of the mine, assuming maximum capacity expansion to 30,000 $m^{3/}$day.

Year	Daily flow	Annual flow	Treated effluent discharged	Secondary waste (RO reject)	Final waste (evaporator bottoms)
1	5,000	1,825,000	1,460,000	365,000	18,250
2	7,083	2,585,417	2,068,333	517,083	25,854
3	9,167	3,345,833	2,676,667	669,167	33,458
4	11,250	4,106,250	3,285,000	821,250	41,063
5	13,333	4,866,667	3,893,333	973,333	48,667
6	15,417	5,627,083	4,501,667	1,125,417	56,271
7	17,500	6,387,500	5,110,000	1,277,500	63,875
8	19,583	7,147,917	5,718,333	1,429,583	71,479
9	21,667	7,908,333	6,326,667	1,581,667	79,083
10	23,750	8,668,750	6,935,000	1,733,750	86,688
11	25,833	9,429,167	7,543,333	1,885,833	94,292
12	27,917	10,189,583	8,151,667	2,037,917	101,896
13	30,000	10,950,000	8,760,000	2,190,000	109,500
14	30,000	10,950,000	8,760,000	2,190,000	109,500
15	30,000	10,950,000	8,760,000	2,190,000	109,500
16	30,000	10,950,000	8,760,000	2,190,000	109,500
17	30,000	10,950,000	8,760,000	2,190,000	109,500
18	30,000	10,950,000	8,760,000	2,190,000	109,500
19	30,000	10,950,000	8,760,000	2,190,000	109,500
20	30,000	10,950,000	8,760,000	2,190,000	109,500
Total		159,687,500	127,750,000	31,937,500	1,596,875

All values in Table 3 are reported as cubic meters. An 80% RO efficiency is assumed. The secondary waste is treated by evaporation and assumes a 95% volume reduction from the RO brine secondary waste stream to the evaporator bottoms as the final waste product. RO and evaporator efficiencies are based on vendor data provided by Aquatech.

Note that the waste volume estimates as presented in Table 3 is a "worst case" projection based on the maximum capacity expansion case. In the smaller expansion scenarios, the 20-yr totals are presented in Table 4.

Table 4. 20-year projected total flows and wastes for 10,000 m^3/day and 20,000 m^3/day expansions of RO-based treatment alternative.

Expansion flow rate	20-year flow	Treated effluent discharged	Secondary waste (RO reject)	Final waste (evaporator bottoms)
5,000 to 10,000 m^3/day	61,137,500 m^3	48,910,000 m^3	12,227,500 m^3	611,375 m^3
5,000 to 20,000 m^3/day	110,412,500 m^3	88,330,000 m^3	22,082,500 m^3	1,104,125 m^3

Secondary waste may also be used in paste backfill production. The characteristics of the secondary waste cannot be predicted at this time and their suitability for incorporation into paste is unknown. If later work is performed to demonstrate the compatibility of the secondary waste with paste, this would be the preferred method for final disposition.

The potential for development of a deep disposal well is also a possibility. A high capacity deep well could reduce the need for secondary treatment of RO brine. Under the scope of this study, deep well disposal is not evaluated, but would also likely be a preferred option over development of isolation cells for surface disposal over the 20-year life of the mine.

Technical evaluation of Alternative 2 – Evaporator based treatment.

Capacity expansion. The evaporation based system can be expanded by adding parallel units when needed. Evaporation equipment must be run at or close to its design capacity. It has little tolerance for "turn down". The footprint of the initial system will be approximately _____ square meters (10k, 20k, 30k), with footprint expanding in proportion to each throughput step increase (i.e., doubling the footprint to double the flow rate). Some ancillary tankage and equipment could initially be provided as "oversized" but the main processing units of the evaporative system would have to be added in parallel, and almost immediately put into full-flow service.

Evaporation equipment generally has a much longer delivery lead time than RO units. Evaporators may take up to a year to fabricate and deliver, with additional onsite installation time before becoming operational. Capacity expansion will be at least logistically more difficult with evaporators than RO units. With the extreme remoteness of the site, a relatively short schedule slip in evaporator fabrication could result in delivery being delayed by a full year if winter road shipment is required.

Flexibility. Evaporation provides more flexibility in operation that RO for influent water quality characteristics. The influent water quality characteristics do not need to be consistent for efficient operation of an evaporator. Variations in TDS concentrations or the concentrations of individual dissolved species have little effect on the efficiency of evaporator operations.

The influent flow rate must be kept at or close to the full capacity of the evaporator. The evaporator cannot be effectively operated at a "turned down" rate. Given sufficient equalization storage an evaporator based system could be operated semi-continuously to effectively control the throughput rate.

Secondary waste. The secondary waste issues for an evaporator based treatment system are the same as discussed above for the RO based system. An evaporator system may be able to achieve a volume reduction in excess of 99 percent, creating a small waste stream of highly concentrated slurry or crystalline waste. Aquatech's equipment description estimates a 99.8% volume reduction in the evaporator-based treatment system including a brine concentrator followed by a forced circulation concentrator. At this rate the initial 5,000 m^3/day system would produce a secondary waste stream of less than 10 m^3/day. Table 5 shows the accumulation rate for evaporator waste over the 20-year life of the project.

Table 5. Projection of Alternative 2 Evaporation-based treatment system treated effluent and waste generation over the life of the mine, assuming maximum capacity expansion to 30,000 m$^{3/}$day.

Year	Daily flow	Annual flow	Treated effluent discharged	Final waste (Evaporator bottoms)
1	5,000	1,825,000	1,821,350	3,650
2	7,083	2,585,417	2,580,246	5,171
3	9,167	3,345,833	3,339,142	6,692
4	11,250	4,106,250	4,098,038	8,213
5	13,333	4,866,667	4,856,933	9,733
6	15,417	5,627,083	5,615,829	11,254
7	17,500	6,387,500	6,374,725	12,775
8	19,583	7,147,917	7,133,621	14,296
9	21,667	7,908,333	7,892,517	15,817
10	23,750	8,668,750	8,651,413	17,338
11	25,833	9,429,167	9,410,308	18,858
12	27,917	10,189,583	10,169,204	20,379
13	30,000	10,950,000	10,928,100	21,900
14	30,000	10,950,000	10,928,100	21,900
15	30,000	10,950,000	10,928,100	21,900
16	30,000	10,950,000	10,928,100	21,900
17	30,000	10,950,000	10,928,100	21,900
18	30,000	10,950,000	10,928,100	21,900
19	30,000	10,950,000	10,928,100	21,900
20	30,000	10,950,000	10,928,100	21,900
Total		159,687,500	159,368,125	319,375

All values in Table 5 are reported as cubic meters. A 99.8 percent evaporation efficiency is assumed, based on vendor data provided by Aquatech.

Note that the waste volume estimates as presented in Table 5 is a “worst case” projection based on the maximum capacity expansion case. In the smaller expansion scenarios, the 20-yr totals are presented in Table 6.

Table 6. 20-year projected total flows and wastes for 10,000 m^3/day and 20,000 m^3/day expansions of evaporator-based treatment alternative.

Expansion flow rate	20-year flow	Treated effluent discharged	Final waste (evaporator bottoms)
5,000 to 10,000 m^3/day	61,137,500 m^3	61,015,225 m^3	122,275 m^3
5,000 to 20,000 m^3/day	110,412,500 m^3	110,191,675 m^3	220,825 m^3

Similar to the onsite disposal options for the RO-based system, the evaporator waste product will require isolated storage, or could potentially be incorporated into paste backfill, or disposed by deep well injection. Based on the vendor's estimated efficiency of volume reduction for evaporation, the injection capacity of a deep well for evaporation waste disposal could be considerably less than for the RO-based system. It is important to note that over the life of the mine, the flow rate and secondary waste generation rate could increase by a factor of six. The initial feasibility of deep well disposal also needs to take into account the future waste flows.

Technical Evaluation Summary

Capacity Expansion. The RO-based system presents advantages over the Evaporation-based system for the factors of capacity expansion as it can be increased in a wide range of incremental modules. Assuming that adequate pretreatment and post treat capacity is initially installed, relatively small annual increases in capacity are possible with the RO system that are not possible with the evaporation system. RO units also present advantage in ordering/delivery lead times and installation time on site prior to being put into operation.

Flexibility. The Evaporation-based system presents an advantage over RO in flexibility of operation, with regard to influent water quality characterization. The evaporator will run equally as effectively over a broad range of influent characterizations, while the RO unit is considerably less tolerant of changing influent quality. RO efficiency could drop considerably, or operational problems (membrane fouling) could develop due to changes in influent quality. Assuming that the influent equalization basin is of sufficient size to equalize fluctuations in both flow and contaminant concentrations, the potential for changes in water quality are minor and do not present a significant disadvantage for RO operation.

RO provides some level of flexibility in changes to flow rate, in that the RO system would utilize a number of units in parallel operation which could be used in any combination to match incoming flow. The evaporator must be operated at its rated capacity. While storing influent for evaporator campaigns could be done, the evaporator operation will be more efficient if continuous rather than batchwise (with start-ups and shutdowns).

Secondary Waste. The Evaporation-based system presents a significant advantage in consideration of generation of secondary waste. The achievable volume reduction through evaporation as estimated by Aquatech is 99.8 percent. RO efficiency is estimated at 80 percent, with an additional volume reduction of 95 percent when RO brine is evaporated. The overall volume reduction of the RO-Evaporation system is 99 percent. Over the life of the project the five-fold difference in waste generation amounts to the need for disposal of an additional 1,277,500 cubic meters of waste. While the wastes ultimately have similar disposal options and requirements (isolated waste cells, deep well disposal, or incorporation into paste backfill) the considerable difference in volume presents a significant advantage for evaporation operation.

Technical Recommendation

Based on the technical evaluation factors, the Alternative 1, RO-based system is recommended. While producing a much larger volume of waste for disposal, all other factors favour the RO-based system. And if the efficiency of the RO-based system's secondary waste evaporator could be increased from 95 percent to 99 percent, the final waste volume would be equal for both alternatives. The smaller secondary waste evaporator system would also be easier to expand throughout the life of the mine, when compare to the full-scale evaporative system to treat the entire flow.

EVALUATION OF ORDER-OF-MAGNITUDE CAPITAL AND OPERATING ESTIMATES

Capital cost estimates were obtained for the RO-based treatment system and the Evaporation based treatment systems at their initial operating capacity. Estimates were obtained as follows:

- GE Infrastructure Water & Process Technologies (GE), for an ultrafiltration pretreatment, RO treatment system at 5,000 m^3/day. Note that this system did not include equipment for secondary waste volume reduction,

- Aquatech International Corporation (Aquatech), for brine concentrator/forced circulation crystallizer system at 3,000 m^3/day;

- Aquatech for an RO/brine concentrator system at 3,000 m^3/day.

The Aquatech and GE estimates are not directly comparable due to the difference in quoted flow rates and the "completeness" of the estimates. GE did not directly estimate the secondary waste components, but only their main process units (ultrafiltration for pretreatment followed by RO units). Aquatech estimated complete treatment systems but at a lower flow rate than requested. The Aquatech estimates can be scaled in proportion to the necessary increase in flow for comparison purposes.

Another estimate was obtained from Siemens for the fully expanded system capacity of 30,000 m^3/day. Siemens proposal provided for chemical precipitation which is a chemical reagent- and equipment-intensive process. Included in Siemens estimate were clarifiers, filters, RO units, and sludge management equipment including storage tanks and belt filter presses. Chemical reagents required included sodium hypochlorite, coagulant and polymer as flocculation aids, lime and soda ash, and hydrochloric acid for pH adjustment. While the chemical precipitation process was deemed infeasible in the technology screening phase, Siemens estimate is provided as an order-of-magnitude for the fully expanded operational capacity. The budgetary proposal for the Siemens system is USD $28,500,000. This budgetary estimate is inclusive of all required equipment but does not include construction and installation costs. The Siemens proposal, although not used in the cost evaluation, is provided with the other estimates in the attachments.

The primary source of cost data are the Aquatech estimates for both the RO-based and Evaporator-based alternatives. Use of the GE or Siemens estimates would require additional assumptions to be made, while the two estimates from Aquatech are directly comparable as received.

CAPITAL COST COMPARISON

The best direct comparison of capital cost estimates is the two estimates provided by Aquatech, as the basis and equipment supply scope is exactly the same for both. Again as noted above these estimates were for a system capacity of 3,000 m^3/day. In order to scale to the initial baseline capacity of 5,000 m^3/day the "six-tenths rule" (ref. *Chemical Engineers' Handbook, Perry and Chilton, 5th ed., McGraw-Hill*.) is used. The six-tenths rule is expressed as follows:

$$C_n = r^{0.6}C$$

Where C_n is the new plant cost, C is the previous plant cost and r is the ratio of new to previous capacity. Aquatech's estimate for Alternative 1 RO-based treatment for a 3,000 m^3/day system is USD $7,700,000. Scaling to 5,000 m^3/day gives a resulting estimate of $10,460,000.

Aquatech's estimate for Alternative 2 Evaporator-based treatment for a 3,000 m^3/day system is USD $9,500,000. Scaling to 5,000 m^3/day gives a resulting estimate of $12,907,000.

These estimates are for process equipment capital cost only. Associated site work is not included. Additional work is estimated as percentages of total installed cost by the following guidelines:

Table 7. Constructed cost estimation guidelines.

Item	% of Total Constructed Cost
Process equipment	40%
Concrete substructures	4%
Electrical	3%
Insulation	3%
Process structural	7%
Process material labor	10%
Home office engineering	8%
Field expenses	25%
Total	100%

Reference: *Chemical Engineers' Handbook, Perry & Chilton, Fifth Edition, McGraw-Hill.*

Utilizing the scaled estimates for process equipment and the factors for estimation of other associated costs, the capital cost estimates for Alternatives 1 and 2 are as follows:

Table 8. Initial Capital Cost Estimates for RO-based and Evaporator-based Treatment.

Item	Alternative 1 RO-based	Alternative 2 Evaporation-based
Process equipment	$10,460,000	$12,907,000
Concrete substructures	1,046,000	1,290,700
Electrical	784,500	968,000
Insulation	784.500	968,000
Process structural	1,830,500	2,258,700
Process material labor	2,615,000	3,226,700
Home office engineering	2,092,000	2,581,400
Field expenses	6,537,500	8,067,000
Total installed capital estimate	**$26,150,000**	**$32,267,500**

While site-specific item estimates could vary from the comparison provided above, it is assumed that any changes would equally affect both alternatives, and would not change the "ranking" of capital cost estimates. Alternative 1 presents a 20 percent advantage in initial capital cost estimate.

OPERATIONS COSTS

Operations costs include operations labor, supervision, maintenance support, chemical reagents, utilities and waste disposal. The two alternatives will have similar labor, supervision and maintenance requirements. Significant differences in operations cost estimates will arise in utilities (electrical power) and waste disposal.

UTILITIES COST ESTIMATION

Initial utilities cost estimate for the RO-based system. Aquatech's estimates for the two systems includes estimates of total power consumption. The RO-based system power consumption is estimated at 2,500 kilowatts (kW). Assuming continuous operations this treatment alternative will consume 21,900,000 kW-hours over the course of a year. Based on information provided by De Beers, the cost of electricity at the mine is $0.264 per kW-hr. The annual cost estimate for power to supply the RO-based treatment system is $5,782,000. Note that when the power cost estimate was obtained, a diesel fuel cost was also provided. Diesel fuel at the time (December, 2007) was quoted at "$1.00 per liter with a $0.85 per liter off the rack fee and $0.15 freight and surtax". All electrical power at the mine is provided by diesel-fueled generators. If the diesel fuel price has increased since the previous estimate, then the estimated cost of an "onsite kW-hr" should also be increased.

Diesel fuel storage for annual operation of the RO-based treatment system is estimated at 1,932,000 liters. If excess storage capacity is not available on site, new storage capacity will have to be installed to support operation of the proposed wastewater treatment plant.

Initial utilities cost estimate for the Evaporator-based system. Aquatech estimates total power consumption for the brine concentrator / forced circulation crystallizer treatment system at 5,800 kW. Again, under continuous operation this treatment system will consume 51,100,000 kW-hrs per year. The annual cost estimate for power to the supply the evaporator-based treatment system is $13,491,000. Diesel fuel storage required (available or new) is estimated at 4,507,000 liters.

Projected Utilities Cost Estimates. Utilities costs will increase in proportion to water treatment capacity expansion. For the purpose of waste volume estimation, a “straight-line” increase in water treatment capacity was assumed through the first thirteen years of mine operation, from initial capacity at 5,000 m^3/day to a maximum capacity of 30,000 m^3/day. Capacity for years 13 through 20 remain at the maximum value. A similar approach to power cost estimation over the life of the mine yields the following:

Table 9. Projected 20-year Utilities Annual and Total Cost Estimates for RO-based and Evaporator-based Treatment at 30,000 m3/day

			Alternative 1 RO-based Treatment		Alternative 2 Evaporator-based Treatment	
Year	**Daily flow (m^3)**	**Annual flow (m^3)**	**Annual power (kw-hr)**	**Power cost ($)**	**Annual power (kw-hr)**	**Power cost ($)**
1	5,000	1,825,000	21,900,000	5,781,600	50,808,000	13,413,000
2	7,083	2,585,417	31,025,000	8,190,600	71,978,000	19,002,000
3	9,167	3,345,833	40,150,000	10,599,600	93,148,000	24,591,000
4	11,250	4,106,250	49,275,000	13,008,600	114,318,000	30,180,000
5	13,333	4,866,667	58,400,000	15,417,600	135,488,000	35,769,000
6	15,417	5,627,083	67,525,000	17,826,600	156,658,000	41,358,000
7	17,500	6,387,500	76,650,000	20,235,600	177,828,000	46,947,000
8	19,583	7,147,917	85,775,000	22,644,600	198,998,000	52,535,000
9	21,667	7,908,333	94,900,000	25,053,600	220,168,000	58,124,000
10	23,750	8,668,750	104,025,000	27,462,600	241,338,000	63,713,000
11	25,833	9,429,167	113,150,000	29,871,600	262,508,000	69,302,000
12	27,917	10,189,583	122,275,000	32,280,600	283,678,000	74,891,000
13	30,000	10,950,000	131,400,000	34,689,600	304,848,000	80,480,000
14	30,000	10,950,000	131,400,000	34,689,600	304,848,000	80,480,000
15	30,000	10,950,000	131,400,000	34,689,600	304,848,000	80,480,000
16	30,000	10,950,000	131,400,000	34,689,600	304,848,000	80,480,000
17	30,000	10,950,000	131,400,000	34,689,600	304,848,000	80,480,000
18	30,000	10,950,000	131,400,000	34,689,600	304,848,000	80,480,000
19	30,000	10,950,000	131,400,000	34,689,600	304,848,000	80,480,000
20	30,000	10,950,000	131,400,000	34,689,600	304,848,000	80,480,000
Total		**159,687,500**	**1,916,250,000**	**$ 505,890,000**	**4,445,700,000**	**$1,173,665,000**

As shown in the table above, over the 20-year life of the mine, the power cost estimated for operating an RO-based system is less than half the power cost estimated for the evaporator-based system and amounts to an estimated difference of $667,775,000.

The 20-year total comparison of power consumption and cost for the capacity expansions to 10,000 m^3/day and 20,000 m^3/day are shown below.

Table 10. 20-year projected total power consumption and cost for 10,000 m^3/day and 20,000 m^3/day expansions of RO-based and Evaporator-based treatment alternatives.

		Alternative 1 RO-based Treatment		Alternative 2 Evaporator-based Treatment	
Capacity expansion	**Total flow (m^3)**	**Annual power (kw-hr)**	**Power cost ($)**	**Annual power (kw-hr)**	**Power cost ($)**
5,000 to 10,000 m^3/day	159,687,500	733,650,000	$ 193,683,600	1,702,068,000	$ 449,349,000
5,000 to 20,000 m^3/day	159,687,500	1,324,950,000	$ 349,786,800	3,073,884,000	$ 811,504,000

WASTE DISPOSAL COST ESTIMATION

As described above in the alternatives evaluation of technical factors, there are a variety of waste disposal options including isolation cells, incorporation of waste into paste backfill, or deep well injection. Both alternative waste forms (RO brine, or evaporator bottoms) would require isolation if disposed in the North Pile. Both wastes forms are expected to have similar compatibility if incorporated into paste backfill. And both waste forms could be deep well injected if the site geology and hydrogeology allows for this alternative. The primary difference in waste that will affect the operations cost estimate for disposal is the volume of waste produced. As noted in Tables 3 and 4 above, the RO-based treatment system is estimated to produce a volume of 1,596,875 cubic meters over the 20-year life of the mine. The evaporator-based treatment alternative is estimated to produce 319,375 cubic meters over the 20-year life of the mine.

Since all three disposal options are possible for the two waste forms, the cost differential that can be estimated is based on waste volume only. The evaporator-based system is estimated to produce only 20 percent of the waste volume when compared with the RO-based system. Without an estimated unit cost for disposal, the cost estimation comparison is limited to the relative volumes of waste produced, with the clear advantage to the Evaporator-based system.

The waste disposal savings realized by the evaporator-based system would have to be greater than the power consumption cost difference described above, in order for the evaporator-based system to show an estimated operations cost advantage over the RO-based system. The power cost disparity is estimated at $667,775,000 over the 20-year life of the mine. The evaporator waste volume is estimated at 1,277,500 cubic meters less than the RO waste. Dividing the power cost differential by the waste volume differential results in the cost per cubic meter of waste disposed to reach a "break even" point between the operating cost estimates for the two alternatives. The "break even" unit cost for waste disposal is approximately $520 per cubic meter. This unit cost estimate is approximately double the unit cost for disposal of “hazardous waste” in a specialized landfill.

Onsite disposal, as an internal cost should be less than the threshold value of $520 per cubic meter. Without additional data, it is assumed that the RO-based system is preferred over the Evaporator-based system based on evaluation of utilities and waste disposal costs. Key to this evaluation is the assumption that adequate disposal space is available onsite for the wastes generated by either treatment alternative.

20-YEAR CAPITAL AND OPERATING COST ESTIMATES

Cost analysis for operations and capital improvements (capacity expansions) have also been performed as described below.

Capacity expansion under three scenarios has been considered:

- Increasing capacity from 5,000 to 10,000 m^3/day;
- From 5,000 to 20,000 m^3/day; and
- From 5,000 to 30,000 m^3/day.

“Straight-line” increases to the maximum values are assumed through year 13, then continuing operation at the maximum value is assumed through year 20. As discussed in the evaluation of technical factors, RO units can be added incrementally year-by-year, while evaporation capacity is somewhat more difficult to increase. Excess evaporation capacity will have to be provided by installation of parallel units, with one unit running continuously at full capacity, with the second unit run in campaign fashion until the influent flow requires both units in full operation.

ALTERNATIVE 1 - RO-BASED TREATMENT SYSTEM 20-YEAR COST ESTIMATE

Capital equipment purchases for the RO-based system, combined with operating costs (utilities only) are estimated in constant dollars as follows:

Table 11. Estimated capital and operating costs (constant dollars) for RO-based plant capacity expansions to maximum flow of 10,000 m^3/day.

Year	Daily flow (m^3)	Estimated Capital Cost for Expansion	Operations Cost Estimate (Utilities)	Total Annual Estimated Cost
1	5,000	26,150,000	5,781,600	31,931,600
2	5,417		6,263,400	6,263,400
3	5,833	5,970,000	6,745,200	12,715,200
4	6,250		7,227,000	7,227,000
5	6,667	5,970,000	7,708,800	13,678,800
6	7,083		8,190,600	8,190,600
7	7,500		8,672,400	8,672,400
8	7,917	5,970,000	9,154,200	15,124,200
9	8,333		9,636,000	9,636,000
10	8,750	5,970,000	10,117,800	16,087,800
11	9,167		10,599,600	10,599,600
12	9,583	5,970,000	11,081,400	17,051,400
13	10,000		11,563,200	11,563,200
14	10,000		11,563,200	11,563,200
15	10,000		11,563,200	11,563,200
16	10,000		11,563,200	11,563,200
17	10,000		11,563,200	11,563,200
18	10,000		11,563,200	11,563,200
19	10,000		11,563,200	11,563,200
20	10,000		11,563,200	11,563,200
Total		**$ 56,000,000**	**$ 193,683,600**	**$ 249,683,600**

For the capacity expansion from 5,000 to 10,000 m^3/day as shown in Table 11, expansions in 1,000 m3/day increments are assumed, and scaled from the equipment cost for the initial 5,000 m3/day facility. It is also assumed that out-year infrastructure improvements can be made at a cost of 1.5 times the equipment cost. Expansions are made in out-years to ensure that the facility is always slightly larger than the daily required flow.

Table 12. Estimated capital and operating costs (constant dollars) for RO-based plant capacity expansions to maximum flow of 20,000 m^3/day.

Year	Daily flow (m^3)	Estimated Capital Cost for Expansion	Operations Cost Estimate (Utilities)	Total Annual Estimated Cost
1	5,000	26,150,000	5,781,600	31,931,600
2	6,250		7,227,000	7,227,000
3	7,500	10,350,000	8,672,400	19,022,400
4	8,750		10,117,800	10,117,800
5	10,000	10,350,000	11,563,200	21,913,200
6	11,250		13,008,600	13,008,600
7	12,500	10,350,000	14,454,000	24,804,000
8	13,750		15,899,400	15,899,400
9	15,000	10,350,000	17,344,800	27,694,800
10	16,250		18,790,200	18,790,200
11	17,500	10,350,000	20,235,600	30,585,600
12	18,750		21,681,000	21,681,000
13	20,000	10,350,000	23,126,400	33,476,400
14	20,000		23,126,400	23,126,400
15	20,000		23,126,400	23,126,400
16	20,000		23,126,400	23,126,400
17	20,000		23,126,400	23,126,400
18	20,000		23,126,400	23,126,400
19	20,000		23,126,400	23,126,400
20	20,000		23,126,400	23,126,400
Total		**$ 88,250,000**	**$ 349,786,800**	**$ 438,036,800**

For the capacity expansion from 5,000 to 20,000 m^3/day as shown in Table 12, expansions in 2,500 m^3/day increments are assumed, and scaled from the equipment cost for the initial 5,000 m^3/day facility. It is also assumed that out-year infrastructure improvements can be made at a cost of 1.5 times the equipment cost. Expansions are made in out-years to ensure that the facility is always equal to or slightly larger than the daily required flow.

Table 13. Estimated capital and operating costs (constant dollars) for RO-based plant capacity expansions to maximum flow of 30,000 m^3/day.

Year	Daily flow (m^3)	Estimated Capital Cost for Expansion	Operations Cost Estimate (Utilities)	Total Annual Estimated Cost
1	5,000	26,150,000	5,781,600	31,931,600
2	7,083	15,690,000	8,190,600	23,880,600
3	9,167	15,690,000	10,599,600	26,289,600
4	11,250		13,008,600	13,008,600
5	13,333	15,690,000	15,417,600	31,107,600
6	15,417		17,826,600	17,826,600
7	17,500		20,235,600	20,235,600
8	19,583	15,690,000	22,644,600	38,334,600
9	21,667		25,053,600	25,053,600
10	23,750	15,690,000	27,462,600	43,152,600
11	25,833		29,871,600	29,871,600
12	27,917		32,280,600	32,280,600
13	30,000		34,689,600	34,689,600
14	30,000		34,689,600	34,689,600
15	30,000		34,689,600	34,689,600
16	30,000		34,689,600	34,689,600
17	30,000		34,689,600	34,689,600
18	30,000		34,689,600	34,689,600
19	30,000		34,689,600	34,689,600
20	30,000		34,689,600	34,689,600
Total		**$ 104,600,000**	**$ 505,890,000**	**$ 610,490,000**

For the capacity expansion from 5,000 to 30,000 m^3/day as shown in Table 13, expansions in 5,000 m^3/day increments are assumed, and scaled from the equipment cost for the initial 5,000 m^3/day facility. It is also assumed that out-year infrastructure improvements can be made at a cost of 1.5 times the equipment cost. Expansions are made in out-years to ensure that the facility is always equal to or slightly larger than the daily required flow.

ALTERNATIVE 2 - Evaporator-Based Treatment System 20-Year Cost Estimate

Capital equipment purchases for the Evaporator-based system, combined with operating costs (utilities only) are estimated in constant dollars as follows:

Table 14. Estimated capital and operating costs (constant dollars) for Evaporator-based plant capacity expansions to maximum flow of 10,000 m^3/day.

Year	Daily flow (m^3)	Estimated Capital Cost for Expansion	Operations Cost Estimate (Utilities)	Total Annual Estimated Cost
1	5,000	48,910,000	13,413,000	62,323,000
2	5,417		14,531,000	14,531,000
3	5,833		15,649,000	15,649,000
4	6,250		16,767,000	16,767,000
5	6,667		17,884,000	17,884,000
6	7,083		19,002,000	19,002,000
7	7,500		20,120,000	20,120,000
8	7,917		21,238,000	21,238,000
9	8,333		22,356,000	22,356,000
10	8,750		23,473,000	23,473,000
11	9,167		24,591,000	24,591,000
12	9,583		25,709,000	25,709,000
13	10,000		26,827,000	26,827,000
14	10,000		26,827,000	26,827,000
15	10,000		26,827,000	26,827,000
16	10,000		26,827,000	26,827,000
17	10,000		26,827,000	26,827,000
18	10,000		26,827,000	26,827,000
19	10,000		26,827,000	26,827,000
20	10,000		26,827,000	26,827,000
Total		**$ 48,910,000**	**$ 449,349,000**	**$ 498,259,000**

For the capacity expansion from 5,000 to 10,000 m^3/day as shown in Table 14, an initial installation of 10,000 m3/day capacity is assumed. Excess treatment capacity would be utilized batchwise campaigns to meet the annual flow requirements. No out-year expansions would be necessary.

Table 15. Estimated capital and operating costs (constant dollars) for Evaporator-based plant capacity expansions to maximum flow of 20,000 m^3/day.

Year	Daily flow (m^3)	Estimated Capital Cost for Expansion	Operations Cost Estimate (Utilities)	Total Annual Estimated Cost
1	5,000	48,910,000	13,413,000	62,323,000
2	6,250		16,767,000	16,767,000
3	7,500		20,120,000	20,120,000
4	8,750		23,473,000	23,473,000
5	10,000	19,360,000	26,827,000	46,187,000
6	11,250		30,180,000	30,180,000
7	12,500		33,533,000	33,533,000
8	13,750		36,887,000	36,887,000
9	15,000	19,360,000	40,240,000	59,600,000
10	16,250		43,593,000	43,593,000
11	17,500		46,947,000	46,947,000
12	18,750		50,300,000	50,300,000
13	20,000		53,653,000	53,653,000
14	20,000		53,653,000	53,653,000
15	20,000		53,653,000	53,653,000
16	20,000		53,653,000	53,653,000
17	20,000		53,653,000	53,653,000
18	20,000		53,653,000	53,653,000
19	20,000		53,653,000	53,653,000
20	20,000		53,653,000	53,653,000
Total		**$ 87,630,000**	**$ 811,504,000**	**$ 899,134,000**

For the capacity expansion from 5,000 to 20,000 m^3/day as shown in Table 15, an initial installation of 10,000 m^3/day capacity is assumed followed by expansions in 5,000 m^3/day increments. Excess treatment capacity would be utilized batchwise campaigns to meet the annual flow requirements. It is also assumed that out-year infrastructure improvements can be made at a cost of 1.5 times the equipment cost. Expansions are made in out-years to ensure that the facility is always equal to or greater than the daily required flow.

Table 16. Estimated capital and operating costs (constant dollars) for Evaporator-based plant capacity expansions to maximum flow of 30,000 m^3/day.

Year	Daily flow (m^3)	Estimated Capital Cost for Expansion	Operations Cost Estimate (Utilities)	Total Annual Estimated Cost
1	5,000	48,910,000	13,413,000	62,323,000
2	7,083		19,002,000	19,002,000
3	9,167		24,591,000	24,591,000
4	11,250	29,350,000	30,180,000	59,530,000
5	13,333		35,769,000	35,769,000
6	15,417		41,358,000	41,358,000
7	17,500		46,947,000	46,947,000
8	19,583	29,350,000	52,535,000	81,885,000
9	21,667		58,124,000	58,124,000
10	23,750		63,713,000	63,713,000
11	25,833		69,302,000	69,302,000
12	27,917		74,891,000	74,891,000
13	30,000		80,480,000	80,480,000
14	30,000		80,480,000	80,480,000
15	30,000		80,480,000	80,480,000
16	30,000		80,480,000	80,480,000
17	30,000		80,480,000	80,480,000
18	30,000		80,480,000	80,480,000
19	30,000		80,480,000	80,480,000
20	30,000		80,480,000	80,480,000
TOTAL		**$ 107,610,000**	**$ 1,173,665,000**	**$ 1,281,275,000**

For the capacity expansion from 5,000 to 30,000 m^3/day as shown in Table 16, an initial installation of 10,000 m3/day capacity is assumed followed by expansions in 10,000 m^3/day increments. Excess treatment capacity would be utilized on a daily, intermittent basis to meet the annual flow requirements. It is also assumed that out-year infrastructure improvements can be made at a cost of 1.5 times the equipment cost. Expansions are made in out-years to ensure that the facility is always equal to or greater than the daily required flow.

CONCLUSIONS AND RECOMMENDATIONS

The technical factors evaluated favor the RO-based system, as do the cost-based evaluation factors. The recommended treatment alternative on the basis of pre-feasibility evaluation factors is the RO-based system with a brine concentrating evaporator for volume reduction of RO reject.

Based on vendor review of design basis influent data, pretreatment for both alternatives may be limited to a relatively simple injection of antiscalant. Pretreatment equipment and costs have not been extensively researched, as they would be insignificant by comparison to the main treatment units.

The primary operating cost factor is power consumption. All other operating costs (labor, supervision, maintenance, and chemical reagents) are considered to be approximately equal for the two alternatives. Since they would weigh in equally on both alternatives, these costs have not been extensively researched.

Waste disposal is considered to be of critical importance due to the extremely remote location of the mine. The evaporation-based treatment alternative is preferred for generation of the smallest possible volume of secondary waste. The final disposition options for both waste streams include isolation cell storage in the North Pile, incorporation into paste backfill, or deep well injection. In the event that a deep well of adequate capacity can be developed, the cost advantage of the RO-based system will be enhanced. If waste must be stored in isolation cells, a “trade-off” analysis between power consumption costs for the smallest possible waste stream versus isolation cell construction and installation costs for a larger waste stream should be performed.

Further evaluation of the suitability of the waste as a paste backfill additive would also play into the cost evaluation for waste disposal.

The RO alternative was developed assuming a permeate generation rate (throughput rate) of 75%. The RO treatment efficiency can be increased to 90% using secondary, higher pressure RO modules for reduction of the reject stream flow rate. Since power requirements are a predominant O&M cost, a trade-off analysis should be conducted comparing the increased capital cost associated with achieving up to a 60% reduction in reject (from 25% down to 10% of the influent flow rate) with the reduced O&M cost associated with the concomitant reduction in power requirement for evaporation of the smaller reject stream.

A “hybrid” of the two alternatives could also be developed, utilizing RO for the primary treatment unit, and a smaller (compared to the full-scale) brine concentrator/crystallizer as a secondary waste treatment unit. While power costs would increase due to the increased level of evaporation intensity, the majority of waste volume reduction would still be achieved by the more economical RO treatment process.

The future quantity of haulage drift water generated by mine dewatering operations is a driving force in the cost and scale of the water treatment facility. The cost of minimizing or controlling the total flow of dewatering flow should be evaluated as a cost/benefit against the cost of increasing treatment capacity.

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ATTACHMENT 1

KICKOFF – SITE VISIT REPORT

ATTACHMENT 1 Kickoff - Site Visit Report

MEMORANDUM

Golder Associates Ltd.
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Telephone No.: 403-299-5600
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DATE:	December 7, 2007	Proj No. 07-1334-0052
TO:	Rob McLean	
FROM:	Paul Pigeon	
RE:	Snap Lake Water Management Project, Site Visit Follow-up and Project Schedule	
CC:	Pete Lemke, Lasha Young, Ken DeVos, Mark Digel, Dawn Kelly	

This memorandum confirms key points of the site visit by Paul Pigeon and Pete Lemke on November 27, 2007, and the project kick-off meeting. Specifically, agreements on project approach and assumptions for the Phase 1 evaluation are listed, and commitments by De Beers and Golder to supply information or results are also identified here. A deliverable-based schedule is provided.

Water Quality & Quantity Characterization

In response to Golder's request for expanded water quality data sets on the haulage drift ground water, De Beers provided scanned copies of laboratory reports from samples collected during 2007, with a sample number key to identify those samples representing the haulage drift water quality. Those samples included only a few with data for parameters other than the major cations and anions that comprise total dissolved solids (TDS). Some more recent analyses are going to be provided by De Beers. Also, Golder has agreed to supply a list of analytes that are significant in the evaluation of water treatment technologies, with additions such as total organic carbon (TOC) and certain metals (iron, aluminum, etc.). That list is attached.

The change in haulage drift water quality that may occur with depth of the workings is not well understood at this point. Golder will initially rely upon its own geochemical knowledge of the Snap Lake water chemistry. We also understand that a 65o boring is being drilled to 300 meters and packed and instrumented to allow water quality sampling from discrete depths, which will contribute to the knowledge base about ground water quality and variations of water quality with depth of the mine workings: Data sets from that effort may be available before Phase 1 work is scheduled to be concluded in January (see below). Golder understands that the completion schedule of Phase 1 might be altered to allow assessment of information from this and other emergent investigations, if it appears that the conclusions and recommendations of Phase 1 would be too tentative without such data.

De Beers has asked Golder to incorporate the effects of grouting on haulage drift water quality and dewatering flow rates. For the monitoring period prior to July 21, 2007, De Beers has identified samples collected during or immediately following grouting of water-bearing fractures in the haulage drift. Golder will extrapolate the limited data set to establish maximum pH, TDS and ionic strength values in the water quality design basis for haulage drift water treatment. We understand that grouting activities also can increase haulage drift flow by about 200 m3/day, with a possible maximum increase of 1000 m3/day if a really large area of fracturing is encountered.

Since the site visit, Golder has identified additional water quality data that are needed for Phase 1. The water quality of the effluent from the existing water treatment plant is of interest, because it will help in gauging the effectiveness of chemical conditioning and media filtration as a pre-treatment process train for haulage drift ground water. Also, Golder would like to see field (instantaneous) temperature readings for the haulage drift sump water and for water influent to the existing water treatment plant. These data should include ore zone temperature as well, since the ore and haulage drift waters are commingled at the WTP. Temperature data will help Golder in estimating resistance to chemical conditioning and potential permeation rates of candidate membrane treatment technologies.

<u>Phase 1 Technical Scope</u>

We had an excellent discussion of a number of items that define the scope of Phase 1.

Alternatives for treatment of haulage drift water will have an effluent target of 350 mg/l TDS, even though higher TDS effluents might be sufficient to control whole lake average TDS levels and avoid exceeding the permit limit by effective water management. This conservative approach will account for higher than expected flows, increases in TDS in the ore zone water and reduced natural inflows to Snap Lake.

The existing surge pond will be evaluated for influent and reject water storage for a haulage drift water management system. Golder needs design drawings for the surge pond in addition to drawings of the industrial area.

Management options for treatment residuals will include incorporation of sludges into tailings. When paste backfilling begins in two years, the sludge could be partially dewatered and incorporated as a flowable material. For reject flows (brines), liquid disposal will not be assumed available. Brine dewatering and crystallization will be needed; disposal in a specially contained section of a tailings disposal area.

Since haulage drift flows have already exceeded 3,000 m3/day on occasion, the initial plant size considered for all three of the requested flow rate scenarios will be 5,000 m3/day.

For estimating when treatment plant additions are needed and for calculation of net present value (NPV) of the alternatives, a project life of 20 years will be assumed. De Beers will provide escalation and discount percentage rates.

Although separate pre-treatment facilities will be provided for the haulage drift water, the existing treatment plant tour was very helpful in identifying facilities that may be compatible for use on the haulage drift water. De Beers will provide additional drawings of the existing plant. As discussed above, Golder would also like to review effluent quality data for the plant. We note that a second phase expansion of the existing plant, which on first review appears to double plant capacity, might be used as a separate pre-treatment facility for the haulage drift water.

Phase 1 Schedule

Golder plans to complete a draft report for Phase 1 by January 18, 2008. To do this, we will have to complete our technology analysis and put out requests for vendor cost quotations on major equipment by December 21, 2008. December 21 is also a good target date for receipt of all the items we are requesting from De Beers.

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ATTACHMENT 2

GOLDER REQUEST FOR ADDITIONAL SAMPLING AND ANALYSES

ATTACHMENT 2 – Golder Request for Additional Sampling and Analyses

Analyte/Analyte Group	**Justification for analysis**	**Comments**
Volatile organic compounds (VOCs) and chlorine	Will degrade membranes in a filter application and would be untreated by evaporation (carried over with water vapour).	If presence of VOCs and/or chlorine can be ruled out by "process knowledge" then sampling and analysis will not be necessary. Golder can identify method(s) of analysis if required.
Oil and grease (O&G), hydrogen sulphide (H_2S), surfactants	Will degrade membranes in a filter application.	If presence of O&G, H_2S and/or surfactants can be ruled out by "process knowledge" then sampling and analysis will not be necessary.
Total organic carbon (TOC)	Maximum acceptable concentration for membrane filtration influent is 2 mg/L. Some of the existing data shows TOC at or above this limit.	If higher values for TOC in the existing data are representative of short-term spikes, then no additional sampling and analysis is needed. If TOC levels remain elevated for days or weeks, treatment by membrane filtration will fail. Time-weighted composite samples for future analysis would be preferred.
Barium, Strontium	Barium and strontium salts are of very low solubility and form as a fine powdery solid – fouling filtration membranes, even at low concentrations.	Limited data in historical sampling and analysis records.
Aluminum, Iron, Manganese	Manganese can foul filtration membranes at an influent concentration of 0.5 mg/L by oxidation and precipitation at membrane surfaces. Aluminum can precipitate with pH changes at permeation membrane surfaces, while Iron can foul filtration membranes at influent concentrations of 0.1 to 0.2 mg/l by oxidation and precipitation at membrane surfaces over a wide range of pH.	Limited data in historical sampling and analysis records.
Silica, reactive soluble and colloidal	Limited data in historical sampling and analysis records. Silica will scale membranes. Colloidal fraction determined by laboratory filtration; filter pore size per procedure.	Influent concentration of <10 mg/L is preferred for membrane filtration. Higher concentrations can be handled with addition of anti-scalant. Additional data will allow for determination of whether anti-scalant equipment will be needed.

NOTE: The above list assumes that water treatment will be targeted solely on reduction of TDS; therefore, the need to monitor constituents that may have human health or aquatic toxicity effects is omitted from the determination of analytes.

Sampling Regime

In all cases, it would be preferable to collect volume/flow-weighted or time paced, 24-hour composite samples. The existing data, even for the common ions which have been analyzed frequently, shows a wide range between minimum and maximum observed values. If a very short-term spike in contaminant concentration has been caught by a grab sample, the treatment process may be "over-designed" due to anomalous data. Development of the design basis influent on a nominal (average) basis and design for maximum anticipated spike concentrations will benefit from collection of time-weighted composites, if possible.

As a fallback approach, assuming that De Beers will institute collection of samples at DW 1011 on a twice monthly frequency, grab sampling could be used. In this monitoring approach, the minimum water treatment influent database for establishing a detailed design/equipment procurement basis would be 40 to 50 samples for major constituents and a minimum of 20 samples for the above additional analytes, allowing for use of a statistically-based determination of the maximum influent quality design basis. In so doing, the effect of a single anomalous spike in water quality data (a spike not attributable to a known condition that is expected to repeat itself periodically) can be smoothed out of the data set.

Assumed Existing Routine Analyte List

The above additions are assumed to add to the analyte list Golder sees in a large number of the DW10 and DW11 analytical reports provided by De Beers. That list is as follows:

Routine Water Analysis–Low Level	**Other Analytes**
ICP metals	Acidity
Calcium	Ammonia-as N
Magnesium	Fluoride
Potassium	Nitrate-as N
Sodium	Orthophosphate
Ion Balance	Phosphorus-Total & Total Dissolved
Hardness	Silica-Reactive Soluble
Ion Balance (%)	Selenium

TDS (calc)

pH, Conductivity, Alkalinity

Alkalinity (total)

Bicarbonate

Carbonate

Conductivity (EC)

Hydroxide

pH

Other Anions

Chloride

Nitrite

Sulphate

TDS

Total Kjeldahl Nitrogen

Total Suspended Solids

Turbidity

ATTACHMENT 3

VENDOR DATA

Aquatech International Corporation
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www.aquatech.com

April 16, 2008

Peter Lemke
Golder Associates Inc.
44 Union Blvd. Suite 300
Lakewood, CO 80228

Ref.: DeBeers Mine WWT AIC #08-5035

Peter,

Thank you for contacting me in regards to this project. The following is Aquatech's budgetary proposal for the waste water treatment system for the DeBeers Canadian Diamond mine.

This system would be designed to treat a waste stream of 550GPM as described in supplied water analysis. We are offering two options for your review, a membrane system for initial concentration and a thermal based system.
I have considered the existing pretreatment clarifier and multimedia filter will remain in service in conjunction with the proposal systems.

<u>Scope of Supply for 550 gpm Brine Concentrator/Forced Circulation Crystallizer:</u>

Brine Concentrator

1.	One (1) Wastewater Storage Tank with agitation
2.	Two (2)Wastewater Transfer Pump with Feed Strainer
3.	One (1) Feed Tank and Pump Skid
4.	Three (3) Chemical Dosing Skids
5.	One (1) Pre-heater and Deaerator
6.	One (1) Brine Concentrator Vessel
7.	One (1) Vapor Compressor Skid
8.	One (1) Recirculation Pump Skid
9.	One (1) Distillate Tank and Pump Skid

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10.	One (1) Lot of Prefabricated Recirculation Piping and Vapor Ducting
11.	One (1) Lot of On-skid Piping
12.	One (1) Lot of Instrumentation and PLC Based Controls within Battery Limits
13.	One (1) Lot of Structural Steel platforms, access ladders for BC Vessel
14.	One (1) Interconnecting Piping between Skids
15.	One (1) Lot of Electrical Conditioning and MCC by others
16.	One (1) Lot of Power and Instrument Wiring to Skid Junction Boxes by Others

FCC and Filter Press

1.	One (1) Concentrate Tank
2.	Two (2) Concentrate Pumps
3.	One (1) MVC forced circulation evaporation unit
4.	One (1) Heat exchanger
5.	One (1) Flash tank
6.	One (1) Mist eliminator
7.	One (1) Vapour compressor with motor and auxiliaries
8.	One (1) Distillate receiver
9.	One (1) Lot of pumps and motors for liquid flows within the Crystallizer unit
10.	One (1) Lot of chemical dosing systems for crystallizer
11.	One (1) Lot of process piping and ducting
12.	One (1) Lot of Instrumentation
13.	One (1) Slurry Pump
14.	One (1) Belt Filter Press
14.	One (1) PLC Based Control Panel with HMI

Base budget Price for BC/FCC/Filter Press, Ex-works ***$ 9,500,000***

Approximate Distillate from System; 549 GPM
Total Power Consumption; 3500 kW
Solid waste at 10% solids content; 1100 #/hour

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Typical expected delivery of this equipment would be 55-60 weeks.

The equipment described is constructed of high end alloys which are subject to material cost escalations due to volatility in availability and pricing.

Scope of Supply 550 GPM UF/RO - 220 GPM Brine Concentrator/Forced Circulation Crystallizer

RO System

1.	One (1) Sodium Hypochlorite Dosing Skid
2.	One (1) 3000 gallon Sodium Hypochlorite Storage Tank
3.	One (1) Ultrafiltration system
4.	Two (2) UF Backwash pump
5.	One (1) Filtrate Storage Tank 10,000 gallons
6.	Two (2) Filtrate Forwarding Pumps
7.	One (1) Sodium Bisulfite Dosing Skid
8.	One (1) 5000 gallon Sodium Bisulfite storage Tank
9.	One (1) Acid Dosing system
10.	One (1) 5000 gallon Acid Storage Tank
11.	Two (2) RO Cartridge Prefilter
12.	Two (2) RO Booster Pumps
13.	One (1) RO Membrane System
14.	One(1) Membrane CIP Skid

Brine Concentrator

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2.	Two (2)Wastewater Transfer Pump with Feed Strainer
3.	One (1) Feed Tank and Pump Skid

4.	Three (3) Chemical Dosing Skids
5.	One (1) Pre-heater and Deaerator
6.	One (1) Brine Concentrator Vessel
7.	One (1) Vapor Compressor Skid
8.	One (1) Recirculation Pump Skid
9.	One (1) Distillate Tank and Pump Skid
10.	One (1) Lot of Prefabricated Recirculation Piping and Vapor Ducting
11.	One (1) Lot of On-skid Piping
12.	One (1) Lot of Instrumentation and PLC Based Controls within Battery Limits
13.	One (1) Lot of Structural Steel platforms, access ladders for BC Vessel
14.	One (1) Interconnecting Piping between Skids
15.	One (1) Lot of Electrical Conditioning and MCC by others
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12.	One (1) Lot of Instrumentation
13.	One (1) Slurry Pump
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14.	One (1) PLC Based Control Panel with HMI

Base budget Price for UF/RO/FCC/Filter Press, Ex-works ***$ 7,700,000***

Approximate RO Permeate & Distillate from System; 530 GPM
Total Power Consumption; 1500 kW
Solid waste at 10% solids content; 1500 #/hour
Typical expected delivery of this equipment would be 55-60 weeks.

The equipment described is constructed of high end alloys which are subject to material cost escalations due to volatility in availability and pricing.

If I can be of further assistance please feel free to contact me at your convince.

Regards,

Terry LaPrise
Regional Sales Manager

Zero Liquid Discharge System

Overview

The Aqua-Chem ICD Zero Liquid Discharge System is a fully integrated automated system incorporating a mechanical vapor compression brine concentrator, a forced circulation crystallizer, and solids dewatering. High purity distillate produced in this system can be used for cooling tower or boiler makeup water.

The Aqua-Chem ICD Zero Liquid Discharge System typically follows a reverse osmosis (RO) preconcentrator. High TDS and saturation in low solubility scaling salts such as calcium sulfate ($CaSO_4$) and silica (SiO_2) limit the percentage of water which can be recovered by an RO system. Feedwater saturated in $CaSO_4$ and/or SiO_2 is also very difficult to concentrate in a normal evaporator but can be handled in the Aqua-Chem ICD brine concentrator. The process, also called seeded slurry evaporation, involves establishing and maintaining a slurry of calcium sulfate seed crystals in the circulating brine in the evaporator. With careful thermal and mechanical design, the SiO_2 and $CaSO_4$ will precipitate preferentially on the recirculating crystals instead of on the tubes. The brine concentrator is capable of concentrating the wastewater to near saturation in the sodium salts without scaling the heat transfer tubes.

The remaining water is evaporated in the forced circulation crystallizer. This evaporator easily handles the crystallization of the remaining salts regardless of the exact chemical analysis. The salts are removed as a cake by a (filter press, centrifuge).

The Aqua-Chem ICD Zero Liquid Discharge System is designed for automatic steady state operation and will require little operator attention. The materials of construction have been selected to resist corrosion and ensure a long plant life. The system is very reliable. The pumps and compressor typically operate years without significant problems, given periodic maintenance typical for rotating equipment. Almost any problem can be fixed in a day. The system is designed to minimize scaling of the heat transfer surfaces; however, it is also designed to operate in a slightly fouled condition, so normal fouling or scaling will not affect the design capacity of the unit. Chemical cleaning of the system is typically required once or twice per year.

Process Description

The feed is acidified with H_2SO_4 to a pH of 5.5 which converts bicarbonate to dissolved CO_2 for removal in the deaerator. The bicarbonate is removed to prevent scaling of the brine concentrator tubes with calcium carbonate ($CaCO_3$). A small amount of scale inhibitor is metered into the feed to avoid scaling in the feed/distillate plate heat exchanger. Depending on the amount of calcium in the feed, the anti-scale may be reduced or eliminated.

The feed/distillate heat exchanger, a plate and frame type with titanium plates, preheats the feed with outgoing hot distillate. The heated feed flows to the deaerator to remove dissolved carbon dioxide and oxygen, to minimize corrosion in the system. Aqua-Chem ICD uses a flashing deaerator which does not utilize packing, thereby avoiding plugging problems. The feed is sprayed into the pressurized, barometric half of the deaerator which further heats the feed with low pressure evaporator vent vapors. The feed then flashes into the low pressure portion of the deaerator. A small fraction of water from the feed is vaporized, along with the dissolved carbon dioxide and oxygen, which are virtually eliminated by this step. Typical dissolved oxygen content in the deaerated feed is 10 ppb.

The feed then flows to the brine concentrator vessel. Calcium sulfate scale is managed in this vessel by proper feed pretreatment and by providing adequate seed crystal surface area dispersed homogeneously in the brine slurry. The seed crystals prevent supersaturation extremes and promote crystal growth rather than scaling on the heat transfer surface.

The seed crystals are added as gypsum to the seed makeup tank at startup to establish the circulating slurry. As the brine is concentrated and some is pumped to the crystallizer, seed crystals are replenished by natural generation from calcium and sulfate ions in the incoming feed water. A seed thickening tank is provided to recycle seed crystals back into the brine concentrator if the natural seeding level is too low. A $CaCl_2$ injection system is provided to add Ca+2 directly into the feed line if the incoming Ca+2 concentration is too low. Both of these systems are used to maintain adequate seed crystal concentration in the brine concentrator.

The brine concentrator vessel is designed with a long bottom channel to provide sufficient residence time for crystal growth. A vapor separator with mist eliminators is used to remove entrained droplets of brine from the vapor before it flows to the compressor. The mist eliminators are periodically sprayed with hot distillate to dissolve any accumulated solids.

Vapor generated in the brine concentrator flows to a mechanical compressor, which increases its saturation pressure and temperature. Then the compressed vapor flows to the shell side of the brine concentrator in lieu of external heating steam. The vapor is condensed on the outside of the tubes, transferring heat to the circulating brine on the tubeside. Condensed vapor (distillate) is pumped out of the system. Some of the distillate is sprayed into the compressor discharge duct to desuperheat the compressed vapor.

The brine concentrator is designed with a very low delta-T (temperature difference between the heating medium and the boiling brine) and a high recirculation rate. The two main benefits are reduced scaling rate and a lower compressor power requirement. Energy economy is maximized by utilizing distillate and vent stream heat. The system is designed for low make-up steam at steady state operation.

The brine is concentrated to approximately 25% total solids in the brine concentrator. To maintain a solids balance in the system, part of the concentrated brine is continuously pumped from the brine concentrator to the forced circulation crystallizer.

Recirculated brine is pumped through the forced circulation heat exchanger where it is heated with steam from the brine concentrator to above its normal boiling temperature. Boiling of the brine in the heat exchanger is suppressed due to sufficient static head. Boiling in the heat exchanger would cause scale formation on the heat transfer surface. The heated brine then enters a flash tank operating at a slightly lower pressure, causing flash evaporation of water and formation of salt crystals in the brine. High recirculation rates are used to keep the contact time on the heated surface low, reducing the scaling rate of the heat transfer surface.

Once every eight hours the a batch of slurry is discharged from the crystallizer to the filter press feed tank. This slurry is fed to the filter press, which separates out the salt crystals as a cake. The liquid portion, saturated in dissolved salts, is returned to the forced circulation crystallizer. The salt cake is dumped at 8 hour intervals into a hopper for disposal. This sequence is manually initiated, and requires an operator to be present to assure that the plates have properly released the salt cake.

Vertical Tube Falling Film Evaporator (Brine Concentrator)

Falling film vertical tube evaporators use vertical tube bundles with brine evaporating from a thin film on the inside of the tubes. Brine is distributed in a thin film down the inside of the tubes. The brine absorbs heat from condensing water vapor on the outside of the tubes. The latent heat of vaporization transfers from the water vapor through the tube wall to the thin brine film on the inside of the tube. For every kilogram of water vapor that condenses, approximately one kilogram of water is evaporated from the brine film.

The vapor condensing on the tube bundle is primarily water vapor but can also contain air and other non-condensables. These non-condensables will stay in the vicinity of the tube walls and impede heat transfer unless swept away by sufficiently high vapor velocities. A vent on the evaporator body continuously removes the non-condensables to maintain high heat transfer coefficients and to prevent loss of driving force (differential temperature) through excess subcooling of the heating vapor.

The brine is introduced at the top of the vessel and flows in a downward direction as a falling film. The brine is uniformly and generously directed to the full circumference of each tube as a thin film. Because the recirculation rate is many times greater than the evaporation rate, only a small change in concentration occurs down the tube length as evaporation takes place. The recirculation rate is chosen conservatively to ensure that the heat transfer surface is well wetted and localized drying is not encountered.

A proprietary dual perforated plate distributor ensures that the liquid is evenly distributed to the tubes. The plates have holes larger than 13 mm and have been proven to be much less susceptible to plugging than other designs including individual weir inserts or swirler inserts.

Careful design eliminates areas where the solids and impurities may collect and impede liquid flow and heat transfer. Design features include large holes in the distribution system, sloped bottoms, and smooth entrance to pump suctions.

Mechanical Vapor Compression (VC)

Vapor compression is a highly efficient process using mechanical energy input to achieve evaporation and condensation. The fundamental difference between the vapor compression unit and the conventional evaporator is that the latent heat of vaporization is fully utilized in the VC evaporator. Since the evaporator also serves as the condenser, essentially all of the latent heat is recycled, with no rejection of heat to cooling water.

The evaporated vapor flows through the mist eliminator to the suction of the compressor. The compressor does work on the water vapor increasing the saturation pressure of the water vapor so that when it condenses, it does so at a higher temperature. The compressed vapor flows to the heating side of the evaporator. As it condenses, it transfers the latent heat of vaporization back to the liquid film on the tubeside.

The compression process produces discharge vapors that are superheated (i.e. hotter than the corresponding saturation temperature). Scaling, excessive fouling, and stress corrosion can occur if the superheated vapor is allowed to condense on the evaporator tube bundle. This scaling would occur as the sensible heat is transferred through the tube. To remove the superheat in the compressed vapor discharge, desuperheating water (in the form of distillate) is sprayed into the vapor stream. This distillate is very near the saturation temperature so latent heat is not removed from the vapor stream and can be used for the evaporation process.

A multi-stage centrifugal blower is used for the brine concentrator. It is coupled to a motor-driven gearbox. This type of compressor is very simple and easy to maintain. System turndown is achieved by the adjustment of the blower discharge damper valve. Turndown to 65% of rated capacity can be attained in this manner.

Control

The system is designed for automatic cascade control. Evaporation rate in the brine concentrator is based on an operator setpoint. The damper valve at the compressor discharge controls vapor flow to the brine concentrator based on the distillate flow rate out of the system. All other flow rates automatically adjust based on this setpoint. The feed rate is based on distillate outflow and brine level in the brine concentrator. Pressure (and indirectly temperature) in the brine concentrator is controlled by venting excess steam to the atmosphere or by allowing external steam into the system. The concentrated brine flow rate is remotely set based on feed and distillate flows. Operational parameters of system pressure, sump level, distillate level, and concentrate flow will be automatically controlled based on changes to the desired evaporation rate.

Operation

The system is designed for manual start-up and automatic operation. The feed chemistry should be monitored periodically. Sufficient safeguards and interlocks to prevent unsafe conditions or equipment damage are included in this design. When the system is shut down it is important to either keep the system pressurized with steam to keep oxygen out or drain and flush the system to remove the chlorides. Chlorides in the presence of oxygen will accelerate corrosion and reduce equipment life.

Maintenance

The required maintenance for this Aqua-Chem ICD Zero Liquid Discharge System is typical for commercial process equipment containing high quality industrial duty components. The unit's rotating equipment, such as pumps and compressors, require periodic adjustment, lubrication, and servicing of components such as seals. Instrumentation was specifically chosen to be durable and trouble free, but will require periodic adjustment and recalibration. If recommended spare parts are kept on hand and a preventative maintenance program is implemented, then the net availability (operating factor) can be expected to exceed 95%. The required maintenance procedures, recommended spare parts, and recommended preventative maintenance program will be provided by Aqua-Chem ICD.

Washing

The heat transfer surface has been designed to operate at capacity with lightly scaled heat transfer surfaces. An occasional manual adjustment of the compressor valve will maintain the system capacity as the evaporators slowly scales and loses performance. When this valve has been fully opened and the necessary capacity can no longer be maintained, a chemical wash will be required to restore performance. A complete chemical cleaning procedure will normally take between 12 and 24 hours. The evaporators are normally cleaned by recirculating a hot 10% EDTA solution (diluted Nalco 760 for example) with the recirculation pumps. The cleaning solution is injected into the recirculation line. The solution is maintained hot (70°C) by using a small amount of steam flow through existing controls. Cleaning frequency for an evaporator of this type is typically once or twice per year.

It may be economical to hydroblast prior to cleaning with EDTA. This reduces the amount of EDTA required. We recommend a professional hydroblast crew do this work. Two 600 mm manholes on the top channel facilitate easier distribution plate removal and tube blasting.

Materials of Construction

Due to the relatively high chloride content the major vessels wetted materials are 6% molybdenum stainless steel such as 254 SMO or AL6XN. Tubes are titanium grade 2. Other materials used for brine service include fiberglass, CD4MCu, Hastelloy C, and 316L Stainless Steel as applicable. Use of these materials will assure equipment life beyond 20 operating years.

Spare Parts

Installing spare pumps in brine service would lead to stagnant areas and potential corrosion. Considering the high reliability of these pumps, it is better not to install spares but keep shelf spares. In the event a pump replacement is necessary, the feed storage tank would be used to collect the feed flow as it would be when the unit was shut down for cleaning. Upon startup the excess capacity designed into the unit will process the stored feed.

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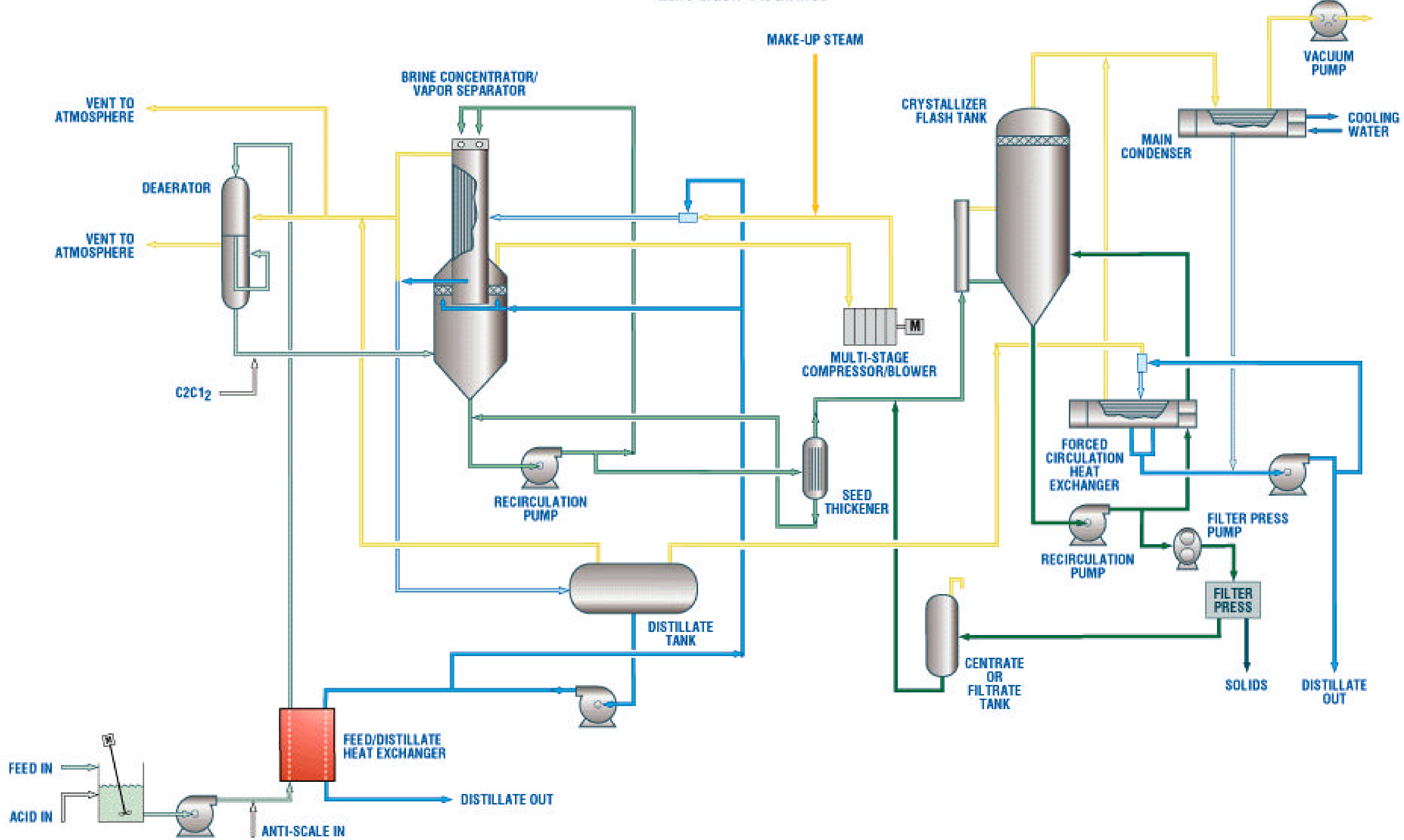
www.aquatech.com

aqua-chem ICD
Industrial Concentration & Desalination

ZERO LIQUID DISCHARGE



GE Infrastructure
Water & Process Technologies

Jonathon Dueck BSc PChem
Equipment Solutions Specialist

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T 403 346 8620
F 866 527 9518
Jonathon.Dueck@ge.com

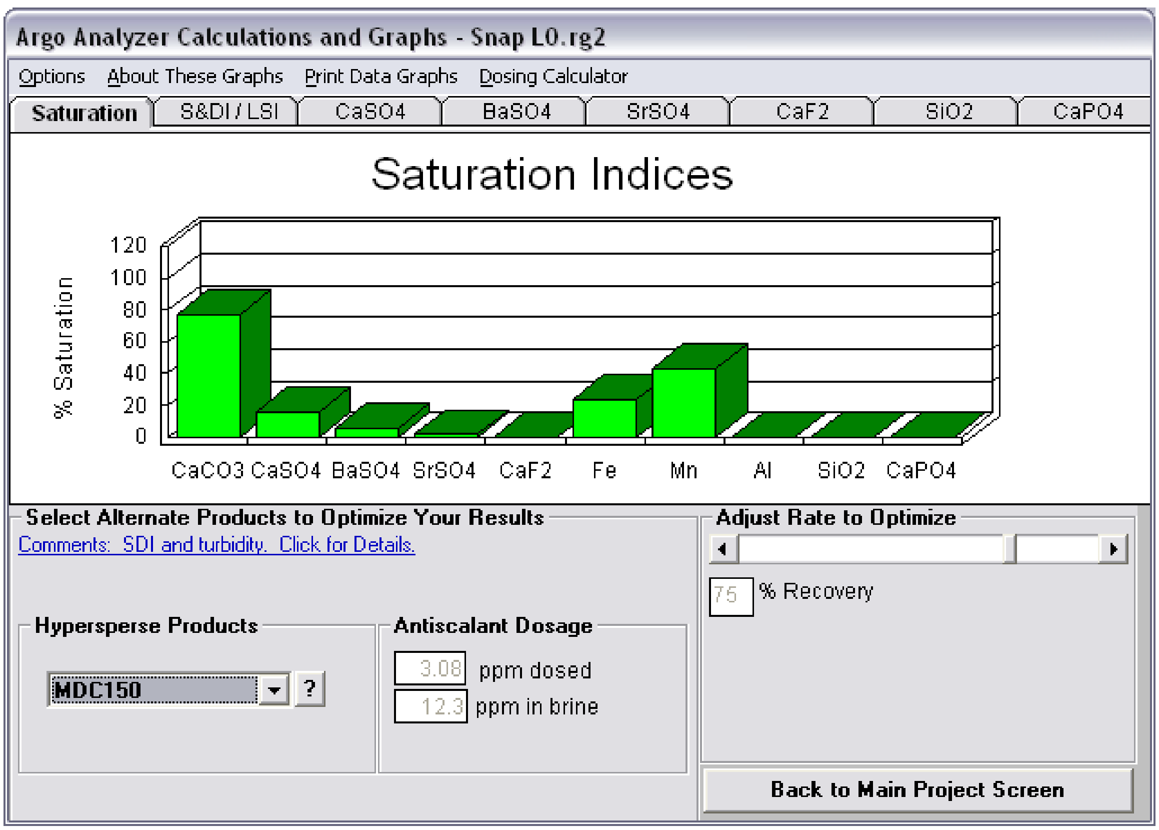
April 10, 2008

Peter Lemke
Golder Associates
Denver, CO

Dear Pete;

RE: DeBeer's Snap Lake Drift Water Treatment

From an initial modeling of the data provided, this water looks to be very treatable with a combination of UF to remove suspended solids and RO to reduce the TDS. Below you will see a graphical output from our modeling tool showing the scaling tendency of the water. None of the mineral scales are even within 80% of saturation, indicating that scaling issues should not be of concern for this application. This graph was generated using the maximum concentration values from the analyses provided to give an indication of worst-case scenario. The entire report from this modeling is included with this email as a separate file.



To treat this water with standard equipment at the flow rates you require, we would suggest using two Z+PRO450, Zeeweed (UF) and RO trains fitted with high recovery, low energy, cold water membranes. Each of these trains would produce 450 gpm of permeate and would come with a VFD to reduce the total flow through the RO by up to 25%. Dual train operation would allow you to continue to process water from the mine at a rate of 450 gpm while one of the trains is in cleaning, while also permitting higher water production rates than the 550 gpm requirement without having to expand the system.

A spec sheet and general dimensional drawing of these units is attached. These trains will remove the suspended solids via the UF component and remove >95% of the dissolved solids via the RO component. The ZeeWeed UF membrane is ideal for this type of application due to the high solids loading, which would plug spiral wound membranes and cause excessive backwashing of conventional multimedia filters (MMF). The overall water recovery of the system would be around 75%. It can be estimated that the RO permeate (good) water quality will contain approximately 3% of the inlet TDS, with slightly higher passage of the monovalent cations and anions and lower passage of the divalent ions. Virtually all the trivalent and higher ions would be removed from the permeate stream.

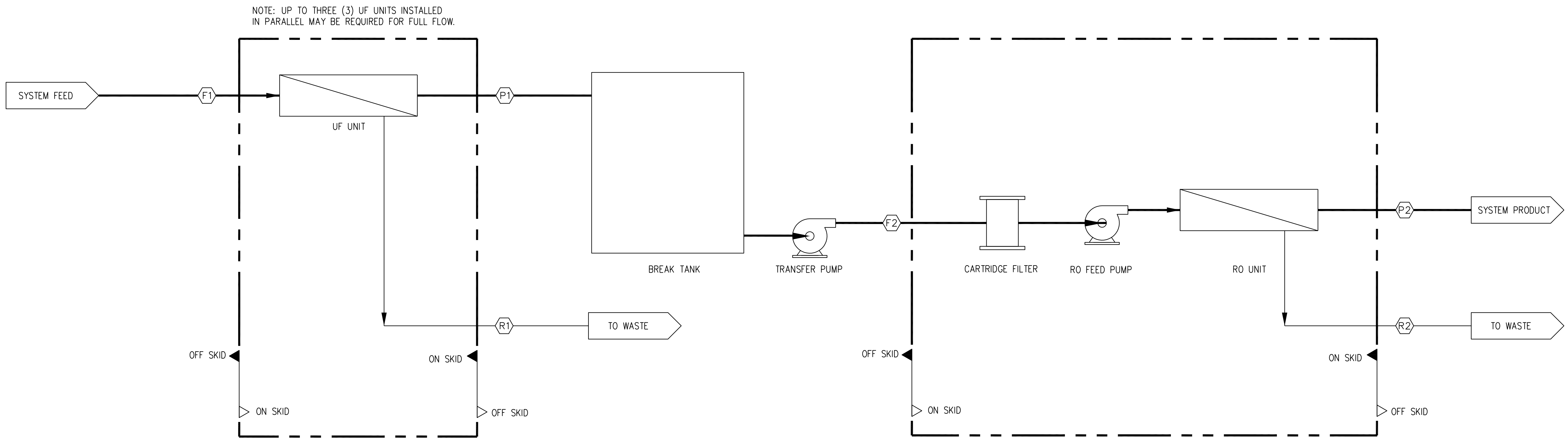
Budgetary pricing on 2 Z+PRO450 trains would be $1,900,000 plus freight, installation, interconnecting piping and any PLC changes to make the machines communicate with each other. Engineering specifications would be reviewed and changed to meet customer requirements, and pricing would be adjusted accordingly.

I will give you a call in a week or so, once you have had a chance to review this, and we can discuss what other information you need for a path forward.

Best regards,

Jonathon Dueck BSc PChem
Equipment Solutions Specialist

GE Water & Process Technologies
(403) 350 6631
Jonathon.Dueck@ge.com



*NOTE: ACTUAL FEEDWATER SPECIFICATIONS NEED TO BE REVIEWED PRIOR TO FINAL DESIGN.

FEED WATER	LIMIT
AVERAGE TURBIDITY	<100 NTU
SILICA	SEE SCALING LIMITS
CONCENTRATION NaCl TDS (MG/L)	1500–2500
pH	5.0–8.5
MINIMUM INLET PRESSURE	4 PSI
F+Mn	<15Mg/L
TSS (SECONDARY EFFLUENT)	<30Mg/L

MODEL	UF MODEL AND QUANTITY	RO MODEL AND QUANTITY	(F1) SYSTEM FEED FLOW (GPD)	(P1) INSTANTANEOUS UF PERMEATE (GPD)	(R1) INSTANTANEOUS UF REJECT (GPD)	(F2) RO FEED (GPD)	(P2) RO PERMEATE (GPD)	(R2) RO CONCENTRATE (GPD)	TANK CAPASITY (GALLONS)	TANK DIMENSIONS (INCHES) (DxH)
Z+PRO–50	S12 QTY 1	PRO–50–PRE FRP QTY 1	107,200	96,480	10,720	96,480	72,000	24,480	360	48"x42"
Z+PRO–100	S18 QTY 1	PRO–100–PRE FRP QTY 1	212,500	191,520	21,250	191,520	144,000	47,520	540	48"x75"
Z+PRO–150	S24 QTY 1	PRO–150–PRE FRP QTY 1	320,000	288,000	32,000	288,000	216,000	72,000	840	48"x109"
Z+PRO–200	S18 QTY 2	PRO–200–PRE FRP QTY 1	427,200	384,480	42,720	384,480	288,000	96,480	540	48"x75"
Z+PRO–300	S24 QTY 2	PRO–300–PRE FRP QTY 1	640,000	576,000	64,000	576,000	432,000	144,000	840	48"x109"
Z+PRO–450	S24 QTY 3	PRO–450–PRE FRP QTY 1	960,000	864,000	96,000	864,000	648,000	216,000	840	48"x109"

REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE	–	–	–	–	–

TOLERANCES UNLESS NOTED
DECIMALS ANGLES
.X ± ±
.XX ±
.XXX ±
FRAC ±

DRAWN BY B.N. DATE 20Sep06
CHECKED BY DATE
APPROVED BY DATE
APPROVED BY DATE

GE Infrastructure
Water & Process Technologies
4101 E. WOOD STREET, PHOENIX, AZ 85040 USA (602) 437–1355 WWW.GEWATER.COM

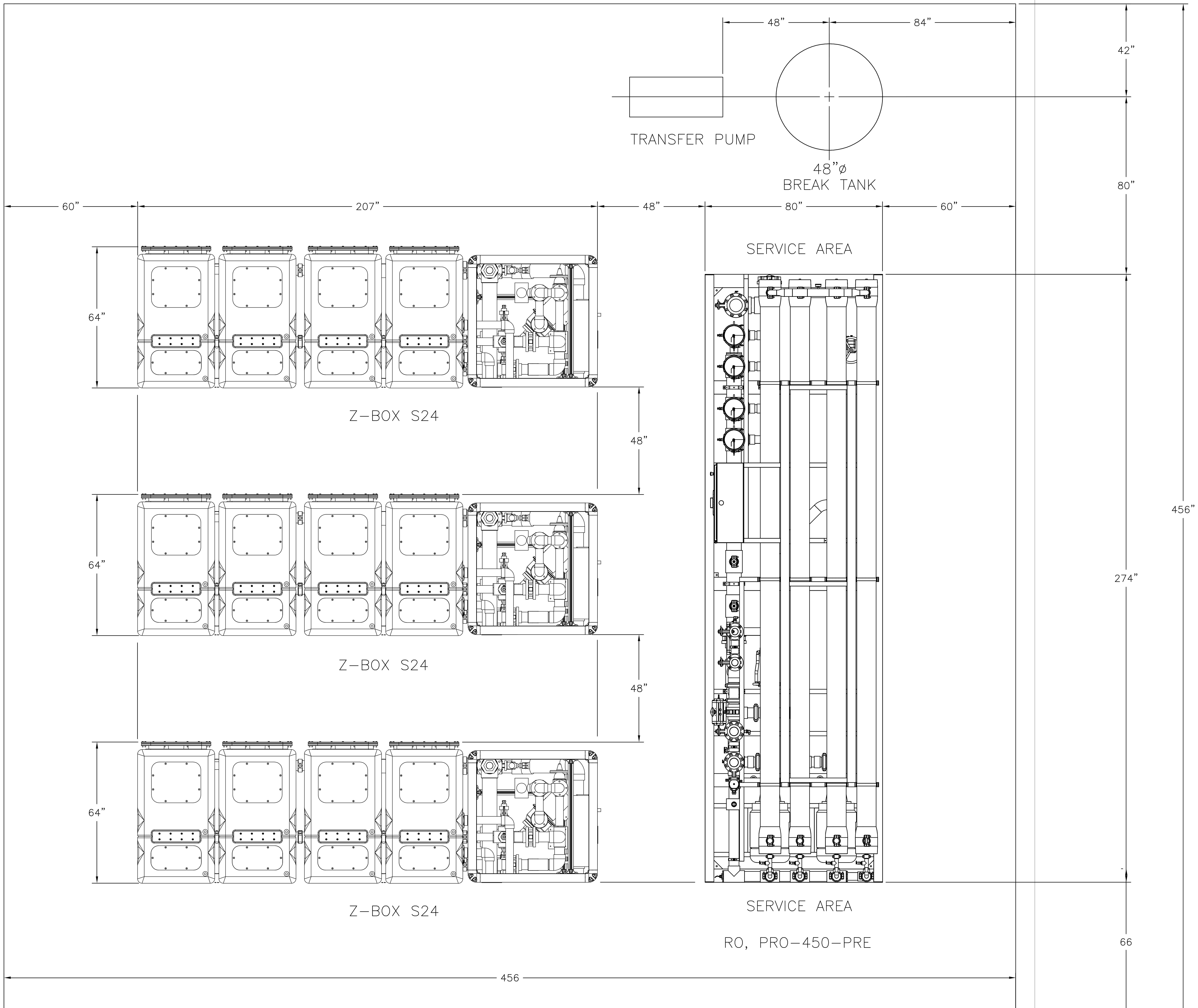
CLIENT/JOB
FILE ACR2004

DWG DESCRIPTION
Z+PRO SERIES
PDF

MATERIAL/BOM NO.

SIZE D | DRAWING NO. | REV A
PROJECT
SCALE | SHEET 1 OF 1

P/N 1300486–RAP01



REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE	12313	–	–	–	–

TOLERANCES UNLESS NOTED
DECIMALS ANGLES
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FRAC
±

DRAWN BY	DATE 20Sep06
CHECKED BY	DATE
APPROVED BY	DATE
APPROVED BY	DATE

GE Infrastructure
Water & Process Technologies
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CLIENT/JOB
FILE ACR2004

DWG DESCRIPTION
FLOOR LAYOUT SKETCH,Z+PRO-450
MATERIAL/BOM NO.

SIZE D
DRAWING NO. 1302182
REV A
PROJECT
SCALE
SHEET 1 OF 1

P/N 1300486-RAP01

Argo Analyzer

Report for 550 USGPM Membrane Separation Plant at Snap Lake

Prepared by : Jonathon Dueck
Thursday, April 10, 2008

If you have questions or concerns about the use or distribution of Argo Analyzer please contact your regional GE representative.

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Argo Analyzer

Report for 550 USGPM Membrane Separation plant at Snap Lake

INTRODUCTION.

The following report is prepared from the details completed for the Raw Water prepared to be supplied to a Membrane Separation Plant operating as specified. The information is given for guidance only.

RAW WATER.

The Raw Water details show :
Well Water has been selected as the source of the raw water.
The date of analysis is not known. It is advisable to have the results confirmed with an up to date analysis

FEEDWATER.

The following is reported for the Feedwater using the Raw Water as basis :

Total Hardness is derived from Calcium ion and Magnesium ion values
Calcium Hardness is derived from the Calcium ion Value
Magnesium Hardness is derived from the Magnesium ion Value
Alkalinity value is derived from the Bicarbonate ion Value
CO2 value is calculated from the raw water pH and Bicarbonate/Alkalinity value
The raw water TDS value has been calculated by summing the individual ions
The Sodium Absorption Ratio (SAR) indicates that this water is suitable for irrigation

PRETREATED WATER.

The Pretreated Water is as follows :
The feedwater has been prepared for introduction into a membrane separation plant operating at 75.0% recovery.
The pH does not need adjustment. Scale control will be by the addition of Chemical Inhibitor only.
In order to control the precipitation of limited solubility salts it will be necessary to dose 3.08 ppm of Hypersperse MDC150
An arrangement to flush out pretreated water from the membranes at each plant shutdown is highly recommended.
The following ions are presented at the maximum permitted concentration (mg/l) as the presence was not indicated in the Raw Water:
Fluoride - 34.12mg/l Aluminium - 0.25mg/l Silica - 31.25mg/l
The maximum values are given for guidance only and are not considered in the program calculations.It may be necessary to increase the dose of antiscalant to control the above salts at these levels.

BRINE.

The following is reported for the Brine :
The Brine projection is from the pretreated feedwater passing over polyamide spiral wound membranes when operating at a recovery of 75.0%
The S&DI of the brine is 2.31
The saturation indicies of the limited solubility salts being controlled by inhibition are :
BaSO4 :0.1,
The above are based on the maximum inhibition possible for the selected product
The maximum possible recovery using this pretreated water, with the selected antiscalant, based on the scale potential, is 98.0%
The limiting salt is Barium Sulphate

CHEMICAL DOSING.

Feed water chemical consumption :
The plant output is 550 USGPM operating at 75% recovery
The raw water requirement will be 733 USGPM
Based on the plant operating 24 hours per day, 7 days per week, 52 weeks per year, this plant will produce 288,300,000 US Gallons per year from a feed flow of 384,400,000 US Gallons per year . The plant will consume a total of 9,890 pounds per year of Hypersperse MDC150

Argo Analyzer

	Raw Water	Feed Water	Pretreated Water	Brine	units
Calcium Hardness	1210.00	1210.00	1210.00	4840.00	as CaCO3
Magnesium Hardness	46.70	46.70	46.70	186.80	as CaCO3
Total Hardness	1256.70	1256.70	1256.70	5026.80	as CaCO3
Alkalinity		47.53	47.54	190.10	as CaCO3
pH	8.50	8.50	8.49	9.10	
Temperature	15.00	15.00	15.00	15.00	as °Cent
Conductivity	6090.00	6090.00	6090.00	24452.37	µS / cm
TDS	3178.00	3729.73		14918.92	mg/l
Chlorine	0.00	0.00	0.00	0.00	mg/l
Calcium	484.97	484.97	484.97	1939.87	mg/l
Magnesium	11.36	11.36	11.36	45.43	mg/l
Sodium	543.00	557.08	557.08	2228.34	mg/l
Potassium	436.00	436.00	436.00	1744.00	mg/l
Iron	0.03	0.03	0.03	0.12	mg/l
Manganese	0.03	0.03	0.03	0.11	mg/l
Barium	0.06	0.06	0.06	0.25	mg/l
Strontium	11.20	11.20	11.20	44.80	mg/l
Aluminium	0.00	0.00	0.00	0.00	mg/l
Copper	0.00	0.00	0.00	0.00	mg/l
Lead	0.00	0.00	0.00	0.00	mg/l
Zinc	0.00	0.00	0.00	0.00	mg/l
Chloride	1980.00	1980.00	1980.00	7920.00	mg/l
Sulphate	191.00	191.00	191.00	764.00	mg/l
Bicarbonate	58.00	58.00	58.00	232.00	mg/l
Nitrate	0.00	0.00	0.00	0.00	mg/l
Fluoride	0.00	0.00	0.00	0.00	mg/l
Silica	0.00	0.00	0.00	0.00	mg/l
Phosphate	0.00	0.00	0.00	0.00	mg/l
Bromide	0.00	0.00	0.00	0.00	mg/l
TOC	0.00	0.00	0.00	0.00	mg/l
BOD	0.00	0.00	0.00	0.00	mg/l
COD	0.00	0.00	0.00	0.00	mg/l
Phenols	0.00	0.00	0.00	0.00	mg/l
Hydrocarbons	0.00	0.00	0.00	0.00	mg/l
Bacteria	0.00	0.00	0.00	0.00	mg/l
CO2		0.30	0.30	0.30	mg/l
H2S	0.00	0.00	0.00	0.00	mg/l
RSI				9.10	
LSI					
S&DI				2.31	
Ionic Strength	0.08		0.08	0.30	
SAR	4.75	4.87	4.87	9.74	
Total cations	3008.12	3038.75	3038.75	12155.00	as CaCO3
Total anions	3038.22	3038.22	3038.22	12152.87	as CaCO3

Argo Analyzer

This projection has been prepared for the 550 USGPM membrane plant at Snap Lake

Dose Projection and Product Selection Summary

Selected Product : Hypersperse MDC150
Required Dosage : 3.08 mg/l
Usage Rate : 27.16 lb/day

Degrees of Saturation in Concentrate as %

Saturation	CaSO4	BaSO4	SrSO4	CaF2	SiO2	CaPO4
No Inhibitor	55.6	576.3	57.3	0.0	0.0	0.0
Inhibitor	15.9	5.5	1.6	0.0	0.0	0.0

The projected calcium carbonate saturation level is 2.31 expressed as S&DI
The limit for S&DI is 3 with inhibitor and 0.0 without.

The projection is for a 550 USGPM membrane separation plant, operating at 75% recovery.

The foregoing recommendations are given in good faith and are based on the analytical and operation data you have entered, and on application data which we believe to be correct. No warranty as to specific application is expressed or implied since conditions of use and other contributory factors are beyond our control Please seek advice from your GE membrane specialist with regard to any particular query.

Argo Analyzer

This projection has been prepared for the 550USGPM membrane plant at Snap Lake

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Saturation	CaSO4	BaSO4	SrSO4	CaF	SiO2	CaPO4
Without Inhibitor	55.6	576.3	57.3	0.0	0.0	0.0
With Inhibitor	15.9	5.5	1.6	0.0	0.0	0.0

The projected calcium carbonate saturation level is 2.31 expressed as S&DI
The limit for S&DI is 3 with inhibitor and 0.0 without

The projection is for a 550 USGPM membrane separation plant, operating at 75% recovery.

Water Analysis

The above recommendations have been made based on the following feed water analysis :

Ion	Raw Water	Feed Water	Brine	
Calcium	484.97	484.97	1939.87	
Magnesium	11.36	11.36	45.43	
Sodium	543.00	557.08	2228.34	
Potassium	436.00	436.00	1744.00	
Iron	0.03	0.03	0.12	
Manganese	0.03	0.03	0.11	
Barium	0.06	0.06	0.25	
Strontium	11.20	11.20	44.80	
Aluminium	0.00	0.00	0.00	
Chloride	1980.00	1980.00	7920.00	
Sulphate	191.00	191.00	764.00	
Bicarbonat	58.00	58.00	232.00	
Nitrate	0.00	0.00	0.00	
Fluoride	0.00	0.00	0.00	
Silica	0.00	0.00	0.00	
Phosphate	0.00	0.00	0.00	
pH	8.50	8.49	9.10	
Temperatur	15.00	15.00	15.00	°Cent

The foregoing recommendations are given in good faith and are based on the analytical and operation data you have entered, and on application data which we believe to be correct. No warranty as to *specific application is expressed or implied since conditions of use and other contributory factors are beyond our control Please seek advice from your GE membrane specialist with regard to any particular query.*

GE
Water & Process Technologies

Fact Sheet

Z+PRO 60 Hz

UF+RO Packaged Plants

50-450 gpm (11.4-102.2 m^3/hr)

Key Benefits:

- Compact treatment system for variable water quality
- Fully skid-mounted; reduces onsite installation time and costs
- Easy to install
- Simple to operate
- Easily integrated into an existing facility
- UF side-loading tank provides easy access to membrane modules

Standard Features:

- GE Fanuc control package mounted on frame
  Text and pictorial operating screens
  Keypad and touchscreen controls
- 4-20 mA instruments on QuickPanel
- Permeate/backpulse pump and associated valving mounted on equipment frame
- Extruded aluminum equipment frame for UF unit; painted carbon steel on RO
- Polyethylene membrane and backwash tanks mounted on equipment frame
- 0.5 mm self cleaning screen
- RO permeate flush on shutdown
- Voltage 480 or 575 V, 3 phase, 60 Hz (other voltages available)

Documentation Included

- Operation and maintenance manuals included
- Drawings: piping and instrumentation, electrical general dimensional, and process flow diagram

Operating Parameters

Recovery	65-85%
Design temp.	60°F (15.6°C)
Operating range	35 to 85°F (1.6 to 29.4°C)
Minimal inlet pressure	4 psi

Materials of Construction

High-pressure piping	Stainless Steel, Sch. 10
Low-pressure piping	Sch. 80, PVC
Enclosure	NEMA 12 (painted blue)
Clamps/fittings	Zinc-plated[jh1]

Membrane Elements

UF membrane model	ZeeWeed® 1000
RO membrane model	OSMO PRO RO 365
RO membrane rejection	99.6%
Manufacturer	GE

Global Headquarters
Trevose, PA
+1-215-355-3300

Americas
Watertown, MA
+1-617-926-2500

Europe/Middle East/Africa
Heverlee, Belgium
+32-16-40-20-00

Asia/Pacific
Shanghai, China
+86-21-5298-4573

Table 1: Standard Instrumentation

Flow	RO permeate, concentrate, UF permeate
Turbidity meter	UF permeate
Conductivity	RO feed, permeate
PH	RO feed
ORP	RO feed
Pressure	Pre-filter, post-filter, primary, final, pump discharge, interstage, UF permeate suction/backpulse
Pressure Switch	RO feed, permeate, concentrate
Level Transmitter	Membrane tank, UF/RO break tank

Table 2: Major Component Manufacturers

Equipment	Manufacturer
UF permeate pump	G&L
RO high pressure pump	GE Tonkaflo
Air compressor	Quincy
Cartridge filter housing	GE
RO membrane housing	Wave Cyber
Flow & level measure-ment	E&H, GF Signet
Conductivity, pH, ORP	Thornton
Turbidity meter	Hach
PLC Components	GE Fanuc
Chemical Pumps	Prominent
Valves	Keystone, Bray, Chemline

Table 3: Application Dependent Options

Option	Description
Feed water turbidimeter	Feed water turbidity monitoring
Enhanced coagulation (E.C.) system	Coagulant dosing pump, flocculation tank, and mixers for TOC removal
Oxidation system	Oxidation dosing pump, oxidation tank, and mixers for iron and manganese removal
+/- pH adjustment	Automatic feed pH adjustment and monitoring system for E.C. and Oxidation.

Table 4: Optional Features

Option	Description
Allen Bradley Control Package	Replaces GE Fanuc components with equivalent AB
PRO Clean-in-Place	Cone-bottom HDPE tank with painted carbon steel stand for chemical recirculation
PRO Chemical Feed Systems	Electronic metering pump for antiscalant or sodium bisfulfite injection
RO Motor Starters	Motor starters for high pressure and CIP pumps, shipped loose for field installation
NaOCl cleaning system	Cleans organics from UF membranes
Citric cleaning system	Cleans inorganics from UF membranes
Chemical neutralization pumps	Neutralize cleaning solution after membrane cleaning
Air compressor	Valve operation, membrane aeration and MIT
Online spare air compressor	Redundant air compressor[jh2]

GE Water & Process Technologies Z+PRO Models

	Z+PRO-50	Z+PRO-100	Z+PRO-150	Z+PRO-200	Z+PRO-300	Z+PRO-450
Product rate:	72,000 gpd	144,000 gpd	216,000 gpd	288,000 gpd	432,000 gpd	648,000 gpd
Concentrate Rate:	35,200 gpd	68,500 gpd	104,000 gpd	139,200 gpd	208,000 gpd	312,000 gpd
Feed Rate:	107,200 gpd	212,500 gpd	320,000 gpd	427,200 gpd	640,000 gpd	960,000 gpd
Models						
Z-BOX-S Model:	S12	S18	S24	S18	S24	S24
Z-BOX-S Quantity:	1	1	1	2	2	3
PRO Model:	PRO-50-PRE, FRP	PRO-100-PRE, FRP	PRO-150-PRE, FRP	PRO-200-PRE, FRP	PRO-300-PRE, FRP	PRO-450-PRE, FRP
PRO Quantity:	1	1	1	1	1	1
Break Tank & RO Feed Pump						
Tank Volume:	360 gallon	540 gallon	840 gallon	540 gallon	840 gallon	840 gallon
Tank Dimensions (DxH):	48"x 42" (122cm x 107cm)	48"x 75" (122cm x 191cm)	48"x 109" (122cm x 277cm)	48"x 75" (122cm x 191cm)	48"x 109" (122cm x 277cm)	48"x 109" (122cm x 277cm)
Pump Flow:	70 gpm	135 gpm	200 gpm	270 gpm	400 gpm	600 gpm
Pump Pressure:	60 psig (4.1 bar)	50 psig (3.4 bar)	40 psig (2.8 bar)	55 psig (3.8 bar)	40 psig (2.8 bar)	45 psig (3.1 bar)
Pump Power:	5 HP (3.7 KW)	7.5 HP (5.6 KW)	10 HP (7.5 KW)	15 HP (11 KW)	15 HP (11 KW)	20 HP (14.9 KW)
Installation and Utility Requirements						
UF Inlet:	4.0" flange	6.0" flange	6.0" flange	6.0" flange	6.0" flange	6.0" flange
UF Permeate:	3.0" flange	4.0" flange	4.0" flange	4.0" flange	4.0" flange	4.0" flange
UF Drain:	4.0" flange	6.0" flange	6.0" flange	6.0" flange	6.0" flange	6.0" flange
RO Inlet:	2.0" flange	3.0" flange	3.0" flange	4.0" flange	4.0" flange	6.0" flange
RO Permeate:	1.5" flange	3.0" flange	3.0" flange	3.0" flange	4.0" flange	4.0" flange
RO Concentrate:	1.0" flange	1.5" flange	1.5" flange	2.0" flange	2.0" flange	3.0" flange
Inlet Water Pressure:	5 psig, minimum	5 psig, minimum	5 psig, minimum	5 psig, minimum	5 psig, minimum	5 psig, minimum
Air Pressure:	100 psig	100 psig	100 psig	100 psig	100 psig,	100 psig
Drain to be Sized for:	67 gpm (15.2 m^3/hr)	133 gpm (30.2 m^3/hr)	200 gpm (45.4 m^3/hr)	267 gpm (60.6 m^3/hr)	400 gpm (90.9 m^3/hr)	600 gpm (136.3 m^3/hr)
Power:	460 VAC, 3-phase, 60Hz	460 VAC, 3-phase, 60Hz	460 VAC, 3-phase, 60Hz	460 VAC, 3-phase, 60Hz	460 VAC, 3-phase, 60Hz	460 VAC, 3-phase, 60Hz
Control Circuit:	120 VAC, 1-phase, 60Hz	120 VAC, 1-phase, 60Hz	120 VAC, 1-phase, 60Hz	120 VAC, 1-phase, 60Hz	120 VAC, 1-phase, 60Hz	120 VAC, 1-phase, 60Hz
UF Skid (per train)						
Height:	71" (180 cm)	71" (180 cm)	71" (180 cm)	71" (180 cm)	71" (180 cm)	71" (180 cm)
Width:	59" (150 cm)	59" (150 cm)	59" (150 cm)	59" (150 cm)	59" (150 cm)	59" (150 cm)
Depth:	121" (307 cm)	155" (394 cm)	190" (483 cm)	155" (394 cm)	190" (483 cm)	190" (483 cm)
Operating Weight Estimate:	9,000 lb (4082 kg)	13,000 lb (5897 kg)	16,500 lb (7484 kg)	13,000 lb (5895 kg)	16,500 lb (7484 kg)	16,500 lb (7484 kg)
RO Skid						
Height:	76" (193 cm)	76" (193 cm)	76" (193 cm)	76" (193 cm)	76" (193 cm)	99" (251 cm)
Width:	46" (117 cm)	46" (117 cm)	46" (117 cm)	80" (203 cm)	80" (203 cm)	80" (203 cm)
Depth:	194" (493 cm)	194" (493 cm)	274" (696 cm)	194" (493 cm)	274" (696 cm)	274" (696 cm)
Operating Weight Estimate:	4400 lb (1996 kg)	5850 lb (kg)	7800 lb (3538 kg)	9200 lb (4173 kg)	12500 lb (5670 kg)	18,000 lb (8165 kg)

SIEMENS

February 4, 2008

Mr. Chris Beck
Golder Associates Inc. - Denver Office
Phone No. 303-980-0540
e-mail: chris_beck@golder.com

Reference: Diamond Mine Project

Subject: Budgetary Proposal to Supply a Wastewater Treatment System

Siemens Water Technologies Proposal No. PK-0802-01-SYS-1

Dear Mr. Beck:

In response to your request, Siemens Water Technologies Corp. (Siemens) is pleased to provide the following preliminary information and budget pricing for the wastewater treatment system for the above-referenced project.

PROCESS OVERVIEW

♦ **Basis of Design**

- Influent analyses are as listed in your document "Design Basis Influent."
- All ions are assumed to be reported as the substance, except for total hardness and alkalinity.
- To balance the analysis provided, either the sodium or chloride values have been increased from the reported values.
- Objective of the treatment system is to achieve treated water quality TDS of $\leq$ 375 ppm.

♦ **Treatment Scheme Proposed**

- **Primary Treatment - For Feed Water Treatment**
  - The feed water is treated in the primary solids contact clarifier (SCC) for the purpose of reducing TSS and precipitating hardness and other heavy metals, to make it suitable as feed to the reverse osmosis (RO) units. Chemicals used are:
    - ∗ Sodium Hypochlorite - For disinfection
    - ∗ Coagulant - To coagulate the larger floc particles
    - ∗ Lime and Soda Ash - To precipitate hardness and other heavy metals
    - ∗ Polymer - To agglomerate the finer floc particles and enhance the coagulation process
    - ∗ Acid - To pH adjust after lime and soda ash softening to avoid post precipitation

- The SCC effluent goes through a filtration step for reduction and removal of any iron, manganese and suspended solids.

  The filter effluent is treated with sodium bisulfite, antiscalent and acid for destroying residual chlorine, prevent scaling in the reverse osmosis membranes and pH adjustment, respectively.

- The filter effluent is treated in primary RO units using brackish water membranes for reduction of TDS. RO permeate is discharged back to the lake and the primary RO reject undergoes further treatment, as described below under "Secondary Treatment."

- The primary SCC blowdown undergoes further treatment, as described below under "Waste Treatment."

- **Secondary Treatment - For Treatment of Primary Reject**

  - The scheme employed is similar to that employed for the primary treatment, except for the following:

    - The filters employ multimedia in lieu of iron and manganese media.
    - The RO units use sea water membranes in lieu of brackish water membranes.

  - The RO permeate is discharged back into the lake and the RO reject and secondary SCC blowdown is sent to the evaporation pond.

- **Waste Treatment - For Treatment of the Primary SCC Blowdown**

  - The primary SCC blowdown is concentrated by gravity separation and stored. When a sufficient volume has accumulated, the solids are pumped to the filter press. Filter cake from the press is discharged while the press filtrate is returned to the secondary SCC for reprocessing.

PRIMARY TREATMENT - EQUIPMENT LIST
Note: Equipment quantities listed are for the maximum flow rate of 5,500 gpm.

- Three (3) Clarifiers - Solids contact type, 50% capacity each, 40 ft diameter, coated concrete construction. Concrete tank by Purchaser.
- Clarified Water Storage Tank - By Purchaser
- Four (4) Filter Feed/Filter Backwash Pumps - CD4MCu construction
- Five (5) Horizontal Filters - 10 ft diameter x 42 ft long
- Seven (7) High Pressure Reverse Osmosis Pumps - Shipped loose
- Seven (7) Reverse Osmosis Units - 24 x 12 array, shop fabricated
- Treated Wastewater Effluent Tank - By Purchaser, if required
- Treated Waste Forwarding Pumps - By Purchaser, if required
- One (1) Lime Silo - 8,000 cu ft capacity. Requires field erection.
- One (1) Lime Slurry Feed System - Including slurry tank and 2 x 100% slurry feed pumps. Shop fabricated.
- One (1) Soda Ash Silo - 8,000 cu ft capacity. Requires field erection.
- One (1) Soda Ash Feed System - Including solution tank and 2 x 100% solution feed pumps. Shop fabricated.
- One (1) Sodium Hypochlorite Storage Tank - FRP construction. Shop fabricated.
- One (1) Sodium Hypochlorite Feed System - Including 2 x 100% metering pumps. Shop fabricated.
- One (1) Ferric Chloride Storage Tank - FRP construction. Shop fabricated.
- One (1) Ferric Chloride Feed System - Including 2 x 100% metering pumps. Shop fabricated.
- One (1) Polymer Feed System - Including 3 x 100% Polyblends. Shop fabricated. Chemical is supplied in totes by others.
- One (1) Hydrochloric Acid Feed Tank - FRP construction, with fume scrubber. Shop fabricated.
- One (1) Hydrochloric Acid Feed System - Including 3 x 100% metering pumps, shop fabricated.

SECONDARY TREATMENT - EQUIPMENT LIST

Note: Equipment quantities listed are for the maximum flow rate of 5,500 gpm.

- Three (3) Clarifiers - Solids contact type, 50% capacity each, 18 ft diameter, coated carbon steel construction. Requires field erection and coating.
- Clarified Water Storage Tank - By Purchaser
- Three (3) Filter Feed/Filter Backwash Pumps - CD4MCu construction
- Four (4) Vertical Filters - 12 ft diameter x 5 ft SSH
- Three (3) High Pressure Reverse Osmosis Pumps - Shipped loose
- Three (3) Reverse Osmosis Units - Single array with 20 housings each, shop fabricated.
- One (1) Sodium Hypochlorite Feed System - Including 2 x 100% metering pumps. Shop fabricated.
- One (1) Ferric Chloride Feed System - Including 2 x 100% metering pumps. Shop fabricated.
- One (1) Polymer Feed System - Including 3 x 100% Polyblends. Shop fabricated. Chemical is supplied in totes by others.
- One (1) Hydrochloric Acid Feed System - Including 3 x 100% metering pumps, shop fabricated.

WASTE TREATMENT - EQUIPMENT LIST

Note: Equipment quantities listed are for the maximum flow rate of 5,500 gpm.

- Two (2) Sludge Storage Tanks - 35 ft diameter x 32 ft high, coated carbon steel construction. Requires field erection and coating. Agitator included.
- Five (5) Belt Filter Press Feed Pumps - Centrifugal type, rubber-lined, ductile iron construction. Skid-mounted. Shop fabricated.
- Five (5) Belt Filter Presses - 2 m each, semi-automatic. Shop fabricated.
- One (1) Filtrate Sump - By Purchaser
- Two (2) Filtrate Sump Pumps - Vertical sump pumps, high chrome construction. Field installation.
- One (1) Polymer Feed System - Including 5 x 100% Polyblends. Shop fabricated. Chemical is supplied in totes by others.

COMMON EQUIPMENT

- One (1) set of interconnecting piping
- One (1) PLC-based control system

PROJECT SCHEDULE

Delivery of equipment is typically 11 to 12 months from date of order. Installation and start-up will require an additional 8 to 10 months.

BUDGETARY PRICE

Siemens would supply the wastewater treatment system as described herein for approximately TWENTY-EIGHT MILLION FIVE HUNDRED THOUSAND DOLLARS . . . . $28,500,000.

Any applicable taxes or duties are not included.
Freight to the jobsite is included.

We trust this information meets your requirements. Please contact us if you have any questions.

Sincerely,

Jeffrey L. Gutierrez
Capital Sales Engineer
480-706-1022

cc:

Siemens Water Technologies
Chris Edmonds
Prakash Khanolkar