TECHNICAL MEMORANDUM

Golder Associates Ltd.
32 Steacie Drive | Telephone: 613-592-9600
Kanata, Ontario K2K 2A9 | Fax Access: 613-592-9601

TO:	Louise Grondin Agnico-Eagle Mines Ltd.	**DATE:**	August 28, 2007
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FROM:	Nural Kuyucak, Ph.D., P.Eng.	**DOC NO:**	467
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RE: **PROPOSED WATER TREATMENT METHODS MEADOWBANK GOLD PROJECT**

A list of commitments that were made by Meadowbank Mining Corporation (MMC), formerly Cumberland Resources Ltd. (Cumberland), to the Nunavut Impact Review Board (NIRB) at the close of environmental impact review process was included as part of the NIRB submission to the Minister for approval of the Meadowbank Gold Project. The NIRB compiled these commitments into conditions to be met as part of the Type-A Water License Application for the Meadowbank Project.

The following Technical Memorandum is provided to address Condition #9, which states:

> *"Cumberland shall provide detailed plans for water treatment for the tailings (reclaim pond) discharge, and on a contingency basis for the attenuation pond discharge(s) and for the pits, including estimates of treatment efficiency for each parameter of concern and the description of pH adjustments in the water license application to the NWB."*

Studies prepared as supporting documents for the Type-A Water License Application present mine water management and predicted water quality over the life of mine (MMC 2007a and Golder 2007a). The quality of the Attenuation Pond water to be discharged from the Portage and Vault areas into the receiving environment in the first years of operation is expected to meet Federal Government Metal Mining Effluent Regulation (MMER 2002, 2006) chemical criteria, based on *Possible Poor-End* water quality predictions (Golder 2005 and 2007a). The Tailings Storage Facility (TSF) and Reclaim Pond will be operated as a closed-circuit system during the operating period. Reclaim water will only be discharged at the end of mine life. Reclaim water will be discharged to the Third Portage Pit Lake or Goose Island Pit Lake, both of which will be isolated from adjacent lakes at that time by the water retention dikes. Reclaim water treatment requirements will be evaluated prior to transfer to the pit lakes, and will be based on achieving drinking water quality within the pit lakes after incorporation of Reclaim water.

The purpose of this Technical Memorandum is to present proposed contingency water treatment plans for Attenuation Pond and Reclaim Pond water, and estimates of potential equipment and reagent requirements and waste product volumes. The reagent requirements are evaluated based on an earlier iteration of water quality predictions (Golder, 2005) which predicted slightly higher constituent concentrations that the current predictions (Golder, 2007a) and as such, they should be considered as higher end estimates. As indicated in the Final Environmental Impact Statement (FEIS) for the Project (Cumberland, 2005a), the final treatment design and reagent requirements would be developed during the operating period based on the actual water qualities to be measured as part of the Meadowbank Gold Project Water Quality and Flow Monitoring Plan (MMC 2007b).

1.0 SITE WATER QUALITY MANAGEMENT REQUIREMENTS

The water management options and application stages planned for the site as presented in MMC (2007a) are briefly summarized below. Since open-water conditions at the site are limited to between approximately middle of June to middle of September, water treatment and discharge of the treated water, if required, would be conducted on a seasonal basis, once a year, and would be completed within the four-month ice-free season. It is considered that four different methods could be applicable to manage the water quality at the site, should it be required, during four different stages of mining activities, as follows:

1.1 Portage Area

Operating Year 1 to Year 5: The Portage Attenuation Pond will collect, hold and then discharge runoff and seepage water from the following infrastructure:

- The Portage Rock Storage Facility (RSF);
- Third Portage, North Portage and Goose Island open pit sumps (including dike and groundwater seepage, if any); and,
- Mine contact water from the plant site and airstrip.

The discharge of mine contact water accumulated in the Portage Attenuation Pond (approximately 500,000 m^3 average annual volume, with a possible peak at 1,500,000 m3 in Year 5) is predicted to be required during ice-free months to maintain pond storage capacity (MMC 2007a). The quality of Portage Attenuation Pond water is expected not to require treatment before discharge in order to meet the proposed receiving water quality targets (Golder, 2007b). Nonetheless, the quality of the water in the Portage Attenuation Pond would be monitored and, if required to comply with MMER discharge criteria, contingency treatment would be applied prior to discharge Third Portage Lake.

In addition, during this period, tailings from the Process Plant will be pumped to the TSF as a slurry, with any excess process water reporting to the Reclaim Pond. The process water collected in the Reclaim Pond will be recycled back to the Process Plant for re-use in the process. It is anticipated that no process water will be discharged to the receiving environment during this operating period (MMC, 2007a). Figure 1 presents the water management plan for the early phase of mine operations (approximately Year 1 to Year 5) (MMC, 2007a).

The proposed contingency treatment for Portage Attenuation Pond water aims to adjust pH and remove metal ions to MMER objectives using a lime neutralization/precipitation process. This process is presently accepted as the “Best Available Technology Economically Achievable

(BATEA)" for the mining and metallurgical industry (www.nrcan.gc.ca). Water in the Portage Attenuation Pond would be treated with lime, as required, and used to meet process water demand or released to Third Portage Lake. If necessary, water within the Portage Attenuation Pond would be stored and treated in-situ to increase residency time and promote the settlement of solids. The potential need for treating ammonia (NH_4-N) in ponded environments was discussed in an AMEC, 2005.

Should water quality not immediately meet discharge criteria, it may alternatively be redirected to the Reclaim Pond. It is anticipated that there would be excess capacity within the TSF during this period of time to accommodate storage of attenuation pond water that may not satisfy discharge criteria (MMC 2007a).

At the end of Year 4, when mining of the Goose Island Pit is complete, excess mine contact water could also be redirected to the Goose Island Pit to assist with pit flooding.

Operating Year 6 to Year 8: The deposition of tailings will occur within the basin of the former Portage Attenuation Pond in this period, and mine contact water will be directed to the mined-out Portage and/or Goose Island pits for flooding. Flooding is expected to take 5 to 8 years to complete (MMC 2007a). Figure 2 presents the water management plan for the late phase of mine operations (approximately Year 6 to Year 8) (MMC 2007a).

The quality of water within the Portage and Goose Island pit lakes will be monitored during flooding (MMC 2007b). The predicted pit lake water quality is such that treatment is not expected to be required (Golder 2005, 2007a); nonetheless, should it be required, a proposed contingency treatment scenario is described in Section 3.2. Water treatment requirements will be evaluated prior to transfer to the pit lakes, and will be based on achieving drinking water quality within the pit lakes after incorporation of Reclaim water.

Year 8 - Preparation for Site Closure: Following completion of mining, the Reclaim Pond will be drained to prepare for closure activities within the TSF, including final grading and capping of the tailings with acid-buffering ultramafic (UM) run-of-mine waste rock (MMC 2007a). Portage RSF drainage water will continue to be routed to the Reclaim Pond during this period.
Reclaim Pond water will be pumped to the Goose Island or Portage Pit Lakes following monitoring of water quality and appropriate treatment, if required. As tailings water is planned to be discharged to the still fully diked pit lakes, no active discharge to the receiving environment is expected to occur during this period. The Goose Island Dike will be breached after reclaim water has been released to the pit lakes and water quality has met Nunavut Drinking Water guidelines and MMER criteria (Cumberland, 2005).

Figure 3 presents the water management plan for the Closure Phase of operations (MMC 2007a).

Post Closure: It is anticipated that the post-closure phase would be initiated once all mine water discharges would be of acceptable quality for release to the receiving environment. As such, no post-closure or long-term active treatment of water is anticipated. One source of mine contact water which could generate drainage quality that may not meet criteria is drainage from the Portage RSF. Mine site drainage water quality would be monitored during operation and preparation for closure to evaluate requirements, if any, for water quality management prior to closure. Furthermore, the Goose Island Dike will not be breached until water quality in the Portage and Goose pit lakes meets MMER and Nunavut DW levels and is acceptable for mixing with Third Portage Lake (MMC 2007a). Figure 4 presents the water management plan for the Post Closure phase of operations (MMC 2007a).

1.2 Vault Area

Operating Year 4 to Year 8: Vault area mining operations will be initiated in Year 4 (MMC 2007a). The Vault Attenuation Pond will collect, hold and discharge runoff and seepage water from the following infrastructure:

- the Vault RSF;
- Vault Pit sumps (including groundwater inflows);
- Vault Dike seepage (if any); and,
- Mine contact water from the Vault area drainage basin.

All mine contact water from the Vault area will be conveyed to the Vault Attenuation Pond (Figure 2). The discharge of contact water accumulated in Vault Attenuation Pond (approximately 475,000 m^3 per year) will occur during ice-free months to maintain storage capacity within the pond for the spring freshet (assuming average annual runoff conditions) (MMC 2007a). The water quality predictions indicate water treatment will not be required during this period (Golder 2007a). Nonetheless, the water quality in the Vault Attenuation Pond will be monitored and treated if required prior to discharge (MMC 2007a, 2007b).

Year 8 - Preparation for Vault Closure: Following completion of mining, Vault Lake, including the Vault Pit, will be flooded using runoff from the Vault Lake catchment, supplemented by spring freshet runoff redirected from Wally Lake (Figure 3). Flooding is expected to require 5 to 7 years to complete. Water quality predictions indicate that pit lake water treatment will not be required during this time (Golder 2007a). Also, no active discharge to

Wally Lake is expected to occur during this period. Nonetheless, the water quality during flooding will be monitored and treated if necessary (MMC 2007a, 2007b).

Post Closure: Drainage contact water originating from the Vault RSF, if any, is expected to be the only water source that could conceivably require management, although water quality predictions indicate that treatment will not be required (Golder 2007a). The water collected in drainage ditches during ice-free months would be routed to the Vault Pit Lake (Figure 4). The Vault Dike will not be breached until water quality is acceptable for mixing with Wally Lake (MMC 2007a).

2.0 PREDICTED WATER QUANTITY AND QUALITY FOR EACH PERIOD

The quantity of water that may require management and potential mitigation over the life of the mine is detailed in the *Meadowbank Gold Project Mine Waste & Water Management* (MMC 2007a), while predicted water qualities are summarized in the *Water Quality Predictions, Meadowbank Gold Project, Nunavut* (Golder 2005 and 2007a).

Potential water treatment requirements for each period (early and later operations, closure and post-closure) are discussed below as well as the proposed treatment methods. For the Portage Area, the predicted water quality for each period of the mine life on which contingency treatment requirements are made is summarized in Table 1a (*Predicted Poor-End* Golder, 2005), with the more recent results presented in Table 1b (*Predicted Poor-End* Golder, 2007a) for comparison.

2.1 Portage Area

Operating Year 1 to Year 5: It is predicted that about 500,000 m^3 of Portage Attenuation Pond water will require discharge on an annual basis during this period, with a peak of up to 1,500,000m^3 (MMC 2007a). It is anticipated that pH would be the prime parameter that may need adjustment (e.g., increasing from 6-6.5 to pH 7-7.5), especially if acid rock drainage (ARD) production starts within the waste rock before freezing of the Portage RSF. Water quality predictions (Golder 2007aa) indicate that the pH in the water collected in the Portage Attenuation Pond could possibly be about 6 (based on the *Possible Poor-End* scenario), which is at the lower end of acceptable MMER criteria.

Ammonia from explosive residues in the RSFs and open pits ultimately reports to the Portage Attenuation Pond during Years 1 to 5. Ammonia from CN destruction process reports to the Reclaim Pond, which is not to be discharged until the end of mine life. The MMER do not regulate and/or provide guidelines for ammonia (NH_4-N) and nitrates (NO_3). However, since residual NH_4-N and NO_3 from the use of explosives and degradation of cyanide are of particular concern to NIRB, MMC plans to monitor the concentration of ammonia and nitrate (MMC 2007b). It is further understood that MMC plans to pay particular attention to the effectiveness of explosives management during operation so as to minimize as much as possible any residues.

Discharges in Years 1 to 5 from the Portage Attenuation Pond are proposed to meet MMER criteria (Golder 2007b). The predicted water quality standards and minimum discharge criteria that need to be met for this period are given in Tables 1a and 1b. Should the observed water quality be worse than the predicted *Possible Poor-End* scenario, application of a contingency in-situ water treatment system would be considered to reduce the concentrations of parameters such as: total suspended solids (TSS), arsenic (As), copper (Cu), lead (Pb), nickel (Ni) and zinc (Zn) prior to release to the receiving environment. TSS, although not specifically modeled, could occur due to secondary construction effects and soil erosion. In addition to pH and metal ions, TSS may also require removal/reduction. A monitoring scheme could be developed using on-line sensors (e.g., turbidity as a surrogate for TSS). A proposed contingency in-situ treatment method for the Portage Attenuation Pond is described in Section 3.1.

Operating Year 4 to Year 8: According to the results of the water quality predictions for the Portage and Goose Island Pit Lakes (Tables 1a and 1b), it is expected that water quality would be in compliance with the regulated standards (MMER) and would not require treatment during this period. Should the pit lake water quality be worse than the predicted *Possible Poor-End* concentrations, it may become desirable to attenuate some constituents as the pit lakes flood. Some potentially sensitive parameters could be As.

Year 8 - Preparation for Site Closure: The total volume of reclaim water that may require treatment prior to discharge to the Goose Island and Portage Pit Lakes at the end of mine life (in Year 8) is estimated to be about 1.6 Mm^3 (MMC, 2007a). As shown in Table 1a, As, Cu, Ni and Zn are predicted to possibly exceed the MMER criteria in Reclaim pond water during mine life. Should the use of explosives be such that more residual products remain in the waste rock than anticipated, the concentration of un-ionized ammonia could reach toxic levels and would be identified by the aquatic toxicity tests. In addition, the quality of water would benefit significantly by the dilution factor that exists in the Pit Lakes. The Portage Pit Lake is estimated to have a volume of approximately 22 Mm^3 (considering the waste rock disposed of in the pit), corresponding to an assimilative capacity of about 18 times for the tailings reclaim water.

Post Closure: It is anticipated that the post-closure phase would be initiated once all mine water discharges would be of acceptable quality for release to the receiving environment. As such, no post-closure or long-term active treatment of water is anticipated. One source of mine contact water which could generate drainage quality that may not meet criteria (Table 1a), is drainage from the Portage RSF. If any drainage is captured at the toe of the Portage RSF, it would collect within sumps or drainage ditches during the ice-free summer months. It is predicted that runoff and drainage from infiltrated water may release up to 80,000 m^3 of water to the Portage Pit Lake on an annual basis, which represents an insignificant volume of water considering the size of Portage and Goose Pit Lakes and Third Portage Lake. If any, arsenic might be of potential concern with respect to the MMER objectives and N-DW standards (Table 1a, 1b). Should predictions be off, other parameters could also be targeted for attenuation prior to release to the Portage Pit Lake, including pH and some metal ions (e.g., Cu, Ni, Pb and Zn). Mine site drainage water quality would be monitored during operation and closure to evaluate requirements, if any, for water quality management at closure.

2.2 Vault Area

Operating Year 4 to Year 8 - Vault Area: It is predicted that about 475,000 m^3 of Vault Attenuation Pond water will be discharged annually during this period (MMC, 2007a). *Possible Poor-End* water quality predictions indicate that the water will meet MMER-regulated parameters (Golder, 2007a). If any of the parameters of concern exceed the regulated MMER criteria, a contingency treatment process would need to be applied prior to discharge to the receiving environment (MMC, 2007a). A proposed contingency in-situ treatment method for the Vault Attenuation Pond is described in Section 3.1.

Year 8 - Preparation for Vault Closure: Water quality predictions suggest that all constituents will meet MMER levels (Golder, 2007a). Moreover, no active discharge to the receiving environment is planned to occur during this period (MMC, 2007a). If monitoring results indicate that attenuation of certain parameters is required prior to complete flooding of the lake, contingency treatment may be required. This scenario is considered highly unlikely as the Vault Pit Lake would consist mostly of water pumped from Wally Lake, and the proportion of pit lake water originating from overland runoff, including water from the Vault RSF, would be relatively minor over a 5-year flooding period. The final volume of Vault Pit Lake is estimated to be about 21.5 Mm^3, giving more than 250 times dilution to Vault RSF drainage water.

Post Closure: It is anticipated that the post-closure phase would be initiated once all mine water discharges would be of acceptable quality for release to the receiving environment. As such, no post-closure or long-term active treatment of water is anticipated at the Vault area. Similar to the Portage area, runoff and seepage from the Vault RSF represents an insignificant volume of water to the Vault Pit Lake; up to approximately 65,000 m^3 on an average annual basis (over the summer months). Water quality predictions indicate all parameters would be below receiving water quality guidelines such that the water quality is not expected to require treatment over the long-term (Golder, 2007a).

The water quality from the Vault catchment area is predicted to be acceptable for discharge without treatment during all mining stages (Golder, 2007a). Nevertheless, should metal attenuation be required, the use of a contingency in-situ treatment system should be adequate. A proposed contingency in-situ treatment method applicable to both the Vault and Portage attenuation ponds is described in Section 3.1.

3.0 PROPOSED TREATMENT METHODS FOR EACH PERIOD OF MINING

According to the results obtained from water quality modelling (Golder, 2007) there should be no need for water treatment during the operating period. At the end of the mine life, treatment of reclaim water may be required prior to its release to the Portage Pit Lake because of concentrations of some constituents being above MMER criteria. The discharge of Reclaim water is anticipated to be to either the Portage or Goose Island Pit Lake which will be fully diked at that time. Treatment requirements will be evaluated during operation, and will be based on achieving MMER and Nunavut DW quality objectives in the Pit Lakes after inflow of Reclaim water. The treatment studies presented herein are provided as contingency treatment options should there be water quality criteria exceedances and treatment requirements during the life of mine.

3.1 Contingency In-situ Treatment Method for Attenuation Pond Water

Assumptions: For design of a contingency treatment system, it is assumed that about 500,000 m^3 of water having about pH 6 (i.e., calculated total acidity of 0.05 mg/L as $CaCO_3$) could be treated and discharged within a maximum of a three-month period annually (e.g., mid June to mid September, 90 days). As discussed further below, lime as $Ca(OH)_2$ would be used to increase the pH to about 7 to 7.5. Ferric iron salt and flocculant polymer for removal/reduction of arsenic (As) and/or TSS would also be added if required. It should be noted that a factor of safety (FS) ranging from 2-4 times and 75% lime usage efficiency were assumed in the treatment reagent requirements volumes provided. A volume of 1,500,000 m^3 of water could be treated in the same way, using the same reagents although at a higher consumption rate and higher treatment rate, over a 100-day period.

Treatment Method Design Criteria: Increasing pH from approximately 6 to 7.5 with an alkaline reagent (i.e., lime as $Ca(OH)_2$) and completing the discharge of the treated water within 60 to 100 days.

Proposed Treatment Process for pH Adjustment: In-situ treatment of water in the Attenuation Pond(s) by adding lime in a slurry form is proposed. Based on the predicted water quality of the Attenuation Pond water (Table 1a), it is predicted that about 100kg of lime (as $Ca(OH)_2$ with about FS 4) or about 1 m^3 (10% w/w) to 2 m^3 (5% w/w) of lime slurry would be required to increase the pH from 6 to 7 in a slurry form. For a similar water chemistry, increasing the volume of water to be treated would proportionately increase reagent consumption. Treatment of 1.5 Mm^3 of water (from 500,000 m^3) would require three times the amount of reagents: 300kg of lime or $3m^3$ (using 10% w/w) to $6m^3$ (5% w/w) of lime slurry. Since removal/reduction of metal

ions is not expected, the addition of these amounts of lime to adjust the pH is not expected to produce a significant quantity of sludge requiring handling.
During the operating years the site is expected to have lime storage and slurry preparation units as part of the processing plant. Since the quantity of lime needed would be reasonably small, lime in about 5 to 10% w/w slurry form could be obtained from the ore processing plant. Lime would then be introduced into the Attenuation Pond from one corner, or diagonally from two corners. During lime addition, the water within the pond would be mixed with the help submersible pumps (e.g., six to ten pumps depending on their pumping capacity, possibly more pumps to mix 1.5 Mm^3 of water) installed on floating bases (i.e., a barge). The pumps would gently re-circulate the water and facilitate mixing of the water without disturbing the deposited tailings. Figure 5 schematically illustrates the proposed contingency in-situ treatment method. The mixing process would continue until stable pH and homogeneous treatment conditions are reached in the treated water (e.g., about 3 to 5 days depending on their pumping capacity).

If removal/reduction of TSS is also required, the addition of a polymer (flocculant) following the addition of lime into the pond may be done to enhance separation and settling of TSS. The polymer should be in either non-ionic or weak anionic form (e.g., Magnafloc 338 or Magnafloc 10 from Ciba Speciality Products or equivalent). A dosage of about 0.5 to 1 mg/L (e.g., about 250-500 kg) would be sufficient to treat 500,000 m^3 of water, and may be proportionately increased to treat three times the volume of water (1.5 Mm^3). The polymer should be prepared as a dilute solution (e.g., 0.05% - 0.1%) before being added to the pond. Mixing of polymer can be managed in the same way as the addition of lime using pumps to circulate and mix the contents of the pond.

The discharge of the treated water could also be achieved with the help of one or two submersible pumps placed on a floating barge. The use of floating barge for pumping would allow pumping of water from shallower depths with a minimal sediment disturbance at the bottom of the pond. A pumping and discharge rate of approximately 350 m^3/hr of water for 24 h/day would empty 500,000m3 of water from the pond within 60 days. A discharge rate of approximately 700 m^3/hr would be required for release of 1.5 Mm^3 of water in about 100 days.

If removal/reduction of As is required, a ferric salt (such as ferric sulphate or ferric chloride) would be added to the water first, followed by pH adjustment to neutral conditions or slightly alkaline conditions (e.g., pH 7 - 9). The treatment steps described above for adjusting the pH and for removal/reduction of TSS and solids (precipitates) formed as a result of iron addition would then be applied. Ferric iron addition is expected to result in increased lime consumption. The addition of ferric iron salts would provide additional benefits by reducing the concentration of other ions such as Mo and Se.

Since the proposed treatment processes are based on the predicted water quality values and site conditions, actual treatment requirements (e.g., chemical reagent types and consumption, dosages, retention time, etc.) would need to be determined by conducting treatability tests during the operating periods prior to discharge. For example, if a requirement for removal of 1 mg/L As is assumed, about 2:1 Fe^{3+}:As molar ratio would be required (Mend Report, 1994). If a FS 2 is considered, addition of about 3:1 Fe^{3+}:As would be required by weight. This would require the addition of about 6 gram of lime and about 149 gram of $Fe_2(SO_4)_3$ with about 60% iron sulphate content (or about 12% Fe^{3+} content) per m^3 of water. Treatment of 500,000 m^3 of water would require about 3 tonnes of dry lime or about 30 m^3 of 10% (w/w) lime slurry and about 75 tonnes of $Fe_2(SO_4)_3$ at 60% solution (containing about 12% Fe^{3+}). If the formation of ferric arsenate ($FeAsO_4.xFe(OH)_3$ or $FeAsO_4.2Fe(OH)_3$) precipitates are assumed, a production of about 12.4 gram dry sludge (or about 210-350 mL of sludge with about 5% solids content) per m^3 water treated is expected, resulting in about 105-175 m^3 sludge for disposal and storage for the treatment of 500,000m^3 of water. Sludge production would increase to about 315-525 m^3 from treatment of 1.5 Mm^3 of water.

Concentrations of ammonia and nitrate in the water are predicted to be less than 4 and 6 mg/L, respectively (Table 1; Golder, 2007a). Unionized ammonia (NH_3) imparts toxicity to the waters rather than ammonia (NH_4^+) itself. Partitioning ammonia to give off un-ionized ammonia is a function of temperature and pH. At low temperatures and acidic to neutral pH conditions, the concentration of un-ionized ammonia would be lower than the concentrations that could be found at higher temperatures and pH level conditions (e.g., 10^0C and pH 7). For an assumed average water temperature of about 10^0C and pH of about 7, it is expected that un-ionized ammonia fractions would be about 0.0018 in the Attenuation Pond water, resulting in occurrence of less than 0.007 mg/L unionized ammonia. This level would be lower than the reported toxic levels for aquatic life (Acute unionized ammonia (NH_3) toxicity levels for fish is about 0.6 mg/L as chronic levels are about 0.06 mg/L) (SRAC, 1997). Therefore, attenuation pond water is not anticipated to require treatment for ammonia.

If the treatment of un-ionized ammonia is required, treatment options could include volatilization above a pH of 9; biological methods through phytoplankton growth and bacterial nitrification where NH_4–N is converted to NO_3; and ion exchange. Although the selection of method of choice would need further studies to consider the actual water temperature and short treatment season, the use of biological methods or selective ion exchange columns/resins is considered feasible. A detailed evaluation of un-ionized treatment requirements should be completed during the operating period, as the actual concentration of un-ionized ammonia would largely depend on the concentration of ammonia, dynamics of water circulation within the attenuation ponds, and the temperature and pH of the Attenuation Pond water at the time of treatment. The evaluation of other potential treatment options for nitrogen species is based on total ammonia concentrations is also given in Appendix IX of Golder (2005). A summary of the proposed treatment requirements including the estimated quantity and dosage of chemicals and equipment for each period is given in Table 2. The approximate quantity of sludge expected to be produced from the proposed treatment methods is also provided in Table 2.

3.2 Contingency In-situ Treatment Method Proposed During Flooding of Goose Pit Lake

Assumptions: The quality of the mine contact water diverted to Goose Island Pit for flooding is predicted to be suitable (Table 1a) and therefore, treatment is not anticipated during this period. However, if the actual water quality values differ from predicted and water requires pH control or metals, As, ammonia and/or TSS attenuation, the proposed treatment method described above for In-Pond Treatment (Section 3.1) could be applied.

Treatment Method Design Criteria: Adjusting the pH to about neutral levels with an alkaline reagent (i.e., lime as $Ca(OH)_2$). If removal/reduction of TSS and As is required, addition of ferric iron salt and flocculant polymer would be appropriate.

Proposed Treatment Process: Similar to Section 3.1, water could be treated in-situ within the Goose Pit Lake by adding lime in a slurry form. Lime would be supplied from the processing plant in a slurry form (e.g., 5-10% w/w). The pit lake would be mixed with the help of submersible pumps (e.g., six to 10 pumps could be sufficient depending on their capacity). The pumps would re-circulate the water and facilitate mixing. The mixing process would continue until homogenous pH and treatment conditions are reached (e.g., a few days).

3.3 Treatment Method Proposed for Tailings Reclaim Water

Assumptions: About 1.6 Mm^3 of water would need to be removed from the Reclaim Pond and treated prior to release to the Portage Pit Lake or Goose Island Pit Lake at the end of mine life. Should predictions be off, the tailings reclaim water could potentially need adjustment for pH and treatment for removal/reduction of metals such as possibly As, Cu, Ni and Zn (Table 1a). For a conservative approach, removal of 10 mg/L As is assumed in calculations.

Treatment Method Design Criteria: If removal/reduction of metals are not of a concern and only an adjustment in pH is desired, the contingency treatment method described above for the attenuation ponds (Section 3.1) could be applied using an alkaline reagent (i.e., lime as $Ca(OH)_2$) and discharge of the treated water could be completed within a three-month period (June, July and August; about 90 days) with the help of appropriately sized pumps.

Proposed Treatment Process: Treatment could be achieved with the help of either an in-situ (Option 1) or active treatment (Option 2) processes depending on the site conditions.

Option 1 proposes in-situ treatment of the water within the Reclaim Pond using a similar method for As removal, if required, as described above for the Attenuation Pond. First, ferric iron salt in a liquid form could be added to remove/reduce As, and then lime and a polymer would be added. The use of submersible pumps (e.g., eight to twelve) would facilitate mixing of the impounded portion of the Reclaim Pond. Following the settling of solids (e.g., clarification of the treated water which may take a few days), the treated water would be discharged.

If the removal/reduction of Ni is required, the pH would have to be increased to about 11 in order to obtain low Ni solubility levels (low dissolved concentrations). Then, the pH would need to be reduced to meet regulated levels (e.g., <pH 9) by using either carbon dioxide (CO_2) or sulphuric acid. The use of CO_2 (in gas or liquid form) may be more desirable since it could result in formation of a carbonate buffering in the water. CO_2 (i.e., acid) addition could be done using in-line mixing systems or in a tank. A tank would be placed in the processing plant which would require conveying of the treated water to the plant.

Decreasing the pH back to about pH 8.5, after in-situ water treatment within the Reclaim Pond (Option 1), would also require a tank. About 3-minute retention time would be suitable for this purpose. Given the predicted water volume, a suitable tank size would be about 10 m diameter x 3 m depth. Such a tank size would already be available in the processing plant. In order to be able to complete the treatment process within the summer period (90 days), the water should be pumped to the tank on a continuous basis, at a rate of approximately 560 m^3/h. Figure 6 schematically illustrates the proposed in-pond treatment alternative (Option 1) method.

If the removal of Ni is required and the pH is increased to about pH 11, the precipitation of solids formed in the process can be facilitated in a conventional clarifier/thickener or in a settling pond. Otherwise, due to low content of solids, recycling of sludge back to the process (e.g., High Density Sludge “HDS”) to increase the solids quantity and subsequently enhance settling could be considered. Treatment trials should be conducted to assess actual sludge characteristics (e.g., % solids contents, volume, metals leaching tests (such as Toxicity, Control, Leaching, Protocol (TCLP), to characterize chemical stability, etc.) and determine disposal requirements.

If removal of As is required a treatment similar to the method described above where the ferric iron addition is followed by lime addition could be applied. The required quantities can be estimated by repeating the calculations similar to above calculations. For instance, treatment of about 1,600,000 m^3 water containing about 10 mg/L As would require about 96 tonnes of lime and about 2400 tonnes ferric sulphate (as supplied liquid form containing about 60% $Fe_2(SO_4)_3$

with about 12% Fe^{3+}). It is predicted that about 198.4 tonnes dry (or 3360 m^3 to 5600 m^3 respectively with about 5% to 3% solids content) ferric arsenate sludge will be produced.

Possible 18 times dilution within the Portage Pit Lake would also be taken into account. For instance, lime neutralization process can remove/reduce SO_4^{2-} to about 2000 mg/L which is the theoretical solubility limit of gypsum. After about 18 times dilution within the Portage Pit Lake is expected to result in about 111 mg/L SO_4^{2-} in the lake water. Other parameters could also be assessed similarly.

Option 2: If the in-situ treatment of tailings reclaim water cannot be facilitated, an active treatment method (Option 2) would be considered. An "Active Treatment" facility could be assembled in the mill and processing plant using the equipment left over from processing of the ore after the end of mining.

The treatment facility could consist of mixed tanks for addition of chemicals and a clarifier/thickener for separation of precipitates formed in the treatment process. Readjustment of pH would also take place in this system. A review of the list of proposed equipment for the mill and processing plant indicates that some tanks (e.g., with ~2 m to 3 m diameter) and thickeners (with 10m diameter and 20m diameter) would be suitable for the proposed treatment facility. The proposed active treatment facility, including the process units, is presented in Figure 7.

Retrofitting of the largest tank in the processing plant (i.e., a thickener tank of about 20m diameter) to a clarifier/thickener could achieve a treatment flow rate of about 560 m^3/h over a 90-day treatment period. The solution pH could control the overall treatment process with the help of a programmable logical control (PLC) system. Sludge separated in the clarifier/thickener could be disposed of in the TSF, which could then be covered and allowed to freeze with the rest of the tailings. Sludge to be produced from the treatment processes would have about 3-5% solids content (S) unless an HDS process used. An HDS process could produce sludge with about 20-30% S. Until the closure of the Reclaim Pond, the sludge could be co-disposed with tailings in the TSF, which could then be covered with a cap of waste rock and allowed to freeze. In post-closure, any sludge produced could be disposed of areas of the TSF left uncapped for this purpose, or within areas excavated in the capped material. The disposal area(s) would be recapped once sludge disposal is complete.

3.3.1 Cyanide and Derivatives

Since tailings slurry as produced before reporting to the tailings storage pond would be subjected to the SO_2/Air (strong oxidation) cyanide treatment process, cyanide (CN) and derivatives such as cyanate (CNO), thiocyanide (SCN), ammonia (and un-ionized ammonia) and nitrates are expected to be present in Reclaim Pond water. Total CN levels are predicted to exceed MMER (Table 1b).

Degradation of CN to CNO and SCN species can be relatively fast and these compounds are known to be at least three orders of magnitude less toxic in comparison to cyanide itself (www.metsoc.org). Since the addition of peroxide compounds (e.g., hydrogen peroxide or calcium peroxide) to the outflow of the cyanide destruction process can further decrease residual cyanide concentrations, if additional polishing of the treated water is required during the operating period, further peroxide addition could be practiced.

Treatment efficiencies for cyanide and derivatives could be realized with higher concentrations of oxygen in the water in colder temperatures since the solubility of oxygen in water is higher at lower temperature. For instance, the solubility of oxygen at standard atmospheric pressure is about 10 mg/L at 15°C but is about 7.5 mg/L at 30^{o}C (www.metts.com.au). However, bacterial activities are reduced at colder temperatures, especially below 10^{0}C. In-situ treatment of CN and derivatives by adding nutrients to enhance bacterial activities to achieve acceptable rates of removal for thiocyanate and cyanate and to support phytoplankton growth to enhance ammonia removal (as explored at the Colomac site (www.nwt-tno.inac.gc.ca) could be considered once the actual quality of tailings reclaim water is assessed (AMEC, 2005). The potential consequences of the addition of phosphate, and possibly nitrogen compounds, on the receiving environment would need to be evaluated before this option is implemented.

The fate of cyanide derivatives in Reclaim Pond water was also addressed earlier in the Technical Memorandum entitled: *Meadowbank - Treatability of Ammonia in Attenuation Pond, Reclaim Pond and Pit Lake* (AMEC, 2005) which was included in Appendix IX of the of the Water Quality Predictions Report submitted as part of the Project EIA documents (Golder, 2005). AMEC (2005) examined the expected fate and behaviour of ammonia, thiocyanate, cyanate, nitrate and cyanide in the above facilities. The conclusion drawn from this examination was that given the expected residence times of water in the Vault Attenuation Pond and in the Portage Attenuation and Reclaim Ponds, ammonia, thiocyanate and cyanate (the latter cyanide and derivatives could only occur in the Portage Reclaim pond) should remain at levels acceptable for release to the environment, when these ponds reach full height after closure. One major difference with the Colomac site is the relatively elevated levels of metals that could be present in tailings reclaim water relative to the Colomac site and to the Meadowbank Attenuation Ponds and Pit Lakes. Based on experience with bio-treatment of mining effluents, the predicted reclaim pond chemistry is not expected to be an issue with metal-related micro organism toxicity. Alkalinity could be added in the pond to raise pH and precipitate dissolved metals from solution prior to implementing bio-treatment. The memo in Attachment 2 also provided details on potential chemical requirements and application methods for in-situ biological treatment as practiced at the Colomac site.

Assessment of the Impact of Residual Nutrients in Case of Application of Bio-Treatment

As indicated in AMEC (2005), the quantity of phosphorous that could be required to enhance bio-remediation is not possible to predict with accuracy at this stage as it would also depend on site characteristics that are not possible to duplicate in laboratory such as sun exposure, temperature, currents, etc. Laboratory and pilot studies could be initiated at the start of mine operation to determine the kinetics of ammonia degradation and the required amount of nutrients to assist in enhanced bio-degradation. Based on experiences elsewhere, the actual required concentrations are expected to be low. It is important to note that the phosphorous added would be largely consumed by the phytoplankton during the summer months and ultimately precipitate out and be immobilized in the sediments at the end of each growing season when the phytoplankton dies and settles out. The addition of phosphorous for bio-remediation should not result in elevated levels in the final effluent discharged at closure as long as the correct dosages are utilized. The impact of residual nutrients and other end-of-pipe parameters should be carefully monitored as part of the Environmental Effects Monitoring program that would be conducted as part of the MMER regulations, the results of which could be used to adapt up-stream control measures.

3.4 Treatment Method Proposed for the Post Closure Period

Assumptions: In the Portage area, up to about 80,000 m^3 of contact water from the Portage RSF may be released annually. Should water quality predictions be off, this water could potentially require treatment for removal of As (e.g., 1 mg/L) and adjustment of pH.

Portage RSF drainage chemistry would have been monitored for a number of years prior to the post-closure period in view of assessing post-closure water management requirements The quality of water will be monitored before removing the dykes and releasing the water to the pit lakes, to avoid potential fowling up in the pit lakes. Possible dilution factors would also be taken into account in calculating the treatment requirements. It is expected that no treatment would be required.

Treatment Method Design Criteria: The Portage RSF drainage water could be treated post-closure should it be required. Treatment and discharge of the treated water could be completed within a four-month period (i.e., mid June to mid September; approximately 120 days) using appropriate pump sizes.

Proposed Treatment Process: If a significant volume of Portage RSF drainage water still requires treatment during post-closure, active treatment could be extended to this period using the existing water treatment plant. RSF drainage water would have been monitored for a long period prior to post-closure. This would be a short-term solution until treatment requirements (e.g., for a passive treatment system) could be identified for the long-term post closure.

The chemistry of the Portage RSF drainage water is expected to be simpler and more dilute than that of tailings reclaim water to be treated during the closure period. As such, only minor adjustments (e.g., pH) to the water treatment system may be required, if any at all. The treatment process would be similar to that proposed for tailings reclaim water (Option 2) described in Section 3.3.

Drainage water collected from the Portage RSF to be treated post-closure would flow into sumps and then be pumped to the (active) treatment plant. The treatment plant would consist of the following process units, as required: ferric iron addition unit; lime supply and slurry preparation and dosing units; reaction tanks (i.e., for iron and lime addition and mixing); polymer preparation and dosing units; and solid/liquid separation unit (i.e., a clarifier/thickener). If removal/reduction of Ni is required, the pH in the water should be increased to about 11. Then, the pH in the treated water would require readjustment to the regulated limits (e.g., pH 6.5 -9.5). The pH adjustment to a pH of about 8.5 could be achieved with carbon dioxide (CO_2). If any toxicity due to un-ionized ammonia would be of a potential concern, the use of sulphuric acid to reduce the pH around 6.5-7 could be considered as an alternative.

The treated water could be released to Portage Pit Lake (now part of Third Portage Lake) via gravity flow within an open channel which could be furnished with rip-rap to minimize potential erosion and subsequent increases in TSS concentrations in the water. The quality of the effluent will be monitored to ensure the quality of discharge.

Based on the predicted water quality values (e.g., 1 mg/L As and pH 6.5) and the proposed treatment method, it is estimated that addition of about 0.5 tonnes lime and about 12 tonnes $Fe_2(SO_4)_3$ containing about 60% $Fe_2(SO_4)_3$ with about 12% Fe^{3+} would be required. The treatment of water could produce about 17 to 28 m^3/y sludge respectively containing about 5% to 3%S (e.g., about 1 truck load, see Table 2). Sludge separation could be facilitated with the help of a clarifier/thickener and then would be disposed of in the TSF and allowed to freeze with the rest of the tailings. Freeze thaw cycles could result in significant dewatering of the sludge (e.g., up to 80% dewater after one cycle). This would require a portion of the TSF to remain uncapped in order to receive the sludge, or if the TSF has been capped, the excavation of capping material to facilitate co-disposal of the sludge with tailings. The excavated capped material could be stockpiled nearby and re-used to cover the area once sludge disposal is complete.

Treatment Efficiency: The proposed BATEA lime neutralization process is expected to remove/reduce metal ions of concern to levels that could comply with the MMER criteria.

Sludge Management: Disposal and Storage

Indian and Northern Affairs Canada (INAC) have requested additional information with regard to sludge management that would be generated from the operation of the active water treatment plant (PHC Decision Commitment 33, 34, 34a and 37). CRL was asked to present a plan to manage sludges at the site. As also discussed below, a practice similar to the following response provided to INAC could be used. Considering the near-neutral pH of the reclaim water and the selected treatment process where addition of ferric sulphate and lime followed by addition of flocculant would take place. The volume of the sludge generated will largely depend on its solids content. A high density sludge (HDS) type system could produce sludge with about 20-30% solids(??). The report presented to INAC (the FEIS) (Cumberland 2005a, p. 166), indicated that treatment of about 1,000,000 m^3 tailings reclaim water containing about 10 mg/L was assumed to generate approximately 3,000 m^3 of 30% solids density sludge (or about 30,000-50,000 m^3 with 3-5%solids density if HDS process is not used). The sludge may be subjected to Toxicity Control Leaching Protocol (TCLP) to test for its chemical stability and is expected to be chemically stable. Sludge disposal options could include disposal back into the TSF and eventual cover with run of mine acid-buffering UM rock. The sludge material would freeze along with the underlying tailings. A second option would be to pump the sludge to the base of Portage Pit Lake, similar to current practices used for HDS sludge disposal at the Equity Silver mine near Houston, British Columbia.

4.0 SUMMARY AND RECOMMENDATIONS

Based on the material presented above, the following summary and recommendations are provided:

The objective is to meet MMER criteria for water discharged to the receiving environment.

- The proposed lime/neutralization precipitation (BATEA) method should be efficient to meet MMER criteria.
- Based on the predicted water quality values by geochemical studies, it is expected that no treatment would be required for the site during operation. If any water treatment is considered, it would primarily focus on adjustment of pH and metal concentrations (e.g., As) to comply with the MMER objectives. As a contingency, application of both in-situ and active treatment processes could be considered. Both processes could be controlled by the process pH with the help of a programmable logical control (PLC) system. The same PLC system could also be used for different treatment periods.
- The proposed contingency treatment processes and reagent calculations given in this report are based on the predicted water quality values, assumptions and site conditions per earlier predictions of *Possible Poor-End* water quality (Golder, 2005) but which reflect slightly higher constituent concentrations than more recent water quality predictions of a *Possible Poor End* scenario (Golder, 2007a) They aim to provide an example for an assumed treatment case. Before conducting and designing the final treatment processes, it is recommended that treatability tests must be performed to verify the effectiveness of the treatment process and refine treatment requirements (e.g., reagent type and consumption, optimal dosages, retention times, etc.).
- If As concentrations need to be attenuated, the addition of a ferric salt and lime would be required followed by addition of flocculant to enhance settling/separation of solids (precipitates). Other ions such as molybdenum and selenium would also be attenuated with the addition of ferric iron.
- If removal of Ni is required, it could be achieved by increasing the pH levels as high as 11. The pH of the treated water would then require re-adjustment to meet discharge criteria (e.g., pH 9 or lower). Carbon dioxide (CO_2) could be used to reduce the pH to approximately 8.5. However, if lowering of un-ionized ammonia levels is required for discharge purposes, it is suggested that the pH should be lowered to around neutral levels (e.g., 6.5 to7.5 range). In this case, the use of sulphuric acid (H_2SO_4) could be beneficial, as lowering the pH below 8.5 could otherwise require a significant amount of CO_2.

- In addition to pH and metal ions, TSS which could occur due to construction and soil erosion, and may also require removal/reduction. Every effort should be made to minimize potential TSS generation at the site. Point source discharges would need to meet TSS discharge guidelines (e.g., 15 mg/L by MMER). A monitoring scheme could be developed using on-line sensors (e.g., turbidity as a surrogate for TSS).

- A need for treating ammonia and nitrate, due to the use of explosives and degradation of CN, is not expected based on the results of prediction tests. The actual concentration of ammonia and nitrate in the water would depend on the management of explosives. The fate of cyanide (CN) derivatives for cyanate (CNO), thiocyanide (SCN), ammonia (and un-ionized ammonia) and nitrates need to be assessed and their concentrations should be monitored at the outlet of the processing plant during the operating period. The addition of peroxide compounds (e.g., hydrogen peroxide or calcium peroxide) can be used should further reduction in residual cyanide concentrations be required following the main cyanide removal process.

- In-situ bio-treatment of CN and derivatives by adding nutrients (e.g., phosphorus) to enhance bacterial activities could be considered (AMEC, 2005) once the actual tailings reclaim water quality is known. However, this practice would need to be evaluated further along with the potential consequences of nutrient addition to the receiving environment and the potential need for removal/reduction of phosphate.

- If the removal of Ni is required and the pH is increased to above 10 (e.g., ~pH 11), the precipitation of solids formed in the process can be facilitated in a conventional clarifier/thickener or settling pond. Otherwise, due to low content of solids, recycling of sludge back to the process (e.g., High Density Sludge “HDS”) to increase the solids quantity and enhance settling, or the use of a filtration unit (e.g., sand filter) might be required. Treatment trials should be conducted to assess actual sludge characteristics (e.g., % solids contents, volume, etc.) and determine disposal requirements.

- Sludge to be produced from the treatment processes could have about 3-5% solids content (S). Until the closure of the Reclaim Pond, the sludge could be co-disposed with tailings in the TSF, which could then be covered with a cap of waste rock and allowed to freeze. In post-closure, any sludge produced could be disposed of target areas of the TSF left uncapped, or within areas excavated in the capped material. The disposal area(s) would be recapped once sludge disposal is complete. The use of HDS process may result in a decrease in the quantity of sludge by generating sludge with about 20-30% solids content. The applicability of the process and process requirements should be identified with lab and pilot tests during the operating period of the mine.

- The Portage Pit Lake may contain as much as about 22 Mm^3 of water after the placement of waste rock and flooding. The presence of a large volume of water could offer an assimilative capacity for the treated effluent at closure. It is predicted that discharge of the treated water to the Portage Pit Lake could result in a dilution rate of about 18 times. During the post closure period, the assimilative capacity available in Portage Pit Lake (now part of Third Portage Lake) would increase to about 268 times. The assimilative capacity could provide a significant means for reducing potential impacts that may result from the disposal of treated water from the site.

- All treated and untreated water from the site discharged to the open receiving environment (Attenuation Pond discharges to Third Portage and Wally Lakes) will be subjected to the Aquatic Effects Monitoring Program (AEMP) and Environmental Effect Monitoring Program as required under MMER (Cumberland 2005b, 2006). The water quality should be non toxic to *Rainbow trout* and *Daphnia magna*. Pit Lake Water Retention Dikes will not be breached until the quality of water contained within them meets MMER and Nunavut DW criteria after discharge of Reclaim water into the Pit Lake.

5.0 CLOSURE

This Technical Memorandum is prepared by Golder Associates Ltd., (Golder) for the Meadowbank Mining Corporation (MMC). The Contingency Treatment Plan proposed herein was developed at the request of MMC to address the requirements for the Type-A Water License. It is understood that the construction and operation of the mine, including the implementation of this Contingency Treatment Plan, are the responsibility of MMC.

GOLDER ASSOCIATES LTD.

ORIGINAL SIGNED BY:

Nural Kuyucak, Ph.D., P.Eng.
Associate/Waste Management and Process Specialist

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Attachments

Table 1a – Summary of Portage Area Predicted Water Quality (Golder 2005)
Table 1b – Summary of Portage Area Predicted Water Quality (Golder 2007a)
Table 2 – Summary of Possible Contingency Treatment Processes Including Required Equipment and Chemicals

Figure 1 - Water Management Plan, Early Operation Phase
Figure 2 - Water Management Plan, Late Operation Phase
Figure 3 - Water Management Plan, Closure Phase
Figure 4 - Water Management Plan, Post-Closure
Figure 5 - Schematic Illustration of Contingency In-Situ Treatment System
Figure 6 - Schematic Illustration of Option 1, In Pond Treatment Alternative, Closure Phase
Figure 7 - Schematic Illustration of Option 2, Active Treatment System Alternative, Closure Phase

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AMEC Americas Limited (AMEC), 2005. Meadowbank Treatability of Ammonia in Attenuation Pond, Reclaim Pond and Pit Lake. Technical Memorandum prepared for Golder Associates. In: Appendix IX of Golder 2005 Report on Mine Site Water Quality Predictions, Meadownbank Gold Project, Nunavut. November, 2005

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TABLE 1a
Summary of Portage Area Predicted Water Quality Range (Golder 2005), Meadowbank Gold Project, Nunavut

Treatment Period		Parameters of Ineterest																		
		pH	Ag	Al	As	Cd	Cu	F	Fe	Hg	Mn	Mo	Ni	un-ionized NH_3	NO_3_N	Pb	Se	SO_4	Tl	Zn
RRNWT-DW Criteria[1]		6.5 – 8.5		0.1	0.025	0.005	1	1.5	0.3	0.001	0.05				11	0.01	0.01	500		5
MMER criteria[2]		6.0 – 9.5			0.5		0.3						0.5			0.2				0.5
Operating Year 1 to Year 5 (May) (Portage Attenuation Pond)	*min*	6.0	0.00001	0.04	0.001	0.00003	0.001	0.05	0.01	0.00001	0.05	0.0004	0.003	0.0002	3.77	0.0002	0.0001	7.66	0.00001	0.004
	max	6.0	0.00003	0.04	0.016	0.00020	0.004	0.29	0.01	0.00006	0.26	0.0046	0.020	0.0005	11.4	0.0011	0.0004	43.3	0.00004	0.024
	average	6.0	0.00002	0.04	0.008	0.00010	0.002	0.15	0.01	0.00003	0.14	0.0024	0.009	0.0004	7.84	0.0005	0.0002	23.8	0.00002	0.011
Operating Year 6 to Year 8 (Goose Island and Portage Pit Lakes)	*min*	6.7	0.00000	0.02	0.001	0.00002	0.001	0.02	0.01	0.000003	0.06	0.001	0.002	0.0000	0.001	0.0002	0.0001	6.47	0.00001	0.004
	max	6.7	0.00002	0.04	0.002	0.00005	0.002	0.10	0.01	0.000027	0.15	0.003	0.008	0.0005	2.22	0.0005	0.0005	26.4	0.00010	0.034
	average	6.7	0.00001	0.02	0.002	0.00004	0.002	0.07	0.01	0.000022	0.08	0.001	0.007	0.0003	1.07	0.0005	0.0005	9.63	0.00008	0.031
Year 8 - Preparation for Closure (Reclaim Water)	*min*	8.0	0.003	0.02	5.70	0.004	2.10	1.10	0.01	0.02	4.31	0.32	1.35	0.001	118	0.008	0.03	4125	0.002	0.74
	max	8.0	0.005	0.02	10.8	0.007	4.09	2.08	0.01	0.04	8.33	0.63	2.62	0.003	229	0.014	0.05	4125	0.004	1.43
	average	8.0	0.003	0.02	7.74	0.005	2.91	1.48	0.01	0.02	5.94	0.42	1.87	0.002	153	0.010	0.04	4125	0.003	1.02
Post Closure (Portage RSF drainage)	*min*	6.5	0.00002	0.03	0.21	0.0002	0.002	0.02	0.24	0.0001	0.09	0.0002	0.01	0.000000	0.04	0.001	0.002	6.59	0.0002	0.02
	max	6.5	0.00006	0.11	1.01	0.0003	0.009	0.03	1.80	0.0003	0.30	0.0004	0.06	0.000008	0.12	0.004	0.005	8.27	0.0005	0.05
	average	6.5	0.00004	0.06	0.70	0.0002	0.004	0.02	0.76	0.0002	0.17	0.0003	0.03	0.000000	0.08	0.002	0.004	7.40	0.0004	0.03

All concentrations are dissolved, mg/L; from Golder, 2005

Notes: Grey highlight indicates predicted parameters that may exceed MMER criteria

1. As requested by the NIRB, the quality of which would report pit lakes water prior to breach of the containment dyke
2. Minimum objective

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TABLE 1b

Summary of Portage Area Predicted Water Quality (Golder 2007a), Meadowbank Gold Project, Nunavut

Treatment Period		pH	Ag	Al	As	Cd	Cu	F	Fe	Hg	Mn	Mo	Ni	un-ionized NH_3	NO_3_N	Pb	Se	SO_4	Tl	Zn
RRNWT-DW Criteria[1]		***6.5 - 8.5***	***0.05***	***0.1***	***0.025***	***0.005***	***1***	***1.5***	***0.3***	***0.001***	***0.05***				***11***	***0.01***	***0.01***	***500***		***5***
MMER criteria[2]		**6.0 – 9.5**			**0.5**		**0.3**						**0.5**			**0.2**				**0.5**
Operating Year 1 to Year 5 (Portage Attenuation	*min*	*6.0*	0.00001	0.09	0.0002	0.00004	0.0006	0.062	0.068	0.00001	0.02	0.0009	0.002	0.0002	1.62	0.0002	0.0001	5	0.00001	0.002
	max	*6.0*	0.00003	0.32	*0.046*	0.0002	0.008	0.23	*2.2*	0.00005	*0.33*	0.008	0.053	0.0009	8.49	0.004	0.0006	30	0.00006	0.07
	average	*6.0*	0.00002	*0.20*	0.022	0.0001	0.004	0.17	*1.0*	0.00003	*0.20*	0.007	0.025	0.0005	5.04	0.002	0.0003	23	0.00004	0.03
Operating Year 6 to Year 8 (Goose Island and	*min*	6.7	0.00001	0.06	0.010	0.00005	0.001	0.095	0.26	0.00002	*0.06*	0.003	0.005	0.0001	0.19	0.0008	0.0004	10	0.00007	0.0074
	max	6.7	0.00002	0.06	0.010	0.00005	0.001	0.096	0.28	0.00002	*0.07*	0.004	0.005	0.0002	0.34	0.0008	0.0004	10	0.00007	0.0075
	average	6.7	0.00001	0.06	0.010	0.00005	0.001	0.095	0.27	0.00002	*0.07*	0.003	0.005	0.0001	0.26	0.0008	0.0004	10	0.00007	0.0074
Year 8 - Preparation for Closure (Reclaim Water)	*Summer average*	8.0	0.00002	0.052	0.013	0.0001	0.014	0.068	0.200	0.00002	*0.061*	0.055	0.015	0.0001	0.13	0.0003	0.0020	*721*	0.000203	0.01
Post Closure (Portage RSF drainage)	*Summer average*	6.5	0.0005	0.29	**8.3**	0.002	0.018	0.20	2.0	0.002	0.9	0.004	0.09	6.3E-22	0.88	0.006	0.045	62	0.004	0.18

Notes:

All concentrations are dissolved, mg/L; from Golder, 2007a

Grey highlight indicates predicted parameters that may exceed MMER criteria

1. As requested by the NIRB, the quality of which would report pit lakes water prior to breach of the containment dyke
2. Minimum objective

TABLE 2
Summary of Possible Contingency Treatment Processes Including Required Equipment and Estimated Chemicals
Meadowbank Gold Project

Treatment Period, Method Water Quantity	Process Description and Proposed Equipment	Treatment Chemicals Dosages and Quantities
Operating Year 1 to Year 5 - 500,000 m^3/yr water to be treated (requirements for 1.5Mm^3 discussed in text) - In-situ Treatment (see Figure 5)	• Lime in a slurry form to the Portage Attenuation Pond • Submersible pumps (e.g., 6 to 10 with 2"-3" size) to mix and recirculate water • 1 or 2 submersible pump (e.g., 50L/s would be suitable) to discharge treated water • Pumps placed on a floating base to avoid bottom sediment disturbance	• No treatment is expected • If any, pH adjustment (e.g., an increase from pH 6 to 7) • Lime: ~100 kg or about 1 -2 m^3 as 10% or 5% (w/w) slurry • If TSS removal is required: in addition to lime, about 0.5-1 tonne polymer to be dissolved and diluted to a 0.1% to 0.05% (w/w) slurry form
Operating Year 5 to Year 8	• 1-2 submersible pumps (and one or two stand-by) to discharge water (e.g., 50 L/s to 100 L/s depending on the discharge time window) • Placing the pump on a floating base is recommended.	• No treatment is expected • If TSS removal is required about 1-2 mg/L polymer in 0.05% - 0.1% w/w conc.
Year 8 - Preparation for Site Closure - 1,600,000 m^3 of tailings water to be treated in one season - OPTION 1 In Pond Treatment (see Figure 6)	• Fe^{3+} iron addition tank and dosing pump to control arsenic • Tanker truck to transport lime slurry to the Reclaim Pond • Polymer preparation unit (tank, mixers, dosing pump) for TSS settling • Submersible pumps (e.g., 8 to 12 with 2"-3") to mix and recirculate water within Reclaim Pond • Placing the pump on a floating base is recommended • CO_2 addition in Goose Pit Lake • 1-2 submersible pumps (and 1-2 stand-by) to discharge water (e.g., 150 L/s to discharge within 90 d). Sludge produced would remain in the TSF.	• Ferric sulphate (about ~2:1 Fe^{3+}/As molar ratios) with FS2 • Assuming 10 mg As removal 2400 tonnes $Fe_2(SO_4)_3$ as 60% $Fe_2(SO_4)_3$ (with ~12%Fe^{3+}) slurry, as supplied • Lime ~96 tonnes to neutralize the water followed by Fe^{3+} addition • Additional lime to increase the pH to ~11 for Ni removal: ~13 tonnes • Polymer (at ~1-2 mg/L dosage): 1.6-3.2 tonnes, to be dissolved and diluted to about 0.1% (w/w) slurry form • CO_2 for pH adj. to pH ~8.5 or H_2SO_4 for pH ~7 • ~5600 – 3360 m^3 sludge @ 3-5% solids

TABLE 2 (continued)

Treatment Period, Method Water Quantity	Process Description and Proposed Equipment	Treatment Chemicals Dosages and Quantities
- OPTION 2 tailings water pumped to Water Treatment Plant (modified from Process Plant) (see Figure 7)	• Fe^{3+} supply & dosing pump for arsenic control • Lime supply and dosing for pH control • Reactor tanks with a mixer • Polymer preparation unit (tank, mixers, dosing pump) for TSS settling • A solid/liquid separation tank (clarifier/thickener) • Process control by a Programmable Logical Control (PLC) unit • Process is controlled with pH • pH re-adjustment with CO_2 or H_2SO_4 • Sludge disposal to the TSF	• Ferric sulphate (about ~1.5-3:1 Fe^{3+}/As molar ratio) • 2400 tonnes as 60% $Fe_2(SO_4)_3$ slurry with 12%Fe^{3+} as supplied • Additional lime to increase the pH to ~11 for Ni removal: 13 tonnes • Polymer (@ 1-2 mg/L dosage): 1.6 - 3.2 tonnes • CO_2 for pH adj. to pH ~8.5 or H_2SO_4 for pH ~7 • 5600-3360 m^3 sludge @ 3-5% solids
<u>Post Closure</u> - 80,000 m^3/yr water to be treated - Active Treatment (Equipment for Option 2 can be used, see Figure 7)	Treatment plant to add Fe^{3+} to control arsenic, consisting of: • Fe^{3+} supply & dosing pump • Tank with a mixer • Polymer preparation unit (tank, mixers, dosing pump) • A solid/liquid separation tank (clarifier/thickener) • Sludge disposal to the tailings storage facility	• Ferric sulphate or ferric chloride (about ~2:1 Fe^{3+}/As molar ratio assuming 1 mg/L As and FS 2) • About 2 tonnes (Fe^{3+}) or about 12 tonnes containing ~60% $Fe_2(SO_4)_3$ slurry with 12% Fe^{3+} as supplied • Lime to increase the pH ~ 7.5-8: ~0.5 tonne • Polymer (at ~1-2 mg/L dosage): 80 - 160 kg polymer to be diluted as 0.1% to 0.05% slurry • ~28 to 17 m^3/y sludge @ 3-5% S for disposal

Pumps could be rented or purchased.

All values are given above are based on assumptions indicated in the attached Technical Memorandum.

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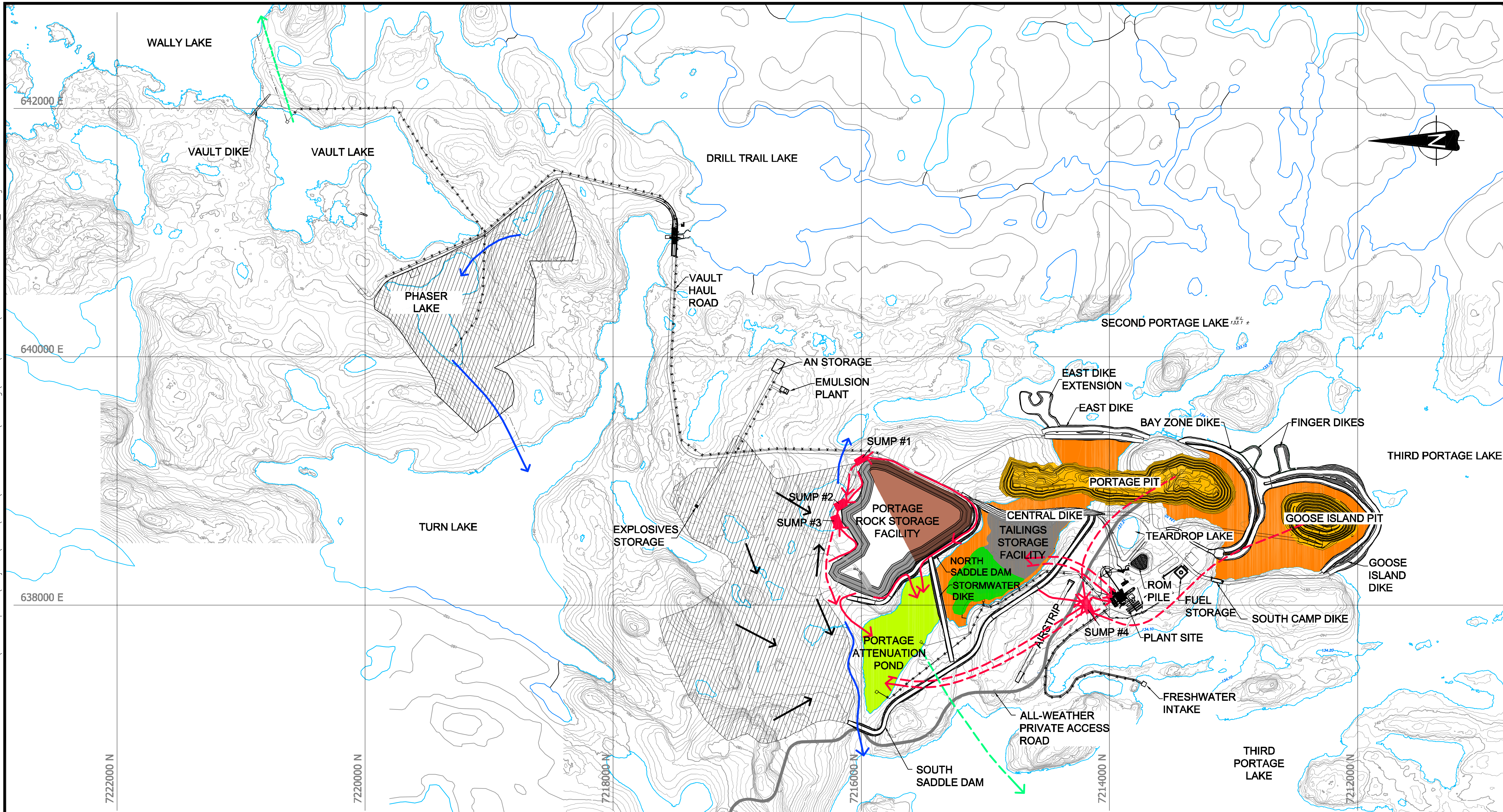

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LEGEND

	TAILINGS		CONTACT WATER INTERCEPTION
	WASTE ROCK		PUMPED CONTACT WATER
	RECLAIM POND		NON-CONTACT WATER DIVERSION
	ATTENUATION POND		SURFACE RUNOFF
	DEWATERED LAKE		PUMPED ATTENUATION POND WATER
	DIVERTED AREA		SUMP
	OPEN PIT		

NOTES

1) GRID REFERENCE: NAD 83, UTM ZONE 14.
2) CONTOUR INFORMATION ON LAND SUPPLIED BY MEADOWBANK MINING CORPORATION.

REFERENCES

1) AMEC AMERICAS LTD., DRAWING NUMBER A1-131395-100-C-0001 (100-C-0001.DWG), MEADOWBANK FEASIBILITY STUDY, APRIL 2005.

0 300 600 900 1200 1500

Scale in Metres

PROJECT

MEADOWBANK
MINING CORPORATION

TITLE

WATER MANAGEMENT PLAN
EARLY OPERATION PHASE
MEADOWBANK GOLD PROJECT

Golder Associates

PROJECT No.	06-1122-386	FILE No.	061122386-4000-FIG_1
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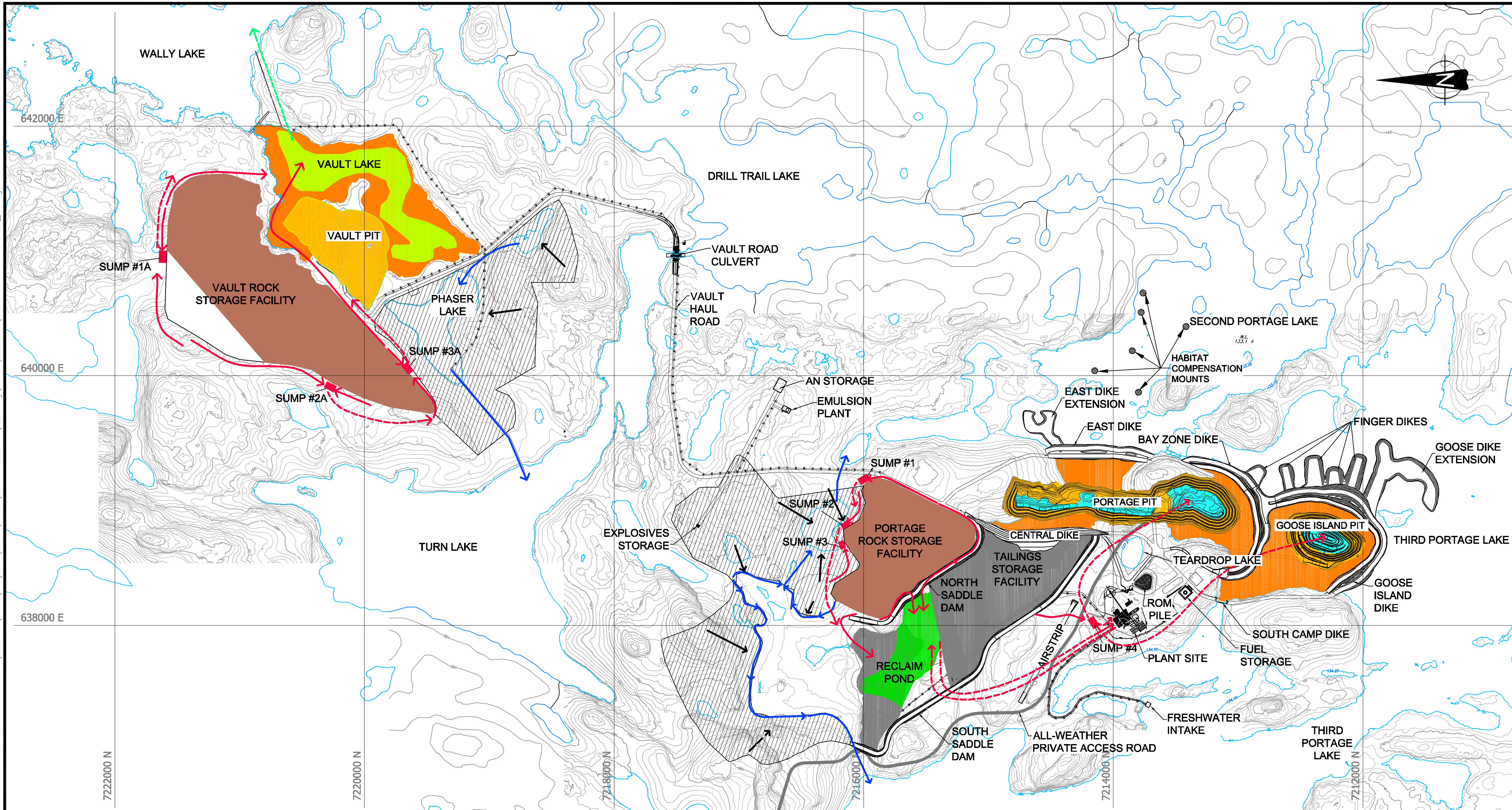
CADD	AS	15AUG07	
CHECK			**FIGURE 1**
REVIEW			



LEGEND:

TAILINGS	CONTACT WATER INTERCEPTION
WASTE ROCK	PUMPED CONTACT WATER
RECLAIM POND	NON-CONTACT WATER DIVERSION
ATTENUATION POND	SURFACE RUNOFF
DEWATERED LAKE	PUMPED ATTENUATION POND WATER
DIVERTED AREA	SUMP
OPEN PIT	
PIT LAKE	

NOTES

1) GRID REFERENCE: NAD 83, UTM ZONE 14.
2) CONTOUR INFORMATION ON LAND SUPPLIED BY MEADOWBANK MINING CORPORATION.

REFERENCES

1) AMEC AMERICAS LTD., DRAWING NUMBER A1-131395-100-C-0001 (100-C-0001.DWG), MEADOWBANK FEASIBILITY STUDY, APRIL 2005.

0 300 600 900 1200 1500

Scale in Metres

PROJECT

MEADOWBANK
MINING CORPORATION

TITLE

WATER MANAGEMENT PLAN LATE OPERATION PHASE MEADOWBANK GOLD PROJECT

Golder Associates

PROJECT No.	06-1122-386	FILE No.	061122386-4000-FIG_2
DESIGN	LL	15AUG07	SCALE AS SHOWN REV. –
CADD	AS	15AUG07	
CHECK			
REVIEW			

FIGURE 2

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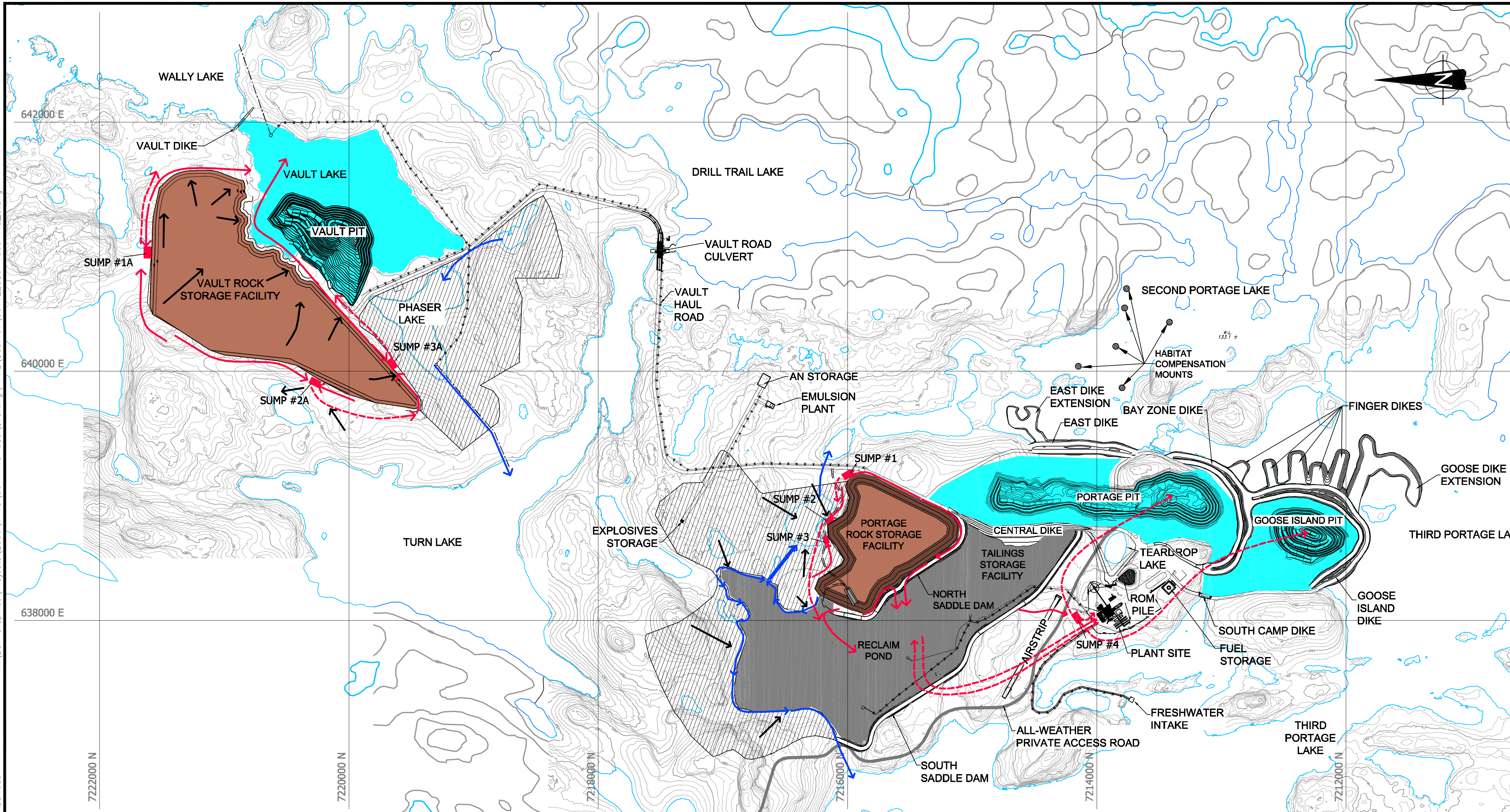


LEGEND:

- TAILINGS
- WASTE ROCK
- PIT LAKE
- DIVERTED AREA
- WATER DIVERSION DITCH
- SURFACE RUNOFF

NOTES

1) GRID REFERENCE: NAD 83, UTM ZONE 14.
2) CONTOUR INFORMATION ON LAND SUPPLIED BY MEADOWBANK MINING CORPORATION.

REFERENCES

1) AMEC AMERICAS LTD., DRAWING NUMBER A1-131395-100-C-0001 (100-C-0001.DWG), MEADOWBANK FEASIBILITY STUDY, APRIL 2005.

0 300 600 900 1200 1500

Scale in Metres

PROJECT

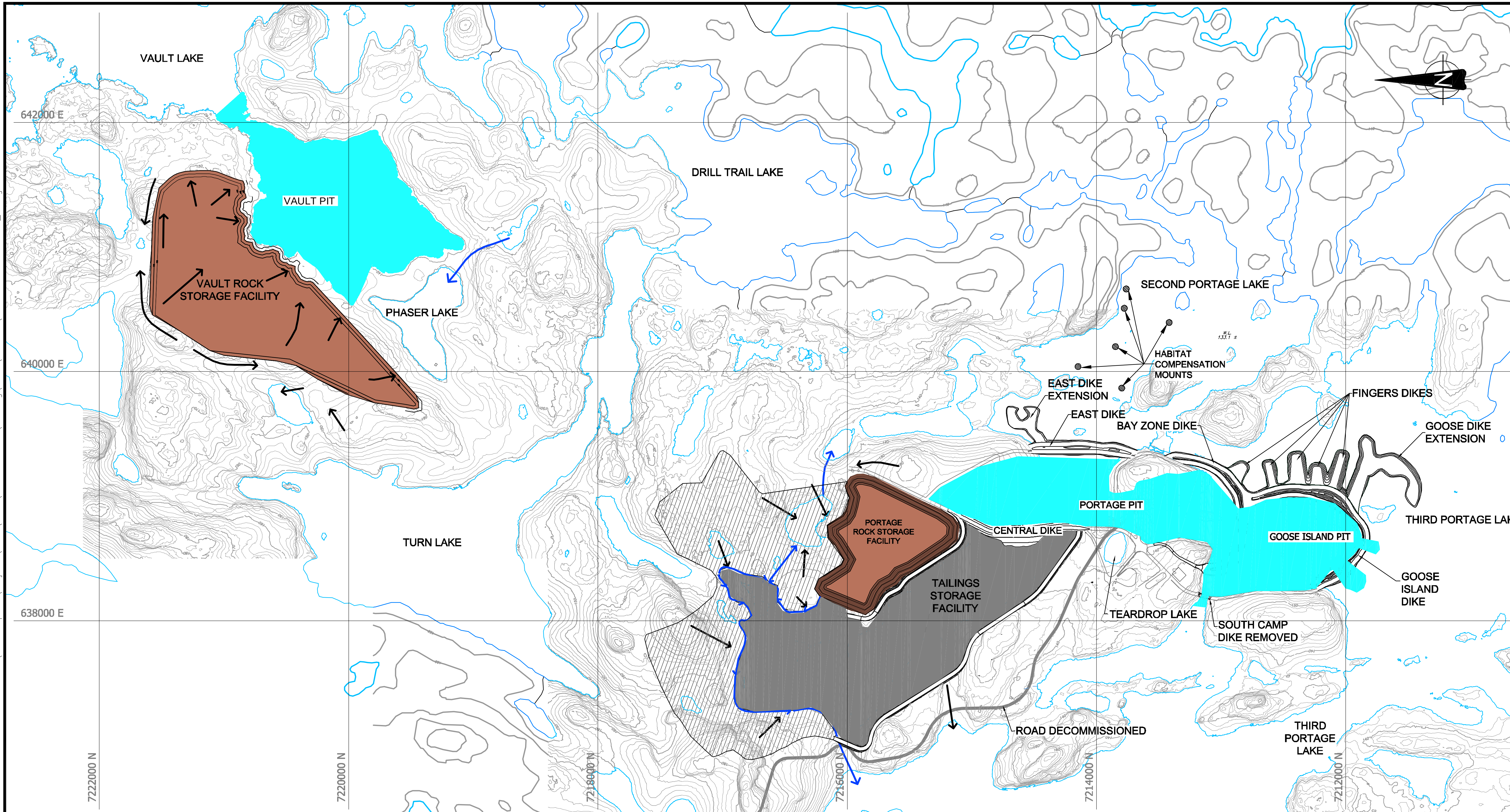
MEADOWBANK
MINING CORPORATION

TITLE

WATER MANAGEMENT PLAN
CLOSURE PHASE
MEADOWBANK GOLD PROJECT

Golder Associates

PROJECT No.	06-1122-386		FILE No.061122386-4000-FIG_3	
DESIGN	LL	15AUG07	SCALE AS SHOWN	REV. –
CADD	AS	15AUG07	FIGURE 3	
CHECK				
REVIEW				



LEGEND

- TAILINGS
- WASTE ROCK
- PIT LAKE
- DIVERTED AREA
- WATER DIVERSION DITCH
- SURFACE RUNOFF

NOTES

1) GRID REFERENCE: NAD 83, UTM ZONE 14.
2) CONTOUR INFORMATION ON LAND SUPPLIED BY MEADOWBANK MINING CORPORATION.

REFERENCES

1) AMEC AMERICAS LTD., DRAWING NUMBER A1-131395-100-C-0001 (100-C-0001.DWG), MEADOWBANK FEASIBILITY STUDY, APRIL 2005.

0 300 600 900 1200 1500
Scale in Metres

PROJECT
MEADOWBANK MINING CORPORATION

TITLE
WATER MANAGEMENT PLAN POST-CLOSURE MEADOWBANK GOLD PROJECT

Golder Associates

PROJECT No.	06-1122-386		FILE No.	061122386-4000-FIG_4
DESIGN	LL	15AUG07	SCALE AS SHOWN	REV. –
CADD	AS	15AUG07		
CHECK			FIGURE 4	
REVIEW				

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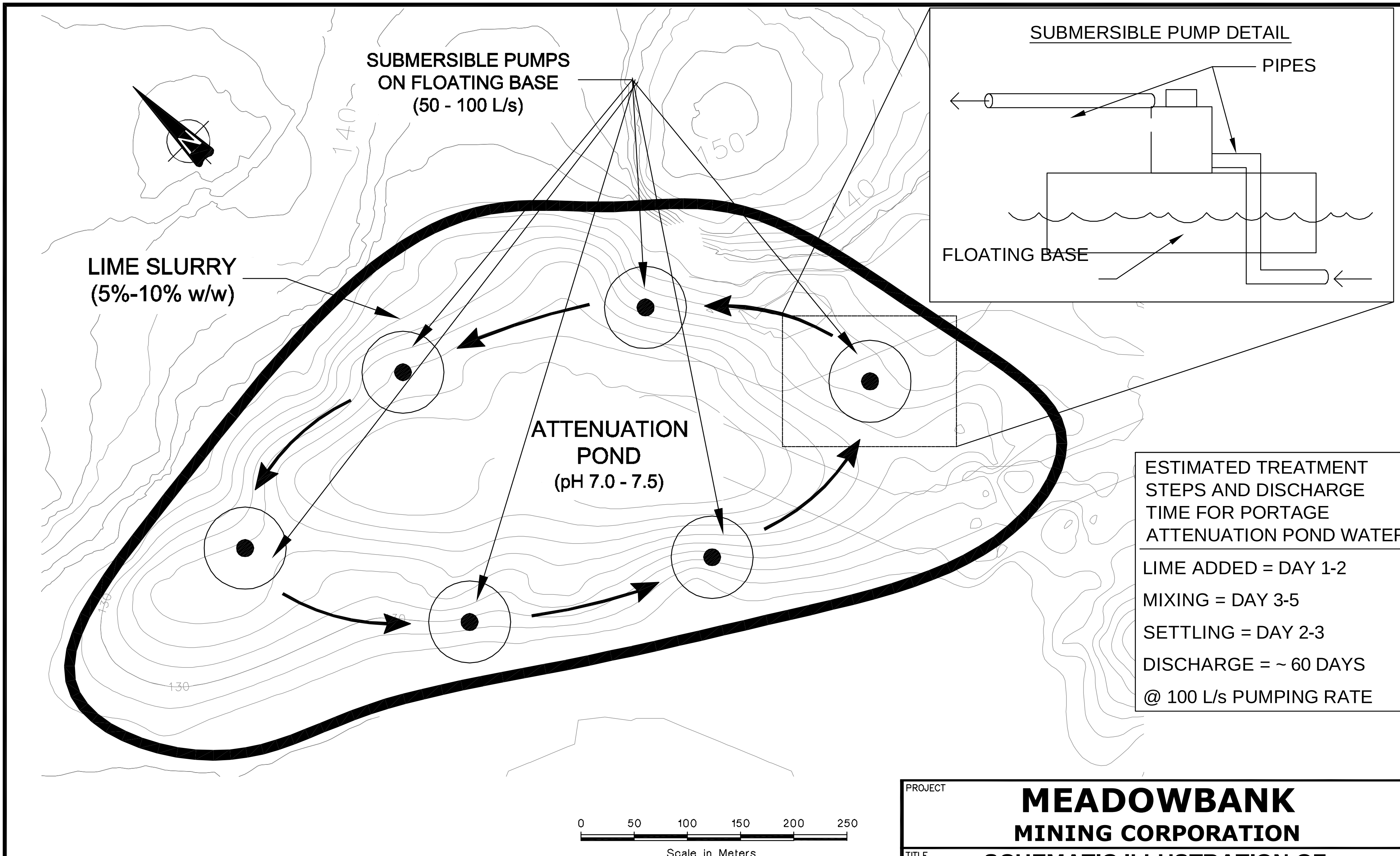


ESTIMATED TREATMENT STEPS AND DISCHARGE TIME FOR PORTAGE ATTENUATION POND WATER

LIME ADDED = DAY 1-2

MIXING = DAY 3-5

SETTLING = DAY 2-3

DISCHARGE = ~ 60 DAYS

@ 100 L/s PUMPING RATE

NOTE:

1) SAME ARRANGEMENT CAN BE USED FOR CLOSURE PHASE OPTION 1, SEE FIGURE 6.

PROJECT

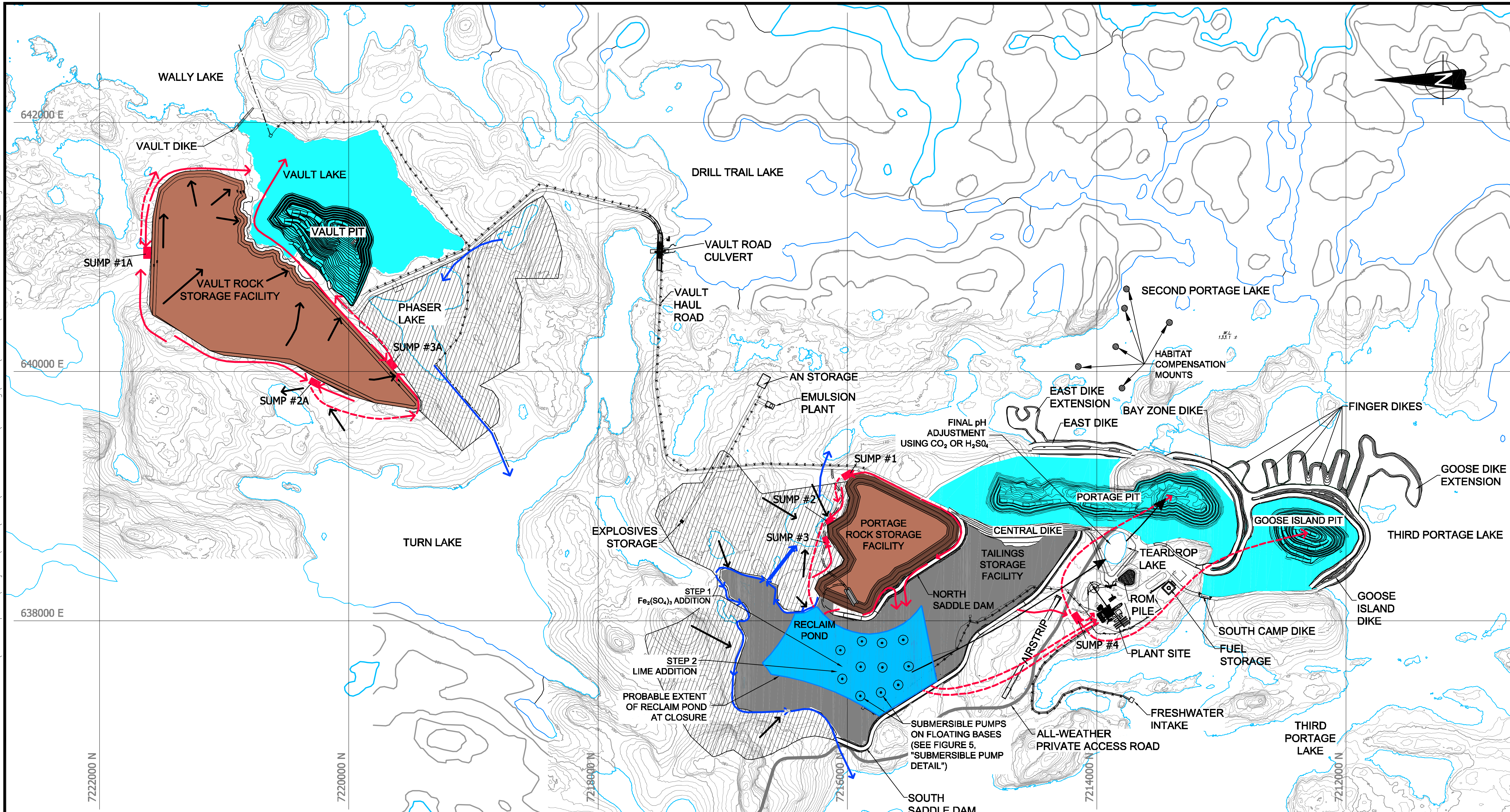
MEADOWBANK
MINING CORPORATION

TITLE

SCHEMATIC ILLUSTRATION OF CONTINGENCY IN-SITU TREATMENT SYSTEM MEADOWBANK GOLD PROJECT

Golder Associates

PROJECT No. 06-1122-386			FILE No.061122386-4000-FIG_5	
DESIGN	NK	09MAY07	SCALE AS SHOWN	REV. -
CADD	NBHS/JM	09MAY07	**FIGURE 5**	
CHECK				
REVIEW				



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LEGEND:

- TAILINGS
- WASTE ROCK
- PIT LAKE
- DIVERTED AREA
- WATER DIVERSION DITCH
- SURFACE RUNOFF

NOTES

1) GRID REFERENCE: NAD 83, UTM ZONE 14.
2) CONTOUR INFORMATION ON LAND SUPPLIED BY MEADOWBANK MINING CORPORATION.

REFERENCES

1) AMEC AMERICAS LTD., DRAWING NUMBER A1-131395-100-C-0001 (100-C-0001.DWG), MEADOWBANK FEASIBILITY STUDY, APRIL 2005.

0 300 600 900 1200 1500

Scale in Metres

PROJECT

MEADOWBANK MINING CORPORATION

TITLE

SCHEMATIC ILLUSTRATION OF OPTION 1: IN-POND TREATMENT ALTERNATIVE CLOSURE PHASE MEADOWBANK GOLD PROJECT

Golder Associates

PROJECT No.	06-1122-386		FILE No.	061122386-4000-FIG_6
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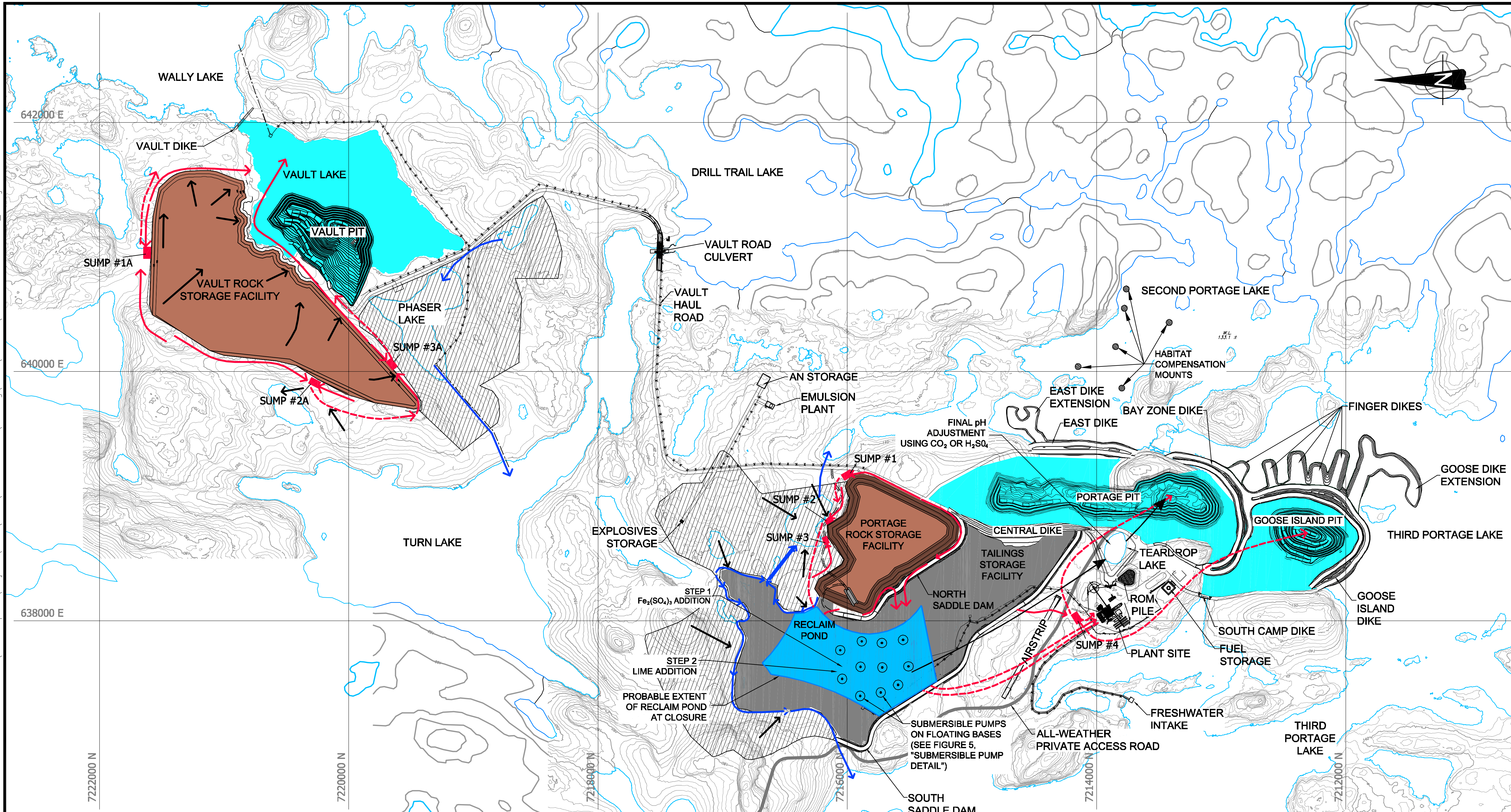
CADD	AS	15AUG07		
CHECK			FIGURE 6	
REVIEW				



LEGEND:

- TAILINGS
- WASTE ROCK
- PIT LAKE
- DIVERTED AREA
- WATER DIVERSION DITCH
- SURFACE RUNOFF

NOTES

1) GRID REFERENCE: NAD 83, UTM ZONE 14.
2) CONTOUR INFORMATION ON LAND SUPPLIED BY MEADOWBANK MINING CORPORATION.

REFERENCES

1) AMEC AMERICAS LTD., DRAWING NUMBER A1-131395-100-C-0001 (100-C-0001.DWG), MEADOWBANK FEASIBILITY STUDY, APRIL 2005.

0 300 600 900 1200 1500

Scale in Metres

PROJECT

MEADOWBANK
MINING CORPORATION

TITLE

SCHEMATIC ILLUSTRATION OF OPTION 1: IN-POND TREATMENT ALTERNATIVE CLOSURE PHASE MEADOWBANK GOLD PROJECT

Golder Associates

PROJECT No. 06-1122-386			FILE No. 061122386-4000-FIG_6
DESIGN	LL	15AUG07	SCALE AS SHOWN REV. –
CADD	AS	15AUG07	FIGURE 6
CHECK			
REVIEW			

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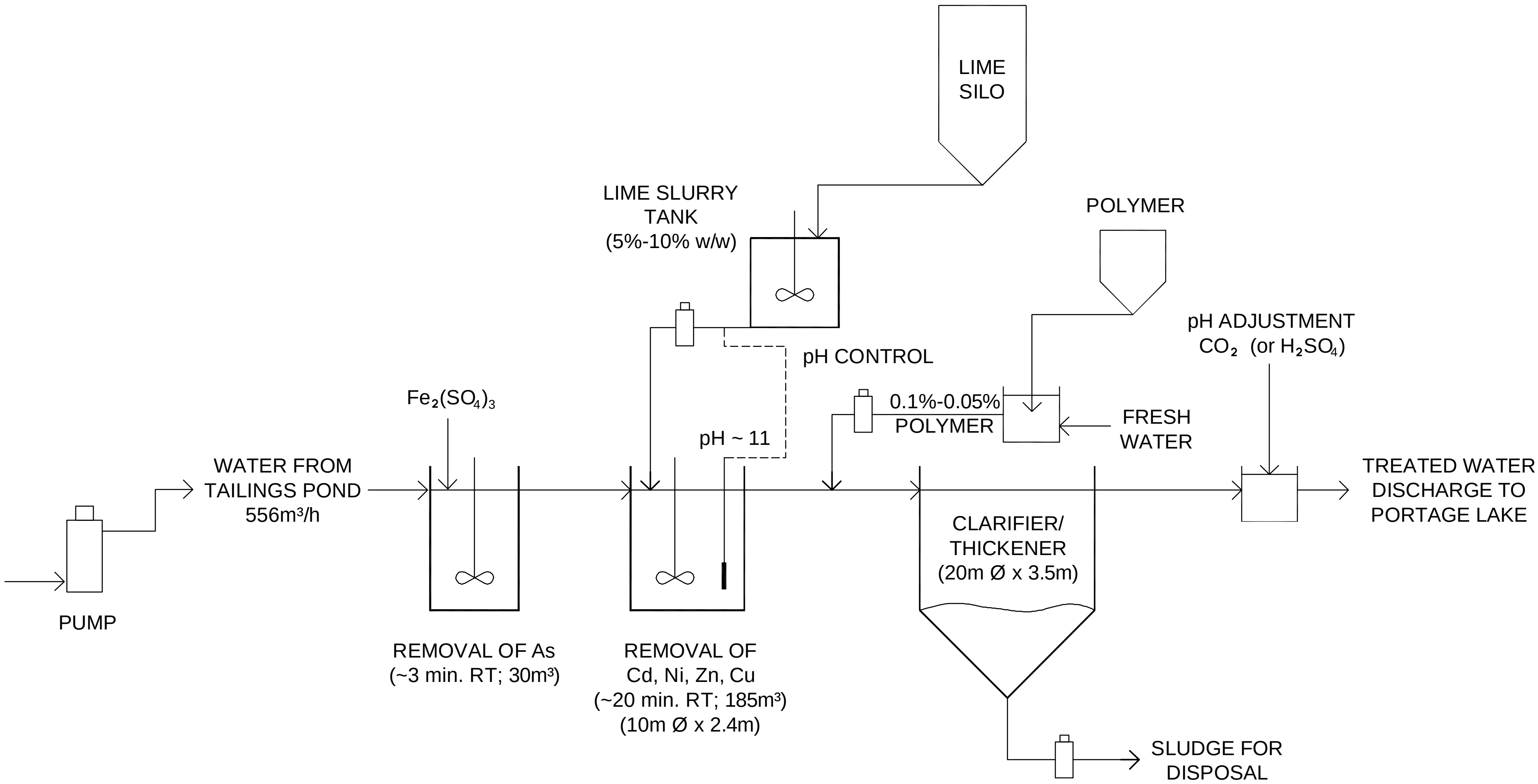
REVISION DATE: 07/08/22 05:04PM By: ASalvador CADD FILE: N:\Bur-Graphics\Projects\2006\1413\06-1413-089\Drafting\FINAL\Doc.467\061122386-4000-FIG_7.dwg



NOTE:
1) OPTION 2 FOR THE CLOSURE PERIOD. PROVIDES ~ 90 DAY TREATMENT. SAME SYSTEM USED DURING THE "POST CLOSURE" PERIOD IF REQUIRED. PROVIDES ~ 20 DAY TREATMENT.

PROJECT
MEADOWBANK
MINING CORPORATION

TITLE
SCHEMATIC ILLUSTRATION OF OPTION 2:
ACTIVE TREATMENT SYSTEM ALTERNATIVE
CLOSURE PHASE
MEADOWBANK GOLD PROJECT

Golder Associates

PROJECT No. 06-1122-386			FILE No.061122386-4000-FIG_5
DESIGN	NK	09MAY07	SCALE AS SHOWN REV. –
CADD	NBHS/JM	09MAY07	**FIGURE 7**
CHECK			
REVIEW			