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03-1221-310

Dillon Consulting
4920 47th street
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Attention: Mr. Gary Strong, P. Eng.

RE: REHABILITATION OF THE SEWAGE LAGOON, POND INLET (REV. 1)

Dear Sir,

Dillon Consulting (Dillon) mandated Golder Associates Ltd. (Golder) to provide technical guidance during the rehabilitation of a sewage lagoon in Pond Inlet, Nunavut. A first letter was issued on September 10, 2003 following a review by Dillon. The current version of this letter addresses comments made by the Government of Nunavut following their review of the September 10 letter.

The lagoon has been active around 1993 and has experienced progressive problems since approximately 1995. The government of Nunavut mandated Ferguson, Simek & Clark Engineers and Architects (FSC) of Yellowknife to design the rehabilitation of the pond in 2002. Mosher Engineering Ltd. of Halifax initiated on-site construction activities in early July 2003 under the supervision of Dillon.

1.0 INTRODUCTION

The rehabilitation program calls for the drainage of the existing lagoon, placement of a sufficient thickness of granular material to stabilize the accumulated sludge, a 0.3 m thick sand layer, a geocomposite clay liner (GCL), and a 0.3 m thick surficial layer of sand. Re-compaction of the existing north dyke and raising of all perimeter dykes are also part of the construction program. The pond will service the community of Pond Inlet once the rehabilitation is completed. The pond is irregularly shaped, with overall equivalent dimensions of approximately 300 m x 150 m.

Problems encountered by the contractor are related to the instability of the current pond base. In order to obtain a stable pond base for his equipment and achieve the 1 % specified base slope the contractor has to put a minimum thickness of 500 to 1000 mm of cobbly gravel and sand onto the existing pond base (see photograph 1). This layer is being spread as a single lift over the pond sludge and the active layer of permafrost. Both the contractor and Dillon site personnel are worried that the specified compaction of 95 % Proctor will not be achieved within the lower portion of this single lift layer resulting therefore in potential settlement problems and failure of the GCL membrane at the joints. The difficulty of compacting the imported gravel is further complicated by persistent water seepage from the underlying active layer of the permafrost. It is assumed that placement of fill material will not result in mud wave where the sludge could be extruded and flow.

We understand the Government of Nunavut requested an opinion from an independent geotechnical expert, and the Government obtains clarification from FSC from time to time as and when needed.

2.0 SITE OBSERVATIONS

Mr. Michel Lemieux of Golder was on site on August 30, 2003 to assess conditions of the lagoon with Dillon personnel. At Golder's request, the contractor agreed to conduct some additional surveys of surrounding site topography and to perform a series of three (3) test pits. The purpose of the survey was to help define the direction of surface flow and the probable direction of underground flow within the active layer of the permafrost. The test pits were undertaken to assess the thickness and composition of the active layer of permafrost. Survey elevation at the test pit locations was also performed by the contractor.

Survey information and site observations indicate the lagoon is located in a low spot with higher ground on the east, south and west faces. A 1992 geotechnical report, prepared by Thurber Consultants, was consulted and indicates the presence of a natural pond at the time prior to construction. The pond had an overflow to the ocean in 1992. Observations made in August 2003 indicate the occurrence of former water ponding immediately outside the east end of the south dyke. The contractor reported this water disappeared when he pumped the central portion of the basin, suggesting a direct hydraulic connection between the pond and this area outside the lagoon.

The pond at the time of the site visit was quite low with an approximate elevation of 96.0 m. The contractor reported that daily pumping was required to maintain the water level at the current elevation. Despite the relatively low water level in the pond at the time of the site visit, the presence of surficial seepage was observed outside the lagoon roughly 100 m north of the north dyke. Ground surface at this location is much lower than the toe of the dyke.

These last two observations tend to indicate that preferential channels capable of carrying large flows of water could exist within the active layer of permafrost. The last two observations also indicate the existing dykes have naturally thawed sufficiently in the last few weeks to become permeable and allow water to flow through their foundations.

The location of the three (3) test pits undertaken at the site is shown on Figure 1. The results are described in the following table:

Depth (m)	Elevation (m)	Soil Description
Test Pit N° 1		
0-1.0	98.5-97.5	Gravel, cobbles and boulders with some sand and silt infilling, wet to saturated
1.0	97.5	Permafrost (end of test pit) Stabilized water level after 30 minutes is located at a depth of 0.75 m (elev. 97.75 m)

Depth (m)	Elevation (m)	Soil Description
Test Pit N° 2		
0-0.2	96.3-96.1	Cobbles
0.2-1.1	96.1-95.2	Black sludge
1.1	95.2	Permafrost (end of test pit) Little water accumulation in the test pit after 2 hours despite the presence of an adjacent pond at elevation 96.0 m (approx.)
Test Pit N° 3		
0-1.25	98.3-97.05	FILL: brown, moist compact sand and gravel with numerous cobbles and boulders
1.25-1.28	97.05-97.02	Black sludge, saturated
1.28-2.1	97.02-96.2	Brown, saturated compact silty sand with some cobbles and boulders
2.1	96.2	Permafrost (end of test pit) Slight water seepage was noted at the interface with the black sludge.

The contractor reported he has dug a test pit adjacent to our Test Pit N° 2 and encountered very high water inflow conditions that filled the test pit rapidly. The contractor also exhibited photographs showing how he backfilled the base of the lagoon so far. It appeared that three (3) east-west oriented channels were left open for some time adjacent to various fill zones in order to allow seepage water to flow to the central pond where it was pumped out. These channels were subsequently filled up with compacted pit run material. At the time of the site visit, the area around Test Pit N° 3 was found to be soft and wet and slightly unstable, with indications that subsurface pore pressure conditions were significant enough to obtain somewhat quick conditions. Loaded trucks could, however, still travel over these areas.

The material used for backfilling was encountered in the upper portion of Test Pit N° 3 (see description above). This material is obtained from the active layer of the permafrost located on a high ridge some 2 km south of the site.

3.0 DISCUSSION

The project is now suspended for the winter season and will resume next summer.

3.1 2003 Construction Season

It is our opinion that current water inflow problems will continue to prevail within localized areas of the pond base for the remainder of the construction season. These wet areas, as delineated by Mosher Engineering, are shown on Figure 1. They are believed to result from the actual location of the pond in a low lying area combined with anticipated natural pockets or tongues of high permeability material within the active layer of the permafrost and the lack of perimeter drainage outside the pond.

The contractor's suggestion of adding French drains or ditches in specific areas within the pond is supported and recommended by Golder. Such drains or ditches will reduce the risk of further deterioration of the newly constructed raised pond base during the remaining weeks of the 2003 construction season. These features will also help control any inflow during the 2004 thawing season prior to and during the installation of the GCL.

French drains or ditches should connect any wet zones occurring within the pond to the central low point of the basin. A similar French drain or an open ditch should then connect the pond central low point to the exterior topography north of the north dyke. This means a portion of the north dyke will have to be breached open to accommodate the new ditch or drain.

French drains

The use of a geotextile and clear stone are recommended for the construction of the French drains. Such drains should be totally wrapped with the above noted geotextile, with 300 mm minimum overlap at the top joint to prevent migration of sand and fines into the drain which could potentially result in the plugging of the drain and loosening of the adjacent soil.

The top of the French drain should not be set too deep within the base of the pond in order to remain active for the next construction season and not be incorporated within the permafrost following the raise of the permafrost line within the next 12 months. It is therefore recommended that the top of the French drain be set 0.5 m below the level of earthworks to be attained at the end of the 2003 construction season. The longitudinal profile of these drains and/or ditches should be as regular as possible to avoid any intermediate points of water ponding.

Instrumentation

Under proper circumstances, it may be useful to consider instrumentation of the pond new basal layer upon completion of construction activities in 2003. Instrumentation consisting of thermistors could be installed within the surficial 1.5 to 2 m of soils this year, and could be monitored during the installation of the GCL next summer. Such monitoring would be useful in determining how much thawing of the subgrade is taking place during the summer 2004. Under proper circumstances, such information may help predict long term performance of the GCL. It is believed, however, that the information gained would be quite limited since the contractor will most probably want to complete GCL installation as soon as possible in the 2004 construction season before the subgrade undergoes substantial thawing. The contractor may also be interested in demobilizing his crew and equipment as soon as possible in 2004 for the benefit of other projects.

Placement of the GCL itself will also compromise the ability to further monitor the thermistors since surface leads will be covered during the deployment of the GCL and will no longer be accessible. Ways to alleviate this difficulty include the provision of a more complex wiring system reaching the top of the dykes.

Based on the assumptions made in the previous paragraphs regarding the contractor's schedule and the limited amount of information to be expected from the thermistors, instrumentation of the subgrade is not viewed as a valuable undertaking to help complete construction. Such instrumentation is not recommended if monitoring is not to be extended beyond summer 2004.

3.2 2004 Construction Season and Long Term Operational Period

As mentioned before, the presence of French drains and/or ditching leading to the outside of the north dyke should help control basal stability during the installation of the GCL in summer 2004. The remainder of this section addresses the question whether these French drains should be maintained operational over the long term, i.e. after the GCL is installed, or should be plugged.

The risk of maintaining the French drain system operational over the long term is related to the possible failure of the GCL. According to the contractor, the top of the rip rap within the emergency outlet spillway will be at an elevation of 101.75 m while the GCL in the lowest area of the pond will be at an elevation of approximatety 97.3 m. If the pond is not operated properly in the future and ever gets full of waste water and precipitation, the GCL will have to resist to a 3.45 m maximum water head. Assuming the French drains remain fully efficient over the long term, the proposed 500 mm thickness of subgrade material (sand and gravel) placed over a French drain thaws out every summer and the permeability of this material to be high, then the pore pressure differential through the GCL located immediately over the location of French drains will be as high as 34 kPa. Concerns are expressed that this head may be a source of leak for the GCL especially along the joints. If such leaks occur, the French drains would then act as preferential channels and would rapidly carry the waste outside the limits of the dyked area.

However, maintaining the French drains operational over the long term may be beneficial to minimizing the risk of developing groundwater pressure beneath the GCL. The site is recognized to be located in a natural low spot, subject to collect water from the outside. The amount of water anticipated from the neighboring areas cannot be assessed with any certainty. Such amounts will depend on the future ability of the raised and enlarged dykes to become permanently frozen and to act as efficient water barriers against the flow of surface water and groundwater occurring within the thawed zone outside the pond area. The amount of water reaching the pond will determine how much pore pressure will develop within the subgrade and be felt by the GCL. Excess pore pressure, when combined to high permeability soil conditions, could result in uplifting of the GCL and top 0.3 m cover, and eventual failure at the joints. The confining pressure of the cover sand is expected to be 8 kPa. The natural soil surface east of the pond is at elevation 101 m while pond base is at 97.3 m. If the perimeter dyke does not remain frozen and does not stop the outside flow, the potential exists for a 36 kPa pore pressure to develop beneath the liner, in excess of the 8 kPa effective confining pressure. If such conditions were to prevail; uplifting of the membrane would occur. Such conditions are more susceptible to occur during the first few years of operation when little sludge weight is available to further confine the GCL.

The combined presence of the lower sand layer beneath the GCL and active French drains would considerably decrease the risk of such pore pressure development beneath the membrane.

On the other hand, if French drains are plugged at the north dyke outlet but remain in place beneath the rest of the pond, the drains could act as preferential channels to transfer pore pressure conditions toward more detrimental locations beneath the base of the pond causing uplifting problems of the GCL. The same negative occurrence could also result from the presence of the lower sand layer beneath the GCL. We are assuming in this case that the French drains or lower sand layer will become fully saturated some time after the drain outlet is plugged in 2004, and that the active layer within the permafrost would continue to reach, seasonally, the soil beneath the GCL resulting in the development of pore water pressures.

Globally, the disadvantages related to the long term fate of the French drains are as follows:

<u>Leaving the French drains active:</u>

- The active pond will maintain permanent substantial water pressure over the GCL with the risk of leakage over the drains and contamination of the exterior environment

Plugging of the French drains:

- A risk of causing the uplift of the GCL exists every summer if the saturated drains act as preferential channels and transmit high pore pressure conditions to the centre of the pond. Such high pore pressure conditions could either result from the perimeter of the base or from the external site conditions. Such a risk also exists from the presence of the sand basal layer which is part of the current design. These phenomena are described on Figure 2.

Altogether, it is believed the French drains should be plugged prior to the deployment of the membrane in 2004, and a minimum water pressure should be maintained at all time afterwards to avoid uplifting of the GCL as a result of pore pressure transmission through the basal sand layer and/or French drains.

4.0 RECOMMENDATIONS

4.1 2003 Activities

The contractor's suggestion of adding French drains or ditches in 2003 at specific areas within the pond is supported and recommended by Golder. Work procedures for the implementation of such drains are provided in Section 3.

4.2 2004 Activities

In view of the discussion presented in Section 3 regarding the long term fate of the French drains, the solution to minimize long term risks includes the implementation of the following measures:

- Plug the outlet of the French drains to minimize the risk of creating a downward gradient that could cause failure of the GCL over the drains;
- Provide permanent minimum weight on to the GCL to minimize the risk of uplifting the GCL; and
- Minimize the risk of having external water reach the base of the basin by diverting external runoff away from the site.

Plugging of the drain

The use of an open trench through the north dyke in 2003 seems to become more attractive than building a French drain at this location since it will be easier to plug the open trench in 2004.

Extra weight on the GCL

Permanent minimum weight on the GCL could be obtained by pumping fresh water into the basin once construction is completed in 2004. A minimum of 1.0 m thick layer of water is recommended in the shallowest perimeter points of the pond base. Such minimum weight should be maintained over the long term. Salt water shall not be used to obtain the minimum water cover since salt water will react with the sodium bentonite and could result in the degradation and loss of efficiency of the GCL. Over the long term, the recommended minimum weight can also be provided with sludge. When sludge is being added, the recommended minimum water cover can be reduced accordingly. The intent is to have at least 30 kPa total stress applied at all time in the lower part of the basin.

The presence of a large body of water over the basal permafrost in August 2004 will not differ from the long term site condition when wastewater and precipitation will accumulate within the pond. If[1] the active layer of the permafrost is to thicken as a result of water placement in 2004, the same will also occur over the long term as a result of improved impermeability and water retention capability of the basin. If the dyke fill material is initially properly compacted and if the GCL maintains its efficiency as a water barrier, then it is expected the dykes will perform satisfactorily when the presence of the large body of water induces additional seasonal thawing.

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[1] The increased thawing effect resulting from a shallow pond can not be concluded without the benefit of a proper thermal analysis. The presence of a shallow pond may have the opposite effect of creating a thermal barrier against deep summer thaw.

Diversion of external runoff

Ditches should be excavated in 2003 and possibly deepened in 2004 to drain as much water as possible away from the site. The east side of the pond could be drained toward the south east corner of the pond. From there, a shallow ditch could be extended southward over the height of land. The material resulting from excavation of the ditch located at the toe of the dyke should be cast onto the toe of the dyke to widen the dyke width and improve the likelihood the dyke core will remain frozen during the summer period. A ditch should also be excavated along the west side of the basin. Such excavation within the permafrost will require more effort.

4.3 Instrumentation

Although the use of thermistor instrumentation within the pond may be interesting for long term monitoring, such instrumentation would not provide substantial information to be used in a timely fashion for the 2004 construction season. The owner may still decide to put instrumentation for long term monitoring if he wishes to do so.

4.4 Risk Assessment

Risk # 1: The GCL membrane has been stored on site for two years and may have undergone partial hydration with time. Premature hydration could make deployment operations more difficult and could result in a loss of efficiency. It is recommended that the actual condition of the membrane be assessed as part of any future risk assessment.

Risk # 2: Despite the implementation of the proposed measures (Sections 4.1 and 4.2), some risks remain concerning the long term behavior of the GCL. The risks are related to the presence of organic soft sludge beneath the current pond base, the difficulty of properly compacting the 500 to 1000 mm thick single layer of cobbly soil put by the contractor, and the occurrence of areas of instability within the new fill of the pond base. Any of these three factors may result in future differential settlement of the base of the pond. Such differential settlement may impair the joints of the GCL and create some localized leaks. This is especially true if the future active layer of the permafrost is to reach the existing sludge layer located beneath the new fill. The risk of developing localized leaks as a result of future differential settlement is considered as high. It is therefore important that the owner be advised of this risk and be willing to adjust his performance expectations accordingly. The fact that some localized leaks occur in the future should not be interpreted, however, as a complete failure of the system.

If the owner wants a solution with a lower risk level, the addition of rigid insulation may have to be considered. The addition of thermal insulation will increase the likelihood of keeping the sludge layer permanently frozen in the future, therefore reducing future differential settlement. Thermal modeling analysis of the pond base using varying thicknesses of rigid insulation and water cover could prove helpful in defining the risk of undergoing substantial seasonal basal thaw and settlement. The idea of adding supplemental GCL strips and/or bentonite powder along the joints should also be discussed with the manufacturer to see how much risk reduction could be achieved out of this undertaking. Otherwise, relocation to a more favorable new site may have to be contemplated.

Overall risks cannot be defined at this stage with any absolute percentage numbers. A quantitative risk assessment could only be derived from a thorough estimation of settlement following a thermal analysis of the pond. This assessment also needs to define what is considered as a " 100% failure of the GCL ".

No valuable discussion can be put forth at this point in time regarding the cost effectiveness of risk reduction alternatives, including relocation of the pond to a different site. Such discussion could only follow the completion of a risk assessment and the definition of the costs of the various corrective scenarios. A schematic of the decision making process is presented in Figure 3.

4.5 Operational Manual

We recommend that the pond operator be provided with operational guidelines to make sure future pond operation will not compromise pond performance.

5.0 CLOSURE

The current project does not include a review by Golder of the design documents prepared by FSC. Even though such a review is not part of this mandate and has not been performed, some issues were noted and deserve to be further clarified or reconsidered by the owner. A non-exhaustive list of these points includes the following:

- No provision for an erosion protection layer is included along the interior slopes of the pond. It is anticipated that wave action could lead to progressive erosion of the surficial 0.3 m thick layer of sand over the GCL;
- The outlet emergency spillway seems close to the dyke's crest; and
- There appears to be confusion on site with respect to the reference Proctor value to be used (standard or modified).

We trust the information provided will help you provide the best long term solution to the site owner. Please do not hesitate to contact us for any queries related to this presentation.

GOLDER ASSOCIATES LTD.

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ML/MRJ/lr

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Att. Reference List
Photograph 1
Figure 1 Pond Inlet Sewage Lagoon - Drawing From Mosher Engineering Limited (September 01, 2003)
Figure 2 Mechanisms That Could Cause Upward Failure of the CGL
Figure 3 Schematic of the Decision Making Process