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PROJECT MEMORANDUM

To:	**Nunavut Water Board**	**Fax No.:**	**Via email**
Attention:	**Ms. Dionne Filiatrault, P. Eng. Acting Executive Director**	**CC:**	**D. Hohnstein J. Grainger**
From:	**Holger Hartmaier (Ext. 113)**	**Date:**	**June 7, 2007**
Subject:	**Cape Dorset Sewage Lagoon- March 30, 2007 Re-Submission- Geotechnical Review**		
No. of Pages (including this page): 16 Pages		**Project No:**	**0308-003-02**

As requested in your telephone call of May 17, 2007 and in the email from Dave Hohnstein at the same time, BGC Engineering Inc. (BGC) has undertaken a preliminary geotechnical review on behalf of the Nunavut Water Board (Board) of the documentation recently provided by Dillon Consulting Limited (Dillon) for the new sewage lagoon at Cape Dorset, NU.

This memorandum presents a summary of our comments on the recent submission. We have also provided comments with respect to ancillary documentation provided to BGC as part of the documentation package received from the Board.

1.0 BACKGROUND

On May 15, 2006, the Board requested BGC review the following design and tender documents for the new sewage lagoon prepared by Dillon:

- P Lake Area Sewage Lagoon System, Final Design Report, dated January 2006.
- Construction Tender.
- Construction Contract.
- 2005 Geotechnical Investigation Report, prepared by AMEC Earth and Environmental (AMEC) for Dillon.

BGC's geotechnical review comments on the above documents were transmitted to the Board in a memorandum dated June 2, 2006. BGC's comments were forwarded by the Board to Dillon. Dillon's response to BGC's comments were transmitted to the Board in a letter report dated July 14, 2006. Although Dillon's response addressed some of the issues raised by BGC, there were numerous technical details that remained unresolved as well as several broad issues of concern. As a result, BGC, at the request of the Board prepared a memorandum dated August 9, 2006 that covered the outstanding areas of concern and recommended that the Board convene a technical hearing for all concerned parties to resolve these issues.

The technical hearing was held on September 19, 2006 in Cape Dorset to allow Dillon to provide additional information regarding the design of the sewage lagoon and to give all interested parties the opportunity to clarify the outstanding issues.

BGC prepared a memorandum summarizing the meeting notes pertaining to the geotechnical concerns raised during the meeting dated October 5, 2006. The purpose of this memorandum was to provide the Board with the information required to draft a suitable response to Dillon with respect to the next steps in securing approval of the proposed water licence amendment for the new sewage lagoon.

Since October 5, 2006, BGC has not been actively involved in the Cape Dorset file.

2.0 SCOPE OF CURRENT REVIEW OF RE-SUBMISSION

BGC received the following documents from the Board on May 17, 2007 with respect to the recent re-submission of the Cape Dorset sewage lagoon application:

- P Lake Sewage Lagoon Water Licence Application Design Report, Cape Dorset, NU, dated December 21, 2006, submitted by Dillon Consulting Limited to Government of Nunavut, Community and Government Services March 30, 2007. The document includes the following appendices:
    - Appendix A- Figures
    - Appendix B- Photos
    - Appendix C- P Lake Water Shed Calculations
    - Appendix D- Population Statistics
    - Appendix E- Lake Bathymetry and Volume
    - Appendix F- Technical Specifications
    - Appendix H- Construction Drawings
        - Drawing 100- Site Plan
        - Drawing 101- Lagoon Containment Berms and Truck Turnaround Pad
        - Drawing 109- Earthworks and Sewage Discharge Details and Sections
        - Drawing 111- Lagoon Berm and Details
        - Drawing 112- Access Manhole Details
- Geotechnical Investigation for P Lake Sewage Lagoon, Cape Dorset, NU. Report dated October 13, 2005, prepared by AMEC Earth and Environmental for Dillon Consulting Limited.
- Examination of Drawings- Cape Dorset Sewage Lagoon. Letter report dated September 12, 2006, prepared by AMEC Earth and Environmental for Dillon Consulting Limited.
- Geotechnical Investigation- Sewage Lagoon, Cape Dorset, NU. Letter report dated November 1, 2006. Prepared by AMEC Earth and Environmental for Dillon Consulting Limited.

In addition, the following ancillary documentation was provided by the Board:

- April 2, 2007. Letter from Babesh Roy, M.A.Sc., P.Eng., Municipal Planning Engineer, Community and Government Services, Baffin Region, Government of Nunavut to Zhong Liu, Technical Advisor, Nunavut Water Board, re: Cape Dorset Licence Application- P Lake Sewage Lagoon, Response to NWB Letter dated June 21, 2006 (sic).
- December 13, 2006. Letter from Art Stewart, Senior Administrative Officer, Municipality of Cape Dorset to Richard Dwyer, Licensee Trainee, Nunavut Water Board, re: Approval from Cape Dorset Hamlet Council.
- December 7, 2006. Letter from Art Stewart, Senior Administrative Officer, Municipality of Cape Dorset, to Richard Dwyer, Licensee Trainee, Nunavut Water Board, re: Cape Dorset Water Licence Application.
- Draft of amended water licence.

3.0 REVIEW COMMENTS MARCH 30, 2007 APPLICATION

This section provides a summary of the preliminary comments for each of the above noted documents. In general, these comments should be read in conjunction with previous commentary provided by BGC to the Board.

3.1 Design Report

1. The review copy is not signed and professionally sealed. The Board should confirm to BGC that the original documents received from Dillon are signed and bear the professional seal of the responsible engineer, registered to practice in Nunavut.
2. In Section 1, there should be a paragraph noting that this document addresses the concerns and issues raised by the previous review, particularly the items noted to Dillon during the September 19, 2006 technical hearing (technical hearing).
3. In Section 1.1, 2nd paragraph, Dillon has now been involved in this project over the course of 6 years.
4. In Section 2, the water licence requirements should include the technical requirements derived from the technical hearing held in Cape Dorset, September 19, 2006.
5. There is no section that discusses the design criteria or design constraints.
6. There are numerous typo's, formatting problems and missing details (i.e. "Error! Reference source not found") to suggest that this is draft version, not a final document. The Board should insist that Dillon submit a completed version, especially considering that the report may not be signed and sealed. This is even more disconcerting considering the fact that this document has also passed through the hands of Government of Nunavut (GN) prior to being submitted to the Board. Many of the deficiencies noted herein should have been dealt with by the GN directly with Dillon.
7. In Section 4.1 there are minor discrepancies with respect to the design volume of sewage to be treated. At the top of page 8, a value of 96,100 m^3 is given, Table 4.1 shows 96,047 m^3 and at the bottom of the page it is set at 96,000 m^3.

8. In Section 5.4, Dillon noted that Chart 5.1 indicates a significant recharge component to P Lake and that in this respect, P Lake is not practical as a sewage lagoon unless recharge water is directed away from the proposed lagoon. Therefore, the use of ditching to divert recharge water is carried forward in the conceptual design development. There is however, no further discussion of this issue in the rest of the design document, nor are diversion ditches shown in the drawings or mentioned in the specifications. It is noted that the north and south berms are intended to act as diversion berms. However they are constructed out of granular materials so their effectiveness needs to be demonstrated. BGC also notes that use of ditches in permafrost affected terrain is not recommended.
9. The statements made in Section 5.5 regarding groundwater movement from the lagoon are not supported. As discussed later in subsequent sections of this memorandum, the site investigations and analyses completed to date do not support the fact that the lagoon, as currently designed will hold water.
10. The design report lacks details concerning the design and construction of the lagoon dikes. This is a major deficiency, considering the previous comments made by BGC, the discussions of the technical hearing and the fact that additional site investigations were carried out, leading to a revised design. No discussion is provided regarding the basis for the design changes from the previous submission.
11. In Section 11, Dillon noted that "The design elements have used standard engineering practices and reviewed by the geotechnical engineer". This statement is not supportable based on the geotechnical deficiencies noted in this memorandum. In addition, this section omits addressing the specific issues previously raised by the Board.

3.2 Appendices A through E

BGC has no specific comments on these appendices at this time.

3.3 Appendix F- Technical Specifications

It is not normal practice to be in a situation where a project has been tendered, awarded and construction started before a water licence has been obtained. As such, the Board should not be concerned with respect to the potential contractual issues associated with this project. The technical specifications would normally be included as supporting documentation to the water licence application and reviewed on that basis. The following comments therefore are of a technical nature and do not address potential contractual issues. Any contractual issues related to this project should be addressed by Dillon and the Government of Nunavut (GN) with the contractor.

1. The specifications do not seem to be properly updated:
    - On the "Special Provisions" page, in the bottom right corner is a date of "February 2006".

- The top right corners of the rest of the documents show "November 2005".
- Under Section 0110, "Summary of Work", Part 1.3.3 states that "Work to be completed prior to October 2006."
  This raises a question as to whether these contract documents are in fact the ones being used to construct the facility, or whether a new contract is in effect. The Board must be satisfied that this supporting document to the water licence application reflects the current plans.

2. What is the revised construction schedule?
3. Section 01705 is duplicated.
4. In Section 02072 "Geotextiles":
   - Part 1.3.1, define "GCL", (Should be Geosynthetic Clay Liner).
   - Part 2.1.1, 2.1.2 and 2.1.6, Tables 1523-3-1 and 1523-3-2 were not found.
   - Part 3.1.10 seems to be written "generically". The drawings do not show a clay liner, a granular sub-liner sampler blanket or a geomembrane. The term "geosynthetic clay liner" is introduced. If this means "GCL" then it is in conflict with the drawings, which show "Granular Clay Liner".
   - See subsequent sections of this memorandum for further comments on the liner details.
5. Section 02315, "Excavating, Trenching and Backfilling", Part 1.3.4, unsuitable materials should include massive ice lenses.
6. Section 02316, "Rock Removal":
   - Part 1.2.1, not sure what circumstances would warrant a minimum rock excavation of "50 mm".
   - Part 3.2, the drawings do not distinguish between soil and rock, but show excavated slopes (i.e. liner trench) vertical, assuming rock conditions. There is no guidance with respect to excavated slopes in soil.
7. Section 02661, "Sewage Storage Lagoons":
   - Part 2, in several locations there is reference to a rip rap specification. There is no Section 02371- Rip-Rap or Section 02454- Rip-Rap.
   - Part 3.3.2, indicates that dike is to be constructed in the summer in unfrozen condition. There is no statement regarding the foundation condition, although summer construction would indicate that it too would not necessarily be frozen. Based on these specifications, the berms are not being constructed as a frozen dam. As such, the GCL is the primary liner. This is not the normal application of a GCL. The role of a GCL is to act as a secondary liner as would have been the case if the berm was designed and constructed as a frozen dam. A HDPE liner is considered to be a primary liner and could be backed up with a GCL for secondary containment.

- Part 3.3.3, ASTM D 698 applies only to soils having ≤ 30% retained on the ¾" (19 mm) sieve. Berm core material shown on the drawings is Type II Granular, which according to Section 02315, Part 2.1.3 is crushed, pit run or screened stone, gravel or sand with a maximum particle size of 75 mm. For this material, compaction specifications should be based on relative density, as per ASTM D 4253 "Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table" and D 4254 "Standard Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density". The dike fill is considered to be structural fill and should be placed as dense as possible, based on field trials. Compaction of granular fill should include moisture conditioning to improve density. The field trials should establish the maximum relative density achievable using the available equipment.
- Part 3.5 Flexible Lining- assume this is the same as "GCL". Terminology for the liner should be consistent.
- Part 3.5.1, requires that a layer of granular material in unfrozen condition be placed on the bottom and sides of the lagoon as indicated. Where is this detail indicated? Normally there should be a layer of bedding sand on either side of the GCL. This is not shown. Note that the liner is shown being placed on a 1:1 slope on Drawing 111. This slope appears too steep to safely work on and to carry out the installation procedures as specified and would also be too steep for placing any of the bedding material that has been omitted from the drawings, but alluded to in the specifications (part 3.1.10). Compaction of the cover layer on a 1:1 slope would be difficult. Dillon should confirm if placing the liner on a 1:1 slope is in compliance with the manufacturer's specifications. In a recent review of GCL liner construction it was found that embankment stability was compromised whenever the GCL slope was steeper than 3H:1V, with excessive strains (5.5%) and extension at the top of the slope developing within one day on 1:1 slopes (Bouazza, 2002). Dillon should present a stability analysis to confirm that the proposed liner configuration is stable.
- Part 3.5.9 indicates that the liner sheets are to be cut to fit accurately around inlets, outlets, sleeves, concrete structures and other projections through the lining. There are no further details provided in either the specifications or the drawings with respect to this critical component of the lagoon retention system.
- Part 3.7 Leakage Testing. This section is completely inadequate for the purpose intended and poorly conceived. The purpose of the lagoon is to retain water in order for the sewage to be treated. There is no way that the method given in the specifications will yield any defensible data to determine that a leak exists or to conclusively direct the contractor to undertake repairs at no cost to the Owner. Some of the major concerns with respect to the methodology provided are as follows:

- The test assumes that the boundary conditions of the 1 m^2 pan are the same as the lagoon and that the only losses are evaporation and seepage and the only inputs are direct precipitation. This model is fundamentally wrong, as the lagoon pond surface receives water from the adjacent contributing runoff areas as well as direct rainfall. Also, as the base of the lagoon is unlined there may be seepage into the lagoon area through the active layer from the unlined valley slopes. Also there is potential for seepage to flow around the ends of the liner in each abutment as well as through the base of the lagoon.
- Liners are located both in the west berm and the east berm. Filling to a depth of 450 mm would only test the deepest portion of the west berm and would not test the east berm at all. In order to have a minimum water cover of 450 mm along the liner, the lagoon would essentially have to be filled to its containment limit. Any water level that is lower than operating level doesn't test the entire containment system, which has to include the unlined floor of the lagoon. If acceptance of leak tests is done at low pond levels, there is a risk that the pond may leak when the pond is filled to its operational level through leakage zones that existed above the tested pond level.
- Measuring pond water levels to an accuracy of 1 mm would be difficult to achieve in practice. Doing so would require creating an enclosed observation well so that the true static level is measured, unaffected by waves. The details should be specified by Dillon, not left up to the Contractor.
- The test would require checking for leaks only if the pond has lost more than 25 mm of water compared to the loss in the pan. The basis for this criterion was not explained in the design report. Regardless of its validity, there may be other outcomes to the test that make it impossible to unambiguously interpret that leakage is or is not occurring, especially if precipitation events have occurred due to the boundary conditions noted above.
- The method assumes that the leak is in the liner. Leaks can also occur through the base of the unlined lagoon through the active layer.
- It is not clear how this test actually locates the leak, since the liner is embedded within the core of the berms. Even if a specific leak location could be identified, undertaking repairs would be not be an insignificant undertaking. First, the water inside the lagoon would have to be pumped out entirely. Excavation of the upstream shell of the berm would be required down to leak level in order to expose the liner and patch any leaks. The berm material would have to be replaced. Re-compaction of the berm material would likely be done using hand tampers and may result in a lower density fill compared to the rest of the berm that was constructed using heavier compaction equipment.

A better approach is a well-thought out quality assurance and quality control program within Section 02661 that addresses liner integrity. The focus should be on seam testing, visual inspection and testing selected areas, using methods as recommended by the manufacturer. Design provisions should include downstream seepage collection ponds to collect any seepage and pump it back into the lagoon.

3.4 Drawings

BGC was provided copies of Drawings 101, 109, 111 and 112 to review. These copies were unstamped- presumably originals on file with the Board are stamped copies. If not, they should be. It is assumed that the other drawings pertain to the access road and were not included in the present submission. The Board should however be satisfied with the details and as-built information with respect to the road, for completeness, in order to issue a water licence for the entire facility.

- Drawing 101: There is no information to show that the lateral extent of the GCL is sufficient to prevent end-run seepage around the ends of the liner at the abutments for both the east and west berms.
- Drawing 109: The north berm is constructed using Type II granular material. It is also designed to act as a surface water runoff diversion berm. There is a minor fines component in this material, however it will not act as a seepage barrier, particularly since the steepest hydraulic gradient is straight through the berm. Therefore, some seepage into the lagoon can be expected. The same problem applies to the road on the south side of the lagoon.
- Drawing 111:
    - In general the slope of the GCL is too steep (1 Horizontal: 1 Vertical). A slope of 2H: 1V or flatter would be preferable to allow access for personnel for construction and QA/QC purposes.
    - There are no dimensions or setting out points for the configuration of the liner. Presumably, the location of the liner is critical for the geothermal stability of the structure, however this detail has not been provided.
    - The GCL is referred to as a “Granular Clay Liner”. The specifications refer to a “geosynthetic clay liner”. The legend identifies this as a “Bentomat ST Liner, see specs”. As discussed above, the details of the “GCL” were missing from the specifications, so it is not clear exactly what this liner actually consists of.
    - The type of foundation material is not defined. The legend just shows “Existing Ground”. As such, it is not clear whether the embedment detail (3) is in soil or rock.
    - Detail 1 shows no foundation stripping or excavation. Therefore, the 2 m minimum depth is assumed to be from the existing ground surface.

- Detail 3 shows the liner embedment trench to be backfilled with Type II Granular Material. The AMEC design recommended this be backfilled with compacted clay or grout.
- It is not clear what Detail 4 applies to.
- Detail 6:
  - The depth of the excavation under the lagoon outfall section is not shown.
  - There are no details showing how the liner penetration of the outfall pipe is to be sealed.
  - The portion of the outfall pipe downstream of the liner is subject to freezing. The valve is located in the manhole downstream, so it is possible that water within the pipe can freeze and there is no way to drain it beforehand. Cracking of the pipe will expose the berm interior to the maximum head in the lagoon, creating a potential instability of the berm, possibly resulting in a breach and/or loss of containment.
  - There are two keys in the foundation. One is the embedment trench for the liner, the other is under the manhole. Why not combine the two?
- Detail 8:
  - The configuration of the liner at the crest of the berm will allow water to flow through the berm material between the liner and the Geoweb. This flow will exit somewhere on the downstream face, potentially creating instability within the granular materials overlying the liner.
  - At the downstream toe, the overflow weir exits against an excavated face of foundation material, potentially creating an erosion problem.
- Detail 10: The section shown does not reflect the crest anchor trench details shown in Detail 8. It is not clear how the berm liner and overflow weir liner actually interface in this location.

4.0 GEOTECHNICAL INVESTIGATIONS

Geotechnical investigations were conducted in 2005 and 2006. BGC has already reviewed and commented on the 2005 site investigations, which were considered inadequate. The deficiencies in the geotechnical data were expressed to both Dillon and AMEC representatives at the September 2006 public hearing in Cape Dorset, as well as in prior correspondence from BGC to the Board.

At the public hearing, Dillon/AMEC described their proposed drilling program to be conducted in the week following the meeting. The program involved using the airtrack precussion drill rig used by the contractor to blast the access road. BGC expressed concern that this method would not yield any details on the subsurface conditions, particularly the nature of the frost affected bedrock and ground ice conditions. In addition, ground temperature measurements, which were to be made shortly after drilling would not be representative of stabilized in-situ conditions.

Despite BGC's recommendations, as described in the meeting notes sent to the Board, Dillon/AMEC carried out a program that failed to yield any useful permafrost data. The results of the 2006 investigation program were presented in a report dated November 1, 2006, prepared by AMEC for Dillon.

The following comments pertain to this report:

- The report states that the site investigations were carried out on September 8-9, 2006, comprising 22 shallow boreholes and two test pits. The timing pre-dates the September 19, 2006 public hearing in Cape Dorset where Dillon/AMEC stated that the program was planned for the following week. The Board should confirm with Dillon if there was another program carried out, or if the drilling program schedule was mis-represented in the meeting.
- Section 2 of the report indicates that the method of drilling limited the maximum depth to 3.1 m. The method of drilling is not stated, however this depth limitation would be typical for an air track drill. The fact that no core was recovered indicates that a percussion rig was used.
- AMEC was only able to obtain temperature measurements in one hole (BH 4), which is located under the east berm truck turnaround. BGC expressed concern about this at the public hearing, indicating that the proposed program would not yield reliable temperature measurements. As such the 2006 investigations failed to provide reliable temperature data under the main water retention element of the lagoon.
- The temperature measurements in BH 4 showed a temperature of -0.6^{o}C at a depth of 3 m. This temperature is not considered reliable by BGC as it does not reflect stabilized in-situ ground temperatures, since the reading was taken on the same day as drilling was carried out. Nevertheless, AMEC has used this information to extrapolate the mean annual temperature at a depth of 15 m to be in the range of -4.0 to -5.0^{o}C. No details are provided as to how this extrapolation was carried out, assuming the initial data is even reliable.
- AMEC admits that "The method of the drilling did not allow for an assessment of the material composition or the ice/moisture content for overburden…". The drilling was also not able to check for the presence of ice in the frost affected bedrock in the foundation or lagoon floor.
- The bedrock surface was determined by drilling rate and shape and mineral composition of cuttings as they were returned to the surface. In areas of overburden cover (in excess of 3.1 m in some areas), coring data is required to accurately confirm the bedrock surface. The extent of the frost affected bedrock zone below the bedrock surface is a critical item for the design of the cut-off trench under the lagoon berms and has not been defined by this program. AMEC notes in Section 3 that "The lagoon site was noted to be mostly covered with shattered granite blocks, up to 5 m in size…"

- The drilling results presented in Section 4 showed that the thickness of the active layer could not be determined at 20 out of the 24 locations were site investigations were carried out.
- Despite this lack of data, AMEC concluded that the drilling program confirmed that the soil and permafrost conditions at the lagoon site are in close agreement with the assumed subsurface conditions described in the 2005 AMEC geotechnical report.
- As a result, AMEC considered that the results of the geothermal modelling (see 2005 AMEC report) provided reliable data on the temperature regime of the berm and berm subgrade. AMEC considered that the depth of the cut-off trench recommended in the 2005 report was sufficient to eliminate seepage under the berm. This statement is unsupported without having direct evidence of the nature of the frost affected bedrock and ice content under the dikes. This information was not obtained from the 2006 investigation program.

5.0 DESIGN ISSUES

As noted in the above section, AMEC considered the 2005 geothermal modelling to provide reliable data on the predicted temperature regime in the berm and berm foundation.

BGC provided commentary to the Board in 2006 on the 2005 AMEC geotechnical report. With respect to the current submission, the following design issues were identified:

- The geothermal design is fundamentally flawed in that it uses an n-factor approach, whereby a single coefficient (n-factor) has been used to relate ground temperatures to mean monthly surface temperatures, with no calibration with actual dam foundation ground temperature measurements.
- The ground temperature measurements used in the analyses were based on estimated values. In 2006, only one set of temperature measurements could be obtained and these are considered unreliable by BGC, as discussed in the previous section.
- The geothermal model does not reflect the current berm design or foundation conditions, specifically:
    - The 2006 investigations included 5 boreholes under the main berm (Boreholes 1, 2, 3 and 5) and two holes under the northeast berm (Boreholes 4 and 22). The modelled 2 m of overburden depth was found in only one hole under the main berm (Hole 5). Borehole 22 found 2.4 m under the downstream toe. The rest of the holes found bedrock at the surface or minimal (0.6 m) cover.
    - Given similar geothermal conditions, the active zone in bedrock is deeper than the active zone in overburden. Therefore, over most of the dike foundations, the active zone is expected to be much deeper than the 2 m assumed by AMEC. As such, it can also be expected that the zone of frost affected bedrock that must be penetrated by the cut-off trench extends deeper than 2 m. This depth was not determined or confirmed by the 2006 drilling program.

- The modelled upstream and downstream slopes of the dike are 2H: 1V. The current design section shows upstream and downstream slopes at 2.5H: 1V.
- The modelled section assumes that the dike is constructed with silty sand and gravel. The current design section is constructed using Type II Granular fill, which is essentially sand and gravel with little to no silt.
- In the model, the surface of the dike is covered with a 0.5 m thick layer of coarse rockfill. The current design section does not have rockfill on the crest or downstream slope.
- The geothermal model shows the geosynthetic liner placed directly under the 0.5 m thick rock fill on the upstream face of the dike, then folding under the upstream toe on top of the foundation. The liner extends downstream to tie into the cut-off trench, which is located under the mid-point of the upstream shell slope. The design section shows the liner within the upstream shell and tying into the cut-off trench under the crest.
- The modelled section assumed that the cut-off trench was backfilled with either compacted clay or grout. The current design section shows the cut-off trench filled with Type 11 granular material.

  These differences are significant enough to warrant another geothermal analysis as the key assumption by AMEC is that the lagoon will hold water due to the fact that the subgrade under the berm will remain frozen. Under the current design configuration, the heating effects of the lagoon water affect the upstream half of the upstream shell (upstream of liner will be saturated) as well as most of the upstream foundation, including the liner embedment cut-off trench. Since the cut-off trench is backfilled with gravel, there is a potential seepage path under the liner.

- No stability analyses were conducted for the current design. It would appear from inspection, that the 1H: 1V slope of the GCL is too steep and thereby introduces a potential failure plane in the upstream slope. Dillon should be requested to provide a stability analysis for the proposed design, along with justification of the strength parameters used in the stability assessment.

- The design report lacks any discussion regarding the water retention design criteria or the design of the liner. In fact, there appears to be a suggestion in the documentation that the dike is expected to act as a frozen core structure. This seems to be the impression of Dillon's client, GN Community and Government Services. In their April 2, 2007 response to the Board's letter of June 21, 2006, regarding a lack of seepage analyses in the submission, the GN representative, Mr. Babesh Roy, P. Eng., Municipal Planning Engineer states, "No analysis for seepage possible for a frozen core dam. This is also true for the stability analysis". It is apparent that Mr. Roy, is under the mistaken impression that this is a frozen core structure and that perhaps the GCL is considered to be a back-up containment system.
- At a Hamlet Council meeting (#16/06-07), Hamlet Council passed resolution #181/06-07 to approve the design changes to the new sewage lagoon following the geothermal analysis as presented by Mr. Babesh Roy and Jonathan Palluq of the GN. Is this a new geothermal analysis? If so, the Board should request a copy for review.
- Given the above, it is the responsibility of the GN to be satisfied that the design prepared under contract by Dillon meets acceptable design standards and has addressed the concerns raised by the Board. The fact that this re-submission still contains numerous deficiencies indicates that the GN has not addressed these concerns directly with Dillon before submitting the documentation to the Board.
- In a letter dated September 12, 2006 to Dillon, AMEC summarized their comments on drawings issued for construction of the Cape Dorset sewage lagoon dated September 7, 2006. AMEC's comments echo many of the comments made by BGC above. With respect to the water retention elements, AMEC stated:

  "It was stated in the geotechnical report for this project prepared by AMEC (dated October 13, 2005, page 9) that "the concept of a frozen core dyke to provide the primary containment of lagoon waters is considered to (be) technically tenuous at best…". AMEC discussed the installation of a synthetic liner through the dike and a cut-off curtain below the dyke. The bentonite liner shown on the drawings therefore represents a back-up primary containment system; it should be designed and installed to be fully competent during all stages of the project life".

- AMEC's comments on the September 7, 2006 design drawings raises two questions:
  - Why were these revisions not presented to the Board at the September 19, 2006 public hearing in Cape Dorset?
  - Why have the deficiencies noted by AMEC still not been addressed in the current submission dated March 30, 2007?

6.0 COMMENTS ON AMENDED WATER LICENCE

The objective of the amended water licence being prepared by the Board was to attempt to address any outstanding deficiency noted in the current submission by means of terms and conditions that the applicant would have to satisfy. BGC considers the March 30, 2007 submission to be technically incomplete. Once the technical deficiencies noted herein have been addressed, BGC would be pleased to provide comments to the Board on a draft water licence with respect to this application.

7.0 CONCLUSIONS

It is recommended by BGC that the Board reject the current submission due to the numerous technical deficiencies noted in this memorandum. The primary flaw is the fact that lagoon containment has not been demonstrated. If the lagoon cannot hold water, then it is ineffective as a means of sewage treatment and should not be constructed. The lagoon is not designed as an exfiltration pond.

It is unfortunate that despite the input by the Board and others on the original submission, the original concerns have not been adequately addressed. The Hamlet is seriously in need of a new sewage lagoon and is currently not being well served by the GN or Dillon who are responsible for delivering a facility that is designed to acceptable engineering standards.

8.0 CLOSURE

The design work for the Cape Dorset sewage lagoon is being undertaken by professional engineers at both Dillon and AMEC. Review comments provided herein by BGC do not relieve those companies of their professional responsibilities. BGC accepts no responsibility for the actions, designs and structures finally undertaken by those companies. That responsibility lies with the engineer of record.

BGC Engineering Inc. (BGC) prepared this report for the account of the Nunavut Water Board. The material in it reflects the judgement of BGC staff in light of the information available to BGC at the time of report preparation. Any use which a third party makes of this report, or any reliance on decisions to be based on it are the responsibility of such third parties. BGC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

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