Sewage and Solid Waste Sites, Kugaaruk, NU

Pre-Design, Phase 2

February 2006

Sewage and Solid Waste Sites, Kugaaruk, NU

Public Works & Services, Government of Nunavut

GN Project Number 03-4305
GN Contract Number CT05-3800

Gary Strong, P. Eng - Project Manager

Submitted by
Dillon Consulting Limited

(In reply, please refer to)
Our File: 05-4755-2000

February 23, 2006

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Attention: Navjit Sidhu, Bsc., EIT

Pre-Design Report - Phase 2, Kugaaruk Sewage and Solid Waste Facilities Design

Dear Navjit:

Please find attached a copy of the Pre-Design Report for Phase II of the Kugaaruk Sewage & Solid Waste Facility project.

Potential options are presented for the location of the new sewage lagoon as well as improvements and changes that should be made to the solid waste facility and bulky metals site. Requirements for the application of a new water licence are also summarized.

If you have any questions regarding the information contained within the document, please don't hesitate to contact me.

Yours sincerely,

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EXECUTIVE SUMMARY

The Hamlet of Kugaaruk is responsible for the disposal of liquid and solid waste generated from community activities. These facilities are currently operating without a water license. The lagoon is undersized, and exfiltrates throughout the year. The level of exfiltration exceeds the levels that are acceptable to the Hamlet and the regulators. Further, in order to obtain a water licence through the Nunavut Water baord improvements are required to the sewage lagoon and solid waste site. This report presents a number of options for upgrades to the sewage lagoon system as well as potential improvements to the solid waste and bulk metals sites.

The current sewage lagoon exfiltrates treated (primary) sewage into the wetlands below. Phase I of this project attempted to mend the breaches in the berms to allow the community to continue to use the sewage lagoon for another two to three years (see Appendix D, Four Phase 1 Options). The chosen solution involved raising the berm and spreading a layer of bentonite along the inside face of the berm to seal the gaps and cracks that had developed. Additional proposed solutions included the installation of a Granular Clay Liner (GCL) and blasting the bottom of the sewage lagoon to increase lagoon capacity to be able to meet the community's sewage needs for the long term. Construction of Phase I began at the end of the summer. Recent reports have indicated that the solution was not totally successful (see Appendix F, Regional Engineer's Comments).

Phase II identified three possible locations for a new sewage lagoon large enough to accommodate a year's worth of sewage for the next 20 years. All three locations are in the same relative area, just off the road between the Bulky Metals site and the existing landfarm.

Recommendations for the solid waste site included upgrading fencing, spreading a layer of cover over existing waste and improving signage as well as segregating hazardous wastes so that they may be shipped south for processing when sufficient quantities have accumulated. Similarly, the bulky metals site should be re-organized and some of the materials at the current site should be organized and shipped south for processing to a scrap metals facility.

1.0 INTRODUCTION

Dillon Consulting Limited (Dillon) has been retained by the Department of Community and Government Services (CGS), Government of Nunavut, to design waste facility alternatives for the Hamlet of Kugaaruk – formerly known as Pelly Bay. This project has been divided into two phases, the first of which concentrated on achieving regulatory compliance with the existing sewage treatment facility for the immediate future The second phase concentrates on modification, planning, and design for the longer term solutions for the waste facilities. This document presents the pre-design of Phase 2 of the project as developed by Dillon Consulting, in collaboration with representatives from the Department of Community and Government Services.

The Hamlet of Kugaaruk is located 68.52° north latitude and 89.9° west longitude in central Nunavut. This places Kugaaruk along the east coast of Pelly Bay, which is roughly nine hundred and sixty kilometers (960 km) west of the capital of Iqaluit.

The annual snowfall in Kugaaruk is approximately 125 cm and the annual rainfall is approximately 11 cm. In January the daily mean temperatures is approximately -33^{0}C while in July the daily mean temperature is approximately 6^{0}C. Freeze up usually occurs during the month of November but may happen as early as September or October while spring thaw usually happens between late May and June.

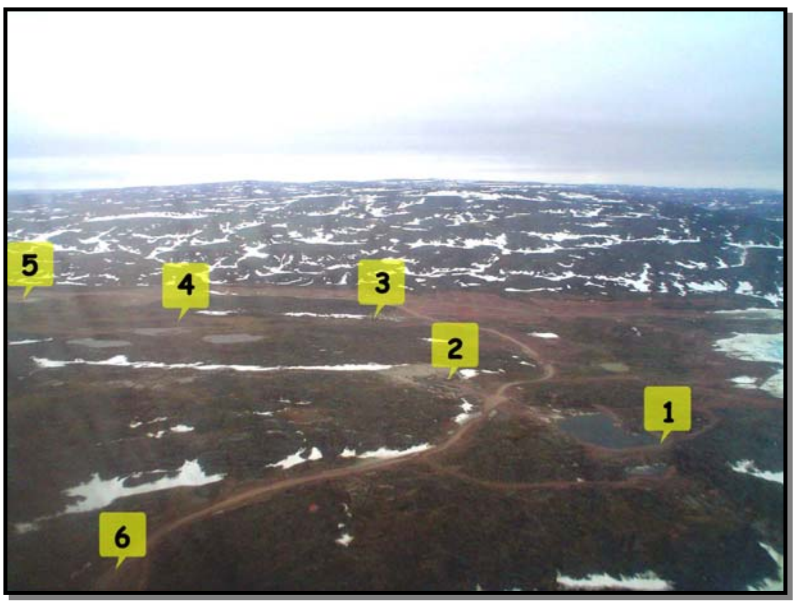


Figure 1.1 Aerial Image of Project Area

1. Sewage Treatment Lagoons and Wetlands, 2. Solid Waste Landfill, 3. Bulk Metal/Hazardous Waste Storage, 4. Proposed Site for New Sewage Treatment Facility and Wetlands, 5. Existing Landfarm, 6. Road heading back towards Community.

The community uses trucked services for both water delivery and sewage collection. The Hamlet continues to use a two cell sewage lagoon system that began operation about 14 years ago. The original lagoon was designed as a single cell. The second cell was only constructed later as an ad hoc addition to the system by hamlet crews and does not have much capacity. The system developed leaks and attempts were made to reinforce the berms surrounding the cells in the summer of 2004. Subsequent to the repairs, the leaking was reduced however the effluent continues to leak from the system at an elevated rate. Dillon Consulting made an initial site visit to the community in July 2005 to assess the breaches in the lagoon berms and to test the quality of the effluent being discharged into the ocean. Phase 1 designs were based on the information gathered on site and is outlined in section 2.2 of this report.

Phase 2 of the project will focus on the siting and relocation of the sewage lagoon system, the improvement of the existing solid waste site to a modified sanitary landfill site and the treatment of the bulk metal disposal area. Currently, none of the existing above mentioned facilities is licensed as the Hamlet's previous water license expired on November 1, 1998.

2.0 BACKGROUND

2.1 SCOPE OF WORK

Phase 2 of the project will focus on the siting and relocation of the sewage lagoon system, the improvement of the existing solid waste site to a modified sanitary landfill site and the treatment of the bulk metal disposal area.

The new sewage facilities will consist of a primary storage lagoon with annual discharge of effluent into nearby receiving waters. A location for the new sewage lagoon will be selected from potential sites around the community and will be designed to meet community demand and anticipated effluent standards for a minimum of the next 20 years. Work will include the consideration of landfarm space (whether new or existing) to accept dry sludge from the existing sewage lagoon.

Suggestions will be made for the improvement and upgrade of the existing solid waste facility to allow the current facility to continue to meet the community's solid waste needs over the next 20 years.

Similarly, the existing bulk metals facility will be examined and suggestions will be made to improve operations. The collaborative design team will write the request for tender document for the construction and/or upgrades required for each of the facilities. The facilities will be upgraded to be able to meet the requirements for the application of a new water license that will regulate all of the above.

2.2 PHASE 1 WORK

The following section will present the highlights of the work that was performed as Phase 1 of this project.

The initial site visit was undertaken in July of 2005. Representatives from Dillon met with members of the Community and Government Services team as well as a geotechnical engineer from AMEC to assess and document the current sewage lagoon site. The team was able to discuss possible solutions at that time, as well as look at potential sites for future design, material extraction and construction.

Additional survey work of the site was commissioned by Dillon to more accurately determine the capacity of the existing sewage lagoon and samples of the effluent from the lagoon were taken at appropriate points along the discharge path to be tested for Biochemical Oxygen Demand (BOD5), Ammonia, Total Suspended Solids (TSS) and Fecal Coliforms.

The test samples of the effluent at the final point of discharge on the ocean shore were found to have levels of contamination that were well within the limits defined by the Government of Nunavut (see Appendix E, Effluent Quality, June 2005). The primary concern with the seepage from the lagoon was that the rate of exfiltration into the wetland system below the secondary cell was greater than the rate of inflow into the lagoon. Modifications were planned for the primary cell to allow the lagoon to continue to serve the community until 2008. Two alternative designs were provided for the same site. In addition, another design was presented with capacity to meet expected demand until 2025.

Unfortunately, in mid-August 2005, the old lagoon experienced catastrophic failure, losing most of its sewage through a breach in the native granular berm. Thus an immediate response was requested – a response that would provide a short-term solution, allowing sufficient time and funds for a more permanent design, as originally planned. See Appendix G for a more detailed account.

Primarily, the Phase 1 modifications involved raising the north and west berms to increase the current capacity of the lagoon to meet projected sewage volumes and applying a non-permeable layer of bentonite along the inside face of the berms to eliminate seepage through the berm walls. An overflow flume was also added to the design.

Work was concluded near the end of the summer in 2005. Reports in the fall of 2005 indicated that the implemented chosen solution had not been completely successful in containing the exfiltration from the lagoon. A representative from Dillon Consulting was on site in early November 2005 to assess the continuing seepage from the lagoon. The summary of that inspection is found in Appendix B.

3.0 SEWAGE LAGOON

3.1 APPLICABLE TECHNOLOGIES

3.1.1 Package Treatment Plants

Package Sewage Treatment Plants generally consist of large fibreglass tanks that may be stored above or below ground where raw sewage is directly deposited for immediate processing. Depending on the system, various processes may take place in the tank/tanks including mechanical mixing/aeration and aerobic digestion. The process is constant in southern operations and digestion products are CO_2 and water (Whitewater Sewage Treatment Systems).

Advantages include maximum treatment efficiencies, producing final effluent that meets all required effluent criteria, easy installation with minimum field assembly and minimum maintenance during operation.

With respect to operation in a northern community such as Kugaaruk, permafrost would not allow such a system to operate underground and winter temperatures would not allow the system to work in the winter months. A package treatment plant would require the construction of a heated building to house the system so that the system could continue to run throughout the entire year. The annual operating cost would therefore include power in addition to trucking the sewage. Shipping would be a substantial part of the initial cost.

3.1.2 Engineered Wetlands (Lagoon Systems)

Engineered Wetland systems are widely used throughout the territories and have proven to be effective in treating municipal waste water to produce an effluent that meets all regulatory criteria. There are a number of different types of sewage lagoon systems, with each option differing primarily in retention time and discharge frequency. Selection of the appropriate option depends greatly on climate conditions and existing topography.

The two main types of engineered lagoon systems are constructed lagoons and natural water bodies converted to lagoons. Either of these two lagoon systems may be designed to accommodate the following discharge/detention options:

- Continuous Discharge
    - Short detention
    - Long detention

- Intermittent Discharge
    - Storage lagoon

- Zero Discharge

In constructed lagoon designs, effluent quality is predictable given lagoon size, retention time and raw sewage quality. In remote communities however, construction costs may be considerable.

Natural lake lagoon systems involve using an existing water body that is not significant in terms of fishing or recreational use. It must be noted that the body of water, once converted into a sewage lagoon, may not be used for any other purpose thereafter without completing extensive remedial activities. The conversion of an existing body of water into a sewage lagoon does decrease construction and maintenance costs however.

Another consideration for natural lake lagoon systems is the quality of the effluent being released into the environment. Because of irregular cell geometry, short circuiting of raw effluent is possible. Several considerations must be evaluated before converting a natural existing water body to a sewage lagoon. These considerations include:

- regional hydrology, precipitation and evaporation rates
- area drainage patterns
- geometry of the lake, area and depth
- detention time of the lake, sources and rate of seepage
- varying temperatures of the lake with the seasons
- surrounding topography, available area for construction of primary cells

Continuous discharge lagoons are not commonly used in the Northwest Territories and Nunavut because ice cover during the winter months all but stops treatment of sewage entirely. As a result, most of the lagoon systems in place in the communities consist of single celled, annually discharged, storage lagoons. The long detention time allows sewage to accumulate throughout the year and for treatment to occur during the summer months after the lagoon has thawed completely. Treated effluent is then decanted into the receiving environment in the late fall before freeze up.

Maintenance requirements for sewage lagoons is minimal. The truck pad and discharge flume need to be cleared of ice, snow and frozen sewage during the winter months and the berms require monitoring for seepage and leakage. Piping and drainage systems need to remain clear of blockages and effluent quality requires regular monitoring.

3.2 DESIGN CRITERIA

The Hamlet of Kugaaruk has experienced steady community growth over the latter part of the twentieth century. This growth will naturally continue and must be considered during the design process. The following section outlines a population projection calculated using data from Nunavut Bureau of Statistics and Statistics Canada.

The new sewage treatment system will be designed for a 20 year life span (2008-2028 Phase II Projection). In order to do so, the sewage generation rates per capita and the population of Kugaaruk for the year 2028 were determined. Predicted population values until the year 2020 were provided by Nunavut Bureau of Statistics (Appendix C). Population values beyond 2020 were predicted using the same growth rate as previous years (20 persons per year), and using a percentage growth rate (2.6%) as illustrated in Figure 3.1. The population for 2028 was predicted to be 1127 persons.

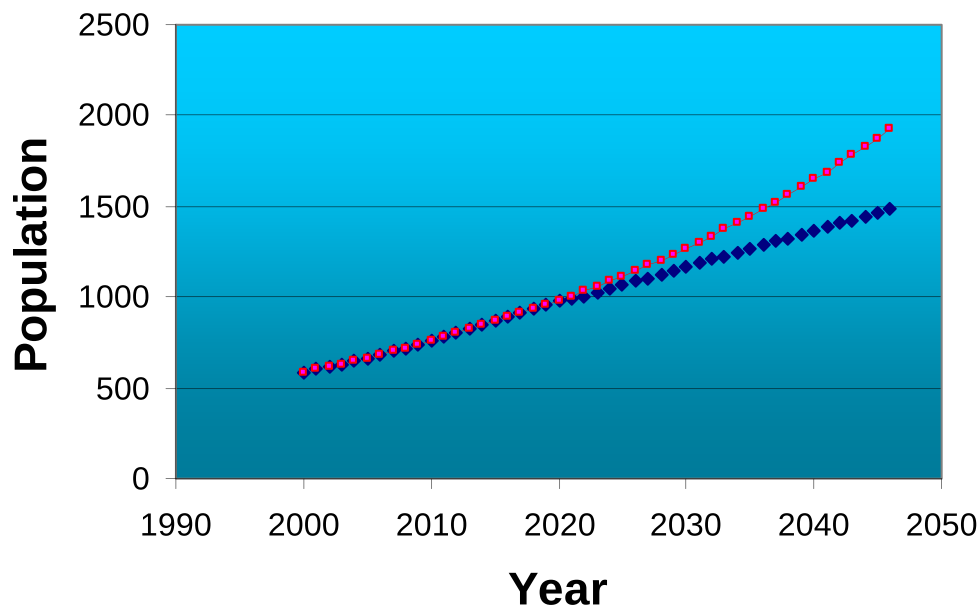


Figure 3.1 Population Growth in Kugaaruk

Data prior 2021 was provided by
Nunavut Bureau of Statistics and data proceeding 2021 was predicted.
Dark blue data points indicate data calculated using a growth rate of
20 persons per year. Red data points indicate data calculated
using a percentage growth rate of 2.6%.

For communities with trucked sewage collection, the amount of sewage generated can be assumed equal to the amount of water consumed. The following formula (Department of Municipal and Community Affairs, Government of the Northwest Territories) is generally used to predict water consumption in Northern communities:

$$\text{Water Usage (l/c/d)} = 90 \text{ l/c/d} \times (1.0 + 0.00023 \times \text{population}) \quad \textbf{[1]}$$

Based on this information, the lagoon will be designed to treat 46 600 m^3, the annual sewage volume for a population of 1127 persons. Table 3.1 shows the calculated sewage generation for years 2006 – 2028.

Table 3.1 Predicted Sewage Generation 2008-2028

Year	Population	MACA Predicted Sewage Production (L)	MACA Predicted Sewage Production (m3)
2006	682	25917944	25918
2007	701	26740630	26741
2008	719	27525049	27525
2009	737	28314363	28314
2010	756	29152840	29153
2011	779	30175137	30175
2012	802	31205428	31205
2013	823	32153109	32153
2014	844	33107455	33107
2015	867	34160336	34160
2016	889	35174920	35175
2017	911	36196818	36197
2018	934	37272986	37273
2019	957	38357147	38357
2020	979	39401651	39402
2021	987	39779893	39780
2022	1007	40735733	40736
2023	1027	41697587	41698
2024	1047	42665455	42665
2025	1067	43639337	43639
2026	1087	44619232	44619
2027	1107	45605140	45605
2028	1127	46597062	46597

3.3 POTENTIAL LOCATIONS

When Phase I work was being completed for repairs to the existing sewage lagoon, one of the options introduced a possible long term solution for the community’s sewage needs. This option involved repairing and raising the berm walls to eliminate seepage out of the existing system and blasting rock out of the centre of the lagoon to substancially increase the capacity of the lagoon. Since the lagoon continues to leak through the berm walls into the receiving environment, extensive work would be required to repair the berm walls before the existing berm could be considered for continued long term use.

In addition to this option involving the existing lagoon, three potential new locations have been identified for the community's sewage lagoon. All three options will make use of existing topography. Each will require the construction of a four walled berm system to contain the sewage.

One main location has been identified as the potential site for the new sewage lagoon. The three options have been proposed for the given site. The site is located alongside the existing road. Drawing 101 in Appendix A shows the three proposed options for the new sewage lagoon. Drawing 201 in Appendix A shows the berm cross sections and details for the three proposed options. No cutting will be required for any of the options. Costs for the amount of berm fill required were based on the volumes from these drawings.

One of the potential issues for the proposed new site is the impact that sewage operations will have on the community's golf course and on cabins in the vicinity. The new site is also farther away from the community than the existing site, resulting in increased trucking costs.

3.4 CELL GEOMETRY

In order to promote plug flow conditions and to avoid short-circuiting of raw sewage, the storage lagoon should be constructed with a rectangular shape. Raw sewage will be discharged from the sewage trucks at one end and treated effluent will be decanted from the lagoon at the opposite end. All three options that have been considered in this report are rectangular and bordered by berms on all four sides, building up on existing topography. The size of the lagoon options in terms of berm height and length varies depending on the existing topography of the option. Generally, the berms will be build up with 3:1 slopes on both the inside and outside faces with a 4m roadway running along the top of the berm for access to the lagoon and decant systems.

Two options exist for the design of the berms that contain the lagoon. The first is the installation of a synthetic liner in the berm. The drawings in Appendix A illustrate this option. The second is the installation of a layer of insulation just below the crest of the berm to encourage the creation of a frozen core inside the berm. Both options are described and illustrated in the AMEC Geotechnical Investigation report in Appendix C.

3.4.1 Drainage Swale

The drainage swale will be a trench that will run approximately 1m from the toe of the berm around the outside perimeter of the new sewage lagoon to collect and direct runoff from the berms to the overflow area for collection and sampling purposes. The drainage swale can be found on Drawing 201 in Appendix A.

3.4.2 Overflow Flume

The overflow flume on the new sewage lagoon will be similar in design to the overflow flume that was installed in the existing sewage lagoon. It serves to provide an outlet for effluent should lagoon levels exceed berm height. It involves a culvert nested into riprap running along the top of the berm and continuing down the outside of the berm to the riprap field in the receiving environment below. Details of the overflow flume can be found on Drawing 201 in Appendix A.

3.5 DISCHARGE FLUME

The discharge flume will be located at the end of the truck turnaround pad at the entrance to the sewage lagoon. The sewage truck will use the discharge flume to deposit raw sewage into the lagoon from the truck pad. There will be a treated lumber wheel stop and bollards at the edge of the pad to prevent the truck from backing into the sewage lagoon. From the truck pad, the offload chute consisting of two 800mm diameter nestable culverts will run down the inside slope of the berm to the rip rap field at the bottom of the lagoon. Details of the discharge flume and truck pad can be found on Drawing 201 in Appendix A.

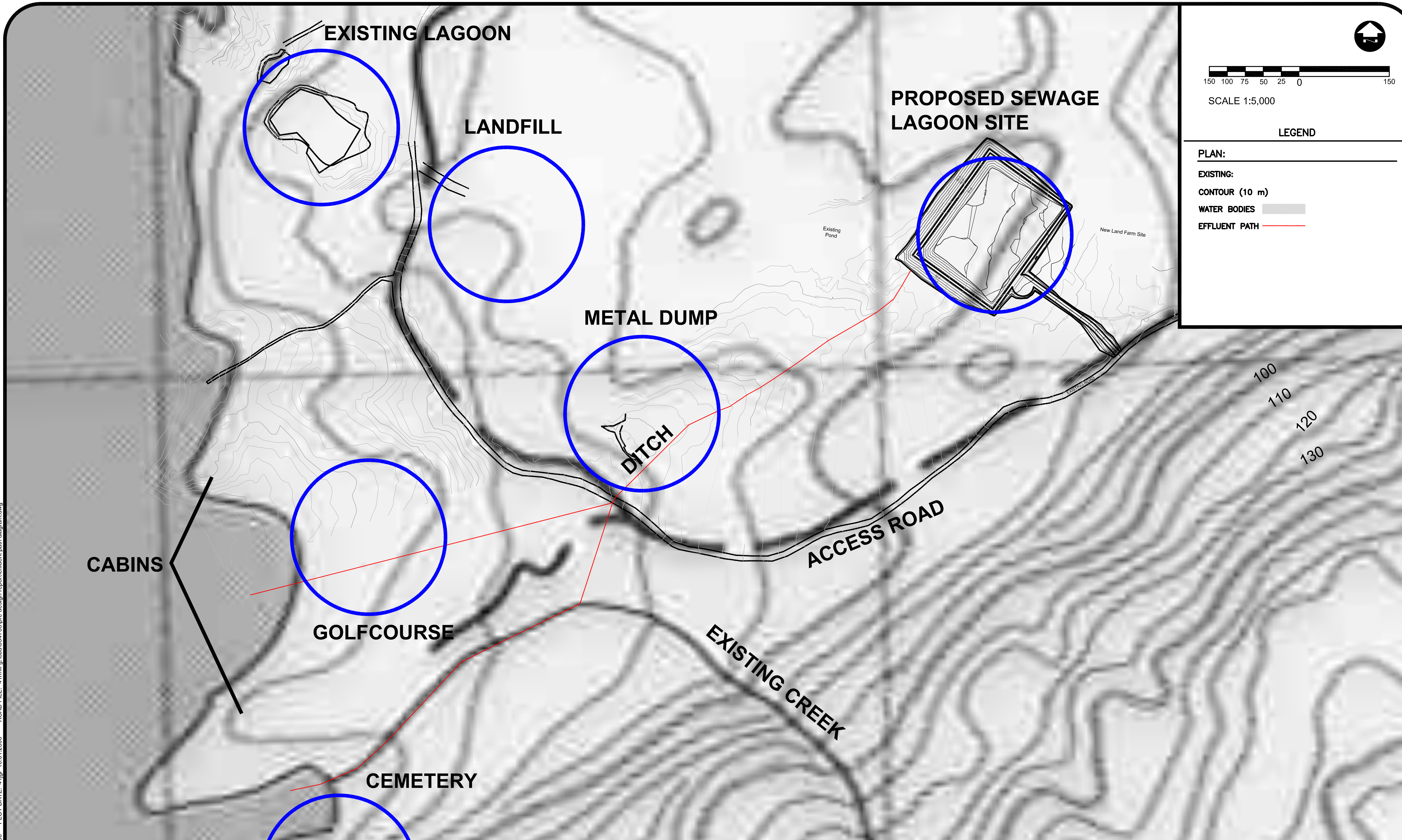
3.6 DECANT SYSTEM/SEWAGE PUMP

The decant system will be located at the opposite end of the lagoon to the truck turnaround pad and discharge flume. The lagoon will be annually discharged by pumping effluent into the receiving environment from the discharge end of the lagoon using a powered pump. Given the maximum annual sewage volume of 46,600m^3 (46.6 million litres), the Gorman Rupp model T6A60S-3054C diesel engine driven self priming pump will be able to decant the lagoon annually over a period of two weeks.

Given the location of the new sewage lagoon, the effluent path is shown in Figure 3.2. Obstacles between the sewage lagoon and the ocean environment include the bulky metal dump, the community's golf course, the cemetery and existing cabins on the ocean shore. The effluent will be diverted around the bulky metal dump site via ditch to the south side of the road. A 300mm culvert runing under the road will be required. From there, the effluent will flow to the ocean through the golf course. Alternatively, although it will not be possible to circumvent the golf course entirely, it may be possible to divert the effluent to flow into the nearby creek that runs to the ocean.

3.7 SPILL CONTINGENCY PLAN

Possible sources for sewage spills in Kugaaruk are the sewage trucks, sewage holding tanks in a home or community building, or through a breach of the sewage lagoon walls. In the event of a sewage spill, the personal safety of those involved should be considered first. The source of the spill should be identified and if safe to do so, the source should be shut off or plugged. The area should be secured so that no vehicles or persons may enter and if safe to do so, the spill should



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PROJECT	SEWAGE LAGOON AND SOLID WASTE FACILITIES KUGAARUK, NUNAVUT	PROJECT NUMBER	05-4755-2000
		DATE	01/9/06
TITLE	Effluent Path Diagram	FIGURE NUMBER	3.2

be contained so that it does not spread. The appropriate authorities should then be notified to activate the Spill Recovery Plan and to notify all relevant government departments. They will then proceed with spill containment and collection, preferably using the back-up sewage truck and a loader and all contaminated materials will be disposed of in the soil landfarm. The spill contact area will be treated with lime and covered with soil.

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A full Spill Contingency Plan will be included in the Operations and Maintenance Manual once the new site is complete. A sample Table of Contents for the Spill Contingency Plan can be found in Appendix G.

3.8 LANDFARM

The sludge from the sewage lagoon will need to be collected approximately every five years. It should be treated in a landfarm either within the solid waste facility site or at another designated location.

At this point, landfarm use is unclear. A new landfarm may be required to accommodate the sludge from the sewage lagoon.

4.0 SANITARY LANDFILL

4.1 APPLICABLE TECHNOLOGIES

Due to their size and often remote location, most smaller communities in the north maintain a form of landfill for solid waste disposal. There are a number of different methods to maximize landfill space. Generally the method chosen depends on the topography of the location. The three main methods are the area method, the trench method and the depression method.

The area method requires the construction of a berm so that waste may be deposited and pushed up against it to create the first cell. Each subsequent cell is deposited and compacted against the previous one until the designated area has been filled. A second berm may be constructed on top of the first cell for additional cells to increase landfill capacity. The area method is appropriate for areas where bedrock exists and trenching is not possible.

The trench method involves the creation of a trench in which waste is deposited and compacted. Waste is alternated with cover material until the trench is full at which point the area method may be applied to increase landfill capacity.

The depression method is used when there is an existing depression at the site. Waste is deposited and compacted down the slope of the depression until it becomes level with the top of the depression. When waste and cover material have filled the depression, the area method may be used to increase landfill capacity.

4.2 DESIGN CRITERIA

To predict solid waste generation, a generation rate of 0.014 m^3/c/d is assumed (Department of Municipal and Community Affairs, Government of the Northwest Territories) for general residential refuse and 0.001 m^3/c/d for school refuse. Projected population statistics used to calculate sewage generation volumes were also used to calculate solid waste generation volumes. Based on a student population of 225 in 2001 (population between the ages of 5 and 19, 2001 census data from Statistics Canada), subsequent student populations for forecasted years were estimated as 37% of the population of the community. Table 4.1 shows the predicted solid waste generation for years 2006-2028. The total amount of solid waste generated from 2006 to 2028 is estimated to be 117,728 m^3.

Table 4.1 Predicted Solid Waste Generation 2008-2028

Year	POP	Student POP (37% of total Population)	MACA Predicted Residential Solid Waste Production (m3)	MACA Predicted School Solid Waste Production (m3)	MACA Predicted Total Yearly Solid Waste Production
006	682	252	3485.0	368.4	3853.4
2007	701	259	3582.1	378.7	3960.8
2008	719	266	3674.1	388.4	4062.5
2009	737	273	3766.1	398.1	4164.2
2010	756	280	3863.2	408.4	4271.6
2011	779	288	3980.7	420.8	4401.5
2012	802	297	4098.2	433.2	4531.5
2013	823	305	4205.5	444.6	4650.1
2014	844	312	4312.8	455.9	4768.8
2015	867	321	4430.4	468.4	4898.7
2016	889	329	4542.8	480.2	5023.0
2017	911	337	4655.2	492.1	5147.3
2018	934	346	4772.7	504.5	5277.3
2019	957	354	4890.3	517.0	5407.2
2020	979	362	5002.7	528.9	5531.5
2021	987	365	5043.6	533.2	5576.7
2022	1007	373	5145.8	544.0	5689.8
2023	1027	380	5248.0	554.8	5802.8
2024	1047	387	5350.2	565.6	5915.8
2025	1067	395	5452.4	576.4	6028.8
2026	1087	402	5554.6	587.2	6141.8
2027	1107	410	5656.8	598.0	6254.8
2028	1127	417	5759.0	608.8	6367.8

4.3 PROPOSED OPTIONS

The existing solid waste landfill has not yet reached capacity and space still exists to continue to serve the community's solid waste disposal needs. Further design and development of the site should be performed to control the impact current operations are having on the surrounding environment however the site is able to continue to accommodate the community's waste for the next 20 years. Figure 4.1 shows several views of the current landfill operations. The upper left image shows wayward waste material as well as runoff flowing towards the road. The upper right image shows how ineffective the current wind fence is for windblown debris and litter. The bottom image illustrates a panoramic view on the landfill site as of summer 2005.

Work done on improving operations at the solid waste facility will include the creation of an Operation and Maintenance manual for the site. A sample table of contents for this document is found in Appendix G. The Abandonment and Restoration Plan for the site will also be developed at this time.

Figure 4.1 Existing Solid Waste Landfill Site

4.4 SITE GEOMETRY

The solid waste site should be reorganized to be able to accommodate a total of 117,730m^3 of additional solid waste over the projected 20 year life span of the revised facility. A layer of cover should be applied over the entire site and litter should be contained within the site. Surveys of the existing solid waste site indicated that additional space existed to accommodate more of the community's waste.

4.5 FENCING

The new landfill should be entirely fenced in with a lockable gate to keep wildlife out and to confine windblown waste and debris. Perimeter fencing will also help to keep children from playing near the landfill. Snow fencing should also be installed to reduce snow accumulation within the site.

Fencing will be installed on top of the perimeter berm and will be permanent. Wooden fences are not recommended as they may pose a fire hazard if open burning is to take place on the landfill site to reduce waste volume. A Watchman fence is recommended. This is a low cost, high efficiency, tight-lock construction, steel wire fence fabric that is ideal for industrial applications. T-rail posts are spaced every ten feet and barbed wire may be installed along the top if required.

4.6 SIGNAGE

The landfill requires signage to notify the public of landfill hours as well as to direct the public to the appropriate locations within the site so that waste is deposited in the correct area. The hazardous waste area should be designated so that the public is aware of the dangers associated with these types of waste. A contact number should also be posted at the entrance to the site so that the appropriate people are notified in the event of an emergency at the landfill.

4.7 HAZARDOUS WASTES

Hazardous wastes are potentially hazardous to human health and the environment and require special disposal techniques to eliminate or reduce the hazard. Existing sewage and landfill facilities in Nunavut communities are not designed to handle hazardous wastes when disposed of improperly. Hazardous waste that landfills are unable to handle should be sent south and handled properly by facilities designated to handle hazardous wastes.

Delivery of hazardous waste to the landfill is the responsibility of the waste generator. Household Hazardous Wastes (HHW) include products such as mercury thermometers and switches, insecticides, pesticides, batteries, used oil, oil-based paints, anti-freeze and many small flammable or explosive containers. Other Hazardous wastes include asbestos, glycol and animal carcasses. Proper training is required for the solid waste facility staff that are responsible for the safe shipping of these materials.

Prior to shipping any unknown material, testing must be completed to understand the exact contents within the 55-Gallon drums. Dillon Consulting can complete the testing and identification of the hazardous material. Once the identification process is complete, the material can be classified.

Hazardous waste material is handled similar to bulky steel material (see section 5.0). Crating is to be done on-site in Kugaaruk. Crating material should be sent to the site a year prior to shipping the hazardous waste. The hazardous material, once crated, will need to be placed on the beach in Kugaaruk to be handled by the Canadian Coast Guard.

Shipping this material will require special provisions from the Department of Environment with the Government of Nunavut. The Department of Environment must issue a manifest prior to shipping any hazardous waste material.

Shipping from Nunavut to Valleyfield (Montreal)

Nunavut Eastern Arctic Shipping (NEAS)	1-877-225-6327
Nunavut Sealink and Supply (NSSI)	1-450-635-0833
Canada Coast Guard	1-613-998-1585

Table 4.2 Unit Prices for Shipping Costs

Destination	**Unit Prices**
Kugaaruk to Nanisivik	$103 per Ton or 2.5 cubic metres
Nanisivik to Montreal	$206 per Ton or 2.5 cubic metres

Once the material is received in Montreal, the hazardous waste can be brought to one of two locations that handle hazardous waste:

Stablex – 1-450-430-9230 in Blainville Quebec

Or

Clean Harbors 1-450-691-9610 in Mercier Quebec

Other communities can have metal waste material demobilized by the same method as Kugaaruk. Other communities that are serviced by the Nanisivik route are Arctic Bay, Resolute Bay, Grise Fiord, Pond Inlet, Clyde River, and Qikiqtarjuaq.

4.8 RECYCLING, USE, AND RE-USE STRATEGIES

In consultation with Hamlet administration, foreman, and residents, strategies appropriate to the needs of the community will be sought - strategies to deal with some of the wastes which normally end up in the Sanitary Landfill. Every community in the Arctic uses the dump as a source of spare parts and building materials. There may be cost-effective ways of facilitating this practice and thus keeping more waste from entering the landfill permanently. Some practices thus identified may not be viable at present, but area provision should be made to accommodate them in the future as the community grows.

5.0 BULKY METALS DISPOSAL

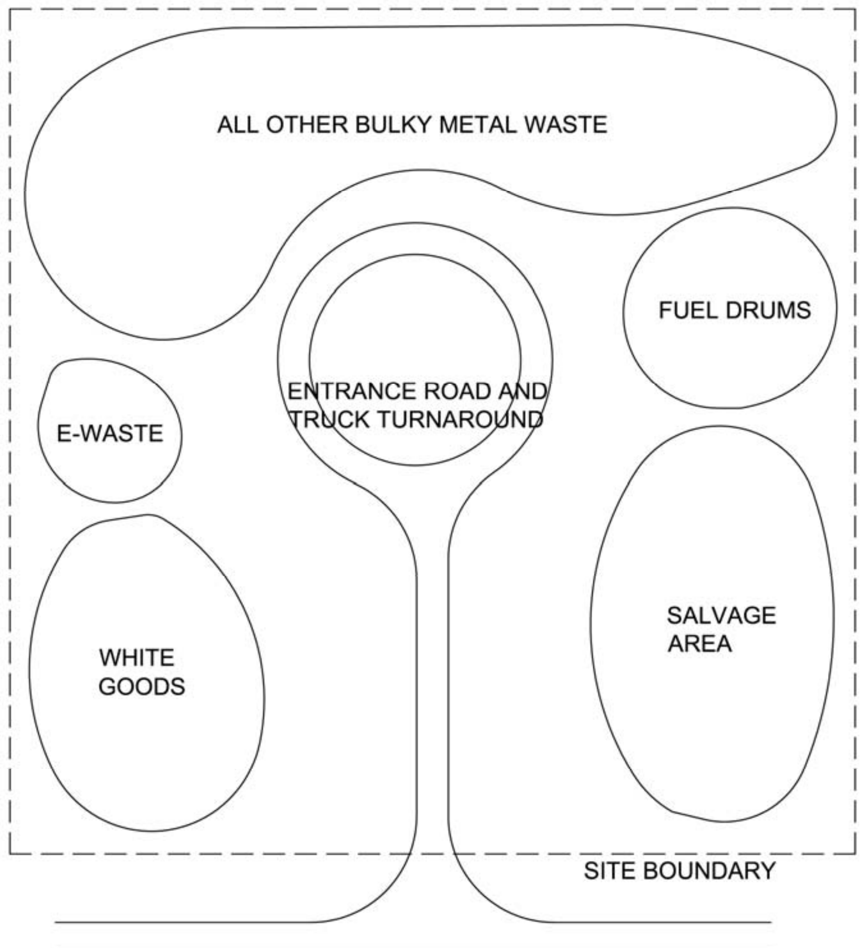
5.1 DESIGN CRITERIA

Currently, the bulky metals area at the landfill is disorganized and unkept (see figure 5.1). Bulky metal wastes include fuel drums, discarded automobiles, decommissioned heavy machinery, scrap metals such as siding, pipes, frames and automotive parts, e-waste such as computers and monitors and white goods or residential appliances, which include refrigerators, stoves, dishwashers, dryers, laundry machines and hot water heaters. These wastes are stored separately from the general waste stream so that they may be shipped south for possible reclamation when sufficient quantities exist.

Figure 5.1: Existing Bulky Metals Disposal Area

The existing materials at the site should be organized and sorted. Materials that may be re-claimed or recycled should be set aside to be shipped. The site should be re-organized to provide designated areas for specific types of waste. Figure 5.2 shows a sample layout for the re-organized bulky metal waste site.

Figure 5.2: Schematic Bulky Waste Site Layout



Some of these bulky metals contain materials that are hazardous to the environment and should be stored separately so that removal of hazardous components may be carried out by a certified technician before the bulky materials are shipped out of the community. White goods containing Ozone Depleting Substances (ODS) include refrigerators and freezers. These fluids need to be removed from the appliances by a certified technician. Batteries should be removed from used automobiles and all fluids should be drained to be stored separately from the vehicles before depositing at the bulky metals area at the site. E-wastes contain components made from heavy metals that should be removed and stored separately to be shipped south for reclamation when sufficient quantities exist. If hazardous materials are drained and removed from the metal wastes, there should be no potential for leaching of hazardous fluids into the environment.

Once the waste has been sorted and the site has been organized, designated areas may be set up to allow for scavenging of certain goods from the bulky metals site for re-use. Anything that might still be of use may be piled seperately for scavenging or recyling by the community.

Materials that have been designated as reclaimable or recyclable will need to be shipped out of the community for processing.

5.2 SHIPPING OPTIONS

Shipping metals off site in the North takes precision planning and logistics. Many communities only have access to one sealift boat a year. As such, material that are being shipping off site need to be prepared and ready prior to the shipping date. Preparations include breakdown of scrap metal and compaction of waste drums. Optional tools can be purchased, which include a 55-gallon drum crusher or a chop saw. A 55-gallon drum crusher can be purchased for $13,500, whereas a chop saw can be purchased for $1,000. The chop saw is labour intensive and would require a large amount of saw blades. A drum crusher is necessary to compress 55 gallon drums. They have the ability to compress a 55-gallon drum down to 9cm in height. Each compaction cycle takes 24 seconds.

Since materials will need to be handled by forklifts, shipping bulky metal waste off site will require preparations through crating or sealift containers. If the materials are to be crated, crating material will need to be shipped to the site a year prior to shipping the metal waste material. This will also allow time to crate the material and have it ready for the sealift boat. Crating the material can be completed by local contractors (Kudlik) or through the Hamlet of Kugaaruk. Once the waste material has been crated, the material must be brought to the beach side for pickup by sealift barge.

Communities such as Kugaaruk only have access to one sealift boat a year. The Canadian Coast guard provides this service between Kugaaruk and Nanisivik. From Nanisivik to the south, Nunavut Eastern Arctic Shipping (NEAS) transports material to the Montreal port of Valleyfield. Since two different cargo boat services Nanisivik and Kugaaruk each year and at different times of the year, the waste material will have to be shipped to Nanisivik from Kugaaruk and stored over the winter months in Nanisivik. From Nanisivik, the material can be shipped south the following year.

Once the material arrives in Montreal, a local shipping company can receive the material and bring it to a local metals depot for recycling.

Shipping from Nunavut to Valleyfield (Montreal)

Nunavut Eastern Arctic Shipping (NEAS) 1-877-225-6327

Nunavut Sealink and Supply (NSSI) 1-450-635-0833
Canada Coast Guard 1-613-998-1585

Table 5.1 Unit Prices for Shipping Costs

Destination	Unit Prices
Kugaaruk to Nanisivik	$103 per Ton or 2.5 cubic metres
Nanisivik to Montreal	$206 per Ton or 2.5 cubic metres

Receiving Metals (Montreal Based)

Lorbec Metals 1-800-688-9135
Globe Metals 1-800-700-6382

Table 5.2 Unit Prices for Scrap Metals

Material	Unit Prices
Steel	$80 per Ton
Aluminum	$0.45 per Pound
Copper	$1.50 per Pound

Assuming a weight of 2000lbs per drum crusher, the purchase and shipment of one drum crusher to each of the seven hamlets in the Kitikmeot would cost approximately $100,000 as shown in Table 5.3 below.

Table 5.3 Option to Purchase Drum Crushers for Communities

Kitikmeot Community	Drum Crusher [$]	NTCL Sealift (from Hay River) [$]	Totals
Cambridge Bay	13,500.00	781.50	14,281.50
Gjoa Haven	13,500.00	859.75	14,359.75
Bathurst Inlet	13,500.00	781.50	14,281.50
Kugaaruk*	13,500.00	630.00	14,130.00
Kugluktuk	13,500.00	712.75	14,212.75
Taloyoak	13,500.00	894.50	14,394.50
Umingmaktok	13,500.00	781.50	14,281.50
			99,941.50

* Kugaaruk Sealift costs from Montreal

Alternatively, one drum crusher could be purchased for use by the entire the region to be stored in the Community and Government Services garage in Cambridge Bay. The drum crusher could then be air-freighted to one or two communities a year to process empty drums.

6.0 REGULATORY REQUIREMENTS

The hamlet requires a new water licence. The following section describes the interests of various regulatory agencies with respect to this project.

6.1 DEPARTMENT OF FISHERIES AND OCEANS (DFO)

The Department of Fisheries and Oceans' main concern with this project is related to the destruction of fish habitat as a result of sewage lagoon outfall. Phase II of the project must consider Sections 35 and 36 of the Fisheries Act when choosing and implementing the new sewage treatment site as well as any road construction that might take place.

Any stream crossings that might occur during construction will require assessment by DFO. Required submissions will therefore include the location of the work (map showing proposed work and possible fish bearing habitats), description of work to be done, the schedule of work and contact information. Once this information has been received, DFO will assess the submission and determine whether or not formal authorization is required. The work planned for this project is not expected to cross any fish bearing habitats.

6.2 DEPARTMENT OF HEALTH AND SOCIAL SERVICES (H&SS)

The primary concern of the Department of Health and Social Services with regards to this project is the possibility of contamination of the community's water source. As a result, the proposed development must be at least 450 meters away from the nearest residential development and 100m away from the nearest road. Confirmation of future development plans must also be made to verify that no new subdivision plans are being made within 450 meters of the new facility location. A design submission needs to be sent to Cambridge Bay Health and Social Services for review prior to construction.

6.3 ENVIRONMENT CANADA (EC)

Environment Canada will have key participation in application for the new water license for the hamlet. Their previous license (NWB3PEL9803) expired in November of 1998 and a new license is required to regulate the new sewage lagoon and landfill operations. Concerns regarding the approval of the water license in Nunavut are directly related to section 36 of the Fisheries Act at this time, which is mentioned above. The required submissions for the review process consist of 95% drawings of the proposed facilities.

6.4 INDIAN AND NORTHERN AFFAIRS CANADA (INAC)

The Department of Indian and Northern Development (DIAND) will be contacted regarding this project by the Nunavut Water Board once the application for the new water license has been submitted for review. DIAND will then inspect the documents and return any comments within 30 days. Regulations for DIAND are also mirrored from DFO Sections 35 and 36 of the Fisheries Act. Water Licensing, to which DIAND tails on, follows the Nunavut Water & Nunavut Surface Rights Tribunal Act.

6.5 NUNAVUT IMPACT REVIEW BOARD (NIRB)

All Nunavut Impact Review Board reviews will be passed down from the Nunavut Water Board.

6.6 NUNAVUT WATER BOARD (NWB)

The Nunavut Water Board's main concern at this time is that the Hamlet is presently operating without a water license. The application process for the new water license should be made as the required drawings for submission are completed. Required submissions include a minimum of 50% design drawings (positioning of the new facilities should be firm), an Abandonment and Restoration Plan for the old lagoon as well as details for the proposed new lagoon.

Obtaining the new water license will require review of the submission from Environment Canada, the Department of Fisheries and Oceans, the Department of Indian and Northern Development, the Hamlet, the Local Hunters and Trappers Association, the Regional Inuit Association and the NTI Land Claims Organization.

7.0 COST ESTIMATES

Canwest Tanks and Ecological Systems provided a quotation for their TYPE 2 Sewage Treatment Plant given projected community population and effluent criteria. The system, capable of servicing a community of 1,127 people came to $168,000. This cost does not include shipping or the building to house the units that would be required for the tanks to operate in northern climates.

Table 7.1 Cost Estimate for New Sewage Lagoon, Synthetic Liner Option 1

	Amt Req		Unit Price	Estimated Total
Overflow Flume Materials				
Nestable Culvert (450mm Dia)	2	m	$1,200.00	$2,400.00
Mounting Flanges	8	flanges	$150.00	$1,200.00
Rip Rap Bedding	4	m^3	$300.00	$1,200.00
Woven Geotextile	9	m^2	$10.00	$90.00
Berm Material				
Granular Material	35179	m^3	$65.00	$2,286,635.00
Bentonite	577	m^3	$500.00	$288,300.00
GCL Liner	2800	m^2	$60.00	$168,000.00
Rip Rap Cover	2306	m^3	$50.00	$115,320.00
Decanting Pump	1		$34,000.00	$34,000.00
Trailer for pump	1		$8,500.00	$8,500.00
				$2,905,645.00
Engineering	10	%		$290,564.50
Contingency	20	%		$581,129.00
GST	7	%		$203,395.15
Total				**$3,980,733.65**

Table 7.2 Cost Estimate for New Sewage Lagoon, Synthetic Liner Option 2

	Amt Req		Unit Price	Estimated Total
Overflow Flume Materials				
Nestable Culvert (450mm Dia)	2	m	$1,200.00	$2,400.00
Mounting Flanges	8	flanges	$150.00	$1,200.00
Rip Rap Bedding	4	m^3	$300.00	$1,200.00
Woven Geotextile	9	m^2	$10.00	$90.00
Berm Material				
Granular Material	52741	m^3	$65.00	$3,428,165.00
Bentonite	646	m^3	$500.00	$322,900.00
GCL Liner	3423	m^2	$60.00	$205,380.00
Rip Rap Cover	2583	m^3	$50.00	$129,160.00
Decanting Pump	1		$34,000.00	$34,000.00
Trailer for pump	1		$8,500.00	$8,500.00
				$4,090,495.00
Engineering		10	%	$409,049.50
Contingency		20	%	$818,099.00
GST		7	%	$286,334.65
Total				**$5,603,978.15**

Table 7.3 Cost Estimate for New Sewage Lagoon, Synthetic Liner Option 3

	Amt Req		Unit Price	Estimated Total
Overflow Flume Materials				
Nestable Culvert (450mm Dia)	2	m	$1,200.00	$2,400.00
Mounting Flanges	8	flanges	$150.00	$1,200.00
Rip Rap Bedding	4	m^3	$300.00	$1,200.00
Woven Geotextile	9	m^2	$10.00	$90.00
Berm Material				
Granular Material	59053	m^3	$65.00	$3,838,445.00
Bentonite	801	m^3	$500.00	$400,250.00
GCL Liner	3933	m^2	$60.00	$235,980.00
Rip Rap Cover	3202	m^3	$50.00	$160,100.00
Decanting Pump	1		$34,000.00	$34,000.00
Trailer for pump	1		$8,500.00	$8,500.00
				$4,639,665.00
Engineering	10	%		$463,966.50
Contingency	20	%		$927,933.00
GST	7	%		$324,776.55
Total				**$6,356,341.05**

The cost estimates for the new sewage lagoon options were calculated based on berm volumes from the drawings in Appendix A. They do not include costs for the construction of ditches to divert the decanted effluent to the receiving environment or the construction of the access road to the new lagoon from the existing road. Costs for the decommissioning of the existing lagoon are also not included.

The following three estimates are for the new sewage lagoon with the frozen core option. It includes the addition of styrofoam insulation. The details and advantages of this option are presented in the AMEC Geotechnical Investigative Report in Appendix C. The cost of the insulation is calculated based on delivery by sea. Delivery by charter flight is another possibility that would add $30,000 to the cost of the styrofoam insulation.

Table 7.4 Cost Estimate for New Sewage Lagoon, Frozen Core Option 1, Sealift

	Amt Req		Unit Price	Estimated Total
Overflow Flume Materials				
Nestable Culvert (450mm Dia)	2	m	$1,200.00	$2,400.00
Mounting Flanges	8	flanges	$150.00	$1,200.00
Rip Rap Bedding	4	m^3	$300.00	$1,200.00
Woven Geotextile	9	m^2	$10.00	$90.00
Berm Material				
Granular Material	35179	m^3	$65.00	$2,286,635.00
Styrofoam Insulation (50mm)	2492	m^2		$118,500.00
Bentonite	577	m^3	$500.00	$288,300.00
Rip Rap Cover	2306	m^3	$50.00	$115,320.00
Decanting Pump	1		$34,000.00	$34,000.00
Trailer for pump	1		$8,500.00	$8,500.00
				$2,856,145.00
Engineering		10	%	$285,614.50
Contingency		20	%	$571,229.00
GST		7	%	$199,930.15
Total				**$3,912,918.65**

Table 7.5 Cost Estimate for New Sewage Lagoon, frozen Core Option 2, Sealift

	Amt Req		Unit Price	Estimated Total
Overflow Flume Materials				
Nestable Culvert (450mm Dia)	2	m	$1,200.00	$2,400.00
Mounting Flanges	8	flanges	$150.00	$1,200.00
Rip Rap Bedding	4	m^3	$300.00	$1,200.00
Woven Geotextile	9	m^2	$10.00	$90.00
Berm Material				
Granular Material	52741	m^3	$65.00	$3,428,165.00
Styrofoam Insulation (50mm)	2145	m^2		$108,000.00
Bentonite	646	m^3	$500.00	$322,900.00
Rip Rap Cover	2583	m^3	$50.00	$129,160.00
Decanting Pump	1		$34,000.00	$34,000.00
Trailer for pump	1		$8,500.00	$8,500.00
				$3,993,115.00
Engineering		10	%	$399,311.50
Contingency		20	%	$798,623.00
GST		7	%	$279,518.05
Total				**$5,470,567.55**

Table 7.6 Cost Estimate for New Sewage Lagoon, Frozen Core Option 3, Sealift

	Amt Req		Unit Price	Estimated Total
Overflow Flume Materials				
Nestable Culvert (450mm Dia)	2	m	$1,200.00	$2,400.00
Mounting Flanges	8	flanges	$150.00	$1,200.00
Rip Rap Bedding	4	m^3	$300.00	$1,200.00
Woven Geotextile	9	m^2	$10.00	$90.00
Berm Material				
Granular Material	59053	m^3	$65.00	$3,838,445.00
Styrofoam Insulation (50mm)	2440	m^2		$117,500.00
Bentonite	801	m^3	$500.00	$400,250.00
Rip Rap Cover	3202	m^3	$50.00	$160,100.00
Decanting Pump	1		$34,000.00	$34,000.00
Trailer for pump	1		$8,500.00	$8,500.00
				$4,521,185.00
Engineering	10	%		$452,118.50
Contingency	20	%		$904,237.00
GST	7	%		$316,482.95
Total				**$6,194,023.45**

Table 7.7 Cost Estimate for Increasing Capacity of Existing Sewage Lagoon

	Amt Req		Unit Price	Estimated Total
Preparation				
Existing Fluid to be Decanted	8000	m^3	5	$40,000.00
Sludge and Solids to be remvd	3000	m^3	40	$120,000.00
Overflow Flume Materials				
Nestable Culvert (450mm Dia)	2	m	$1,200.00	$2,400.00
Mounting Flanges	8	flanges	$150.00	$1,200.00
Rip Rap Bedding	4	m^3	$300.00	$1,200.00
Woven Geotextile	9	m^2	$10.00	$90.00
Berm Material				
Granular Material	5000	m^3	$65.00	$325,000.00
Bentonite	212	m^3	$500.00	$106,000.00
GCL Liner	2250	m^2	$60.00	$135,000.00
Rip Rap Cover	920	m^3	$50.00	$46,000.00
Additional Lagoon Capacity				
Blasting	20000	m^3	$57.00	$1,140,000.00
				$1,916,890.00
Engineering		10	%	$191,689.00
Contingency		20	%	$383,378.00
GST		7	%	$134,182.30
Total				**$2,626,139.30**

8.0 ASSESSMENT OF OPTIONS

8.1 ASSESSMENT PROCESS AND SELECTION

To evaluate the proposed alternatives, the Kepner-Tregoe (K/T) decision making process was used. This process is a management tool used to reduce the subjectivity of the evaluation of various alternatives when several parameters govern the final choice.

The first step in this process involves testing the alternatives against a set of "must" criteria. The "must" criteria represents characteristics that any alternative must have to provide an adequate facility. The "must" criteria are evaluated on a pass or fail basis. In order to proceed further in the analysis, an option is required to meet the "must" criteria. Those options failing this test are eliminated from further evaluation.

The second step in the K/T process involves evaluating the options which pass the "must" criteria against specific "want" criteria. The "want" criteria represents the desired characteristics of the system. Each "want" criteria is assigned a weight factor from 1 to 10, to rank its relative importance against the other criteria. Each alternative is then graded on a scale of 0 to 10 for each criterion, based on how well the alternative meets the requirement. If an alternative completely meets the criterion, it is given a score of 10. If it entirely does not meet the criterion, it scores 0.

Individual criterion scores for each option are then added and the option with the highest total score becomes the recommended alternative.

8.2 CRITERIA FOR SELECTION

The following "must" criteria for sewage treatment system were developed by Dillon, in consultation with community members and officials, with an understanding of the requirements of the regulatory agencies:

1. The facility must be able to satisfy the 20-year design volume requirements;
2. The land selected for the site must be available and suitable (i.e. consistent with community development plans) for use;
3. The facility must provide effluent meeting the requirements of the various Acts and regulations; and
4. The facility must provide year-round service.

The result of the first phase of the K/T analyses is shown in **Table 8.1.** This evaluation resulted in all options being short listed for further analysis.

Table 8.1 Kepner/Tregoe Analysis of Sewage Treatment Against "Must" Criteria

Criteria	**Option**			
	1	**2**	**3**	**4**
Meet 20 Year Demand and allows future expansion	yes	yes	yes	yes
Meets Community Land Use Plan	yes	yes	yes	yes

S1 – Package sewage treatment plant
S2 – New sewage lagoon with liner
S3 – New sewage lagoon with frozen core berms
S4 – Blasting to expand capacity of existing sewage lagoon

"Want Criteria"

Alternatives passing the first phase of the K/T analysis were next analyzed in greater detail against the following "want" criteria, which was again prepared by Dillon in consultation the community officials:

1. Minimize Operating Cost (including power and heat, operator, chemical etc) – 10
2. Minimize Capital Cost - 10
3. Minimize Lifecycle Cost - 5
4. Maximize ability of local operator to maintain plant - 5
5. Minimize Impact on existing golf course - 10
6. Minimize environmental impact - 5
7. Meets new criteria in Canada Wide Strategy for Municipal Waste Effluent - 5

In accordance with the K/T process, each "want" criteria was given a weighing factor, based on its relative importance or significance. Each of the four alternatives was then graded on a scale from 1 to 10, based on how well it met the criterion (10 = fully, 0 = not at all). **Table 8.2** summarizes the "want" criteria, alternative scoring and total scores.

Table 8.2 Analysis of Options Against "Want" Criteria

"WANT CRITERIA"	Criteria Weight	Option 1		2		3		4	
		Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Annual Operating Cost	10	2	20	7	70	7	70	10	100
Capital Cost	10	6	60	7	70	7	70	10	100
Lifecycle Cost	5	2	10	7	35	7	35	10	50
Operator Maintenance	5	7	35	9	45	9	45	10	50
Impact on Golf Course	10	7	70	2	20	2	20	10	100
Environmental Impact	5	8	40	7	35	7	35	10	50
Canadian Waste Effluent Standards	5	10	50	10	50	10	50	2	10
			285		325		325		460

Throughout this document, there are cost analyses of various options. The analyses have been carried out as outlined below:

Cost	Description
Capital Cost	Cost of construction for the facility.
Annual operation and Maintenance Costs	The cost of operation may include: manpower, energy requirements, fuel, general maintenance (light bulbs, paint), and equipment replacement.
Life Cycle Costs	The calculation of the total facility cost over a 20-year period includes the capital, operations and maintenance costs. The life cycle value is shown as a present value, which is calculated at a discount rate of 4%.

Operational costs and capital costs are developed to compare the options. The estimates are based on the best available information, and are considered as Class "C" estimates. As the process moves from preliminary design to detailed design, the estimates will be refined to reflect the increased accuracy of the information gathered in the detail design process.

8.3 RECOMMENDATIONS FOR IMPLEMENTATION

From the foregoing discussions (the Kepner/Tregoe analysis) the best balanced choice for a new facility is option 4 with a weighted score of 460. The second highest scoring option are options 2 and 3 with a score 325. The most cost effective solution to the sewage and solid waste treatment and disposal is option 4. The area where option 4 scored lowest is with meeting the new Canada wide strategy for municipal waste effluent quality. The estimated cost for option 4 was taken from the estimate provided by Kudlik in their submission for Phase I.

9.0 REFERENCES

FSC, 2003. Municipal and Community Affairs Guidelines for the Planning, Design, Operation and Maintenance of Modified Solid Waste Sites in the NWT, Report prepared Ferguson, Simek, Clark Engineers and Architects

GNWT, 1988. Municipal and Community Affairs Guidelines for the Planning, Design, Operation and Maintenance of Wastewater Lagoon Systems in the NWT (Volumes 1 and 2). Report prepared by G.W. Heinke, D.W. Smith and G. R. Finch

GNWT, 1992. Northwest Territories Water Board Guidelines for the Discharge of Treated Municipal Wastewater in the NWT.

GNWT, Municipal and Community Affairs Guidelines for the Siting of Solid Waste Disposal Sites in the Vicinity of Community Airports in the NWT

APPENDIX A

DRAWINGS

Nunavut

THE GOVERNMENT OF NUNAVUT
COMMUNITY AND GOVERNMENT SERVICES

PROJECT: SEWAGE & SOLID WASTE FACILITY
LOCATION: KUGAARUK, NUNAVUT
PROJECT NO:
DATE: NOV 2005

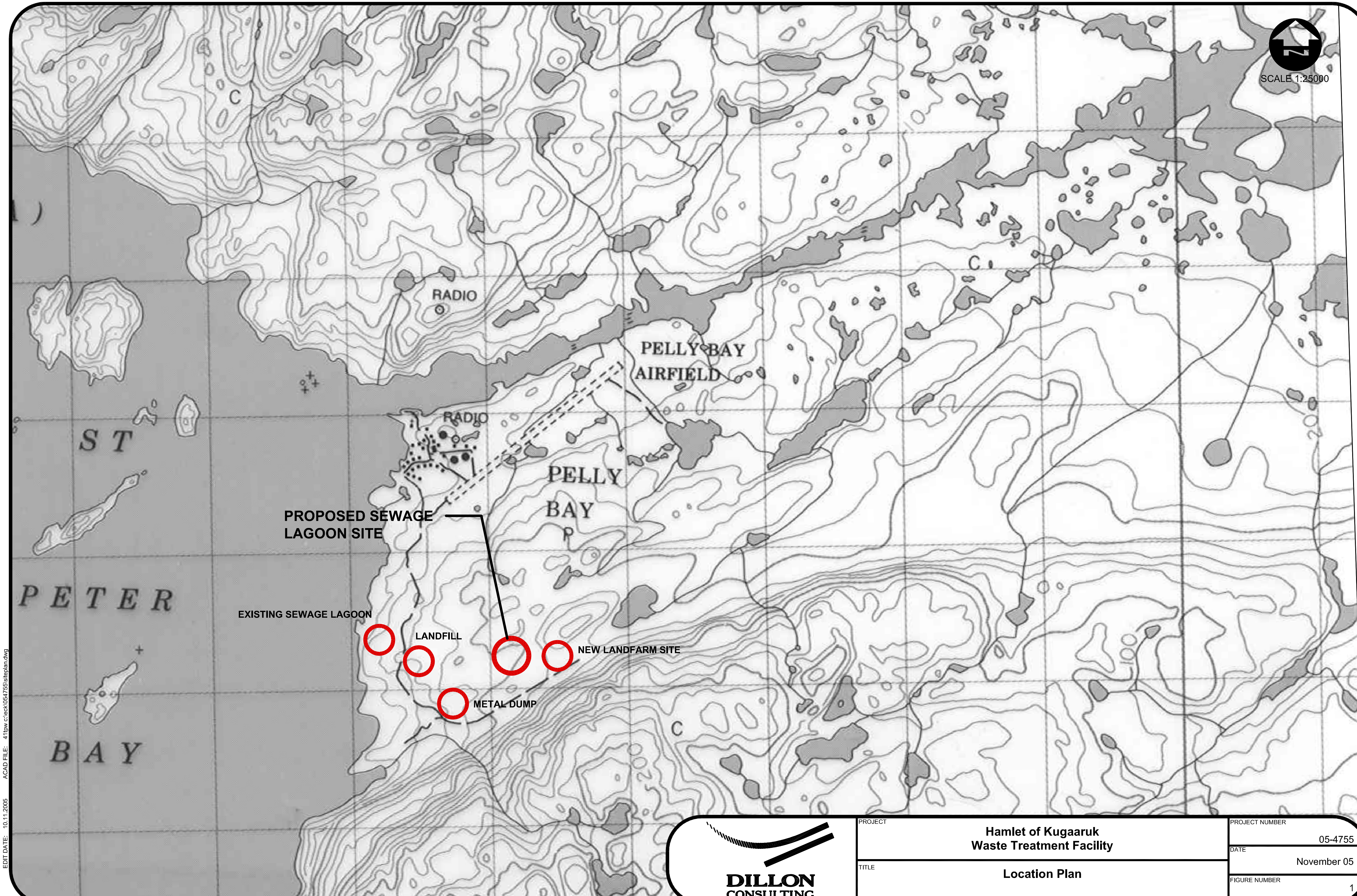
LOCATION PLAN

PRELIMINARY ONLY
NOT FOR CONSTRUCTION

DILLON CONSULTING

EDIT DATE: 10.11.2005 PLOT DATE: 41tpw 11.11.2005 ACAD FILE: administrator c:\eck\054755\dwg\cover.dwg

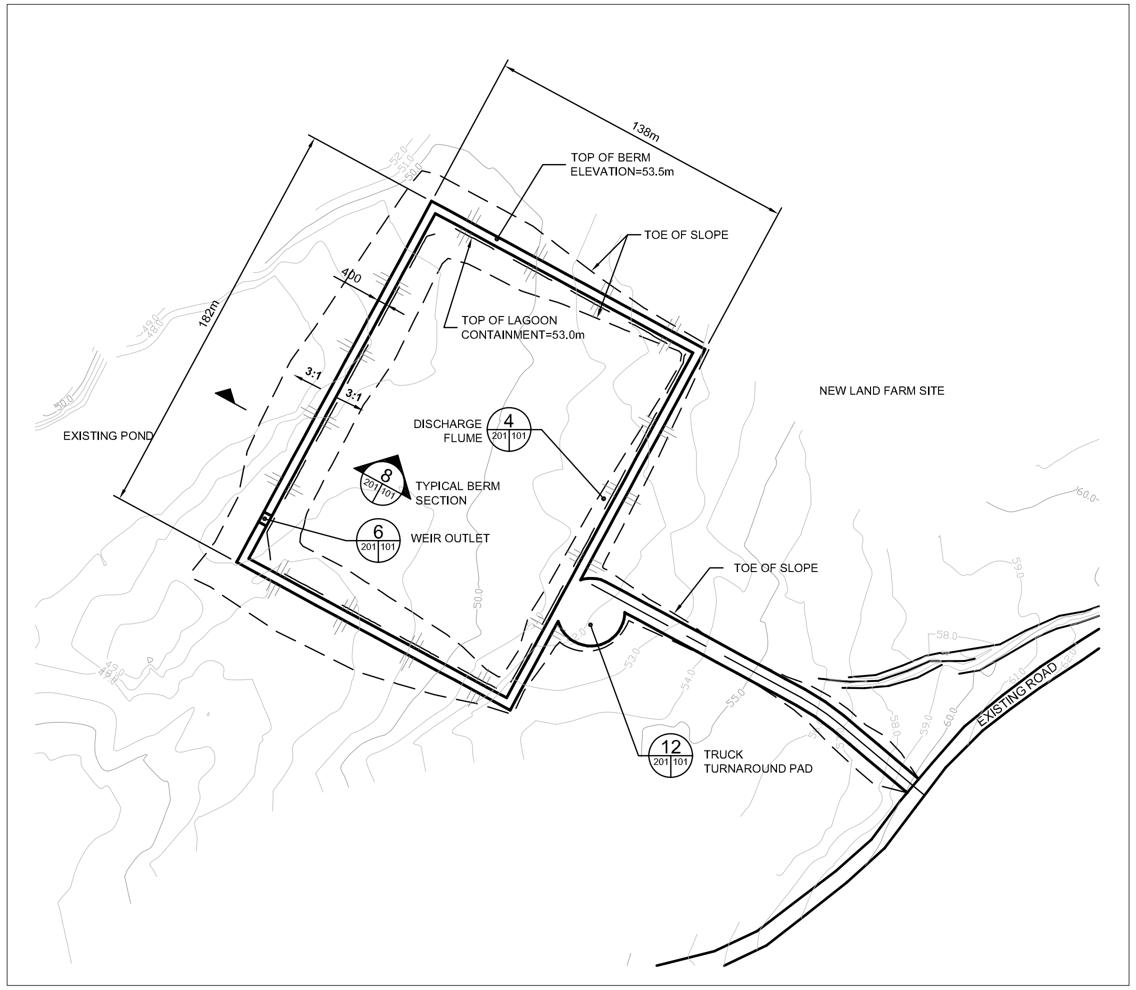
DRAWING NUMBER 001



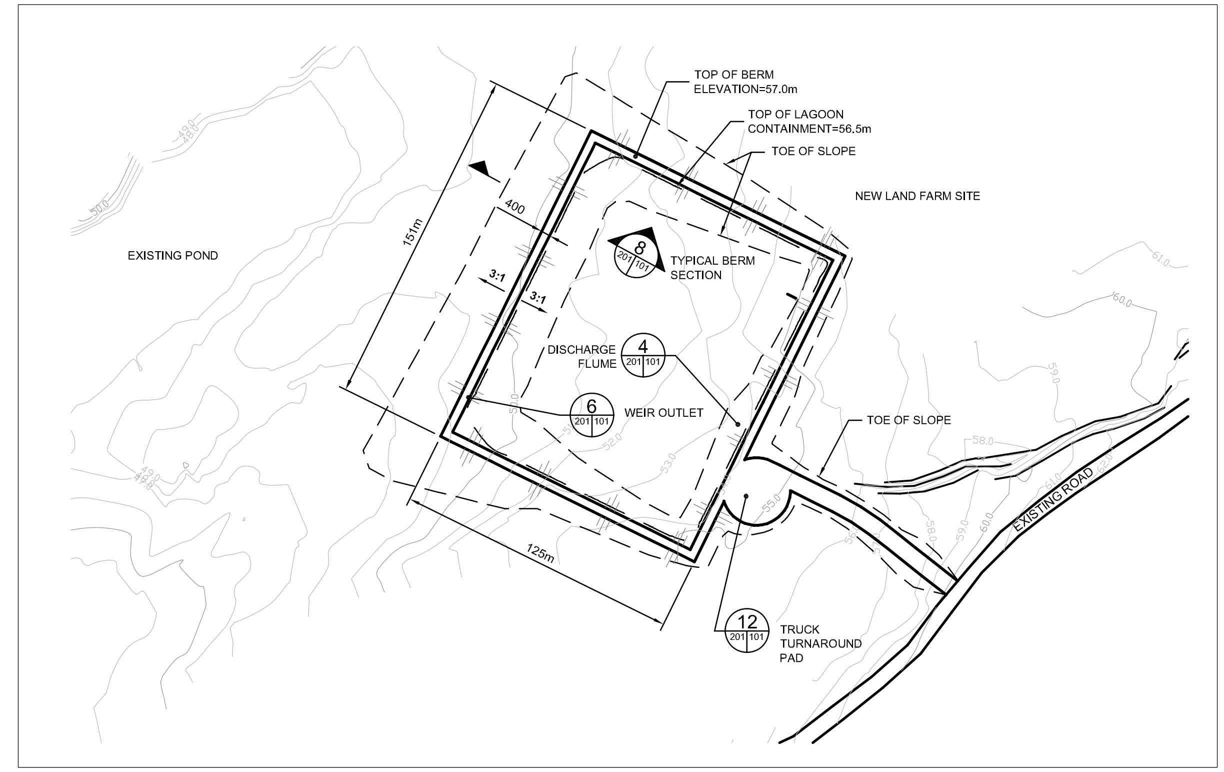
DILLON CONSULTING

PROJECT	Hamlet of Kugaaruk Waste Treatment Facility
TITLE	Location Plan
PROJECT NUMBER	05-4755
DATE	November 05
FIGURE NUMBER	1

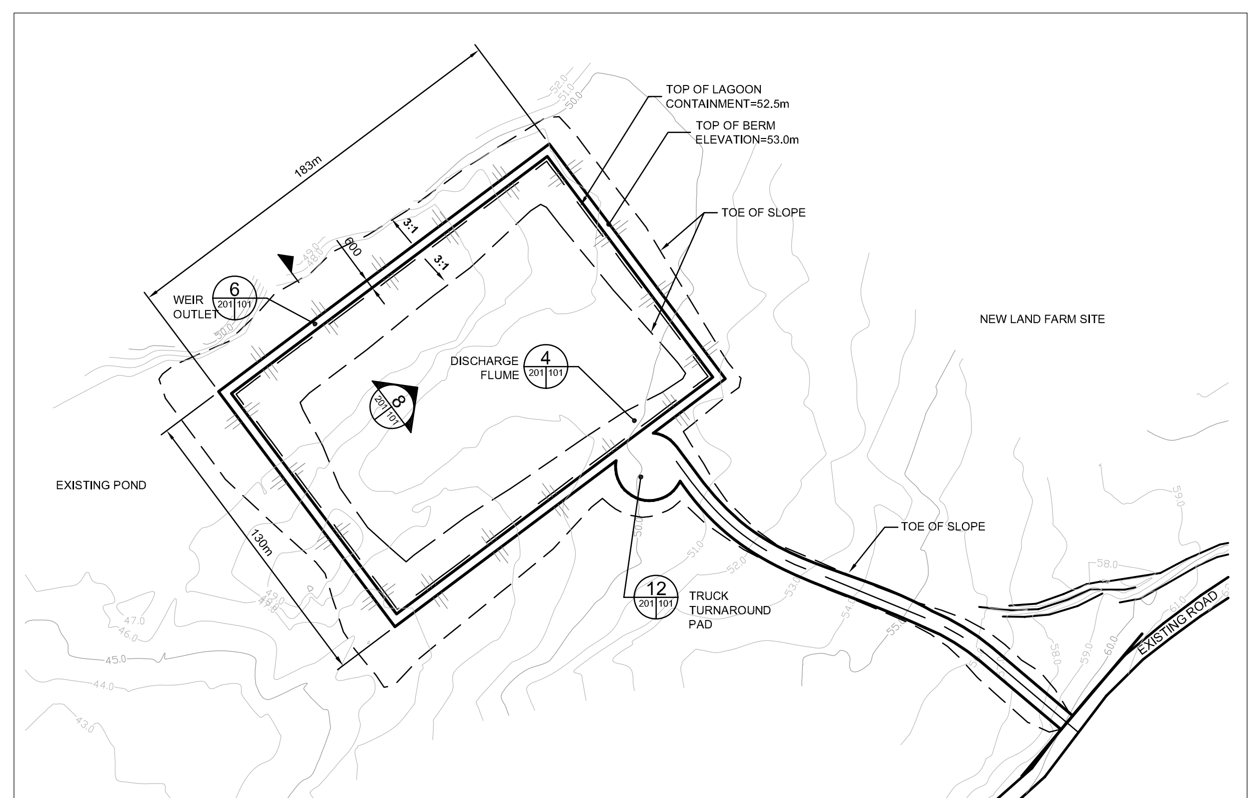
EDIT DATE: 10.11.2005 ACAD FILE: 41tpw c\eck\054755\siteplan.dwg



1 OPTION 1 SEWAGE LAGOON LAYOUT
SCALE 1:1500



2 OPTION 2 SEWAGE LAGOON LAYOUT
SCALE 1:1500



3 OPTION 3 SEWAGE LAGOON LAYOUT
SCALE 1:1500

PRELIMINARY ONLY
NOT FOR CONSTRUCTION

DRAWING REDUCED
NOT TO SCALE

CHANGE	DATE	DESCRIPTION	CHECK

REVISIONS

DESIGN	DRAWN	CHECKED	DATE
GS	----	GS	NOV 2005

Nunavut

PROJECT
SEWAGE & SOLID WASTE FACILITY
KUGAARUK, NUNAVUT
SEWAGE & SOLID WASTE FACILITY

TITLE
OPTIONS

DILLON CONSULTING

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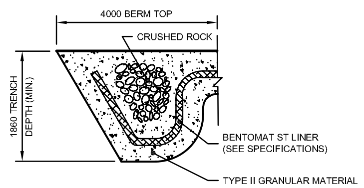
CLIENT PROJECT NUMBER	####
DRAWING NUMBER	101



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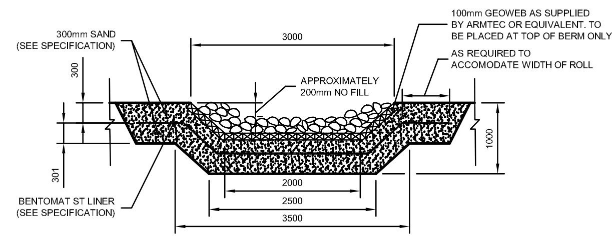

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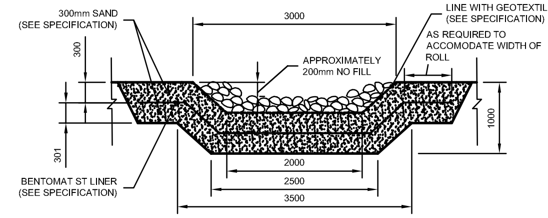

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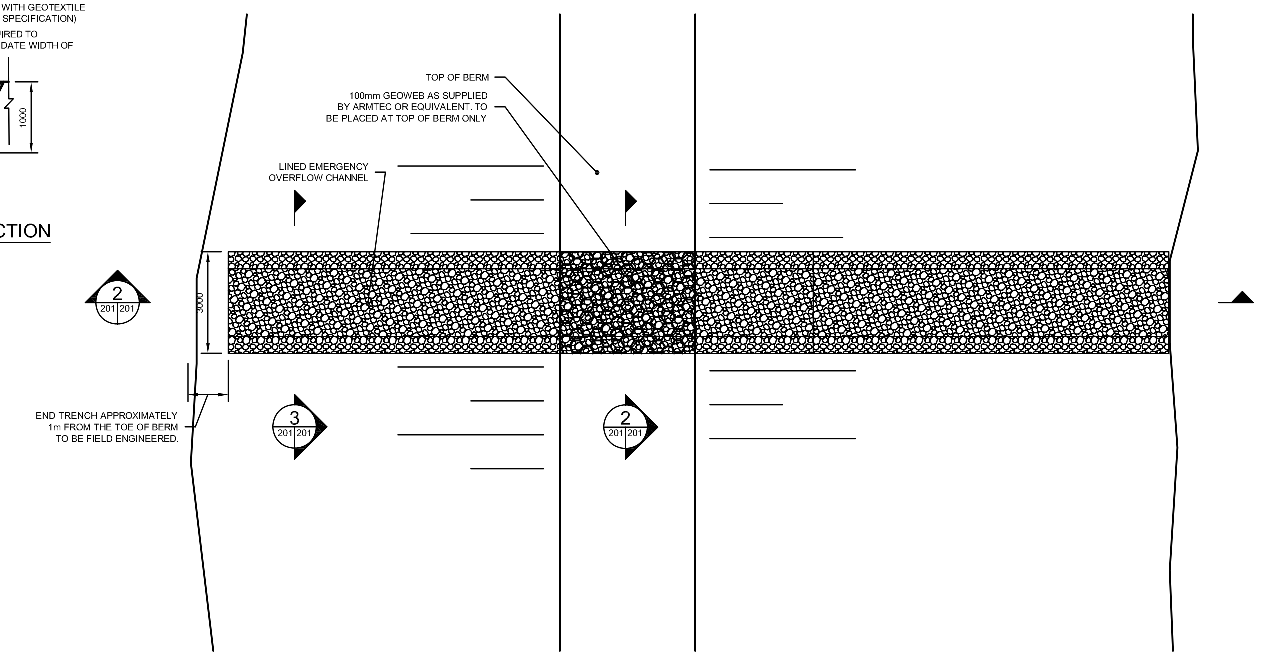

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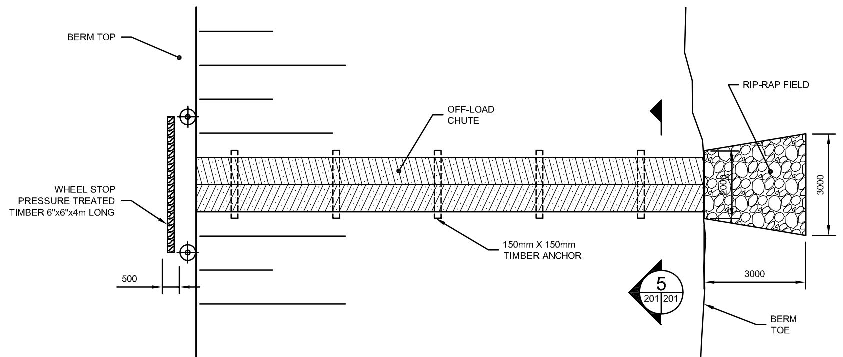

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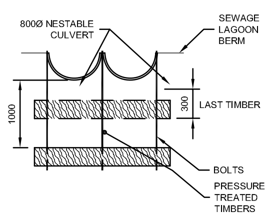

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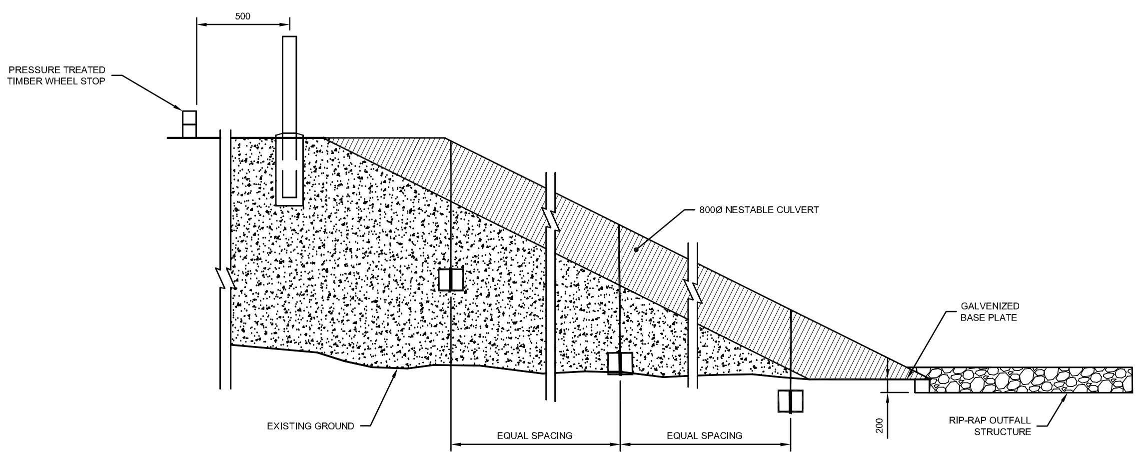

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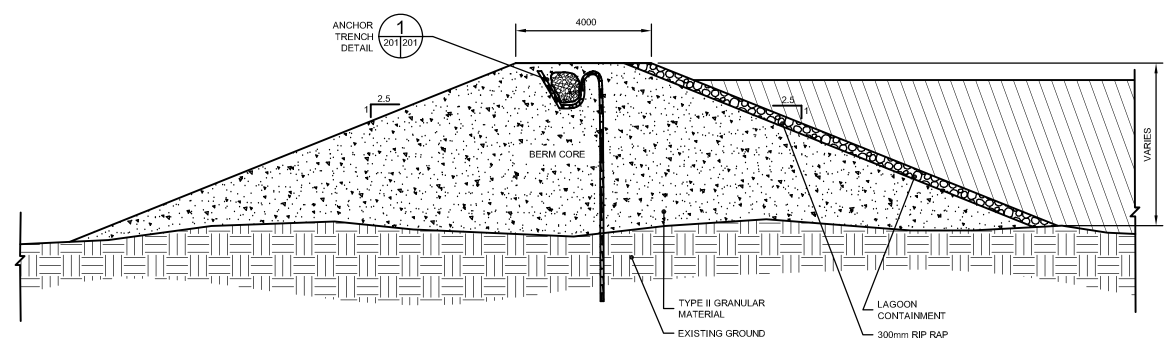

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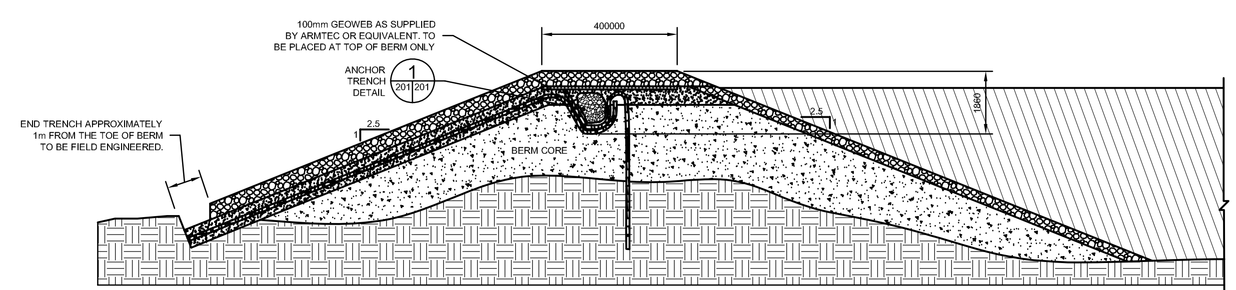

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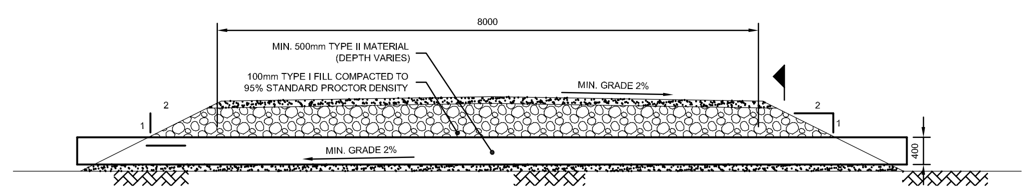

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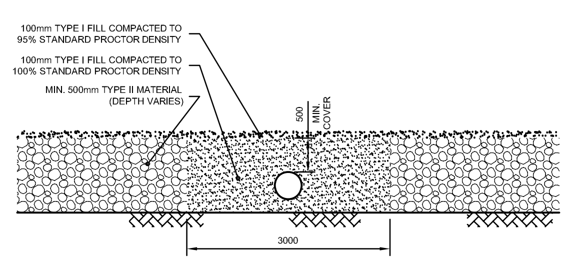

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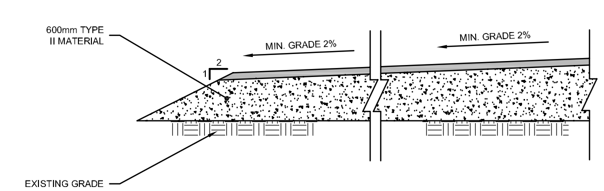

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PRELIMINARY ONLY
NOT FOR CONSTRUCTION

DRAWING REDUCED
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CHANGE	DATE	DESCRIPTION	CHECK

REVISIONS

DESIGN	DRAWN	CHECKED	DATE
GS	----	GS	NOV 2005

PROJECT
SEWAGE & SOLID WASTE FACILITY
KUGAARUK, NUNAVUT
SEWAGE & SOLID WASTE FACILITY

TITLE
DETAILS

DILLON CONSULTING

SCALE	AS SHOWN
DILLON PROJECT NUMBER	05-4755-200
CLIENT PROJECT NUMBER	####
DRAWING NUMBER	201

APPENDIX B

NOVEMBER 2005 SITE INSPECTION REPORT

Repair work on the leakage of the Kugaaruk sewage lagoon was carried out in the fall of 2005. The work involved the drainage of the upper lagoon into the lower lagoon followed by raising of the berm and clearing of the sludge at the bottom of the north berm for the application of a layer of bentonite to the inside face of the berm. No work was done on the western berm or to the lower lagoon berm.

Government of Nunavut Conservation Officer Remi Krikort observed that seepage was still occuring through the upper lagoon's northern berm and through the lower lagoon's berm after the work was complete. He reported the seepage to the Spill Line.

On November 1 and November 2, 2005, Janice Lee, a representative of Dillon Consulting was in Kugaaruk to inspect the site and to document the reported seepage of the lagoon.

The site inspection took place on November 2. Janice was accompanied to the sewage lagoon site by Hamlet Foreman Gaetan Apsaktuan. Visual inspection of the north berm showed that leakage had occurred through the berm at the same locations that had leaked prior to the repairs on the berm. Upon inspection of the berm containing the second lagoon, which was not repaired by Kudlik Construction, leakage was observed coming from the centre of the berm and at both sides, also the same locations that had been leaking prior to the repairs. The leakage appeared to be coming from the base of the berms.

The berm containing the lower lagoon had actually been breached when it was filled to capacity during the repairs. This breach is located in the centre of the berm where most of the seepage is occuring and was repaired by the Hamlet. A culvert was installed at the end of the berm during repairs to accommodate overflow. It was observed that the rate of seepage out of the second lagoon had increased by visually comparing the current levels with the levels in the wetland area the year before. The higher rate of seepage that was observed coming out of the second lagoon may be attributed to increased head caused by the sewage from the first lagoon being pumped into the second lagoon without first draining the second lagoon into the receiving environment.

The hamlet's main concerns are with the mix of raw and treated sewage that had been drained from the first lagoon into the second lagoon that seeped out from the second lagoon as well as that which overflowed into the receiving environment from the second lagoon during the repairs. The sewage between the second lagoon and the ocean is currently frozen, however the spring thaw will release the mix (that contains raw sewage) directly into the ocean.

Due to the timing of construction late in the year, it is possible that the bentonite that was applied to seal the inside face of the berm froze before it could achieve maximum efficiency.

The attached photo sheets illustrate the state of the lagoon system during and after repairs.

Photograph 1
Lower lagoon filled to capacity during repairs, September 2005

Photograph 2
Lower lagoon after a month of seepage, October 2005

Photograph 3
Seepage out of the lower lagoon berm, October 2005

Photograph 4
Seepage out of the lower lagoon berm, November 2005

Photograph 5
Seepage from the north berm of the upper lagoon, November 2005

APPENDIX C

AMEC GEOTECHNICAL INVESTIGATION REPORT

31 October 2005
YX00749

Dillon Consulting Limited
P.O. Box 1409,
4920 47th Street
Yellowknife, NT X1A 2P1

Attention: **Mr. Gary Strong, P.Eng.**
Project Manager.

Dear Mr. Strong:

Re: Geotechnical Investigation for Sewage Lagoon,
Kugaaruk, NU

At the request of Mr. Gary Strong, on behalf of Dillon Consulting Limited (DCL), AMEC Earth & Environmental (AMEC), a division of AMEC Americas Limited conducted a site reconnaissance, compiled geotechnical information for the Kugaaruk area and conducted geothermal modeling for a proposed sewage treatment system in Kugaaruk, NU. The purpose of the investigation is to assist DCL in the design of a new Sewage and Solid Waste Facility in Kugaaruk, as requested by the Government of Nunavut, Department of Community and Government Services (DCGS).

Authorization to proceed with the investigation was received by signing Dillon's Short Form Agreement for Sub-Consultant Service dated June 3, 2005 for the above noted project.

1.0 BACKGROUND INFORMATION AND SCOPE OF WORK

The community of Kugaaruk is located on the southwest shore of the Simpson Peninsula on St Peter Bay near the mouth of the St. Peter River. The community is located approximately 1312 km northeast of Yellowknife.

The proposed sewage lagoon dyke is intended to replace the existing dyke that was built approximately 15 years ago. It is understood that the preferred design of the dyke consist of either a frozen-core, low permeability core, or synthetic liner dam concept. The purpose of the undertaken geothermal analysis was to confirm that the frozen core option is feasible for climate conditions of the Kugaaruk area.

In accordance with AMEC's proposal dated April 29, 2005 and subsequent discussions with DCL, the original scope of the study was to carry out a full scale of geotechnical investigation, including a field reconnaissance, drilling of 6 to 10 boreholes, interpretation of aerial photographs and numerical modeling of the temperature regime of the sewage lagoon dyke.

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Following the site reconnaissance and discussions with DCL, the drilling program and aerial photograph interpretation were not undertaken due to sufficient information being obtained to design the new lagoon dyke on the basis of the site reconnaissance alone.

AMEC conducted the site reconnaissance between July 3 and 6, 2005. Representatives of DCL and DCGS were also on site during the site reconnaissance. The site reconnaissance was conducted by Mr. Keith Barnes, P.Eng. of AMEC's Calgary office. Based on the initial review and site reconnaissance, AMEC was able to:

- Identify or characterize the climate, geological and permafrost conditions within the Kugaaruk area;
- provide a geotechnical characterization of existing dyke;
- perform geothermal modeling of the dyke temperatures; and
- prepare recommendations for the development of low permeability lagoon dyke.

Results and findings of this investigation are presented in subsequent sections of this report.

2.0 EXISTING DYKE DESCRIPTION

The existing lagoon dyke is located about 1 km, south-southwest of the community of Kugaaruk and about 2.4 km southwest of the airport (Figure 1, Appendix A). It is understood that the existing sewage lagoon has been in operation for about 15 years and is of a traditional operational design. Effluent in the lagoon is intended to slowly filter through the downstream berm. It is understood that current water quality tests from water taken downstream of the dyke appears to indicate that the effluent exceeds acceptable values.

Based on discussions with Hamlet personnel and observations made during the site reconnaissance, it appears that the crest of the downstream berm had been breached at times in the past. The effluent appears to flow directly from the lagoon, through or over the breached berm and then downstream. Hence, minimal filtering of the effluent by the berm occurs. Photos 1 and 2 (Appendix A) show the breached portion of the dyke.

One gravel sample was taken from the existing dyke structure in order to assess grain size and moisture content. Results of the testing are presented in Appendix C.

3.0 CLIMATE, GEOLOGY AND PERMAFROST

Kugaaruk is located geographically at approximately 68°32' N latitude and 89°49' W longitude. No weather station is located in the community and therefore climate records for Kugaaruk were estimated based on Igloolik data for the period from 1971 to 2000. Igloolik is located approximately 300 km to the northeast. The average annual mean temperature in Igloolik is reported to be –13.2 °C. The average thawing and freezing indices are calculated to be about 405 °C-days and -5169 °C-days, respectively.

The bedrock in the community and surrounding area generally consists of granite gneiss that is weathered, jointed and foliated extensively. The lines of intersection of these discontinuities have created numerous large rock wedges that have been dislodged to some extent by repeated freeze-thaw cycles.

During the period between the last glaciation and isostatic rebound (approximately 10000 years ago), the waters from Gulf of Boothia inundated coastal areas to an elevation of about 125 m above the recent sea level. The marine waters reworked the surficial glacial sediments and as a result, fine grained sediments can be found between bedrock ridges at the lower elevations.

Kugaaruk is located north of the Arctic Cycle within the continuous permafrost zone. The depth of seasonal thaw has been estimated to vary from about 0.7 m to 1.3 m, depending on ground vegetative cover and surface disturbance. Mean annual permafrost temperature within the study area is estimated to be about -7°C to –11°C at depth of 12 m to 15 m. The lower permafrost temperatures would be typical for terrains with organic cover and small snow cover, while warmer ground temperature would prevail near the ocean shoreline in gravelly and coarse grained sandy soils.

4.0 INFERRED SUBSURFACE CONDITIONS

Based on the field reconnaissance, it is concluded that lagoon site is covered with an organic mat, 50 mm to 100 mm thick (Photographs 3 and 4, Appendix A). Poorly drained, saturated fine grained marine deposits (sand and silt with gravel and inclusions of cobbles and boulders) likely underlie the organics. It is expected that the thickness of the overburden would be 1 to 3 meters. Bedrock outcrops can be encountered randomly over the lagoon impoundment (Photographs 5 and 6, Appendix A).

The mean annual permafrost temperature is expected to be in a range of -10 °C to -11 °C at a depth of about 15 m at the lagoon site. The thickness of the active layer is expected to be 0.7 m to about 1.0 m. This corresponds to sandy/gravelly saturated soil with the organic mat.

5.0 ENGINEERING RECOMMENDATIONS

This section provides recommendations on design and construction of the dyke and results of the dyke temperature modelling.

5.1 Proposed Sewage Dyke - Liner Option

Figure 2 and 3 (Appendix B) provides a cross section of the sewage dyke as it is proposed by DCL. The upstream and downstream slopes of the dyke are 1V:2 H, corresponding to a slope steepness of about 26.5 degrees. The proposed dyke is 5 m high and 4 m wide at the crest.

Silty sand, sand and gravel may be used for the dyke construction. This material should be screened and cobbles and boulders should be removed. One potential material could be from the granular deposit east of the proposed site. Results of material testing conducted on a stockpiled granular deposit east of the proposed site are presented in Appendix C.

The material used for dyke construction should be unfrozen at the time of placement and should be spread by lifts, 250 mm thick or less (compacted thickness). The compaction can be undertaken by bulldozers, D-6 or heavier. Placement and compaction of fill should not be conducted in freezing conditions. At least three bulldozer passes per lift should be applied. The upper layer, 0.5 m thick can contain cobbles, up to 200 mm in size, protecting the dyke slopes against water erosion.

An appropriate synthetic liner should be installed in a near vertical position to an assumed elevation of 98.5 m, 1.5 m below existing ground surface, near the upstream slope. The liner should extend into a 1.5 m deep cut-off trench below the base of the dyke. The cut-off trench should be backfilled with compacted clayey material or grouted. The liner curtain should then extend straight up to the top of the dyke as shown at Figure 2, Appendix B. An alternative liner option is shown at Figure 3, Appendix B. It is understood that the constructability of the alternative option is more favourable however the liner is almost twice as long.

A low-permeability soil cut-off wall within the dyke, designed for unfrozen performance may also be considered. Due to the minimal amounts of fine grained soils observed in the lagoon area, this option was not considered feasible.

5.2 Proposed Sewage Dyke - Frozen Core Option

As it was described in Section 3.0, the Kugaaruk region is characterized by a mean annual air temperature of about -13.2 ^{o}C. AMEC considers that the concept of a frozen core dyke to provide primary containment of lagoon waters is technically feasible. Based on the proposed water level being located 1 m below the dyke crest, a 50 mm thick insulation layer (Styrofoam HI, or equivalent) should be placed immediately below the dyke crest. The intent of the insulation is to reduce the seasonal and long-term thawing that could penetrate the dyke crest, leading to increased percolation of effluent through the dyke. The insulation should be placed on the compacted and smooth gravelly / sandy surface. A sand layer, 100 mm thick, should be placed and compacted on the insulation to 95% of standard Proctor maximum dry density. A protective layer of rock fill about 400 mm thick should be placed over the sand layer (Figure 4, Appendix B).

5.3 Existing Dyke Repair

If it is desired to re-design the existing dyke with a frozen core, the dyke should be re-built to the dimensions presented in Figure 4. All loose material should be removed from the existing dyke surface and all erosion features should be cleaned of water and ice. The erosion features should be backfilled with engineered fill and compacted with a heavy bulldozer.

Following to the removal of the loose material and backfilling of the erosion features, the dyke should be raised to the design elevation in 250 mm (compacted) lifts. A 50 mm insulation layer should be placed on the compacted and smooth gravelly / sandy surface of the dyke crest as shown at Figure 4, Appendix B. A sand layer, 100 mm thick, should be placed and compacted on the insulation to 95% of standard Proctor maximum dry density. A protective layer of rock fill about 400 mm thick should be placed over the sand layer.

5.4 Sewage Dyke Geothermal Analyses

The geothermal modeling program SIMPTEMP, 2D version, (developed in-house by AMEC) was used to analyze the geothermal regimes for the two types of dykes. The geothermal simulator uses the finite element method to compute a numerical solution of the heat transfer problem. Physical/mathematical algorithms used in the SIMTEMP model have been published, and the simulation process has been verified- both against well-known analytical solutions of the heat transfer problem, and as compared with numerical solutions produced by other commercial/non-commercial geothermal software. AMEC has successfully used the SIMPTEMP program for a variety of geothermal applications over a ten years period.

Detailed geothermal analysis has been carried out to assess the present and future thermal regime within the Kugaaruk sewage lagoon dyke, and within the dyke foundation soils. The analysis considered the following geometry:

- Height of dyke is 5 m.
- Width of crest is 4 m.
- Upstream and Downstream slopes of dyke are 1V:2H.
- Local soil (silty sand, sand and gravel) is proposed for the dyke core construction.
- Water proof liner is proposed to place over core material at upstream slope of the dyke (see Figure 3).
- The dyke core will be covered up with rockfill, about 0.5 m thick.

This section briefly describes the initial geothermal conditions assumed for dyke subgrade, the model setup, input parameters and the result of the SIMPTEMP analysis.

5.4.1 Boundary Conditions for Dyke Numerical Analysis

The air temperature data and snow depth used for the present analysis were based on the Climate Normals for Igloolik weather station for period from 1970 to 2000. The data on snowfall were converted in thickness of the snow cover assuming the following snow densities:

- September through December - 0.22 g/cm^3;
- January through March – 0.25 g/cm^3;
- April and May – 0.27 g/cm^3.

The mean monthly air temperatures and calculated snow thicknesses used for the SIMPTEMP model are presented in Table 1.

Table 1: Mean Monthly Air Temperatures and Snow Thicknesses

Data	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temp., ^{o}C	-30.6	-31.2	-28.0	-19.3	-8.3	1.6	7.0	4.9	-0.4	-8.9	-19.5	-26.1
Snow, m	0.43	0.47	0.53	0.55	0.63	---	---	---	0.07	0.22	0.35	0.43

Mean monthly surface temperatures were applied over the exposed dyke surface, ground surface beyond downstream slope of the dyke and over water surfaces beyond upstream slope of the dyke. To obtain the mean monthly surface temperatures, various n-factor coefficients were used over the dyke, downstream ground surface beyond the dyke and water surface. No allowance for climate warming was made to the air temperatures over the period of the simulation.

Dyke slopes and crest. It was assumed that practically no snow would accumulate on the dyke slopes and crest. Therefore, an n-factor of 0.9 was applied to the mean monthly air temperatures to obtain the mean monthly winter temperatures on the dyke surfaces. An n-factor of 1.2 (which corresponds to a bare rockfill surface) was applied to the mean monthly air temperatures to obtain the dyke surface temperature in the summertime.

Downstream Terrain Beyond Dyke. It was assumed that snow could accumulate beyond the toe of the dyke. The calculated snow thickness for the Kugaaruk area is similar to the measured snow thicknesses at the Cape Dorset weather station. It was therefore assessed that the n-factors for the Kugaaruk lagoon site would be 0.65 and 0.83 for the winter and summer air temperatures, respectively. The n-factors represent the insulating/warming effect of snow cover in the winter, and the cooling effect of the moss/lichen vegetation in the summer.

Water (Upstream Beyond Dyke). It was assumed that snow could accumulate on the ice surface. Similar to the downstream terrain area, an n-factor of 0.65 was applied to the mean monthly air temperatures for the winter months (October through May). From June through September, it was assumed that the water temperature over the entire depth of the water column was the same as the mean monthly air temperatures (n – factor = 1.0). Table 2 provides data on the mean monthly surface temperatures that were applied over the upper boundary of the geothermal models.

Table 2: Mean Monthly Surface Temperatures on Model Mesh

Data	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dyke Crest and Slopes	-27.5	-28.0	-25.2	-17.4	-7.5	1.9	8.4	5.9	-0.4	-8.0	-17.6	-23.5
Downstream Surface	-19.9	-20.3	-18.2	-12.5	-5.4	1.3	5.8	4.1	-0.3	-5.8	-12.7	-17.0
Water / Ice Surface	-19.9	-20.3	-18.2	-12.5	-5.4	1.6	7.0	4.9	-0.3	-5.8	-12.7	-17.0
						Water Temperature equals air temperature						

5.4.2 Physical and Thermal Soil Properties

Estimates of physical properties for various typical soils expected to be encountered within the dyke and dyke foundation were based on the published information (see Section 3.0) and results of the tested material obtained during the site reconnaissance. Thermal properties of the materials (thermal conductivity and heat capacity) were selected based on available published data, and on previous experience with similar materials. Table 3 summarizes the material physical and thermal properties applied for the geothermal analyses.

Table 3: Physical and Thermal Soil Properties

Soil Type	Dry Density, kN/m^3	Moisture Content, %	Thermal Conductivity, $W/m/^oC$		Heat Capacity, $MJ/m^3/^oC$	
			Frozen	Unfrozen	Frozen	Unfrozen
Bedrock	28	2	2.90	2.90	2.58	2.58
Unsaturated overburden and dyke sand and gravel	20	7	2.90	2.73	2.26	2.68
Saturated rockfill, overburden and dyke sand and gravel	19.6	15	2.61	2.26	2.26	2.51
Unsaturated rockfill	20	5	2.9	2.73	2.09	2.26
Water	10	---	2.20	0.58	1.95	4.19

5.4.3 Grid and Soil Layers Description

The following soils/materials were identified within the sewage dyke cross-section:

- Unsaturated Rockfill on downstream face of dyke
- Saturated Rockfill on upstream face of dyke
- Unsaturated dyke core and native overburden
- Saturated dyke core and native overburden
- Bedrock
- Water

Dimensions of each of the individual layers are shown on the Figures of Appendix B. Physical and thermal properties of the constituent soils/materials identified are provided in Section 5.3.2.

The geothermal modeling grid extended about 104 m below the crest of the dyke and contained 9350 finite elements and 4816 nodes. The average dyke and active layer initial temperatures were taken as +2 ^oC, corresponding to the assumed dyke material temperature and active layer temperature at the end of summer. The initial water temperature was also taken as +2 ^oC. The initial soil temperature from the base of the active layer and to a depth of 12 m was taken to decrease gradually from 0 ^oC to -5 ^oC. The soil temperature was then warmed gradually down to the bottom of the grid with the geothermal gradient of 0.02 $^oC/m$.

Zero heat flux was applied at lateral boundaries of the grid, while the heat flux at the mesh bottom corresponded to the geothermal gradient of 0.02 $^oC/m$.

5.5 Results of Geothermal Modelling

Containment Dyke with Liner

Figure 5 (Appendix B) shows that after the first year of the dyke operation, the active layer at the dyke crest is about 1.7 m. The majority of the dyke core has a temperature in a range from -1 ^oC to -2 ^oC while the ground temperature under the dyke is about -4 ^oC. One can see that due to the warming effect of the lagoon water the ground temperature beyond the upstream slope of the dyke is about 2 degrees warmer than the ground temperature beyond the downstream slope of the dyke.

Figures 6 through 9 (Appendix B) show that no significant changes in the dyke temperature regime were observed from the fifth to thirtieth year of the dyke operation. It can be seen that the thickness of the unfrozen zone under the lagoon increases up to 5 m, while the ground temperature at the base of the central part of the dyke decreases down to -5 ^{o}C.

Frozen Core Containment Dyke

Figure 10 (Appendix B) shows that the placement of insulation across the crest of the dyke decreases the thickness of the active layer at the crest to about 0.75 m. A comparison of Figures 5 and 10 shows that the active layer thickness is reduced by about 1 m. The insulation did not change the internal dyke temperature and after the first year of the operation, the majority of the dyke core has a temperature in a range from -1 ^{o}C to -2 ^{o}C.

Figures 11 through 14 (Appendix B) shows that after five years of the operation, the thickness of the active layer at the crest of the dyke is decreased to about 0.5 m. No significant changes in the dyke temperature regime are observed from the fifth to thirtieth year of the dyke operation (dyke temperature remains in a range from -1 ^{o}C to -5 ^{o}C, considerably colder than after the first year of operation). It can be seen that the unfrozen zone thickness under the lagoon is increased up to 5 m, while the ground temperature at the base of the central part of the dyke is decreased down to -7 ^{o}C. These latter temperatures are the same both design options.

Conclusions from Numerical Analyses

The numerical simulation of the liner and frozen core dyke options show that both options are technically feasible. The performance of each option are however dependant on many variables that can not be simulated in a numerical model. For example, for the liner option, cuts and tears in the liner will result in seepage that will cause warming of the core and the potential weakening and settlement of the dyke structure (and piping losses). Extreme climate warming effects could result in a thicker than predicted active layer across the dyke crest, which would lead to increased seepage.

5.6 Monitoring and Contingency Planning

If a frozen core design option is implemented, then monitoring observations should confirm that the design assumptions made during design are still valid over the life of the structure. Monitoring provides an opportunity to identify variations from the design basis and gives advance warning of developing issues. This monitoring is intended to provide lead time so that contingency measures may be developed and implement in a pro-active approach, rather than reacting to problems as they arise.

Monitoring should consist of the following:

- multi-bead thermistor cables installed through the dyke and into the native foundation. A minimum of two thermistor cables should be installed along the crest of the dyke. These thermistor cables are intended to provide information on the temperatures within the dyke and foundation. They should be read on a bi-monthly basis (six times per year) by

local personnel for the first ten years and quarterly (every three months) thereafter. If temperature anomalies are identified, increased monitoring should be initiated.
- At the time of bi-monthly temperature readings, a visual inspection should also be conducted of the dyke. The inspection should be conducted to confirm dyke integrity and locate any seepage paths that may have formed.

AMEC may provide additional information on the monitoring program and instrumentation upon request.

Contingency planning for potential performance issues in the dykes should be part of the design process. For example, in the event that deeper than expected thawing across the crest of the dyke occurs, the installation of thermosyphons to intercept surface warming may be needed. The design of the dykes should address how and when mitigation options should be installed.

The owner and operators of the dykes should be advised that monitoring of the dykes is an important component of an operations plan and that mitigation against potential seepage and thawing may be needed to address future events.

6.0 CLOSURE

The engineering recommendations presented herein are based on results of the site reconnaissance, geothermal analysis and review of the available information. No drilling was undertaken at the prospective borrow source locations to determine soil composition.

Results of the geothermal modeling have shown that the dyke temperature range should be from -1 ^{o}C to -5 ^{o}C during the operation years. The dyke may be designed with a liner placed as shown in Figures 2 and 3, Appendix B. An alternative option would be to construction a clayey cut-off core of the dyke. Implementation of this latter option depends on quality and quantity of the available clayey material within the Kugaaruk area (which is expected to be minimal in the vicinity of the site). If insulation is placed within the dyke structure as shown at Figure 4, Appendix B, then a frozen core dyke can be designed. A frozen core design is also suitable for the repair of the existing dyke structure. Monitoring of the performance of the dyke is considered an important component of the design of all options.

It should be stated that the results of modelling are valid for the boundary conditions and soil properties described in Section 5.4. If actual boundary conditions (soil properties) will differ considerably of applied parameters, then the actual temperatures of the dyke would vary from the predicted temperatures. Performance of the dyke will vary accordingly.

This report has been prepared for the exclusive use of Dillon Consulting Limited and its agents for the specific application described in this report. The use of this report by third parties is done so at the sole risk of those parties. It has been prepared in accordance with generally accepted permafrost and foundation engineering practices. No other warranty, expressed or implied, is made.

All field work conducted in regards to this work was for the sole purpose of determining geotechnical parameters. No environmental assessment of the existing dykes or surrounding areas was conducted by AMEC. An appropriate environmental assessment of the dykes and surrounding lands should be completed prior to undertaking any remedial work or new construction.

Respectfully submitted,

AMEC Earth & Environmental,
a division of AMEC Americas Limited

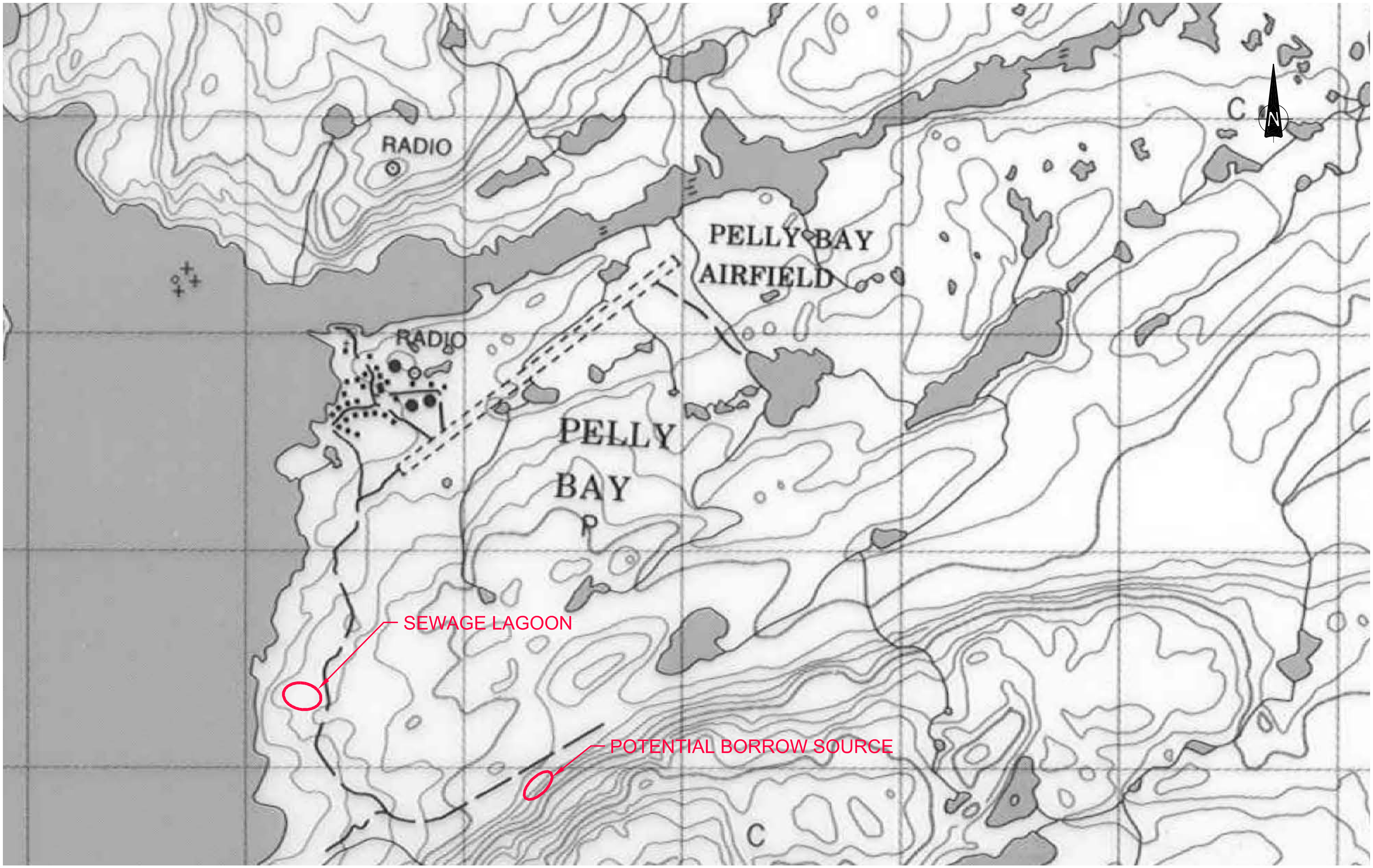
Keith Barnes, P.Eng.
Geotechnical / Permafrost Engineer

Alexandre Tchekhovski, P. Eng.,
Senior Permafrost Engineer

Reviewed by: Jim Oswell, P. Eng.,
Senior Permafrost Engineer

Appendix A

Figure 1: Site Location Plan
Plates: Select Photographs



SCALE
1:25 000
0 250 500 m

amec Earth & Environmental

CLIENT:
DILLON CONSULTING LIMITED

PROJECT:
GEOTECHNICAL INVESTIGATION FOR SEWAGE LAGOON, KUGAARUK, NU

TITLE:
SITE LOCATION PLAN

DATE:	JOB No.:	CAD FILE:	FIGURE No.:	REV.
OCTOBER 2005	YX00749	00749B03.dwg	FIGURE 1	A

Plate 1: View looking east at existing downstream lagoon.
Note breach in dyke

Plate 2: View looking west at existing downstream lagoon.
Note breach in dyke

Plate 3: View looking west at potential site of new lagoon.
Note thin organic mat

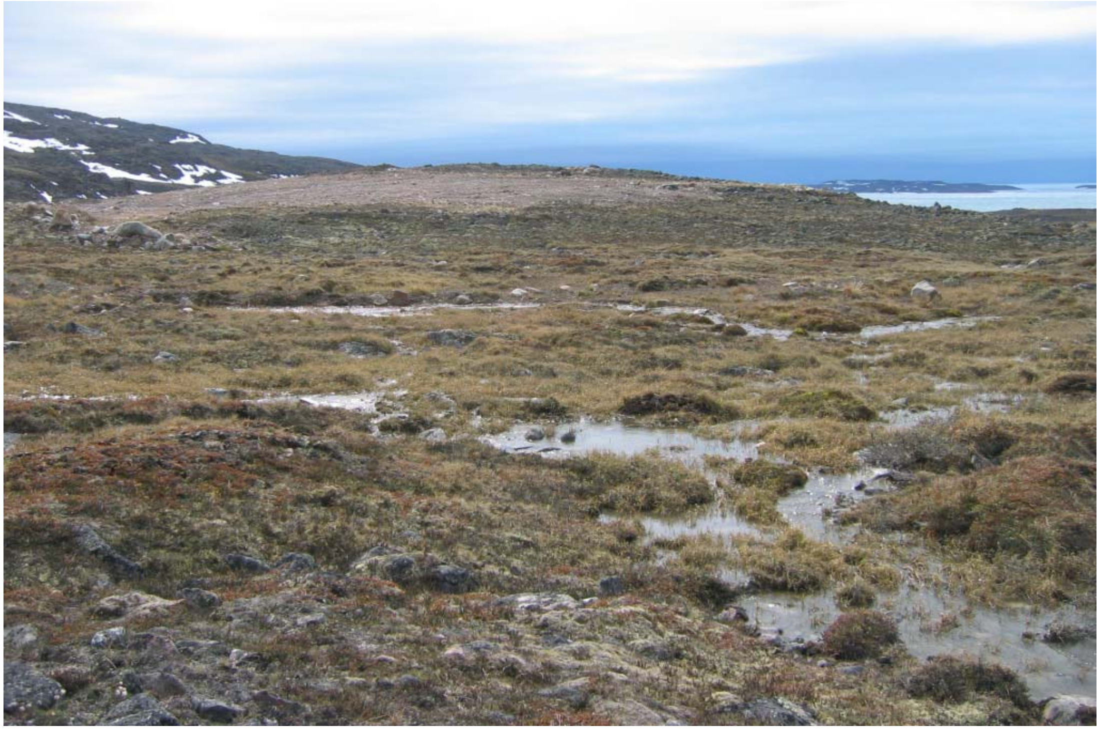
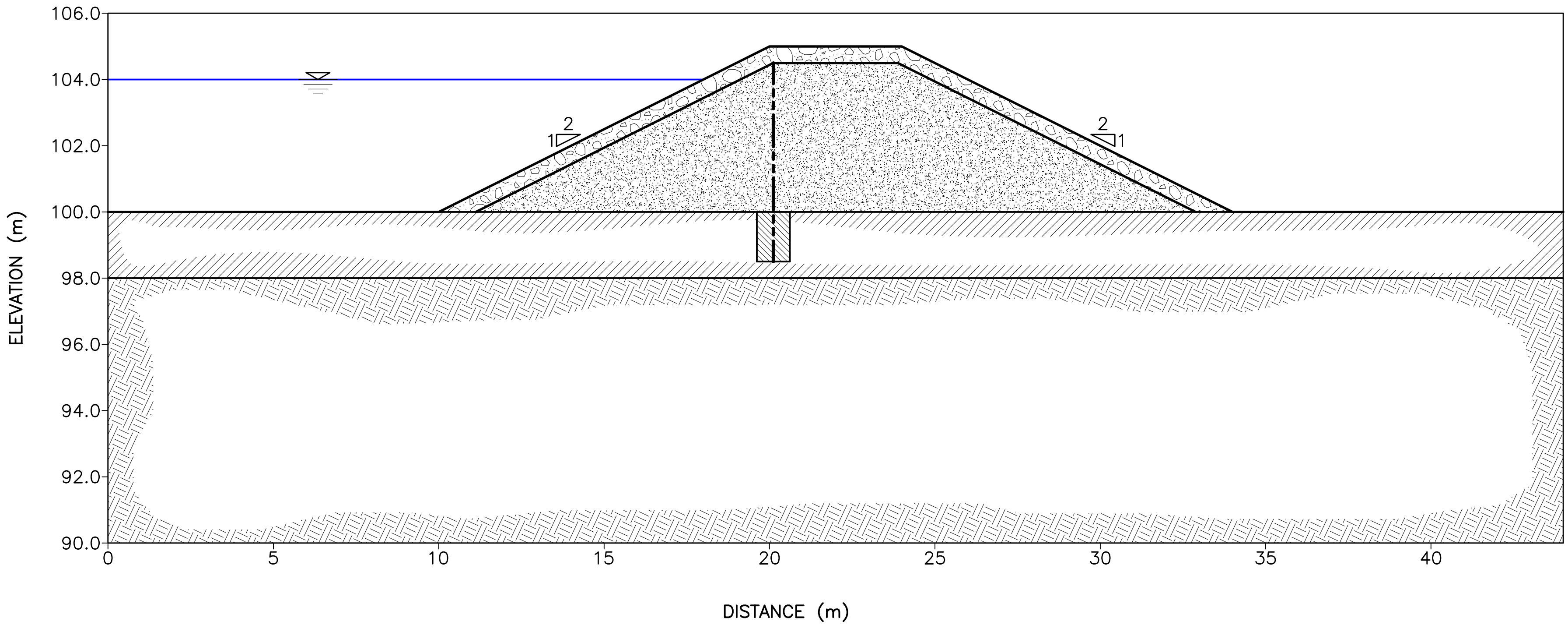


Plate 4: View looking southwest at potential site of new lagoon.
Note thin organic mat

Plate 5: View looking northwest at potential site of new lagoon. Note bedrock outcrops

Plate 6: View looking southwest at potential site of new lagoon. Note bedrock outcrops

Appendix B



LEGEND:

- ROCKFILL
- SAND AND GRAVEL
- OVERBURDEN
- BEDROCK
- CLAY OR GROUT
- HDPE LINER

SCALE
1: 200
0 1 2 3 4 m

amec Earth & Environmental

CLIENT: DILLON CONSULTING LIMITED

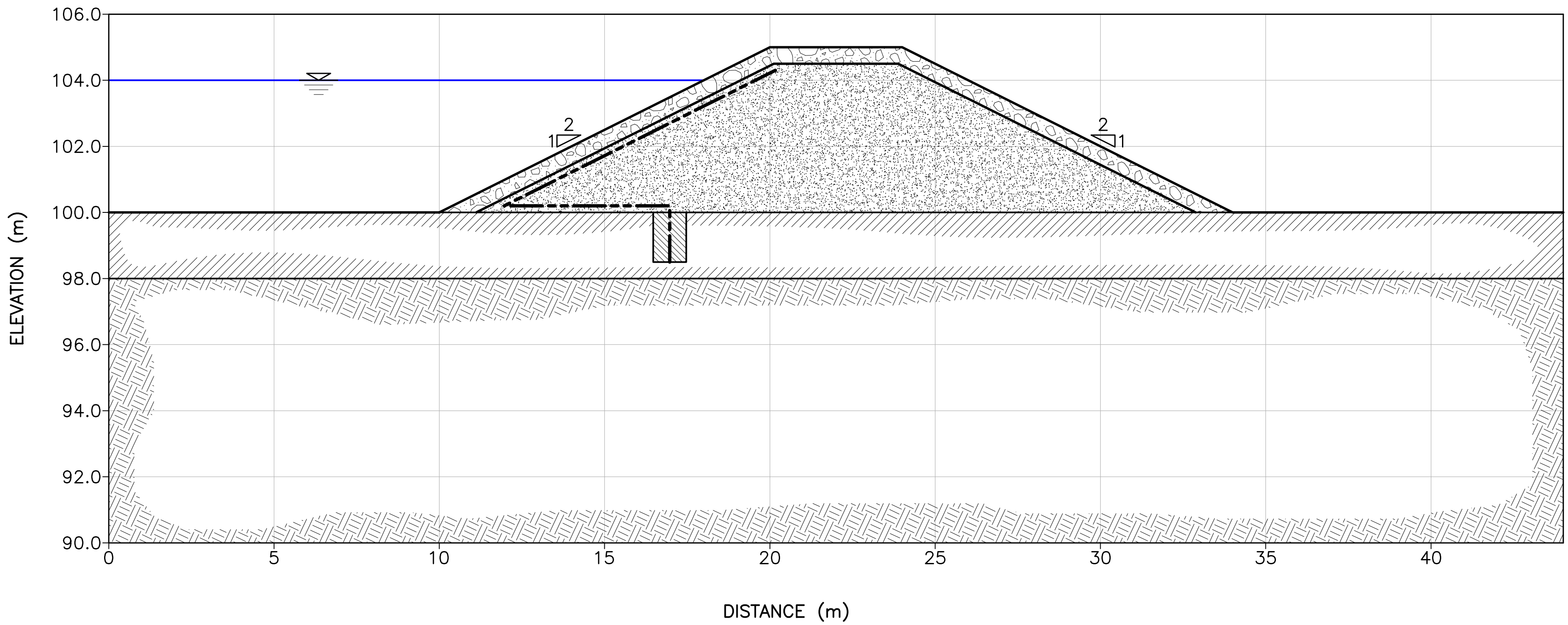
PROJECT: GEOTECHNICAL INVESTIGATION FOR SEWAGE LAGOON, KUGAARUK, NU

TITLE: PROPOSED DYKE CROSS SECTION OPTION 1

DATE:	JOB No.:	CAD FILE:	FIGURE No.:	REV.
OCTOBER 2005	YX00749	00749B01.dwg	FIGURE 2	A

*PLOT 1:1=A (L)

I:\YX\00749\00749B01.dwg – FIGURE2 – Dec. 01, 2005 2:12pm – shelley.brown



LEGEND:

- ROCKFILL
- SAND AND GRAVEL
- OVERBURDEN
- BEDROCK
- CLAY OR GROUT
- HDPE LINER

SCALE

1: 200

0 1 2 3 4 m

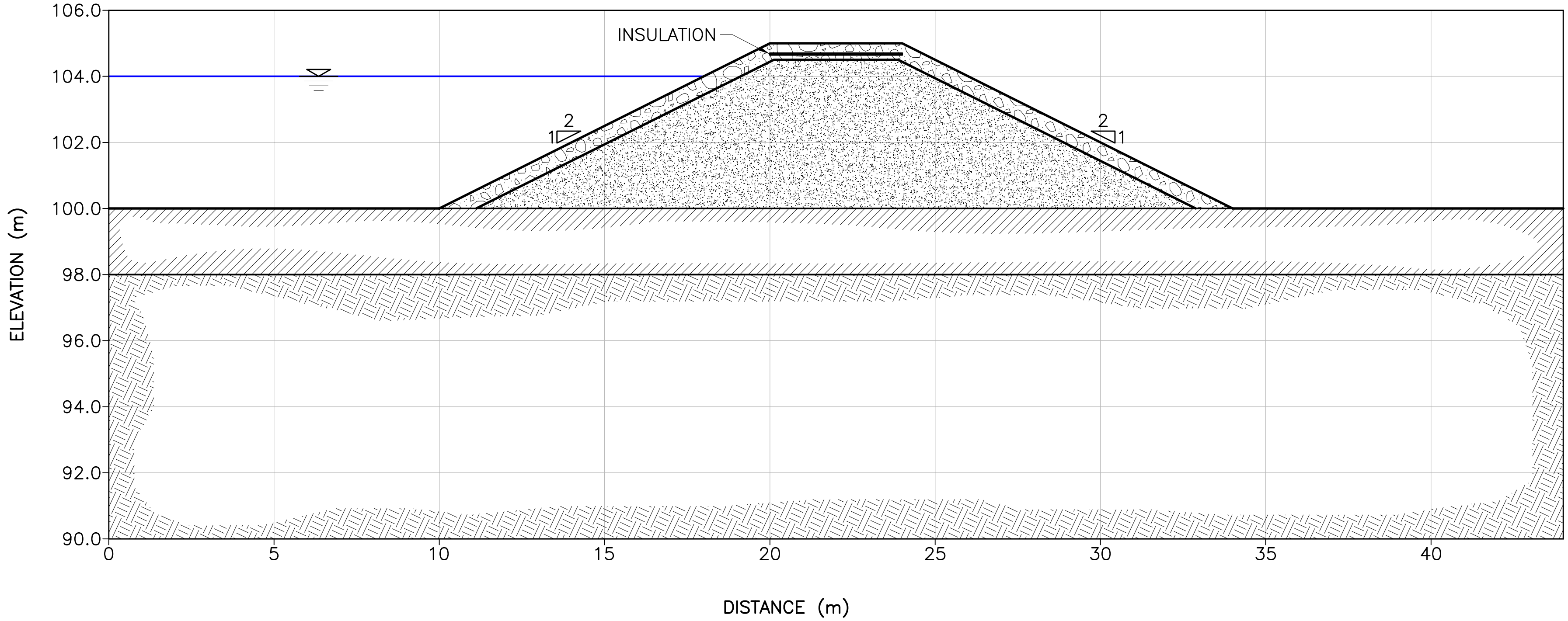
amec Earth & Environmental

CLIENT: DILLON CONSULTING LIMITED

PROJECT: GEOTECHNICAL INVESTIGATION FOR SEWAGE LAGOON, KUGAARUK, NU

TITLE: PROPOSED DYKE CROSS SECTION OPTION 2

DATE:	JOB No.:	CAD FILE:	FIGURE No.:	REV.
OCTOBER 2005	YX00749	00749B01.dwg	FIGURE 3	A



LEGEND:

ROCKFILL

SAND AND GRAVEL

OVERBURDEN

BEDROCK

SCALE

1: 200

0 1 2 3 4 m

amec Earth & Environmental

CLIENT: DILLON CONSULTING LIMITED

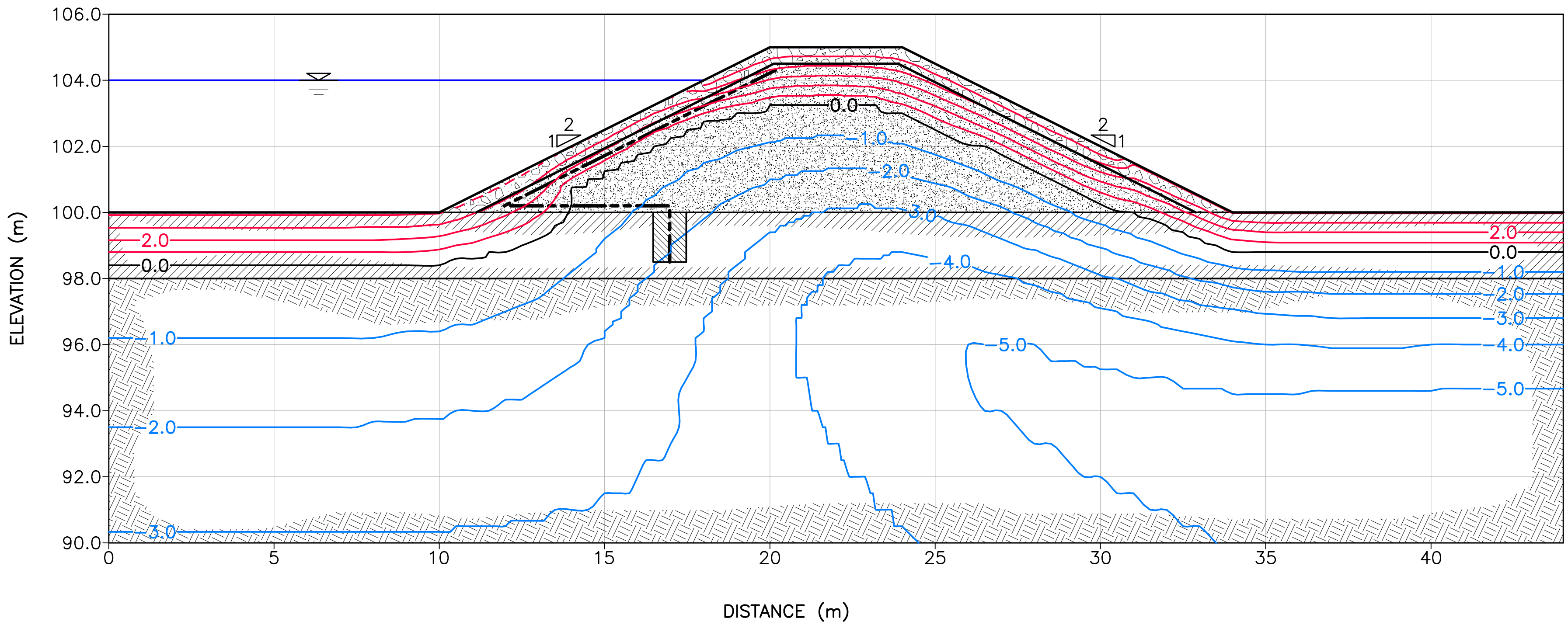
PROJECT: GEOTECHNICAL INVESTIGATION FOR SEWAGE LAGOON, KUGAARUK, NU

TITLE: PROPOSED DYKE CROSS SECTION - FROZEN CORE OPTION

DATE:	JOB No.:	CAD FILE:	FIGURE No.:	REV.
OCTOBER 2005	YX00749	00749B02.dwg	FIGURE 4	A

*PLOT 1:1=A (L)

I:\YX\00749\00749B02.dwg – FIGURE4 – Dec. 01, 2005 2:06pm – shelley.brown



LEGEND:

- ROCKFILL
- SAND AND GRAVEL
- OVERBURDEN
- BEDROCK
- CLAY OR GROUT
- HDPE LINER

SCALE
1: 200
0 1 2 3 4 m

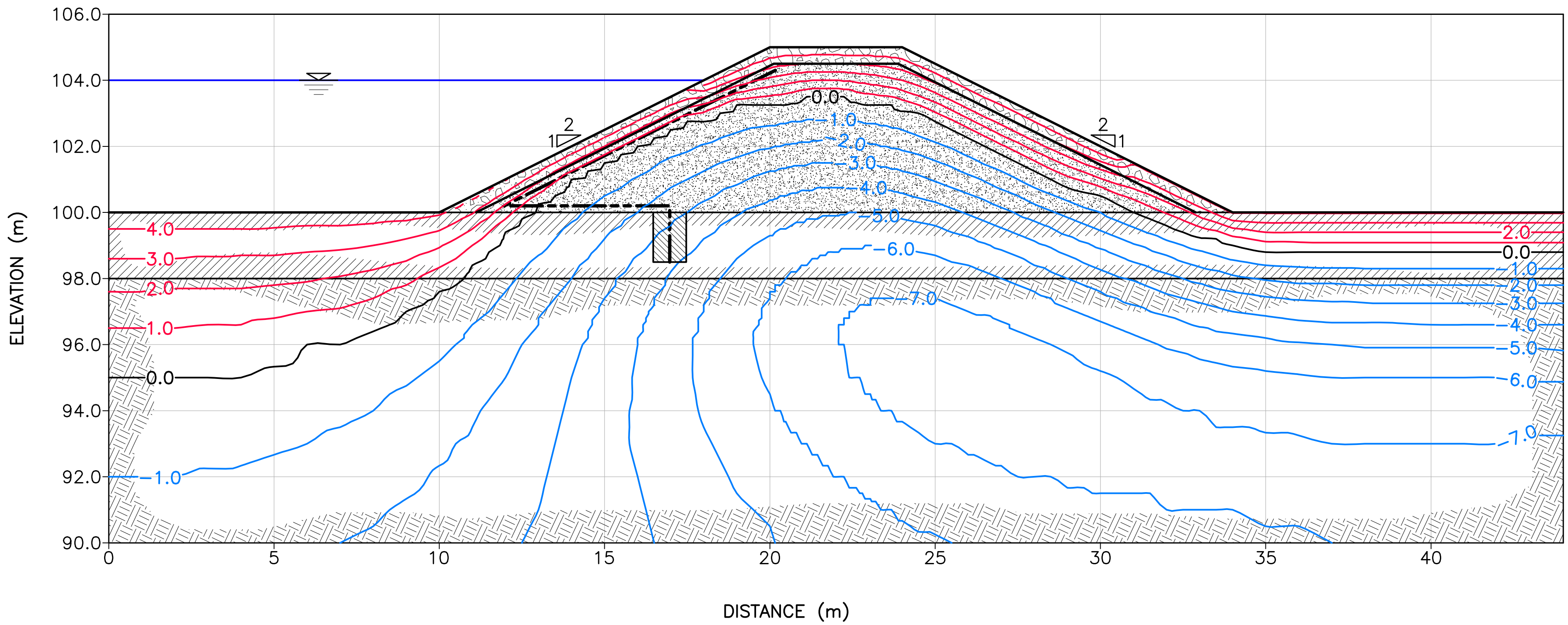
amec Earth & Environmental

CLIENT: DILLON CONSULTING LIMITED

PROJECT: GEOTECHNICAL INVESTIGATION FOR SEWAGE LAGOON, KUGAARUK, NU

TITLE: DYKE TEMPERATURES AFTER 1 YEAR OF OPERATION, OPTION 1 & 2

DATE:	JOB No.:	CAD FILE:	FIGURE No.:	REV.
OCTOBER 2005	YX00749	00749B01.dwg	FIGURE 5	A



LEGEND:

- ROCKFILL
- SAND AND GRAVEL
- OVERBURDEN
- BEDROCK
- CLAY OR GROUT
- HDPE LINER

SCALE

1: 200

0 1 2 3 4 m

amec Earth & Environmental

CLIENT:

DILLON CONSULTING LIMITED

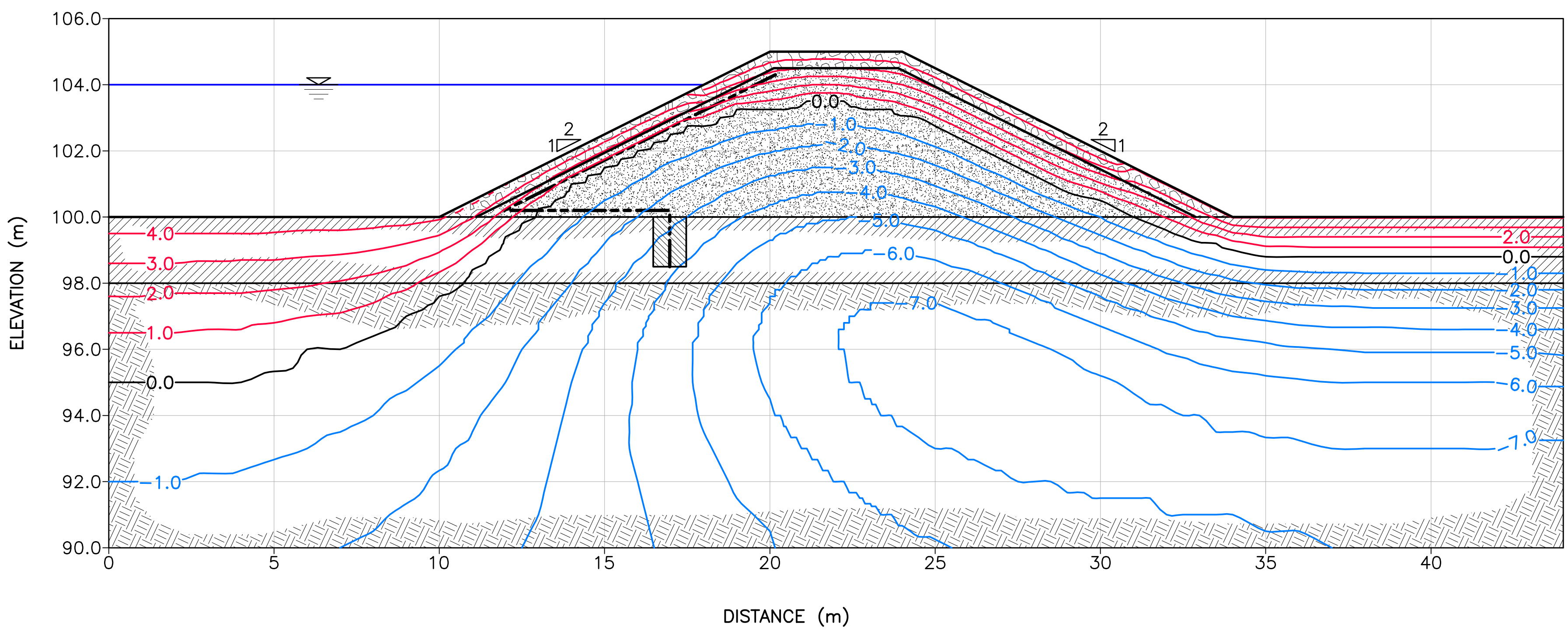
PROJECT:

GEOTECHNICAL INVESTIGATION FOR SEWAGE LAGOON, KUGAARUK, NU

TITLE:

DYKE TEMPERATURES AFTER 5 YEARS OF OPERATION, OPTION 1 & 2

DATE:	JOB No.:	CAD FILE:	FIGURE No.:	REV.
OCTOBER 2005	YX00749	00749B01.dwg	FIGURE 6	A



LEGEND:

- ROCKFILL
- SAND AND GRAVEL
- OVERBURDEN
- BEDROCK
- CLAY OR GROUT
- HDPE LINER

SCALE
1: 200
0 1 2 3 4 m

amec Earth & Environmental

CLIENT: DILLON CONSULTING LIMITED

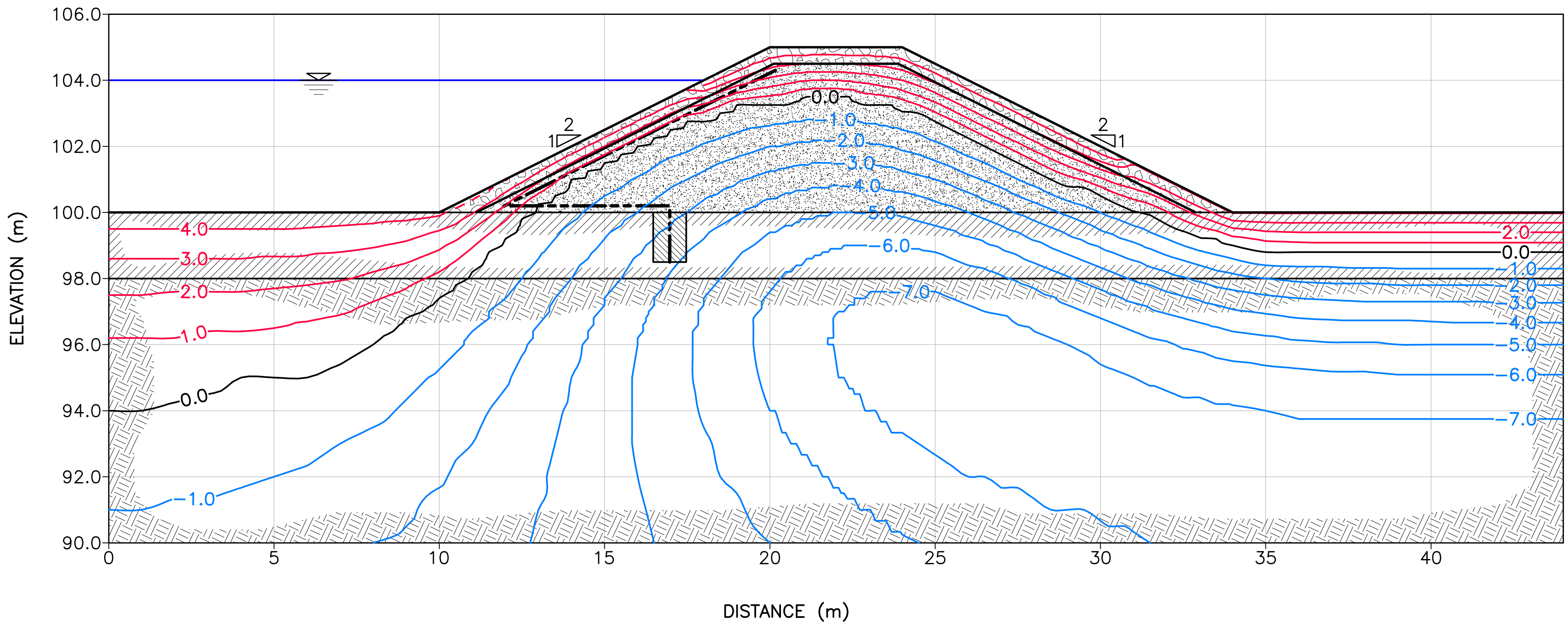
PROJECT: GEOTECHNICAL INVESTIGATION FOR SEWAGE LAGOON, KUGAARUK, NU

TITLE: DYKE TEMPERATURES AFTER 5 YEARS OF OPERATION, OPTION 1 & 2

DATE:	JOB No.:	CAD FILE:	FIGURE No.:	REV.
OCTOBER 2005	YX00749	00749B01.dwg	FIGURE 6	A

*PLOT 1:1=A (L)

I:\YX\00749\00749B01.dwg – FIGURE6 – Dec. 01, 2005 2:10pm – shelley.brown



LEGEND:

ROCKFILL

SAND AND GRAVEL

OVERBURDEN

BEDROCK

CLAY OR GROUT

HDPE LINER

SCALE

1: 200

0 1 2 3 4 m

amec Earth & Environmental

CLIENT:

DILLON CONSULTING LIMITED

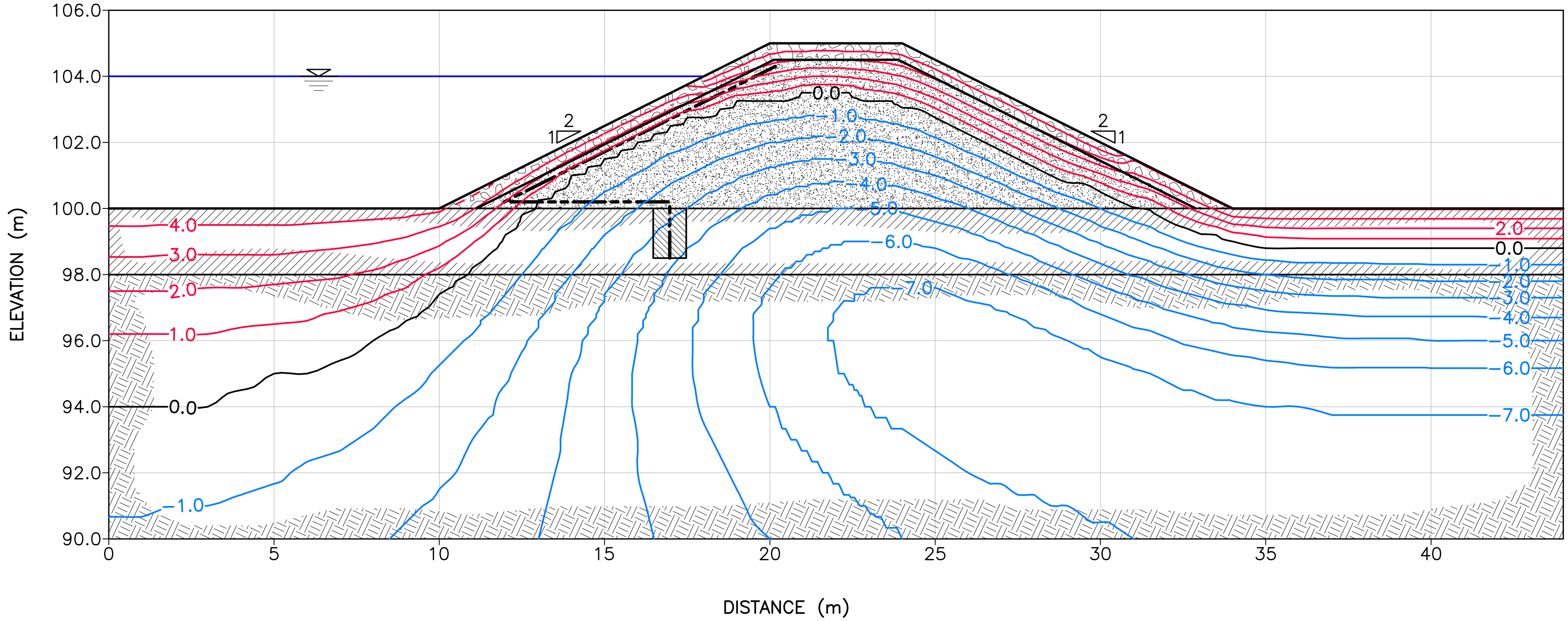
PROJECT:

GEOTECHNICAL INVESTIGATION FOR SEWAGE LAGOON, KUGAARUK, NU

TITLE:

DYKE TEMPERATURES AFTER 10 YEARS OF OPERATION, OPTION 1 & 2

DATE:	JOB No.:	CAD FILE:	FIGURE No.:	REV.
OCTOBER 2005	YX00749	00749B01.dwg	FIGURE 7	A



LEGEND:

- ROCKFILL
- SAND AND GRAVEL
- OVERBURDEN
- BEDROCK
- CLAY OR GROUT
- HDPE LINER

SCALE
1: 200
0 1 2 3 4 m

amec Earth & Environmental

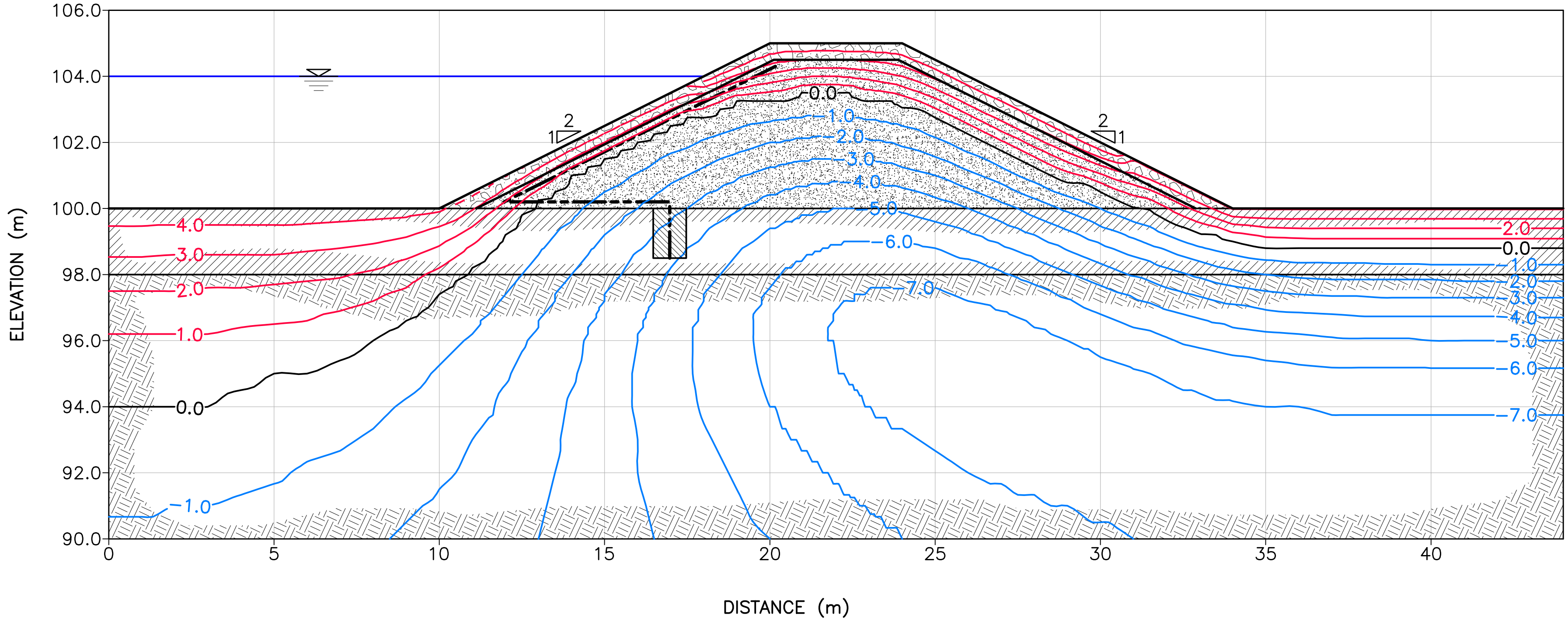
CLIENT:
DILLON CONSULTING LIMITED

PROJECT:
GEOTECHNICAL INVESTIGATION FOR SEWAGE LAGOON, KUGAARUK, NU

TITLE:
DYKE TEMPERATURES AFTER 20 YEARS OF OPERATION, OPTION 1 & 2

DATE:	JOB No.:	CAD FILE:	FIGURE No.:	REV.
OCTOBER 2005	YX00749	00749B01.dwg	FIGURE 8	A

*PLOT 1:1=A (L)



LEGEND:

- ROCKFILL
- SAND AND GRAVEL
- OVERBURDEN
- BEDROCK
- CLAY OR GROUT
- HDPE LINER

SCALE
1: 200
0 1 2 3 4 m

amec Earth & Environmental

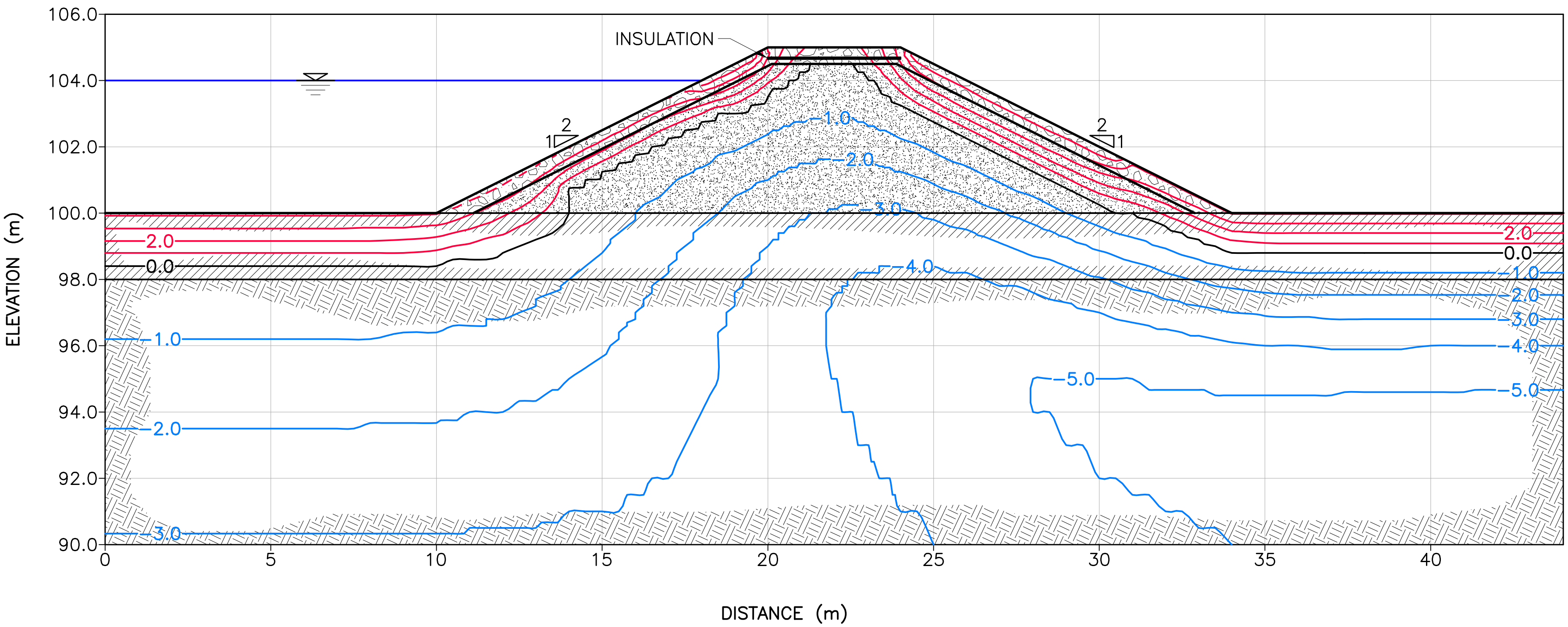
CLIENT: DILLON CONSULTING LIMITED

PROJECT: GEOTECHNICAL INVESTIGATION FOR SEWAGE LAGOON, KUGAARUK, NU

TITLE: DYKE TEMPERATURES AFTER 30 YEARS OF OPERATION, OPTION 1 & 2

DATE:	JOB No.:	CAD FILE:	FIGURE No.:	REV.
OCTOBER 2005	YX00749	00749B01.dwg	FIGURE 9	A

I:\YX\00749\00749B01.dwg - FIGURE9 - Dec. 01, 2005 2:07pm - shelley.brown



LEGEND:

- ROCKFILL
- SAND AND GRAVEL
- OVERBURDEN
- BEDROCK

SCALE
1: 200
0 1 2 3 4 m

amec Earth & Environmental

CLIENT: DILLON CONSULTING LIMITED

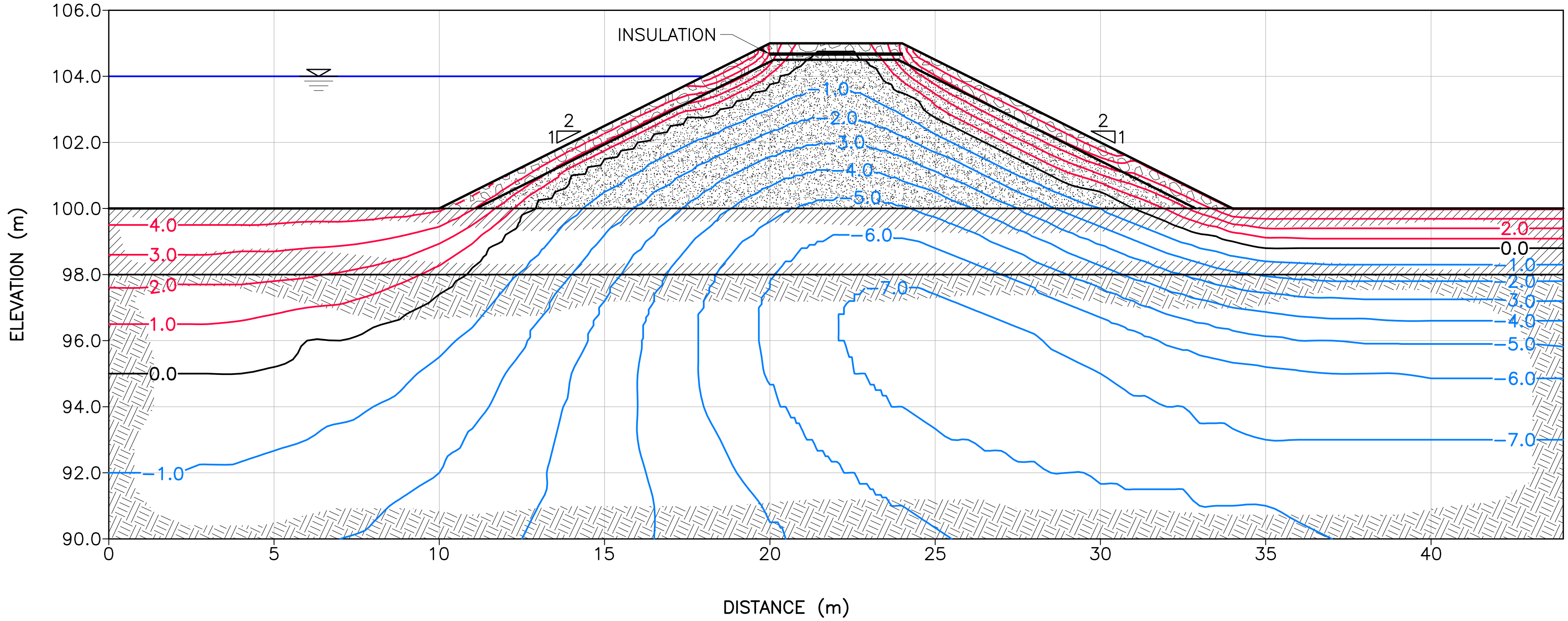
PROJECT: GEOTECHNICAL INVESTIGATION FOR SEWAGE LAGOON, KUGAARUK, NU

TITLE: DYKE TEMPERATURES AFTER 1 YEAR OF OPERATION, FROZEN CORE OPTION

DATE:	JOB No.:	CAD FILE:	FIGURE No.:	REV.
OCTOBER 2005	YX00749	00749B02.dwg	FIGURE 10	A

*PLOT 1:1=A (L)

I:\YX\00749\00749B02.dwg – FIGURE10 – Dec. 01, 2005 2:05pm – shelley.brown



LEGEND:

ROCKFILL

SAND AND GRAVEL

OVERBURDEN

BEDROCK

SCALE

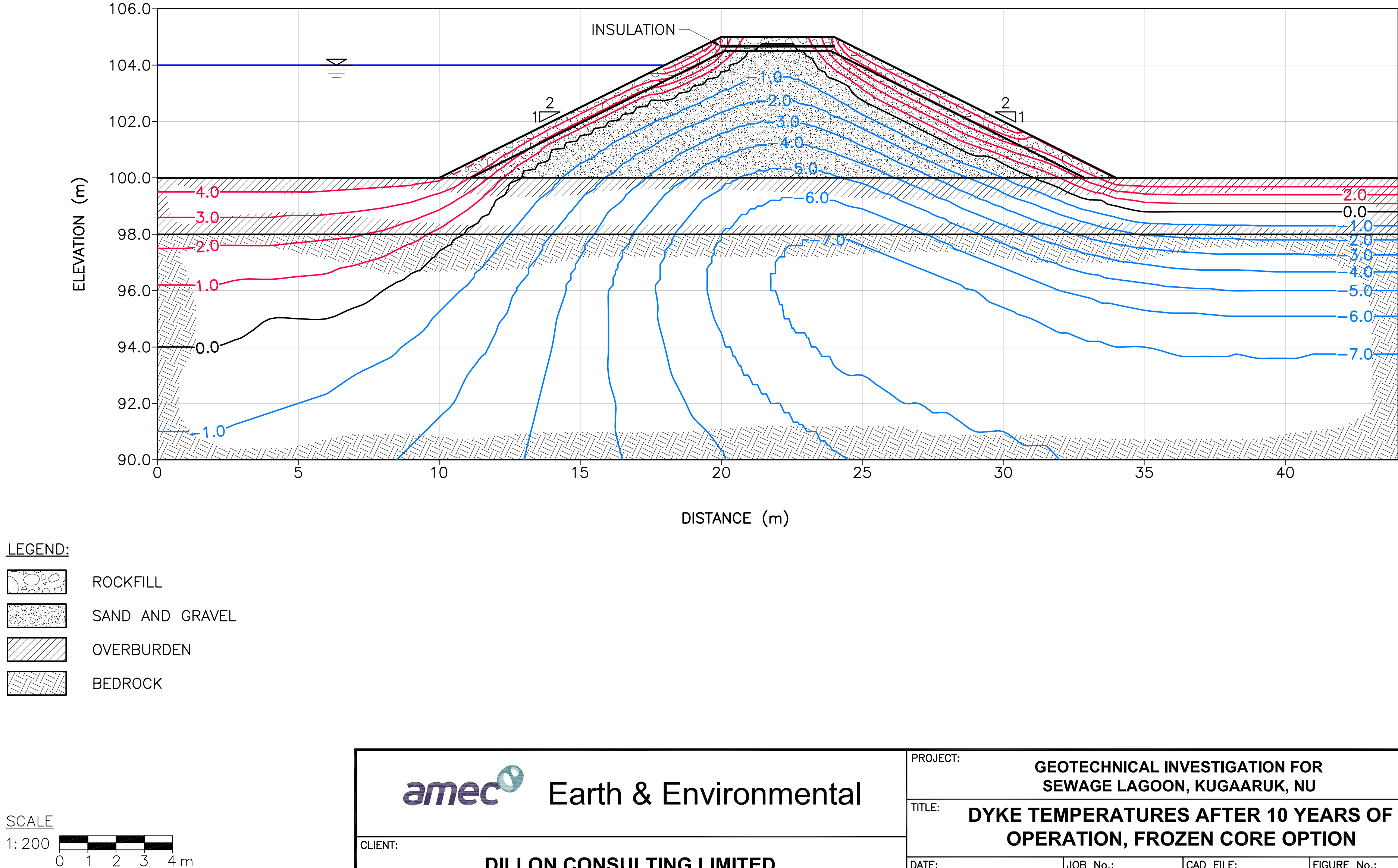
1: 200

0 1 2 3 4 m

amec Earth & Environmental

PROJECT:	GEOTECHNICAL INVESTIGATION FOR SEWAGE LAGOON, KUGAARUK, NU
TITLE:	DYKE TEMPERATURES AFTER 5 YEARS OF OPERATION, FROZEN CORE OPTION
CLIENT:	DILLON CONSULTING LIMITED

DATE:	JOB No.:	CAD FILE:	FIGURE No.:	REV.
OCTOBER 2005	YX00749	00749B02.dwg	FIGURE 11	A



amec Earth & Environmental

CLIENT: DILLON CONSULTING LIMITED

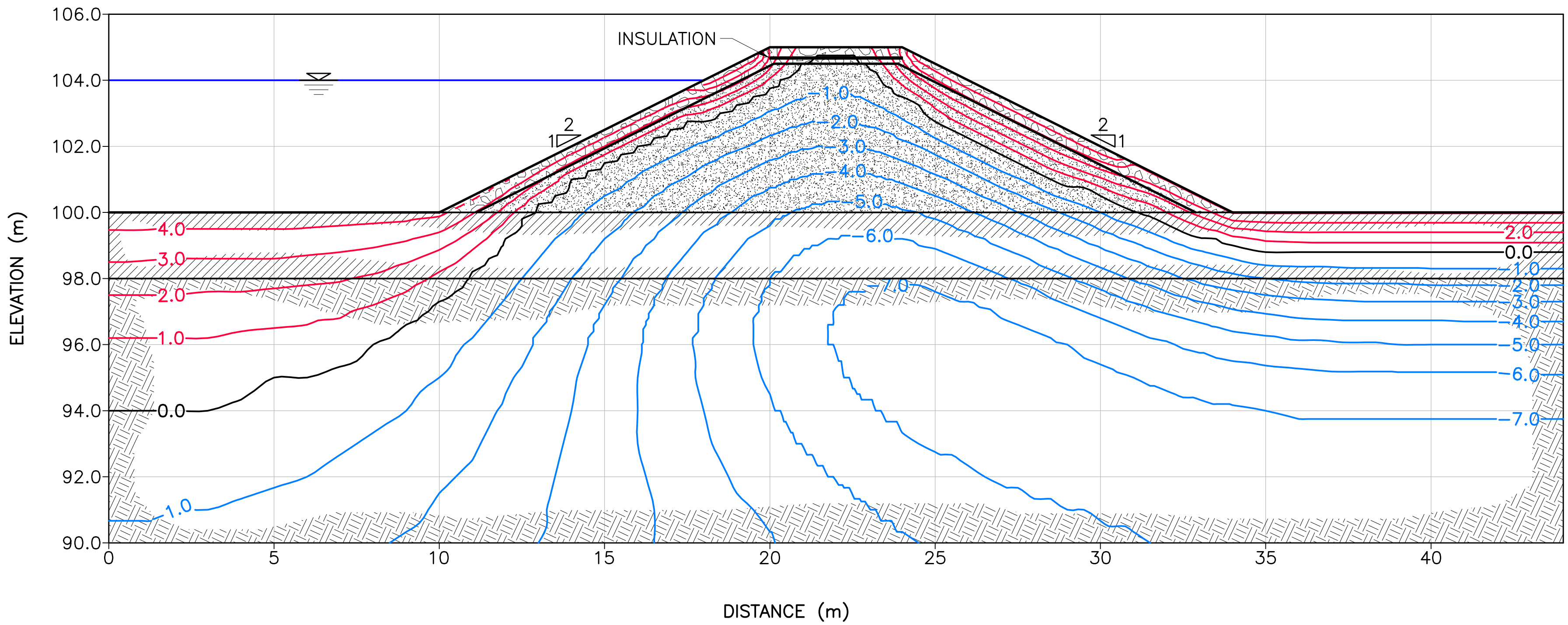
PROJECT: GEOTECHNICAL INVESTIGATION FOR SEWAGE LAGOON, KUGAARUK, NU

TITLE: DYKE TEMPERATURES AFTER 10 YEARS OF OPERATION, FROZEN CORE OPTION

DATE:	JOB No.:	CAD FILE:	FIGURE No.:	REV.
OCTOBER 2005	YX00749	00749B02.dwg	FIGURE 12	A

*PLOT 1:1=A (L)

I:\YX\00749\00749B02.dwg – FIGURE12 – Dec. 01, 2005 2:04pm – shelley.brown



LEGEND:

ROCKFILL

SAND AND GRAVEL

OVERBURDEN

BEDROCK

SCALE

1: 200

0 1 2 3 4 m

amec Earth & Environmental

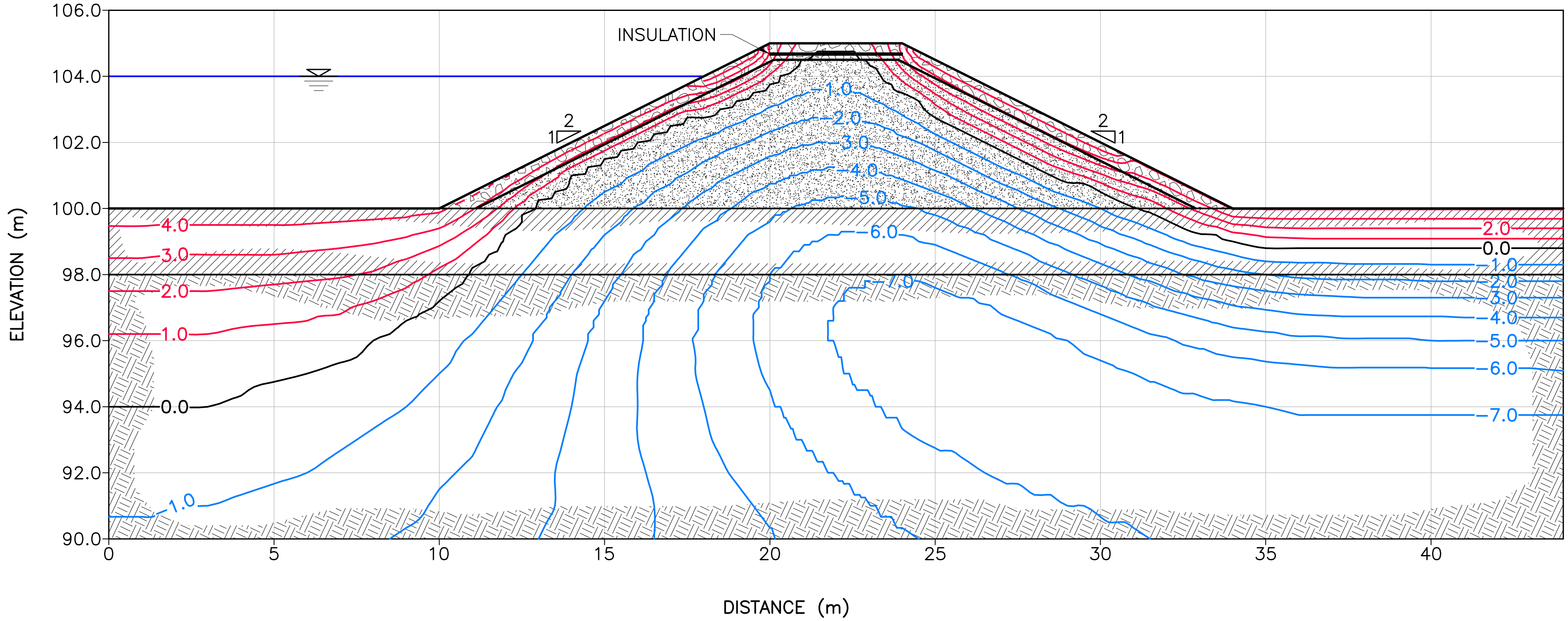
CLIENT: DILLON CONSULTING LIMITED

PROJECT: GEOTECHNICAL INVESTIGATION FOR SEWAGE LAGOON, KUGAARUK, NU

TITLE: **DYKE TEMPERATURES AFTER 20 YEARS OF OPERATION, FROZEN CORE OPTION**

DATE:	JOB No.:	CAD FILE:	FIGURE No.:	REV.
OCTOBER 2005	YX00749	00749B02.dwg	FIGURE 13	A

*PLOT 1:1=A (L)



LEGEND:

- ROCKFILL
- SAND AND GRAVEL
- OVERBURDEN
- BEDROCK

SCALE

1: 200

0 1 2 3 4 m

amec Earth & Environmental

PROJECT: GEOTECHNICAL INVESTIGATION FOR SEWAGE LAGOON, KUGAARUK, NU

TITLE: DYKE TEMPERATURES AFTER 30 YEARS OF OPERATION, FROZEN CORE OPTION

CLIENT: DILLON CONSULTING LIMITED

DATE:	JOB No.:	CAD FILE:	FIGURE No.:	REV.
OCTOBER 2005	YX00749	00749B02.dwg	FIGURE 14	A

I:\YX\00749\00749B02.dwg – FIGURE14 – Dec. 01, 2005 2:02pm – shelley.brown

Appendix C

Grain Size Analysis

SIEVE ANALYSIS REPORT

AMEC Earth & Environmental
a Division of AMEC Americas Limited

To: Dillon Consulting Limited
Suite 303, 4920 47 Street,
PO Box 1409
Yellowknife, NT X1A 2P4

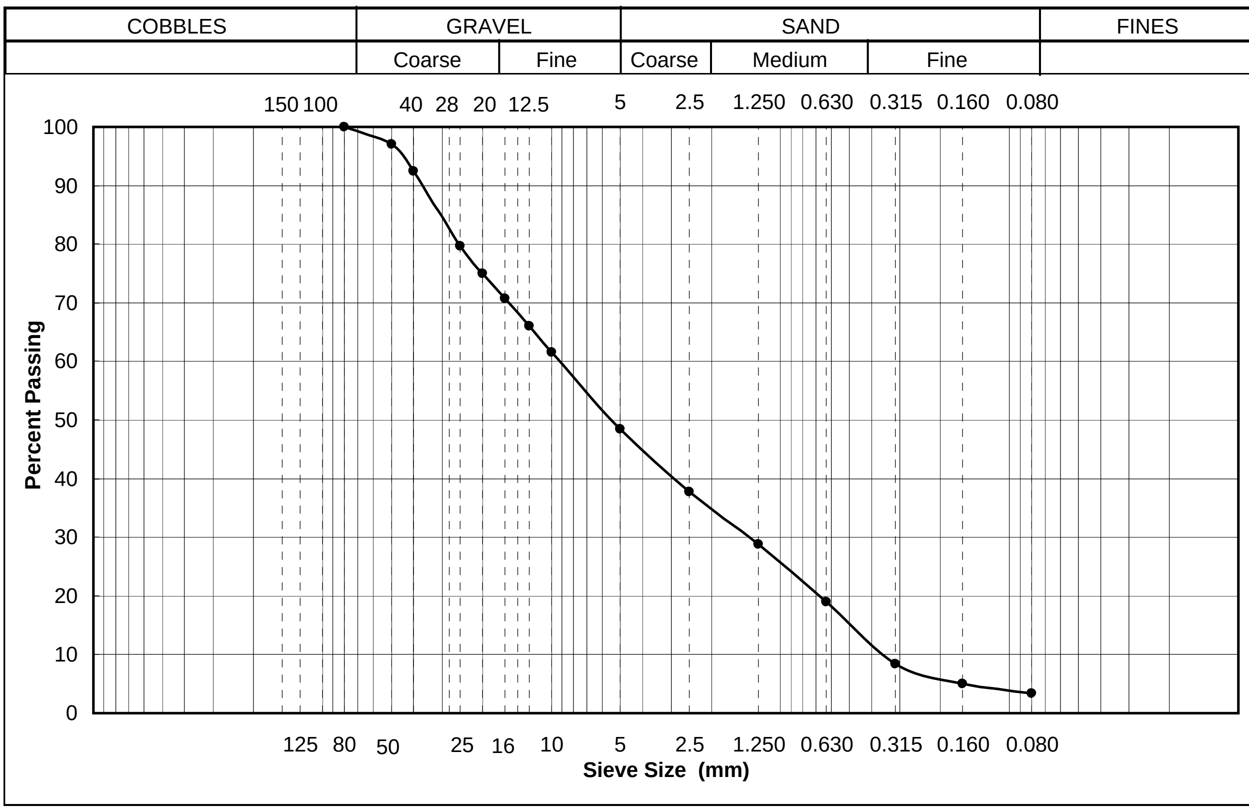
Office : Calgary
Project No: YX00749
Client : Dillon Consulting Limited
Copies to : Client

Attn: Gary Strong

Project: Sewage and Solid Waste Facility, Kugaaruk

Sample ID: 05-391 **Sample Type:** Sand and Gravel **Sampled By:** AMEC

Date Sampled: **Date Received:** **Date Tested:** 20-Oct-05



Sieve Size	% Passing
150.0	
125.0	
100.0	
80.0	100.0
50.0	97.1
40.0	92.4
28.0	
25.0	79.7
20.0	75.0
16.0	70.7
14.0	
12.5	66.1
10.0	61.6
5.0	48.5
2.5	37.8
1.250	28.8
0.630	19.0
0.315	8.4
0.160	5.0
0.080	3.4
C_u	
C_C	

Source: Bucket #1, Potential Borrow Source
Sample Description: Sand and Gravel with trace fines
Comments : No Specifications
Fracture Count = n/a

AMEC Earth & Environmental
a Division of AMEC Americas Limited

Per: ______________________

Reporting of these test results constitutes a testing service only. Engineering interpretation or evaluation of the test results is provided only on written request.

SIEVE ANALYSIS REPORT

AMEC Earth & Environmental
a Division of AMEC Americas Limited

To: Dillon Consulting Limited
Suite 303, 4920 47 Street,
PO Box 1409
Yellowknife, NT X1A 2P4

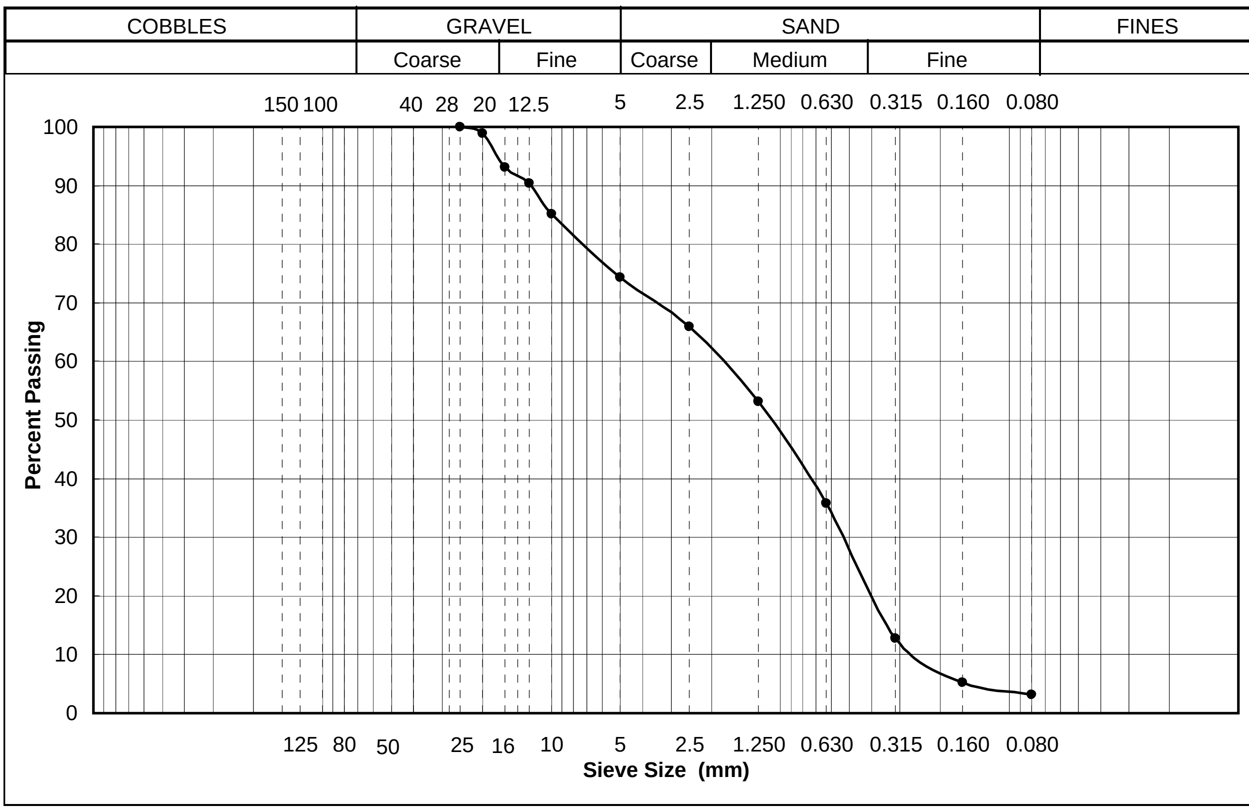
Office : Calgary
Project No: YX00749
Client : Dillon Consulting Limited
Copies to : Client

Attn: Gary Strong

Project: Sewage and Solid Waste Facility, Kugaaruk

Sample ID: 05-392 **Sample Type:** Gravelly Sand **Sampled By:** AMEC

Date Sampled: **Date Received:** **Date Tested:** 20-Oct-05



Sieve Size	% Passing
150.0	
125.0	
100.0	
80.0	
50.0	
40.0	
28.0	
25.0	100.0
20.0	99.0
16.0	93.1
14.0	
12.5	90.4
10.0	85.2
5.0	74.4
2.5	65.9
1.250	53.1
0.630	35.8
0.315	12.7
0.160	5.3
0.080	3.1
C_u	
C_C	

Source: Bucket #2, Existing Dyke
Sample Description: Gravelly Sand with trace fines
Comments : No Specifications
Fracture Count = n/a
Sample had a distinct odor

AMEC Earth & Environmental
a Division of AMEC Americas Limited

Per: ____________________

Reporting of these test results constitutes a testing service only. Engineering interpretation or evaluation of the test results is provided only on written request.

APPENDIX D

PHASE 1 DESIGN OPTIONS

Nunavut

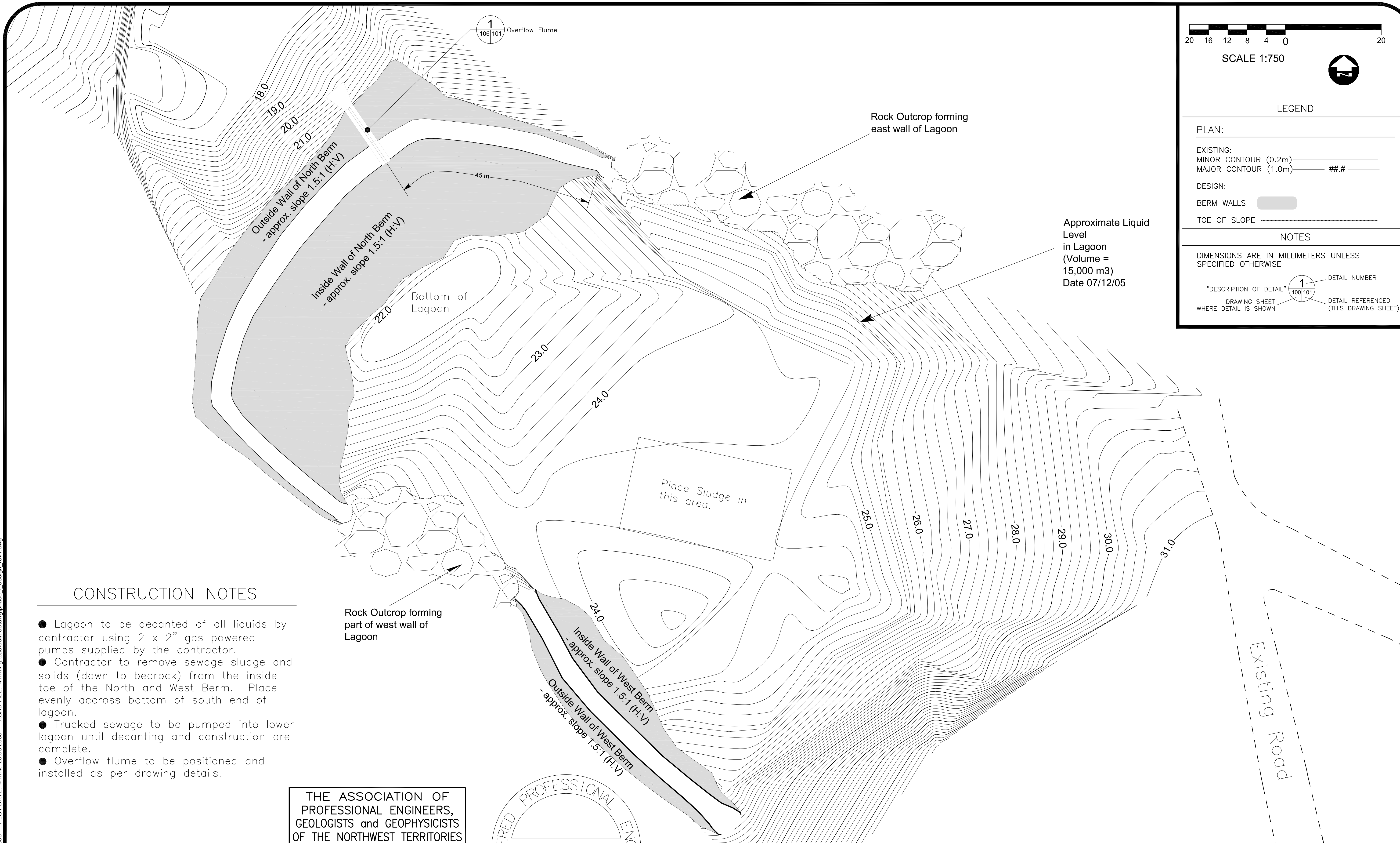
THE GOVERNMENT OF NUNAVUT
COMMUNITY & GOVERNMENT SERVICES

PROJECT: SEWAGE LAGOON & SOLID WASTE FACILITIES - Phase I
LOCATION: KUGAARUK, NUNAVUT
PROJECT NO: 03-4305
DATE: AUGUST 05

LOCATION PLAN

LIST OF DRAWINGS	
Sheet Number	Sheet Title
000	COVER
100	SITE PLAN
101	SEWAGE LAGOON WITH POSITIONING OF OVERFLOW FLUME
102	OPTION # 1 RAISING NORTH & WEST BERM
103	OPTION # 2 RAISING NORTH & WEST BERM WITH INSTALLATION OF GCL LINER
104	OPTION # 3 RAISING NORTH & WEST BERM WITH INSTALLATION OF GCL LINER AND BLASTING
105	OPTION # 4 QUICK FIX OF NORTH BERM
106	SPECIFICATIONS & CONSTRUCTION DETAILS

DILLON CONSULTING



20 16 12 8 4 0 20

SCALE 1:750

LEGEND

PLAN:

EXISTING:
MINOR CONTOUR (0.2m)
MAJOR CONTOUR (1.0m) ##.#

DESIGN:

BERM WALLS

TOE OF SLOPE

NOTES

DIMENSIONS ARE IN MILLIMETERS UNLESS SPECIFIED OTHERWISE

"DESCRIPTION OF DETAIL" 1 100 101 — DETAIL NUMBER; DRAWING SHEET WHERE DETAIL IS SHOWN; DETAIL REFERENCED (THIS DRAWING SHEET)

CONSTRUCTION NOTES

- Lagoon to be decanted of all liquids by contractor using 2 x 2" gas powered pumps supplied by the contractor.
- Contractor to remove sewage sludge and solids (down to bedrock) from the inside toe of the North and West Berm. Place evenly accross bottom of south end of lagoon.
- Trucked sewage to be pumped into lower lagoon until decanting and construction are complete.
- Overflow flume to be positioned and installed as per drawing details.

THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF THE NORTHWEST TERRITORIES
PERMIT NUMBER
P 010
DILLON CONSULTING LIMITED

REGISTERED PROFESSIONAL ENGINEER
G. STRONG
N.W.T.

DILLON CONSULTING

PROJECT	**SEWAGE LAGOON AND SOLID WASTE FACILITIES KUGAARUK, NUNAVUT**
TITLE	**SEWAGE LAGOON WITH POSITIONING OF OVERFLOW FLUME**
PROJECT NUMBER	05-4755-2000
DATE	08/23/05
FIGURE NUMBER	101

EDIT DATE: 26.08.2005 PLOT DATE: 41mk 26.08.2005 ACAD FILE: 41mk g:\cad\054755\dwg\phase_i_design_rev1.dwg

SCALE AS INDICATED

LEGEND

PLAN:

EXISTING GROUND

NEW BERM MATERIAL

NOTES

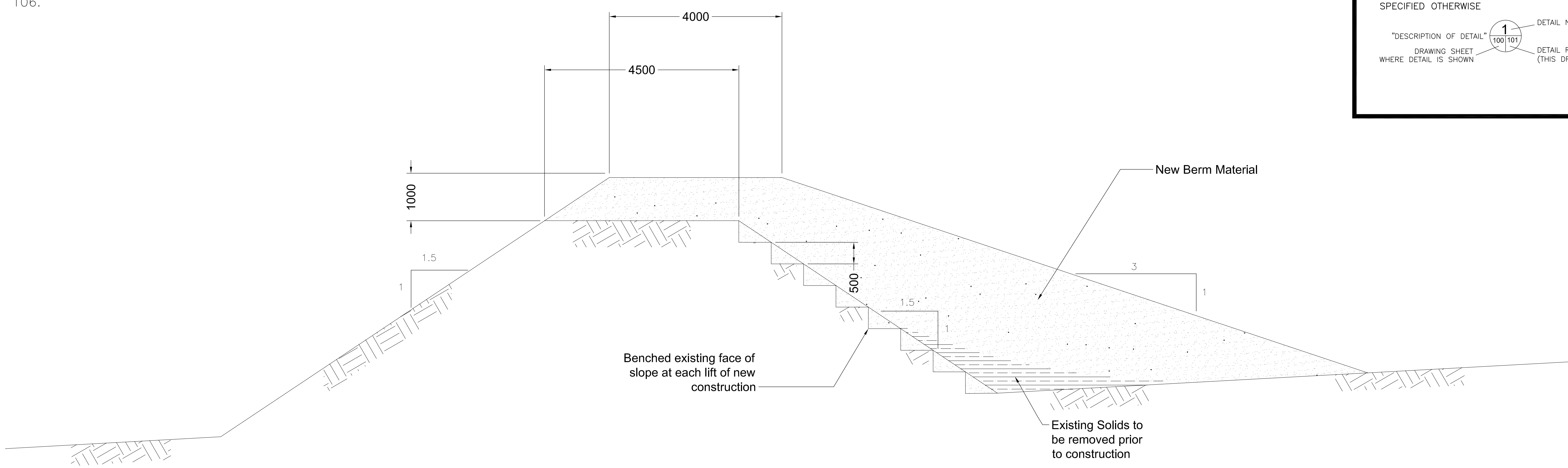
DIMENSIONS ARE IN MILLIMETERS UNLESS SPECIFIED OTHERWISE

"DESCRIPTION OF DETAIL" — 1 — DETAIL NUMBER

DRAWING SHEET WHERE DETAIL IS SHOWN — 100 | 101 — DETAIL REFERENCED (THIS DRAWING SHEET)

CONSTRUCTION NOTES

- This Option involves raising the North and West Berm by 1 meter and installing an overflow flume on the North Berm as per drawing details.
- Sewage sludge and solids to be removed from the toe of the inside wall of the North and West Berm upon completion of decanting and prior to construction.
- For North Berm overflow flume refer to drawing 106.
- Fill material specifications see drawing 106.



3 (102 | 102) Option # 1 Cross Section of North and West Berm
Scale 1:100

THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF THE NORTHWEST TERRITORIES
PERMIT NUMBER
P 010
DILLON CONSULTING LIMITED

DILLON CONSULTING

PROJECT	SEWAGE LAGOON AND SOLID WASTE FACILITIES KUGAARUK, NUNAVUT
TITLE	OPTION # 1 RAISING NORTH & WEST BERM
PROJECT NUMBER	05-4755-2000
DATE	08/25/05
FIGURE NUMBER	102

EDIT DATE: 25.08.2005 PLOT DATE: 41mk 26.08.2005 ACAD FILE: 41mk g:\cad\054755\dwg\phase_i_design_rev1.dwg

SCALE AS INDICATED

LEGEND

PLAN:	
EXISTING GROUND	
NEW BERM MATERIAL	
Rip-Rap	
GCL LINER	

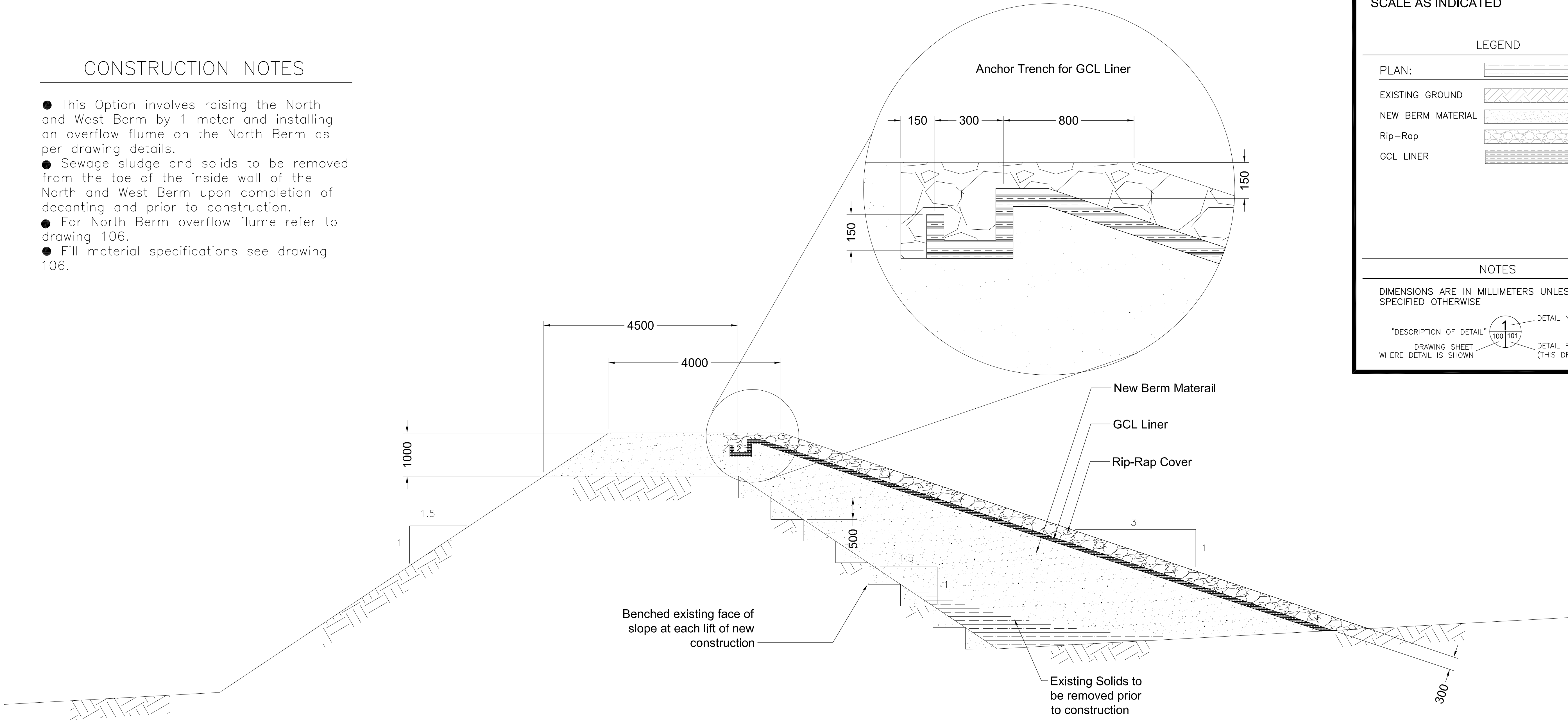
NOTES

DIMENSIONS ARE IN MILLIMETERS UNLESS SPECIFIED OTHERWISE

"DESCRIPTION OF DETAIL" 1 100 101 — DETAIL NUMBER; DRAWING SHEET WHERE DETAIL IS SHOWN; DETAIL REFERENCED (THIS DRAWING SHEET)

CONSTRUCTION NOTES

- This Option involves raising the North and West Berm by 1 meter and installing an overflow flume on the North Berm as per drawing details.
- Sewage sludge and solids to be removed from the toe of the inside wall of the North and West Berm upon completion of decanting and prior to construction.
- For North Berm overflow flume refer to drawing 106.
- Fill material specifications see drawing 106.



4 103 103 Option # 2 Cross Section of North and West Berm
Scale 1:100

THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF THE NORTHWEST TERRITORIES
PERMIT NUMBER
P 010
DILLON CONSULTING LIMITED

REGISTERED PROFESSIONAL ENGINEER
G. STRONG
N.W.T.

DILLON CONSULTING

PROJECT: **SEWAGE LAGOON AND SOLID WASTE FACILITIES KUGAARUK, NUNAVUT**	PROJECT NUMBER	05-4755-2000
	DATE	08/2/05
TITLE: **OPTION # 2 RAISING NORTH & WEST BERM WITH INSTALLATION OF GCL LINER**	FIGURE NUMBER	103

EDIT DATE: 25.08.2005 PLOT DATE: 41mk 26.08.2005 ACAD FILE: 41mk g:\cad\054755\dwg\phase_i_design_rev1.dwg

SCALE AS INDICATED

LEGEND

PLAN:

EXISTING:
MINOR CONTOUR (0.2m)
MAJOR CONTOUR (1.0m) ##.#

DESIGN:

BERM WALLS

Blast Outline

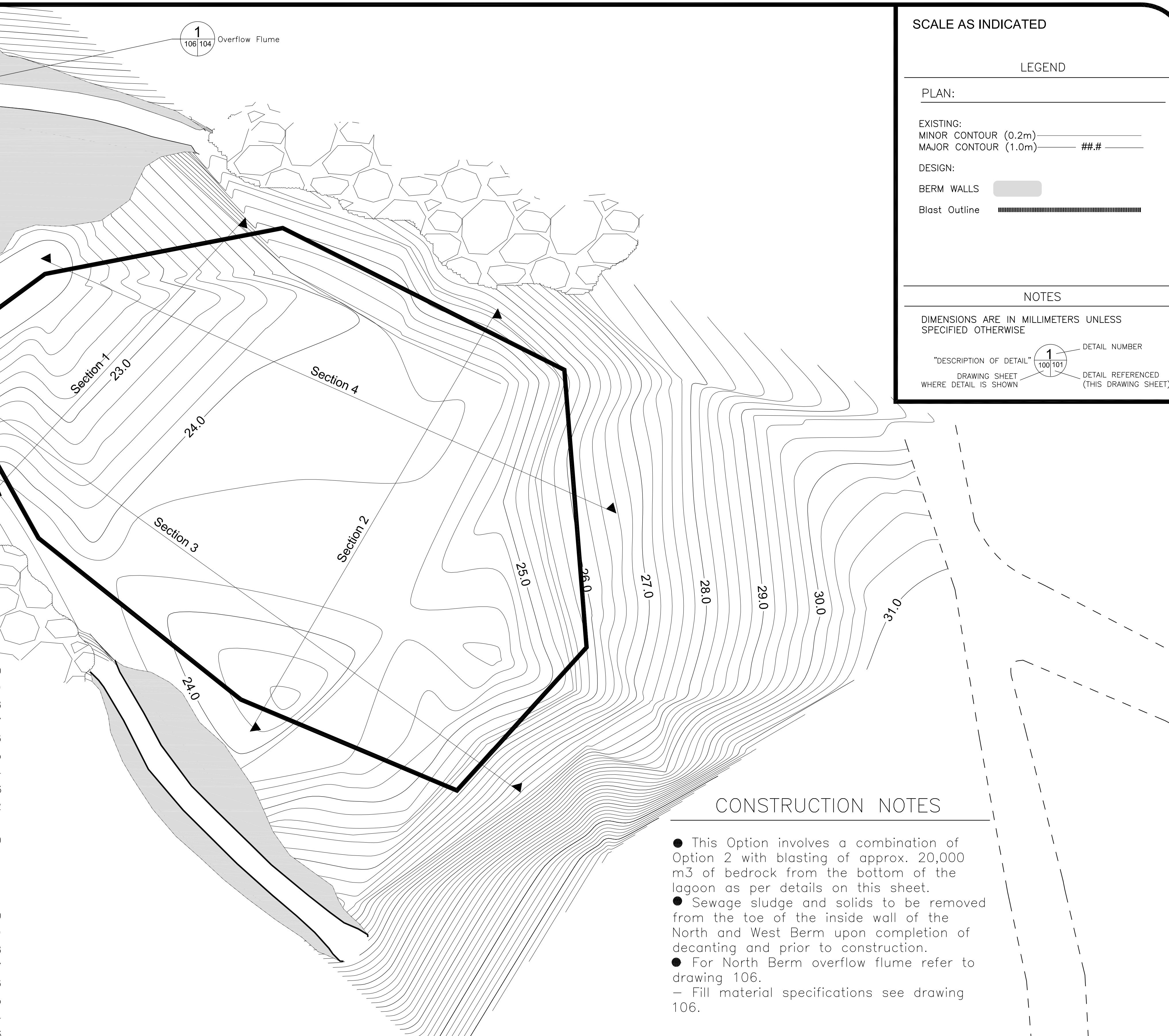
NOTES

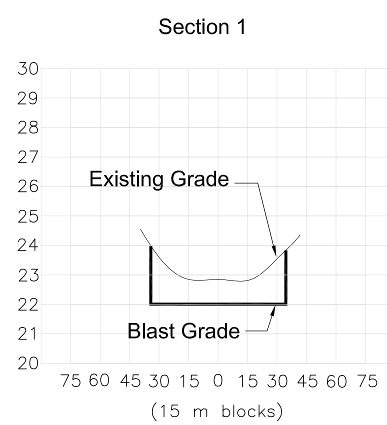
DIMENSIONS ARE IN MILLIMETERS UNLESS SPECIFIED OTHERWISE

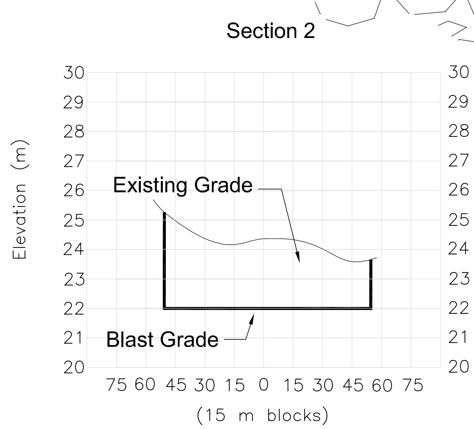
"DESCRIPTION OF DETAIL" 1 / 100 101 — DETAIL NUMBER; DRAWING SHEET WHERE DETAIL IS SHOWN; DETAIL REFERENCED (THIS DRAWING SHEET)

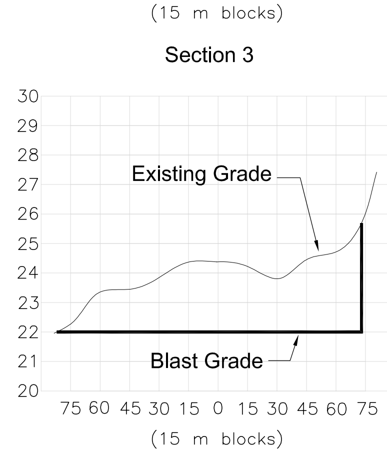
REGISTERED PROFESSIONAL ENGINEER
G. STRONG
N.W.T.

THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF THE NORTHWEST TERRITORIES
PERMIT NUMBER P 010
DILLON CONSULTING LIMITED









CONSTRUCTION NOTES

- This Option involves a combination of Option 2 with blasting of approx. 20,000 m3 of bedrock from the bottom of the lagoon as per details on this sheet.
- Sewage sludge and solids to be removed from the toe of the inside wall of the North and West Berm upon completion of decanting and prior to construction.
- For North Berm overflow flume refer to drawing 106.

– Fill material specifications see drawing 106.

EDIT DATE: 25.08.2005 PLOT DATE: 41mk 26.08.2005 ACAD FILE: 41mk g:\cad\0547555\dwg\phase_i_design_rev1.dwg

DILLON CONSULTING

PROJECT
SEWAGE LAGOON AND SOLID WASTE FACILITIES
KUGAARUK, NUNAVUT

TITLE
OPTION # 3
RAISING NORTH & WEST BERM WITH INSTALLATION OF GCL LINER AND BLASTING

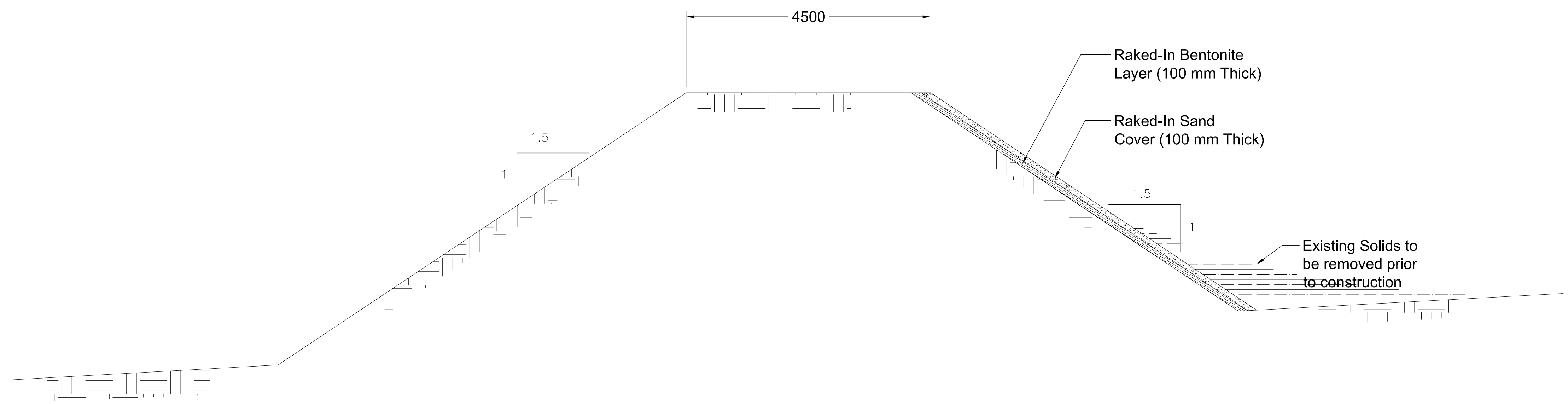
PROJECT NUMBER 05-4755-2000

DATE 08/25/05

FIGURE NUMBER 104

CONSTRUCTION NOTES

- This Option is a quick fix option which involves installing an overflow flume on the North Berm as per drawing details and raking in a bentonite layer (100 mm thick) and sand cover (100 mm thick) on the the inside wall of the North Berm.
- Sewage sludge and solids to be removed from the toe of the inside wall of the North and West Berm upon completion of decanting and prior to construction.



6 (105 | 105) Option # 4 Cross Section of North Berm
Scale 1:100

SCALE AS INDICATED

LEGEND

PLAN:

EXISTING GROUND
RIP–RAP
NESTABLE CULVERT
BENTONITE LAYER
SAND COVER

NOTES

DIMENSIONS ARE IN MILLIMETERS UNLESS SPECIFIED OTHERWISE

"DESCRIPTION OF DETAIL" 1 (100 | 101) — DETAIL NUMBER; DRAWING SHEET WHERE DETAIL IS SHOWN; DETAIL REFERENCED (THIS DRAWING SHEET)

THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF THE NORTHWEST TERRITORIES
PERMIT NUMBER
P 010
DILLON CONSULTING LIMITED

REGISTERED PROFESSIONAL ENGINEER
G. STRONG
N.W.T.

DILLON CONSULTING

PROJECT	**SEWAGE LAGOON AND SOLID WASTE FACILITIES KUGAARUK, NUNAVUT**
TITLE	**OPTION # 4 QUICK FIX OF NORTH BERM**
PROJECT NUMBER	05-4755-2000
DATE	08/25/05
FIGURE NUMBER	105

EDIT DATE: 25.08.2005 PLOT DATE: 41mk 26.08.2005 ACAD FILE: 41mk g:\cad\054755\dwg\phase_i_design_rev1.dwg

APPENDIX E

JULY 2005 FIELD SAMPLING RESULTS

PRELIMINARY RESULTS

DILLON LIMITED

ATTN: ROB KUTA

PO BOX 1409

YELLOWKNIFE NT X1A 2P1

DATE: 13-JUL-05 11:32 AM

Lab Work Order #: L284184 **Sampled By:** RK **Date Received:** 06-JUL-05

Project P.O. #:

Project Reference: 05_4755_1000

Comments:

DOUG JOHNSON
Director of Operations, Edmonton

RACHEL JONES
Account Manager

ENVIRO-TEST ANALYTICAL REPORT

Sample Details/Parameters		Result	Qualifier	D.L.	Units	Extracted	Analyzed	By	Batch
L284184-1	20050705_05_4755_WL1 WETLANDS OCEAN								
Sample Date:	05-JUL-05 10:30								
Matrix:	SEWAGE								
	Ammonia-N	42.3		0.05	mg/L		07-JUL-05	WNG	R300756
	Biochemical Oxygen Demand	19		2	mg/L		06-JUL-05	FY	R301814
	MF - Fecal Coliforms	90		1	CFU/100mL		08-JUL-05	PB	R302425
	Total Suspended Solids	8		3	mg/L		07-JUL-05	SVG	R300750
L284184-2	20050705_05_4755_WL2 WESTLANDS MIDSLOPE								
Sample Date:	05-JUL-05 10:35								
Matrix:	SEWAGE								
	Ammonia-N	39.3		0.05	mg/L		07-JUL-05	WNG	R300756
	Biochemical Oxygen Demand	34		2	mg/L		06-JUL-05	FY	R301814
	MF - Fecal Coliforms	2000		1	CFU/100mL		08-JUL-05	PB	R302425
	Total Suspended Solids	11		3	mg/L		07-JUL-05	SVG	R300750
L284184-3	20050705_05_4755_WL3 WETLANDS LOWER B								
Sample Date:	05-JUL-05 10:40								
Matrix:	SEWAGE								
	Ammonia-N	65.7		0.05	mg/L		07-JUL-05	WNG	R300756
	Biochemical Oxygen Demand	73		2	mg/L		06-JUL-05	FY	R301814
	MF - Fecal Coliforms	12000		1	CFU/100mL		08-JUL-05	PB	R302425
	Total Suspended Solids	46		3	mg/L		07-JUL-05	SVG	R300750
L284184-4	20050705_05_4755LC1 LOWER CELL								
Sample Date:	05-JUL-05 10:45								
Matrix:	SEWAGE								
	Ammonia-N	52.2		0.05	mg/L		07-JUL-05	WNG	R300756
	Biochemical Oxygen Demand	70		2	mg/L		06-JUL-05	FY	R301814
	MF - Fecal Coliforms	21000		1	CFU/100mL		08-JUL-05	PB	R302425
	Total Suspended Solids	20		3	mg/L		07-JUL-05	SVG	R300750
L284184-5	20050705_05_4755_UC1 UPPER CELL NORTH								
Sample Date:	05-JUL-05 10:50								
Matrix:	SEWAGE								
	Ammonia-N	64.9		0.05	mg/L		07-JUL-05	WNG	R300756
	Biochemical Oxygen Demand	152		2	mg/L		06-JUL-05	FY	R301814
	MF - Fecal Coliforms	68000		1	CFU/100mL		08-JUL-05	PB	R302425
	Total Suspended Solids	25		3	mg/L		07-JUL-05	SVG	R300750
L284184-6	20050705_05_4755_UC2 UPPER CELL NORTH WATER								
Sample Date:	05-JUL-05 10:55								
Matrix:	SEWAGE								
	Ammonia-N	63.9		0.05	mg/L		07-JUL-05	WNG	R300756
	Biochemical Oxygen Demand	116		2	mg/L		06-JUL-05	FY	R301814
	MF - Fecal Coliforms	120000		1	CFU/100mL		08-JUL-05	PB	R302425
	Total Suspended Solids	22		3	mg/L		07-JUL-05	SVG	R300750
L284184-7	20050705_05_4755_UC3 UPPER CELL SOUTH								
Sample Date:	05-JUL-05 11:00								
Matrix:	SEWAGE								

ENVIRO-TEST ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier	D.L.	Units	Extracted	Analyzed	By	Batch
L284184-7 20050705_05_4755_UC3 UPPER CELL SOUTH								
Sample Date: 05-JUL-05 11:00								
Matrix: SEWAGE								
Ammonia-N	71.0		0.05	mg/L		07-JUL-05	WNG	R300756
Biochemical Oxygen Demand	133		2	mg/L		06-JUL-05	FY	R301814
MF - Fecal Coliforms	62000		1	CFU/100mL		08-JUL-05	PB	R302425
Total Suspended Solids	19		3	mg/L		07-JUL-05	SVG	R300750
L284184-8 20050705_05_4755_WSI1 WEST SLOPE UPPER CELL								
Sample Date: 05-JUL-05 11:05								
Matrix: SEWAGE								
Ammonia-N	0.06		0.05	mg/L		06-JUL-05	WNG	R300309
Biochemical Oxygen Demand	<2		2	mg/L		06-JUL-05	FY	R301814
MF - Fecal Coliforms	<1		1	CFU/100mL		08-JUL-05	PB	R302425
Total Suspended Solids	37		3	mg/L		07-JUL-05	SVG	R300750
L284184-9 20050705_05_4755_PWL1 UPPER PROPOSED WET LAND								
Sample Date: 05-JUL-05 14:10								
Matrix: WATER								
Ammonia-N	<0.05		0.05	mg/L		06-JUL-05	WNG	R300309
Biochemical Oxygen Demand	<2		2	mg/L		06-JUL-05	FY	R301814
MF - Fecal Coliforms	<1		1	CFU/100mL		08-JUL-05	PB	R302425
Total Suspended Solids	<3		3	mg/L		07-JUL-05	SVG	R300750
L284184-10 20050705_05_4755_PWL2 LOWER PROPOSED WET LAND								
Sample Date: 05-JUL-05 14:15								
Matrix: WATER								
Ammonia-N	<0.05		0.05	mg/L		06-JUL-05	WNG	R300309
Biochemical Oxygen Demand	<2		2	mg/L		06-JUL-05	FY	R301814
MF - Fecal Coliforms	<1		1	CFU/100mL		08-JUL-05	PB	R302425
Total Suspended Solids	<3		3	mg/L		07-JUL-05	SVG	R300750
L284184-11 20050705_05_4755_LF1 LANDFILL RUNOFF								
Sample Date: 05-JUL-05 11:10								
Matrix: WATER								
Biochemical Oxygen Demand	2		2	mg/L		06-JUL-05	FY	R301814
Total Suspended Solids	8		3	mg/L		07-JUL-05	SVG	R300750
L284184-12 20050705_05_4755_LF2 LANDFILL PONDING								
Sample Date: 05-JUL-05 11:15								
Matrix: WATER								
Biochemical Oxygen Demand	322		2	mg/L		06-JUL-05	FY	R301814
Total Suspended Solids	37		3	mg/L		07-JUL-05	SVG	R300750
L284184-13 BLANK COOLER 1 CONT. CONTROL								
Sample Date: 05-JUL-05 13:00								
Matrix: WATER								
MF - Fecal Coliforms	<1		1	CFU/100mL		08-JUL-05	PB	R302425

ENVIRO-TEST ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier	D.L.	Units	Extracted	Analyzed	By	Batch
L284184-14 BLANK COOLER 2 CONT. CONTROL Sample Date: 05-JUL-05 13:00 Matrix: WATER								
MF - Fecal Coliforms	<1		1	CFU/100mL		08-JUL-05	PB	R302425

Refer to Referenced Information for Qualifiers (if any) and Methodology.

Reference Information

Methods Listed (if applicable):

ETL Test Code	Matrix	Test Description	Preparation Method Reference(Based On)	Analytical Method Reference(Based On)
BOD-ED	Water	Biochemical Oxygen Demand (BOD)		APHA 5210 B-5 day Incub.-O2 electrode
FCC-MF-PB	Water	Fecal Coliform Count-MF		APHA 9222D MF
NH4-ED	Water	Ammonia-N		APHA4500NH3F Colorimetry
SOLIDS-TOTSUS-ED	Water	Total Suspended Solids		APHA 2540 D-Gravimetric

** Laboratory Methods employed follow in-house procedures, which are generally based on nationally or internationally accepted methodologies.

Chain of Custody numbers:

204285 204286

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location	Laboratory Definition Code	Laboratory Location
ED	Enviro-Test Laboratories - Edmonton, Alberta, Canada	PB	PBR LABARATORIES

GLOSSARY OF REPORT TERMS
Surr - A surrogate is an organic compound that is similar to the target analyte(s) in chemical composition and behavior but not normally detected in enviromental samples. Prior to sample processing, samples are fortified with one or more surrogate compounds.
The reported surrogate recovery value provides a measure of method efficiency. The Laboratory warning units are determined under column heading D.L.
mg/kg (units) - unit of concentration based on mass, parts per million
mg/L (units) - unit of concentration based on volume, parts per million
< - Less than
D.L. - Detection Limit
N/A - Result not available. Refer to qualifier code and definition for explanation

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
UNLESS OTHERWISE STATED, SAMPLES ARE NOT CORRECTED FOR CLIENT FIELD BLANKS.
Although test results are generated under strict QA/QC protocols, any unsigned test reports, faxes, or emails are considered preliminary.

Enviro-Test Laboratories has an extensive QA/QC program where all analytical data reported is analyzed using approved referenced procedures followed by checks and reviews by senior managers and quality assurance personnel. However, since the results are obtained from chemical measurements and thus cannot be guaranteed, Enviro-Test Laboratories assumes no liability for the use or interpretation of the results.

APPENDIX F

REPORT ON BREACHING FAILURE OF ORIGINAL LAGOON

Breaching Failure of Original Lagoon
Regional Engineer's Account

This is a brief history of the project to date. Since these Reports form a part of the on-going history of a project and of a Region, it is important that the record be kept clear – so that we can learn from decisions in the past, and also so that we can understand the context within which those decisions were made.

Much was accomplished in a very short time during the season of 2005. The Dillon/CGS team scheduled the first date possible to visit the community after break-up (to go in before would have been pointless, due to snow cover). Three weeks after the visit, Dillon produced three alternative designs – two of which with the intention of adding somewhat to the existing lagoon capacity. The third option involved blasting out the native granite on the existing site, thus increasing the lagoon size sufficiently to meet projected effluent production for the year 2025. Part of the rationale for providing the first two options was to buy time, if needed, until more funding could be identified. In addition, we wished to explore a new location farther away, not far from where other studies (Wardrop's 2002 study being one) had identified some wetlands potential. The latter designs would entail more design time, and would also be partially dependent on the outcome of community consultations. A further complication lay in the difficulty former designers has in assuring an effluent path that would avoid the community golf course and cabins near the ocean.

Figure 1

The CGS Project Officer and the Regional Engineer were in the midst of discussing the three options with Dillon staff when word came that the old lagoon had breached catastrophically, spilling 80 to 90 percent of its contents (see fig. 1). This necessitated a radical and immediate change of plans. The Regional Engineer asked Dillon to come up with a "quick fix" to the problem. This became the "Base Option" for the contract tender, with the stipulation that work be completed immediately. There were no guarantees that this "quick fix" option would work: this was understood at the outset. In addition, we were already approaching a change in season, and all involved were, though hopeful, somewhat realistic about the effectiveness of Option Four. However, the Regional Engineer felt that this was the only viable way to enable the community to survive for another season, and preserve as much of the project budget as possible, so that a proper long-term solution would be feasible. Both the request for the "quick fix" design and the decision to go ahead with the work were solely the responsibility of the Regional Engineer. That the repaired lagoon is leaking at this time is disappointing, but no surprise. There is still some reasonable hope that the bentonite will, with time, do its job and stop (or at least slow significantly) the flow. Below is the chronology of this project so far, followed by the Scope of Work for the construction tender issued on September 9, 2005.

Chronology of the project to date:

Dillon proposal accepted	June 1, 2005
Site visit by representatives from Dillon, AMEC, and CGS[1]	July 3 to 6, 2005
Dillon prepared three alternative designs for Phase 1 (Appendix E)	July 25, 2005
On-going discussions between CGS and Dillon teams	July 35-Aug 13
Original Lagoon had a major breach, losing 80% of effluent	August 13, 2005
Regional Engineer asked Dillon to design a fourth emergency option	August 14, 2005
Dillon's Fourth Option is presented to CGS	August 18, 2005
Contract Issued to construct Fourth Option	Sept. 9, 2005

[1] Note that this was the earliest date the team could visit the community after the snow had gone

Construction Finished Sept 21, 2005

Kugaaruk Sewage Lagoon Phase 1 **Scope of Work**

Project No: 03-4305 **Contract No: CT05-3509**

The Sewage Lagoon in Kugaaruk has been failing repeatedly for many years. This failure is due to a combination of several reasons, some of which are: 1). The porosity of the imported fill for the berms is too high, 2), the slope of the berm sides may be too steep to provide sufficient retaining strength, 3). Fissures within the granite outcrop may contribute to excessive leaking, and 4). The interface between the berm and the granite outcrop may provide a drainage path for effluent.

In addition, the capacity of this lagoon is not sufficient in its present configuration to meet demand created in the near future by the needs of a fast-growing community.

This request is for quotations on four alternative proposed solutions. Based on the prices and other factors, the GN will decide which one, if any, of these alternatives will be chosen. In simple terms, the four options will involve first draining all fluid and sludge removal from the lagoon, and:

1. Adding (keying in) granular material mixed with bentonite to increase the internal side slope and the height of the two berms retaining the lagoon. An overflow flume consisting of a nestable culvert complete with proper bedding will also be installed for this option as indicated in the drawing details. This construction option will reduce seepage, decrease the possibility of failure and increase the capacity of the lagoon to satisfy the hamlet’s waste production. A pre and post construction survey will also be performed on the lagoon floor and berms.
2. In addition to Option 1, the installation of a liner and cover will be added to construction. It should be noted when accessing this option that the amount of granular/bentonite mix that will be used in option 2 will decrease to allow for the liner and liner cover.
3. In addition to Option 2, blasting will be performed on the bottom of the lagoon. The will allow for long term hamlet waste retaining requirements.
4. This option, unlike the previous three, is a quick fix for the north berm retaining the lagoon. It involves the addition of a bentonite layer and cover applied to the existing inside slope of the berm. An overflow flume consisting of a nestable culvert complete with proper bedding will also be installed for this option as indicated in the drawing details. In contrast to the previous three options, only a post construction survey will be required of the lagoon bottom and berms.

APPENDIX G

SAMPLE TABLES OF CONTENTS

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