SCHEMATIC DESIGN REPORT

Tundra Wetland Sewage Treatment System Design

Chesterfield Inlet, Nunavut

Department of Community and Government Services, Government of Nunavut

PROJECT NO. 1042903

Jacques Whitford AXYS

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REPORT TO: **Department of Community and Government Services**
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ON: **Schematic Design**
Tundra Wetland Sewage Treatment System
Chesterfield Inlet, Nunavut

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EXECUTIVE SUMMARY

Nunami Jacques Whitford Ltd. (NJWL) was retained by the **Department of Community and Government Services (**CGS) of the **Government of Nunavut** (GN) to prepare a schematic design report for a **Tundra Wetland Sewage Treatment System** in **Chesterfield Inlet**, Nunavut. This report presents the schematic design for review by CGS.

The **Hamlet of Chesterfield Inlet** has been disposing of its sewage into a Tundra Wetland at a location approximately 2.5 kilometers west of the community. Previous investigations have confirmed that the Tundra Wetland was successfully treating the sewage. In support of its application to renew its Water Licence, **Chesterfield Inlet** needs to upgrade its sewage treatment system design so that it will continue to achieve compliance with effluent quality standards.

NJWL evaluated the capability of the existing Tundra Wetland to achieve compliance and defined how it might be enhanced as necessary. A preliminary design for enhancements to the Tundra Wetland has been prepared. Upon approval of the preliminary design concept, **NJWL** will prepare construction drawings and tender documents for review by **CGS**.

It is recommended that:

1. The use of a Tundra Wetland as the preferred natural sewage treatment process continue at **Chesterfield Inlet** and that enhancements for this system be selected for formal implementation.

2. The preliminary design be advanced to the 50 percent complete design phase for further review.

3. An application to renew the **Hamlet'**s Water Licence, incorporating the enhanced Tundra Wetland be prepared for submission to the **Nunavut Water Board**.

4. This report focuses on the sanitary wastewater at **Chesterfield Inlet**. However, the possible clean up of the adjacent, abandoned, dump site has to be further addressed in the next design phase.

Table of Contents

List of Tables

List of Appendices

1.0 INTRODUCTION

Nunami Jacques Whitford Ltd. (NJWL) was retained by the **Department of Community and Government Services** (CGS) of the **Government of Nunavut** (GN) to prepare a schematic (conceptual) design report (the Report) for a **Tundra Wetland Sewage Treatment System** (Tundra Wetland) in the **Hamlet of Chesterfield Inlet (**the **Hamlet** or **Chesterfield Inlet)**, Nunavut (the Project). The design and subsequent implementation of this system is intended to enable **CGS** and the **Hamlet** to fully understand the design, approve the design, and achieve compliance with effluent quality standards in its current and future Water Licences issued by the **Nunavut Water Board** (NWB). The comments received from **CGS** and the **Hamlet** will provide the direction necessary to proceed to the detailed design stage and to submit an application to renew the **Hamlet**'s Water Licence, which regulates water use and waste disposal in the community. The next stages in the Project will involve detailed design, submission of the Water Licence application and tendering of the physical works. Construction is expected to occur in fiscal year 2009.

This Report is organized as follows: Section 2 provides background information about the Tundra Wetland and sewage generation forecasts for **Chesterfield Inlet**. Regulatory requirements are identified in Section 3. A preliminary (conceptual) design option is presented in Section 4, followed by a schematic design of the proposed option in Section 5 and conclusions and recommendations in Section 6. The **Appendix** contains references and preliminary figures.

2.0 BACKGROUND

2.1 Community Information

The **Hamlet of Chesterfield Inlet** (or the Hamlet) is located on the west shore of Hudson Bay in the Kivalliq Region of Nunavut. The geographic coordinates of the community are approximate latitude 63^0 20' N, longitude 90^0 42' W. The location of the community is presented in **Figure 1** in Appendix A.

The **Hamlet** is located in the zone of continuous permafrost in the Canadian Shield. There are numerous rock ridges and lakes in the area. Tundra vegetation overlies bedrock, which is mainly Precambrian granite and gneiss. Sandy-gravel beach deposits, scattered boulders, muskeg, and exposed rocks are visible on the surface.

The average annual precipitation in the **Hamlet** consists of 146 millimeters of rainfall and 1,125 millimeters of snowfall, resulting in an annual total of approximately 259 millimeters of equivalent precipitation presented as rain. The July mean high and low temperatures are 13.1^{o}C and 4.6^{o}C, respectively. The July and August average daily temperature is about 10^{o}C. The January mean high and low temperatures are -27.8^{o}C and -35.2^{o}C, respectively. The January average daily temperature is about -32^{o}C. Winds are commonly from the northwest at an annual average speed of 22 kilometers per hour.

Although, the **Hamlet** has regularly scheduled air service, most supplies arrive annually by barge during the summer open water period. Diesel generators operated by the **Nunavut Power Corporation**

(NPC) supply electricity to the community, while the **Hamlet** provides trucked water, sewage and waste disposal services. The **Hamlet**'s water use, solid waste, and sewage disposal is regulated by **Nunavut Water Board Licence # NWB3CHE0308**.

A natural, tundra wetland Sewage Treatment System (the Tundra Wetland) has been in operation near the **Hamlet** since at least 1993. A report entitled "*Chesterfield Inlet Predesign Study Water, Sewer and Solid Waste*" by **I.D. Engineering** completed in 1982, recommended the use of this area for sewage disposal. **Chesterfield Inlet** has holding tanks at individual houses and associated buildings to collect wastewater. This wastewater is collected from the **Hamlet**'s houses and other buildings using vacuum trucks, which then transfer the wastewater to a Tundra Wetland which is located approximately 2.5 kilometers west of the community and 1.0 kilometers south of the airstrip.

In communities where water delivery/sewage collection is by truck, the ratio of residential to commercial/industrial input is very high. Sewage composition is essentially "domestic" in nature. **Table 1** compares estimated **Chesterfield Inlet's** average wastewater composition as reported in a January 1995 report "*Chesterfield Inlet Sewage Disposal Facility Site Characterization and Monitoring Study"* by **M.M. Dillon Limited** (Dillon) with typical wastewater component concentrations for raw sewage from *Treatment Wetlands,* Second Addition*, (*Kadlec and Wallace, 2008).

Table 1: Existing Average Wastewater Composition

Parameter	**Concentration: Kadlec and Wallace**	**Concentration: Dillon**
Fecal Coliforms	1.5 $X10^8$CFU/L (colony forming units/Liter)	< $5X10^7$CFU/L
BOD_5	450 mg/L	800 mg/L
TSS	500 mg/L	500 mg/L
Ammonia	40 mg/L	100 mg/L

Currently, the Tundra Wetland consists of one dumping station, four major ponds, and several intermittent ponds, some small streams, and open, boggy wet tundra areas (natural wetlands) between them through which overland flow occurs. (All of these components together comprise the Tundra Wetland.) The sewage drains from a single discharge point into a small pond (Pond 1). It then flows through a series of four ponds and across the wetlands before entering the ocean at Finger Bay on Hudson Bay. The distance between the discharge point and the sea is approximately 800 meters. Previous measurements indicated the Tundra Wetland covered an area of approximately 165,000 square meters. However, recent (2008) measurements indicate the Tundra Wetland may only have an effective area of approximately 104,000 square meters (10.4 ha). **For purposes of this Report, the more conservative and recently estimated 104,000 square meter (10.4 ha) Tundra Wetland dimensions are utilized.** During winter, the effluent freezes and builds up as an accumulated ice layer near the discharge point and Pond 1. Once temperatures rise and the ice layer melts, the wastewater and snowmelt from adjoining drainage areas flow into the Tundra Wetland.

Concern has been expressed that materials and/or leachate from former and existing solid waste sites nearby may be entering the downstream portion of the Tundra Wetland and negatively affecting the quality of the Tundra Wetland's effluent. An old dump site has been abandoned and replaced with a new fenced solid waste disposal facility. Both this old dump site and the fenced solid waste disposal facility are located adjacent to the Tundra Wetland. Solid waste is collected on a scheduled daily basis from the **Hamlet** and transported to the solid waste disposal facility by truck. Runoff from the solid waste disposal facility enters the Tundra Wetland downstream of the four major ponds, close to Finger Bay. Runoff and leachate from the old dump site enters the Tundra Wetland upstream of Pond 1.

2.2 Sewage Generation Rates and Forecast

System analysis and design requires the projection of wastewater generation rates for a 20-year planning horizon. The population of the community was estimated at 370 in 2007, based on **Statistics Canada**, Demography Division, prepared by the **Nunavut Bureau of Statistics**, May 2008. **Table 2** illustrates population projections for **Chesterfield Inlet** for a 20 year period, based on an annual increase of 1 percent, as projected by the Bureau.

Table 2: Population Projections- Chesterfield Inlet, Nunavut

Year	Population
2009	377
2014	397
2019	417
2024	438
2029	461

Projected sewage generation rates for the period between 2009 and 2029 are shown in **Table 3**. Sewage volumes are anticipated to be equal to water consumption volumes. The annual sewage generation is projected, based on a per capita water consumption rate of 100 Liters per capita per day (L/c/d.). To facilitate annual ice storage, the volume of sewage produced during a ten-month (300-day) period each year is included in **Table 3** (next page).

It should be noted that the current Water Licence for the **Hamlet** indicates the annual quantity of water used for all purposes shall not exceed 20,000 cubic meters. The above projections indicate the Hamlet will not exceed the annual 20,000 cubic meters even through the year 2029. The existing annual quantity water use permitted will not be exceeded until **Chesterfield Inlet** reaches a population of 550 or the per capita water consumption rate increases.

2.3 Review of Background Information

Several documents were made available to NJWL as background to the current study.

Key findings from these materials were reported by **Dillon** in *Sewage Disposal Improvements Design and Operations Concept, Chesterfield Inlet, N.W.T., May 1994 and Chesterfield Inlet Sewage Disposal Facility Site Characterization and Monitoring Study, January, 1995.*

Table 3: Sewage Generation Projections – Chesterfield Inlet, Nunavut

Year	Population	Annual Water Consumption (L)	Annual Sewage Volume (m^3)	10-Month Sewage Volume (m^3)
2009	**377**	13,776,451	13,776	11,323
2010	381	13,914,215	13,914	11,436
2011	385	14,053,357	14,053	11,551
2012	389	14,193,891	14,194	11,666
2013	393	14,335,830	14,336	11,783
2014	**397**	14,479,188	14,479	11,901
2015	401	14,623,980	14,624	12,020
2016	405	14,770,220	14,770	12,140
2017	409	14,917,922	14,918	12,261
2018	413	15,067,101	15,067	12,384
2019	**417**	15,217,772	15,218	12,508
2020	421	15,369,950	15,370	12,633
2021	425	15,523,649	15,524	12,759
2022	430	15,678,886	15,679	12,887
2023	434	15,835,675	15,836	13,016
2024	**438**	15,994,031	15,994	13,146
2025	443	16,153,972	16,154	13,277
2026	447	16,315,511	16,316	13,410
2027	451	16,478,666	16,479	13,544
2028	456	16,643,453	16,643	13,680
2029	**461**	16,809,888	16,810	13,816

The scope and objectives of **Dillon**'s reports were to:

- Review the current literature and develop the design parameters for wetland treatment at the proposed location,
- Develop the site design concepts for the selected treatment option, and
- Develop the operational requirements for the treatment facility.

The report studied three system options:

- Direct discharge to the wetland,
- Preliminary treatment of sewage only, and
- Preliminary sewage treatment and full winter storage.

Dillon's report recommended that a pilot program be undertaken, utilizing and investigating the performance of the direct discharge to wetland option. It also recommended a program of geotechnical investigations and an ecological study be undertaken in the report.

It further investigated the wetland system to assess the following:

- Nutrient uptake and filtration effects, and
- Seasonal performance.

The associated field program involved gathering information on the following parameters:

- Water quality (BOD_5, suspended solids, volatile solids, ammonia, phosphorus, total Kjeldahl nitrogen, total coliforms, and oil & grease),
- Soil (depth, profile, pH),
- Vegetation characterization, and
- Wildlife (subjective observations on species present).

In **Dillon**'s summary, the treatment of the **Hamlet**'s Tundra Wetland is highly effective. Discharge effluent to Finger Bay is well within the Water Licence criteria. Specifically:

- The Tundra Wetland at the Hamlet is defined as the area extending from the truck sewage discharge point to the wastewater effluent discharge location at Finger Bay confined by the north, south, and east by bedrock ridges. The wetland area is made up of a series of ponds, rock boulders, and abundant and diverse vegetation.

- The Tundra Wetland is highly effective in removing solids, nutrients, and coliform loadings achieving greater than 90 percent removals prior to discharge to Finger Bay.

- The discharge concentrations do not appear to be seasonally dependent, possibly due to increased precipitation in early summer causing dilution, hydraulic surge retention/equalization by overland flow expansion, and increased treatment in summer and fall resulting in increased removals.

- The current hydraulic loading rate during the frost-free days is **21.1 m^3/ha/d** well below the 100 to 200 m^3/ha/d suggested as design criteria for natural wetlands by Doku and Heinke, 1993.

- The current organic loading rate during frost-free days is **7.9 kg/ha/d** within the maximum recommended 8 kg/ha/d; identified to maintain aerobic conditions (Doku and Heinke, 1993). Aerobic conditions are maintained through the natural effluent flow through boulder fields, small ponds, and depression areas.

- Soil analysis at two locations identified an organic content of 50 to 70 percent and a neutral pH. The soils pH is an indication that the system is functioning well.

- As recommended in the *Design and Operations Concept Report* (Dillon, 1994), effluent and vegetative monitoring should be continued for two more years to better assess impact effects of the sewage on the Tundra Wetland area. This monitoring could provide a basis for developing design criteria for future wetland site construction using less conservative loading factors than are currently published.

- The current Water Board surveillance point identified to meet licence requirements is "directly below sewage disposal area". The entire defined Tundra Wetland area is used as the wastewater treatment system and should be recognized as such in the Licence. It is also recommended the surveillance point for Licence compliance be identified as being located northwest of Pond 4 near the discharge to Finger Bay. This represents the outfall from the treatment system.

Water Licence for NWB3CHE0308, Nunavut Water Board, December 15, 2003

The **Nunavut Water Board** issued Water Licence NWB3CHE0308 (the Licence) to **Chesterfield Inlet**, for a five year period, effective December 15, 2003. Licence requirements include the submission of annual reports, compliance with a Monitoring Program, the measurement of the volumes of water used and waste discharged, the preparation of an operation and maintenance (O & M) manual, the preparation of an abandonment and restoration (A & R) plan; the posting of signs identifying the stations of the Monitoring Program, reporting any spills of waste, and the maintenance of all licenced facilities.

Four Monitoring Stations are identified under the Licence as follows:

- CHE-1 Raw water supply at the First Lake Water Supply prior to treatment
- CHE-2 Effluent discharge from the Final Discharge Point of the Solid Waste Disposal Facility
- CHE-3 Raw sewage at truck offload point
- CHE-4 Effluent discharge from the Final Discharge Point of the Sewage Disposal Facility.

A number of general conditions are included in the Licence, as well as specific conditions pertaining to water use, waste disposal, modifications and construction, operation and maintenance, abandonment and restoration, and a monitoring program.

The Licence specifies that all effluent discharged from the Sewage Disposal Facilities at Monitoring Program Station CHE-4 shall meet the effluent quality standards presented in **Table 4** of this report.

Environmental Liability Assessment, December 2003

Jacques Whitford Environment Limited (a predecessor of **Jacques Whitford Limited [Jacques Whitford]**) carried out an environmental liability assessment in Chesterfield Inlet. The objectives of the project were to identify environmental liabilities associated with community infrastructure and prescribe actions that would minimize those liabilities. The investigation identified a number of potential environmental liabilities within the Hamlet. The applicable liabilities are as follows:

- The current sewage treatment operation may not comply with the water licence at certain times of the year. It was suggested that a sewage storage cell ahead of the wetlands could improve sewage treatment, making compliance with existing Licence criteria achievable on a consistent basis.

- The Tundra Wetland area below the sewage outfall does provide treatment of sewage effluent. The extent to which it can provide it requires more study.

- The Water Licence compliance monitoring point should be moved further downstream from the INAC monitoring point, and the exact location should be determined after further study.

- The old solid waste dump site should be examined to determine the impact that the water level in the Tundra Wetland is having in terms of leachate generation.

- The visible refuse at the old dump site should be removed and relocated to the new solid waste disposal facility. Some buried refuse may have to be excavated and re-deposited in the new solid waste disposal facility before a new sewage storage cell can be built.

- Sources of cover material should be identified for the current solid waste disposal facility. A Solid Waste Management Strategy should be prepared to ensure safe and efficient operation of the facility. Installing new signs, designating and then using areas for the storage of separable materials should improve safety and efficiency. Proper containment for waste oil barrels and other hazardous materials should be constructed. Alternative methods of waste oil disposal should be evaluated and the most beneficial and least costly alternative implemented.

- Drainage from the old dump site and the current solid waste disposal facility, and the potential impact on the treatment of sewage in the Tundra Wetland, should be determined.

- More information about the old dump site is required to determine what potential liabilities might exist and whether further decommissioning activity may be required. Waste may need to be relocated for proper disposal at the new solid waste disposal facility.

- Further analysis of the potential sewage treatment afforded by the Tundra Wetland should be planned for 2004.

Study of Wetland Sewage Treatment Area, March 2005

Jacques Whitford was commissioned by **Chesterfield Inlet** and the **Government of Nunavut's Department of Community and Government Services** (CGS) to perform a study of the Tundra Wetland. An investigation was undertaken to confirm that the Tundra Wetland could continue to constitute the Hamlet's sewage treatment system, and to provide preliminary design information to enable the Tundra Wetland to meet effluent treatment requirements for a 20 year planning period.

Analyses of effluent samples collected throughout the Tundra Wetland during the open water season of 2004 indicated that compliance with current Water Licence requirements and future sewage effluent parameters was achieved at the proposed new SNP monitoring locations. Microtox results indicated that the various metals in the effluent, some of which exceeded the CWQG [AL], do not appear to be having an adverse impact. This data suggested that during the open water season the Tundra Wetland was capable of treating the **Hamlet**'s sewage effluent to current and future requirements.

Analyses of the same effluent samples for metals concentrations during the same period identified the presence of certain metals at concentrations above the CWQG [AL] throughout the sampling period. Copper and aluminum were consistently detected in concentrations above the guidelines in all water bodies analyzed, including a background pond which was outside of the Tundra Wetland. The elevated copper and aluminum levels were thought to be a result of high background levels and/or impacts from the landfill reaching beyond the Tundra Wetland. Exceedances were noted in a number of other metals at different times and locations including those for silver, iron, selenium, lead, and zinc. For these metals, compliance with guidelines was often achieved by the time the effluent reached the proposed SNP locations.

Since the effluent splits into two flows and both points will require compliance monitoring, two proposed surveillance network points (SNP 1 and SNP 2) were identified for future licence compliance monitoring. As previously recommended in the **Dillon** *Characterization and Monitoring Report*, **Jacques Whitford** also recommended that the surveillance point for Licence compliance be located at the outfall of the Tundra Wetland, closer to Finger Bay.

In general, it was found that the wetland portion of the Tundra Wetland is most effective for secondary and tertiary treatment. However, large loadings of primary solids could hamper performance. To avoid "short-circuiting", holding cells near the discharge points were thought to be desirable to serve as a trap for suspended solids. Therefore, storage at the head of the Tundra Wetland was recommended. However, there are also concerns about potential generation of leachate from the adjacent old dump site. Specifically, it was thought that building a holding cell too close to the old dump site might increase the leachate generation problem. Alternately, it was suggested that the waste material could be removed to eliminate the leachate concern.

Site Investigation Report for the Sewage Disposal System, July 2005

The Government of Nunavut's Department of Community and Government Services (CGS) performed a site investigation of the Tundra Wetland for the purpose of:

- Inspecting the system on site and evaluate its treatment effectiveness;
- Sampling from the designated locations in the disposal area for further chemical and biological analyses to establish the final effluent meets with the **Nunavut Water Board** Licence requirements; and
- Providing appropriate suggestions for issues to be considered.

In summary, the **CGS** observed that the final effluent was clear, and that the Tundra Wetland is effective in decomposing and uptaking organics and nutrients in the sewage. It suggested that signs were needed at the site in conformance with the Water Board Licence requirements. Due to the significant amount of litter and discarded metal barrels found on site, it also suggested that the management of the adjacent solid waste disposal facility should be intensified.

2.4 Nunami Jacques Whitford 2008 Site Investigation

NJWL personnel conducted a site visit at the **Hamlet** in 2008 and results were presented in:

Chesterfield Inlet Field Report, August 2008.

Jacques Whitford personnel visited the Tundra Wetland at the time. The goals of the visit were as follows:

- To identify one or more areas for locating a new sewage holding cell,

- To confirm the location of a new Surveillance Monitor Point (SNP) for compliance monitoring based on an assessment of flows in the area and the ability to control/monitor flow going into Finger Bay,

- To initiate a sampling program,

- To obtain more data on the size of the Tundra Wetland and flows through it to the discharge into Finger Bay,

- To take initial water level measurements throughout the Tundra Wetland,

- To examine the old dump site to confirm its limits and obtain a depth of burial of the waste, and

- To examine the existing solid waste disposal facility.

Recommendations from the visit are as follows:

- Two areas of potential risk to the Tundra Wetland from the operating solid waste disposal facility were observed. Diversion berm(s) need to be installed to direct the associated runoff so that it enters the Tundra Wetland at a location more suitable for treatment (i.e., at the front of the Tundra Wetland).

- Debris and garbage was observed in Pond 1 and in areas downstream (west of Pond 1), and it should be removed and disposed of properly.

- At the existing dumping station, bollards or blocks need to be installed at its edges and proper signing needs to be installed. The existing dumping station also needs to be improved for truck access and safety. A large chute, such as a 600 mm diameter corrugated pipe system, needs to be installed to transfer wastewater from the trucks towards a holding cell.

- Exposed debris from the old dump site needs to either be removed or properly covered. However, removal of all material is not recommended.

- A new Surveillance Monitoring Point (SMP) is proposed.

- Two diversion berms are needed to channel the flow to the new SMP. An associated access road is also needed.

- Three potential holding cell locations were identified, all generally located upstream of Pond 1.

- It is recommended that the addition of any berms (or any construction activity) within the existing Tundra Wetland be minimized.

2.5 Summary

The **Hamlet** has been discharging sewage in the same location since at least 1993. Generally, the sewage flows through the Tundra Wetland. The treatment performance of the Tundra Wetland has been subject to numerous studies since 1994. All investigations generally support that the Tundra Wetland is effectively treating the sewage and could continue to do so in the future. Review of analytical data from samples collected annually throughout the Tundra Wetland indicates that the system is currently treating the sewage to effluent quality standards contained in the Water Licence.

The **Government of Nunavut** has approved the construction of a new sewage holding cell at the existing sewage disposal site. The reason for this approval is summarized below:

1. Without a holding cell, the Tundra Wetland may not comply with discharge criteria (*Fisheries Act*) at certain times of the year, or some time in the future. A new cell ahead of the Tundra Wetland should improve sewage treatment, making compliance with existing and future Licence criteria achievable on a consistent basis. It also provides a place where “additional” treatment measures can be taken if they are required in the future.
2. Regulatory authorities want to ensure that contaminants are not going to cause a problem in the Tundra Wetland and downstream environment. If leachate and runoff is confined and treated within the solid waste disposal facility boundary, or in the Tundra Wetland, there will be greater confidence that the environment is protected. The sample results in **Jacques Whitford’s** report from Monitoring Station CHE-4 indicated some leaching metals. As part of the holding cell addition process, removal of the adjacent, above ground waste that is generating leachate may aid in reducing the problem. However, another concept is to divert, with berms, the leachate into the Tundra Wetland as soon as permissible to allow for additional treatment.
3. The effluent from the Tundra Wetland should comply with the regulations. Unfortunately, the current compliance point used by regulators is nowhere near the point envisioned by the consultants who originally proposed the Tundra Wetland as a treatment system. Use of a compliance point very close to the beginning of the Tundra Wetland virtually ensures non-compliance. The solution is to have a defined compliance point that is recognized by the regulators and is located well downstream of the current compliance point. The point requires careful selection to meet the desired “definition” of a discharge point. A new Surveillance Monitoring Point (SMP) is proposed. Two diversion berms (and associated access roads) are needed to channel the flow to the new SMP.

3.0 REGULATORY REQUIREMENTS

The Water Licence issued by the **Nunavut Water Board** to **Chesterfield Inlet** defines requirements for sewage and solid waste disposal, and includes sewage effluent criteria for *Fecal Coliforms* (as colony forming units per Liter (CFU/L)), *Biochemical Oxygen Demand* (BOD_5), *Total Suspended Solids* (TSS), *oil & grease*, and *pH*. The current Licence will expire December 31, 2008. Effluent quality standards contained in the current Water Licence are presented in **Table 4**.

Table 4: Current Water Licence Effluent Quality Standards

Parameter	**Maximum Average Concentration**
Fecal Coliforms	$1X10^5$CFU/L
BOD_5	80 mg/L
TSS	100 mg/L
Oil and Grease	No visible sheen
pH	Between 6 and 9

The Canadian *Water Quality Guidelines for the Protection of Aquatic Life* apply to the discharge of the effluent from the last control point of the **Hamlet**'s sewage treatment system. A critical contaminant addressed in these guidelines is ammonia. Evaluation of the treatment capacity of the **Chesterfield Inlet** Tundra Wetland should take into account these requirements with compliance assessment relative to the most stringent values. In addition to the above requirements and those in a future Water Licence for **Chesterfield Inlet**, effluent from the **Hamlet**'s wastewater treatment system should not be toxic to fish. Based on the analytical results from effluent samples, it is evident that current and anticipated discharge criteria can be achieved at the proposed Surveillance Monitoring Point (SMP) located near Finger Bay.

4.0 DESIGN IMPROVEMENTS

A primary objective of this Report is to present the conceptual design of a sewage holding cell that will meet effluent discharge criteria and enable **Chesterfield Inlet** to create permanent wastewater infrastructure necessary for sustainable growth. In support of the primary objective, the following tasks were addressed:

1. Summarize historical information.
2. Determine types, locations and limits of waste. Review previous studies and initiate a sampling program.
3. Recommend site location(s) for a sewage holding cell(s).
4. Prepare a schematic design for the holding cell(s) and other recommended improvements to the Tundra Wetland.
5. Ensure the plan meets all CCME standards and NWB requirements and regulations.

In the future, **NJWL** will address the following:

- Monitoring programs in 2009,
- Contract documents for construction in 2009,
- Site visits during construction and submit inspection reports, and
- The survey of new boundaries for enlarged sewage wetlands and new holding cell(s).

The purpose of the facility design presented herein is to enable the **Hamlet** to achieve compliance in the 20 year design period with the sewage effluent quality standards contained in the Water Licence issued by the **Nunavut Water Board**. The design selected, that with the lowest present worth cost, is to improve the existing Tundra Wetland with holding cells. Other than not having the holding cells, the **Hamlet** currently has an adequate Tundra Wetland.

4.1 Holding Cells and Associated Improvements

Holding cells are a common method for treating sewage in northern communities. Following a typical northern holding cell and pond system with a regime of 10 months (300 days) storage and release in the late summer/fall; the sewage holding cells and ponds at **Chesterfield Inlet** will have to have a capacity of **13,816 cubic meters** to address the 20 year planning horizon ending in 2029, as shown in **Tables 2 and 3**. For the **Hamlet**, the design flow is the total annual sewage (16,810 cubic meters per year) divided by the release period (65 days per year) 259 cubic meters per day.

The area of the holding cells and ponds necessary to meet future demand needs to be approximately 10,000 square meters (100 meters by 100 meters), and they should have a 1.5-meter depth. However, the relative flatness of the existing topography in the Tundra Wetland does not allow a 1.5 meter depth unless a berm were constructed across the existing Tundra Wetland; which is not recommended. There are two areas located upstream and adjacent to Pond 1 that will allow for an increase to the effective storage volume available, and assist in treating the sewage before it flows into Pond 1 and the remainder of the Tundra Wetland. However the volume available from these two holding cells would total only about 10 percent (1,325 cubic meters) of the required storage. The available storage, from existing grade to elevation 17.5 masl, is not adequate to meet the 20 year (2029) demand of 13,816 cubic meters. Accordingly, the remaining winter storage volume will need to be obtained from further impoundments downstream of the proposed holding cells. Assuming the average thickness of the frozen sewage will be on the order of 0.5 meters thick, the remaining area necessary for storage equals about 25,000 square meters. The average width of the existing Tundra Wetland is about 65 meters, such that the storage length could extend about 400 meters; encompassing about 50 percent of the existing length of the Tundra Wetland. This area will include both Pond 1, and Pond 2 and the associated wetlands.

The two new holding cells will be constructed with berms located perpendicular to the flow direction and designed with liners, creating impervious barriers. In addition to the two holding cells, at the existing dumping station, bollards or blocks will need to be installed at its edges and proper signage installed. The existing dumping station also needs to be improved for truck access and safety. A large chute, such as a 600 mm diameter corrugated pipe, needs to be installed to transfer wastewater from the trucks towards the holding cell. A second similar dumping station is also proposed, upstream of the second proposed holding cell.

The solution to having a defined compliance point is to construct two diversion berms (with an associated access road) to channel the flow to the new compliance point. A third diversion berm is proposed to divert the leachate from the solid waste disposal facility into the Tundra Wetland as soon as practical to allow additional treatment of it.

A schematic showing the location of a second dumping station, the two holding cells constructed with berms, and the three diversion berms is presented on **Figure 3** in Appendix A.

4.2 Reduction of Fecal Coliforms

For most of the year, the sewage is and will be discharged towards Pond 1 in sub-zero temperatures and it will freeze. This is beneficial as freeze-thaw action is effective for destroying fecal coliforms. Freezing ruptures bacterial cells and results in their death, and this eliminates the potential for infection from them. Due to the melting of frozen sewage, flows through the Tundra Wetland will be higher during the melt period than during the frozen period. However, the quality values of the sewage should be lower as melt period sewage dilutes with and thaws out sub-zero temperature period sewage. For purposes of this evaluation, it was assumed that daily influent sewage has a fecal coliforms value of $1.5X10^8$ CFU/L. However, this value will drop to negligible levels as the sewage freezes. Therefore, when the frozen sewage thaws and mixes with the daily influent sewage during the un-frozen period, a weighed fecal coliforms value of $2.67X10^7$ CFU/L is obtained ($1.5X10^8$ CFU/L X 65 days / 365 days).

Numerous studies have shown that the removal of fecal coliforms in ponds depends on detention time and temperature. This can be modeled (*Natural Wastewater Treatment Systems*, Crites, Middlebrooks, Reed, 2006) using values given in **Table 1** to estimate the level of coliforms at the center of the Tundra Wetland as follows:

$$\mathbf{C_f = C_i / (1 + t(k_T))^n} \qquad (1)$$

where C_f = Effluent fecal coliforms (CFU/L),
C_i = Influent fecal coliforms (CFU/L), $2.67X10^7$ CFU/L
t = Detention time in the cell (d), equal to 54 days [13,816 m^3 / 259 m^3 / day]
k_T = Temperature-dependent rate constant (d^{-1}), equal to $(2.6)(1.19)^{(Tw-20)}$, $(2.6)(1.19)^{8-20}$ d^{-1}
Tw= Mean water temperature in pond (^oC), 8^oC
n = Number of cells in series, 1 cell [holding cell/Pond 1/Pond 2].

Therefore,

$$C_f = 2.67X10^7 / (1 + 54((2.6)((1.19)^{(8-20)})) = 1.45 \times 10^6 \text{ CFU/L}$$

And,

$$C_f = 1.45 \times 10^6 / (1 + 50((2.6)((1.19)^{(8-20)})) = 8.47 \times 10^4 \text{ CFU/ L}$$

for everything downstream of the frozen area, the second cell in series, where the detention time in the cell (d), is equal to 50 days [13,000 m^3 / 259 m^3/ day]. The 13,000 m^3 is the 50 percent area (52,000 square meters) downstream of Pond 2, and assumes an average depth of 0.25 meters. The total area of the Tundra Wetland has a conservatively estimated dimension of **104,000 square meters**.

This value meets the Licence's effluent quality standard of 1 X 10^5 CFU/L when the effluent is discharged in 54 days through the holding cells, Ponds 1 and 2 and associated wetlands; and then 50 days through Ponds 3 and 4 and associated wetlands; and the effluent water temperature is 8 ^oC, or warmer. (The July and August average daily temperature is 10^oC.)

4.3 BOD_5 Reduction

For BOD_5 reduction, the following equation can be utilized to design a facultative wastewater treatment cell (*Natural Wastewater Treatment Systems*, Crites et al., 2006) and can provide an estimate of BOD_5 concentrations after the cells given a design BOD_5 value from **Table 1**:

$$V = (3.5 \times 10^{-5})(Q)(La)(\theta^{(35-T)})(f)(f') \qquad (2)$$

where

V = Cell volume (m^3),
Q = Influent flow rate (L/d), 46,100 L/d
La = Ultimate influent BOD_5 (mg/L), 450 mg/L
θ = Arhennius temperature correction coefficient, 1.085
T = Lagoon temperature (degrees C), 8^oC
f = Algal toxicity factor, 1.0 for domestic wastes and many industrial wastes
f' = Sulfide oxygen demand, 1.0 for sulfate equivalent ion concentration of less than 500 mg/L

When **Chesterfield Inlet** is evaluated at 8^oC,

$$V = (3.5 \times 10^{-5})(46{,}100)(450)(1.085^{(35-8)})(1)(1) = 6{,}570 \text{ m}^3$$

A cell pond depth of 1.5 meters is suggested for systems with significant seasonal variations in temperature and major fluctuations in daily flow. The volume (6,570 m^3) is not obtained at the two proposed holding cells. To provide adequate volume to address BOD_5 reduction, the volume of Pond 1 and Pond 2 plus the associated wetland volumes between the two ponds are necessary. The BOD_5 removal efficiency is projected to be 85 to 90 percent based on unfiltered influent samples and filtered effluent samples. This BOD_5 removal efficiency will be adequate to meet the Licence's effluent quality standard of 80 mg/L prior to entering Finger Bay.

4.4 Total Suspended Solids Reduction

Overland flow systems, such as the drainage from **Chesterfield Inlet** dump station to Finger Bay are generally effective in removing suspended solids (measured as total suspended solids, TSS and commonly referenced as such). However, the slope between the dump station and Pond 1 is about 10 percent, which leads to an increased risk of short-circuiting, channeling, and erosion. The addition of holding cells between the dump station(s) and Pond 1 will create some detention volume, and this will aid in addressing TSS prior to Pond 1. Additional removal of TSS will occur at Pond 1, at the subsequent ponds and the tundra wetlands. The berms around the holding cells should incorporate a liner to aid in reducing TSS.

4.5 Ammonia Reduction

The removal of pollutants such as ammonia in a treatment wetland is dependant on microbially-mediated aerobic transformations which result in the oxidization (nitrification) of the ammonia to nitrate. Wetland plants provide ("leak") some oxygen to microbes in their root zones and some diffuses in from the air. When considering ammonia reduction, the following equation can be utilized to design the wastewater wetland area required (*Treatment Wetlands* Second Addition, Kadlec and Wallace, 2008):

$$\mathbf{C_{out}/C_{in} = 1/(1 + k/Pq)^{P}} \qquad (3)$$

where

C_{out} = outlet concentration, mg NH_3-N/L, = 34mg/L
based on un-ionized ammonia fraction @ T = 10 ^{o}C and pH = 7.5
C_{in} = inlet concentration, mg NH_3-N/L, = 120 mg/L
based on 12 grams/day ammonia nitrogen
k = modified first order areal constant, m/yr [50th percentile] [@ T = 10 ^{o}C] = 10.3 m/yr
P = apparent number of tanks in series, = 3 (per cell) and 2 cells [retention cells/Pond 1/Pond 2 area, and downstream area including Pond 3/Pond 4],
q = hydraulic loading rate, m/d = Q/A, where Q = 259 m^3/d

Solving for q when

$$34/120 = 1 / ((1 + 10.3 / (3)(2)(q)^{(2)(3)})$$

q = Q / A = 7.339 m/yr = 0.020 m/day, such that
A = Q / q = 259m^3/day /0.020 m/day
A = **12,900 m^2**

The area of the existing Tundra Wetland is about 104,000 square meters which is about 8 times as large as required. Removal efficiency will be adequate to meet the effluent quality standard for un-ionized ammonia entering Finger Bay.

4.6 Tundra Wetland Sewage Treatment

Available documentation indicates that the **Hamlet** has been using the Tundra Wetland west of the community since it was constructed in 1993. Sewage is dumped directly from trucks onto the tundra in the area east of the first downstream wetland, Pond 1. The sewage flows through a series of four ponds, including Pond 1, and tundra area (wetlands) before entering the sea at Finger Bay on Hudson Bay. Several studies of the treatment performance of the Tundra Wetland have been undertaken since 1993, all concluding that the Tundra Wetland generally successfully treats sewage effluent. Analytical results from effluent samples collected throughout the Tundra Wetland demonstrated that the wetland is successfully treating sewage effluent to meet current and anticipated regulatory requirements.

The Water Licence requires compliance with the effluent quality standards be achieved at Monitoring Program Station CHE-4, presently considered to be the effluent discharge from the Final Discharge Point of the Sewage Disposal Facilities. Incorporation of these recommended enhancements will ensure the Tundra Wetland is a viable option to meet the Hamlet's sewage treatment requirements over the long term.

Signage needs to be posted along the boundaries of the system to advise residents of the Tundra Wetland location.

4.7 Evaluation of Design

A standard set of criteria have been established from which to evaluate the design option presented above. These criteria are outlined below:

Compliance: Achieve compliance with current and future effluent quality standards established by the Nunavut Water Board.

Long Term Needs: Meet the **Hamlet'**s sewage treatment needs for a minimum 20 year period.

Practicality: The design must be able to be implemented with local expertise and provide a reasonable expectation of being successful.

Public Safety: The option should protect the health and safety of community residents.

Cost: The option should be cost effective from both a capital and operation and maintenance perspective.

4.7.1 Compliance

Compliance with effluent discharge standards are expected to be met with this design. Analytical results have demonstrated that the Tundra Wetland achieves compliance with effluent discharge standards. The purpose of these recommendations is to primarily address existing deficiencies and future needs.

4.7.2 Long Term Needs

Based on a desired decant of storage cells/ponds in the summer/fall of each year, the Tundra Wetland should be sized with a storage capacity of 10 months for the 20 year planning horizon. This will require a capacity of 13,816 cubic meters for the year 2029.

The capacity of the Tundra Wetland to treat sewage over the long term can also be calculated based on loading rates and area of treatment. In the past, a commonly accepted hydraulic loading rate (wastewater flow rate over wetland area) for Tundra Wetlands treating domestic sewage was 5 ha of wetland surface area per 1000 m^3/d of sewage flow introduced (expressed more commonly as 2 cm/d), but more recent studies indicate that up to 7 cm/d can be appropriate if conditions are right, some pre-treatment has occurred, and the wetland can be "engineered" to ensure maximum contact between the wastewater being treated and the vegetation/microbial biofilm matrices in the wetland (Knight et al., 1987). However, a more conservative recommendation is for 50 ha/1000 m^3/d (0.2 cm/d) for municipal wastewaters (Kadlec & Knight, 1996), especially where cold weather conditions are encountered and there is untreated ammonia nitrogen in the wastewater being treated.

Based on the conservative Tundra Wetland sizing criteria of 50 ha/1000 m^3/d (0.2 cm/d), the minimum size necessary to treat the **Hamlet**'s 2029 annual sewage generation rate (16,810 cubic meters or 46 cubic meters per day) would be 2.3 hectares. With the proposed holding cell construction and the boundary of the existing Tundra Wetland area defined as illustrated in **Figures 2 and 3** in Appendix A, the Tundra Wetland encloses an area of approximately 10.4 hectares (104,000 square meters). This natural treatment wetland will consist of deeper bodies of water, connecting channels, shallower bodies of water and overland flow, boggy, tundra areas. Based on these calculations and assumptions, the proposed Tundra Wetland has sufficient area to treat wastewater for the next 20 years.

4.7.3 Practicality

The existing Tundra Wetland is currently in use and has an uneven floor with bedrock outcrops.

Limited improvements are proposed for the Tundra Wetland. Signage will need to be installed along the boundaries of the wetland and new berms will be constructed. The berms on the holding cells will incorporate a geotextile liner. The other berms will either be constructed with liners or such that permafrost will permeate or migrate into the berms and present impervious barriers. Construction of berms with impervious liners, or in a manner to allow permafrost aggregation into the berms to provide an impervious barrier, are practical solutions. Installation of signage and berm construction can be carried out by local contractors.

4.7.4 Public Safety

Construction of holding cells, and the construction of new berms will allow sewage to be contained for a ten month period and will provide for a more managed discharge. Discharged effluent should meet effluent discharge standards at the Surveillance Monitoring Point to be located near Finger Bay.

The Tundra Wetland design provides continuous discharge from the holding cells and upstream ponds (Pond 1 and Pond 2) during the period of the year when ambient temperatures are at or above freezing temperatures (approximately two months). During the remainder of the year, sewage will freeze in the holding cells and upstream ponds and be discharged upon snowmelt. Analysis of effluent samples indicates that the Tundra Wetland concentrations meets and complies with the regulations. The risk to public health and safety with this design is considered low as residents are well aware of the location of the Tundra Wetland.

4.7.5 Cost Summary

Given the limited infrastructure resources available in Nunavut, cost is a very important factor in evaluating the design.

Some general observations are presented here for consideration. Geotextile liners are shown in the conceptual design and will be more practical. Clay is probably not readily available. Even if it were available, it is not known whether local sources of it would be suitable as liner material. The volume of clay required is proportional to both the area required to be lined and the hydraulic conductivity of the clay material. Evaluation as to whether clay is available and suitable will be evaluated in the next phase of design. Installation of liners in the holding cells will require the purchase, transport, and installation of synthetic liner material and the placement of material to anchor and protect the liner. Construction of diversion berms to promote permafrost aggregation will require considerable volumes of coarse gravel material. All of the construction items are considered to have high capital costs. Ongoing operation and maintenance costs will involve annual maintenance and repair of the berms, holding cells and the sewage discharge locations; and monitoring of permafrost aggregation.

Improvements to the Tundra Wetland will require the preparation and installation of signage.

The construction cost estimate for this option is presented in **Table 5** (next page).

Table 5: Conceptual Design Construction Cost Estimate

ITEM	UNITS	ESTIMATED QUANTITY	UNIT PRICE	AMOUNT
Diversion Berm No. A				
Plastic Liner	m^2	300	$ 40.00	$ 12,000.00
Liner Trenching	LM	60	$ 40.00	$ 2,400.00
Coarse Gravel, 50-75mm, Length = 60m	m^3	200	$ 70.00	$ 14,000.00
Sand	m^3	65	$ 70.00	$ 4,550.00
Diversion Berm No. B				
Plastic Liner	m^2	420	$ 40.00	$ 16,800.00
Liner Trenching	LM	60	$ 40.00	$ 2,400.00
Coarse Gravel, 50-75mm, Length = 60m	m^3	125	$ 70.00	$ 8,750.00
Sand	m^3	80	$ 70.00	$ 5,600.00
Access Road 20 m long	m^3	60	$ 70.00	$ 4,200.00
Diversion Berm No. C				
Plastic Liner	m^2	420	$ 40.00	$ 16,800.00
Liner Trenching	LM	60	$ 40.00	$ 2,400.00
Coarse Gravel, 50-75mm, Length = 60m	m^3	125	$ 70.00	$ 8,750.00
Sand	m^3	55	$ 70.00	$ 3,850.00
Holding Cell 1				
Plastic Liner	m^2	480	$ 40.00	$ 19,200.00
Liner Trenching	LM	60	$ 40.00	$ 2,400.00
Coarse Gravel, 50-75mm, Length = 60m	m^3	432	$ 70.00	$ 30,240.00
Sand	m^3	108	$ 70.00	$ 7,560.00
Hand Placed Rip Rap 150-300 mm dia.	m^3	6	$ 200.00	$ 1,200.00
Access Road 40 m long	m^3	120	$ 70.00	$ 8,400.00
Holding Cell 2				
Plastic Liner	m^2	320	$ 40.00	$ 12,800.00
Liner Trenching	LM	40	$ 40.00	$ 1,600.00
Coarse Gravel, 50-75mm, Length = 40m	m^3	288	$ 70.00	$ 20,160.00
Sand	m^3	72	$ 70.00	$ 5,040.00
Hand Placed Rip Rap 150-300 mm dia.	m^3	6	$ 200.00	$ 1,200.00
Access Road 40 m long	m^3	120	$ 70.00	$ 8,400.00
Miscellaneous				
Mobilization	LS	1	$ 12,000.00	$ 12,000.00
Warning Signs	Each	4	$ 500.00	$ 2,000.00
Improve Existing Discharge Location	LS	1	$ 40,000.00	$ 40,000.00
New Sewage Discharge Location	LS	1	$ 60,000.00	$ 60,000.00
Anticipated Construction Cost				$ 334,700.00

The estimated construction cost is expected to be approximately **$335,000**, not including contingency, taxes, fees or escalation.

Annual operation and maintenance costs will be very low, and will be related to sampling costs and the maintenance of the berms, cells and discharge locations.

5.0 SCHEMATIC DESIGN

The current Tundra Wetland consists of a dumping station that discharges to a tundra area consisting of ponds, channels and boggy overland flow areas. Improvements to the Tundra Wetland will optimize its treatment capacity such that the Tundra Wetland can effectively treat the **Hamlet**'s sewage for a 20-year period in compliance with applicable legislation.

The proposed Tundra Wetland begins at the current and proposed discharge sites. Sewage haulers will alternately transport untreated sewage to the existing sewage dumping station and a new dumping station. Wastewater will be deposited into two new holding cells to allow initial settling. The holding cells begin the treatment process. The northwesterly (downstream) sides of the holding cells will require impervious berms. Initially, a gravel material will be placed. A 150 mm thick layer of sand will be placed on top of this gravel layer. An impermeable high density polyethylene (60 mil thick, textured HDPE) liner then will be placed on the sand layer. The liner will be anchored into the inside of the berm and into the native ground material as best as practical and possible; however, shallow bedrock may limit the anchor trench depth in some areas. The HDPE liner will then be covered by another 150 mm thick layer of sand. The entire berm will then be covered with 150 mm of coarse gravel to provide erosion control. The location of the holding cells is shown in **Figures 3 and 6** and a cross section of a holding cell berm is shown in **Figure 7** in **Appendix A**. By leaving the native ground material in place, a permafrost layer should build up over time and provide an impermeable layer to prevent water from flowing under the coarse gravel material.

Water will outlet through the holding cell berms at specified outlets and enter the Tundra Wetland, and specifically Pond 1. Flow then currently travels in the areas between bedrock outcrops.

Two new flow diversion berms are proposed between the end of the Tundra Wetland and Finger Bay. In addition, a third berm is proposed within the solid waste disposal facility. The location for these three berms is shown in **Figures 3, 4 and 5** and a cross section of the berms is shown in **Figure 7** in **Appendix A**.

6.0 CONCLUSIONS AND RECOMMENDATIONS

The **Hamlet of Chesterfield Inlet** has been disposing of its sewage into a Tundra Wetland at a location approximately 2.5 kilometers west of the community. Previous investigations have confirmed that the Tundra Wetland is successfully treating the sewage. The sewage is delivered to a pond. The sewage flows from the pond onto the downstream Tundra Wetland in generally an uncontrolled manner.

The sewage disposal and treatment in **Chesterfield Inlet** is currently regulated by the **Nunavut Water Board,** under a Water Licence. Effluent quality standards prescribed in the Licence require compliance from the "*Sewage Disposal Facilities*", which is currently considered to be Monitoring Program Station CHE-4. In support of its application to renew its Water Licence, **Chesterfield Inlet** needs a sewage treatment system design that will allow it to achieve compliance with effluent quality standards, now and in the foreseeable future.

NJWL evaluated the existing Tundra Wetland to achieve compliance and enhancement of the Tundra Wetland is necessary. A Tundra Wetland was selected as the preferred design for sewage treatment for the community. A preliminary design for enhancements to the Tundra Wetland has been prepared. Upon approval of the preliminary design concept, **NJWL** will prepare construction drawings and tender documents for review by **CGS**.

6.1 Recommendations

It is recommended that:

1. The use of a Tundra Wetland as the preferred natural sewage treatment process continue at **Chesterfield Inlet** and that enhancements for this system be selected for formal implementation.

2. The preliminary design be advanced to the 50 percent complete design phase for further review.

3. An application to renew the **Hamlet'**s Water Licence, incorporating the enhanced Tundra Wetland be prepared for submission to the **Nunavut Water Board**.

4. This report focuses on the sanitary wastewater at **Chesterfield Inlet**. However, the possible clean up of the adjacent, abandoned, dump site has to be further addressed in the next design phase.

7.0 CLOSURE

This Report has been prepared by **Nunami Jacques Whitford Ltd**. (NJWL) for the sole benefit of the **Department of Community and Government Services, Kivalliq Region, of the Government of Nunavut**. This Report may not be relied upon by any other person or entity without the express written consent of Community and Government Services.

Any uses that a third party makes of this Report, or any reliance on decisions to be made based on it, are the responsibility of such third parties. **Nunami Jacques Whitford Ltd**. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this Report.

The conclusions presented represent the best judgment of **NJWL** based on current site conditions observed on the date cited within this Report. If any conditions become apparent that differ significantly from our understanding of conditions as presented in this Report, we request that we be notified immediately to reassess the conclusions provided herein.

It is noted that **NJWL**'s partner, **Jacques Whitford Limited**, has been acquired by **Stantec Inc**, and will continue business as **Stantec.** This change will have no affect on the Project.

We trust that the report meets your current requirements. Should you have any questions or concerns regarding the above, please do not hesitate to contact the undersigned.

Respectfully submitted,

NUNAMI JACQUES WHITFORD LTD.

REGISTERED PROFESSIONAL ENGINEER
J.P. HIGGINS
LICENSEE
NWT/NU

R. Jeff Elliott
Project Engineer

Jim Higgins, Ph.D., P.Eng.
Chief Engineer

APPENDIX A

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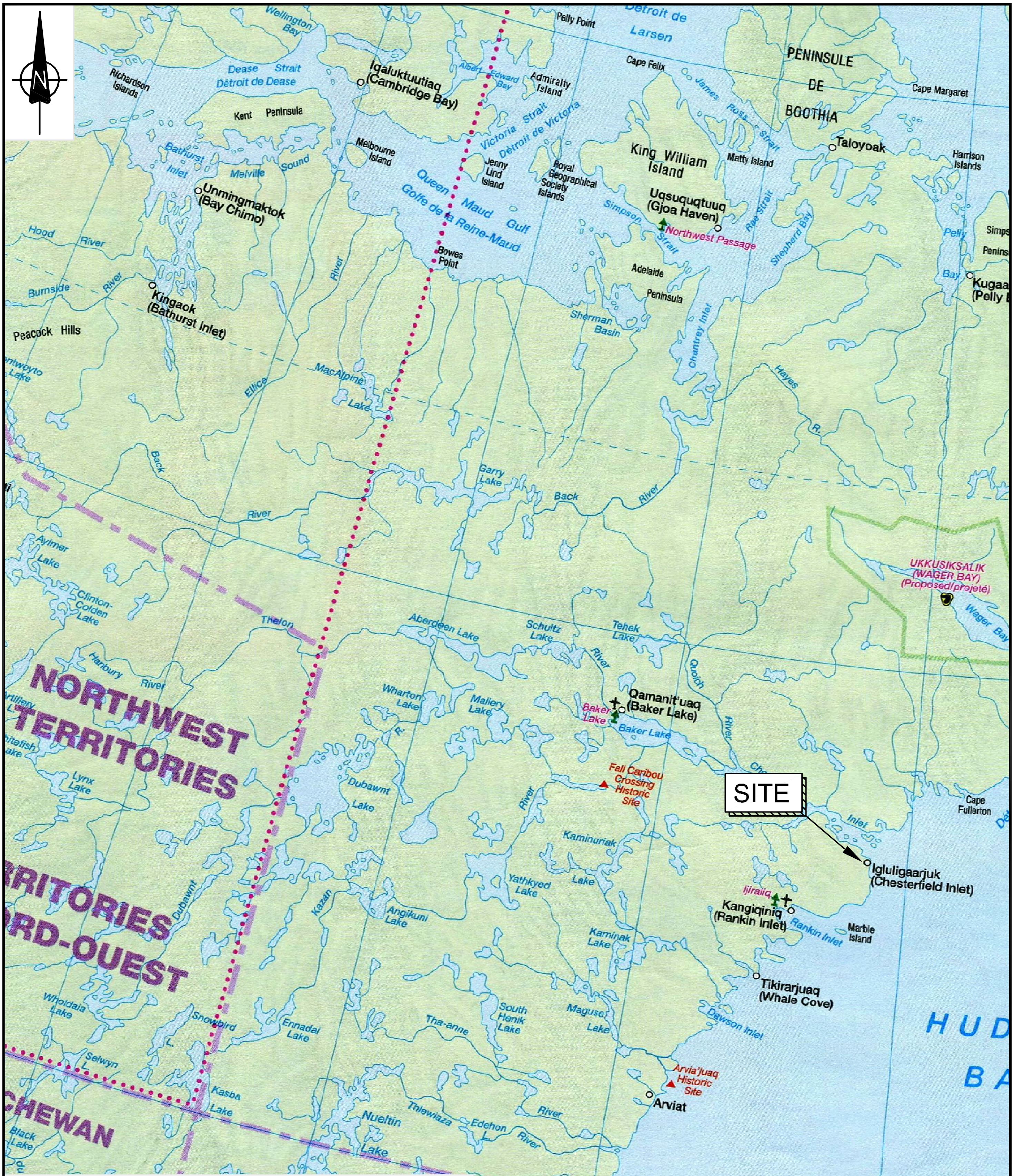
APPENDIX B

Drawings and Figures

Jacques Whitford AXYS



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SCALE 1 : 5 000 000

*IMAGE REFERENCE: MAPART PUBLISHING, ALBERTA ROAD ATLAS, 2003

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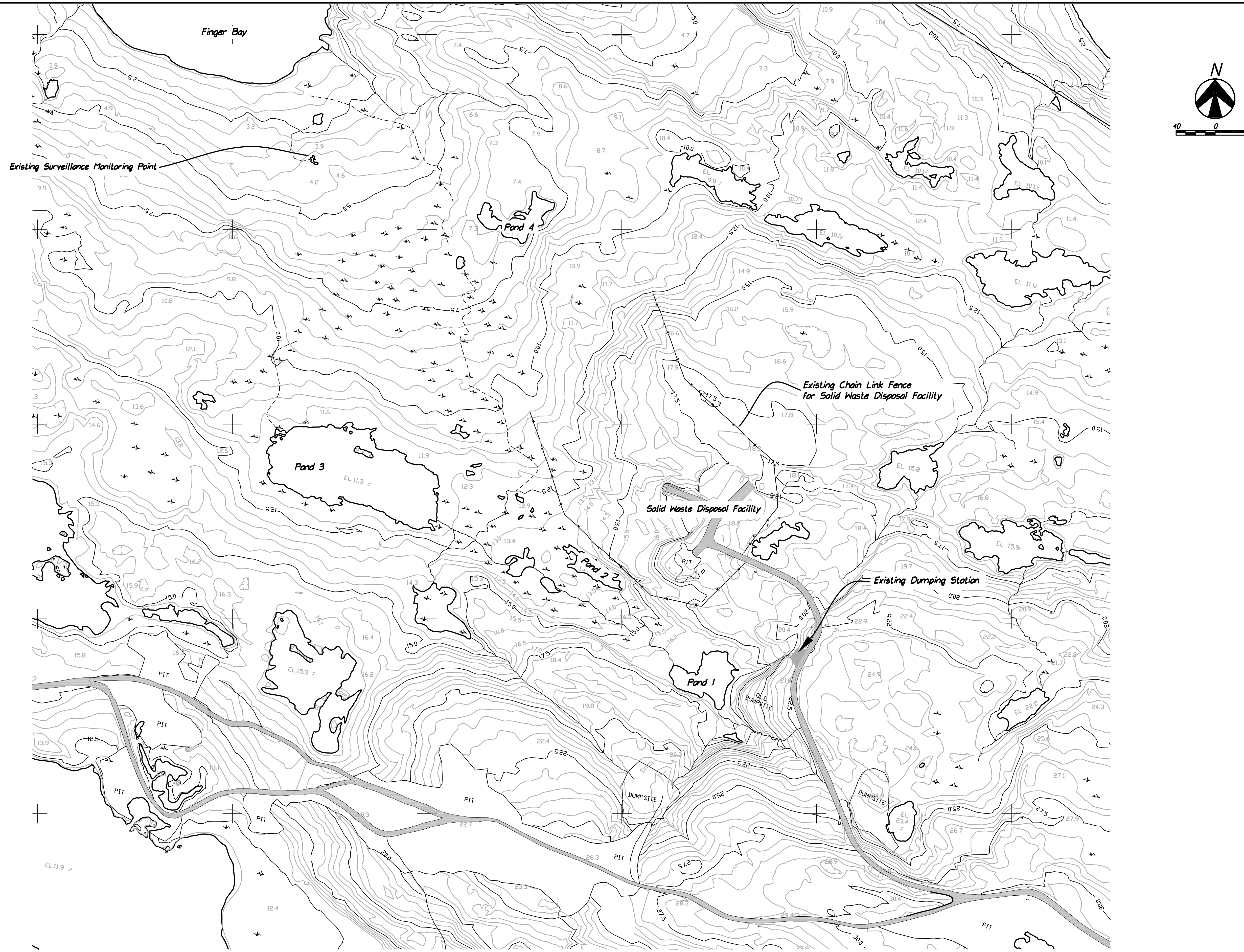

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Rev	Date	Description
0	1/2/09	Issue for Review

GOVERNMENT OF NUNAVUT DEPARTMENT OF COMMUNITY AND GOVERNMENT SERVICES
TUNDRA WETLAND SEWAGE TREATMENT SYSTEM
CHESTERFIELD INLET SEWAGE SYSTEM
IGLULIGAARJUK, NU

Site Plan
Existing Conditions

Figure 2

Figure 2.dwg

Plot Date: 2 January 2009 By Henkel, Marc

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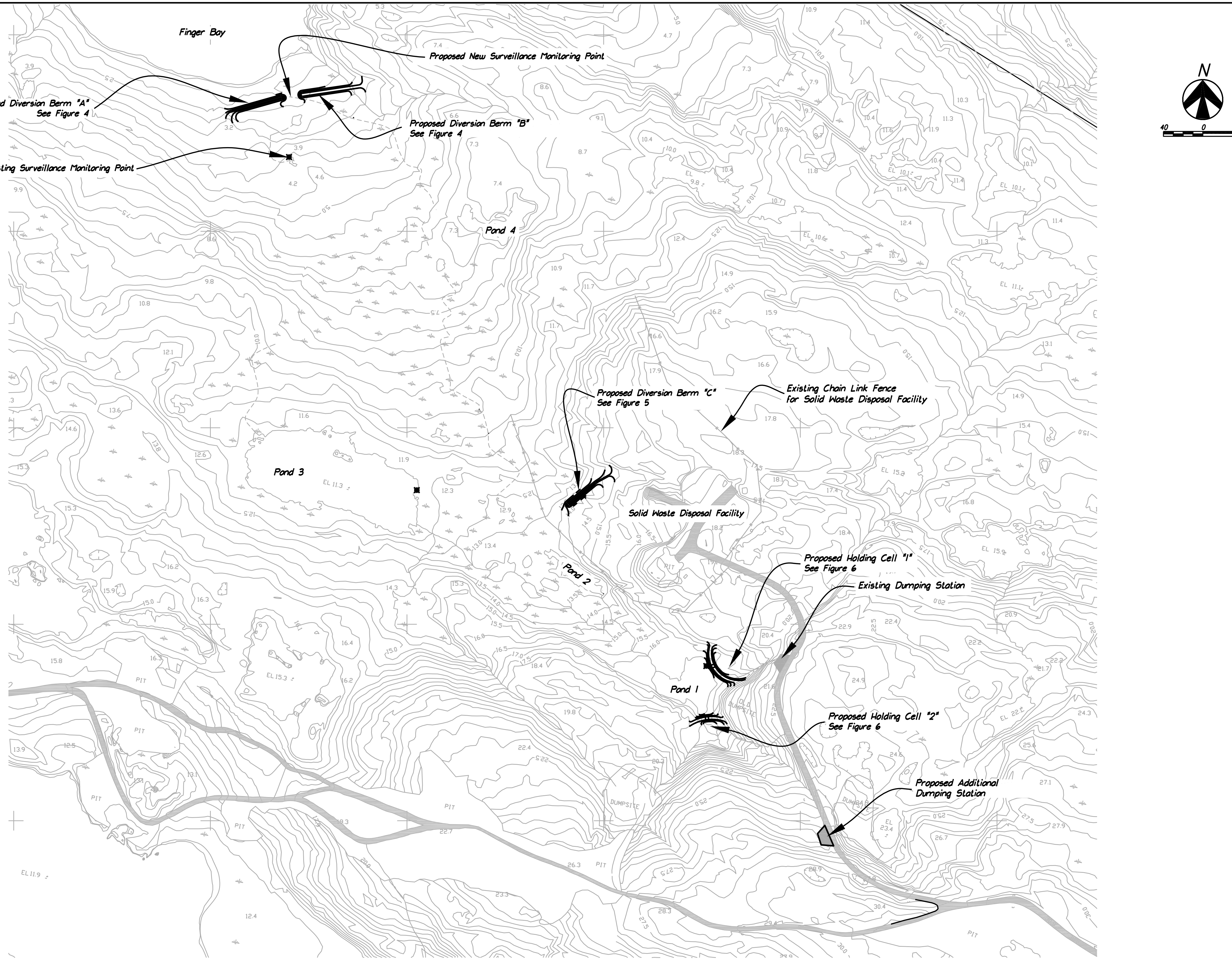

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CHESTERFIELD INLET SEWAGE SYSTEM
IGLULIGAARJUK, NU

Site Plan
Proposed Design Layout

Figure 3

Figure 3-6.dwg

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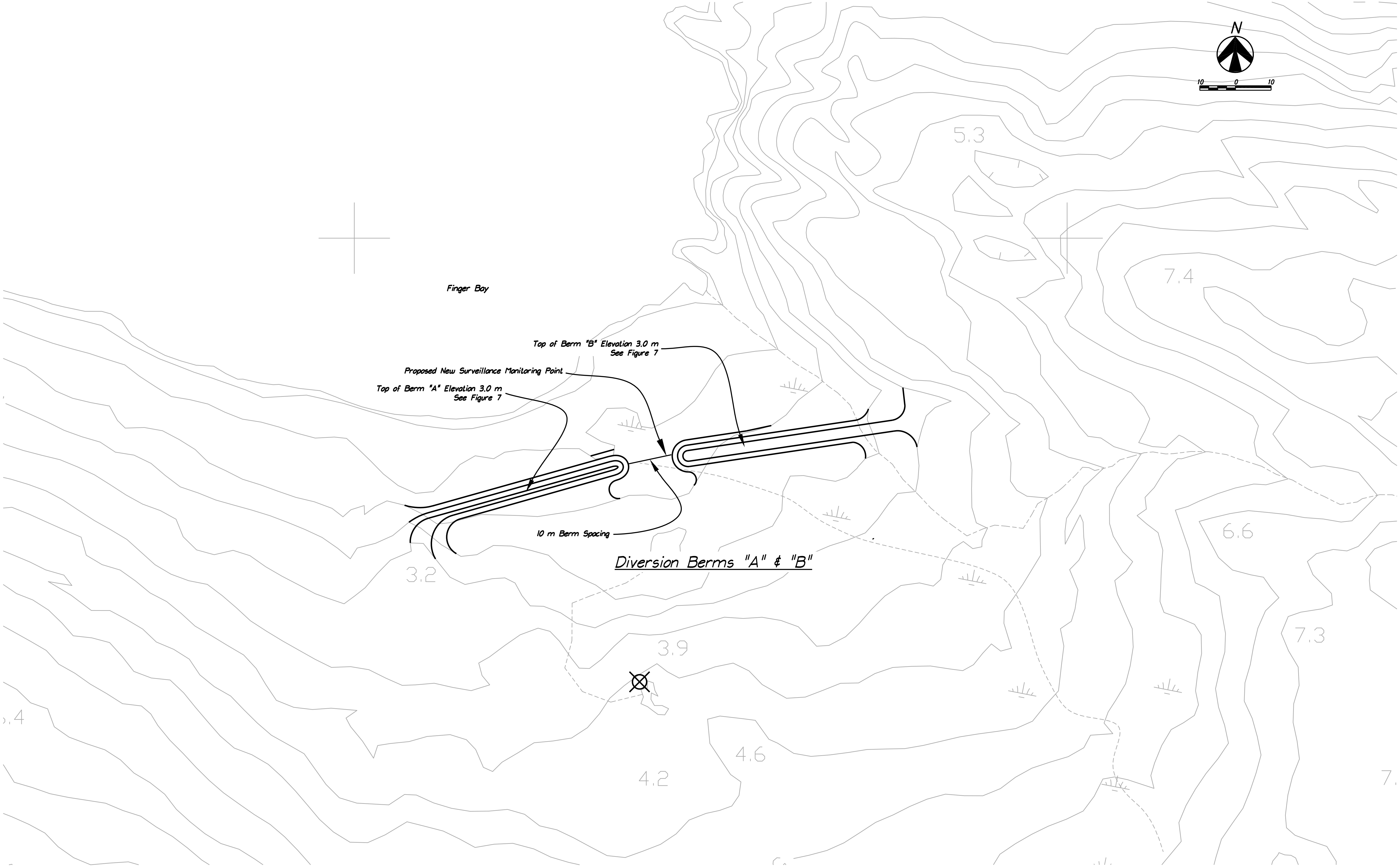

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CHESTERFIELD INLET SEWAGE SYSTEM
IGLULIGAARJUK, NU

Diversion Berms "A" & "B" Plan

Figure 4

Figure 3-6.dwg

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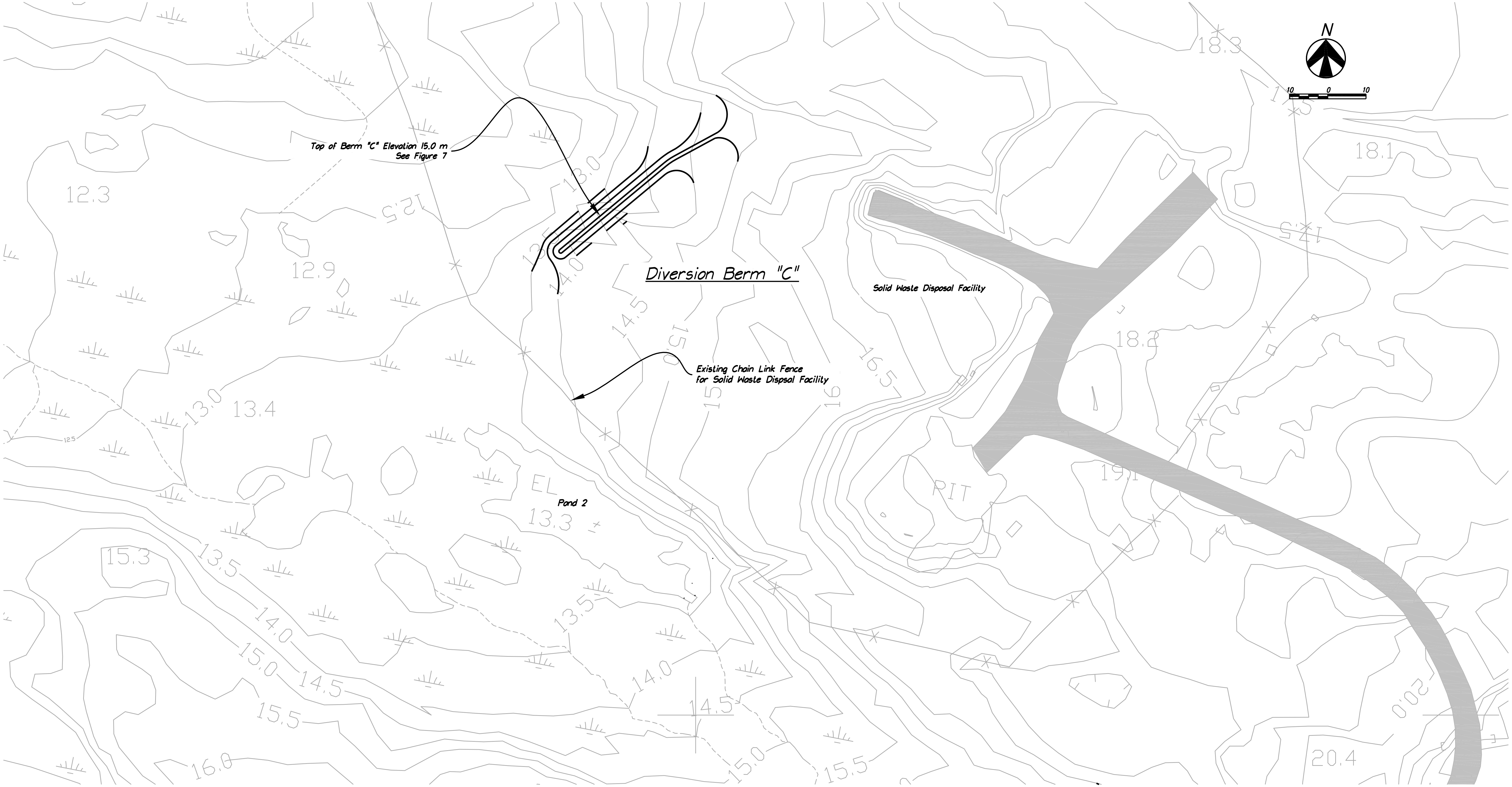

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JACQUES WHITFORD LIMITED

Rev	Date	Description
0	1/2/09	Issue for Review

GOVERNMENT OF NUNAVUT DEPARTMENT OF COMMUNITY AND GOVERNMENT SERVICES
TUNDRA WETLAND SEWAGE TREATMENT SYSTEM
CHESTERFIELD INLET SEWAGE SYSTEM
IGLULIGAARJUK, NU

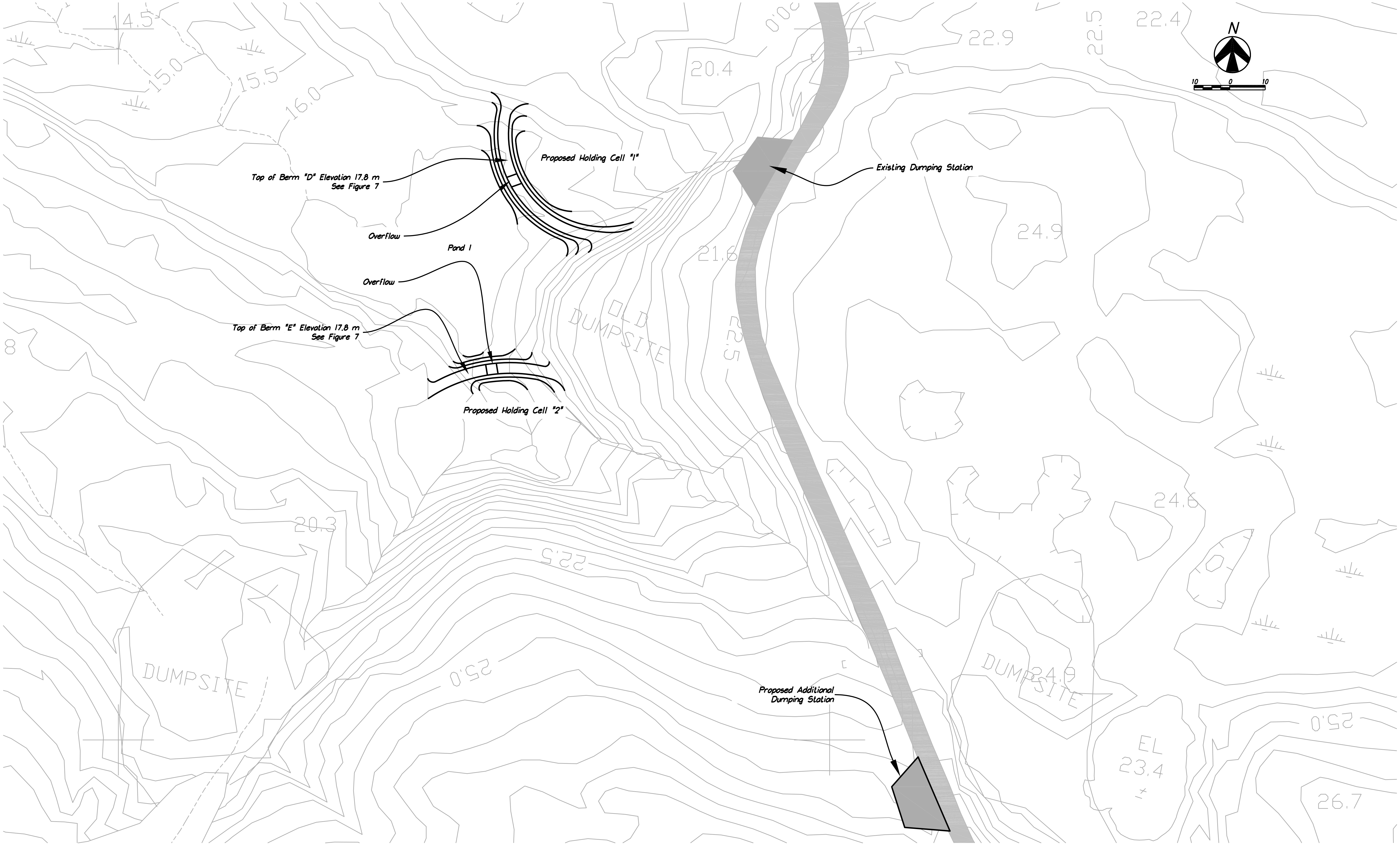
Diversion Berm "C" Plan

Figure 5

Figure 3-6.dwg

Plot Date: 2 January 2009 By Henkel, Marc

K:\1042903 Chesterfield Inlet\dwg\Figure 3-6.dwg



Plot Date: 2 January 2009 By: Henkel, Marc

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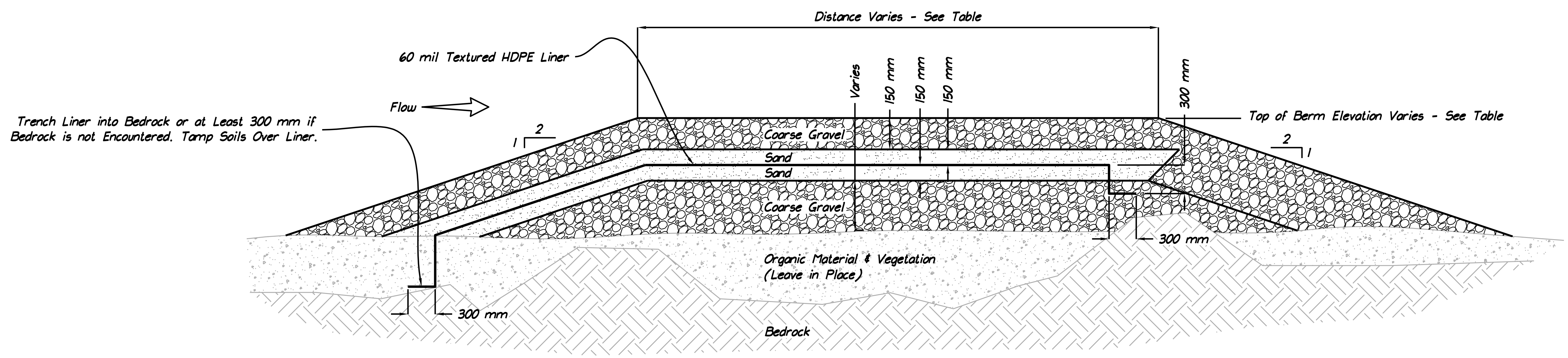
Holding Cells "1" & "2" Plan

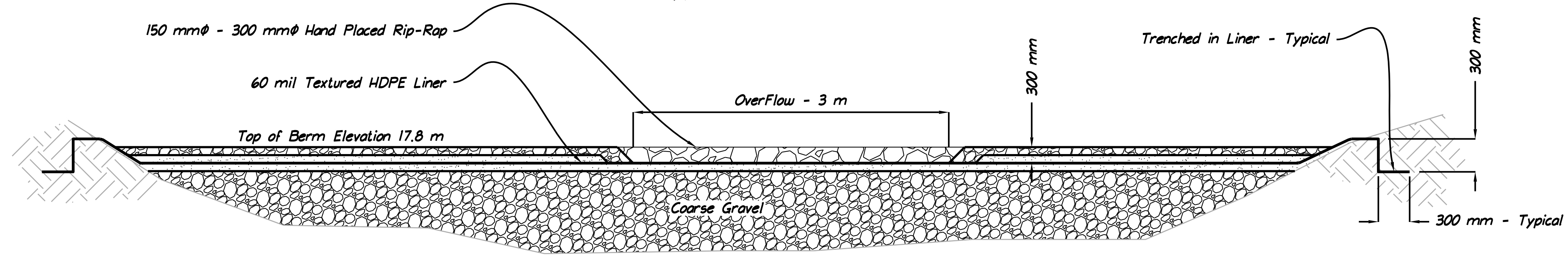
Figure 6

Figure 3-6.dwg

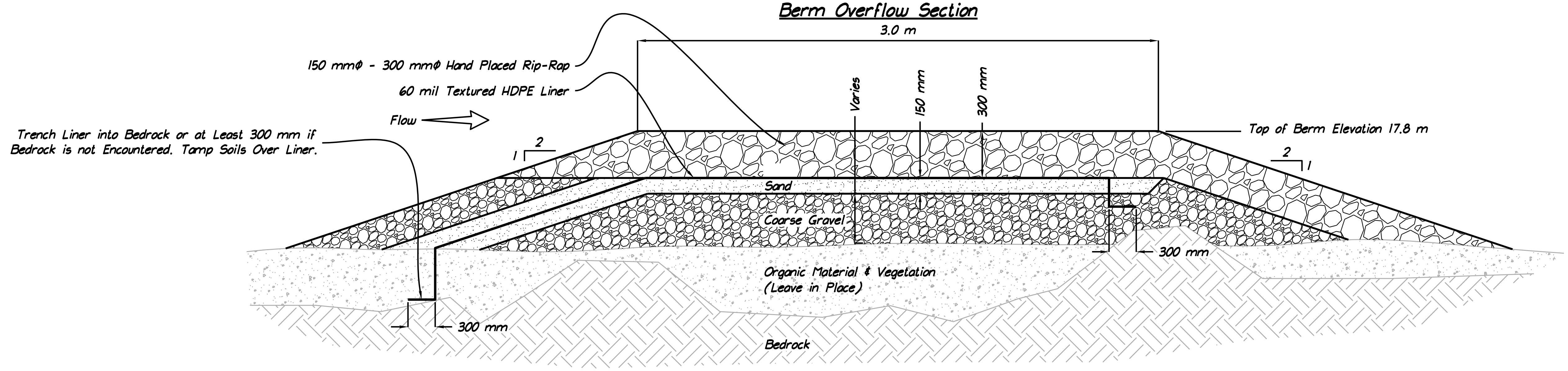
K:\1042903 Chesterfield Inlet\dwg\Figure 3-6.dwg



Typical Berm Cross Section



Berm Overflow Section



Berm Overflow Cross Section

BERM					
	"A"	"B"	"C"	"D"	"E"
TOP OF BERM ELEVATION (msl)	3.0	3.0	15.0	17.8	17.8
TOP OF BERM WIDTH (in Meters)	1	3	1	3	3

Conceptual Design - Not For Construction

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Proposed Berm Cross Sections

Figure 7

Figure 5.dwg

K:\1042903 Chesterfield Inlet\dwg\Figure 5.dwg