Trow

FINAL REPORT
CITY OF IQALUIT
DAM SAFETY REVIEW FOR
SEWAGE LAGOON

Prepared for:

Mr. Matthew Hough
City of Iqaluit
P.O. Box 460
Iqaluit, Nunavut
X0A 0H0

Trow Consulting Engineers Ltd.

1074 Webbwood Drive
Sudbury, Ontario P3C 3B7
Telephone: (705) 674-9681
Facsimile: (705) 674-8271

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APPENDICES

Executive Summary

The City Of Iqaluit retained Trow Consulting Engineers Ltd., (Trow), in October 2001, to prepare a Dam Safety Review (DSR) for the Lake Geraldine Dam and for the City's Sewage Lagoon. The draft report for the Lake Geraldine Dam has been presented separately. This report addresses the dam safety review for the Sewage Lagoon dykes, only.

The DSR was conducted in October and November 2001, in general accordance with the Dam Safety Guidelines, (DSG) prepared by the Canadian Dam Association.

As a result of the DSR, the following conclusions and recommendations have been made regarding the sewage lagoon dykes:

i. The dykes have been classified as having a Consequence Category of Low for both the Life Safety category and Socioeconomic, Financial and Environmental categories.

ii. There is inadequate information available concerning the as-built construction of the dykes, including topographic information, geotechnical conditions, and hydrological/hydraulic information.

iii. The existing west dyke has experienced a series of stability problems and breaches, related to seepage problems, ice lensing and blockage, overtopping, and downstream toe erosion. While repairs appear to be effective, other sections of the dyke(s) may be vulnerable to stability problems. Because of their past history, and current stability concerns, the Dam Safety Review indicates that the sewage lagoon dykes cannot be considered "safe" in their present condition and are non-compliant with the design and performance standards of the DSG. Significant improvements are required to improve the structural integrity of the lagoon to meet the DSG.

iv. Three remedial options are provided which include: 1) providing an impermeable liner for the lagoon bottom and upstream sideslopes of the dykes; 2) buttressing the dykes with rock fill; and 3) redesigning and building a new lagoon to current dam safety requirements and environmental standards.

5. In the interim period prior to implementation of remedial measures, the structures should have a Dam Safety Inspection (DSI) conducted in 2002. This is essentially a yearly non-invasive review comprising a visual inspection to identify any changes in condition, or any observed concerns.

1. Introduction

The Nunavut Water Board, as a condition of the City's water license, required the City Of Iqaluit to complete an inspection of the Lake Geraldine Dam in accordance with the Canadian Dam Association publication, Dam Safety Guidelines (DSG), published in January 1999. In conjunction with this inspection, the City requested a similar inspection and report for the City's Sewage Lagoon. The following report addresses dam safety issues related to the Sewage Lagoon dykes, only.

The DSG applies to those structures that are at least 2.5 meters in height, and which have at least 30,000 cubic meters of storage capacity. There are sections of the lagoon dykes which exceed 2.5 m in height. The storage volume is less than 30,000 m^3. However, because of the environmental impact associated with the sudden release of raw sewage, the DSG apply to this facility.

The DSG document is far reaching in terms of applicability and requirements for conformance. This is understandable as the type and complexity of structures that fall under the jurisdiction of the document varies considerably, from relatively small and simple embankments or dykes to massive and complex dams associated with hydroelectric generating facilities, irrigation, flood control, etc.

The DSG requires that all structures exceeding the height and volume minimums described above be classified according to their "consequence category", that is, the consequence of dam failure in terms of life safety, and socio-economic/environmental impact. The category assigned may range from very low to very high. The consequence category dictates the requirement and frequency of Dam Safety Reviews.

A Dam Safety Review (DSR) is a comprehensive, formal review process, conducted at regular intervals, that involves completion of checklist of items in accordance with the Dam Safety Guidelines. The DSR forms a baseline of dam history, condition, repair requirements, and extensive documentation of monitoring, operating, safety and emergency procedures.

The frequency of DSR's varies depending on consequence category. For structures where significant life safety and/or socio-economic consequence exist, the DSR is usually conducted every five (5) to ten (10) years. In the case of the City of Iqaluit Sewage Lagoon, the required interval is ten (10) years.

It is required in the DSG document that in the interval between DSR's, a Dam Safety Inspection (DSI) would be performed on an annual basis. The DSI is a much less comprehensive review, comprising a visual inspection to identify any changes in condition, or any observed concerns. The results of the DSI are incorporated into the DSR documentation. A DSI may trigger repairs, or changes in standard operating procedures.

Under the current DSG, a DSR was required for the sewage lagoons simply because no previous DSR exists.

The level of detail required for a DSR is influenced by several factors as follows:

- Importance of structure
- Complexity of structure
- Consequences of failure
- Completeness, continuity, and availability of record documentation
- Current condition

Although there is reasonably extensive documentation concerning the problems related to the stability and seepage problems associated with the west sewage lagoon dyke, there is very little information available on the as-built structures (i.e. layout, dimensions and elevations), especially for the east and southeast dykes. As this is the first DSR and benchmark document for any subsequent inspection, we have included a complete review of the required tasks.

A summary of our methodology to complete the work is presented below:

1. Acquire and assemble chronological documentation, including but not limited to:
    - Design Documents
    - Repair Specifications
    - Past Condition Assessment Reports
    - Records of Alteration
2. Review all available record documentation.
3. Perform a site inspection to assess the current condition of the structures. No invasive work was performed; the condition assessment was visual in nature.
4. Interview maintenance and management personnel as required and appropriate.
5. Execute the DSR checklist of items.
6. Prepare the draft DSR report based on available information. Submit to and discuss with the City's Engineer.
7. Submit the final DSR report.

2. History & Background

In the following chronological summary, record documents have been referenced. After each reference, a number appears in parenthesis. That number corresponds to tabulated record document numbers in Section 4, where details are provided on the document source.

2.1 Sewage Lagoon

The existing sewage lagoon is located to the west of the City, and immediately south of the Iqaluit Airport runway, on the tidal plain at the head of Koojesse Inlet. The sewage lagoon was reportedly constructed at this location in 1978, with the design by Reinders Northern Engineering Ltd.

The sewage lagoon was formed by the construction of two main dykes that connect the northwestern shoreline to a natural island formation in the Inlet. The man-made structures form the east and west boundaries of the lagoon, while the north and south boundaries utilize the natural topography. There is also a shorter 3rd dyke in the southeast corner of the lagoon, which blocks a narrow gap between a small island and the main island acting as the southern barrier for the lagoon. The layout of the sewage lagoons is provided on the attached Figure 1, in Appendix 2, obtained from a report by UMA Engineering (Ref 1 - 2.1d).

The original area and capacity of the lagoon are reported in the literature to be approximately 17,000 square meters and 32,000 cubic meters, respectively.

The dykes were originally designed as "leaky" dams, constructed of relatively pervious local sand & gravel materials, designed to allow seepage and partial treatment of the effluent to occur. A typical cross section through the west dyke, developed by Hardy BBT Limited in conjunction with UMA (Ref 2 - 2.1.e), is provided in Figure 3, attached in Appendix 2.

2.2 History

In 1981, a partial wash out of the north end of the west dyke occurred during high tide, which was subsequently repaired. The repair reportedly washed out again one month later. Subsequent upgrades in 1983 increased the capacity of the lagoon to approximately 56,0000 meters.

According to the literature, the lagoon was the subject of investigative studies in 1983 and 1984, which proposed various upgrades, including the following:

- Lining of exterior slopes with filter cloth and rip-rap.
- Construction of an overflow (spillway) in the west dike.
- Construction of a positive outlet control.
- Installation of an impermeable liner on the interior slopes.

In 1987, the lagoon reportedly overflowed during the spring runoff and a portion of the west dyke was washed out. In June 1991, an 18 m wide breach of the west dyke occurred in the vicinity of the lagoon level control structure, resulting in a major effluent spill into Koojesse Inlet. The cause was again attributed to excessive surface runoff discharge into the lagoon during the spring runoff. Following repairs to the breach, a minor washout occurred in December 1991 at the lagoon overflow channel.

A preliminary engineering report by UMA Engineering Ltd. (ref 1 - 2.1.d), dated July 1991, indicates that the previously recommended spillway and impermeable liner upgrades had not been done, and that as-built drawings for the previous upgrades could not be located. The 1991 report recommended specific repairs and improvement for the west dyke reconstruction area. These included erosion protection (filter cloth and rip-rap) on the upstream and downstream sides, section conformity (2H:1V and 3H:1V) slopes on the upstream and downstream sides respectively), and construction of a spillway section. The repaired section was intended to match the existing construction, maintaining the "leaky dam" concept.

In December 1991, a supplementary report by UMA (ref 2 - 2.1e), which included a report by their sub-consultant Hardy BBT Limited, expressed concern over material suitability for the west dyke repairs (i.e. the silty sand & gravel placed was not sufficiently free-draining). These concerns prompted the recommendation to further flatten the slopes to 3H:1V and 4H:1V on the upstream and downstream sides, respectively, with rip-rap protection. It was recognized that the substitute material would be more susceptible to erosion and frost action, and that the downstream slope of the dyke would be subjected to periodic wetting by tide level fluctuations. Slope stability analyses were carried out by Hardy to confirm the suitability of the above slope angles, assuming a variety of conditions, such as rapid drawdown, and rapid drawdown with thaw consolidation on the downstream ocean side, and low lagoon levels and thaw consolidation for the upstream stability. Minimum factors of safety ranging from 1.4 to 1.9 for the upstream slopes and 1.8 to 2.7 for the downstream slopes were obtained, depending on the pore pressure conditions assumed. Based on these results, Hardy considered the repaired dyke to have an appropriately conservative slope design and cross section. Recommendations were also provided for the design of the overflow spillway section, to be located further to the south along the crest of the west dyke.

In December 1997, significant high level seepage developed on the downstream face of the west dyke, 7 m to 17 m to the south of the outflow pipe and control vault, and beyond the section repaired previously by UMA. The seepage was investigated by Ferguson Simek Clark Engineers & Architects (FSC). The ice associated with the seepage was clear with a green colour. There was concern that the significant accumulation of ice and snow along the downstream face was blocking the internal drainage system of the dyke. Although the dyke was considered stable, recommendations were made in FSC's February 5, 1998 engineering report (ref 5) to increase monitoring, to develop a spill preparedness plan, and to maintain the lagoon at its lowest possible level. Without the ability to manage the accumulated ice cover along the downstream face at the toe drains and French drains, seeps could be expected to reoccur, depending on weather, snow and ice conditions, and tide conditions. Also, surface runoff from outside the immediate watershed (i.e. airport and road side ditches) should be diverted away from the lagoon.

As a result of lowering the level of the sewage lagoon, the current retention volume was estimated to range from between 12,000 m^3 and 25,000 m^3, at operating water levels of 0.7 m and 1.5 m, respectively. The sewage production rate in 1998 was estimated at 1,800 m^3 per day, providing a retention time varying between 6.7 and 13.8 days. Sewage is transferred to the lagoon by gravity sewers, forcemains, and trucking.

In June 1998, a Spill Contingency Plan (ref 7) was prepared for the City of Iqaluit by Dillon Consulting Limited, which included a Sewage Lagoon Preparedness Plan. In that document, it is stated that City staff checks the sewage lagoon 5 days per week for lagoon level and leaks. If problems are suspected, the monitoring frequency increases to 7 days per week. It is recognized that the potential exists for further uncontrolled sewage releases due to dyke failure.

2.3 Relevant Record Documents

The following documentation has been utilized in the preparation of this report. Other record documentation was provided but not directly applicable to the DSR.

Table I
Relevant Record Documentation
Sewage Lagoon

No.	City of Iqaluit Ref No.	Date	Description	Author
1	2.1d	July 1991	Preliminary Engineering Report on Repairs to Iqaluit Sewage Lagoon	UMA
2	2.1 e	Dec. 1991	Supplement to Preliminary Engineering Report on Repairs to Iqaluit Sewage Lagoon	UMA
3	2.1f	Dec. 1992	Performance Evaluation for Sewage Lagoon 1990 to 1992	UMA
4		May 1995	Geotechnical Evaluation Proposed Sewage Lagoon	Agra
5		Feb. 5, 1998	Iqaluit Sewage Lagoon Investigation Final Report	FSC
6		Jan 1998	Draft Discussion Paper – Seepage from a Sewage Lagoon – What is a reasonable rate ?	FSC
7	2.9A	June 1998	Municipality of Iqaluit Spill Contingency Plan Appendix B – Sewage Lagoon Preparedness Plan	Dillon

The bulk of the record documents were retrieved from the City records. However, detailed drawings showing the original construction apparently do not exist.

3. Commentary On Dam Safety Review Requirements

According to the Dam Safety Guidelines, the document applies to those structures that are at least 2.5 meters in height, and which have at least 30,000 cubic meters of storage capacity. The City of Iqaluit Sewage Lagoon exceeds these minimum criteria. As well, since the lagoon dykes retain raw sewage, the environmental consequences of failure are considered significant.

The Dam Safety Guidelines document is far reaching in terms of applicability and requirements for conformance. This is understandable as the type and complexity of structures that fall under the jurisdiction of the document varies considerably, from relatively small and simple embankments or dikes to massive and complex dams associated with hydroelectric generating facilities, irrigation, flood control, etc.

The document requires a systematic checklist review, which includes the following items. For each item, the applicable Section number from the Dam Safety Guidelines is shown in parenthesis.

3. Dam Classification	(1.4)
4. Site Inspection	(2.2.2)
5. Design & Construction Review:	(2.2.3)
a. Earthquakes	(5.0)
b. Floods	(6.0)
c. Discharge Facilities	(7.0)
d. Geotechnical Considerations	(8.0)
e. Concrete Structures	(9.0)
f. Reservoir & Environment	(10.0)
g. Construction	(11.0)
6. Operation & Testing	(2.2.4 & 3.2)
7. Maintenance	(2.2.5 & 3.3)
8. Surveillance & Monitoring	(2.2.6 & 3.4)
9. Emergency Preparedness	(2.2.7 & 4.0)
10. Compliance With Previous Reviews	(2.2.8)

4. City of Iqaluit Sewage Lagoon DSR

4.1 DAM CLASSIFICATION (DSG SECTION 1)

Based on our knowledge of the Dam Safety Guidelines and the construction of the sewage lagoon dykes, the dyke structures are considered to have a consequence category of "Low" in terms of Consequences of Failure, with respect to Table 1-1 in the DSG.

3. Life Safety Criteria – No fatalities are anticipated in the event of a dyke failure. The lagoon is relatively small and there is no development downstream of the perimeter dykes. A dyke failure or breach would result in untreated sewage effluent discharging directly to the ocean inlet.

4. Socioeconomic, Financial and Environmental Criteria – Moderate environmental damages would occur as a result of the untreated sewage being discharged directly into the inlet. The effect on fish habitat would need to be established, however, sewage has been discharged directly over many years. In the event of a dyke failure, there is no alternate storage site for sewage so repairs to the dykes would have to be carried out quickly. The financial cost would be moderate although fines levied by the regulatory agencies could increase the financial damages.

Based on the Low Consequence Catagory, a Dam Safety Review is required every ten (10) years (Table 2-1).

4.2 SITE INSPECTION (DSG SECTION 2)

A visual site inspection of the dam structures was performed on October 20, 2001, by Mr. A.J. Schell, P. Eng., Sr. Geotechnical Engineer (based in Trow's Sudbury, Ontario branch office). The inspection was non-invasive in nature, and did not include an underwater assessment. A photographic record of our inspection was made, and appends this report (Appendix 1).

The eastern and western dykes, as well as the shorter southeastern dyke, were visually inspected. The eastern dyke, approximately 80 m in length, extends from higher ground adjacent to an existing road along the northeastern shoreline of the Inlet to a small bedrock island at the south end. The maximum height appears to be about 4 m along the northern section of the dyke, reducing to about 1.5 m high near the south end.

The shorter southeastern dyke, located between the small bedrock island and the larger bedrock island forming the southern boundary of the lagoon, is oriented NE-SW, and is approximately 30 m in length, with a maximum height of approximately 2.0 m to 2.3 m, as measured from the downstream toe.

The western perimeter dyke, oriented north-south, is approximately 70 m in length. There is a concrete discharge control structure located along the upstream crest of the dyke, which allows direct discharge via a buried pipe through the dyke from the lagoon to the Inlet. The northern section of the dyke appears to have been flattened and widened with a dozer with additional silty sand & gravel fill placed, creating an outwash plain into the Inlet. The fill material appeared to be saturated during our inspection. There is also a small overflow spillway located in the south-central section of the berm. The overflow channel is approximately 1.5 m – 2.0 m in width, about 450 mm in depth, with rip-rapped sideslopes of about 3H:1V. The channel is underlined by a layer of grey, non-woven geotextile, and reportedly a layer of HDPE. Where exposed at the top of the channel, the geotextile is shredded, but the material is probably in good condition beneath the rip-rap surface.

All 3 dykes appear to have been constructed with local silty sand & gravel fill, with crest widths of approximately 4 m to 5 m, and sideslopes generally ranging between 2H:1V to 3H:1V, with some flatter sections. The downstream face of all 3 dykes is protected with coarse rip-rap, generally comprised of 300 mm to 450 mm rounded boulders. The upstream face has finer sized rip-rap ranging from 100 mm-200 mm in size.

At the time of the inspection, there did not appear to be any significant seepage discharging from the toe of either the southeastern dyke or the western dyke. There was some frozen water ponded below the southeastern dyke, but it was not discoloured and may be local surface runoff. Below the western dyke, the ocean water did not appear discoloured from seepage, however, it would be difficult to tell because of the discharge from the adjacent open pipe from the discharge chamber. The fill material placed across the northern section of the West dyke appeared to be saturated, probably from a combination of surface runoff and possibly internal seepage.

There was obvious discoloured brown sewage effluent seeping through the deeper section along the downstream toe of the eastern dyke, across a horizontal distance of at least 25 m. The volume of flow was difficult to estimate because it was partially frozen, and was beginning to accumulate as ice along the toe.

The foundation for all 3 dykes appears to be bedrock, although there may be a very thin layer of topsoil/lichens, if the bedrock was not completely cleaned during the original construction in 1978 (Note: based on available documentation, the lagoon was reportedly founded on an outwash plain – thus the dykes may not be founded on bedrock in all areas).

The pond level was being maintained about 1 m below the crest of the dykes at the time of the inspection. There was no evidence of any wave erosion along the upstream faces of the 3 dykes, nor was there any evidence of any piping conditions along the downstream faces or toe areas of the 3 dykes.

4.3 Design & Construction Review (DSG Section 3)

4.3.1 Geotechnical Considerations (DSG Section 8)

Section 8 of the DSG presents Geotechnical considerations for proposed dams, as well as for several types of existing dams. Requirements for embankment dams founded on soil foundations, rock foundations, and permafrost are also discussed.

As discussed in Section 2 of this report, the lagoon dykes were originally designed as "leaky" dams, which rely on seepage through the moderately pervious sand & gravel structure, with the phreatic level maintained low for stability. A higher permeability underdrainage layer, consisting of crushed gravel, was reportedly placed directly over the foundation to ensure a low phreatic level within the dyke. The main section of the dyke reportedly consists of minus 3 inch (minus 75 mm) sand & gravel with a silt content ranging from about 2% to 20%. The upstream and downstream faces of the dykes are protected with rip-rap. A layer of non-woven geotextile is believed to underlie the rip-rap along the upstream face only. As-built drawings of the dykes, indicating design elevations, cross sectional profiles, and foundation conditions, apparently do not exist.

Stability analyses carried out by Hardy BBT as part of the UMA study in 1991 (ref 2) indicated that the upstream and downstream slopes were stable, assuming the phreatic conditions used in the design. Hardy apparently observed slopes measuring 3.5H:1V to 4H:1V on the ocean side and 2.3H:1V to 4H:1V on the lagoon side.

The stability of the section of the west dyke, as sketched by Hardy, was analysed under various static loading conditions, under both normal and flood level conditions. The Dam Safety Guidelines require a minimum factor of safety of 1.5 for the downstream slope for steady state seepage conditions with a maximum storage pool. The stability analyses indicate acceptable factors of safety, assuming the dyke is unfrozen, and standard soil strength parameters are applicable. With a maximum upstream water level, the dam has a computed factor of safety of 2.16 against a total failure, which would cause a major breach in the dam.

For the full or rapid drawdown condition, a minimum factor of safety of 1.2 to 1.3 is required for the upstream slopes. Our analyses indicate a factor of safety of 1.46 for this case.

The results of the stability analyses are provided on Figures 3-1 to 3-6 in Appendix 3. The above stability analyses are not considered valid for the case where ice lensing occurs within the structure in combination with a high phreatic level/saturated downstream slope.

The western dyke has reportedly been breached several times in the early 1980's and again in June 1991 and December 1991. The failures appear to have occurred as a result of either overtopping due to high pond levels occurring during the spring runoff period, the occurrence of very high tide conditions, which eroded the toe, and possibly from high-level seepage and resulting instability. The repair work has typically involved rebuilding the western dyke to its original design as a "leaky" dam. Recommendations to provide an impervious liner, which would remove some of the inherent risks associated with a leaky dam, have apparently not been implemented by the City.

Over the years, "seeps" and ice lenses have been reported, especially in the western dyke, resulting in stability concerns and further engineering review. The most recent recommendations, which have been implemented, are to maintain the lagoon pond levels at near minimum levels and to carry out an on-going monitoring program. A spill preparedness plan has also been prepared.

From our observations and review of the available documentation, it is clear that there are some inherent weaknesses with the present construction and design of the 3 dykes. While the concept of a "leaky" dam may have some merit, it is clear that the ongoing problems associated with seepage through the sand & gravel fill structures are problematic. Probably the most dangerous factor is that the seepage draining from the toe of the dykes in the fall months freezes and accumulates as ice along the toe of the dyke, forming an increasingly thick impervious barrier. This ice barrier gradually blocks the drainage at the toe and will move higher up into the embankment as the ice accumulates, resulting in high phreatic levels within the interior of the dyke. Ice lensing within the sand & gravel embankment also likely occurs under this scenario. While the ice cap may provide additional stability to the downstream structural section of the dyke during the winter months, in the spring, when the exposed ice and frozen soil begins to melt, the soil structure is weakened and in combination with the high phreatic levels, the factor of safety against instability at this stage is significantly reduced.

Another weakness identified is that the existing silty sand & gravel-sand & gravel materials are considered to be highly erodible, especially to wave action or overtopping. High tides could result in sloughing of the downstream section of the western dyke and possibly the other two structures.

From an environmental standpoint, the various seeps and occasional overtoppings may be perceived by the Regulatory Agencies and Courts as uncontrolled discharges of untreated wastewater. Charges may be laid against the City as there is presently no way of controlling these discharges, especially the seepage.

From a Dam Safety perspective, these potential deficiencies in the design/construction of the dyke structures must be addressed.

4.3.2 Earthquakes (DSG Section 5)

According to the DSG, dams shall be evaluated to withstand a Maximum Design Earthquake (MDE) without release of the reservoir. For a Low Consequence Category dam, the DSG requires an evaluation for a 100 yr to 1000 yr event.

According to the Canadian Foundation Engineering Manual, Iqaluit is located in a Zone 1 Seismic Zone. The range of peak horizontal ground accelerations for Zone 1 is between 0.04g to 0.08 g for a 10% probability of exceedance in 50 years (i.e. a 500 yr event). According to the mapping showing contours of peak horizontal ground acceleration, a factor of 0.04 g is considered appropriate for the City of Iqaluit.

Psuedostatic stability analyses indicate acceptable factors of safety for the dykes under the design seismic conditions, assuming a horizontal and vertical acceleration of 0.04g (i.e. a factor of safety of 2.00 was obtained). As well, the potential for liquefaction of the foundation material is considered remote, especially if the dam is founded on bedrock or the foundation soils are frozen.

4.3.3 Floods (DSG Section 6)

According to the DSG, dams shall be evaluated to safely pass an Inflow Design Flood (IDF), which is based on Consequence Category and the Probable Maximum Flood (PMF). The PMF is an estimate of the most severe "reasonably possible" flood at a particular location and time of year. For a Low Consequence Category, the DSG requires an IDF with an Annual Exceedence Probability (AEP) of between 1/100 and 1/1000.

A hydrology study was carried out by UMA in their July 1991, preliminary engineering report. Two drainage area scenarios (1.15 km^2 and 0.39 km^2) were analysed with return period events ranging from 1 to 100 years. Peak design inflows of 7.54 m^3/s and 2.56 m^3/s for rainfall only were established for the above two drainage areas scenarios, respectively. UMA recommended that the lagoon system be designed for the lower 1:100 year event of 2.56 m^3/s. However, no information was provided with respect to total volumes of runoff reporting to the sewage lagoon, the discharge capacity of the discharge control structure, and the probable flood level in the lagoon. Based on the previous documentation, the sewage lagoon has been overtopped in the past during the spring runoff/snow melt season. As such, it is therefore very unlikely that the lagoon could handle a 100 year event without overtopping, even with the control structure and small spillway in place.

As previously recommended, diversion of surface runoff flows from the areas to the north must be implemented to prevent flooding of the lagoon. The lagoon would be considered safe from overtopping if it was only subjected to local runoff from within the lagoon itself.

4.3.4 Discharge Facilities (DSG Section 7)

Section 7 of the DSG has a broad applicability that includes flow control equipment, instrumentation, and emergency backup equipment, which are typically relevant to more complex structures. In the case of the sewage lagoon dykes, the applicability really only involves the discharge structure and the overflow spillway section.

According to the DSG, discharge facilities shall be capable of passing an Inflow Design Flood (IDF) without adversely affecting the freeboard. Freeboard is defined as the vertical distance between the water surface elevation and the lowest elevation of the top of the containment structures.

The freeboard should satisfy the requirements of DSG section 7.2, Freeboard. That section indicates that sufficient freeboard be provided such that the percentage of overtopping waves during extreme flood or wind conditions is limited to an amount that would not lead to dam failure.

The sewage lagoon dykes essentially have only one effective discharge facility, that being the discharge structure. Based on sketches provided in the UMA report (ref 3), the discharge pipe has two 6 m lengths of 200 mm diameter piping. Wave action overtopping the gravity structure is not considered significant given the relatively small fetch of the pond and the fact that the site is generally sheltered from the prevailing winds by higher ground to the north and on either side of the Inlet.

Section 7 of the DSG also requires consideration of the following for discharge facilities:

- Resistance to erosion
- Adequate energy dissipation
- Capability to pass floating debris

At this time, these items are not considered priority concerns.

4.3.5 Concrete Structures (DSG Section 9)

Not Applicable

4.3.6 Reservoir & Environment (DSG Section 10)

According to the DSG, the following conditions should be assessed as they relate to the reservoir and environment:

a) The stability of slopes around the reservoir rim.

b) Detrimental effects of groundwater, reservoir water, soil, etc., on dam safety.

c) Silt deposition affecting discharge facilities or dam stability.

d) Hazards to local ecology.

e) Reservoir drawdown capability.

f) Reservoir debris and ice should not present an unacceptable risk to dam safety.

Based on our review and inspection, the only significant items are d), e) and f). Items a), b), and c) are not a concern at this time.

Regarding item d), the sewage lagoon is considered to be a continuous discharge, short detention (SD) type of lagoon, providing only primary treatment of the sewage wastewater. The capacity of the lagoon appears to be undersized for the City's population, and only partially treated sewage is being discharged directly into Koojesse Inlet. Contaminated effluent is also escaping as seepage from the lagoon dykes. From an environmental standpoint, the sewage lagoon is not considered to meet present design standards for municipal sewage lagoons.

It is noted that there is a new sewage treatment plant located next to the sewage lagoon that is not yet operational, due to a number of problems. It is understood that the City is working towards completing and commissioning the plant. Once completed, the sewage lagoon may be incorporated into the future sewage treatment system for primary treatment or as a polishing pond. If the lagoon was utilized as a final polishing pond, the environmental impact from a spill or breach would be less significant.

Regarding item e), the sewage lagoon probably could be drawn down to a lower level, although the drawdown capability would not be considered as rapid. Also, other than dumping raw sewage into the ocean, there is no other available storage area to dump sewage during the drawdown period. Section 10.5 of the DSG indicates a requirement for rapid drawdown for those dams subject to severe damage by earthquake, or where a high potential for internal erosion exists. In our opinion, these risk factors do not apply, and thus rapid drawdown is not required.

Regarding item f), ice thrust is not considered a major factor for the stability analyses because of the relatively gently sloping sideslopes along the upstream face of the dykes. Ice lensing within the dyke, and ice accumulation along the downstream toe are major concerns. Debris within the sewage wastewater could be a problem if it clogs the inlet to the discharge control structure, and should be cleared periodically

4.3.7 Construction (DSG Section 11)

This section applies to new construction and therefore is not applicable.

4.4 Operation & Testing (DSG Section 3)

The applicable reference section of the DSG is Section 3: Operation, Maintenance, and Surveillance.

Our interpretation of this section of the DSG requires some clarification on the meaning and intent of the words "operation" and "testing". In this section of the DSG, "testing" generally refers to the testing of equipment required to operate discharge facilities. In the case of the sewage lagoon, the primary discharge facility is the discharge control structure. Other than a pinch valve and a knife valve, no other equipment exists. Therefore, there should be no testing requirement, other than ensuring that the valves are operable.

The word "operation" in the DSG is associated with the premise that "the operation of a dam shall not violate any important design assumptions that could impair the safety of the dam." The operation relates primarily to maintaining lagoon levels at low levels to prevent further dyke failures. There should be some basic operational procedures for ice management and cleaning of upstream debris that would form part of the OMS Manual (see below).

Other applicable requirements of Section 3 are described below.

In the DSR checklist of required items, the DSG indicate that a Permanent Record File (PRF) suitable for transfer to the regulatory agency be maintained as an ongoing historical reference. The file should contain the following:

- OMS Manual (see below)
- Permanent Log Book (see below)
- History and photographic record
- As-Built Drawings
- Performance reports
- All design data
- Records of all inspections and DSR's

Based on our preliminary review of available documentation, a PRF does not exist, however, some of the raw data is readily available. The available documentation provides a reasonable history of the sewage lagoon and its associated dyke stability problems. However, the absence of as-built drawings and other design data is a major shortcoming.

The DSG indicate that a dam Operation, Maintenance, and Surveillance (OMS) Manual shall be provided for every dam structure. The manual may be quite involved depending on the complexity of the dam. For the Sewage Lagoon Dykes, an acceptable manual would likely be relatively simple and concise. The manual should contain information and procedures that include the following:

- General description, history, location, access, etc.
- Chain of operational responsibilities
- Requirements for training of involved staff
- Responsibility and mechanism for review and update, including DSR input
- Requirements for operation, maintenance and surveillance as per Sections 3.2, 3.3, and 3.4 of the DSG (See below)

Based on our review and correspondence, an OMS Manual does not exist.

The DSG indicate that a Permanent Logbook shall be provided for every dam structure. The logbook should contain notations or records of the following:

- Changes to normal operation
- Unusual events or conditions
- Inspection activity
- Weather conditions and trends
- Unusual maintenance activities
- Tests of any control equipment

We have not yet been able to review the Permanent Logbook, if it does exist.

4.5 MAINTENANCE (DSG SECTION 3)

The applicable reference section of the DSG is Section 3: Operation, Maintenance, and Surveillance.

Maintenance Procedures (MPS) as described in Section 3.3 of the DSG are intended to ensure that the structures are maintained in a safe and serviceable condition. We have yet to determine if there are any Formal Maintenance Procedures in place. These should form part of the OMS Manual.

4.6 SURVEILLANCE & MONITORING (DSG SECTION 3)

The applicable reference section of the DSG is Section 3: Operation, Maintenance, and Surveillance.

Surveillance Procedures (SPS) as described in Section 3.4 of the DSG are intended to ensure adequate inspection and monitoring. Applicable considerations are as follows:

a) Procedures or requirements for routine visual inspection by staff, including inspection records.

b) Procedures for implementation of any required action as a result of a routine inspection.

c) Procedures or requirements for more detailed regular inspections, such as underwater assessments.

d) Procedures or requirements for special inspections due to extreme events or unusual observations.

It is our understanding that procedures outlined in the Sewage Lagoon Preparedness Plan are being followed, and that routine monitoring of lagoon levels and seepage is being carried out 5 days per week. The Sewage Lagoon Preparedness Plan should form part of the OMS Manual.

4.7 EMERGENCY PREPAREDNESS (DSG SECTION 47)

Section 4 of the DSG involves Emergency Preparedness. The primary requirement is that an Emergency Preparedness Plan (EPP) exists. An EPP should describe the actions to be taken by the owner and operator in the event of an emergency. The EPP should include the following:

- Emergency identification and evaluation
- Preventative action
- Notification procedure and flowchart
- Response during darkness, adverse weather, etc.
- Available resources and their allocation
- Inundation maps, based on an Inundation Study

It is our understanding that procedures outlined in the Sewage Lagoon Preparedness Plan, which addresses the above items, are being followed. Inundation mapping is not applicable.

4.8 Compliance With Previous Reviews (DSG Section 2.2.8)

No previous Dam Safety Review documents exist at this time.

5. Summary

Based on our inspection, review of available documentation, and our analyses, we summarize the results of the DSR for the City of Iqaluit Sewage Lagoon as follows:

1. In accordance with Section 1 of the DSG, the sewage lagoon dykes have been classified as having a Low Consequence Category for both the Life Safety and Socioeconomic, Financial and Environmental categories.

2. The absence of original design drawings and as-built drawings, survey data, or any significant geotechnical information concerning the structure and material properties of the dykes, and the foundation conditions, does not allow for a detailed dam safety analysis of the stability of the structures. As well, available hydrology information, such as the storage capacity of the lagoon at various levels and discharge capacity of the control structure, is apparently not available. Without this information, the safety of the lagoon dykes cannot be accurately evaluated to an acceptable level in accordance with the DSG.

3. In light of the on-going stability problems associated with seepage, ice lensing and ice blockage and previous breaching of the dykes, and the environmental issues related to the escape of contaminated seepage and further possible breaches of the dykes, the sewage lagoon dykes are considered to be unsafe from a Dam Safety perspective. Maintaining the level of the lagoon at minimum levels and daily monitoring of lagoon levels and seepage is considered to be a temporary short term solution but not an acceptable long term solution for dam safety requirements. The City's Spill Contingency Plan and Sewage Lagoon Preparedness Plan are useful and essential documents. However, improvements to the sewage lagoon should be implemented so that the City staff is not always on alert.

4. The dam is in non-compliance with the requirements of Sections 3 and 4 of the DSG. The following documents do not exist at this time:

    - Permanent File
    - OMS Manual
    - Logbook
    - Emergency Preparedness Plan

6. Recommendations & Required Action

1. Additional fundamental information is required to meet the requirements of the DSG. This information includes:

    a. A detailed topographic survey of the lagoon and the dyke structures,

    b. A detailed geotechnical program involving boreholes to assess the integrity and material properties of the dyke structures and their foundations, and installation of piezometers to monitor phreatic levels within the dyke structures at various locations.

    c. Development of as-built drawings with a detailed site plan and dyke cross sections at various locations indicating the geometry and material properties of the structures.

    d. Detailed hydrology analyses are also needed to more accurately assess the impact of flooding on lagoon levels in order to prevent potential overtopping conditions. Diversion schemes to prevent outside surface water from entering the lagoon need to be developed.

2. Serious consideration should be given to the following options to address the dam safety concerns:

    Option #1 - Consideration should be given to abandoning the "leaky" dam concept for the sewage lagoon and installing an impervious liner (i.e. a geosynthetic clay liner) across the lagoon bottom and along the upstream face of the dykes. This action would reduce or eliminate seepage through the dykes, thereby stabilizing the structures, especially during the vulnerable winter-spring period. Lining the lagoon would also address the environmental concerns related to uncontrolled discharge of partially treated waste water escaping to the natural environment. Additional rip-rap should be provided on the downstream slopes, to protect against potential wave action from high tide levels as well as rapid drawdown conditions.

    Option #2 - If the "leaky" dam concept is to be maintained, then it is essential that the downstream side of each of the dykes be reinforced with a coarse, free draining rock fill buttress, with a non-woven geotextile placed along the existing downstream slope to act as a filter to prevent soil from migrating through the rock fill. The rock fill buttress must be designed to provide support for the sand & gravel fill, assuming totally saturated conditions.

    Option #3 – Consideration could be given to relocating the sewage lagoon with the new design based on present engineering and environmental standards.

3. A revised Dam Safety Review will be required assuming that one or more of the options listed above are implemented. Until such time, the existing structures should have a Dam Safety Inspection (DSI) conducted in 2002, preferably by mid-October of that year. This is essentially a yearly non-invasive review comprising a visual inspection to identify any changes in condition, or any observed concerns. The summary written report generated would form a permanent record document to be included in the Permanent Record File.

4. In terms of time to compliance, we would expect that discussions with the regulatory agencies would be required in conjunction with development of the options discussed above. A suitable time frame for compliance would likely be negotiated as part of this process.

We would be pleased to discuss this report with you at your convenience.

Yours truly,

Trow Consulting Engineers Ltd.

A.J. Schell, M.Sc., P.Eng.,
Branch Manager/Sr. Geotechnical Engineer

Surinder Aggarwal, P.Eng.
Manager, Geotechnical Services, Ottawa

Enclosures:

AS/jot/geo/reports/8786G

APPENDIX 1

Site Photographs
Town of Iqaluit Sewage Lagoon

Photo 1 - View of Town of Iqaluit Sewage Lagoon taken from north end of East Dyke looking west across the lagoon towards the West Dyke.

Photo 2 View taken from north end of West Dyke looking south along upstream face and crest of West Dyke. The Discharge Control Structure for the lagoon is in the foreground

Photo 3 View looking north at downstream (ocean) side of West Dyke.

Photo 4 View looking south along crest and downstream face of West Dyke.

Photo 5 View taken from north end of West Dyke showing area that appears to have been previously breached and was infilled with local silty sand & gravel fill. The fill material appears to be saturated.

Photo 6 View looking south-southwest at lagoon. The East Dyke is on the LHS of the lagoon.

Photo 7 View from north end of East Dyke looking south along crest and downstream slope of East Dyke.

Photo 8 View looking north along upstream face of East Dyke. Sewage outfall is located adjacent to the north end of the East Dyke.

Photo 9 View looking southwest at crest and upstream face of the smaller Southeast Dyke.

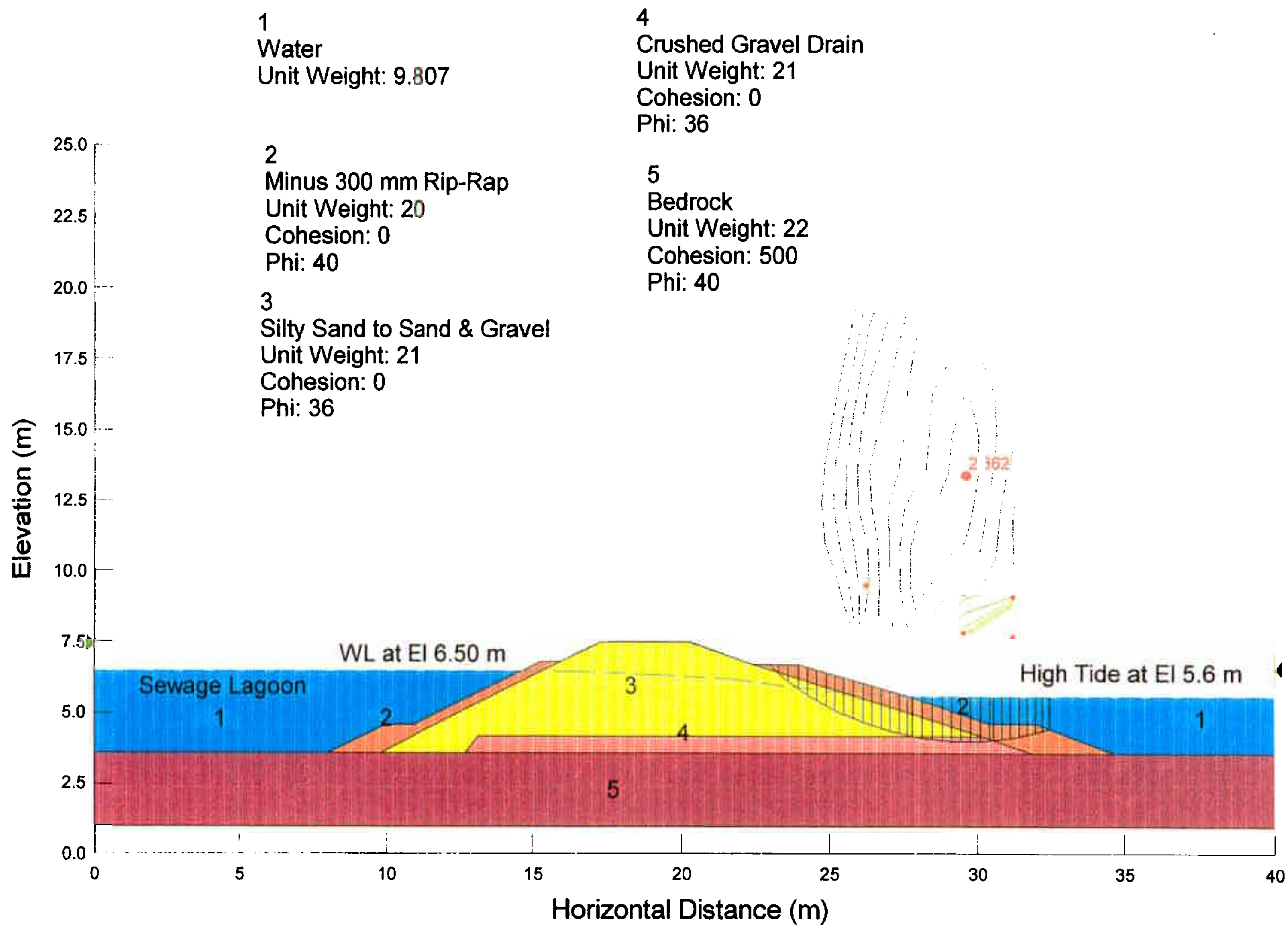
Photo 10 View looking northeast at downstream slope of Southeast Dyke. Some seepage ponding is evident along the toe.

APPENDIX 2

Stability Analyses
Sewage Lagoon Dyke

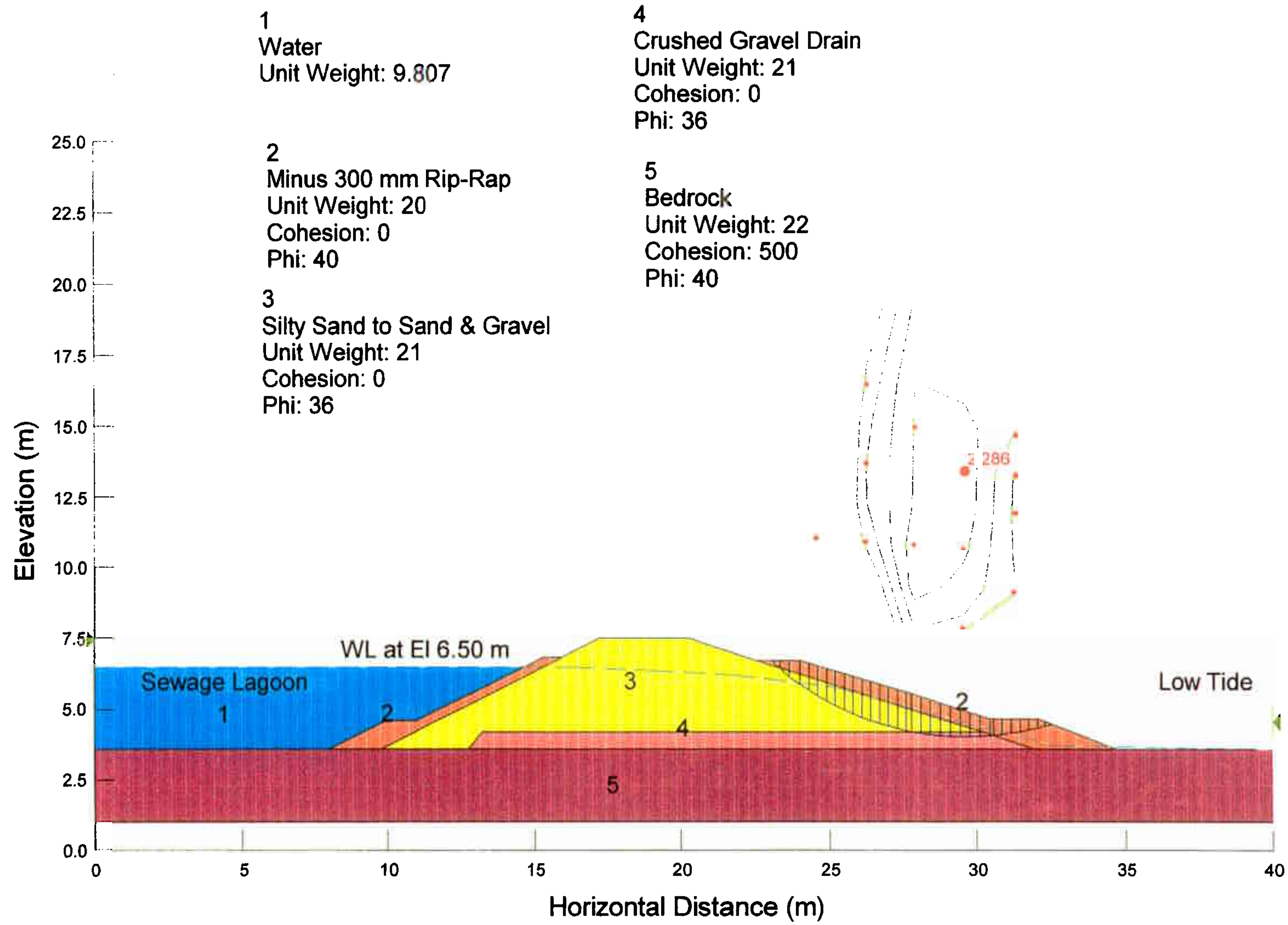
Iqaluit Sewage Lagoon
Review of Dyke Slope Stability
File Name: IQS-1.slp

Fig 3-1 High Tide Conditions



Iqaluit Sewage Lagoon
Review of Dyke Slope Stability
File Name: IQS-2-Low Tide.slp
Fig 3-2

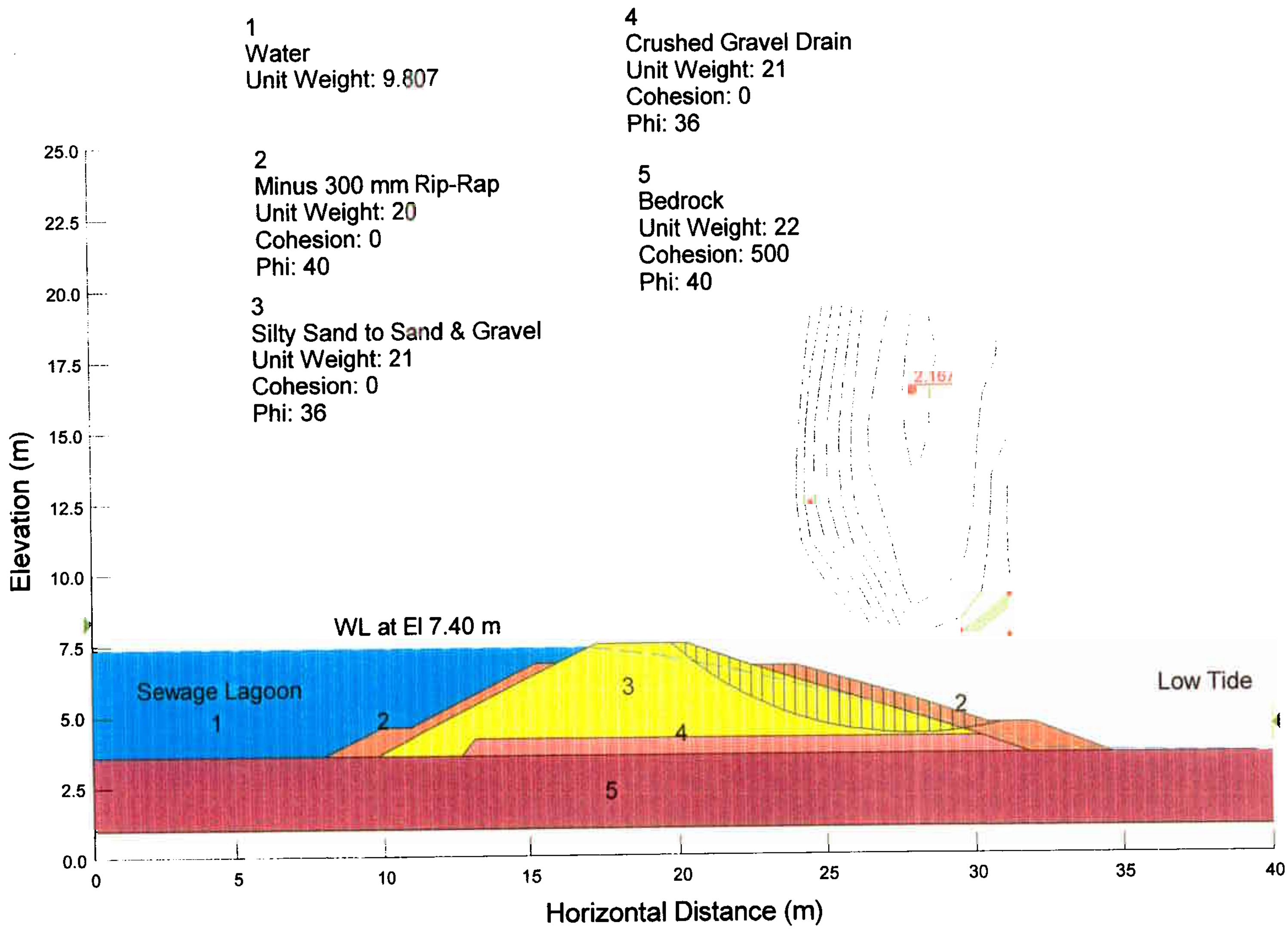
Analysis with High Phreatic Level & Low Tide

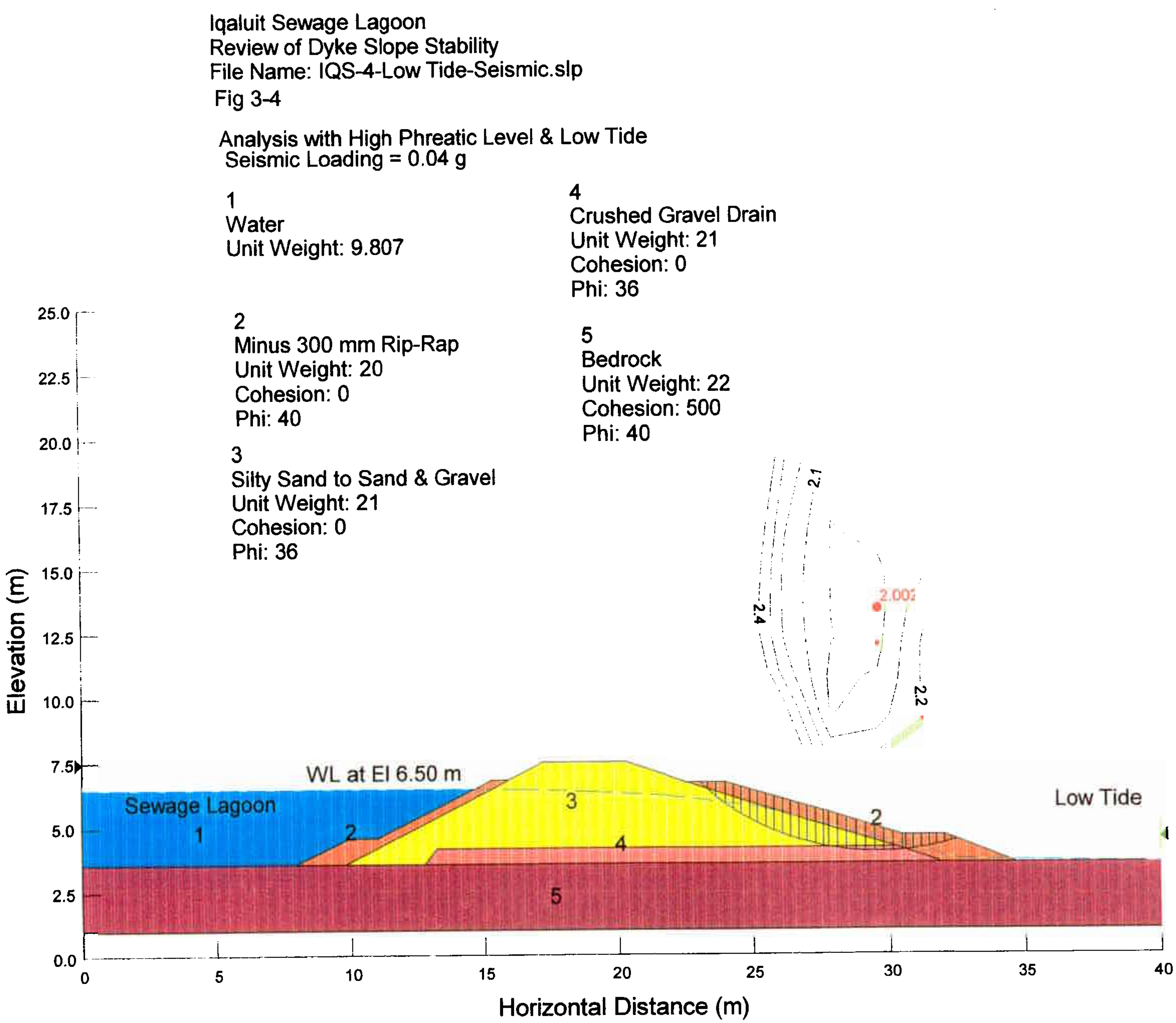


Iqaluit Sewage Lagoon
Review of Dyke Slope Stability
File Name: IQS-3- Flood Level - Low Tide.slp

Fig 3-3

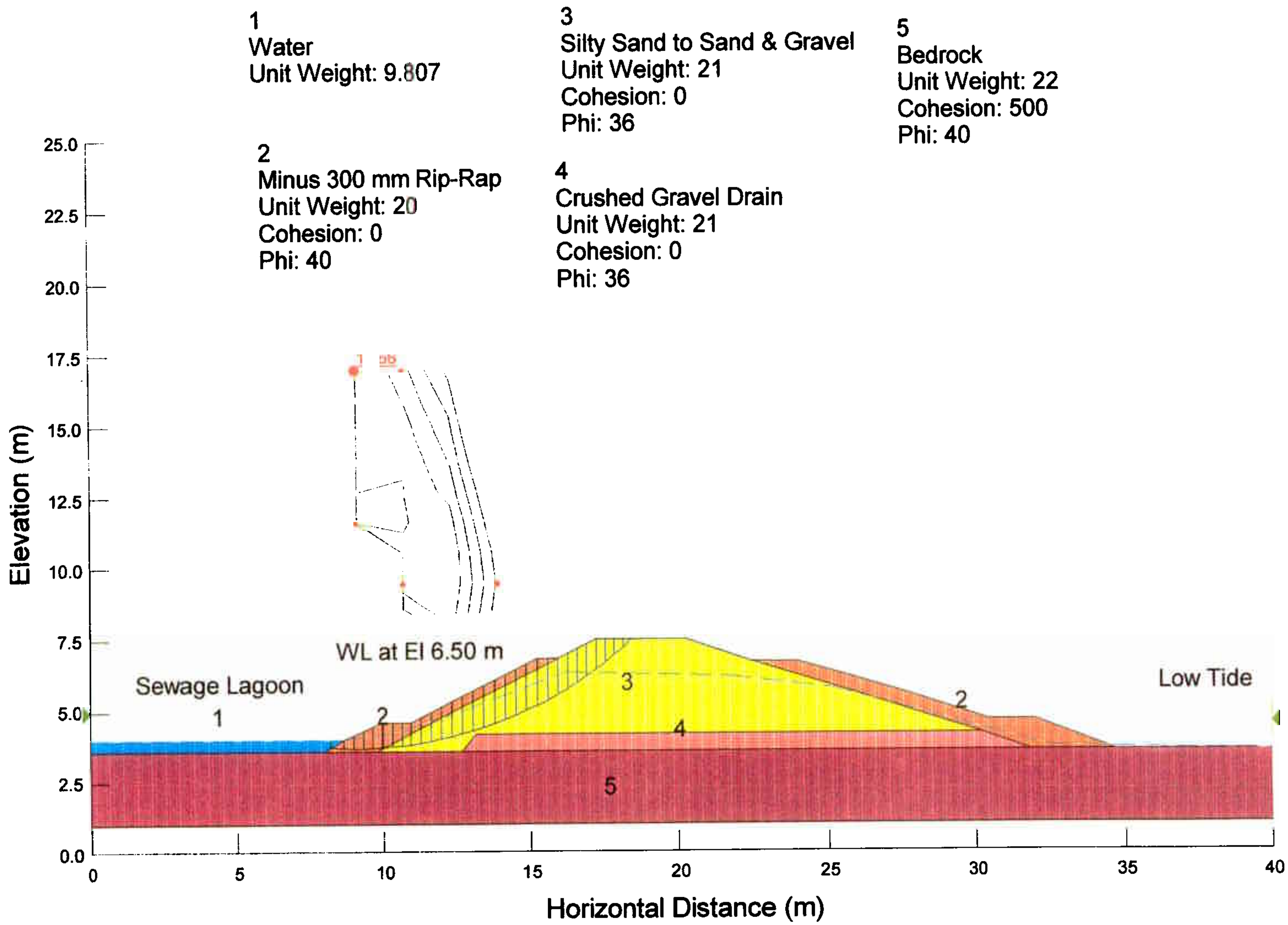
Analysis with High Phreatic Level & Low Tide




Iqaluit Sewage Lagoon
Review of Dyke Slope Stability
File Name: IQS-4-Low Tide-Seismic.slp
Fig 3-4
Analysis with High Phreatic Level & Low Tide
Seismic Loading = 0.04 g
1
Water
Unit Weight: 9.807
2
Minus 300 mm Rip-Rap
Unit Weight: 20
Cohesion: 0
Phi: 40
3
Silty Sand to Sand & Gravel
Unit Weight: 21
Cohesion: 0
Phi: 36
4
Crushed Gravel Drain
Unit Weight: 21
Cohesion: 0
Phi: 36
5
Bedrock
Unit Weight: 22
Cohesion: 500
Phi: 40
2.1
2.4
2.2
WL at El 6.50 m
Sewage Lagoon
Low Tide
Elevation (m)
Horizontal Distance (m)

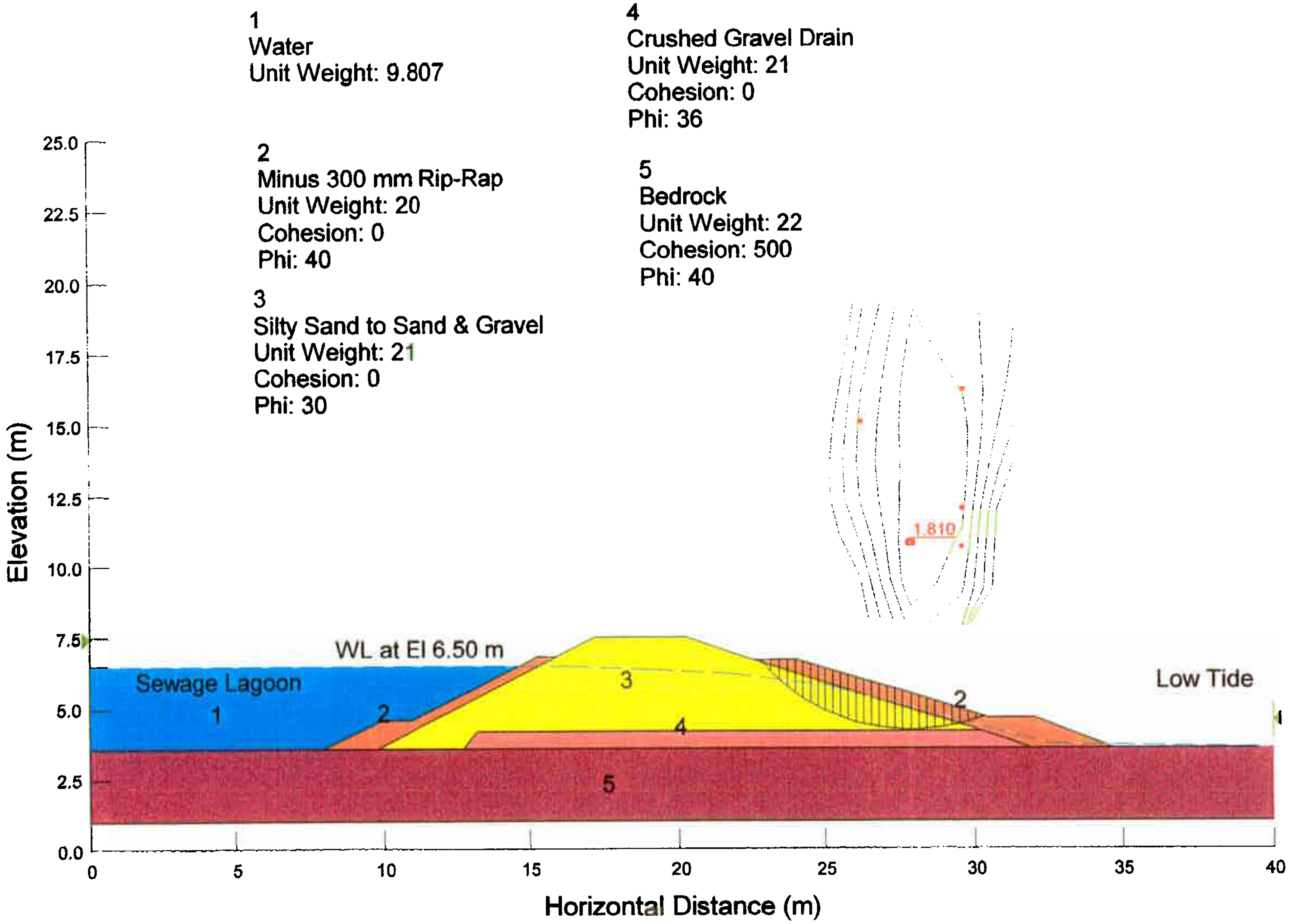
Iqaluit Sewage Lagoon
Review of Dyke Slope Stability
File Name: IQS-5-Rapid Drawdown US.slp

Fig 3-5 Rapid Drawdown Condition
on Upstream Slope



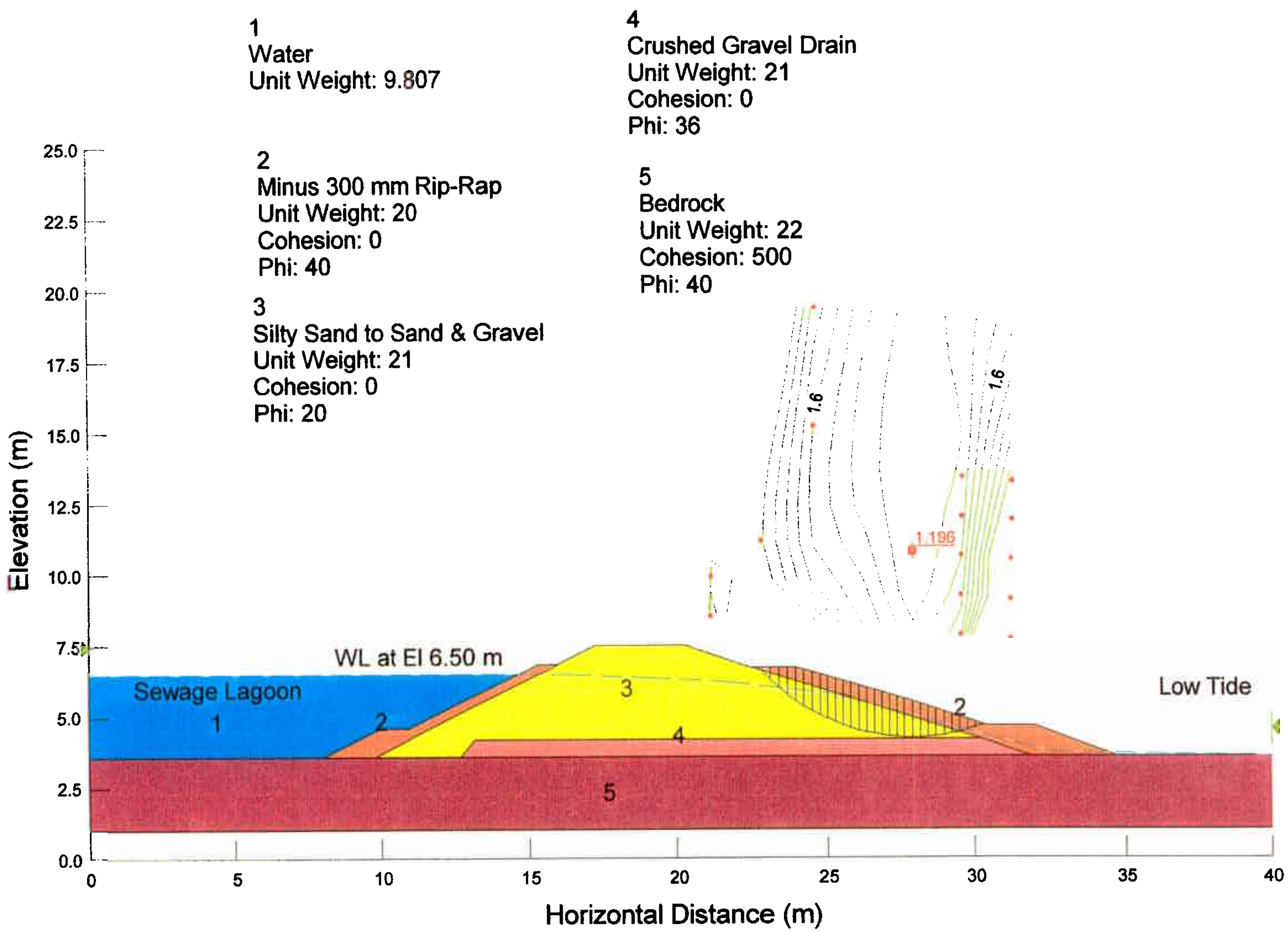
Iqaluit Sewage Lagoon
Review of Dyke Slope Stability
File Name: IQS-6-Weakened Soil.slp
Fig 3-6

Analysis with High Phreatic Level & Low Tide, Weakened Soil



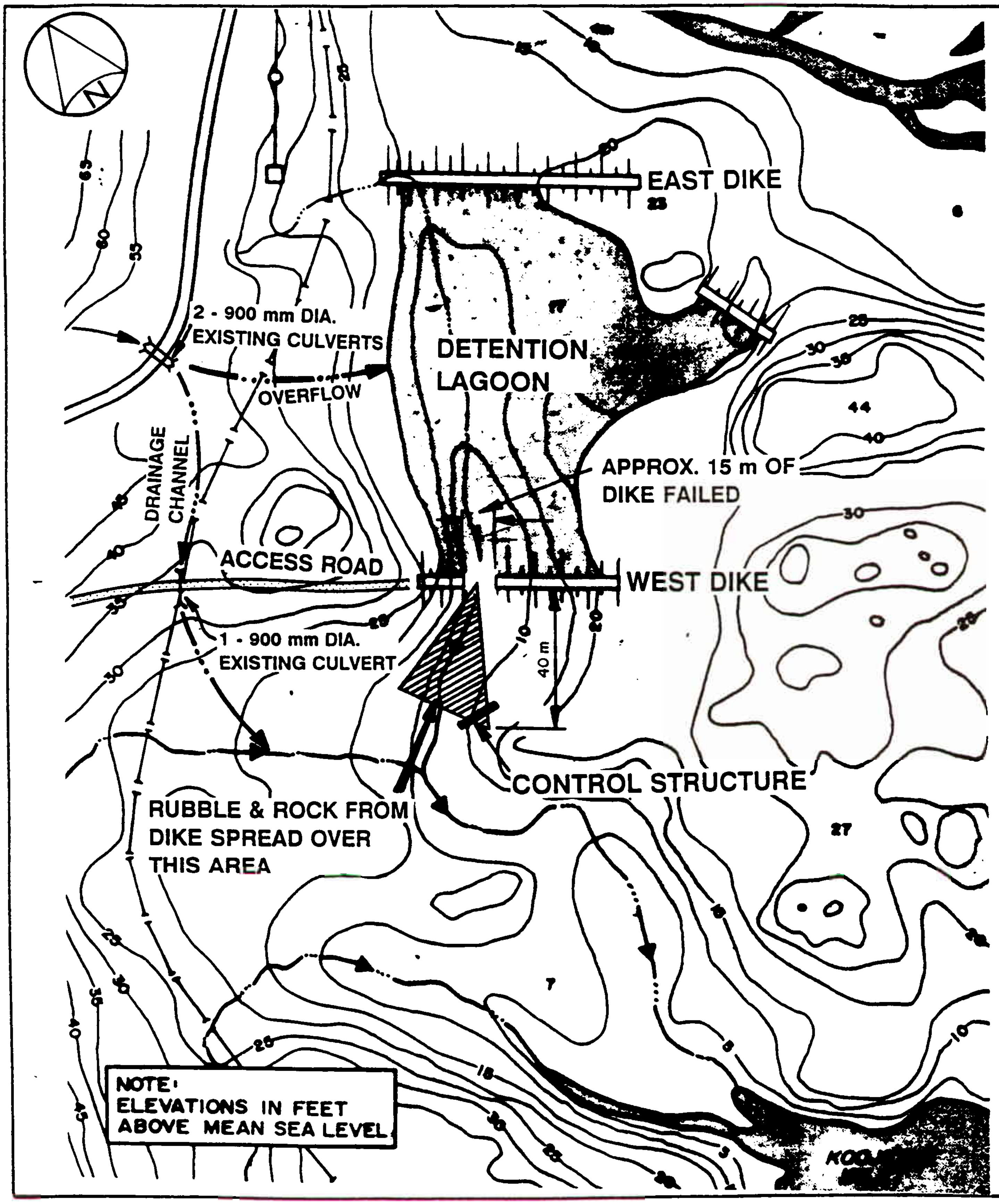
Iqaluit Sewage Lagoon
Review of Dyke Slope Stability
File Name: IQS-7-Weakened Soil-phi=24.slp
Fig 3-7

Analysis with High Phreatic Level & Low Tide, Weakened Soil Due to Thawing



APPENDIX 3

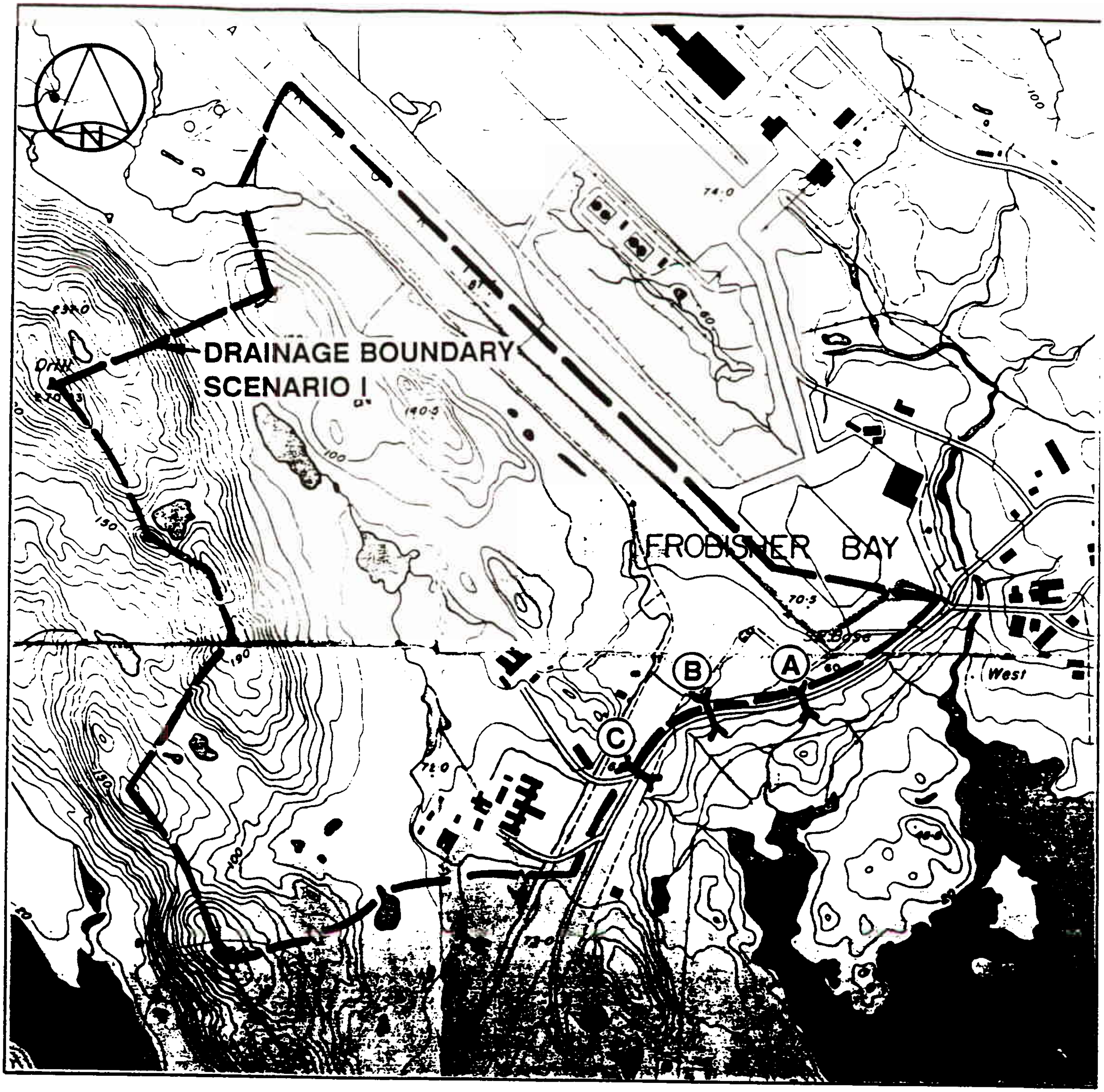
Reference Figures



IQALUIT, NWT
LAGOON DIKE BREACH

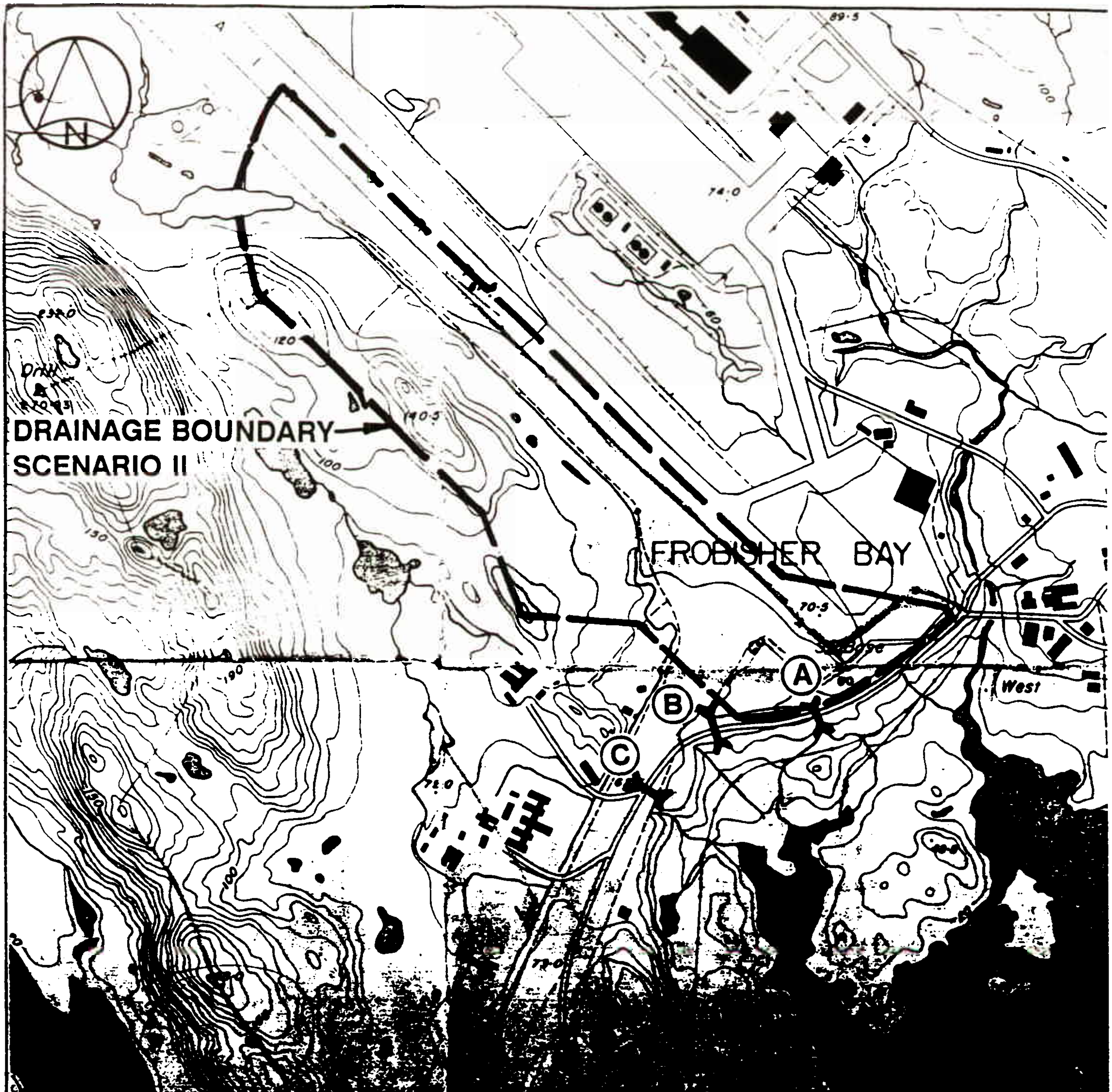
uma

FIGURE 1



SCENARIO I

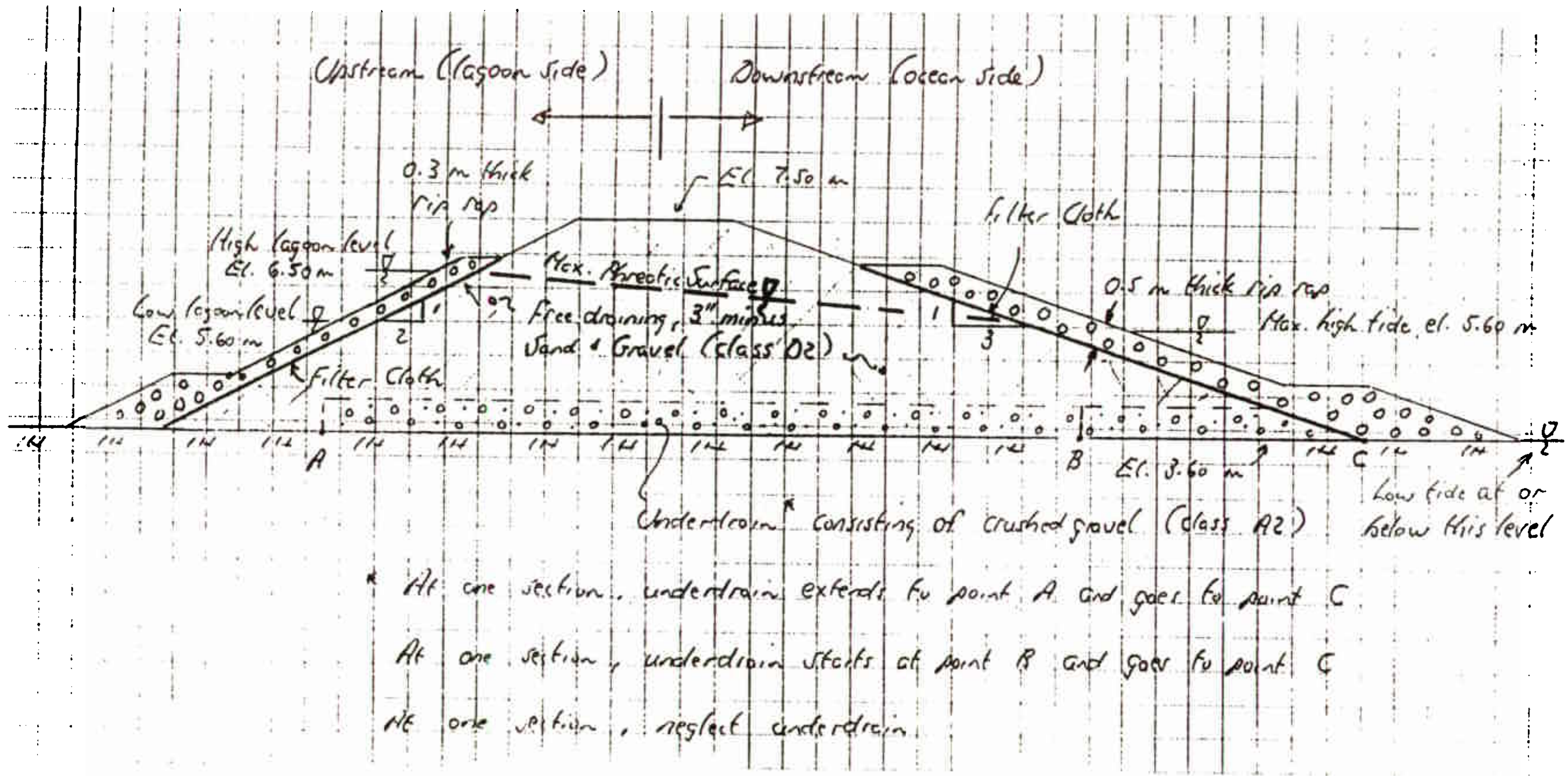
FIGURE 3



SCENARIO II

FIGURE 4

uma



REVISIONS

REFERENCES

Hardy BBT Limited
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

Proposed Original Dyke Cross-Section (after UMA Engineering)

SCALE 1:125 | DATE Oct. 1/91 | MADE WBG | CHKD. | JOB No. VG-05912 | FIGURE 1

HBLT 53-87/11