Trow

Preliminary Design Report
Expansion of City of Iqaluit
Raw Water Storage,
City of Iqaluit, Nunavut

Draft Report

Prepared for:
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1.0 Introduction

Trow Associates Inc. (Trow) was retained by the City of Iqaluit to provide engineering services in relationship to the expansion of the City's Raw Water Storage. The City authorized this work in a letter dated September 29, 2004.

1.1. Background

The City of Iqaluit receives its water supply from Lake Geraldine Reservoir, which is retained by a cast-in-place concrete gravity dam. The storage capacity of the Lake Geraldine Reservoir has been increased three times since the original construction of the concrete dam in the 1960's.

Lake Geraldine Reservoir does not receive any recharge during the winter months and therefore must have sufficient storage capacity to meet the City's over-winter water demands. Lake Geraldine Reservoir has an estimated 1,076,000 cubic metres of total storage, and provides an estimated 570,000 cubic metres of usable over winter storage. It is recharged during the spring and summer by runoff from the Lake Geraldine watershed, which has a surface area of 385 hectares and receives an annual mean precipitation of approximately 424.1 millimetres. The "City of Iqaluit Raw Water Supply and Storage Review" completed by Trow in 2004, estimated a total available recharge of 968,000 cubic metres.

The "Water and Sewer Study" completed by Trow, in 2002, identified that the future storage requirements of the City of Iqaluit would not be met by the current storage capacity of Lake Geraldine Reservoir. Based on these findings, the City of Iqaluit commissioned Trow to complete the "Raw Water Supply and Storage Review". This study confirmed that the current Lake Geraldine Reservoir did not have the capacity to meet the City's long-term storage requirements.

The "Raw Water Supply and Storage Review" reviewed alternatives for increasing the capacity of the Lake Geraldine Reservoir including increasing capacity through excavating the existing reservoir and increasing the capacity through raising the dam and berm structures. The report recommended that the City storage requirements would best be met through raising of the existing dam and berm structures by 2.0 metres. This recommendation has been accepted by the City and is the basis for this project.

1.2. Scope of Project

The expansion of the Lake Geraldine Water Reservoir is to be undertaken through increasing the height of the Lake Geraldine Dam by 2.0 metres. Raising the Dam will also require raising the existing berms to the north of the dam and the construction of a new earth berm to the south of the dam. The enclosed drawing SP1, shows the location of these structures and labels them for future reference in the report.

1.3. Storage Requirements

The Lake Geraldine Reservoir is required to provide the over-winter water supply for the City from freeze-up to the beginning of recharge (Oct 1 to May 31). The Raw Water Storage Report discussed several population projections summarized in Table 1, from different sources and recommended the use of the High Growth rate projection.

Table 1 - Population Projections

Year	Low Growth Projection	Medium Growth Projection	High Growth Projection
2003	6,200	6,200	6,200
2004	6,344	6,417	6,408
2005	6,491	6,642	6,624
2006	6,642	6,841	6,846
2007	6,796	7,046	7,076
2008	6,953	7,257	7,314
2009	7,115	7,475	7,560
2010	7,280	7,699	7,814
2011	7,449	7,930	8,076
2012	7,621	8,168	8,348
2013	7,798	8,413	8,628
2014	7,979	8,666	8,918
2015	8,164	8,926	9,218
2016	8,354	9,149	9,527
2017	8,548	9,378	9,848
2018	8,746	9,612	10,178
2019	8,949	9,852	10,520
2020	9,156	10,099	10,874
2021	9,369	10,351	11,239
2022	9,586	10,610	11,617
2023	9,808	10,875	12,007
2024	10,036	11,147	12,410
2025	10,269	11,426	12,827

The City of Iqaluit currently uses a design per capita consumption rate of 400 litres per capita per day (lpcd). The City of Iqaluit Water and Sewer Study estimated the average current consumption rate at 123 lpcd for truck services and 277 lpcd for pipe services. Based on these current average consumption rate the design consumption rate is relatively conservative, however, as the City grows and becomes more urbanized, it is projected that the consumption rate shall increase closer to those observed in a more southern environment. The City of Iqaluit's major infrastructure (water treatment plant, waste water treatment plant) are all based on the design consumption rate of 400 litres per capita per day, therefore, it is recommended that the expansion of the Lake Geraldine Reservoir also be based this design consumption rate.

The over-winter storage period in the City of Iqaluit is generally accepted to be from October 1st through to May 31st of the subsequent year. Observed overtopping of the dam, which indicates full recharge of the reservoir, has been witnessed to occur in early June in recent years. This indicates that extending the over-winter storage period through to May 31st, may in fact be conservative, however, for the purpose of sizing the water reservoir, the conservative approach is justified.

Based on the projected population of 12,827 in 2025, and a daily consumption rate of 400 litres per capita, the overwinter storage capacity to meet the City's needs is 1,247,000 cubic metres.

1.4. Drawdown Analysis

To determine a reservoir's ability to meet the overwinter supply requirements, a drawdown analysis must be carried out. The drawdown analysis considers both consumption and ice growth throughout the winter months in determining the available capacity of the reservoir. Tables 2 and 3 list the monthly consumption rates and the ice generation rates respectively. A three dimensional computer model of the Lake Geraldine Reservoir was prepared based on bathometric survey data generated by Trow (then Oliver, Mangione & McCalla) during the 1984, topographic mapping of Iqaluit from November 2002 and survey data collected by Trow in October 2005. Based on this model, a detailed draw analysis was performed and results are included in Appendix A. The draw analysis confirmed that the proposed 2.0 metre extension to the Dam and associated structures would increase the capacity of Lake Geraldine Reservoir sufficiently to meet the City of Iqaluit's overwinter storage requirements until the year 2025.

Table 2 - Over winter consumption (October to May)

	2025		2025
Month	**400 lpcd**	**Month**	**400 lpcd**
October	159,000	**February**	144,000
November	154,000	**March**	159,000
December	159,000	**April**	154,000
January	159,000	**May**	159,000

Table 3 - Lake Geraldine freeze depth analysis

Month	Depth of Freeze for Month (m)	Total Freeze Depth (m)
October	0.1	0.1
November	0.3	0.4
December	0.4	0.8
January	0.3	1.1
February	0.3	1.4
March	0.2	1.6
April	0.1	1.7
May	0.0	1.7

2.0 History of Structure

The original cast-in-place concrete gravity dam and a section of earth berm with a central cast-in-place concrete cut-off wall were designed and constructed by the Department of National Defence circa 1958. All the concrete structures are believed to be founded on rock, and engage rock at their abutments. The exception to this is a portion of the cut-off wall north of the spillway structure where the rock is deep. This portion of the wall was founded in the overburden.

In 1979 the concrete gravity dam was raised 0.3 metres by extending the concrete structure. The new concrete structure was dowelled into the existing structure.

In 1985, the spillway structure was increased in height by 1.15 metres and the embankment portion was widened and heightened. The extension was of concrete construction and dowelled into the existing structure. Steel formwork was used for this extension and still remains in place to this day, in a corroded condition.

In 1996 the concrete gravity structure was again raised by a further 1.5 metres of concrete and the berm geometry increased as well. To maintain a stable structure against overturning and sliding an extensive rock-anchoring program for the gravity dam portion was undertaken. The rock anchors were installed and tested in 1995.

2.1.1. Description of Structure

The Lake Geraldine Dam has been classified in the High Consequence Category for both Life Safety and Socio-economic; Financial and Environmental categories, based on the Dam Safety Guidelines (DSG) prepared by the Canadian Dam Association. The "High" classification is assigned by DSG, in the case of life safety when loss of life would likely occur as a result of the failure of the dam. A "High" category is assigned in the socio-economic category if, in the event of the failure of the dam, the cost to the community in terms of social and financial impact would be significant.

2.1.1.1. Dam Spillway Section

A typical section of the existing dam spillway is provided in Appendix B of this report. The crest of the 15.7 metre wide spillway section is at an elevation of approximately 109.33 metres, which currently represents the normal operating level of the lake. At this level, the dam has approximately 0.95 metres of freeboard. Minimal temperature and steel reinforcement is provided in the faces of the upper portions of the dam.

Available drawings for the dam spillway indicate that six rock anchors were installed in 1995 at 2.7 metre intervals along the length of the dam. The double corrosion anchors, Dywidag 36 mm diameter grade 1030 MPa threadbar anchors were installed at an inclination of approximately 13 degrees approximately to the vertical and comprised of a free length of 1 metre and a bonded length of 4 metres in the bedrock. The anchors were designed to be passive/no lock off load, fully grouted in two stages, with an allowable load of 765 kN/anchor. Two anchors were tested extensively at the time of installation with a four-hour creep test to monitor the stability of the potential rock mass failure cone while also proof loading the grout/hole bond stress. Dywidag has confirmed in recent correspondence dated January 13, 2005 that the design of the rock anchors took into consideration the shear cone failure of the rock mass based on group effect and the shear strength of the rock. Failure of the grout/rock bond and the failure of the steel tendon were also modes of failure considered in the original design.

2.1.1.2. Gravity Dam Section

A typical section of the existing gravity dam is provided in Appendix B of this report. The crest of the 32.7 metre section to the south of the spillway section of the dam and the 13.3 metre long section to the north of the spillway section is at an elevation of approximately 110.28 metres.

The dam approximately 8.8 metres in height have a vertical upstream face and a sloped downstream face (51° with respect to the horizontal) for a height above the base of approximately 5.3 metres. Minimal temperature and shrinkage steel is provided in the upper 2.4 metres of the dam.

Available drawings for the dam spillway indicate that thirteen rock anchors were installed in 1995 at a 2.6 metre intervals throughout the length of the dam. The double corrosion anchors, Dywidag 36 millimetre diameter grade 1030 MPa threadbar anchors were installed vertically and comprised of a free length of 1 metre and a bonded length of 4 metres in the bedrock. The anchors were designed to be passive/no lock off load, fully grouted in two stages, with an allowable load of 830 kN/anchor. Three anchors were tested extensively at the time of installation with a four-hour creep test to monitor the stability of the potential rock mass failure cone while also proof loading the grout/hole bond stress. Dywidag has confirmed in recent correspondence dated January 13, 2005 that the design of the rock anchors took into consideration the shear cone failure of the rock mass based on group effect and the shear strength of the rock. Failure of the grout/rock bond and the failure of the steel tendon were also modes of failure considered in the original design.

2.1.1.3. Existing Earth Embankments with Concrete Cut-off Walls

To the north of the existing gravity dam there are sand, gravel and rock embankments with a 200 mm thick concrete cut-off wall reportedly founded on bedrock. A typical section of the existing earth berms are provided in Appendix B of this report. The top of the embankment is at elevation 110.50 metres with the concrete cut-off wall reportedly at elevation 110.30 m. It is therefore our understanding that the elevation of the top of the concrete cut-off wall in the embankment portion of the dam is at least equal to the elevation of the top of the concrete gravity dam portion of the dam, at 110.28 m.

3.0 Condition Survey

The existing dam site was inspected on October 14-15, 2004 by R.W. Potter, P.Eng., Ismail Taki, P.Eng. and Michel Asselin, P.Eng., of the Trow Project Team. Mr. Potter performed an inspection of the existing dam structures to observe their present conditions.

3.1. Gravity Dam

The existing dam is in sound condition. The 1985 steel formwork used in the central spillway area is corroded and unsightly, but has no significance on the structural capacity. Concrete surfaces are in good condition, without excessive scaling or spalling. A number of vertical shrinkage cracks are present at spacings varying from 1.6 to 2.3 metre spacing along the length of the top of the dam (above the lake level), though no leakage was present at these locations. In the older concrete at lower elevations on the downstream face of the dam, vertical cracks were present which had varying degrees of leakage, from wet staining to slow seepage. Only five of these cracks had any appreciable leakage during our inspection.

Injection ports for past crack repairs were also observed on the downstream side of the south end of the dam, and at the north end, adjacent to the central spillway. City staff later reported that the crack injection had been performed in 2003, but that no technical details of the repair program were available. Reportedly, the crack injection repairs had reduced the amount of leakage at the cracks considerably.

The vertical orientation of the observed cracks is consistent with expectations, considering the vertical compression introduced in the concrete structure by the 1995 rock anchor installation, and the modest quantity of horizontal reinforcement (i.e. temperature and shrinkage rebar) in the structure.

The observed leaks do not affect the overall structural stability of the dam. However, as part of the dam extension program, further repairs should be performed on the persistent leakage at a few of the vertical cracks. Such repair work has been included in our cost estimate later in this report.

3.2. Earth Berms

There are two existing berms located to the north of the gravity dam structure. Both of the berms are gravel berms with a concrete cut-off wall. The first section of berm has a sufficient width along the top to allow vehicular access to the berm. The up-stream or Lake Geraldine's side of this berm has areas that appear to have experienced some erosion and minor failure of these slopes stability as reported in the dam safety inspection reports. These areas have not yet been addressed. A more northern berm is constructed similar with a concrete cut-off wall, however the top width is approximately 2.4 metres and does not allow vehicle access. A section of the concrete cut-off wall in this berm is reportedly not anchored into bedrock during construction. The bedrock dipped below the excavation capacity of the contractor. Insulation was used in this area to ensure stabilization of the permafrost, which provided the impervious connection between bedrock and the concrete cut-off wall.

4.0 Structural Feasibility

The following work was completed to assess the structural feasibility and develop a preliminary design for raising the existing dam:

(1) Analysis of the existing structures for stability in accordance with the National Building Code and Dam Safety Guidelines of the Canadian Dam Safety Association. The analyses utilized geotechnical parameters from the 2004 geotechnical investigation.

(2) Examination of the structural feasibility of extending the height of the existing concrete gravity dam structures, the spillway and dam, to accommodate an increase of 1.5 to 2 metres in the height of water storage in Lake Geraldine.

(3) Determination of the necessary structural modifications for extension of the existing spillway and dam structures based on preliminary analysis for stability and strength in accordance with the National Building Code and Dam Safety Guidelines of the Canadian Dam Safety Association. The modifications considered are based on construction season limitations, using the construction seasons efficiently, the availability of materials and labour, maintaining dam operation at all times during construction, the project schedule, and to ensure fabrication of specialized equipment to meet sea lifts.

(4) Preparation of a Class "C" estimate based on proposed structural modifications.

4.1. Structural Assessment of Gravity Dam

Two sections of the Lake Geraldine Dam have been assessed; the spillway section and the gravity dam section itself. Basically, the concrete dam/foundation rock mass is required to have adequate strength, especially in the saturated state to resist the tendency of the gravity dam to overturn about the downstream toe at the foundation; and to resist the tendency of the dam to slide downstream under the water pressure.

For each section, the worst case has been assessed, which corresponds to the maximum retained height, that is, the maximum distance from the lake bottom at the base of the dam, to the crest of the dam. As the lake bottom tends to undulate, the retained height varies to some degree.

The loads considered in the assessment of the Lake Geraldine Dam for structural stability include:

- Dead loads of permanent structures
- Maximum normal and flood headwater levels
- Internal (uplift) water pressure
- Horizontal thrust created by an ice sheet (150 kN/m)
- Maximum design earthquake

Temperature effects have not been considered due to the relatively small size and length of the gravity dam.

Backfill/silt loads have not been considered, as there is no evidence of significant silt accumulation in the reviewed documentation.

The load combinations, as defined by DSG, that have been used in the assessment for structural stability are:

- Usual
- Flood
- Earthquake

Using the described loads and load combinations sliding, overturning and overstressing have been considered.

Typically the Dam Safety Guidelines require minimum factors of safety for overturning and sliding of 1.5 and 2.0, respectively for an existing structure.

4.1.1. Existing Dam

In 2001 Trow prepared a Dam Safety Review Report for Lake Geraldine Dam that included Stability Calculations for the concrete portions of the dam. The stability calculations were based on the assumed geotechnical parameters as shown on the structural drawings dated June 1995 prepared by Trow. The rock friction angle was assumed to be 50° for both sections.

In the 2001 report, the minimum factors of safety for the governing case, (here the "usual" loading case), for overturning and sliding were calculated to be 1.33 and 1.72, respectively, for the spillway section; and 1.56 and 1.96 respectively for the gravity dam section. It was determined that the resultant force for the "usual" load case was within the middle third of the section.

For this study the geotechnical parameters utilized have been based on the results and recommendations from the geotechnical investigation conducted by Trow in the fall of 2004 and the information provided by Dywidag for the existing rock anchors as summarized below:

- An allowable bearing capacity for the rock of at least 480 kPa.
- A submerged unit weight for the rock of 16 kN/m^3.
- A coefficient of friction to assess sliding failure between the rock and concrete based on the tan 40°. This is considerably less than the coefficient of friction used in the original design and previous assessments.
- Allowable loads for rock anchors as provided by Dywidag for the actual installation of 765 kN/anchor for the spillway section and 830 kN/anchor for the gravity dam section. It should be noted that Dywidag has relied on some capacity derived from the shear capacity of the rock. This is not the usual practice.

Based on utilizing the recent geotechnical information the minimum factors of safety for the governing case, the "usual" loading case, for overturning and sliding were calculated to be 1.21 and 1.24, respectively, for the spillway section; and 1.56 and 1.85, respectively, for the gravity dam section. It was determined that the resultant force for the "usual" load case was within the middle third of the Section.

Although the calculated values are below our norms of acceptance, it is our opinion that the stability of the dam is adequate. The calculated factors are for the worst case load combination at the spillway section, which is the weakest link of the structure. This section was analyzed as a stand alone structure. In reality, the spillway section is relatively narrow in elevation, and directly engages the wing walls of the gravity section at each end. In effect, the dam sections on either side buttress the central spillway, and this in effect is not included in the worst-case analysis.

The existing concrete gravity section of the dam is in safe and reasonable condition at this time, with no significant changes in visible condition compared to the last (2001) inspection.

4.1.2. Proposed Dam

To accommodate the new lake level it is proposed to extend the heights of the existing concrete dam and the earth berm. This would involve extending the concrete height of the dam, providing a new spillway, adding additional significantly deeper rock anchors and extending the cut-off wall of the earth berm to the north.

A typical section of the proposed dam spillway is provided in Appendix C of this report. The crest of the 15.7 metre wide spillway section would be established at an elevation of 111.33 metres. At this level, the dam would have approximately 0.95 metres of freeboard. The new concrete section would be dowelled to the existing and reinforced.

A typical section of the proposed gravity dam is provided in Appendix C of this report. The crest of the 32.7 metre section to the south of the spillway section of the dam and the 13.3 metres long section to the north of the spillway would be established at an elevation of 112.28 metres. The new concrete section would incorporate a new sloped spillway surface and would be dowelled to the existing and reinforced.

For each section, the spillway section and the gravity dam, concepts were developed as to how to extend the structures. These proposed sections were then analyzed for stability. Typically minimum factors of safety for overturning and sliding of 1.5 and 2.0, respectively, are required for the proposed structures, as per the Dam Safety Guidelines.

Loads and load combinations considered in the assessment of structural stability of the proposed structures are the same as used in the structural assessment of the existing structures.

For the assessment of the proposed structures the geotechnical parameters and recommendations of the 2004 investigation were used as given below:

- An allowable bearing capacity for the rock of at least 480 kPa.
- A submerged unit weight for the rock of 16 kN/m^3.
- A coefficient of friction to assess sliding failure between the rock and concrete based on the tan 40°.
- Capacity of rock anchors determined based on the following criteria:
  - A maximum working load for rock anchors having an ultimate strength less than 825 MPa limited to 60 percent of the yield strength.
  - A maximum working load for rock anchors having an ultimate strength exceeding 825 MPa limited to 60 percent of the ultimate strength of the anchor.
  - An uplift capacity equated to the weight of the specified rock cone utilizing the submerged weight of rock including for group effects involving interaction to produce a vertical plane at the interface of adjoining cones. The cone of rock should be assumed to have an apex angle of 90 degrees at the midpoint of the fixed anchor length (or bonded length) of the anchor.
  - A maximum allowable bond stress at the interface of the anchor grout and the rock of 1.0 MPa.

Based on the preliminary analyses of the concepts developed the minimum factors of safety for overturning and sliding for the governing case, (here the "usual" loading case), were calculated to be 1.5 and 2.0, respectively, for the spillway section; and 1.5 and 2.0 for the gravity dam section, respectively. It was determined that the resultant force for the "usual" load case was within the middle third of the section.

The proposed concepts require additional rock anchors for both the spillway and gravity dam sections. A new row of rock anchors would be required in between the existing rock anchors spaced at approximately 2.6 metres on centre, and embedded into the rock a minimum of 9.5 metres. These rock anchors could be either 46 mm diameter grade 835/1030 MPa threadbar in a post-tensioned application or 57 mm diameter grade 517/690 MPa threadbar in a fully grouted passive application. Another row of anchors would be placed near the toe at approximately 2.6 metres on centre, and embedded into the rock a minimum of 2.0 metres to provide shear resistance against the sliding mode of failure. Providing these rock anchors achieves the objective of increasing the stability of the dam to be line with current requirements. Double corrosion protected anchors are recommended for this environment and long service life.

4.2. Earth Berms

4.2.1. Existing Earth Berms

Increasing the height of the gravity dam will require that the existing earth berms to the north of the dam also be raised to accommodate raising the water level of Lake Geraldine. Several alternatives for increasing the berms were investigated, included extending the dam structure, and offsetting the berm such that the cut-off wall would act as retaining wall on the upstream face of the berm. These alternatives were determined to be unfeasible due to the limited strength of the existing cut-off wall. It was therefore concluded that the preferable method is to raise the berms and cut-off wall a corresponding 2.0 metres. Included, as part of the extension of the earth berms will be the requirement to extend the concrete cut-off walls approximately 2 metres to a top elevation of 112.3 m to ensure the berms remain impervious. The new section of wall would be minimally reinforced with temperature and shrinkage reinforcement and dowelled to the existing concrete cut-off wall.

It is proposed to maintain the driving surface on the central berm to maintain vehicle access to the dam. The berm will have a 2H:1V slopes on both the upstream side and downstream side of the berm. The extension on the upstream side will be constructed out of blast rock to address the slope stability issues identified in the Geotechnical report, and to reduce the risk of siltation near the water intake. The downstream side will be constructed out of gravel with a layer of riprap to protect the slope from erosion. A typical section of the proposed berm extension is provided in Appendix C of this report.

The top of the northern berm shall be maintained at the current width of 2.4 metres. The berm will have a 3H:1V slope on the upstream side and a 2H:1V slope on the downstream side of the berm. The berm extension will be constructed out of gravel and a layer of riprap will be provided to protect the slopes from erosion. A typical section of the proposed berm extension is provided in Appendix C of this report.

The concrete cut-off wall in both the north and central berm will be raised 2.0 metres. It should be noted that the concrete cut-off walls within the earth berms are intended to prevent seepage through the soil materials. The cut-off wall does not act as a gravity dam.

4.2.2. New Berm Construction

The increase elevation of the dam will require the construction of a new berm (south berm) located to the south of the dam as shown on the Site Plan drawing SP1. The south berm will be constructed similar to the north berm with a 3H:1V slope on the upstream side and a 2H:1V slope on the downstream side of the berm. The new berm will be constructed out of gravel and a layer of riprap will be provided to protect the slopes from erosion. A typical section of the proposed berm extension is provided in Appendix C of this report.

The new earth berm will also require a concrete cut-off wall.

5.0 Cost Estimate

A class C cost estimate has been prepared for the raising of the Lake Geraldine Dam by 2.0 metres. The estimate is based on the information and preliminary design presented, and historical costs for similar works in Iqaluit. A 10% contingency has been included in the cost estimate. The detailed cost estimate is included in Appendix D, and is summarized in Table 4 below.

Table 4 - Class C Cost Estimate Summary

2005 Works – Rock Anchoring Program	$1,206,000
2006 Works – Concrete and Earth Works	$1,791,000
Total Project Cost	**$2,997,000**

6.0 Conclusions and Recommendations

Based on the information provided in this report and the Geotechnical Investigation performed in as part of this project, the following conclusions and recommendations are made:

1. A 2.0 metre extension of the Lake Geraldine dam and associated earth berms will meet expand the raw water storage capabilities to meet the needs of the City of Iqaluit until the year 2025 based on the population projects and consumption rates put forth in this report.

2. The concrete dam can be extended 2.0 metres with the use of additional rock anchors and increased mass.

3. The existing earth berms to the north of the dam can be extended 2.0 metres.

4. As part of the extension of the earth berms, the reported slope stabilization problems should be addressed.

5. The extension of the dam will require the construction of a new earth berm complete with concrete cut-off wall to the south of the dam.

6. The expansion of the dam shall be completed over two construction seasons, with rock anchoring portion of the project proceeding in the summer of 2005, the extension of the dam and berms occurring in 2006.

7. In light of the extensive analysis and remedial measures that are required for the raising of the dam by 2.0 metres, this is the last time the dam can be raised.

We trust this report is satisfactory for your purposes. If you have any questions regarding our submission, please do not hesitate to contact this office.

Trow Associates Inc.

Steven Burden, P.Eng.
Senior Project Manager
Civil Division

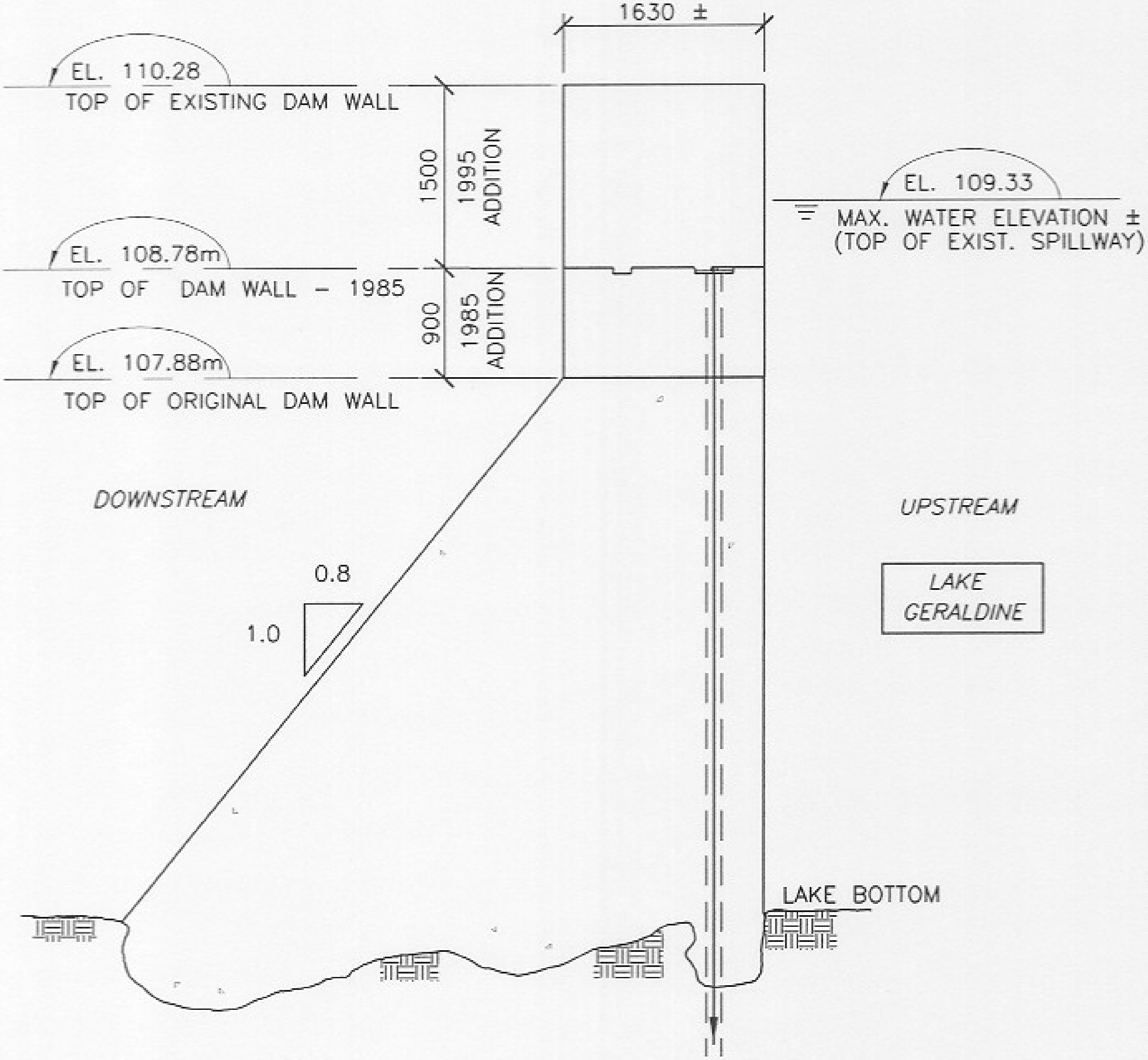
Karen Baker, P.Eng.
Senior Project Manager
Building Science Division

Appendix A – Drawdown Analysis

Lake Geraldine Reservoir Drawdown Analysis

Depth	Volume	
101.3	0	Inlet Pipe
102.6	3,509	159,000m3 water consumption in May
104.64	162,578	0.1m ice generation in April
104.74	173,702	154,000m3 water consumption April
105.94	327,825	0.2m ice generation March
106.14	358,106	159,000m3 water consumption March
107.12	517,685	0.3m ice generation February
107.42	574,374	144,000m3 water consumption February
108.12	718,473	0.3m ice generation January
108.42	785,946	159,000m3 water consumption January
109.06	944,788	0.4m ice generation December
109.46	1,055,550	159,000m3 water consumption December
109.97	1,213,049	0.3m ice generation November
110.27	1,309,088	154,000m3 water consumption November
110.74	1,463,144	0.1m ice generation in October
110.84	1,496,383	159,000m3 water consumption in October
111.3	1,653,218	Spillway Elev.

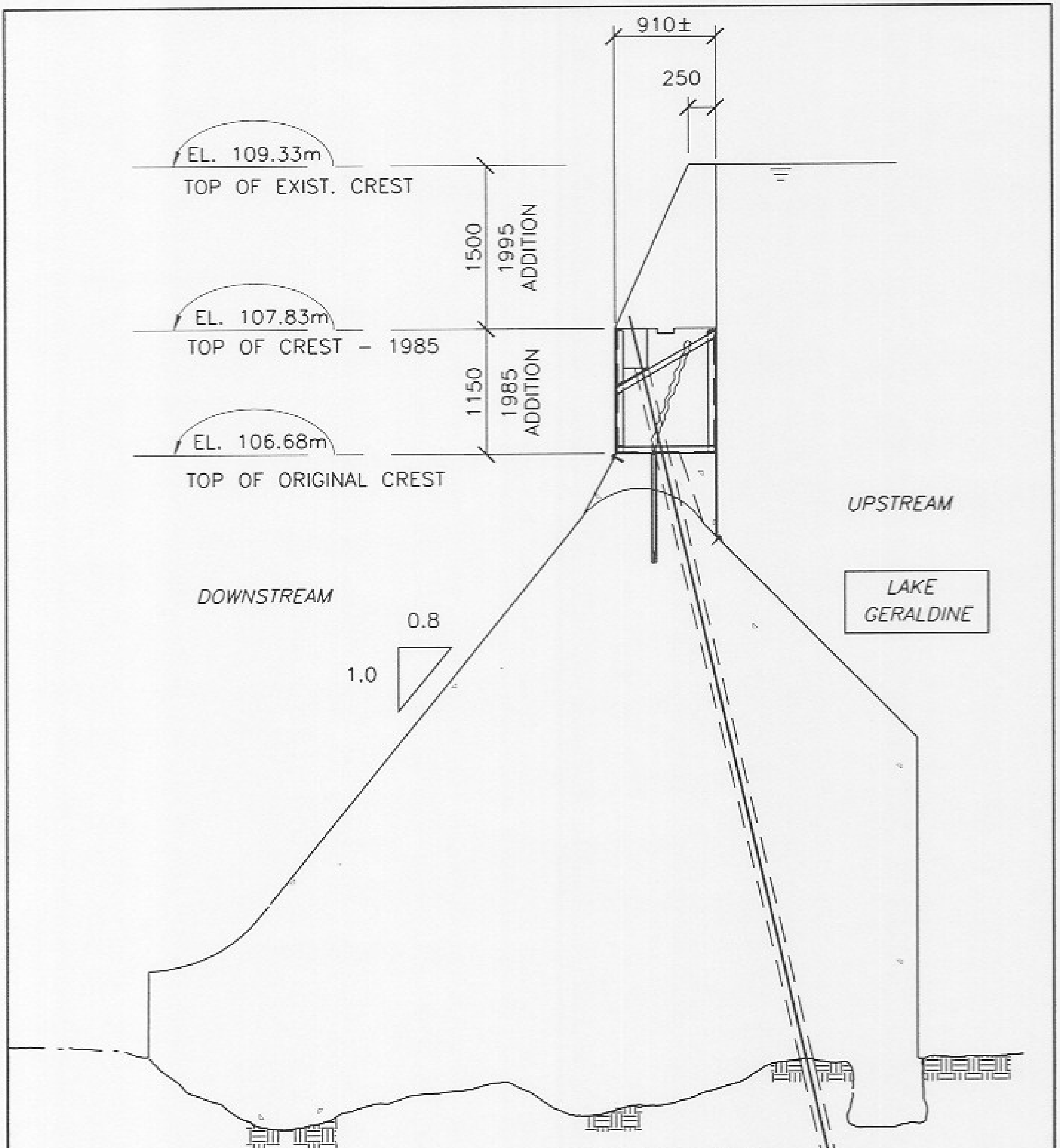
Appendix B – Existing Dam and Berm Sections



EXISTING CONCRETE GRAVITY SECTION OF THE DAM

Trow Associates Inc.
154 Colonnade Road South,
Ottawa, Ontario K2E 7J5
Tel: (613) 225-9940
Fax: (613) 225-7337

SCALE 1:50	CLIENT: MUNICIPALITY OF IQALUIT	JOB NO. OTBS00017616C
DATE: JAN. '05	TITLE: LAKE GERALDINE DAM EXTENSION	SK-1
DRAWN: M.N.		



EXISTING CONCRETE SPILLWAY SECTION OF THE DAM

Trow Associates Inc.
154 Colonnade Road South, Ottawa, Ontario K2E 7J5
Tel: (613) 225-9940
Fax: (613) 225-7337

SCALE: 1:50	CLIENT: MUNICIPALITY OF IQALUIT	JOB NO. OTBS00017616C
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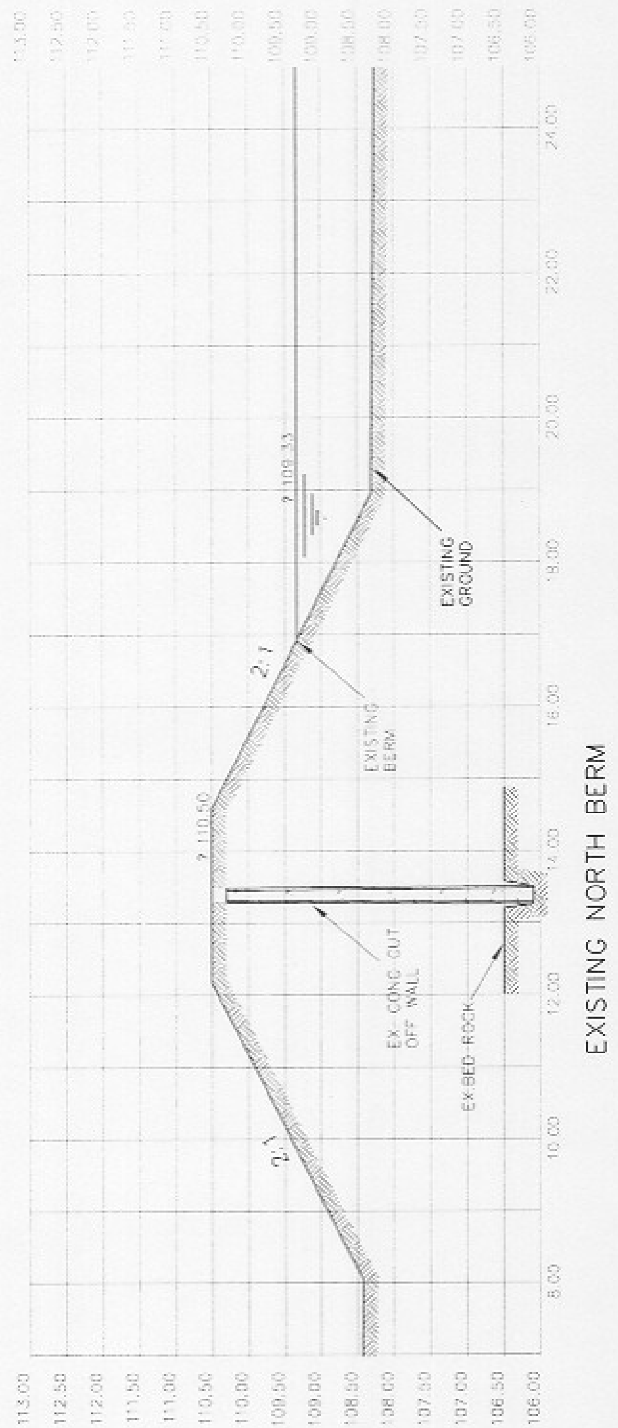
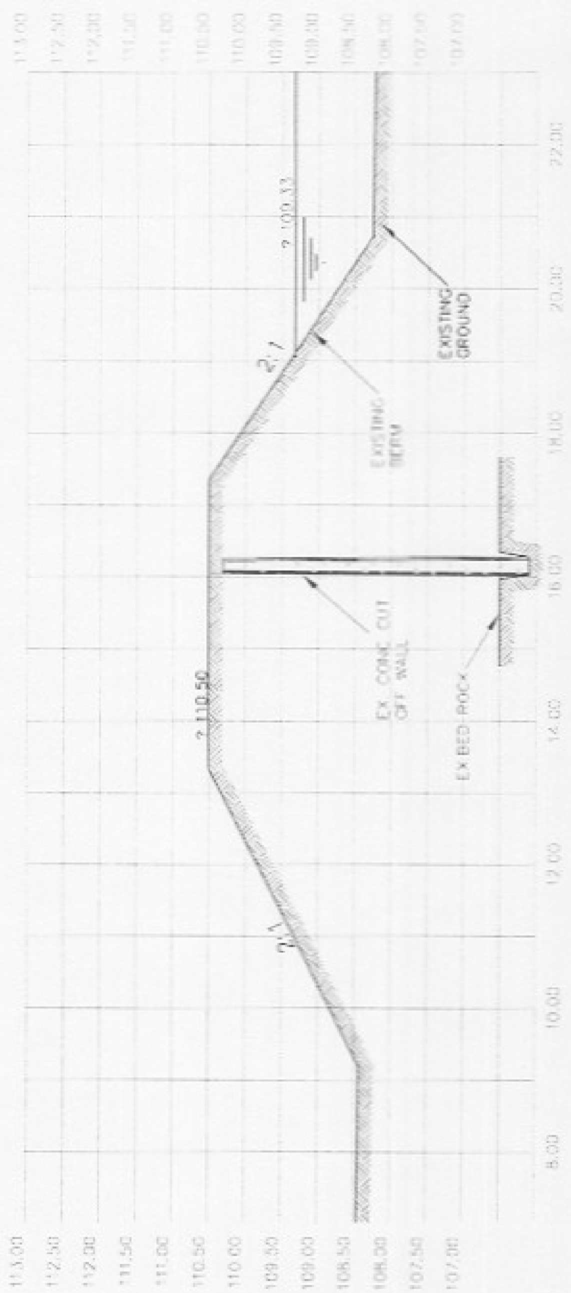
DRAWN: M.N.		



Trow Associates Inc.
154 Colonnade Road South, Ottawa, Ontario K2E 7J5
Tel: (613) 225-9940
Fax: (613) 225-7337

SCALE: 1:100	CLIENT: MUNICIPALITY OF IQALUIT	JOB NO. OTCD00017616D
DATE: MAR 2005	TITLE: EXISTING NORTH BERM	SK-3
DRAWN: MMR		



EXISTING CENTRAL BERM

Trow Associates Inc.
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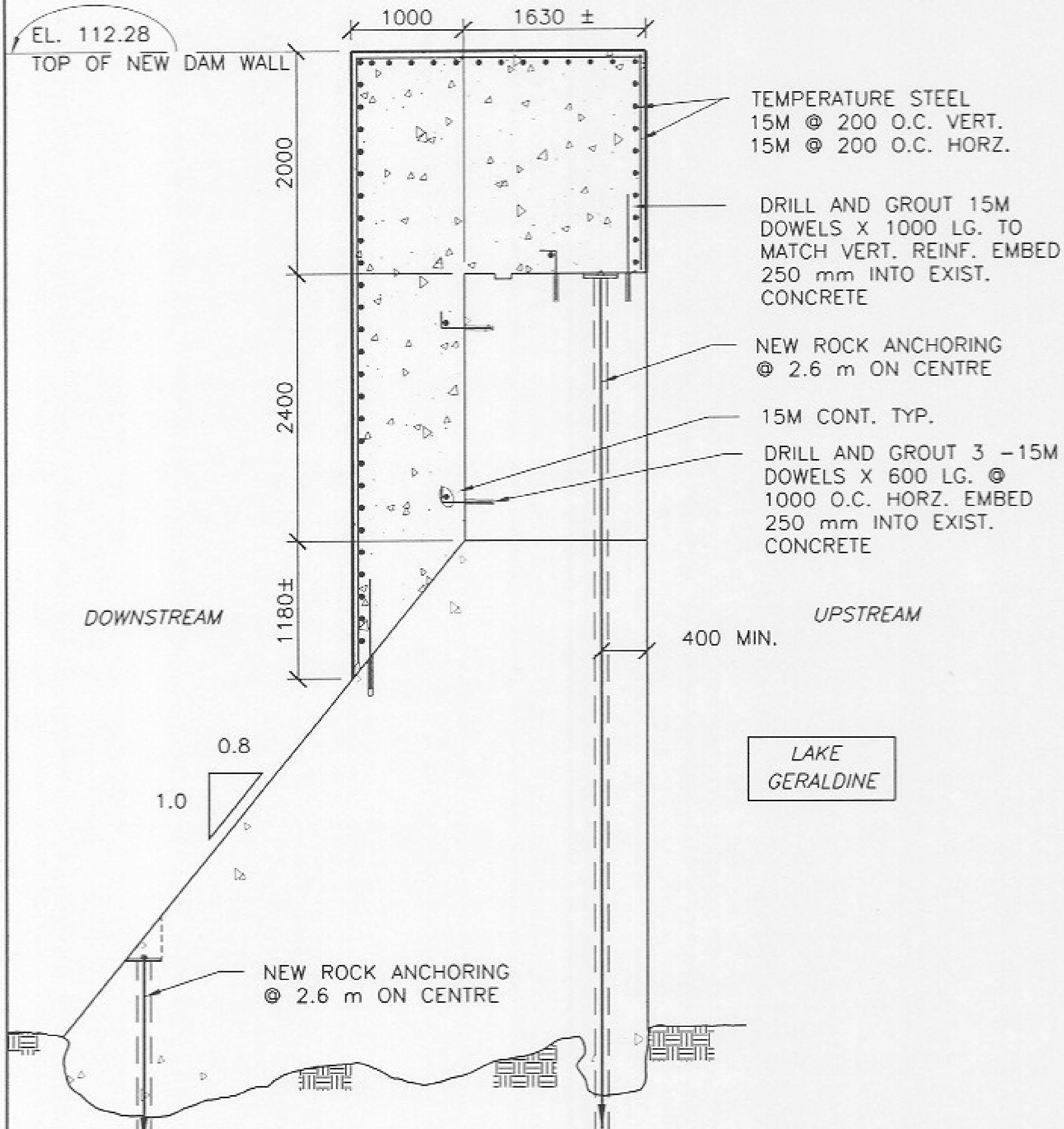
SCALE: 1:100	CLIENT: MUNICIPALITY OF IQALUIT	JOB NO. OTCD00017616D
DATE: MAR 2005	TITLE: EXISTING CENTRAL BERM	SK-4
DRAWN: MMR		

Trow

Appendix C – Proposed Dam and Berm Sections



PROPOSED CONCEPT FOR STRUCTURAL MODIFICATIONS TO THE EXISTING CONCRETE GRAVITY SECTION OF THE DAM

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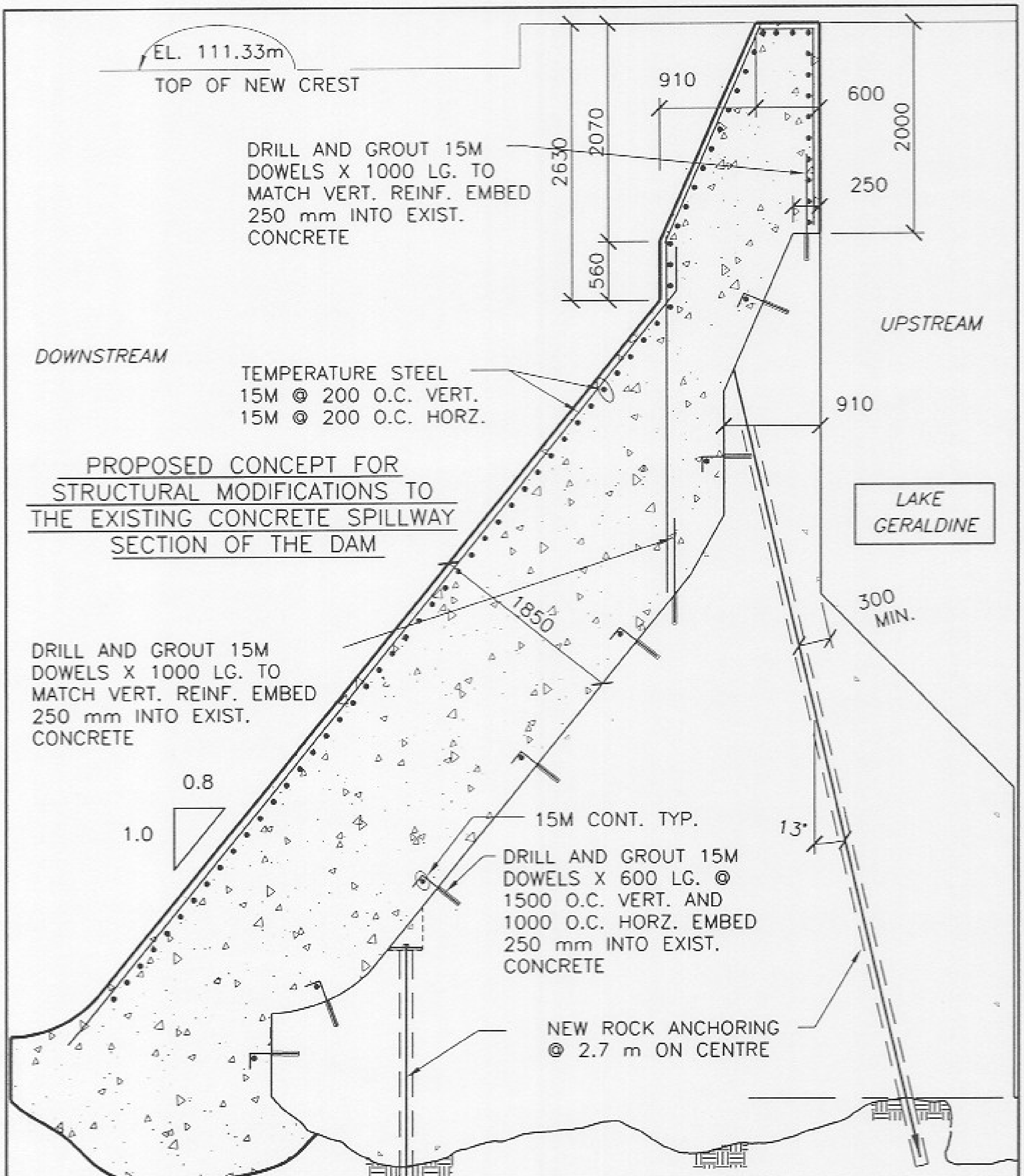
SCALE: 1:50	CLIENT: MUNICIPALITY OF IQALUIT	JOB NO. OTBS00017616C
DATE: JAN. '05		
DRAWN: M.N.	TITLE: LAKE GERALDINE DAM EXTENSION	SK-5



Trow Associates Inc.
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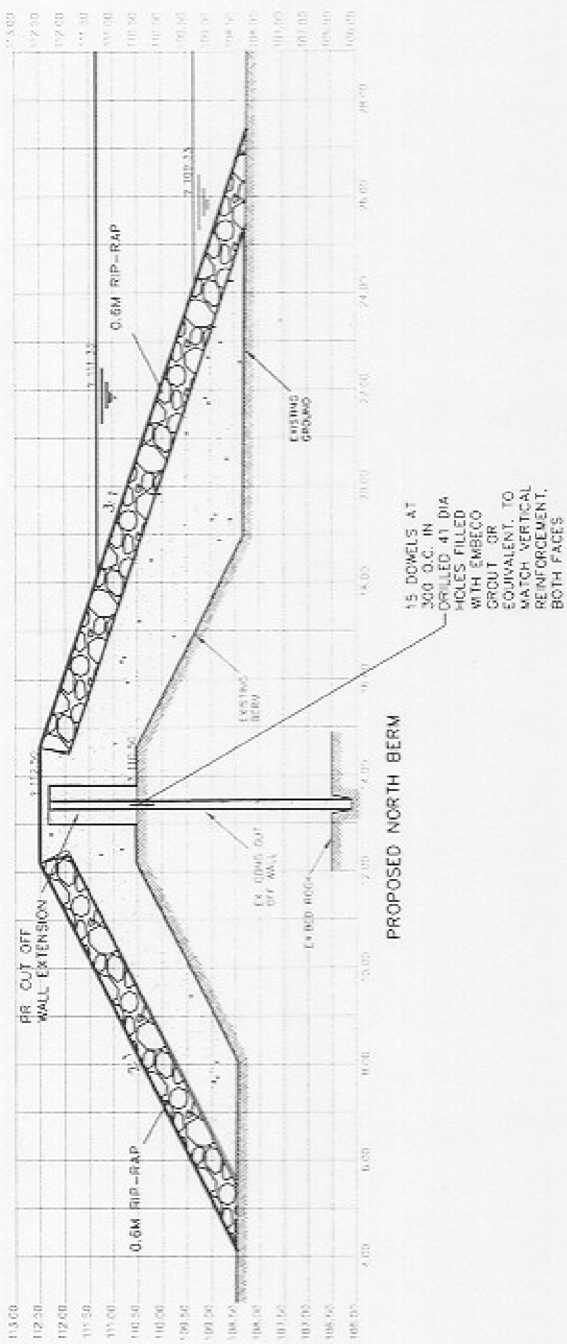
SCALE 1:50	CLIENT: MUNICIPALITY OF IQALUIT	JOB NO. OTBS00017616C
DATE: JAN. '05	TITLE: LAKE GERALDINE DAM EXTENSION	SK-6
DRAWN: M.N.		



Trow Associates Inc.
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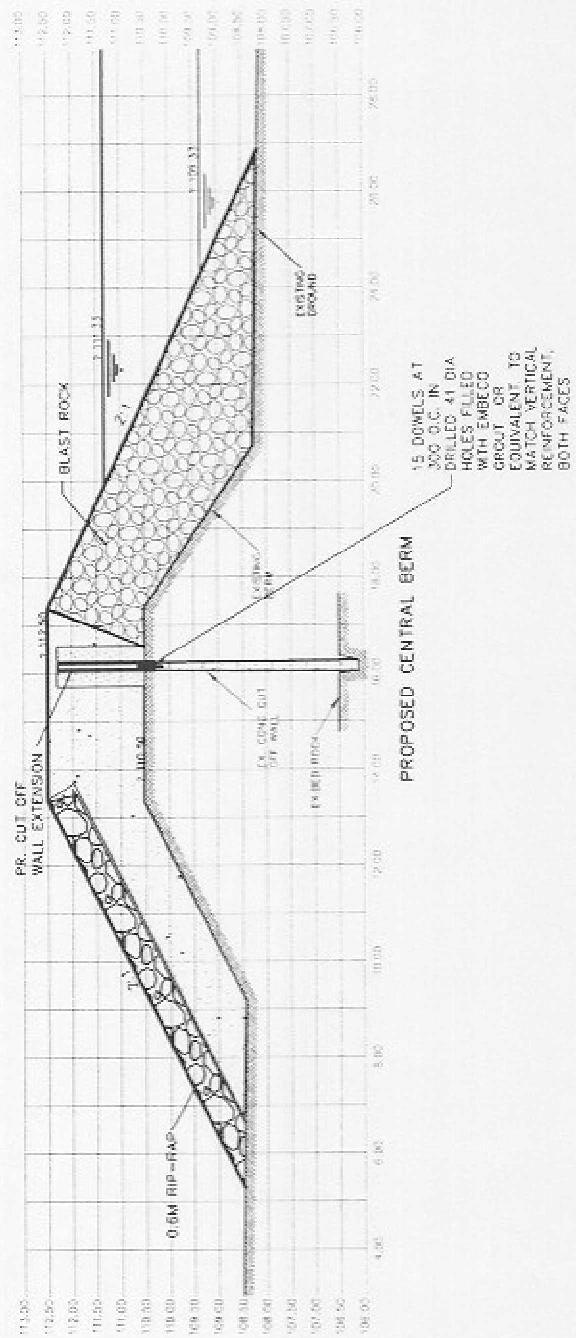
SCALE: 1:150	CLIENT: MUNICIPALITY OF IQALUIT	JOB NO. OTCD00017616D
DATE: MAR 2005	TITLE: PROPOSED NORTH BERM	SK-7
DRAWN: MMR		



Trow Associates Inc.
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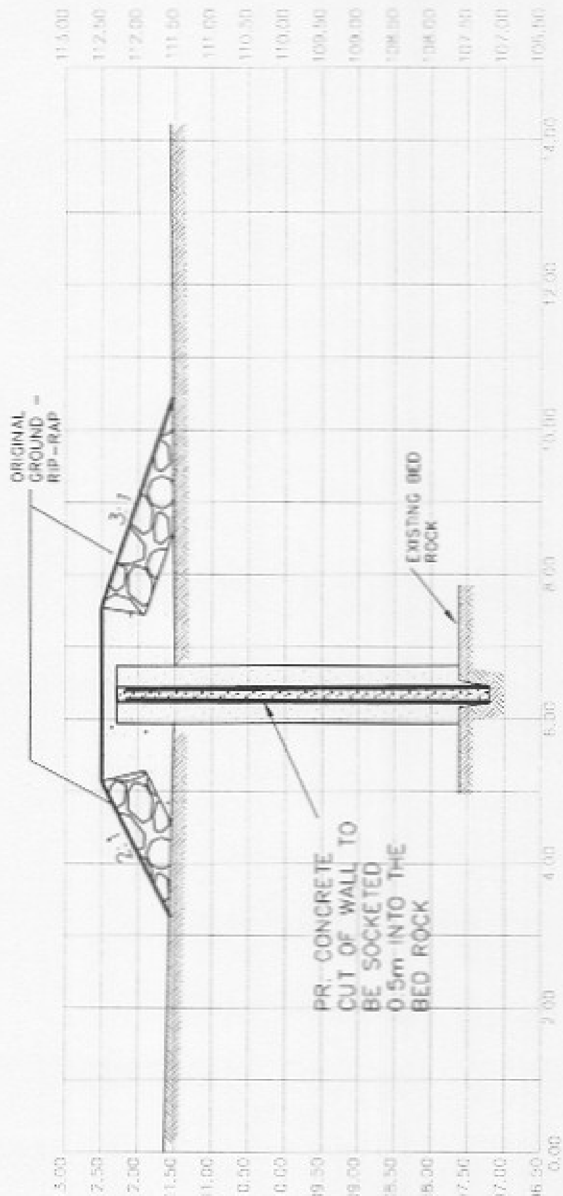
SCALE: 1:150	CLIENT: MUNICIPALITY OF IQALUIT	JOB NO. OTCD00017616D
DATE: MAR 2005	TITLE: PROPOSED CENTRAL BERM	SK-8
DRAWN: MMR		



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SCALE: 1:100	CLIENT: MUNICIPALITY OF IQALUIT	JOB NO. OTCD00017616D
DATE: MAR 2005	TITLE: PROPOSED SOUTH BERM	SK-9
DRAWN: MMR		

Item	Description	Quantity	Unit	Unit Cost	Amount
2005 Works – Rock Anchoring Program					
1	Rock Anchoring in Spillway	1	ls	$350,000	$350,000
2	Rock Anchoring in Dam	1	ls	$755,000	$755,000
	Subtotal 2005 Works				$1,105,000
	10% Contingency				$101,000
	Total 2005 Works				**$1,206,000**
2006 Works – Concrete and Earth Works					
3	Sandblasting at bonding surface	1	ls	$12,000	$12,000
4	Crack Injection Allowance	1	ls	$10,000	$10,000
5	Installation of Waterstop	1	ls	$20,000	$20,000
	Spillway Dam and Wingwalls				
6	Dowels	1	ls	$33,000	$33,000
7	Concrete	740	M^3	$1,200	$888,000
	Extension of Existing Berms				
8	Dowels	1	ls	$42,000	$42,000
9	Concrete	60	M^3	$1,200	$72,000
10	Blast Rock for Slope Stabilization	2000	M^3	$100	$200,000
11	General Fill	2500	M^3	$30	$75,000
12	Rip Rap (600 mm thick)	2500	M^2	$50	$125,000
	Construction of New Berm				
13	Concrete	110	M^3	$1,200	$132,000
14	General Fill	200	M^3	$30	$6,000
15	Rip Rap (600 mm thick)	260	M^2	$50	$13,000
	Subtotal 2006 Works				$1,628,000
	10% Contingency				$163,000
	Total 2006 Works				**$1,791,000**
	Total Project Cost				**$2,997,000**