Bluefish Hydro Comprehensive Dam Safety Review

Northwest Territories Power Corporation
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Stantec

Bluefish Hydro Comprehensive Dam Safety Review

Final Report

Prepared for:
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Prepared by:
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Sign-off Sheet

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Executive Summary

Northwest Territories Power Corporation (NTPC) retained Stantec to perform the Comprehensive Dam Safety Review (DSR) of the Bluefish Hydro-electric Development (Bluefish Hydro).

Bluefish Hydro drainage area including the Yellowknife River drainage basins is approximately 11,655 km^2 in addition to Duncan Dam drainage area which is approximately 7,740 km^2 (NTPC, 2005). Water flows from Duncan Lake through a series of lakes in a southerly direction to Bluefish Lake. The Bluefish power station is located at the north end of Prosperous Lake, approximately 25 km northeast of the city of Yellowknife.

The current Bluefish Dam has been commissioned in October 2012. It consists of a rockfill dam with a stainless steel barrier embedded into a concrete plinth, keyed (blasted) two (2) metres into bedrock. The upstream dam slope is 2H:1V while the downstream slope is 2.5H:1V. The rockfill dam is 250 m long and 5.5 m crest wide. As per the design documents of Bluefish dam, the maximum flood elevation is 170.44 m while the normal operating level is 168. 8 m. The crest elevation of the dam is 171.22 m.

Duncan Dam is a control structure located near the southwest end of Duncan Lake and is approximately 27 m long and 5 m high. Duncan Dam consists of one sluiceway with stoplogs and two ogee-crested uncontrolled spillways. The invert elevation of the sluiceway is 209.4 m, while the top of the dam is at 213.41 m. The crest elevation of the spillway is 212.49 m, and each spillway is about 6 m wide.

Duncan dam has a classification of “significant”, with a IDF of 131 cms (300-year’ recurrence). Bluefish dam has a classification of “high”, with a IDF of 387 cms (1/3 between 1000-year and PMF). A dam break analysis and inundation mapping was performed in this DSR to confirm the dam classification. A methodology to computed the discharge coefficient for Bluefish free overflow spillway has been developed. Operation of gates is not necessary at Bluefish for dam safety, since it can pass the PMF by the spillway (without overtopping). If stoplogs are not removed at Duncan, it can be overtopping, but no failure is foreseen.

The instrumentation on Bluefish dam should be monitored with the proposed equipment and procedures. Bluefish dam meets the CDA criteria for static, seismic and the temporary ice dam conditions (slope stability). Bluefish dam graded filter is correctly designed. Seepage observed at Bluefish is currently not a safety issue.

Stability analysis of Duncan Dam showed that the structure is below the CDA recommendations for global stability.

As part of this DSR, the OMS has been re-written using a structures that meets all the requirements of the current CDA Guidelines. The EPP is revised and updated with respect to the CDA Guidelines requirements. Public Safety measures implemented by NTPC are adequate.

The table below presents a summary of the required activities to be undertaken by NTPC to ensure the safe operation of the Bluefish Hydro development, and their associated priority. The priority rating reflects the urgency of the recommendations as follows:

(VH) Very High: To be performed in the short term, within a maximum period of 12 months

(H) High: To be performed within a period of one to three years

(M) Medium: To be performed within a period of three to five years

(L) Low: To be performed within a period of five to seven years

Bluefish Dam

Section reference	Issue	Recommendations	Priority rating
4.3.1.2.6	Discharge coefficient of spillway is not calibrated	Take measurements when high flows occur over the spillway of water level in the lake, downstream flow, IFR flow and plant flows (eventually hourly measurement).	**L**
5.2	Possible additional seepage below the concrete sill along the spillway.	Seal of the voids to avoid accelerated degradation.	**M**
5.2	No displacement monitoring of the spillway sill	Perform periodical survey of the elevation of the sill.	**M**
5.3.1	Lack of detailed information on piezometer	Ask for the as-built piezometer detail drawings for each set of piezometers, as well as cross sections at instrumented sections (should be completed by EBA) and keep as a record by NTPC as well as added to the OMS manual.	**H**
5.3.1	Lack of uniform method to store piezometer monitoring	Use the spreadsheet developed by Stantec (or develop own spreadsheet) as means of storing all piezometer monitoring data	**H**
5.3.1	No documentation when an issue occurs with a piezometer	Document the details why a piezometer cannot be monitored (access/frozen), there is an issue with a piezometer, or it is dry.	**H**
5.3.1	No monitoring of the tailwater/pond water elevation	Install of a staff gauge to allow for period monitoring	**M**
5.3.1	No threshold water level for the piezometer or required actions	Complete analysis to determine what the threshold water level is for each piezometer and the results be incorporated into the OMS manual and ERP such that appropriate action is taken when the piezometers are monitored.	**H**
5.3.1	No processing of the piezometer values	Process the collected data in a timely manner such that any potential errors or anomalies can be corrected immediately.	**H**

5.3.2	No detail drawing for thermistor	Ask for as-built thermistor detail drawings for each thermistor string (with node locations and elevations) as well as cross sections at thermistor sections (should be completed by EBA) and keep as a record by NTPC and incorporate in the OMS manual.	**H**
5.3.2	Missing connection cable and readout device for thermistor	Request the connection cable and readout device from thermistor cable installation contractor, or alternatively, a new readout box and connection can be purchased.	**VH**
5.3.2	No temperature profile of the soil/rock in contact with the cables of thermistor	Perform monthly monitoring, once a connection cable and readout device are obtained, for at least the first two (2) years to begin to develop a temperature profile of the soil/rock in contact with the cables. An assessment should be made after two (2) years if the frequency of the monitoring can be reduced.	**H**
5.3.3	Outstanding components that remain to be installed for thermistor	Seek additional clarification from EBA or the EOR on the outstanding components that remain to be installed for this system, how it is to be monitored, how to interpret the results, as well as what threshold values should be considered. These details should be incorporated into the OMS manual.	**VH**
5.3.4	No as-built detail drawings and instrument cross sections showing the settlement monitoring points.	Produce as-built detail drawings, as well as instrument cross sections showing the settlement monitoring points.	**M**
5.3.4	Surveys have different datum	Complete all surveys with the same datum, on an annually basis.	**M**
5.3.5	Only visual observation of seepage	Explore the options to install both a weir and a system to monitor both the seepage rate and water quality/turbidity.	**M**
5.6.1	No analysis on the range of water level in piezometer that would yield an FoS against slope instability below the temporary target level of 1.3, set out by the CDA.	Carry a complete analysis for each piezometer and associated cross section to assess the range of water levels for each piezometer which would yield an FoS against slope instability below the temporary target level of 1.3, set out by the CDA. These results would be used in the OMS and/or EAP in order to outline what course of action, if any, is appropriate when carrying out piezometer monitoring.	**M**

Duncan Dam

Section reference	Issue	Recommendations	Priority rating
6.1.3	Damages under the left pier	Repair concrete under the left pier and any crack with injected flowable grout to prevent water from flowing under the pier. This will also reinstate the compression zone in the downstream area of the pier.	M
6.1.3	Dam does not meet the Factor of Safety against sliding	Consider the addition of rock anchors	L
7.3	No indication of the actual rock to concrete friction values	Confirm the value of concrete friction (20 to 34 degrees) before anchoring is undertaken	M
7.3	Original design	Investigate and confirm if the original design used cohesion to satisfy the stability of the structure.	M
7.3	High ice forces	Confirm the ice force, since the narrow approach channel to the structure may result in ice force lower than values from CDA.	M

OMS and EPP

Section reference	Issue	Recommendations	Priority rating
8.2	OMS power plant sections and contact information not updated	Update the power plant related sections and contact information of the OMS manual. As part of this DSR, all the other sections of the OMS Manual were completely revised as per the requirements of the CDA Guidelines.	VH
8.2	The detailed operation, maintenance, inspection, and tests are not compiled in the OMS	Keep track of all the operation, maintenance, inspection, and the tests performed at the Bluefish Hydro Dams in a project log. Procedures, criteria, schedule should be detailed for all conditions operations. Follow-up actions after the evaluation of results should be documented.	H
9.1.2.1	EPP distribution list is incomplete	Fill the EPP distribution list.	VH
9.1.2.7	EPP contact information outdated	Update annually the contact information of the EPP (last update in 2011).	VH
9.1.3	EPP Distribution	Distribute the 2016 version of the EPP to all the required persons.	VH

Abbreviations

ADSMR	Annual Dam Safety Monitoring Report
AEP	Annual Exceedance Probability
CDA	Canadian Dam Association
CS	Control Structure
Cms	Cubic metres per second
DSR	Dam Safety Review
ECCC	Environment and Climate Change Canada
EOP	Emergency Operation Center
EDGM	Earthquake Design Ground Motion
EPP	Emergency Preparedness Plan
FERC	Federal Energy Regulatory Commission
FSL	Full Supply Level
GS	Generating Station
HPC	Hazard Potential Classification
IDF	Inflow Design Flood
LSL	Lower Supply Level
MW	Megawatts
NRCan	Natural Resources Canada
NTPC	Northwest Territories Power Corporation
OMS	Operation, Maintenance, and Surveillance Manual
PMF	Probable Maximum Flood

PMP	Probable Maximum Precipitation
SCC	System Control Center
SCP	Site Command Post
SCS	United States Soil Conservation Service
Stantec	Stantec Consulting Ltd.
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
WMO	World Meteorological Organization

1.0 INTRODUCTION

Northwest Territories Power Corporation (NTPC) has awarded Stantec in 2016 the mandate to complete a Comprehensive Dam Safety Review (DSR) of the Bluefish Hydro Generating Station (Bluefish Hydro GS). The Dam Safety Review was conducted in accordance with the Canadian Dam Association (CDA) Dam Safety Guidelines (2007, 2013 and 2016), which will be referred to as the *CDA Guidelines*. As part of the CDA Guidelines, such a review is to be completed every 7 years for Bluefish (“high”) and every 10 years for Duncan (“significant”).

1.1 BACKGROUND AND SITE DESCRIPTION

The Bluefish Hydro facility uses water from Duncan Lake and the Yellowknife River drainage basins. Water flows from Duncan Lake through a series of lakes in a southerly direction to Bluefish Lake. The total drainage area at the Bluefish Hydro site is approximately 11,655 km^2 compared to the drainage area at the Duncan Dam is approximately 7,740 km^2 (NTPC, 2005). The power station is located at the north end of Prosperous Lake, approximately 25 km northeast of Yellowknife's city centre. A general layout of the area is presented in Figure 1-1.

The hydro facility contains two dams, Bluefish Dam and Duncan Dam, with relevant features of the facility summarized in Table 1-1.

The current Bluefish Dam was constructed in 2012 and consists of a rockfill dam with a stainless steel barrier embedded into a concrete plinth, keyed (blasted) two (2) metres into bedrock. The upstream rockfill slopes at 2H:1V while the downstream rockfill slopes at 2.5H:1V. The crest elevation is 171.22m. The former Bluefish Dam was located at a site upstream of the current dam and was decommissioned following completion of the current structure.

The spillway is a reinforced concrete sill anchored to bedrock to provide level control, U shaped, 128.8 metres long and less than a metre in height, with a sill elevation 168.8 m. Between the dam and the overflow spillway is a one bay reinforced concrete sluice structure with a vertical screw stem gate.

Duncan Dam is a storage dam near the southwest end of Duncan Lake and is approximately 27 m long and 5 m high. The primary purpose of Duncan Dam is to store water and regulate levels in Bluefish Lake. Duncan Dam consists of one sluiceway with stoplogs and two ogee-crested uncontrolled spillways. The sill elevation of the sluiceway is 209.45 m, while the top of the dam is at 213.41 m. The crests of the spillways are at 212.49 m, and each spillway is about 6 m wide.

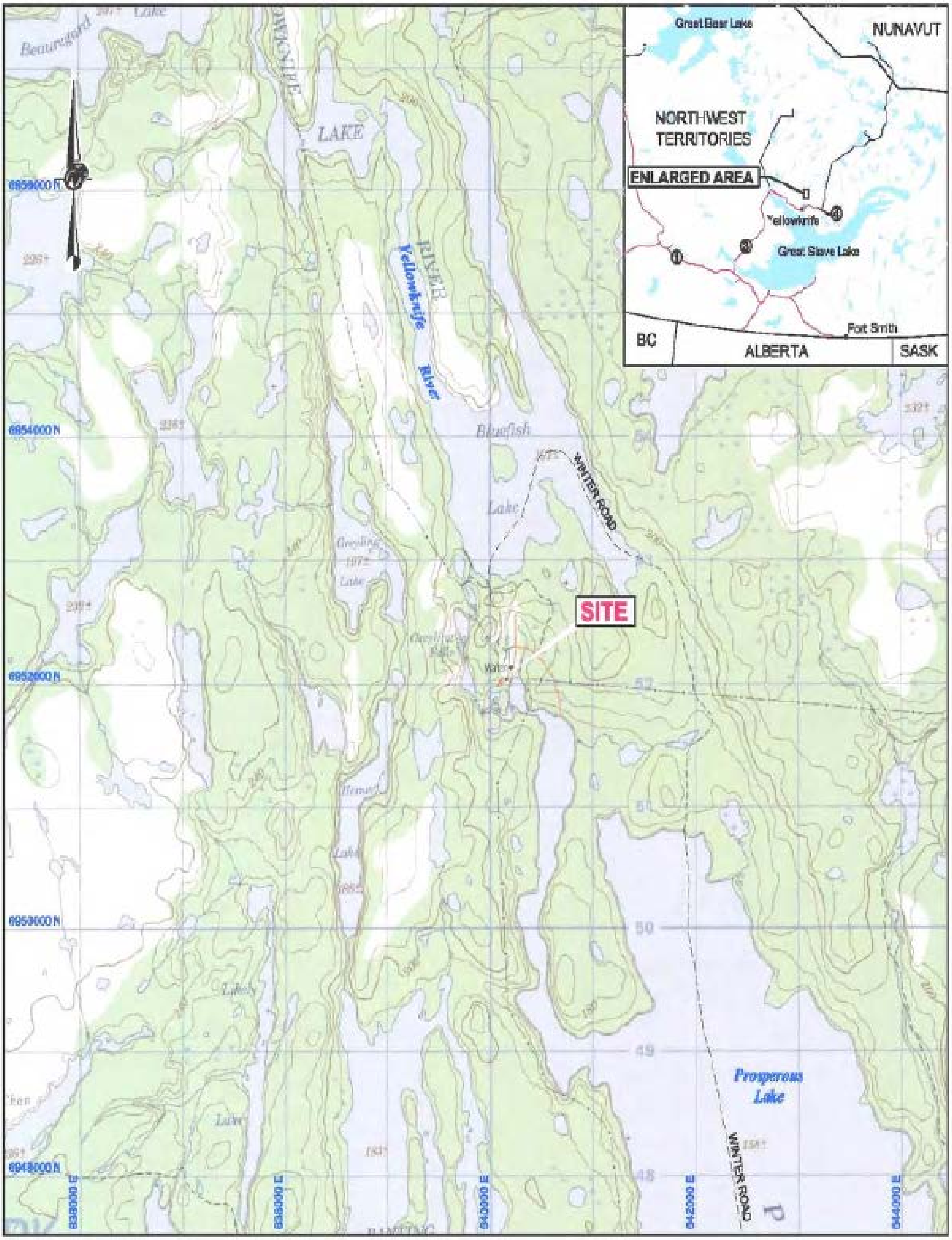

Figure 1-1: Bluefish development location

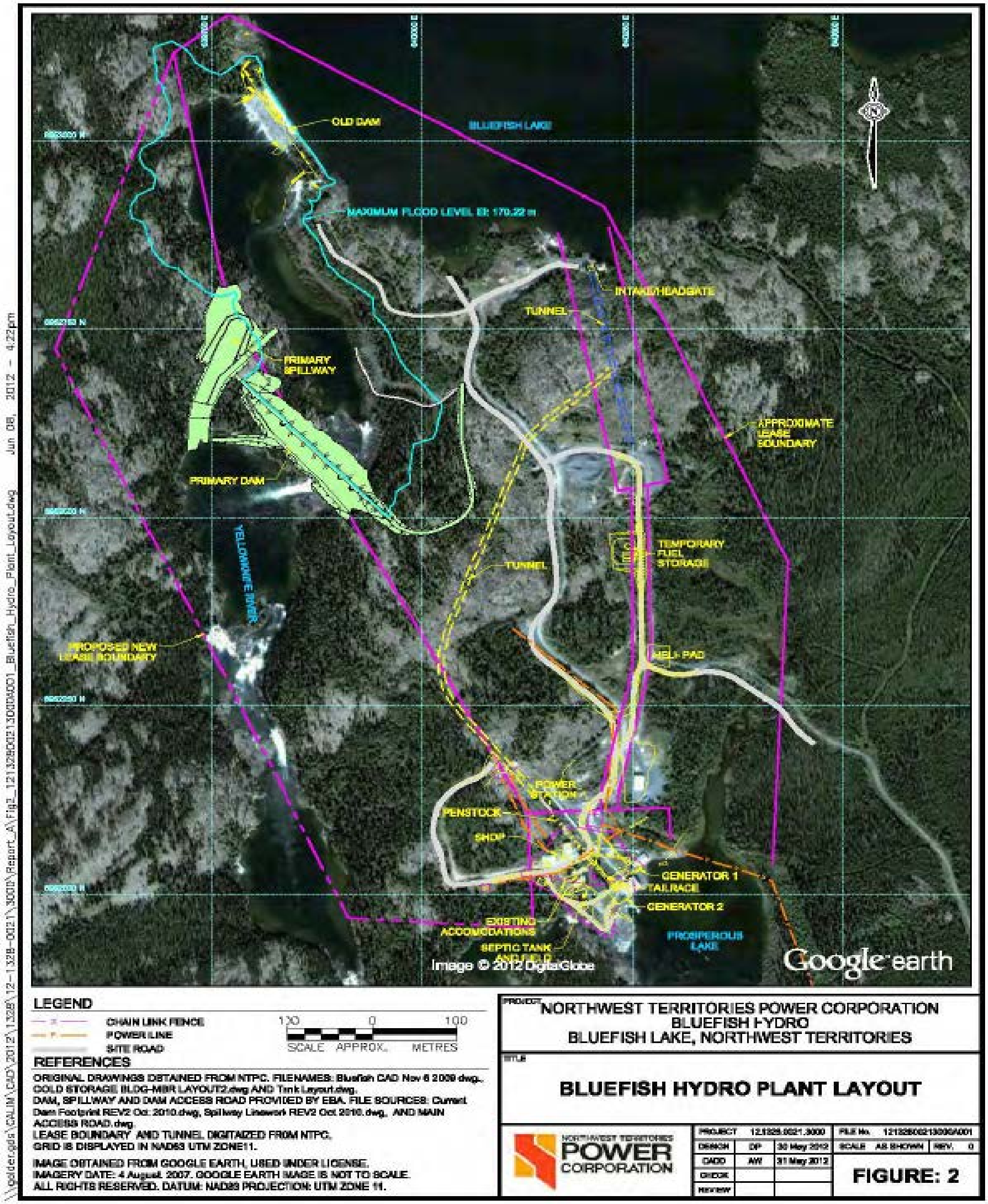

Figure 1-2: Bluefish development site map

1.2 WATER LICENSE

The Bluefish GS holds a type A Water License MV2005L4-0008 from the Mackenzie Valley Land & Water Board, pursuant to the Northwest Territories Waters Act and Regulations. The license commenced April 3, 2006 and expiring April 2, 2021. The maximum quantity of water to potentially be used for power generation and returned to source is 55 m^3/s.

1.3 HYDRAULIC DATA

Table 1-1: Hydraulic Data

	Bluefish	**Duncan**
Drainage area	11,655 km^2	7,740 km^2
Head	33 m	-
Maximum water level at IDF	170.44 m	213.35 m
FSL	168.8 m	212.49 m
Normal operating Level	168.78	212.04 m
Minimum Flow Downstream[1]	0.7 cms (May 15 to Oct. 15) 0.25 cms (rest of year)	-
Structure deck elevation	-	213.41 m
Top of dam crest	171.22	213.41 m
Top of Impervious Core (stainless steel) in Dam	170.72 m	-
Top of overflow spillway	168.8 m	212.49 m
IDF	387 cms	131 cms
PMF	662 cms	-

[1] As per Fisheries Act Authorization 09-HCAA-CA-00079-2

2.0 DESKTOP REVIEW OF AVAILABLE DOCUMENTATION, INFORMATION AND DATA

2.1 REVIEW EXISTING DOCUMENTATION

The available documentation for the Bluefish Dam is substantial, given it was just recently constructed in 2012. However, some key documentation is absent including the record information for the installed instrumentation. All the plans and elevation before the construction of the new Bluefish dam used the previous datum. For the construction of the new Bluefish dam, geodetic elevations were used, and EBA states that the conversion to the previous datum implies to add 17.15 m to the geodetic elevations.

There is limited available documentation for the Duncan Dam. It is understood that an arbitrary datum is used at Duncan dam.

Both dams are for the same generating station, and most of the reports concerns both dams. NTPC provided the following documents for Stantec's review for this DSR. Table 2-1 list the documents, as well as the dam to which it is applies.

2.2 REVIEW OF DAM DESIGN

2.2.1 Bluefish Dam

Bluefish Dam was reconstructed in 2012 and consists of a rockfill dam on a bedrock foundation and abutments, with a stainless steel impermeable liner/barrier embedded into a concrete plinth, keyed (blasted) two (2) metres into bedrock along its centerline. The dam has a crest width of 5.5 m, with an upstream rockfill slope of 2H:1V and downstream rockfill slope of 2.5H:1V. Along the base of the dam is a lower access road with a top width of 5 m and a downstream slope of 1.5H:1V. The overall crest elevation of the dam is 171.22 m, while the top of the impermeable stainless steel liner is at elevation 170.92 m. The dam utilizes graded aggregate filters on both the upstream and downstream sides of the stainless steel barrier, used to both limit the potential damage to the liner during construction and provide a filter for potential seepage gradients which may pass through the clay and silt infilled joints of the predominantly Meta-Greywacke foundation rock.

The design further incorporates blanket and curtain grouting installed to 5 m and 10 m depth below the top of the bedrock surface on the upstream and downstream sides of the key trench to reduce water flow through joints and other discontinuities in the foundation rock. In general, grouting was completed on 3 m centres, except for an area between Sta. 0+176 and 0+230 (along the old river channel bed), where curtain grouting spacing was increased to 6 m centres.

The rockfill slopes consist primarily of 1.0 m minus rockfill with angular rip-rap fill with a diameter range of 0.5 to 1.0 m placed along a significant portion of the upstream face for wave and erosion protection.

Table 2-1: List of existing documentation and reports

Name	Organization	Year	Bluefish Dam	Duncan Dam
One Year Review of Bluefish Dam – Inspection Report	Klohn Crippen Berger	2014	✓	
As-Built Construction Report, including: -As-built Drawings -Hydrotechnical Design	EBA Engineering Consultants	2013	✓	
Bluefish Replacement Dam Design Report	EBA Engineering Consultants	2011	✓	
Inspection Report	Courage Portage LTD.	2014, 2016	✓	✓
Dam Safety Inspection Program	Mitchelmore Engineering Company Ltd.	2015	✓	✓
Weekly Inspection Report	NTPC	2013	✓	
Application for amendment of Water license number MV2005L4-0008	NTPC	2012	✓	
Emergency Preparedness Plan	NTPC	2012	✓	✓
Operation Maintenance and Surveillance Manual	NTPC	2010	✓	✓
Dam Safety Review	EBA Engineering Consultants	2005	✓	✓
Dambreak Inundation Study Bluefish Hydro Facility	Dames & Moore ,Inc.	1997	✓	✓
Bluefish G1 Re-Development – Bluefish Hydro Optimization Study	MECO Ltd	2012	✓	
Duncan Dam Repairs April - May 2007	Courage Projects LTD	2007		✓

In general, the rockfill materials used, shell outslopes, foundation conditions, and use of an low permeability/impermeable barrier with filter and cut-off trench and grout curtain employed for Bluefish dam are consistent with longstanding proven dam design methodologies.

The relatively unique and not commonly employed feature related to the design of this structure is the use of stainless steel as the impermeable barrier/liner. Although not typically observed in this application, based on the design information provided in the supporting documentation, the use of this material generally seems to be appropriate for the anticipated conditions at this site (relative to anticipated movement and design life). As this material is not commonly used in this application, it will be critical to monitor its performance over the lifespan of the dam as it relates to seepage/leakage and corrosion. The system designed to be used to monitor potential corrosion of this liner is discussed in Section 5.3.3.

The spillway is a reinforced concrete sill anchored to bedrock to provide level control, U shaped, 128.8 metres long and less than a metre in height, with a sill elevation 168.8 m.

2.2.2 Duncan Dam

Duncan Darn was originally constructed as a timber crib dam in 1942 and replaced with a reinforced concrete gravity dam in 1974. The new dam was built 20 m downstream from the old dam site. Duncan Dam is located in a narrow draw that constitutes the outlet of Duncan Lake. No design information is available for Duncan Dam. The only available drawing is the plans and profiles of Duncan Dam provided in the previous 2005 DSR. This plan was prepared by Cominco in February 1974, year of construction of the new dam, therefore assumed to be an as-built drawing. The document Duncan Dam Repairs April - May 2007 states that a washout of the material between boulders beneath the left abutment occurred, and was temporarily repaired. In 2007 repairs where done on Duncan Dam. The dam was grouted where the concrete meets the bedrock on the right abutment and where the concrete meets the boulders on the left abutment. Grouting of voids in the foundation did not proceed as planned due to steel encountered when attempting to drill through the dam using percussion type equipment. High strength and high slump concrete was placed to support the dam by filling foundation voids accessible along the toe when constructing the apron. As a result of the rehab work the dam is considered to be adequately supported, according to Courage Project LTD.A impervious bentomat liner was placed on the upstream side of the dam in 2007 to limit seepage beneath the dam. The complete description of the 2007 rehabilitation, along with detailed pictures, are available in the document Duncan Dam Repairs April - May 2007.

3.0 INSPECTION OF DAMS AND ASSOCIATED STRUCTURES

The inspection of Bluefish GS was performed on October 12th 2016 by two engineers of Stantec, M. Ammar Taha, P.Eng., Ph.D. and Joel Pineau, P.Eng., NTPC Project Manager, Mr. Gamini Hettiarachchige, P.Eng., M.Eng., accompanied Stantec inspection team. NTPC provided helicopter transportation from Yellowknife Airport to both sites.

3.1 BLUEFISH DAMS AND ASSOCIATED STRUCTURES

The first site to be inspected was Bluefish Dam. Before undergoing the inspection, Stantec staff assisted an **Health and Safety Training** provided by NTPC (videoconference) along with the operator of Bluefish Dam at the time of the visit, M. Wayne Mercredi. The inspected structures consist of the following:

- Zoned rockfill stainless steel core dam
- Free overflow spillway
- IFR gate and bottom outlet
- Downstream rip rap
- Booms, signage, fences, access roads

Pictures were taken during this visit and are presented in appendix A and along the report. All the observations and findings are described in sections 5 and 6 of this DSR.

The inspection of all the structures associated with power generation are excluded from Stantec mandate (water intake, pipeline, generating station, etc.).

3.2 DUNCAN DAM (CONTROL STRUCTURE)

After the visit of Bluefish, the team was taken to Duncan by helicopter. The inspected structures consist of the following:

- Concrete gravity dam
- Two overflow spillways
- Stoplogs sluiceway and stoplogs lifting winch
- Bedrock abutments
- Helicopter landing pad

Pictures were taken during this visit and are presented in appendix A and along the report. All the observations and findings are described in sections 5 and 6 of this DSR.

3.3 TESTING OF DISCHARGE FACILITIES

3.3.1 Bluefish Dam

In terms of flood control and based on the design documents, the overflow spillway can by itself discharge the full flow of the IDF without any overtopping of the embankment dam. So no operation of other existing gates is required for the IDF passage and do not need to be tested as per CDA Guidelines. The other existing gates at Bluefish dam are the bottom outlet structure (which used as diversion during the construction of the dam) and the IFR bypass gate (fish gate). Bottom outlet structure (low level gate) is operated using a generator of electric power or manually. The gate was not tested during the site visit to avoid losing water at the beginning of the winter. However, the fish gate was tested manually during the site visit and it seems in good operational conditions. Consequently, and since the gates operation is not required to discharge safely the IDF, the overall system can be considered adequate.

Figure 3-1: Bluefish IFR Gate Manual Control

3.3.2 Duncan Dam

Duncan Dam has a stoplogs sluiceway section in the middle of two overflow spillways. In order to achieve the IDF passage without overtopping, all stoplogs need to be removed. A manual winch system is used to remove the stoplogs and is relatively new and seems to be in good conditions. If system fails and the stoplogs are not removed during IDF passage, overtopping will occur, but as a concrete dam built on rock the dam overtopping should not be hazardous for the dam integrity. However, an inspection should be performed after any dam overtopping occurrence.

Figure 3-2: Duncan Manual Winch

3.4 OPERATOR MEETINGS AND STAFF INTERVIEWS

During the site visit of Bluefish Dam, the operator on site, M. Wayne Mercredi, was interviewed by Stantec engineers. The result of this interview is presented in Appendix B in the form of a Dam Operator Questionnaire.

3.5 TRAINING OPERATORS ON INSTRUMENTATION

The Bluefish dam is a relatively new dam (2012) and as such was designed to be well instrumented from its on-set. Based on a review of the available documentation there were four (4) main types of instrumentation installed: standpipe piezometers, ground temperature cables (thermistors), settlement monitoring points, and corrosion monitoring coupons for the stainless steel liner.

Detailed discussion on the instrumentation for the Bluefish Dam, including recommendations for improved monitoring and data storage practices can be found in Section 5.

4.0 HYDROTECHNICAL REVIEW

4.1 REVIEW OF PREVIOUS DOCUMENTS

Reports and documents that have been made available by NTPC for Stantec review consist of the following:

4.1.1 2005 DSR

This study concerns the old Bluefish Dam. The 2005 study showed that routing of the reservoir is negligible and therefore, the spillway must be designed to pass the IDF peak flow, with no consideration to dampening routing in Bluefish Lake.

For Duncan Dam, the 2005 DSR study considered the instantaneous peak values for the 16 measured years and calculated a maximum instantaneous ratio of 1.06. This ratio was applied to the daily flow rates. It should be noted that Stantec reviewed the IDF determination for Duncan Dam to update the 2005 DSR calculated values.

4.1.2 Bluefish Dam, Hydrotechnical Design (2012)

This document was made in March 2012 by EBA and summarizes the hydrotechnical design for the dam which replaces the previous Technical Memos:

- 2010 January Design of Hydrotechnical consideration for the new dam
- 2010 September Bluefish Dam – Hydrotechnical Issues-Revision of spillway and diversion

4.1.3 Dambreak Inundation Study, Bluefish Hydro Facility (1997)

This document consists of a Dam Break study performed by Dames & Moore Inc. in 1997. The study was realised using the HEC-1 software with a simplified method. It presents storage-elevation curves and breach hypothesis that were revised. A new dambreak study has been performed in the present study which replace the 1997 study.

4.2 REVIEW OF FLOOD HYDROLOGY

4.2.1 Review of IDF

It seems that former "Low" classifications given in the 2005 DSR have been made using previous guidelines. The consequence classification of Bluefish Dam is "High" as per EBA, 2012 study and the classification for Duncan Dam should be considered "Significant" as per 2013 CDA Guidelines.

4.2.1.1 Bluefish Dam

- As per our discussion with NTPC, the "High" classification of Bluefish Dam is considered to account the consequences associated with power breakdown losses in Yellowknife as no other resource is available. Therefore, the IDF corresponding to "high" consequence dam is 1/3 between 1000-year and PMF.

- As discussed above, an IDF calculation was made in the 2005 DSR, but another one was performed for the design of Bluefish dam in 2012. The IDF determination for both studies used the data available at station 07SB003. The frequency analysis for the 2012 design was performed on 59 years, not saying which years have been used (like what year is the last year used). It is not stated if the instantaneous ratio in the 2005 DSR was used. Finally, the statistical law used in the calculation (Gumbel, Log-Pearson, etc.) was not stated.
- It is not possible to verify the method used by EBA, since it not sufficiently described, but a verification was performed as part of this DSR using measured flows at station 07SB003 between 1939 and 2014, including the flows after the design. The maximum instantaneous ratio of 1,06 was also applied (as described in 2005 DSR). The Log-Pearson III showed the lowest RMS, and was found to be the best fit. However, the Gumbel law is also shown, as it is commonly used.
- Since all the method used by EBA were not described, it was not possible to confirm the values of EBA, however the verification made by Stantec shows that the IDF flow chosen by EBA represents overall values between Gumbel and Log-Pearson III distributions.

Table 4-1: Bluefish Dam Flow

	Design Flow (EBA)	Flow (Stantec) Gumbel	Flow(Stantec) Log-Pearson III
100 years	NA	170	186
300 years	NA	199	228
1000 years	250	231	277
10 000 years	331	293	385
PMF (twice 10 000 years)	662	586	770
IDF (1/3 between 1000 years and PMF)	**387**	348	414

4.2.1.2 Duncan Dam

- As Duncan dam is used to supply water to bluefish during low hydrology periods, the failure of this dam would reduce the energy production of Bluefish plant, but would not cause the power outage of Yellowknife; so “Significant” hazard classification is considered. The IDF is defined as “between the 1/100 and 1/1000”. The 2005 DSR considered a 300 years return period, and this recurrence will be used in this review.
- The Duncan dam IDF has not been revised for Duncan Dam since 2005 and should be updated to consider new hydrology and to evaluate impacts on Bluefish dam.
- No new flow station is present close to Duncan Dam, so the methodology used in the 2005 DSR is used. Using the relationship presented in the 2005 DSR, the flow at Duncan dam is updated considering the same basins area (A2 and A1), where Q is the flow at Duncan, Q1 is the flow at Bluefish, A2 is the basin area of Duncan, and A1 is the basin of Bluefish.

$$Q = Q_1 \text{ x } (A_2/A_1)^{0.7}$$

- The table 4-2 below presents the mean flows at both dams’ location, where the flow is the average of all the flows recorded by Environment Canada downstream of Bluefish Dam and the mean flow at Duncan was calculated using the formula presented above. The Duncan revised value is 131 cms for the 300-year return period whereas the 2005 DSR had a value of 95 cms.

Table 4-2: Duncan Dam Flow

	Bluefish Flows (cms)	Duncan Flows (cms)
IDF (300 years)	186[1]	**131**
1/3 between 1000 years and PMF	387	223
Mean flow (1939-2014)	29	17

4.3 DISCHARGE CURVES

4.3.1 Bluefish Dam

As part of the design of the new Bluefish overflow spillway, only the IDF value (387 cms) has been computed by EBA and no rating curve has been developed for this spillway. So the establishment of a rating curve is discussed and analysed in this section.

4.3.1.1 Broad-crested spillway

The relationship of Broad-Crest spillway has been used by EBA for the design of the new overflow spillway (Chow, 1959):

$$Q = CLH^{1.5}$$

Where Q is the flow discharge (cms), C is the discharge coefficient, L is the effective length of the spillway (m), and H is the water head above the spillway sill (m).

The review of the spillway design (documentation that made available by NTPC) reveals that design parameters changed during the design process (spillway length of 128.8 m and 136.0 m, discharge coefficient of 1.8, 1.704 and 1.705). However, the final design presented in the Bluefish Dam- Hydrotechnical Design (March 30, 2012) indicates a discharge coefficient of 1.704. and a spillway effective length of 128.8 m. Figure 4.1 below shows the theoretical discharge rating curve using the broad-crest relationship.

Using this relation and to be able to pass the IDF flow (387 cms), the water head upstream of the spillway corresponds to $H = 1.46\ m$

Considering the spillway sill elevation at 168.78 m, the lake water level during IDF passage would be at 170.24 m (170.22 m in EBA design document).

[1] The 300 years' value is not given by EBA for Bluefish Dam. As previously showed, the Stantec's Log-Pearson III always gives higher flows than the method used by EBA, therefore the 300 years' flow of 186 cms is considered for Bluefish Dam. This 300 years' value is necessary to find Duncan revised IDF.

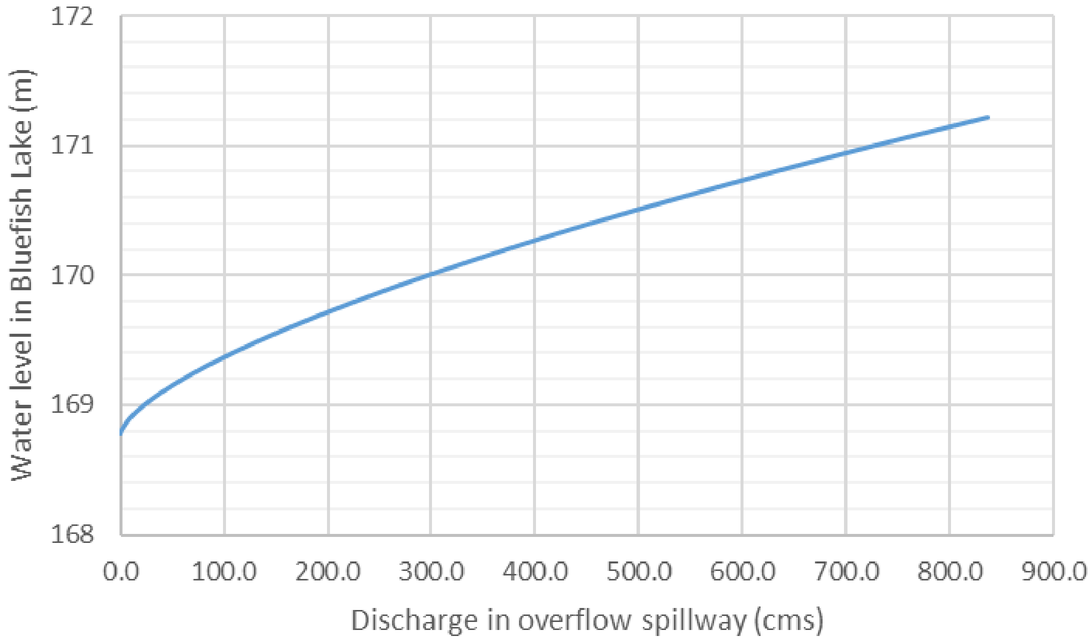

Figure 4-1: Theoretical discharge curve

4.3.1.2 Calibration of the discharge coefficient "C"

The value for the discharge coefficient "Cd" of 1,704 is a theoretical value. In order to develop a more accurate rating curve, this coefficient is revised considering data measured after the construction. Based on the document entitled "One-year review", the first filling of Bluefish Dam occurred in October 2012. So only data after this date concerns the new bluefish dam and will be used for the calculation.

4.3.1.2.1 Plants Flows

The daily plant flows between January 1st, 2013 and November 12, 2016 have been made available by NTPC. Since there are no flows for November and December 2012, the analysis was limited on years 2013, 2014, 2015 and 2016.

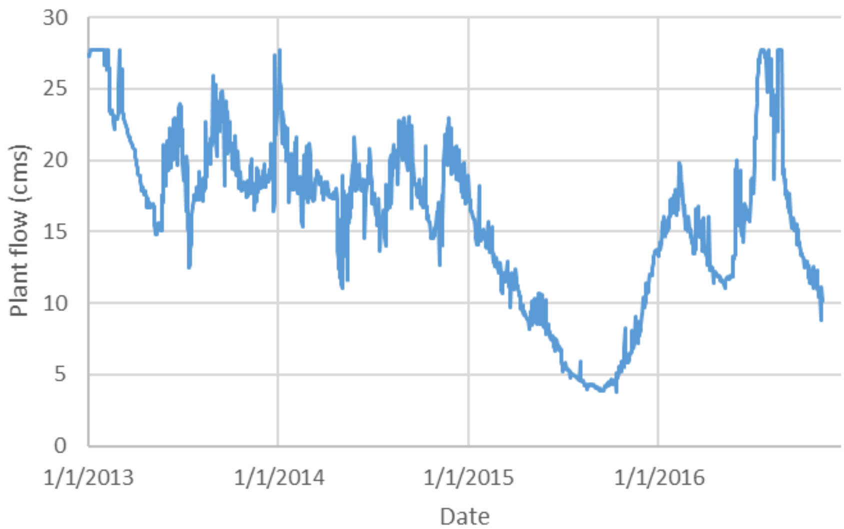

Figure 4-2: Flows discharged by power plant operations

4.3.1.2.2 IFR Flow

The daily IFR flows provided by NTPC are available from November 2012 to 2016. These flows seem to be theoretical value since no fluctuation in values due to the variation of water head (variation of water level in Bluefish lake). In the absence of better values, these values are considered acceptable.

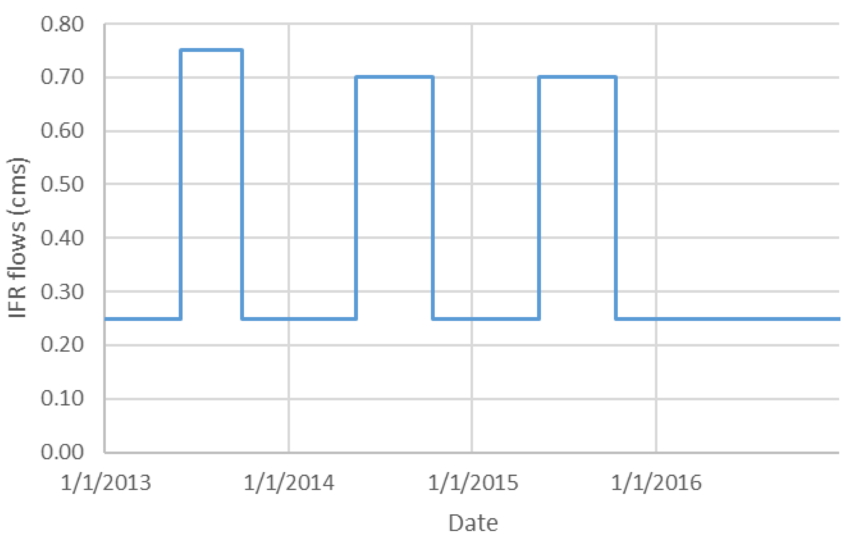

Figure 4-3: Outflow of IFR Gate (fish Gate)

4.3.1.2.3 Water level in Bluefish Lake

Environment Canada provides daily water levels in Bluefish lake at the station 07SB015 located close to the water intake of the Bluefish power plant. These data are available from 2012 to 2015. NTPC made available a list of water levels at the same location with data from April 1st, 2002 to July 15, 2016. There was only a small difference between the two datasets, and NTPC asked us to use NTPC dataset.

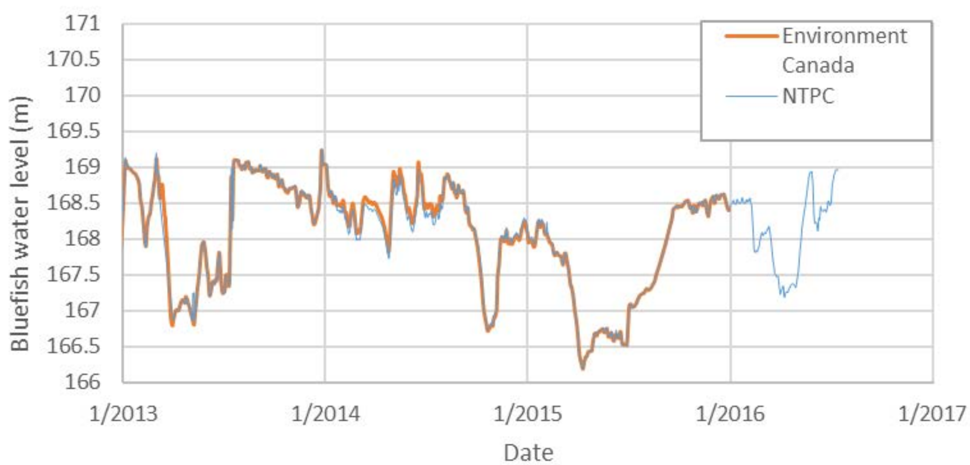

Figure 4-4: Water Levels at Bluefish lake

4.3.1.2.4 Flow in river

The daily flow in Yellowknife river, downstream of Bluefish Dam, at the limit of Prosperous Lake have been retrieved from Environment Canada at station 07SB003. This station also gives the water level downstream of Bluefish dam. This flow station measures the outflow of the Bluefish GS including IFR, power plant flow and spillway overflow, and naturally dam seepage and lateral inflow of the intermediate watershed between the dam and station (this watershed is small and was always neglected in the previous studies).

Flow data provided by NTPC, named “Ken’s Data”, are all the measurements made on daily basis by Ken’s NTPC employee.

Table 4-3: Available data downstream of Bluefish dam

Data sources	Years available
Flow from station 07SB003	1939-2014
Water level from station 07SB003	2002-2014
Flow from “Ken’s Data”	2002-2012
Water level from NTPC at station 07SB003	2002-July 15 2016

Ken's Data could not be used because the daily flows are mostly less than plant flows, which is impossible. The following figure (4-5) shows that the Ken's Data flows are under the plant flow.

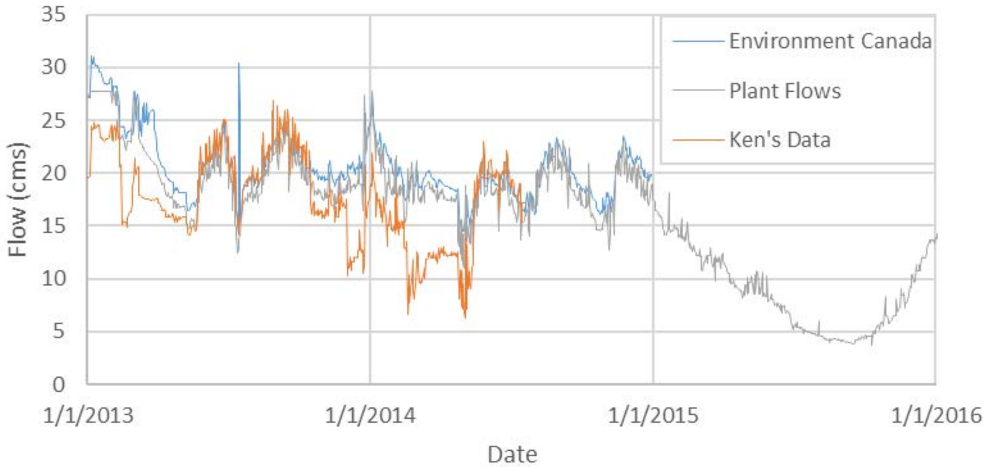

Figure 4-5: Yellowknife river flow downstream of Bluefish dam

For the years 2014 to 2016, only water level downstream of the dam is available, and not the river flow. In order to have the flows between 2014 and 2016, the downstream water level versus river flow is plotted (water level is displayed with its associated flow of the day). The following graph was obtained. The upper curve is for data before 2006, while the bottom curve was obtained from data after 2006. There is room that the rating curve was adjusted after 2006. The rating curve after 2006 was used in this study so flow in Yellowknife River is calculated based on downstream water level.

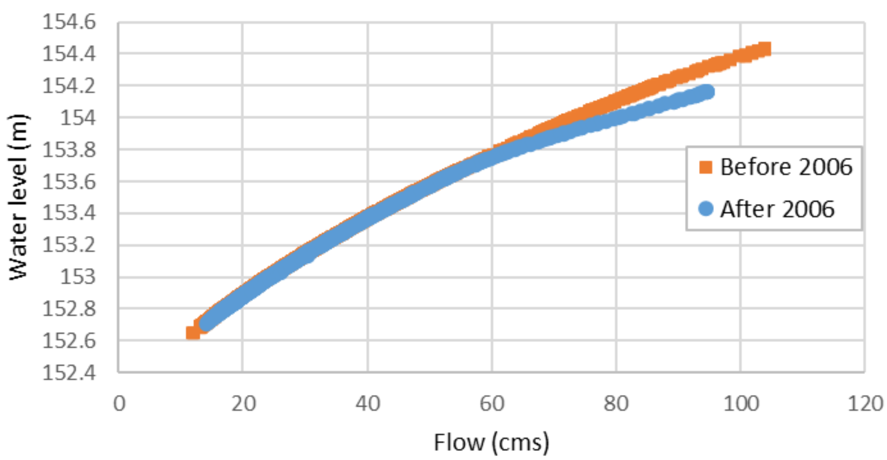

Figure 4-6: Downstream rating curve

4.3.1.2.5 Results

The discharge in the spillway corresponds to the flow of the Yellowknife River minus IFR gate and power plant flows.

$$Q_{spillway} = Q_{river} - Q_{IFR} - Q_{plant}$$

The water head over the spillway corresponds to the water level in Bluefish Lake above the spillway sill elevation (168.78 m).

$$H = WL - 168.78\,m$$

For every day between January 1st 2013 and July 15, 2016, the spillway flow and the water head are calculated. And then the discharge coefficient (C) was computed using the broad-crested equation and considering an effective length of the spillway crest of 128.8 m.

$$C = \frac{Q}{LH^{1.5}}$$

The finding that was observed is that the plant flow constitutes almost all the flow, and the overflow spillway is almost never operated.

Since we have only low flows and no high flows, many irregularities are observed. For instance, sometimes we find a flow in the spillway when the lake water level is under the spillway sill. Therefore, the days when the bluefish lake water level is under the spillway sill are not further considered. Moreover, when the flow over the spillway is negative, these day values are also not considered.

Two sets of discharge coefficient have been computed:

1. Yellowknife River flow and Bluefish water level from Environment Canada data for the years 2013 and 2014. Therefore, we have computed the discharge coefficients from the raw data. Figure 4-7 below shows the discharge coefficient as a function of the water head above the spillway sill. Two points with discharge coefficient over 30 are not shown on the chart.
2. The water levels downstream the dam made available by NTPC were used to compute the flow in the river, with the curve described previously. The water levels in Bluefish lake given by NTPC were also used. Data are available from 2013 to July 15, 2016 (Figure 4-8).

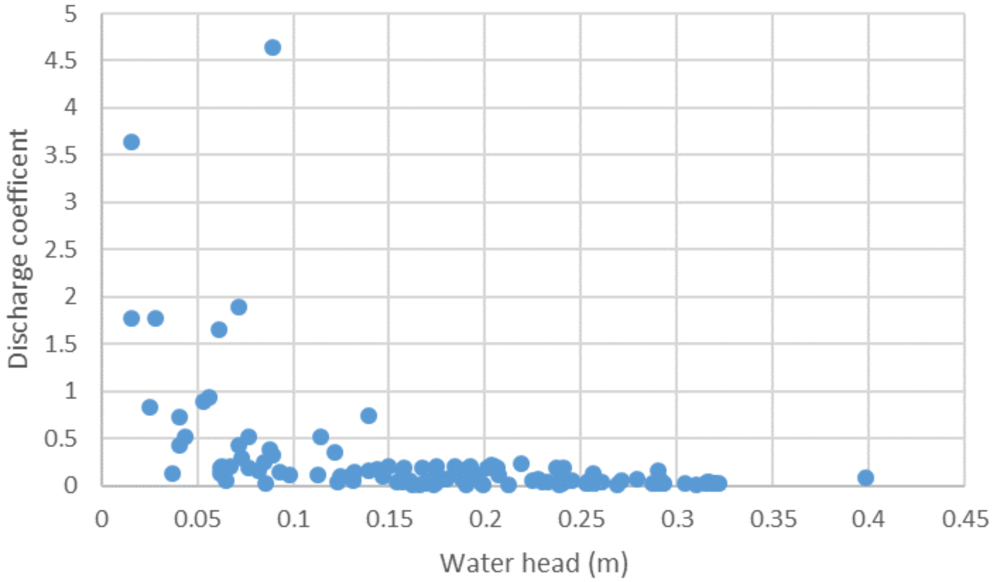

Figure 4-7: Discharge coefficient from EC dataset

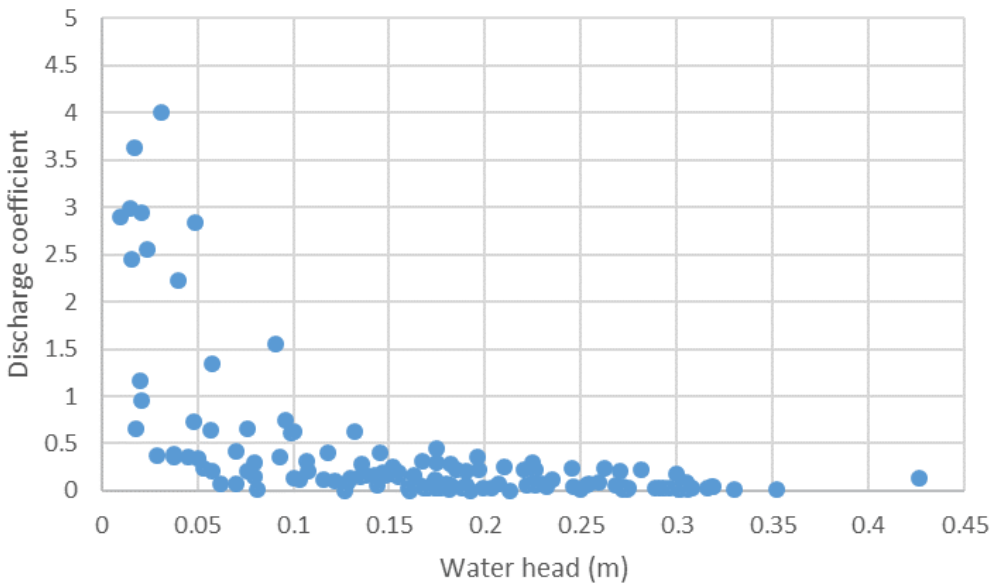

Figure 4-8: Discharge coefficient using NTPC dataset

4.3.1.2.6 Discussion on the discharge coefficient

The discharge coefficient used in the spillway design is around 1,705 for a broad crested spillway. The values that were found in this analysis are too low compared to the theoretical design value of 1,705. Using the computed value of 0.941 for the discharge coefficient would under estimate the flow for a given head (for certain heads, the computed flows would be very low). Almost no high flows were measured at Bluefish dam after the commissioning of the dam; i.e. it is important to monitor and taking measurements of water level in the lake, downstream flow, IFR flow and plant flows when high flow occurs in the future (eventually hourly measurement). These measurements can later be used to calibrate a discharge coefficient using higher flow rates. Table 4-4 below present a comparison for different calculation of discharge coefficients.

Table 4-4: Calculated Discharge coefficients

	Environment Canada datasets	NTPC datasets
Mean value	0.744	0.941
Maximum value	4.635	41.217
Standard deviation	4.23	4.58

4.3.1.3 Flows versus water levels

Figure 4-9 shows no clear relation between Bluefish water levels and spillway flows, so no relationship can be established using these data.

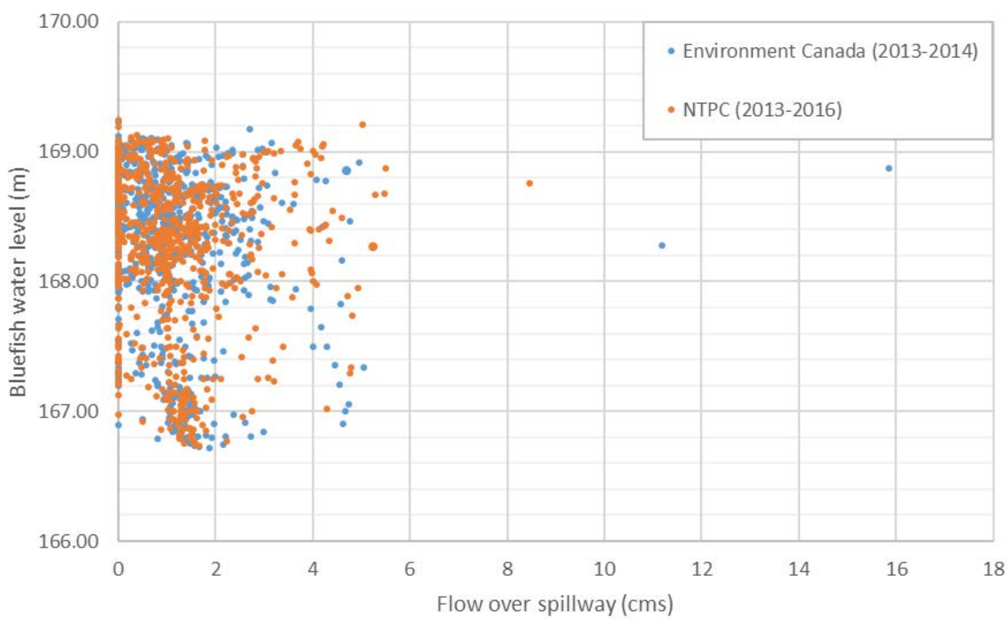

Figure 4-9: Bluefish water levels versus flows over spillway

4.3.2 Duncan Dam

Since no modification occurred since the previous DSR, the same rating curve still applies. Stantec reviewed the methodology used by EBA in 2005, considered it valid. However, the revised IDF value of 131 cms (300-year return period) now correspond to a water level of 213.95 m with all stoplogs in place (overtopping). If all stoplogs are removed during the IDF event, the water level in the lake will be 213.35 m and no overtopping is expected. Figure 4-10 below presents the Duncan dam rating curve extracted from Hay & Company Consultant study.

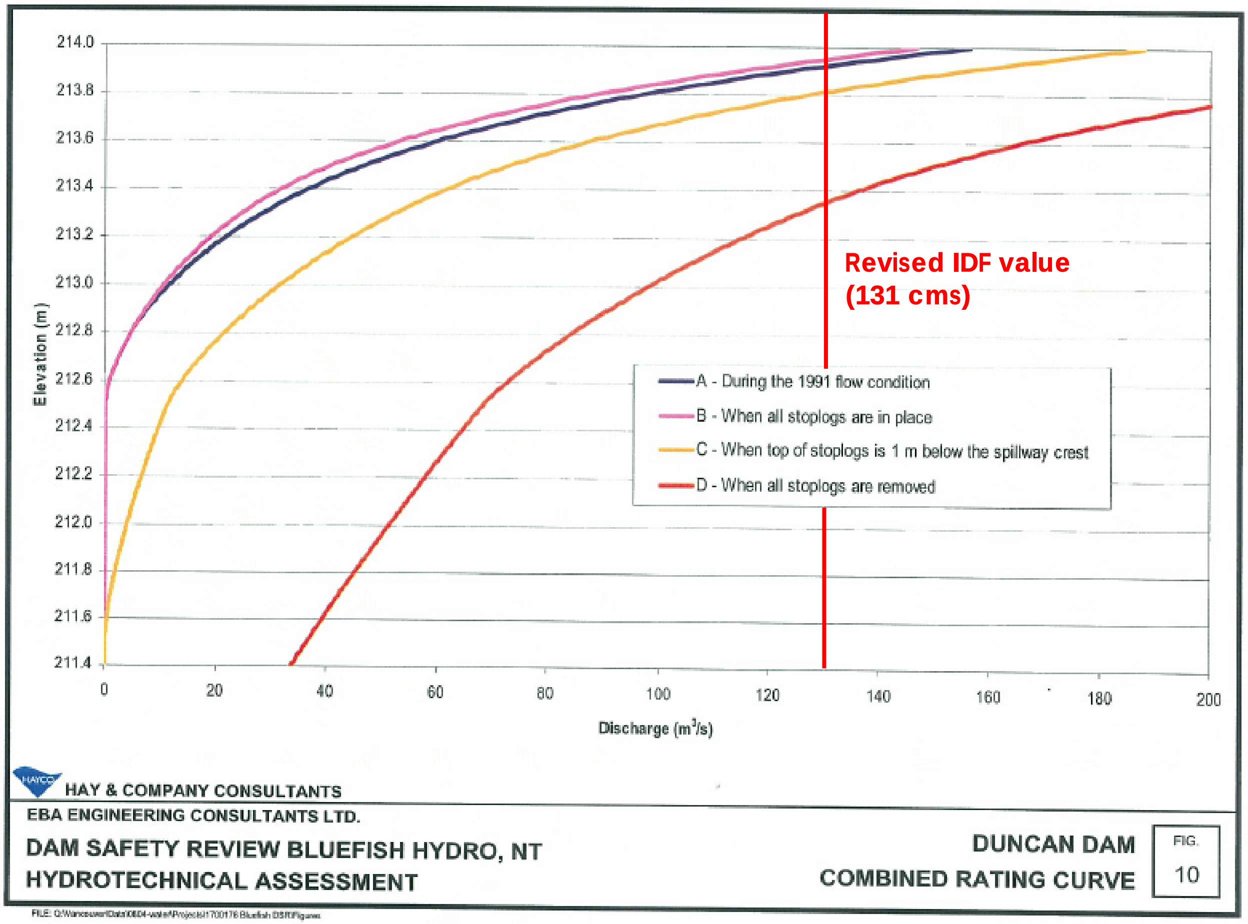

Figure 4-10: Duncan Discharge Curve

4.4 FREEBOARD

4.4.1 Bluefish Dam

The wind and waves analysis was conducted in the Bluefish Dam-Hydrotechnical Design (March, 2012) and resulted in a 0,41 m high waves for the 1000 years' scenario.

The design requirement report for the construction of the Bluefish new dam states that the design reservoir operating level is to be at elevation 168.78 m. The crest of the dam is at elevation 171.22 m (giving a freeboard of 2.44 m above operating level). The normal freeboard is respected, since a waves of 0.41 m is foreseen, while there is 2,44 m freeboard.

The minimum freeboard occurs when the IDF is combined with a 2 years' wind frequency (for a "high" classification dam). The lake water level during an IDF event is 170.22 m, so there is still 1 m above the maximum water level. The wave height for 2 years' wind frequency was not computed by EBA's design report, but the wave would be lower than the 1000 years' wave (0.41 m). Since the 1000 years' wave respect the minimum freeboard, the 2 years' wave necessarily respects the minimum freeboard.

4.4.2 Duncan Dam

A 1000-year return period wind was used in the 2005 DRS, and leaded to a wind setup of 0.056 m and a wave runup of 0.26 m (total of 0.316 m of wind effect). Based on the 2013 CDA Guidelines, the normal freeboard is based on the 1/1000 years' frequency flow combined with the maximum normal operation level. The OMS Manual states that the maximum operating level is at elevation 212.04 m. Therefore, the maximum elevation of the lake water level with waves effects is at elevation 212.356 m which is below the dam crest elevation (213.409 m), therefore no overtopping is expected in normal conditions.

The minimum freeboard is required when combining the water level in the lake during an IDF event with the 10 years' wave frequency (as per "significant" dam class). So, when all stoplogs are removed, the water level in the lake is 213.35 m during an IDF event and 0.059 m still available for waves runup and setup; but in any case, since it is a concrete dam based on rock, overtopping is not considered a significant hazard which could collapse the dam.

4.5 HAZARDS AND FAILURE MODE ANALYSIS

4.5.1 Bluefish Dam

As described in EBA Hydrotechnical Design, the PMF is estimated to be 662 cms. For this flow, the water level in Bluefish lake would be at elevation 170,87 m. Since the dam crest is at elevation 171.22 m, overtopping would not occur considering the PMF event. Consequently, failure caused by dam overtopping would not likely occur. The most overseen failure mode is a piping caused by stainless steel core breaking (caused by earthquake or other) that would lead to a dam failure.

4.5.2 Duncan Dam

Duncan Dam has a stoplogs sluiceway and two overflow spillways. To achieve the IDF passage without overtopping, all stoplogs need to be removed. If lifting system fails and the stoplogs are not removed, overtopping will occur, but as discussed above, since it is a concrete dam and the surrounding and abutments of the dam are bedrock, no failure is likely to occur. Therefore, the probable failure mode could be concrete collapse or by an earthquake which would produce a sudden failure of the whole dam.

4.6 FLOOD ROUTING AND INUNDATION MAPPING

4.6.1 HEC RAS Model

The one dimensional HEC-RAS model (version 5.0.3), developed and distributed by the US. Army Corps of Engineer, was used to compute the flood routing and prepare inundation mapping.

The topography of the region was retrieved from Geobase Canada website. Geobase data have different geodetic referential than EBA drawing. The water level of Bluefish lake is at elevation 183 m, but it is 168.78 m per NTPC referential. Elevation datum showed in EBA study was considered reliable, and a correction was applied to convert all elevation to the same datum.

The HEC-GeoHMS application (version 10.1) was used to create the HEC-RAS geometry. The geometry goes from Duncan Dam, to the junction of Great Slave Lake. Great Slave Lake (downstream condition) will dampen all the flow coming from Yellowknife River, since it can be considered as an inland sea. The total length of the developed model is over 75 km. Cross sections have been generated every kilometer, and additional cross sections have been added to inlets and outlet of lakes, and near the two dams. In total, 102 cross sections have been considered in the model. An average Manning coefficient of 0.035 has been considered for streambed and river banks.

The IDF flow is constant value but the dam breach flows were modeled in transient conditions. Then, additional cross-section interpolation was performed every 100 m to stabilize the numerical process of the simulation.

4.6.2 Breaches Characteristics

Table 4-5 lists the breaches characteristics for both dams. The source of information for each elevation is given in this table.

Table 4-5: Breaches Characteristics

	Bluefish	Duncan
Top of breach (m)	171.22 m (from EBA as-built drawings)	213.41m (from Cominco drawing)
Bottom of breach (m)	158 m (from EBA as-built drawings)	209.91 m(from 1997 Dam Break Analysis)
Height of breach (m)	13.22 m	3.5 m
Width of breach at base (m)	4 x heights=52.88 m	Total width= 27.42 m
Time to develop the breach (h)	0.5h	0
Lateral slopes	1H:1V	3.9 H:1 V[1]

[1] The elevation view of the dam is a triangle shape; therefore, the side slope of the breach will follow the abutments of the dam.

4.6.3 Duncan Dambreak

Duncan dam break is analyzed first because it is the upstream dam, and its flow will go into Bluefish reservoir (to assess if a cascade failure of Bluefish is possible).

4.6.3.1 Duncan Dam Breach Flows

The impoundment-elevation curve from the previous 1997 dambreak analysis was considered the present dam break analysis. This same curve was used also for the flood routing in the 2005 DSR. Duncan Dam combined rating curve was incorporated in HEC-HMS model. Three dam break flow hydrographs were computed for Duncan dam including the 300 years, 1/3 between 1000 years and PMF, and sunny day hydrographs. The inflow for the sunny day failure has been modeled considering the average of inflows recorded between 1939-2014 (which is 17 cms). The following breach discharge flow were computed and incorporated in HEC-RAS as upstream boundary conditions for Duncan dam break scenario. The theoretical rating curve for Bluefish spillway is also included in HEC-RAS model.

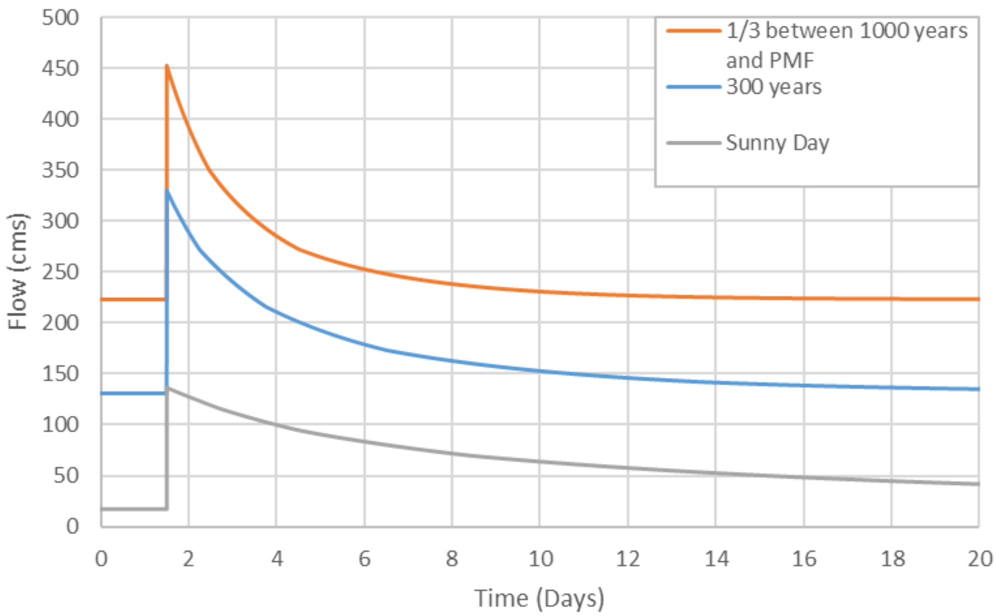

Figure 4-11: Hydrographs of Duncan Dam Breach Flows

4.6.3.2 Duncan Dam and Cascade Failure Analysis

It is understood that the extend of the flooding would cause adverse damages to the environment, therefore the minimum classification to be considered for Duncan dam is "significant" as per 2013 CDA Guidelines. No infrastructure is located between Duncan Lake and Bluefish Lake. A first analysis is here performed to assess if the failure of Duncan Dam can cause the overtopping of Bluefish Dam (leading eventually Bluefish Dam to fail). To verify this, the flow for "high" classification dam is used (1/3 between 1000 years and PMF). In case of Duncan Dam failure, it is shown on figure 4-11 that the peak flow during dam failure is 452.54 cms (including inflow and breach flow) with an additional inflow of 104 cms between the two lakes. Therefore, if no dampening of the flow occurs between the two lakes, the absolute maximum inflow at Bluefish would be 556.54 cms (452.54 cms+104 cms) and the resulting elevation in Bluefish lake would be 170.64 m. There would still be a freeboard of 0.58 m and no overtopping will occur. Consequently, the failure of Duncan dam could not cause the failure of Bluefish dam with no potential Cascade failure. The "significant" classification for Bluefish Dam is verified and retained, with an IDF flow between the 100 years' and 1000 years' return period. The recurrence of 300 years is maintained in this analysis with a new updated 300 years' flow value to be considered for inundation mapping of Duncan Dam. The following tables list the inflows for the Duncan dam flood study in HEC-RAS.

Table 4-6: Inflows for the IDF (300 years) simulation for Duncan Dam

	HEC-RAS location	Input Flow	Cumulative Flow
Duncan Dam	75910	131+Breach flow	131
Downstream Duncan (5% of flow between both dams)	75724	5	136
Quyta Lake (95% of flow between both dams)	49419	92	228
Bluefish Dam	31100	-	228 (from Stantec's Log-Pearson III)

Table 4-7: Inflows for the Sunny Day simulation for Duncan Dam

	HEC-RAS location	Input Flow	Cumulative Flow
Duncan Dam	75910	17+Breach flow	17
Downstream Duncan (5% of flow between both dams)	75724	1	18
Quyta Lake (95% of flow between both dams)	49419	11	29
Bluefish Dam	31100	-	29

4.6.3.3 One-dimensional simulation model results

The figure 4-12 below shows the profile of the Yellowknife river between Duncan Dam and Great Slave Lake.

The table 4-8 below summarize the Duncan dam breach results including peak flow, time of arrival of the first effect of the flood, time of peak water level and peak water levels at different locations. The starting time (00:00) consists of the time of the failure of Duncan dam.

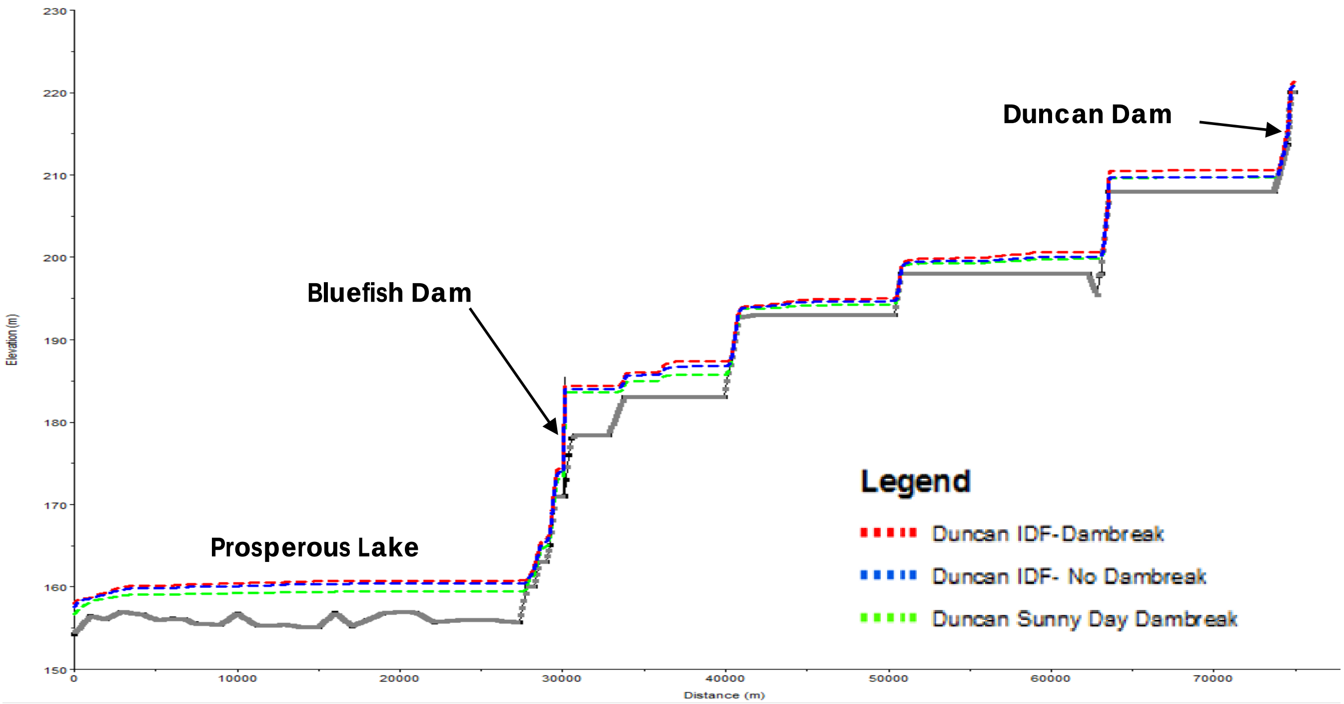

Figure 4-12: HEC-RAS Flood routing of Duncan Dam

Table 4-8: Duncan Dambreak Results

	IDF Flow failure				Sunny Day Failure			
Location (HEC-RAS station)	**Peak Flow (cms)**	**Arrival Time (hours)**	**Time of Max. Water Level (hours)**	**Incremen-tal Water Depth (m)**	**Peak Flow (cms)**	**Arrival Time (hours)**	**Time of Maximum Water Level (hours)**	**Incremen-tal Water Depth (m)**
Duncan Lake (75 910)	330.1	0:00	0:00	0.44	136.44	0:00	0:00	0.45
Short Point Lake (64 073)	262.72	1:30	28:20	0.64	118.66	1:40	50:30	0.97
Angle Lake (56 151)	256.58	2:10	32:20	0.46	107.53	7:30	53:40	0.63
Quyta Lake (49 419)	255.09	5:20	38:30	0.33	106.69	9:30	58:50	0.49
Bluefish Lake inlet (33 828)	345.45	10:00	43:50	0.33	116.66	17:00	75:30	0.4
Bluefish Dam (downstream) (31 100)	345.25	10:50	42:30	0.59	116.58	17:30	79:30	1.04
Bluefish Power House (30 217)	345.25	12:50	42:30	0.3	116.58	20:30	79:30	0.52
Prosperous Lake Inlet (28 318)	344.9	15:00	68:00	0.38	116.42	31:40	165:20	0.73
Prosperous Lake (near outlet) (15 004)	310.92	16:20	82:10	0.37	88.47	35:00	174:50	0.72
Ingraham Trail Bridge (2 963)	310.35	24:30	82:10	0.21	88.19	40:20	179:00	0.5

4.6.4 Bluefish Dambreak

An impoundment volume elevation curve is presented in 1997 Dam Break Analysis, but as It is explicitly said that the curve was an approximate judgement and since the bathymetry is unknown, the safe approach for dam break study is to consider a constant surface over the depth of the lake, so larger flows than reality would be released. In the 1997 study, the bottom of the old dam was set at elevation 164,21 m (geodetic datum). In case of failure of the new Bluefish dam, it can be possible to consider that the old Bluefish dam is eroded due to the high velocities in the forebay but this erosion would end at the base of the old Bluefish dam. That is why the bottom of the Bluefish lake is set at this elevation of 164.21 m (geodetic datum). The IFR and power plant flows are considered null to reach the highest water level in Bluefish lake prior to the dam beach event. The theoretical discharge curve for Bluefish spillway is incorporated in the dam break model.

4.6.4.1 Bluefish Dam Breach Flows

The hydrograph for Bluefish dam break is computed automatically in HEC-RAS with the given breach characteristics. Figure 4-13 shows the hydrograph of Bluefish Dam failure extracted from the HEC-RAS model for the two following scenarios:

- IDF failure scenario: A cumulative flow of 387 cms (computed in section 4.2.1 of this DSR) is the inflow in Bluefish Lake.
- Sunny day failure scenario: A cumulative mean flow of 29 cms (computed in section 4.2.1 of this DSR) is the inflow in Bluefish Lake.

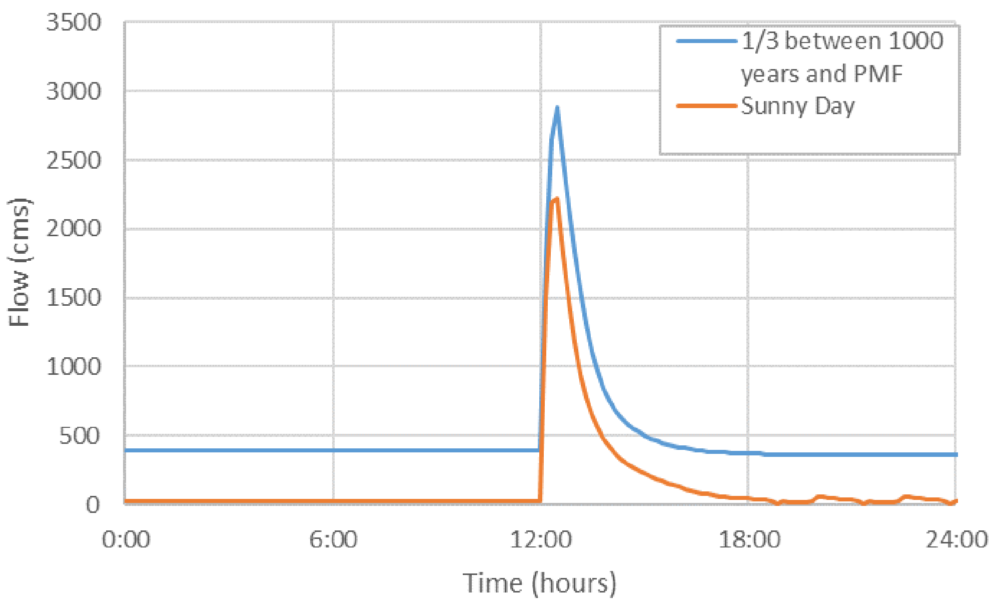

Figure 4-13: Bluefish Dam Breach Flow

4.6.4.2 One-dimensional simulation model results

The figure 4-14 below shows the water profiles of the Yellowknife river between Bluefish Dam and Great Slave Lake.

Table 4-9 shows peak flow, time of arrival of the first effect of the flood, time of peak water level and peak water level at different locations. The starting time (00:00) consist of the time of the failure of the dam.

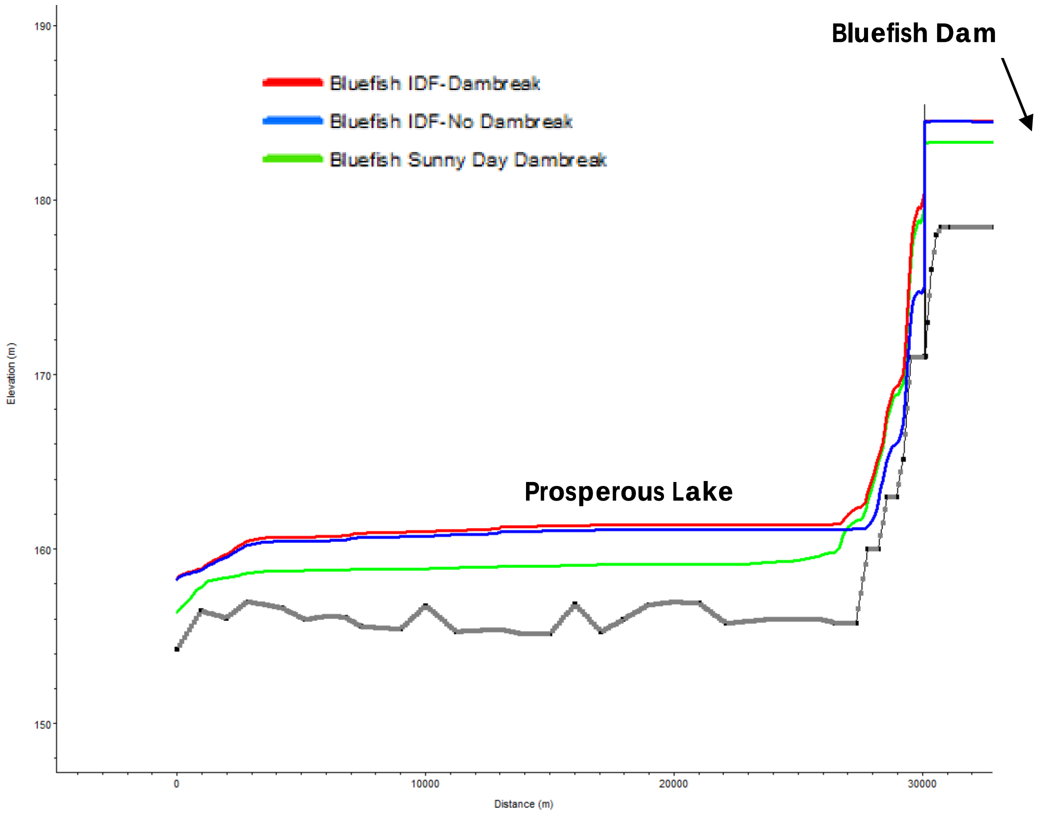

Figure 4-14: HEC-RAS Flood routing of Bluefish Dam

4.6.5 Inundation mapping

Inundation mapping has been realized. Appendix C presents the inundation mapping for both Duncan and Bluefish dam break. The IDF and Sunny-day failure scenarios are presented.

Table 4-9: Bluefish Dambreak Results

	IDF Flow failure				Sunny Day Failure			
Location (HEC-RAS station)	**Peak Flow (cms)**	**Arrival Time (hours)**	**Time of Max. Water Level (hours)**	**Incremental Water Depth (m)**	**Peak Flow (cms)**	**Arrival Time (hours)**	**Time of Maximum Water Level (hours)**	**Incremental Water Depth (m)**
Bluefish Dam (downstream) (31 100)	2956	0:00	0:30	5.48	2337	0:00	0:30	7.13
Bluefish Power House (30 217)	2929	0:10	0:30	2.87	2302	0.:10	0:30	3.65
Prosperous Lake Inlet (28 318)	2830	0:20	0:40	1.22	2171.05	0:20	0:40	2.87
Prosperous Lake (near outlet) (15004)	594	1:00	1:30	0.28	59.6	1:40	8:20	0.33
Ingraham Trail Bridge (2 963)	474	2:00	6:18	0.15	50.44	4:50	8:50	0.26

4.7 DAM CLASSIFICATION (HAZARD POTENTIAL CLASSIFICATION-HPC)

4.7.1 Quantitative and qualitative analysis of incremental consequences in case of dambreak

4.7.1.1 Power production

Duncan Dam is the water reserve of Bluefish GS. In case of Duncan failure, power generation would be reduced, until the rebuild of the dam. Since Duncan dam is a small dam, it can be rebuilt relatively fast and at relatively lower cost, however, the location of the dam with limited access out of winter season would limit the construction schedule.

Bluefish Dam is a necessity for power generation. It creates the water head necessary to the power generation. In the case of Bluefish Dam failure, no power generation would be possible. It would take many years to be rebuilt (3-5 years), since this dam is much bigger than Duncan Dam. According to NTPC's Website, "Bluefish can supply up to 20% of Yellowknife's electricity needs, equivalent to about 11 million litres of diesel fuel each year". To supply power to Yellowknife, NTPC would need to produce diesel generated power, thus having a big economical impact.

4.7.1.2 Prosperous Lake resident (Cassidy Point)

Some houses are present on the shore of Prosperous Lake at Cassidy Point. From the terrain data that are available (Geobase), it seems that no house is flooded. Prosperous lake is large and dampens most of the Bluefish dambreak flow. The incremental water depth is low (around 0.30 m), therefore the risk of lost of life attributed to the dam failure is low. The highest incremental water depth of 0.72 m is not dangerous, since it takes 174:50 (more than a week) after the failure to observe this level. Population will have plenty of time to be evacuated if they are in the flooding area. The expected incremental water level in Prosperous Lake are reported in the table 4-10 below.

Table 4-10: Impact of Bluefish and Duncan dams' failure on Prosperous Lake

	IDF Flow failure		Sunny Day Failure	
	Time of Maximum Water Level (hours)	Incremental Water Depth (m)	Time of Maximum Water Level (hours)	Incremental Water Depth (m)
Duncan Failure	82:10	0.37	174:50	0.72
Bluefish Failure	1:30	0.28	8:20	0.33

4.7.1.3 NTPC buildings and Staff

The buildings located near the power house are likely to be flooded in case of Bluefish failure per the inundation mapping of the area (Figure 4-16). Normally, one operator is present on site in normal operation. Since he controls the water lake elevation, the operator would be aware in case of overtopping (very unlikely since the spillway has the capacity to pass the PMF). The operator is not at risk since he can simply move to the buildings located higher than the flooding limit.

Table 4-11: Impact of dams' failure on NTPC buildings

	IDF Flow failure		Sunny Day Failure	
	Time of Maximum Water Level (hours)	Incremental Water Depth (m)	Time of Maximum Water Level (hours)	Incremental Water Depth (m)
Duncan Failure	42:30	0.3	79:30	0.52
Bluefish Failure	0:30	2.87	0:30	3.65

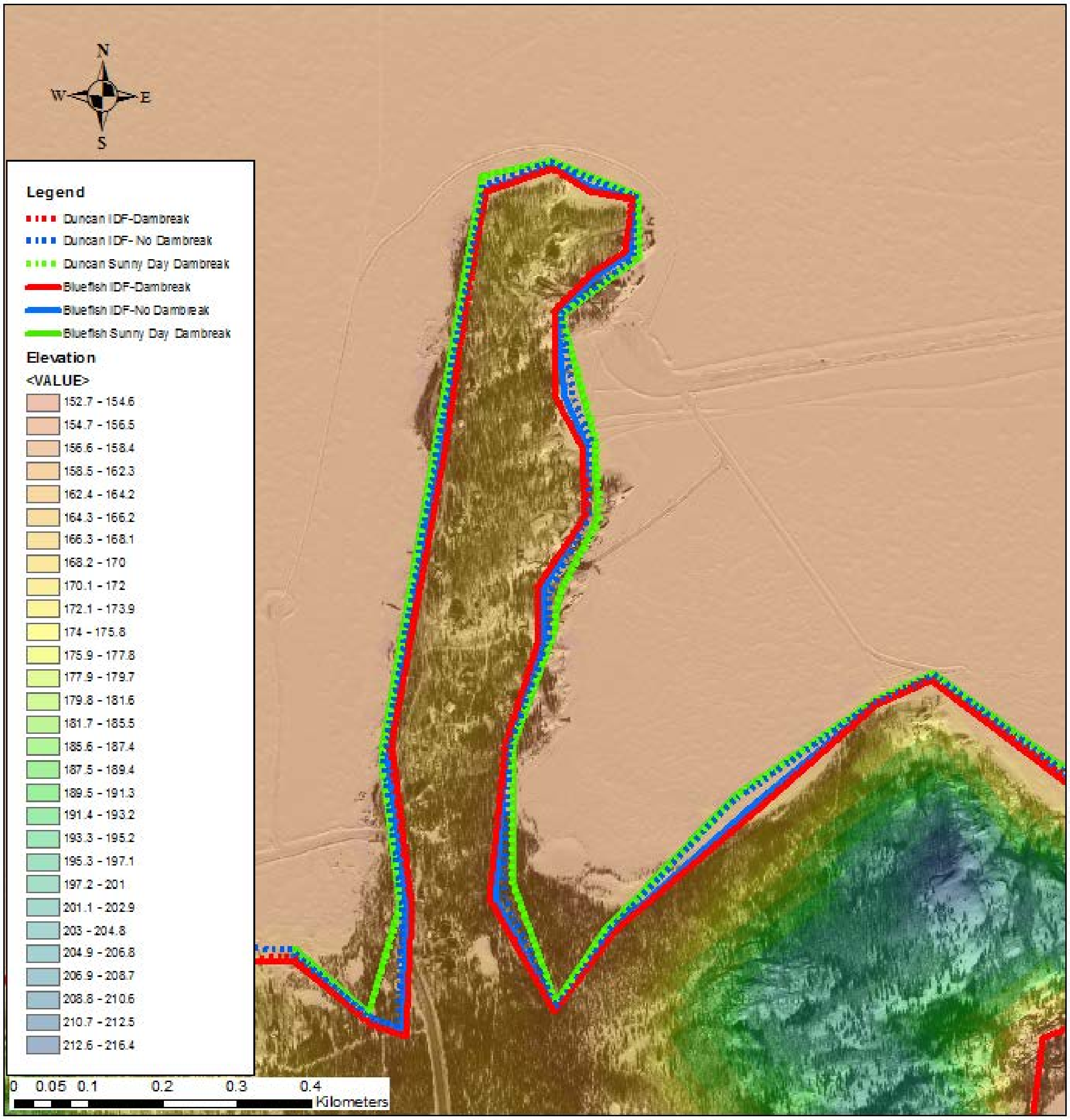

Figure 4-15: Flood mapping at Cassidy Point

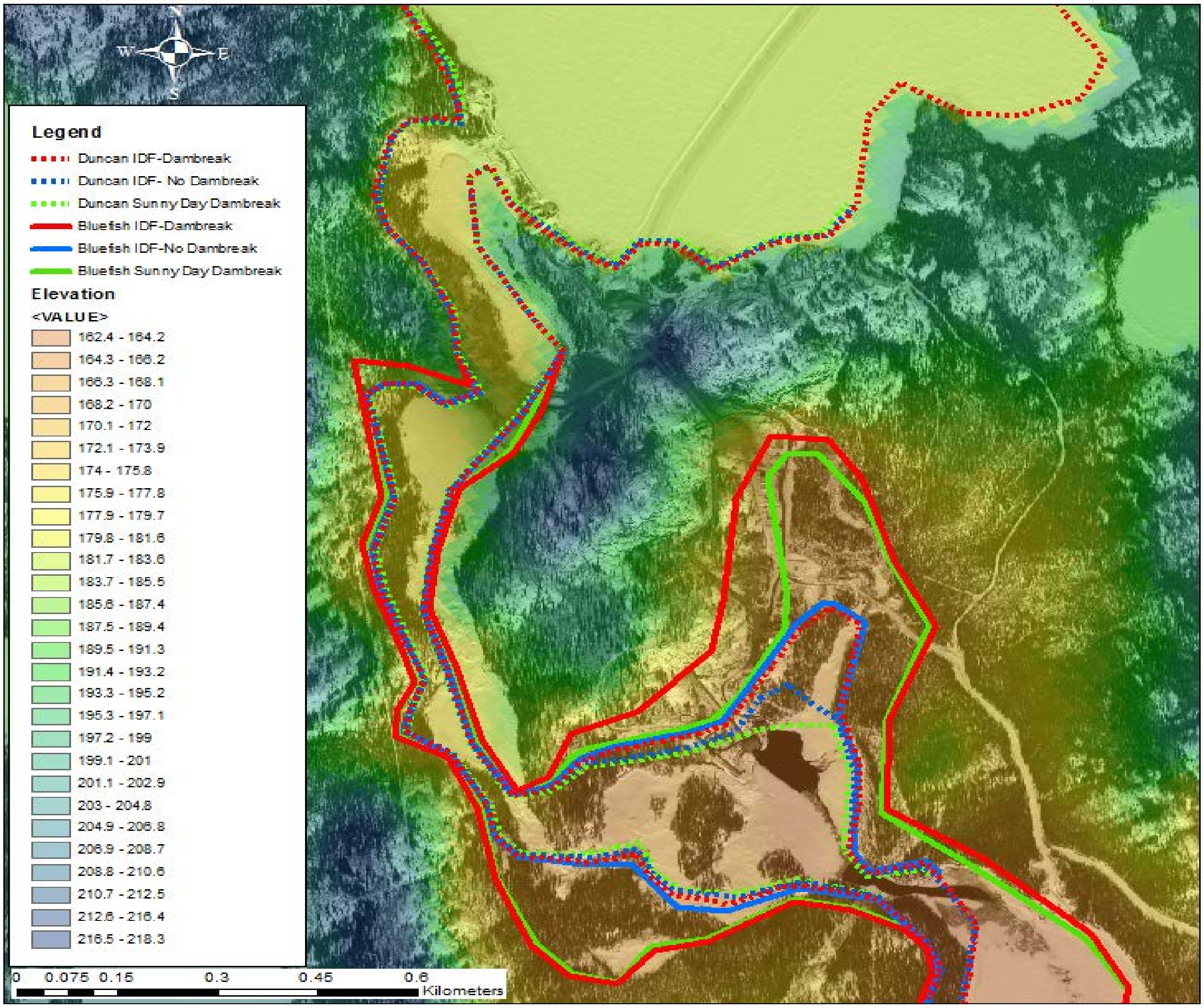

Figure 4-16: Flood mapping around NTPC buildings

Figure 4-17: NTPC Bluefish power plant

4.7.1.4 Ingraham Trail Bridge

Ingraham Trail is a road that links Yellowknife to the eastern communities. The bridge is the unique road that crosses the Yellowknife River. Almost all the dampening of the flood occurs in Prosperous Lake. The elevation of the bridge is not known. Since the incremental water depth is low, the failure of the bridge is not expected to be caused by the failure, but by the flood. Figure 4-18 shows the inundation mapping of this area.

Table 4-12: Impact of dams failure on Ingraham Trail Bridge

	IDF Flow failure		Sunny Day failure	
	Time of Maximum Water Level (hours)	Incremental Water Depth (m)	Time of Maximum Water Level (hours)	Incremental Water Depth (m)
Duncan Failure	82 :10	0.21	179 :00	0.5
Bluefish Failure	6 :18	0.15	8 :50	0.26

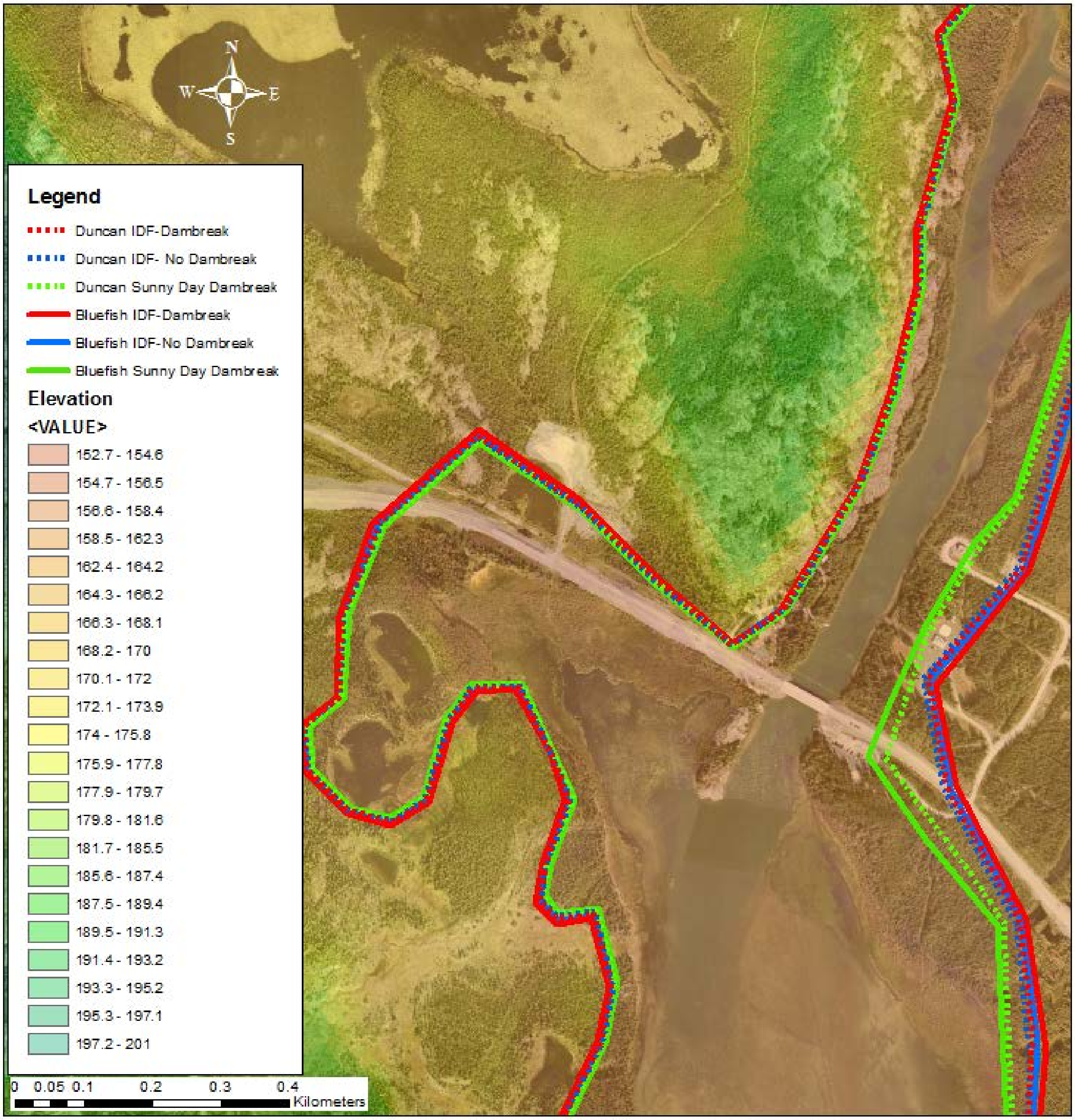

Figure 4-18: Flood mapping at Ingraham Bridge

4.7.2 Dam classification, consequences, sensibilities, and discussion

It is understood that the extend of the flooding would cause adverse damages to the environment, therefore the minimum classification to be considered is "significant" for both dams. Since no risk of loss of life is expected, and the damages foreseen are only located at NTPC facilities close to Bluefish GS (the damages to the dam's associated structures are not to be considered in the classification).

NTPC wants to consider Bluefish Dam as "High" consequences, due to the power shortage in Yellowknife caused by the dam failure consequences. Therefore, the IDF for a "high" consequence dam is 1/3 between 1000-year' and the PMF, which is estimated to be 387 cms for Bluefish Dam.

The failure of Duncan Dam would reduce the energy production temporally, but since its does not have a big impact, the dam failure consequences classification will be considered as "significant" with an IDF flow value between the 100-year and 1000-year' recurrence. The 300-year' recurrence is selected with an IDF value equal to 131 cms.

5.0 REVIEW OF BLUEFISH HYDROELECTRIC DEVELOPMENT

5.1 MAIN EMBANKMENT

No significant issues were noted during the site inspection of the Bluefish dam main embankment. Figures 5.1 and 5.2 demonstrate the various areas of the dam discussed in this section.

Figure 5-1: View of downstream side of the Bluefish Dam

Along the dam crest, minor grading issues were noted resulting in the vehicle path being slightly lower in elevation that the areas of the crest immediately up and downstream, where the instrumentation stick-ups are located. This grading issue is likely due to snow clearing activities, as it is understood that the crest is regularly plowed during winter months to allow for continuous access across the dam. Figure 5.3 shows the condition along dam crest during the site inspection.

Along the downstream slope, discrete and limited areas were observed to have undergone a small amount of settlement resulting in very minor undulation. This settlement is likely a result of smaller rockfill particles shifting into voids of larger particles as the dam is exposed to rain, snowmelt, and freeze thaw cycles. Figure 5.4 shows the condition of the dam downstream slope during the site inspection.

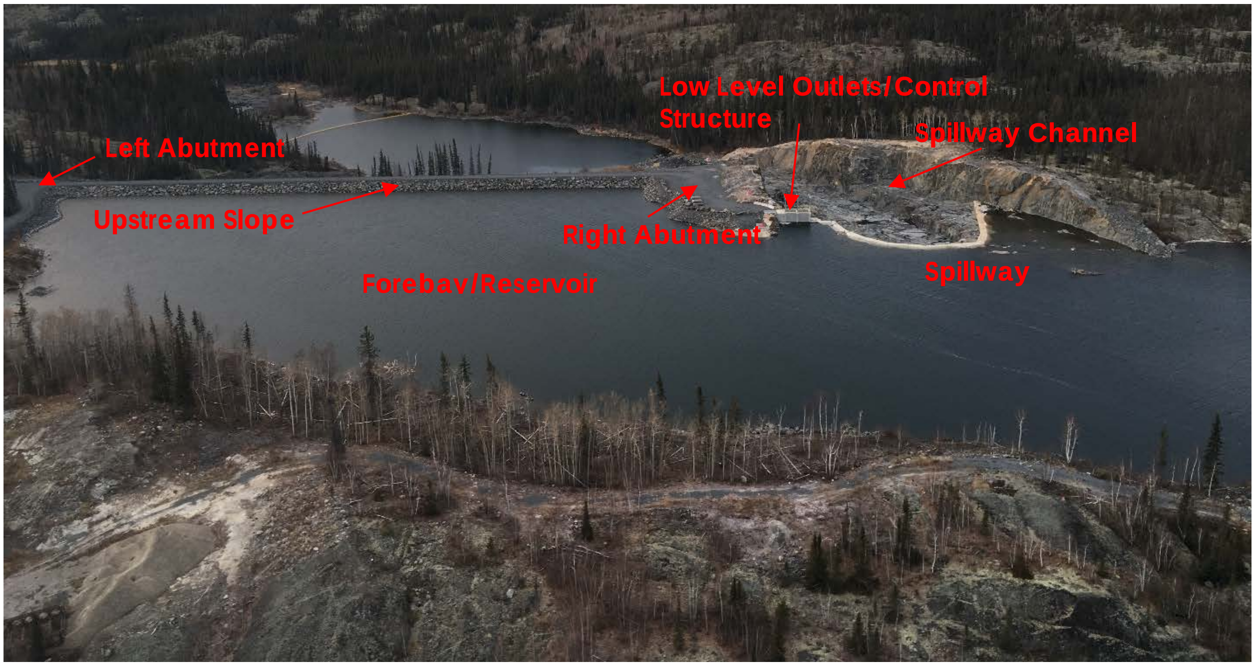

Figure 5-2: View of upstream side of the Bluefish Dam

Figure 5-3: Condition of the dam crest during site inspection.

Figure 5-4: Condition of the dam downstream slope during site inspection.

At the very base of the of dam toe, at the location of the former river channel, a small amount of clear seepage was observed to be flowing between the large native bedrock outcrops and the placed rockfill boulders. The flow was estimated at less than 10 l/min, based on a simple visual assessment. It is understood that this seepage has been observed since the commissioning of the dam. This area has been observed to form a significant ice dam in the winter, whereby ice advances up the downstream face with continuous flowing seepage below.

This area is also where curtain grouting was completed at 6 m intervals versus the recommended design interval of 3 m centers and at natural low-point in the bedrock surface (i.e., former river channel location). As such it is possible that water is passing through the areas with less grout in the bedrock foundation in the area, or that other areas of potential leakage beneath the dam exist and the natural low point in the bedrock surface is where the water is accumulating and exiting the dam. There is currently no mechanism in place to measure the seepage rate, water quantity or quality. The observed seepage is shown in Figure 5.5.

The exposed rip rap on the upstream slope of the dam was observed to be in good condition with no obvious or notable areas that have been impacted by wave erosion or ice damming. Given that the forebay area upstream of the dam is protected by a natural cove, wave and ice related issues with the upstream are expected to be of little concern. The observed condition of the dam upstream slope above the forebay water elevation is shown in Figure 5.6.

Figure 5-5: Observed seepage from base of dam at former river channel location.

Figure 5-6: Upstream slope conditions

5.2 SPILLWAY AND DISCHARGE CHANNELS

The condition of the spillway was observed from the control structure platform as there is no permanent access down to the spillway. As such, observations were limited the upstream and right faces of the spillway rock. In general, the spillway was observed to be in good condition. It is understood that to date, there have only been occasional times when the water level in Bluefish lake has resulted in water passing over the spillway, with all water typically being passed through the low level outlet (for riparian flow) and the generation facility.

Some minor seepage was observed to be occurring in the vertical rock face below the sill elevation at two discrete locations. As the distance was relatively far from where the observations were made, it was not possible to assess the water clarity or flow rate, though it was not immediately obvious that water was flowing, suggesting that the amount was very small. As noted in previous reports by others, the concrete sill poured to correct the over blast of the rock along the spillway could provide an area of concern where water between the rock and concrete could subject to freeze thaw cycles could result in additional seepage paths below the concrete. Sealing of the voids is recommended in order to avoid accelerated degradation. Periodical survey of the elevation of the sill is recommended in order to monitoring displacement over time. The conditions observed at the spillway during the site inspection are shown in Figures 5.7 and 5.8.

Figure 5-7: Condition of upstream spillway vertical rock face.

Figure 5-8: Condition of right side of spillway vertical rock face.

The near vertical excavated rock walls for the spillway and low level outlet channel appeared to be in stable condition. Again, observations were limited, as it was only safe to view these areas from the control structure platform. Rock anchors along the left side of the low level outlet wall (also the right abutment for the dam) were visible, however due to their height and flowing water conditions, no detailed inspection of this area was completed. The observed conditions of the spillway outlet channel and the low level outlet channel are shown in Figures 5.9, 5.10 and 5.11.

Figure 5-9: Spillway outlet channel right wall.

Figure 5-10: Low Level Outlet channel left wall and main spillway channel right wall and rock base

Figure 5-11: Low Level Outlet channel left wall with some anchor locations shown securing areas of the upper rock wall

5.3 MONITORING AND INSTRUMENTATION

Regular monitoring of the dam and instrumentation within dams is critical to understanding if the operational performance of the dam is in conformance with the design assumptions. There are three main components to a well-developed instrumentation system:

1) Installing the correct types of instrumentation in the appropriate locations
2) Monitoring the instrumentation on a regular basis and documenting the results
3) Interpreting the results and assessing whether they are in conformance with design expectations or otherwise determined threshold values.

The Bluefish dam is a relatively new dam (2012) and as such was designed to be well instrumented from its on-set. Based on a review of the available documentation there were four (4) main types of instrumentation installed: standpipe piezometers, ground temperature cables (thermistors), settlement monitoring points, and corrosion monitoring coupons for the stainless steel liner.

However, upon further review of the Bluefish Dam instrumentation system on-site and a review of the monitoring data to date, it is clear that the full system is not well documented, understood, monitored, or critically reviewed.

Each of the following sub-sections discusses the components of the instrumentation for the Bluefish dam as well as additional instrumentation which could be installed.

5.3.1 Standpipe piezometers

Twenty (20) standpipe piezometers were installed at ten (10) locations along the dam crest or lower downslope access road just prior to the commissioning of the dam. At each piezometer location, a set of piezometers consisting of a shallow 50 mm diameter piezometer and a deep 25 mm diameter piezometer have been installed. The piezometer locations are as shown on the as-built plan drawing C209, 'As-Built Instrumentation – Plan' dated March 12, 2013, prepared by EBA.

In general, it is understood that the shallow piezometers were installed just below the dam rockfill/foundation rock interface, while the deep piezometers were installed to some depth into the foundation rock. The shallow piezometers where installed as 50 mm diameter to allow for water sampling to be completed in order to monitor for potential acid rock drainage (ARD) of the dam rockfill. No as-built instrumentation cross sections or as-built detail drawings documenting the elevations of the piezometers screened sections, elevations of the bedrock foundation, dam fills, thicknesses, or type of seal between the nested piezometers have been prepared.

The measured piezometer depths, and estimations of the bedrock and dam crest elevations at the piezometer locations and piezometer stick-up heights was provided in the '2013 One Year Review of Bluefish Dam' report, dated July 2014, by KCB, estimated from the As-built Report (EBA) cross-sections. Based on a review of the Field Memoranda provided in the As-built Report (EBA) from the time (period) when the piezometers were installed, there is possibly enough information within these memos to accurately develop as-built cross sections/instrumentations detail drawings. As-built piezometer detail drawings for each set of piezometers as well as cross sections at instrumented sections should be completed by EBA and kept as a record by NTPC as well as added to the OMS manual.

In general, monitoring of the piezometers has been completed monthly since September 2014. In total, 20 monitoring events have been completed between September 1, 2014 and August 2016. The monitoring data was provided by NTPC in a variety of spreadsheets, with many only capturing a single event, rather than a single spreadsheet with assembled data and piezometer plots. It is recommended that NTPC continue to use the spreadsheet developed by Stantec as means of storing all piezometer monitoring data or develop their own spreadsheet with similar function. Two additional sets of data (March 8 and December 8, 2013) were taken from the '2013 One Year Review of Bluefish Dam' (KCB) report. Stantec has assembled all the provided monitoring data and created readout plots of each piezometer as well as plots of piezometers along the same cross section (i.e., SP02 and SP03, SP04 and SP05, SP06 and SP07, SP08 and SP09).

Since January of 2015, occasionally notes were provided in the monitoring data when a water level was not recorded at a select piezometer (i.e., not accessible, frozen, dry) however other times these notes were not provided and no notes exist prior to January 2015. If a piezometer cannot be monitored (access/frozen), there is an issue with a piezometer, or it is dry, will be important for NTPC staff to document these details for all future piezometer monitoring events.

The headwater/Bluefish Lake water elevation presented on the piezometer plots has been taken from the Government of Canada Website and corrected to site datum elevation (noted in the As-built Report (EBA) as being 17.15 m below Geodetic). Stantec understands that no water elevation data of the tailwater/pond is collected/monitored. It is recommended that a staff gauge be installed to allow for period monitoring of the tailwater/pond water elevation.

Upon review of the plotted data for each piezometer, it is believed that there was a recording/clerical error on February 19, 2015, whereby the data for SP05 and SP06 were reversed, as well as the data for SP07 and SP08. Plotting the data as collected yields unusually high results for each piezometer which do not appear to be representative of actual conditions and is not reflected in other nearby piezometers. Stantec has plotted the data recorded for the February 19, 2015 monitoring event for SP05 (A/B) on the SP06 (A/B) plot (and SP06 A/B on the SP05 A/B plot) and the monitoring data for SP07 (A/B) on the SP08 (A/B) plot (and SP08 A/B on the SP07 A/B plot).

Additional unresolved potential errors include two sets of data both dated September 1, 2014, as well as an oddity at SP02 on May 5, 2015, whereby the reading would have resulted in a water just below the dam crest, well above all other piezometers for that date. It could be that the piezometer was frozen and not noted.

All piezometer monitoring data from March 2013 to August 2016 has been plotted on the figures of Appendix D.

Based on the piezometer data plotted, Stantec has noted the following:

- SP01 – Few monitoring events have been completed at this piezometer as it located outside of the perimeter fence on the right abutment, as shown in Figure 5.12. The monitored piezometer levels to date are well above the foundation rock elevation of the adjacent dam (the right abutment is all rock itself) and could be an indication of water penetrating through the rock abutment and into the low level outlet channel. It was not possible to directly review the condition of the low level outlet channel rock wall for signs of seepage due to access restraints and spilling water conditions. Future site reviews should be completing with the low level outlet temporarily closed and provisions should be made to allow for inspection of the rock excavation for leakage. Further, the perimeter fence should be repositioned to allow for access to SP01.
- SP02, SP03, SP04, SP05 and SP10 (A/B) are all typically monitored below the bedrock elevation, or for SP04, slightly above (around 1 m above).
- SP06 – The deeper piezometer (B) is typically monitored to have a water level above the shallow (A) piezometer (typically 0.5 to 1 m higher). In this case, it could be that the deeper piezometer level is representative of higher pore water pressure within the foundation rock and not representative of a water elevation within the dam. In this instance, the shallow piezometer may be more representative of water level within the downstream shell. SP06A (shallow piezometer) has been monitored as high as 1.8 m above the estimated bedrock elevation on two occasions (March 8, 2013 and Feb 19. 2014) both possibly associated with the noted ice damning at the toe of the dam in this area.
- SP07 – Does not appear to be responsive. Both piezometers have been monitored near el. 159 m (approximately 3 m above the estimate bedrock surface) since monitoring began. Though no tailwater pond water elevation is recorded, it is possible that the SP07 water level is tied to the tailwater/pond elevation.
- SP08 – Similar to SP06, the deeper piezometer (B) is typically monitored to have a water level above the shallow (A) piezometer, while in this case the range is much greater (from 0.1 to 3 m). In this case, it could be that the deeper piezometer level is representative of higher pore water pressure within the foundation rock and not representative of a water elevation within the dam. It is further noted in the '2013 One Year Review Report' (KCB) that this piezometer installation may not have been completed properly and may not be reliable. In this instance, the shallow piezometer may be more representative of water level within the downstream shell. SP08A has been monitored as high as 4.6 m above the estimated bedrock elevation, and has been monitored well above the bedrock during both the winter of 2014/2015 and 2015/2016, likely associated with the noted ice damning at the toe of the dam in this area. It should further be noted that based on a review of the as-built bedrock contours in this area, there could be water ponding occurring in this area as there is a local depression in the bedrock surface (former river channel).
- SP09 – Similar to SP08A, SP09A has been monitored as high as 4.2 m above the estimated bedrock elevation, and has been monitored well above the bedrock during both the winter of 2014/2015 and 2015/2016, likely associated with the noted ice damning at the toe of the dam in this area as well as the same local bedrock depression which could be causing water ponding and could be impacting this piezometer.
- SP06B, SP07B, SP08B, SP09B (if SP08B is taken to be reliable) – At these three locations, the deeper piezometers within the bedrock foundation are monitored to be well above the bedrock surface for portions of, or the entire year. This trend suggests that a substantial upward gradient could exist due to seepage beneath the concrete key trench in the area

of the former river channel. This outcome is plausible as this is also the area where the grout curtain spacing was expanded from the recommended 3 m center to center spacing to 6 m, where a local bedrock surface depression existis, and is also where visible seepage is occurring at the dam toe.

At this time, there is no indication in the OMS manual to outline the monitoring frequency for the piezometers, though they are typically monitored monthly, nor has any analysis been completed to assess the threshold water level (water level at a piezometer at which the stability of the dam is sufficiently impacted that additional monitoring or action is required) for each of the piezometers. It is critical that a series of analyses be completed to determine what the threshold water level is for each piezometer and the results of this analysis be incorporated into the OMS manual and ERP such that appropriate action is taken when the piezometers are monitored. The collected data should also be processed in a timely manner such that any potential errors or anomalies can be corrected immediately.

Figure 5-12: Piezometer SP01 shown outside of the perimeter fence, restricting access which has less led to the instrument not being monitored

5.3.2 Ground Temperature Cables (Thermistors)

It is understood based on a review of the As-built Report (EBA) and the physical identification of thermistor cables within stick-ups on the downslope side of the dam crest that six (6) thermistor cables were installed within vertical boreholes following the construction of the dam. The thermistor cable stick-up locations are as shown on the as-built plan drawing C209, ‘As-Built Instrumentation – Plan’ dated March 12, 2013, prepared by EBA. It is understood that the intent of the thermistor cables was to be able to assess if the concrete key trench was undergoing freeze thaw cycles, or if the core of the dam was protecting the key trench from freezing.

No as-built instrumentation cross sections or as-built detail drawings documenting the elevations/paths of the thermistor strings or the locations of the temperature sensing nodes have been prepared.

Based on a review of the Field Memoranda provided in the As-built Report (EBA), from the time (period) when the thermistors were installed, along with the schematic drawings of the thermistor strings provided by the manufacturer, there is possibly enough information to accurately develop as-built cross sections/instrumentations detail drawings.

As-built thermistor detail drawings for each thermistor string (with node locations and elevations) as well as cross sections at thermistor sections should be completed by EBA and kept as a record by NTPC and incorporated in the OMS manual.

It is further understood that NTPC does not have in their possession the necessary connection cable or readout device to monitor the thermistor cables. As such, no monitoring of the thermistor cables has been completed to date. Stantec has contacted the manufacturer and based on these discussions, the manufacturer has indicated that a readout device and connection cable was procured by the contractor at the time the thermistor cables were provided.

NTPC should request the connection cable and readout device from thermistor cable installation contractor, or alternatively, a new readout box and connection can be purchased from RST Instruments. Stantec has included a cost quotation for this equipment and has provided this information in Appendix E.

It is recommended that once a connection cable and readout device are obtained, that monthly monitoring be completed for at least the first two (2) years to begin to develop a temperature profile of the soil/rock in contact with the cables throughout the significant ambient temperature changes that occur at this dam site throughout the year. An assessment should be made after two (2) years if the frequency of the monitoring can be reduced to capture specific monitoring periods within the year.

5.3.3 Corrosion Monitoring System

Based on a review of the As-Built Report (EBA), it is understood that select components of a corrosion monitoring system have been installed within the dam to monitor potential corrosion of the stainless steel liner. Based on our field observations of empty instrumentation stick-ups along the upslope side of the dam crest, it is further surmised that some elements were left incomplete at the time of completion of construction.

Based on the as-built plan drawing C209, 'As-Built Instrumentation – Plan' dated March 12, 2013, prepared by EBA, there should be six (6) retrievable coupons in buried manholes and three (3) direct burial corrosion installation points installed along the dam crest. These were not observed in the field, as it is presumed they are buried below the crest road fills.

Based on discussions with NTPC, the intended function and monitoring methodology for the corrosion monitoring system is not well understood.

Stantec has contacted the manufacturer of the corrosion monitoring system (RST Instruments) who has provided some e-mail interactions which occurred between themselves and the Engineer-of-Record, Chris Grapel (at the time with EBA). This information is attached in Appendix F. NTPC should seek additional clarification from EBA or the EOR on the outstanding components that remain to be installed for this system, how it is to be monitored, how to interpret the results, as well as what threshold values should be considered. These details should be incorporated into the OMS manual.

As this stainless steel liner system is the only component which provides an impermeable barrier within the rockfill dam, it will be critical to be able properly monitor it for potential signs of corrosion.

5.3.4 Settlement Monitoring Points

Nineteen (19) settlement monitoring points have been installed at the dam site. Eighteen (18) have been installed along dam crest (nine (9) each along the up and downslope sides of the crest, respectively) with one (1) additional settlement monitoring point installed on the right abutment. The settlement monitoring point locations are as shown on the as-built plan drawing C209, 'As-Built Instrumentation – Plan' dated March 12, 2013, prepared by EBA. The protection covers (steel pipe with threaded caps) were observed in the field, however they were not able to be opened. The exact details (material, installation depth, etc.) of the settlement markers is not known as no known as-built detail drawings exist.

As-built detail drawings, as well as instrument cross sections showing the settlement monitoring points should be produced.

In 2015, NTPC had a follow up to the as-built elevation/location survey completed. However, the as-built elevations and the follow-up survey elevations are not in agreement as the datum for each survey was not the same.

Going forward, NTPC should have all surveys completed with the same datum. It is recommended that annual surveys be completed.

5.3.5 Seepage Monitoring

As noted in Section 5.1 seepage has been observed at the toe of the dam in the area of the former river channel since the commissioning of the dam. It is understood that various ideas have been discussed in order to allow for the installation of a weir, such that the seepage could be monitored more closely and the flow rate measured, however no acceptable solution has been identified.

At present, NTPC staff complete a visual observation of the seepage colour and rate on a monthly basis (when the toe is not frozen) and anecdotally note whether or not a significant change has occurred. NTPC should continue to explore the options to install both a weir and a system to monitor both the seepage rate and water quality/turbidity. This information will greatly aid in the understanding of the seepage through the foundation, potential erosion of soil infilled joints and water levels within the dam.

5.4 RESERVOIR

No review of the Bluefish Lake reservoir slopes was completed as a part of this DSR. It is Stantec's general understanding that there are no significant slopes along the reservoir and that the basin is mostly bedrock controlled.

5.5 SEISMIC CONSIDERATIONS

As a High consequence structure, the Association of Professional Engineers and Geoscientist of British Columbia (APEGBC) professional practice guidelines for Site Characterization for Dam Foundations in BC consider that the seismic hazard model from the 2015 National Building Code of Canada (NBCC) is appropriate for use as the Bluefish dam is founded on competent rock.

As a High consequence structure, the CDA Guidelines indicate the EDGM associated with an AEP of 1 in 2,500 years should be considered. During the initial design process completed by EBA, the 2005 NBCC seismic hazard model was utilized to determine the Peak Ground Acceleration (PGA) for an Annual Exceedance Probability (AEP) of 1 in 2,475 years (2% in 50 years), reported as 0.06 g in the EBA documentation.

Based on the 2015 NBCC for an AEP of 1 in 2,475 years and adjusted for Site Class A conditions (competent rock), the PGA for the Bluefish Dam site can be taken as 0.027g, a reduction of greater than 50% from the value considered in the original design.

5.6 ANALYSIS

5.6.1 Slope Stability

Stantec has completed a slope stability assessment to assess the factor of safety of potential slip surfaces along the up and downstream slopes of the Bluefish dam under various conditions for the as-built conditions documented for the dam.

Two-dimensional stability analyses were completed by determining the factor of safety (FoS) against slope instability using the Morgenstern-Price limit equilibrium slope stability method. The commercial software program Slope/W, developed by Geo-Slope International Ltd., was utilized to carry out the analyses.

For the 2016 DSR, Stantec has assessed the factor of safety against slope instability of the dam at a representative section at Station 0+160. Station 0+160 was chosen as the dam height is greatest in this area, the former river channel passes below the dam here, it is within the area where ice damning is observed in the winter, and persistent fluctuations in the piezometers occur.

Stantec has considered six (6) stability cases, with some additional sub-cases, as follows:

1) Forebay water levels at the FSL of 168.78 m (Normal), Tailwater level at 159.5 m and highest recorded piezometer levels for SP06 (163.5 m) and SP07 (159.5 m), Static conditions – Downstream slope
2) Forebay water levels at the FSL of 168.78 m (Normal) and highest recorded piezometer levels for SP06 and SP07, Pseudo static (PGA = 0.027g) – Downstream slope
3) Forebay water levels at the FSL of 168.78 m (Normal) and potentially higher piezometer levels for SP06 and SP07 due to ice damning along the downstream toe, Static conditions – Downstream slope
    a. Stantec has completed a partial threshold analysis for this scenario whereby the water level was increased in 1m increments to simulate potential water build up in the downstream shell due to ice build-up. A similar analysis should be completed for all piezometers.
4) Forebay water levels at the FSL of 168.78 m (Normal), Static – Upstream Slope
5) Forebay water levels at the FSL of 168.78 m (Normal), Pseudo static (PGA = 0.027) – Upstream Slope
6) Forebay water level at the minimum allowable level of 165.73 m – Upstream Slope

For each case/sub-case, Stantec has carried out a stability analysis to assess the factor of safety of a significant slip surface along the main dam embankment as well as for the dam toe (lower toe road). To achieve 'significant' slips surfaces, the minimum depth of failure considered was 2 m.

As only free-draining soils were used in the dam, no undrained or rapid drawdown analyses were considered. Further, no analysis was completed for the IDF forebay water level of 170.22 m, as there is no known impact to downstream water levels (and thus downstream stability) for this scenario.

As there is no tailwater/pond level monitoring data, Stantec has inferred the level based on our site observations and the piezometer data, and selected a level of 159.5 m for the analysis completed here within. For the design conditions, EBA considered a tailwater/pond elevation of 161 m.

The soil conditions and parameters used in the analyses are as noted in Table 5-1. The geometry of the dam slopes used in the analyses are as described in Section 2.2.1 and as shown on the EBA as-built drawings.

Due to the noted changes within the As-built Report (EBA) regarding the adjustments of the dam orientation to avoid faulted zones, the bedrock has been only modelled as impenetrable material with infinite strength relative to the placed gravel and rockfill materials. Similarly, for modelling purposes, the stainless steel liner and concrete key trench backfill have been modelled as impenetrable materials.

The soil properties summarized in Table 5-1, are as per the original design assumptions. Based on a review of the as-built report for material gradations and placement and compaction records, and our experience and published values for similar rockfill materials, the unit weights and strengths are considered to be appropriate.

Table 5-1: Summary of Embankment Soil Properties

Material Name	Unit Weight (kN/m³)	Strength/Phi (˚)
A – RockFill – 1 m minus	22	40
A1 – Rip-Rap – 0.5 to 1 m	22	40
B - Transition – 200 mm minus	22	40
C – Bedding – 20 mm minus	22	35
D – Concrete Key Trench	Impenetrable	
Stainless Steel Liner	Impenetrable	
Bedrock Foundation	Impenetrable	

Table 5-2 summarizes the results of the slope stability analysis. Detailed Slope/W plots are presented in Appendix G.

Based on the results summarized in Table 5-2, the Bluefish dam meets the CDA criteria for static, seismic and the temporary ice dam conditions considered for both the main embankment and lower access road.

At this time, Stantec has only completed an analysis which considers a water back-up with the downstream shell of the dam due to ice damning at the toe for a cross section at Station 0+160, for water levels up to 3 m above the highest recorded level to date. For this scenario, SP06B with a water elevation of 166.5 m, the main embankment FoS against slope instability remained at1.5. For this scenario, SP07B with a water elevation of 163.15 m (equal to the top of the lower access road), the lower access road FoS against slope instability remained at 1.4. A complete analysis should be carried out for each piezometer and associated cross section to assess the range of water levels for each piezometer which would yield an FoS against slope instability below the temporary target level of 1.3, set out by the CDA. These results would be used in the OMS and/or EPP in order to outline what course of action, if any, is appropriate when carrying out piezometer monitoring.

Table 5-2: Summary of Embankment Slope Stability Results

Case/Subcase	Main Embankment FoS/Lower Toe FoS	Required FoS	Notes
1	2.2/1.6	1.5	Minimum forced depth of 2 m
2	2.1/1.5	1.1	Minimum forced depth of 2 m
3	2.2/1.4	1.3	Minimum forced depth of 2 m, high water level from SP06 (163.5 m) carried across to dam outslope. Toe saturated.
3a	1.9	1.3	Minimum forced depth of 2 m, high water level from SP06 +1 m(164.5 m) carried across to dam outslope. Toe saturated. Lower toe stability same as for Case 3.
3b	1.6	1.3	Minimum forced depth of 2 m, high water level from SP06 +2 m(165.5 m) carried across to dam outslope. Toe saturated. Lower toe stability same as for Case 3.
3c	1.5	1.3	Minimum forced depth of 2 m, high water level from SP06 +3 m(166.5 m) carried across to dam outslope. Toe saturated. Lower toe stability same as for Case 3.
4	1.7	1.5	Minimum forced depth of 2 m
5	1.6	1.3	Minimum forced depth of 2 m
6	1.8	1.3	Minimum forced depth of 2 m

5.6.2 Filter Compatibility and Seepage Assessment

For this dam safety review, Stantec has not completed an independent detailed seepage assessment or assessment of the graded filter compatibility.

For the original design assessment, EBA completed an assessment of the filter compatibility of the aggregates used in the up and downstream filters on either side of the vertical stainless steel liner (termed as bedding and transition layer materials) and assumed the bedrock joint infill material to be predominantly fine grained soil based (clays, silts and fine sands). Based on a review of these calculations and the gradation curves of the materials placed for the dam, the graded filter meets the filter compatibility criteria as intended.

As noted in the EBA design report (Foundation Preparation and Treatment Design, Technical Memo, dated January 28, 2011), the geotechnical modeling software used to assess water flow/seepage rates and gradients consider the water flow through a continuous porous material (more realistic for soils), whereas at this site, the water flow through the foundation bedrock will be through rock discontinuities (joints/faults). As such, the software is of limited use in assessing potential seepage rates associated with specific water flow paths. Further, without a quantified rate of seepage occurring at the dam toe, or a the tailwater/pond elevation, key inputs and model calibration are difficult.

Stantec does not consider the current seepage occurring at the dam toe or the potential of bedrock joint infill erosion to be of direct or immediate concern to the overall safety or stability of the dam, but rather an economic impact as it relates to loss of power generation if seepage rates increase over time.

Currently, the seepage rate is observed to be very small. As previously recommended, a mechanism to monitor both the seepage rate and water quality/turbidity is needed. This information will aid in the understanding of the seepage through the foundation, potential erosion of soil infilled joints and aid allow for future seepage assessments to be completed if deemed necessary.

6.0 REVIEW OF DUNCAN DAM

6.1 CONCRETE DAM REVIEW

6.1.1 Past Reports and Discussion

We have reviewed the 2005 report by EBA Engineering Consultants, and the document Duncan Dam Repairs April - May 2007, and compared to the current conditions. The 2005 report noted that the concrete was damaged from freeze-thaw damage, which we have noted in the following section. The 2005 report also noted that there was leakage under the abutment. This leakage was sealed during the 2007 Duncan Dam repair. The owner has also replaced the aged operational platform as well as the wooden stoplogs were replace with metal stoplogs. After comparison to the 2005 pictures to the current conditions, minor amount of changes to the concrete has occurred during the 2007 Dam Repairs. A comparison of the picture of the 2007 repair to the current condition shows no significant changes since 2007.

6.1.2 Visual Review of the Concrete Dam and Structures

Duncan dam is a reinforced concrete structure bearing on the rock below. The pictures describe the current conditions encountered during the field review.

The following comments summarize the field conditions:

- Concrete has freeze-thaw damage on upstream side of the at the waterline.
- Operational platform and hand railing appears to be in good condition.
- Concrete has a few large cracks on the upstream side of the piers should be epoxy injected.
- Areas of spawled/eroded concrete should be patched to protect the reinforcing.
- The wooden stoplogs were replaced with metal stoplogs. The metal stop logs appear to be in good condition.
- Overall the structure has performed well for it’s age.

Figure 6-1: Upstream view of the Dam

Figure 6-2: View of the Dam from downstream.

Figure 6-3: Freeze-thaw damage/spawling at waterline

Figure 6-4: Abutment/overflow section appears to be in good condition. Interface between rock and concrete appears to be tight.

Figure 6-5: Eroded concrete at abutment upstream corner at rollway. Concrete should be rebuilt to protect from further damage.

Figure 6-6: Large cracks (2 cracks) at pier to rollway interface. Cracks should be epoxy injected

Figure 6-7: Crack visible on upstream side of both piers near rollway crest on both piers. Cracks to be epoxy injected

Figure 6-8: Downstream side of piers and side face shows signs of freeze-thaw damage. Eroded concrete zone should be patched to reinstate concrete cover

Figure 6-9: Stepped concrete added to downstream side of dam. Concrete appears to be in good conditions

Figure 6-10: Downstream pier base has eroded and some leakage is evident. Toe of pier should be repaired


Figure 6-11: Abandoned low level conduit appears to be in fair condition


Figure 6-12: Metal stoplogs on operational platform appear to be in good condition.

6.1.3 Summary of Structural Review

We have undertaken a review of the concrete and compared to the 2005 report. We have found minor changes since 2005 report and most of our recommendations are protective in nature and will extend the useful life of the structure. The owner should expect further deterioration of the concrete and with time the repairs will increase. As the changes to the structure appear to be slow, this should be added to the long term maintenance list for this structure.

Based on the current review we recommend the following:

- -cracks in the concrete should be epoxy injected to seal the concrete and protect from water ingress which may lead to concrete deterioration.
- concrete at the toe of the pier should be repaired and patched.
- the eroded abutment upstream corner should be rebuilt to reinstate the concrete.
- spawlled areas deeper than 25mm should be patched to reinstate concrete protection of the reinforcement.
- the previous report notes that the structural may need to be anchored but there were no signs of anchoring completed.

6.2 GEOTECHNICAL ISSUES

As previously discussed, the Duncan dam's right abutment consists of bedrock (likely greywacke or meta greywacke, generally massive) while the left abutment appears to consist of blast rock or rubble, likely overlying near surface bedrock.

At the time of the site inspection, the water level was low and as such limited the head on the dam and the potential for seepage around concrete/rock contacts or beneath the structure.

Minimal seepage was observed along the downstream rock/concrete contact on the right abutment, as shown in Figure 6.13. The seepage was not observed to be flowing, but rather keeping the contact wet from approximately the mid-height of the dam towards the toe.

No seepage was observed along the left abutment; however significant voids were noted in blast rock/rubble immediately adjacent to the concrete contacts. An example of the typical voids observed are shown in Figure 6.14.

A repair to the upstream left abutment, reportedly completed in 2007, which consisted of the placement of low permeability fill with overlying rock appears to be in good condition, however finer soils are exposed in the submerged area as well as within the area that the reservoir is typically operated within. During conditions when the dam is overflowing the side concrete spillways, this slope would be highly susceptible to erosion. Additional, large grained well graded blast rock 0.3 m minus should be placed along this area to protect the low permeability soils from potential erosion.

The condition of the left abutment upstream repair area is shown in Figure 6.15.

Figure 6-13: Minor seepage observed along the rock/concrete contact of the right abutment

Figure 6-14: Example of voids in blast rock/rubble of the left abutment.

Figure 6-15: Upstream left abutment conditions – exposed fine grained soils within water flow areas could be eroded at higher water elevations.

Joints and fractures in the rock on the upstream side of the right abutment are parallel to the direction of water and could also present an opportunity for seepage beneath the concrete contact at higher water elevations. This condition is shown in Figure 6.16.

Figure 6-16: Joints/fractures parallel to the direction of water flow present an opportunity for seepage to pass beneath the concrete during higher water elevations.

6.3 RESERVOIR

No review of the Duncan Lake reservoir slopes was completed as a part of this DSR. It is Stantec's general understanding that there are no significant slopes along the reservoir and that the basin is mostly bedrock controlled.

6.4 SEISMIC CONSIDERATIONS

As previously discussed in section 2.2, there is no known design information available for the Duncan Dam.

As a low consequence structure, the APEGBC guidelines consider that the 2015 NBCC is sufficient for determining design ground motions. Further, as a low consequence structure, the CDA Guidelines indicate the EDGM associated with an AEP of 1 in 500 years should be considered. Based on the 2015 NBCC for an AEP of 1 in 475 years and adjusted for Site Class A conditions, the PGA for the Duncan Dam site can be taken as 0.0015g.

7.0 DUNCAN DAM STABILITY

7.1 STABILITY ANALYSIS

The assessment of the global stability of the structure will be conducted in accordance with the Canadian Dam Safety (CDA) Guidelines 2007-R13. The following includes the loads and values used to assess the stability analysis.

7.1.1 Loads

7.1.1.1 Dead Loads

Dead load considered during the assessment are:

- Unit weight of Mass Concrete = 22.8 kN/m^3
- Unit weight of structural reinforced concrete = 24.0 kN/m^3
- Unit weight of water = 9.81 kN/m^3

Any weights associated with equipment (such as lifting machines, stop logs…), embedded items (such as angles, channels…) and operational platforms (such as catwalks/handrails) have also been neglected which is common in DSR.

7.1.1.2 Hydrostatic Loads

The hydrostatic loads considered in the analysis are based on values provided by the hydraulic analysis and are as follows:

Table 7-1: Hydrostatic Loads

Load Case	Headwater Level (HWL) (m)	Tail water Level (HWL) (m)
Summer (Regulated Water Level)	212.49m (697.16ft)	Below structure
Winter	212.49m (697.16ft)	Below structure
Flood	213.41m (700.16ft)	Below structure
Seismic	212.49m (697.16ft)	Below structure

Uplift pressure applied to the under the concrete structure will be assumed to vary linearly from headwater pressure at the upstream side and reduced to tailwater pressure on the downstream side. If the tailwater is below the base, then the tailwater pressure will assumed to be zero. If the base has cracked during the analysis, then the headwater pressure will be assumed to be full headwater pressure to the end of the crack under the structure. In the case of a grout curtain, then the uplift will be reduced to 2/3 at the grout line and back to tailwater pressure at the downstream side of the structure. In the case where drains are provided, then the water pressure will be modified based on the following diagrams taken from the CDA Guidelines.

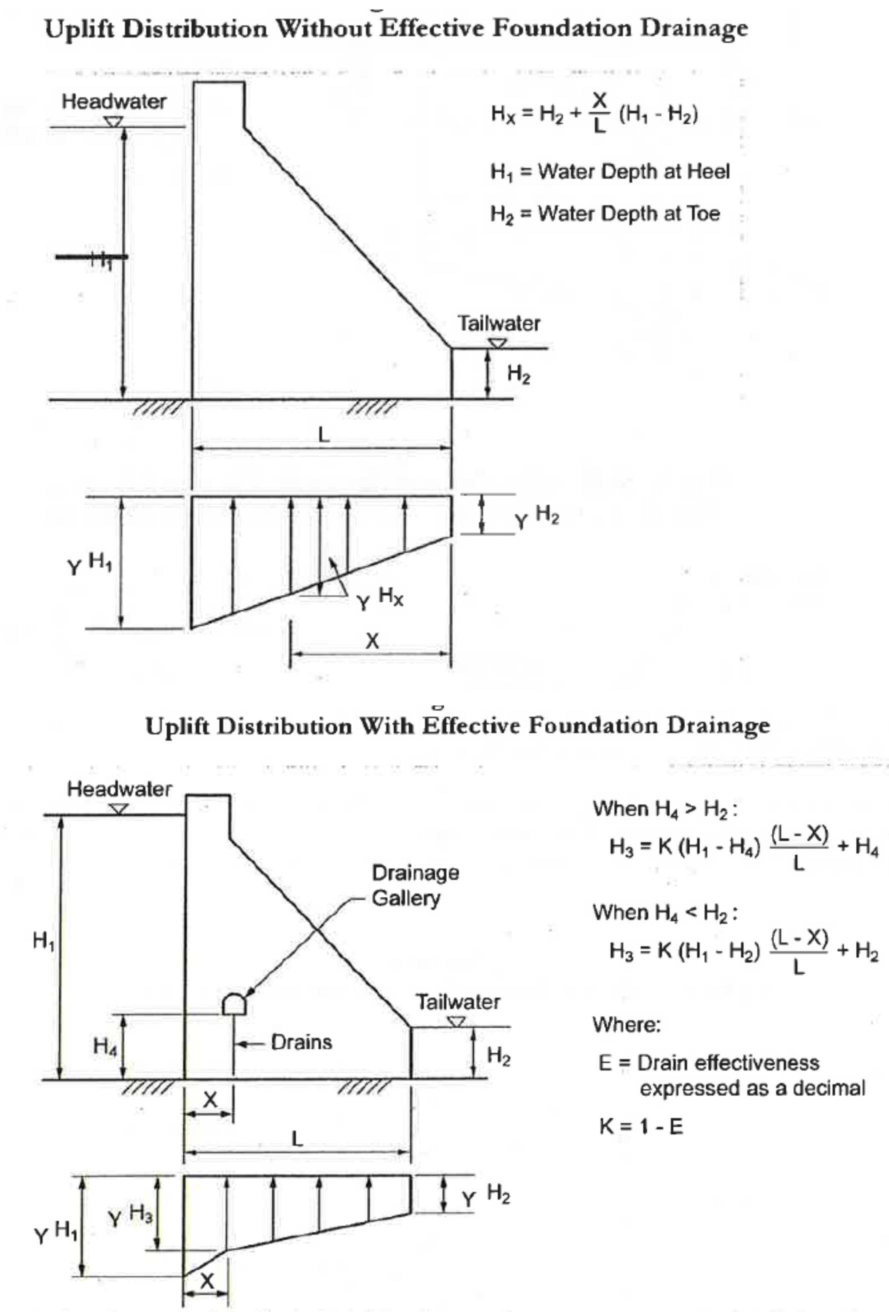

Figure 7-1: CDA Guidelines Diagrams

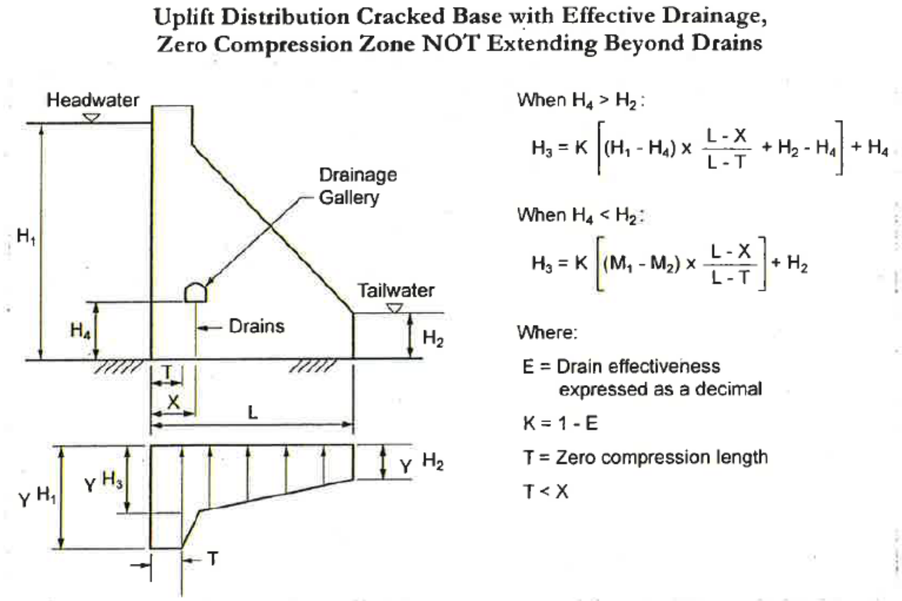

Figure 7-2: CDA Guidelines Diagrams

7.1.1.3 Live Loads

Live loads associated with people or equipment have been neglected.

7.1.1.4 Silt Loads

If silt is present upstream of the structure, then the saturated unit weight will be assumed to be 21 kn/m^3. We have not taken any measurements to validate the assumed density.

7.1.1.5 Ice Loads

The force of ice against the structure will be 150 KN/m and will at 300mm below the water surface which is provided in section 4.6 of the CDA guidelines.

7.1.1.6 Earthquake (Seismic) Loads

The seismic forces used in the analysis have been provided from the Government of Canada 2015 National Building Code Seismic Hazard Calculation software. The peak ground acceleration of 0.03g (3%g) is based on a probability of (1: 2475yrs).

The analysis will be based on a pseudo-static seismic force analysis. The increase in hydraulic pressures are based on the Westergaard equations for loads and distribution.

7.1.1.7 Drag Forces

Drag loads generated on piers are relatively small for the size of this type of structure and thus are neglected.

7.1.1.8 Soil Forces

Soil forces will be applied to the face of the upstream and downstream face if applicable. As site information has been provided, we have assumed a saturated density of 18 kN/m3 and a dry unit density of 16kN/m3.

7.1.1.9 Concrete-Rock Interface

The phi angle of the concrete-rock interface was considered to be 20 to 34 degrees as provided by the geotechnical engineers.

7.1.2 Load Combinations

7.1.2.1 Cases of Load Combinations

The load combinations considered in the review can be described in the following table:

Table 7-2: Load Combination

Case	Load Combination	Description
Summer (Regulated Water Level)	Usual	D+H+U
Winter	Usual	D+H+U+I
Flood (top of structure)	Extreme	D+H(Flood)+U
Earthquake	Extreme	D+H+U + Q
Post- Earthquake*	Extreme	D+H+U*

*post cracking if occurs may increase uplift pressures

- D = Dead Load
- H = Hydraulic Loads
- U = Uplift associated with corresponding water pressures
- I = Ice Load

7.1.3 Acceptance Criteria

7.1.3.1 Acceptance Criteria

The acceptance criteria have been adopted form the CDA Guidelines. For further clarification refer to the CDA Dam Safety Guidelines 2007-R13.

7.1.3.2 Sliding Safety Factor

The sliding safety factor will be considered acceptable if the following is satisfied (Figure 7-3). During this review cohesion is assumed to be zero unless otherwise validated. We will back calculate the cohesion for discussion purposes.

Loading combination	Position of resultant force (percentage of base in compression)	Normal compression stress [note 1]	Sliding safety factor		
			Friction only	Friction and cohesion [note 2]	
				With tests	Without tests
Usual	Preferably within the kern (middle third of the base: 100% compression); however, for existing dams, it may be acceptable to allow a small percentage of the base to be under 0 compression if all other acceptance criteria are met [note 3]	<0.3 × f_c'	≥1.5	≥2.0	≥3.0
Unusual	75% of the base in compression, and all other acceptance criteria must be met	<0.5 × f_c'	≥1.3	≥1.5	≥2.0
Extreme flood	Within the base, and all other acceptance criteria must be met	<0.5 × f_c'	≥1.1	≥1.1	≥1.3
Extreme earthquake	Within the base, except where an instantaneous occurrence of resultant outside the base may be acceptable	<0.9 × f_c'	[note 4]		
Post-earthquake	Within the base	<0.5 × f_c'	≥1.1 [note 5]	[note 6]	

Note 1. Where f_c' = compressive strength of concrete.

Note 2. Given the significant impact a very small amount of cohesion can have on shear resistance of small and medium-sized dams, the use of a cohesive bond in calculating the sliding safety factor should be done with extreme caution.

Note 3. It is very important to verify that all possible failure modes have been addressed under a potential cracked base scenario.

Note 4. The earthquake load case is used to establish post-earthquake condition of the dam.

Note 5. If post-earthquake analysis indicates a need for remedial action, this condition should not be allowed to remain for any length of time. Remedial action should be carried out as soon as possible such that factors of safety are increased to the level of the pre-earthquake conditions.

Note 6. Shear resistance based on friction and cohesion needs to be considered carefully, since the analysis surface may not remain in compression throughout the earthquake but may result in cracking, which will change the resistance parameters.

Figure 7-3: Sliding Safety factor

7.1.3.3 Resultant Location and perpendicular stresses

The location of the resultant will be considered acceptable if it is found to be located as follow in Figure 7-4. Compressive stress are considered acceptable as follows in Figure 7-5.

Load Combination	*Position of the Force Resultant*
Usual	Preferably within the kern (middle third of the base: 100% compression); however for existing dams, it may be acceptable to allow a small percentage of the base to be under 0 compression if all other acceptance criteria are met[1]
Unusual	75% of the base in compression and all other acceptance criteria must be met
Extreme	Within the base and all other acceptance criteria must be met

Figure 7-4: Position of the Force Resultant

Load Combination	*Normal Compression Stress*
Usual	$< 0.3xf'_c$
Unusual	$< 0.5xf'_c$
Extreme – Flood	$< 0.5xf'_c$
Extreme – Earthquake	$< 0.9xf'_c$
Post-earthquake	$< 0.5xf'_c$

Figure 7-5: Normal Compression Stress

7.2 STABILITY RESULTS

The assessment of the stability of the structure based on the previous section and in accordance with the Canadian Dam Safety (CDA) Guidelines 2007-R13 has the following results:

We have found that the structure is below the CDA recommendations for global stability.

Structure would rely on cohesion to stabilize the structure and as such we have determined the amount of cohesion to satisfy a sliding safety factor (SSF). The cohesion values above are conservative but should be confirmed.

The winter ice forces described in CDA most likely have not been generated as the long approach channel would result in ice bridging and may reduce the ice forces.

Table 7-3: Duncan Dam (Main Spillway middle section) Friction Angle = 34 degrees, EL = 682.16ft

Case	Sliding Safety Factor (SSF)	Uplift Safety Factor (USF)	Maximum Base stress (kpa)	Position of resultant	Length of base in compression	Results
Summer (Regulated Water Level)	1.19	2.63	53.0	Kern	100%	SSF below CDA recommendations; (C=55kpa, SSF = 3.0)
Winter	0.49	2.63	-	No	-	Fails in sliding and rotation, winter ice forces not realized to CDA standards.
Flood	0.89	2.28	67.0	Yes	100%	SSF below CDA recommendations; (C=15kpa, SSF = 1.3)
Earthquake	1.1	2.54	53.3	Kern	100%	Satisfactory

Table 7-4: Duncan Dam (Main Spillway middle section) Friction Angle = 20 degrees, EL = 682.16ft

Case	Sliding Safety Factor (SSF)	Uplift Safety Factor (USF)	Maximum Base stress (kpa)	Position of resultant	Length of base in compression	Results
Summer (Regulated Water Level)	0.64	2.63	53.0	Kern	100%	SSF below CDA recommendations; (C=135kpa, SSF = 3.0)
Winter	0.26	2.63	-	No	-	Fails in sliding and rotation, winter ice forces not realized to CDA standards.
Flood	0.48	2.28	67.0	Yes	100%	SSF below CDA recommendations; (C=60kpa, SSF = 1.3)
Earthquake	1.1	2.54	53.3	Kern	100%	Satisfactory

7.3 COMPARISON AND REVIEW OF PAST REPORTS

We have reviewed the 2005 report for Duncan:

- The previous DSR did not provide any comparative values and only reported that the stability factors are less than the 1.5 requirement for sliding and overturning. The report indicated that the repair measures would increase the safety values.

The recommendations regarding Duncan Dam stability are presented in section 10.2.2 of this report.

8.0 REVIEW AND UPDATE OF OPERATION, MAINTENANCE & SURVEILLANCE MANUAL

As stated in the CDA Guidelines, 2013, "the operation, maintenance, and monitoring of dams encompass many activities and constraints defined to ensure the dam is managed with appropriate regard for safety. Documentation to explain the procedures and practices is important to ensure the safe operation of the dam under various conditions. This documentation should also cover the impacts of operations on the public, the environment and other stakeholders. Maintenance activities should be prioritized, carried out, and documented with consideration of dam safety and the implications of failure. Surveillance, including visual inspections and instrument monitoring, is the cornerstone of a dam safety management system, since it is the means for checking whether the dam is performing satisfactorily against criteria established during design or subsequent analysis."

NTPC's OMS Manual for the Bluefish Hydro development was released in January 2010. Since 2012, a new dam was constructed 300 m downstream the old Bluefish Dam (1940) and the main parts of the old dam were removed. OMS Manual needs to be updated considering the new dam facilities features with respect to the present DSR and as per the requirements of the CDA Guidelines. So far, other modifications that have been done in the revised OMS Manual are summarized below.

8.1 REVIEW OF PREVIOUS DSR

The 2005 DSR identified some deficiencies about the previous OMS. With the construction of the new Bluefish some of them are no more applicable and are not discussed in this DSR. The following table lists the 2005 DSR deficiencies and the remedial actions made by NTPC since.

Table 8-1: OMS review of previous DSR

	2005 DSR Deficiencies	NTPC remedial action
Operation and Testing	An operations procedure does not exist for the stoplogs lifting at Duncan Dam;	Operating procedures are quickly defined in the OMS, but must be more detailed.
	Operations, Maintenance, and Surveillance Manuals do not exist for Bluefish Dam or Duncan Dam.	An OMS Manual was completed in 2005 with a revision in 2010. It has been completely reviewed by Stantec as part of this DSR. The 2016 OMS Manual now respects CDA Guidelines.
Maintenance	Maintenance on Duncan Dam has been conducted sporadically since 1994 with focus on reducing the amount of seepage passing beneath the dam. However, it appears that all the known maintenance activities were of a temporary nature (i.e. upstream liner, sand bags placed on upstream toe of dam).	A maintenance program has been documented, but no maintenance sheet applies specifically to Duncan Dam. Works have been done to limit seepage on Duncan dam in 2007.
Inspection and Monitoring	Informal inspections of Bluefish Dam and Duncan Dam are conducted by NTPC operations crews. However, these inspections do not follow any template nor focus on critical dam safety aspects of the dams. Furthermore, the results of these inspections are not recorded nor documented with photographs.	A dam safety surveillance program has since been documented by NTPC inspection sheets are available, evaluated and recorded.

8.2 REVIEW OF OMS MANUAL

The OMS Manual should include a summary of key information related to the dam site. The OMS presentation format of the has been modified as per Stantec standard and many sections were added. The following modifications have been done regarding the project description:

- An Introduction section has been added. It includes the mandate, the OMS manual purpose, a record of revision Table and a list of the existing document used for the OMS Manual.
- In the General section, information about the Authorities, the Project Location, the Hydrology, the GS Facilities, the Site Access, the Communication System, the Public Safety, the Site Security has been added to the Dam General Description.
- The main characteristics of both dam were summaries in two Tables as well as other operating criteria and constraints.
- The Dam Classification section was updated and a Site History section which contains the detailed description of the facilities has been added and updates have been made regarding the new Bluefish Dam. The Spillway Description and Capabilities section was removed because this part is already mentioned in the dam description;
- Operational Responsibilities and Permanent Record File sections has been moved in the Operation section.

8.2.1 Operation

The purpose of defining operation constraints is to ensure operation of the dam does not violate any design assumptions that could affect the safety of the dam. The followings deficiencies have been corrected regarding dam operation:

- Role and responsibility were summarised in a Table with the contact name. The contact list in the reporting section was replaced by the one in the 2012 EEP and added in appendices. NTPC must check if the information is still accurate.
- A Table with all the Permanent Record File, their location and their timeframe review was also created and must be verify by NTCP;
- The Inflow Design Flood (IDF) section has been updated for both dams as per the present DSR (inflow, reservoir elevation and freeboard);
- Operating Procedure were incomplete for normal, flood and emergency conditions as per CDA Guidelines and mostly concerns the power plant. Divers information from the old OMS Manual where regrouped in these sections and updated. Additional information is also given:
    - Normal Operations section presents the minimal and average Reservoir Inflow, Reservoir Allocations (Elevation-Storage curves), the normal operation water level, the Reservoir Release Procedures and Criteria, the spillway rating curves and the Ice and Debris Handling.
    - Flood Operations section presents the Operating Objectives and Rule for Pre-Spilling and Flood-Routing, the procedure in case of IDF and the water level surveillance and decision.
    - Emergency operations sections include a description of events that could lead to the emergency plan activation and the monitoring operation to determine the action to be taken according to the EPP.
    - Operating procedures for Unsual operation such as flow control equipment shutdown rapid drawdown events, inability to access site, sudden increase of seepage, etc. should be prepared. It should outline internal notifications, interim contingency plans for deviation from normal operations, dispatch of additional maintenance staff, criteria for return to service, warning systems, etc.
- Forecasting Methodology and Snow Survey sections were moved in appendices, no update were done. The water balance section has been moved in the Flood Operation section.
- Information about Operation Reports, Emergency Repairs, Standard Operating Procedures and Worker Safety were added but could be improved. All the operation at Bluefish Hydro must be reported.
- Sections about Power Plant Operations (Bluefish G1 and G2) such as Turbine Operating Parameters, Rating Curves, Operational Philosophy, Operating Procedures were moved in appendices since the mandate terms were only for the dam facilities.

8.2.2 Maintenance

Maintenance programs ensure operational availability, safe operations, and integrity of dams. The followings modifications have been made in the OMS maintenance section:

- There is no maintenance program for Duncan Dam. A preventive maintenance program has been detailed for the Embankment, Spillway Structures, Tunnels and Penstock, Site Access and Safety Measures at both dams.
- Maintenance programs for the Head Gate and Power Plant were not modified. All the maintenance sheet are available in appendices.
- Maintenance reports should list the components requiring maintenance, the interval of time, the type of maintenance completed, the problems encountered, the date and the name of the person who did the maintenance. This list is used to keep track of all maintenance and facilitate the planning of future maintenance activities;

8.2.3 Surveillance

The purpose of surveillance is to have warnings prior to adverse consequences. As part of their monitoring activities, NTPC provided Annual Inspection of NTPC Hydro Dams Reports from 2013 and 2016 showing all the repairs and maintenance that should be done, but the completion of these recommended activities are not indicated. The following modifications have been made in the OMS surveillance section:

- Inspection sheets, frequency and results evaluators for visual inspection were already given for routine, engineering (intermediate) and special (comprehensive) inspections but more information have been added. Inspection sheet were moved in appendices. A section for the Dam Safety Review was also added.
- After the evaluation of inspections results by NTCP staff, a procedure for documents storage and required follow up actions to findings must be detailed
- Except water level, there is no instrumentation at Duncan Dam. Information about the new Bluefish Dam Instrumentation have been added, but more documentation and analysis is needed to identify the measuring procedure, the failure modes identification, the reading frequency, the threshold values, the required maintenance and calibration, the recording, the data processing and follow-up actions, etc.

8.2.4 Testing

Mechanical and electrical equipment testing is required to demonstrate that the equipment is in good working conditions and can pass the required flow.

- A testing procedure and checklist for flow control equipment, auxiliary equipment, power supplies and control system is available in each plan. The frequency of testing is at least once a year for normal condition and frequency per equipment vary. For flow control equipment, a full flow test should be carried out periodically and a contingency plan is needed if a problem occurs during test. Test results must be recorded in a log book.

- For good practices, emergency operations and back up procedure (manual operation) should also be tested with operating staff and documented.

9.0 REVIEW OF EPRP AND PUBLIC SAFETY

9.1 EMERGENCY PREPAREDNESS AND RESPONSE PLAN

The Emergency Preparedness Plan (EPP) is prepared as General Contingency Plan (GCP). This GCP is a requirement set out in the Bluefish Water License MV2005L4-0008, issued April 3, 2006. Enabling legislation for the Water License is the Northwest Territories Water Act. The GCP must, as a minimum, meet the requirements of an Emergency Preparedness Plan (EPP) detailed in the Dam Safety Guidelines, published by the Canadian Dam Safety Association (2007; 2013 revision).

The information contained in the document includes all the requirements for an Emergency Response Plan (EPP), and an Emergency Response Plan (ERP). NTPC's EPP for the Bluefish Hydro development was released in September 2010. Since 2012, a new dam was constructed downstream the old Bluefish Dam (1940). The EPP manual has not be completely revised since the new dam is in function. The EPP must be updated considering the new dam facilities features with respect to the present DSR. The review of the EPP is part of Stantec mandate, and the modification have been included by Stantec in the 2016 revision of the EPP.

9.1.1 Review of previous DSR

The 2005 DSR identified some deficiencies. With the construction of the new Bluefish some of them are no more applicable and are not discussed in this DSR. The following table lists the 2005 DSR deficiencies and the remedial actions made by NTPC since.

	2005 DSR Deficiencies	**NTPC remedial action**
Preventative Action	Indicate preventative action to be taken in the event of dam failure	The EPP has been previously reviewed to indicate that the stoplogs needs to be removed at Duncan Dam to lower water pressure on the dam.
Notification procedures and flow chart	Missing phone numbers for RCMP, charter aircraft companies and Emergency Measures Organization. No Dam Failure categories missing in the Emergencies .	The phone list as been previously reviewed to include only the dam related emergencies, including dam failure. The charter aircraft companies phone numbers are still missing.
Communication systems	Mention that emergency power supply for the communication system can be provided by generator.	This precision has been added in the EPP as part of this review in 2016.
Site access	Include a statement that no access road exists to Bluefish Dam	The EPP has been previously reviewed to include this statement
Equipment sources	Include brief inventory of materials present on site	The EPP has been previously reviewed to include the materials on-site.
Inundation Map	Include inundation map in case of failure	The map have been added to the EPP as part of this review in 2016.
Warning systems	Include existing signage at the dams	Not required.

9.1.2 Review of EPP

All the following comments have been added to the 2016 Stantec revision of the EPP.

9.1.2.1 Distribution List

A distribution list was added and should be filled with all the persons who have a copy of the EPP.

9.1.2.2 New Bluefish Dam

Some information in the description of the facilities included reference to the old and new dam. All references to the old dam have been removed.

9.1.2.3 PMF and IDF flows

The EPP presented PMF flows, but no indication was made regarding the IDF. The revised IDF value of this DSR have been added to the EPP, with a description of these values.

9.1.2.4 Dam failure analysis, consequences of failure and dam classification

The consequence classification of the old EPP refered to 1995 CDA Guidelines. CDA Guidelines have been re-issued in 2007 (with a revision in 2013) and the dam classifications has changed. All references to the 1995 CDA classification has been removed. As part of this DSR, consequences associated with dam failure have been identified and dam classification has been revised. Bluefish dam is a “high” consequence dam, and Duncan dam is a “significant” dam. The 2016 dam break results (tables) were incorporated in the EPP. These results include the approximate travel times and river incremental depth of the flood wave, a requirement for the EPP.

9.1.2.5 Inundation mapping

No inundation mapping has been done before this DSR. The inundation maps were added at the end of the EPP, and a summary of the assumptions of this study has been provided.

9.1.2.6 Identification of EOC and SCP

The location of the Site Command Post (SCP) and the Emergency Operation Centre (EOC) were not described. The SCP will be Bluefish power house and the SCP will be in NTPC Yellowknife Office.

9.1.2.7 Update Contact List and Phone Numbers

The EPP’s contact information where last updated in October 2011. As described in section 1.6 of the EPP “the internal contacts list will be updated annually, and the date of update noted on the contact list”. We recommend that NTPC follows its update procedure and updates its list annually.

9.1.3 Distribution of the EPP

The 2016 revision of the EPP, part of this DSR mandate, must be distributed to all the required persons, and the old version should be archived.

9.2 PUBLIC SAFETY AND SECURITY

9.2.1 Public access

There is no road to access both dams. NTPC staff uses helicopters to access both site. In winter, there are ice roads on the various lakes of the region (including Prosperous, Bluefish and Duncan Lakes). When the ice roads are open, a thick ice cover is observed in front of both dams and few hazard is present. Public access is possible by hiking in summer. In winter, public access could be possible if someone wants to cross the entire Prosperous Lake (over 16 km drive). Hiking has been observed around Bluefish Dam, and vandalism was observed in the past, but is not a recurring issue. Since the signs and fences were added during the reconstruction, no public access issues are to be considered.

Duncan Dam is remote and no public access is possible. No fences, booms nor signage is present, but since no interaction is foreseen, it is not a safety issue. If public access occurs in the future, safety measures must be implemented.

9.2.2 Safety boom at Bluefish

The north boom was designed for the expected water velocity of 1.1 m/s and the south boom was designed for the expected velocity of 0.86 m/s during IDF flow. They are correctly located and prevent access close to the dam.

Figure 9-1: Safety booms upstream and downstream of Bluefish dam.

9.2.3 Signage and fences

Sufficient signage and fences are presents at Bluefish so no more actions are required.

Figure 9-2: Signs and protection fence at Bluefish dam.

9.2.4 Guardrails

Guardrails are present at both locations. They are easily visible (yellow) and provide NTPC personnel safety. Buoys are present on the guardrails in case of fall in the water.

Figure 9-3: Guardrails

9.2.5 Requirements for Public Safety

Due to the difficult access to the dam, public interaction is almost none for both dams. Many public safety features are present for Bluefish dam. Therefore, we consider the actual measures to be sufficient. In the actual conditions there is no need, to produce a Public Safety Plan (PSP) as per CDA Guidelines for Public Safety Around Dams.

10.0 CONCLUSION AND RECOMMENDATIONS

10.1 CONCLUSIONS

With the data given by NTPC, Stantec developed a methodology to computed the discharge coefficient for Bluefish free overflow spillway. Since only low flows over the spillway occurred since the dam is in function, the discharge coefficient has not been calibrated, but when high flows will occur in the future, NTPC will have the methodology to calibrate the coefficient. The theorical discharge curve for the overflow spillway is given in this DSR. The 2005 discharge curves for Duncan Dam still applies.

All freeboard requirements are met for Bluefish Dam. Duncan dam respects the normal freeboard requirements. Overtopping would not cause a failure at Duncan, therefore the minimum freeboard requirement is not problematic.

Bluefish Dam can pass the PMF and is not likely to have a failure by overtopping. Piping is the most likely mode of failure of Bluefish dam. Duncan dam is in concrete and overtopping would not cause dam failure. The most likely mode of failure is concrete collapse.

A dam break analysis and inundation mapping was performed in this DSR, and conclude that incremental consequence of Bluefish dam would affect only NTPC's Bluefish buildings. Bluefish dam would have a big economical impact as a loss of power production would greatly impact Yellowknife. Bluefish dam has a classification of "high", with a IDF of 387 cms (1/3 between 1000-year and PMF).

No incremental consequences are associated with the failure of Duncan dam, and the failure of Duncan dam would not cause a cascade failure of Bluefish Dam. Therefore, Duncan dam has a classification of "significant", with a IDF of 131 cms (300-year' recurrence). Stantec reviewed the IDF for both locations, and computed the revised IDF value for Duncan Dam.

Since the gates of Bluefish dam are not required to ensure the safety of the dam (because the overflow spillway can pass the PMF), no backup system is necessary to operate the gates.

The instrumentation on Bluefish dam should be monitored with procedures. Recommendations are issued regarding the need for equipment and monitoring. Bluefish dam meets the CDA criteria for static, seismic and the temporary ice dam conditions considered for both the main embankment and lower access road. Bluefish dam graded filter meets the filter compatibility criteria. Stantec does not consider the current seepage occurring at the dam toe or the potential of bedrock joint infill erosion to be of direct or immediate concern to the overall safety or stability of the dam, but rather an economic impact as it relates to loss of power generation.

Stability analysis of Duncan Dam showed that the structure is below the CDA recommendations for global stability. Sliding Factor of Safety are below 1 for winter and flood scenarios, showing deficiencies. Normal conditions have Factor of Safety over 1, but do not respect CDA requirements. Earthquake condition respects CDA requirements.

A review and complete update of the OMS manual was performed as part of this DSR. The previous OMS manual appears to have been made with previous CDA Guidelines. All the OMS has been re-written using a structure that meets all the requirements of the CDA Guidelines.

A review and update of the EPP was part of Stantec mandate. The 2016 revision should be considered as the current version.

Public safety measures are sufficient, and no PSP is required in the actual conditions.

10.2 RECOMMENDATIONS

10.2.1 Bluefish dam

- Sections 4.3.1.2.6: When high flows occur over the overflow spillway, take measurements of water level in the lake, downstream flow, IFR flow and plant flows (eventually hourly measurement). These measurements can later be used to calibrate a discharge coefficient using higher flow rates.
- Section 5.2: As noted in previous reports by others, the concrete sill poured to correct the over blast of the rock along the spillway could provide an area of concern where water between the rock and concrete could subject to freeze thaw cycles could result in additional seepage paths below the concrete. Sealing of the voids is recommended in order to avoid accelerated degradation.
- Section 5.2: Periodical survey of the elevation of the sill is recommended in order to monitoring displacement over time.
- Section 5.3.1 As-built piezometer detail drawings for each set of piezometers as well as cross sections at instrumented sections should be completed by EBA and kept as a record by NTPC as well as added to the OMS manual.
- Section 5.3.1 It is recommended that NTPC continue to use the spreadsheet developed by Stantec as means of storing all piezometer monitoring data or develop their own spreadsheet with similar function.
- Section 5.3.1 If a piezometer cannot be monitored (access/frozen), there is an issue with a piezometer, or it is dry, will be important for NTPC staff to document these details for all future piezometer monitoring events.
- Section 5.3.1 It is recommended that a staff gauge be installed to allow for period monitoring of the tailwater/pond water elevation.
- Section 5.3.1 It is critical that a series of analyses be completed to determine what the threshold water level is for each piezometer and the results of this analysis be incorporated into the OMS manual and ERP such that appropriate action is taken when the piezometers are monitored.
- Section 5.3.1 The collected data should also be processed in a timely manner such that any potential errors or anomalies can be corrected immediately.

- Section 5.3.2 As-built thermistor detail drawings for each thermistor string (with node locations and elevations) as well as cross sections at thermistor sections should be completed by EBA and kept as a record by NTPC and incorporated in the OMS manual.
- Section 5.3.2 NTPC should request the connection cable and readout device from thermistor cable installation contractor, or alternatively, a new readout box and connection can be purchased from RST Instruments. Stantec has included a cost quotation for this equipment and has provided this information in Appendix E.
- Section 5.3.2 It is recommended that once a connection cable and readout device are obtained, that monthly monitoring be completed for at least the first two (2) years to begin to develop a temperature profile of the soil/rock in contact with the cables throughout the significant ambient temperature changes that occur at this dam site throughout the year. An assessment should be made after two (2) years if the frequency of the monitoring can be reduced to capture specific monitoring periods within the year.
- Section 5.3.3 NTPC should seek additional clarification from EBA or the EOR on the outstanding components that remain to be installed for this system, how it is to be monitored, how to interpret the results, as well as what threshold values should be considered. These details should be incorporated into the OMS manual.
- Section 5.3.4 As-built detail drawings, as well as instrument cross sections showing the settlement monitoring points should be produced.
- Section 5.3.4 Going forward, NTPC should have all surveys completed with the same datum. It is recommended that annual surveys be completed.
- Section 5.3.5 At present, NTPC staff complete a visual observation of the seepage colour and rate on a monthly basis (when the toe is not frozen) and anecdotally note whether or not a significant change has occurred. NTPC should continue to explore the options to install both a weir and a system to monitor both the seepage rate and water quality/turbidity. This information will greatly aid in the understanding of the seepage through the foundation, potential erosion of soil infilled joints and water levels within the dam.
- Section 5.6.1 A complete analysis should be carried out for each piezometer and associated cross section to assess the range of water levels for each piezometer which would yield an FoS against slope instability below the temporary target level of 1.3, set out by the CDA. These results would be used in the OMS and/or EAP in order to outline what course of action, if any, is appropriate when carrying out piezometer monitoring.

10.2.2 Duncan dam

- Section 6.1.3: Concrete under the left pier should be repaired and any crack injected with flowable grout to prevent water from flowing under the pier. This will also reinstate the compression zone in the downstream area of the pier.

- Section 6.1.3: The owner may consider the addition of rock anchors to achieve the safety factors in the CDA guidelines.
- Section 7.3: There was no indication of the actual rock to concrete friction values in past documents. The range of 20 to 34 degrees might be conservatively low and should be reviewed to confirm the value before anchoring is undertaken.
- Section 7.3: It's probable that the original design used cohesion to satisfy the stability of the structure which should be investigated and confirmed.
- Section 7.3: The narrow approach channel to the structure may have resulted in ice force lower than values from CDA. The actual ice force should be confirmed.

10.2.3 Operations, Maintenance, and Surveillance

- Section 8.2: The NTPC OMS manual was updated as per requirements of the CDA Guidelines 2007 and the 2016 Dam Safety Review. The part of the OMS that concerns both power plants was not modify and should be updated. The contact information should be updated if required.
- Section 8.2.: It is recommended to keep track of all the operation, maintenance, inspection and the tests performed at the Bluefish Hydro Dams in a project log. Procedures, criteria, schedule should be detailed for all conditions operations. Follow-up actions after the evaluation of results should be documented.

10.2.4 Emergency Preparedness Plan

- Section 9.1.2.1: A distribution list is now present in the EPP and should be filled by NTPC with all the persons who have a copy of the EPP.
- Section 9.1.2.7: The EPP's contact information where last updated in October 2011. We recommend that NTPC follows its update procedure which consist of and updating it annually.
- Section 9.1.3: The 2016 revision of the EPP, part of this DSR mandate, must be distributed to all the required persons, and the old version should be archived.

11.0 REFERENCE

The list of the reports reviewed in this DSR is presented in section 2.1 of this report. Other references that have been used are presented below:

- Canadian Dam Safety Guidelines 2007 – Revised 2013
- Armstrong and Nelson Site Inspection and Structural Review Report, August 9 2005

APPENDIX A:
PHOTOS OF SITE VISIT

Bluefish Dam – Aerial view 
Bluefish Dam – Spillway 

Bluefish Dam – Generating Station

Bluefish Dam – Generating Station

Bluefish Dam – Crest

Bluefish Dam – Instrumentation

Bluefish Dam – Piezometer

Bluefish Dam – IFR and Bottom gate outlet

Bluefish Dam – Spillway

Duncan Dam – Landing Pad

Duncan Dam

Bluefish Dam – Stoplogs sluiceway

Bluefish Dam – Downstream view

APPENDIX B:
DAM OPERATOR QUESTIONNAIRE

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Dam Safety – General Dam Operator Questionnaire

It is recommended that the dam operator complete this questionnaire for each site at the start of a Dam Safety Review.

This questionnaire will update information on discharge facilities and operating equipment. The information will be used to conduct the Dam Safety Review. The information is broken down into the following categories.

Part I - Site description
Part II - General Operational Information
Part III - Hydraulic Discharge and Operating Facilities
A. Discharge Facilities
B. Operating Equipment
C. Operating Problems
Part IV Past Dam Incidents
Part V - Emergency Preparedness Plan (EPP) Information

Throughout the questionnaire, the following definitions of spillway and sluice apply:

Spillway A structure over which flood flows are discharged. The discharge is uncontrolled, i.e., an overflow structure.

Sluice A structure through which flood flows are discharged; the flow is controlled by gates, stop logs or valves.

An emergency Severe flooding, possible dam failure conditions or a person(s) in danger from a boating accident or drowning.

Office: Bluefish Watershed: 7740 km^2 Site: Bluefish Dam

Prepared by: Ammar Taha Date: ~~12~~ Oct 12, 2016

Person(s) to contact for additional information: WMercredi@NTPC.com

Name: Gamini Wayne Telephone: Wayne Mercredi 867-669-3381 site 867-444-8688

Questions	Answers/Observations/Comments
Part I – Site Description (To be completed prior to distributing questionnaire. Data to be reviewed and confirmed by Operating Staff)	
1. Facilities Summary	
Type	**Number**
Sluices – gate	Bottom outlet (concrete structure with a steel sluice gate)
Sluices – log	

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Sluices – valve (Manufacturer, size, type etc.)	
Debris boom	Y
Non-overflow walls	N
Spillways/overflow walls	25 m wide, el. 168.78 m. On bedrock.
Upstream retaining walls	NA
Downstream retaining walls	NA
Other	
2. Elevation Datum (Canadian Geodetic Datum (CGD) or other – specify	Y
Part II – General Operational Information	
3. Please list any major repairs/maintenance since construction that you know of.	Construction of new dam completed in mid-october 2012, about 300 m downstream of old dam.
4. (a) Who operates this site?	☐Contractor ☑Other NTPC Operator Contact person Legal Agreement in place?
(b) How many staff are normally available to operate this site?	1
(c) Is this person/team responsible for operating other sites?	☑Yes ☐No
(e) If answer to (c) is yes, is there sufficient staff to operate these sites simultaneously?	☑Yes ☐No
(f) If answer to (e) is no, is other assistance available? (g) If yes, who and from where?	☐Yes ☐No YK
5. (a) Is an operations log book kept at the dam? (b) Is an operations log book kept elsewhere? (c) If yes to either (a) or (b), where is it located and what information is logged?	☐Yes ☐No in G2 Plant ☐Yes ☐No
(d) Do staff stay at this site during an emergency?	☑Yes ☐No
(e) How are communications maintained with the area office?	Radio / Phone

(i) at site (ii) traveling to/from site	
6. Most likely means of access under emergency conditions during: (a) Spring (b) Summer/Fall (c) Winter	 ☐Road ☐Boat ☐Snowmobile ☐ATV ☑Helicopter ☐Walk ☐Road ☑Boat ☐Snowmobile ☐ATV ☐Helicopter ☐Walk ☑Road ☐Boat ☐Snowmobile ☐ATV ☐Helicopter ☐Walk
7. Are problems or restrictions for accessing the site in an emergency situation foreseen? (a) Spring (b) Summer/Fall (c) Winter If yes, please describe (e.g. will the access road or a bridge be accessible if there is a major flood?)	 ☑Yes ☐No weather ☐Yes ☐No ☑Yes ☐No weather if ice road not in
8. Length of time it will take staff to access the site under emergency conditions.	1 hour from town 5 min on site
(a) Spring from town	☐Less than ½ h ☑½ to 2 h ☐2h to ½ d ☐½ to 1 d ☐More than 1 d
(b) Summer/Fall 5	☐Less than ½ h ☑½ to 2 h ☐2h to ½ d ☐½ to 1 d ☐More than 1 d
(c) Winter 6	☐Less than ½ h ☑½ to 2 h ☐2h to ½ d ☐½ to 1 d ☐More than 1 d
9. Once at the site, how long will it take staff to achieve maximum spill capacity (assuming headwater level is at Maximum Operating Level)? overflow ~~spil~~/spillway	☐Less than ½ h ☐½ to 1 h ☐1 h to 2 h ☐2 h to ½ d ☐½ d to 1 d ☐2 d ☐3 d ☐More than 3 d No need to operate
10. How many staff members are required to achieve maximum spill capacity for the above time estimate?	
11. (a) Are there any emergency procedures in place to deal with a dam accident or extreme flood condition? (b) If yes, what is the name of the document?	☐Yes ☑No on site Yes in ~~YK~~ YK

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Flash gate

12. How often is this dam operated?	☐Month ☒Year
13. (a) Is there a water level gauge at this site? (b) If no, is there a gauge at a dock nearby? (c) What is the location of the gauge (if applicable)? (d) To what is this gauge referenced? (e) Is the gauge metric or imperial?	☒Yes ☐No ☐Yes ☐No Headgate ☐CGD ☒Local structure datum ☐Other datum ☒Metric ☐Imperial
14. (a) Are there any recreational activities (such as boating, fishing, canoe portages, hiking or snowmobiling) in close proximity to the dam in either upstream or downstream areas? (b) If yes, please describe.	☒Yes ☐No snowmobiling, hunting boating, fishing, Portages,
15. (a) What other agencies re involved with flow regulation along the river? (b) Who are the contact people?	EC Marc Dionne Phone 867 669-4790 cell 867-446-0926
16. What else may be affected by changes in water levels?	☒Cottagers ☒Recreational boaters ☒Municipal water supply ☐Private water supply ☒Sensitives fisheries/habitat ☐Float plane landing
17. (a) Are there any known operator safety issues or equipment deficiencies? (b) If yes, please explain. (c) Has the Ministry of Labor visited the site? (d) If yes, please list any comments they made.	☒Yes ☐No No Power at gate, No building with heat ☐Yes ☐No
18. Is the public allowed on the dam?	☐Yes ☒No
19. (a) Are there any public safety concerns? (b) If yes, please explain (c) Is vandalism a problem? Please elaborate.	☒Yes ☐No hiking through site ☒Yes ☐No has been in the Past
20. What signage is provided at this dam?	☐Danger – Fast Water ☒No Trespassing ☐No Swimming ☒Other
21. (a) Is there a debris boom upstream of the dam? (b) If yes, is it chained (logs) or cable-strung (manufactured)? (c) Is it permanent or seasonal? (d) Is there a safety boom upstream? (e) Is it permanent or seasonal?	☒Yes ☐No ☒Chained ☐Cable strung ☒Permanent ☐Seasonal ☒Yes ☐No Permanent

	☒ Permanent ☐ Seasonal
22. What structural aspects of the dam do you inspect during operational visits?	dam, spill way & gates
23. Log Settings (a) What is the normal regulated water level (b) How many logs are usually in for the normal summer setting? (c) How many logs are normally removed for the winter drawdown condition? (d) How many logs can actually be removed in an emergency? (e) Is the bottom log fixed in place and not removed?	Gauge CGD local NA ☐ Yes ☐ No
Part III – Hydraulic Discharge and Operating Facilities	
A Discharge Facilities	
24. (a) Is a rating curve/table available for this site? (b) Have any structural or channel modifications been made since the date on the rating table? (e.g., different size stoplogs, additional stoplogs, shaved stoplogs, dredging, etc.) (c) If yes, please describe the modifications and how they will affect the rating table?	☐ Yes ☒ No No Rating curve ☐ Yes ☒ No
25. (a) Does fully open represent lifting the gates clear of the deck? (b) If no, can they be easily lifted clear of the deck during an emergency?	☐ Yes ☐ No ☒ Not applicable ☐ Yes ☐ No ☐ Note applicable
26. (a) Have all log sluices and/or all gate sluices ever been fully opened? (b) If yes, under what headwater elevation and when? (c) If no, what is the constraint?	☐ Yes ☐ No ☒ Not applicable for maintenance
B Operating Equipment	
27. Type of equipment used to operate the discharge facilities:	
(a) Sluice Operation with disel electric	☒ Crab winch ☐ Spud winch ☐ Other – specify With: ☒ Diesel ☐ Electric ☐ Hand ☐ Other - specify

(b) Log Chutes and other outlet works	☐Crab winch ☐Spud winch ☐Other – specify With: ☐Diesel ☐Electric ☐Hand ☐Other - specify
28. (a) Is primary (pole) power available at the site? (b) Is auxiliary power available? (c) If yes, specify source. on site but not to the dam	☒Yes ☒No ☐Not applicable ☒Yes ☐No ☐Not applicable generator
29. (a) Is the discharge facility operating equipment located at the site (keys, winch handles, chain falls, etc.)? (b) If no, where are they located? (c) Is there more than one set?	☑Yes ☐No ☐Not applicable ☐Yes ☑No
30. (a) If the gates are automated, is the operation remotely controlled? (b) If yes, from where?	☐Yes ☒No ☐Not applicable
31. (a) Have any backup provisions been made should the equipment fail? (b) If yes, what are the provisions? (c) If yes, is the backup located on site? (d) If no, where is backup located?	☒Yes ☐No ☐Not applicable manual ☐Yes ☐No
32. If the backup is located off-site, how much more time is required to achieve maximum discharge?	5 hrs manual
33. (a) Has the mechanical equipment ever failed? (b) If yes, when did the failure occur? (c) What was the nature and extent of the failure? (d) Has it been satisfactorily repaired?	☐Yes ☒No ☐Note applicable dust for testing last year in fall time fish gate Bolt Broken ☐Yes ☐No
C Operating Problems	
34. (a) Are there problems that may reduce the number of stop logs which can be removed or the number of gates that can be opened during normal or flood conditions? (b) If yes, please describe.	☐Yes ☐No ☒Not applicable
35. (a) Has debris blockage ever occurred at this site? (b) If yes, at what time of the year does blockage	☑Yes ☐No ☐Not applicable Spring

occur? (c) What was the nature & extent of the blockage?	☐All the time ☐During spring only ☐During floods only
36. Is there potential for debris from upstream to interfere with operations at the site under:	
(a) Normal Operation	☑Yes ☐No ☐Not applicable
(b) Flood/Emergency Operation	☑Yes ☐No ☐Note applicable
(c) If the answer to (a) or (b) is yes, please describe the situation.	No trash rack & at spill gate
37. (a) Is there a debris management program in place (e.g. debris boom, regular removal of debris, etc.)?	☑Yes ☐No
(b) If yes, briefly describe program.	Booms in Place
38. (a) Do ice jams affect this site?	☑Yes ☐No
(b) Are there special operations to accommodate ice jam inflows?	☐Yes ☐No
(c) Do ice jams block/hinder discharge facilities?	☑Yes ☐No
(d) Do ice jams break booms?	☑Yes ☐No
(e) If answer to any of the above is yes, please describe the situation.	in the fall when we have ice forming a wind can break it up causing a ice dam
39. Has an ice sheet formation been observed:	
(a) in the headpond or reservoir area?	☑Yes ☐No
(b) against the intake headwork?	☑Yes ☐No ☐Not applicable
(c) against the gate sluices?	☑Yes ☐No ☐Not applicable
(d) against the log sluices?	☐Yes ☐No ☐Not applicable
(e) against gravity walls/bulkheads?	☐Yes ☐No ☐Not applicable
40. (a) Are there any measurements or other estimates of the ice thickness?	☐Yes ☑No
(b) If yes, please indicate these.	
41. What is the duration of the headpond/reservoir ice cover (months)?	Dec To End of May
42. Is the frozen headpond generally covered with snow?	☑Yes No
43. (a) Are any photographs of the headpond ice conditions available?	☑Yes ☐No
(b) If yes, where are they located and when were they taken?	NTPC
44. (a) Are there any other observations regarding ice cover?	☑Yes ☐No

Ice Boom is Broken by Ice and ice hit the ~~head~~ trash Rack and gate was blagued. 2 years a go

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(b) If yes, please describe.	
45. (a) What is the deck surface? (b) Describe snow/ice removal concerns.	☑Concrete ☐Wood ☑Metal grating
Part IV – Past Dam Incidents	
46. Describe any past dam incidents (such as seepage, overflow during flooding, sinkholes in the headpond, washout of an abutment, etc.)	seepage D.S.
Part V – EPP Information	
47. Please provide the following emergency contact phone numbers. (a) Dam Operator No (b) Alternate Dam Operator (c) District Emergency Response Coordinator (d) Regional Engineer (e) Provincial Response Center (f) OPP (g) Medical Emergencies	Name Office # Home# Cell# old EPP at YN
48. (a) Are there permanent residents living within 0,5 km downstream of the dam? (b) If yes, please indicate their names and phone numbers.	☐Yes ☑No Name Phone #
49. (a) Is there an access road to this site? (b) Who maintains the access road to the site? (c) Is this access road plowed in the winter and spring?	☐Yes ☑No ☐Yes ☐No ☐Not applicable
50. (a) Is there emergency equipment available at the site such as life preservers and a firs-aid kit? (b) If not available at the site, where are the nearest available ones?	☑Yes ☐No First aid building
51. Note and describe any physical features that use you use to cue yourself that water levels are abnormal (both during flood and drought).	

3 operators 1 every week

Wayne

Frank

Tony

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Discharge Facilities

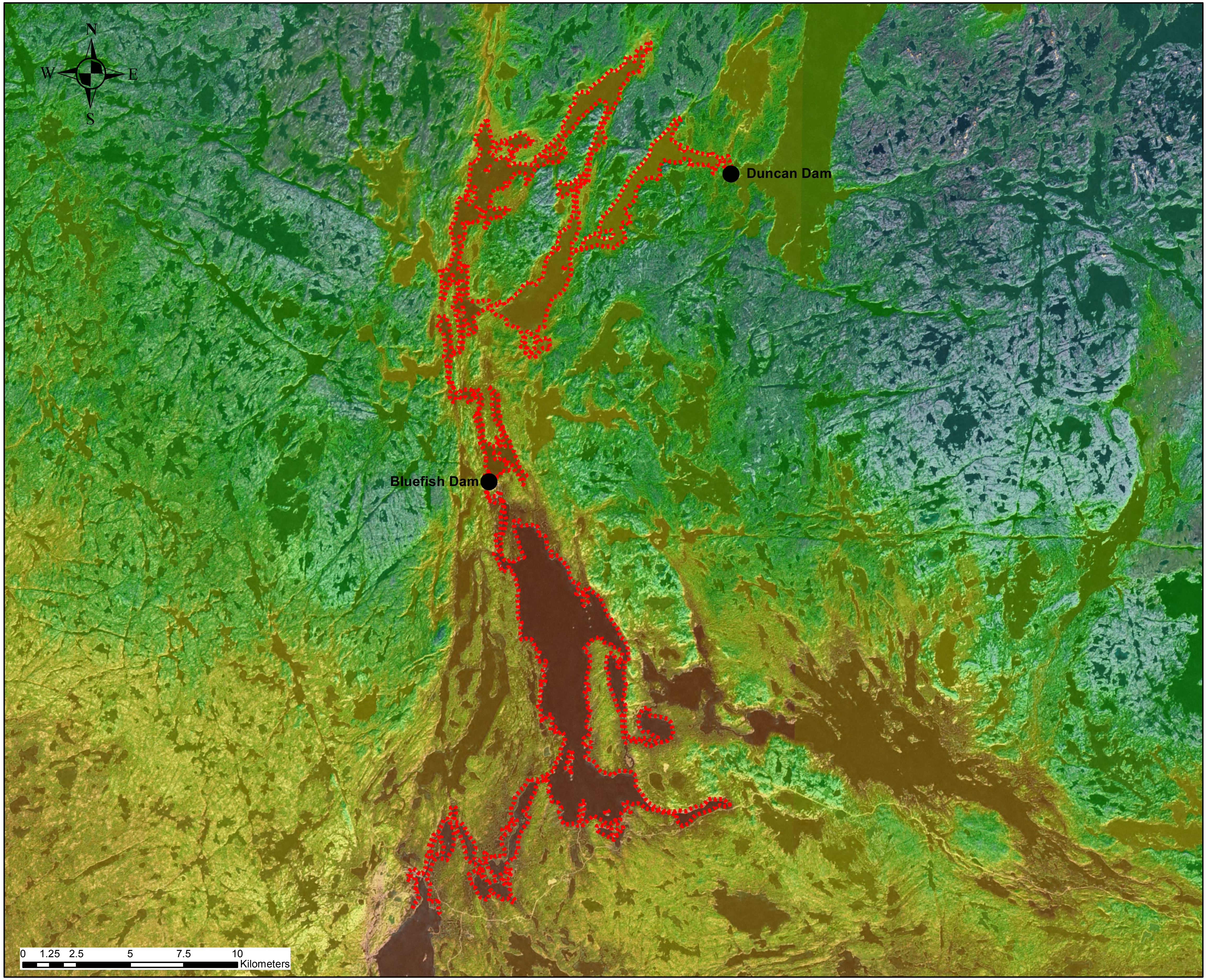
(One line for each discharge structure – sluices, spillways, turbines, etc.)

Facility	Structure					Rating Table		Operation			
	Number/ID	Width (m)	Crest/Sill Elev. (m)	Log Height (m)	Capacity (m^3/s)	Table No.	Date	Log Sluices			Gate Sluides[1] Yes/No/ Unknown
								Logs per Sluice	Logs that can be Removed		
									Normal Condition	Emergency Condition	
over flow spillw											
Low level gate											
Fish gate											
Road gate											

1- Can gates be fully opened under emergency conditions? If no, to what percentage can they be opened?

No, Low level gate → Because of Ice
Fish gate ↗

APPENDIX C: INUNDATION MAPPING (STANTEC 2016)



10 cm 5 4 3 2 1 0

Legend

Duncan IDF-Dambreak

Elevation

<VALUE>

- 152.6 - 156.5
- 156.6 - 160.4
- 160.5 - 164.2
- 164.3 - 168.1
- 168.2 - 173.9
- 174 - 179.7
- 179.8 - 183.6
- 183.7 - 189.4
- 189.5 - 193.2
- 193.3 - 197.1
- 197.2 - 202.9
- 203 - 206.8
- 206.9 - 210.6
- 210.7 - 214.5
- 214.6 - 220.3
- 220.4 - 224.1
- 224.2 - 228
- 228.1 - 233.8
- 233.9 - 239.6
- 239.7 - 243.5
- 243.6 - 247.3
- 247.4 - 251.2
- 251.3 - 255.1
- 255.2 - 260.9
- 261 - 266.7
- 266.8 - 270.5
- 270.6 - 274.4
- 274.5 - 280.2
- 280.3 - 286
- 286.1 - 289.8
- 289.9 - 295.6
- 295.7 - 299.5

Note: At this scale, the flooding limits of the three studied scenarios are overlapped, and only one flooding limit is shown.

Client
Northwest Territories Power Corporation

Project
Bluefish Hydro Comprehensive Dam Safety Review

Title
Duncan Dam Inundation Mapping

Stantec

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Scale As shown
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Sequence No.
01 of 09

Serv. char.	Project	Wbs	Disc.	Type	Drawing No.	Rev.
	159100263	120	HY		01	

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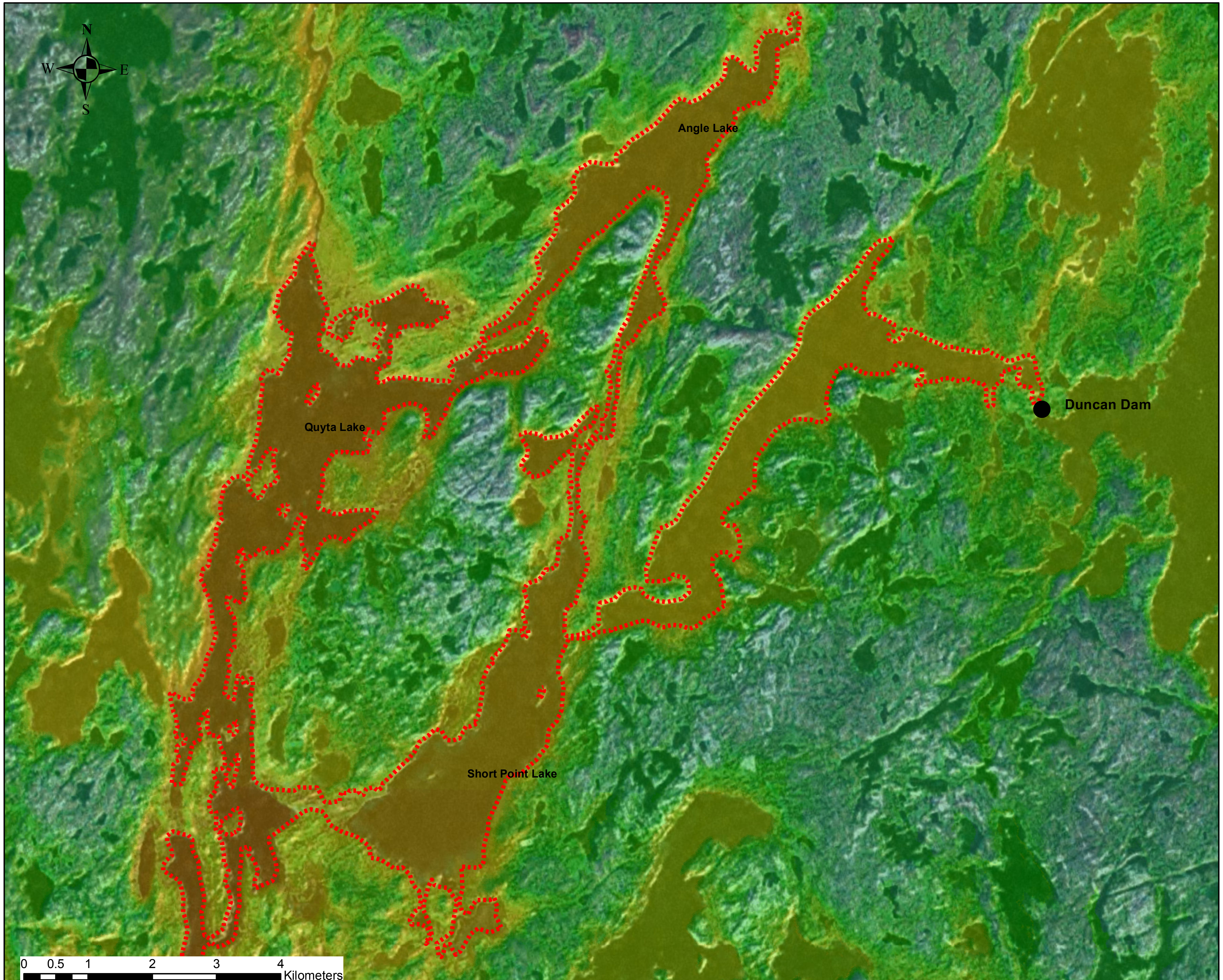

Legend

Sheet1$ Events

Duncan IDF-Dambreak

Elevation

<VALUE>

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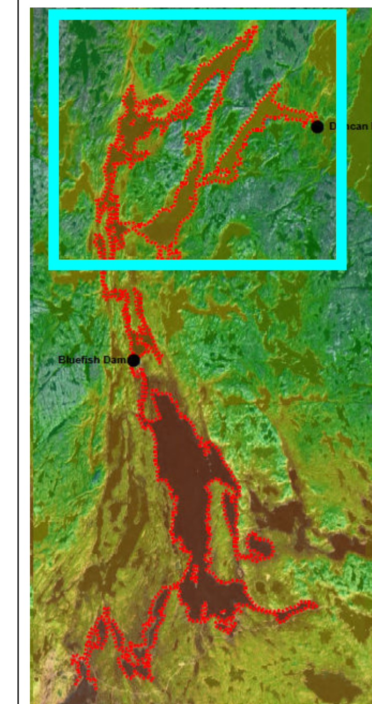
- 183.7 - 189.4
- 189.5 - 193.2
- 193.3 - 197.1
- 197.2 - 202.9
- 203 - 206.8
- 206.9 - 210.6
- 210.7 - 214.5
- 214.6 - 220.3
- 220.4 - 224.1
- 224.2 - 228
- 228.1 - 233.8
- 233.9 - 239.6
- 239.7 - 243.5
- 243.6 - 247.3
- 247.4 - 251.2
- 251.3 - 255.1
- 255.2 - 260.9
- 261 - 266.7
- 266.8 - 270.5
- 270.6 - 274.4
- 274.5 - 280.2
- 280.3 - 286
- 286.1 - 289.8
- 289.9 - 295.6

Note: At this scale, the flooding limits of the three studied scenarios are overlapped, and only one flooding limit is shown.



Client
Northwest Territories Power Corporation

Project
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Title
Duncan Dam Inundation Mapping

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Scale	As shown
Date	2016-12-06
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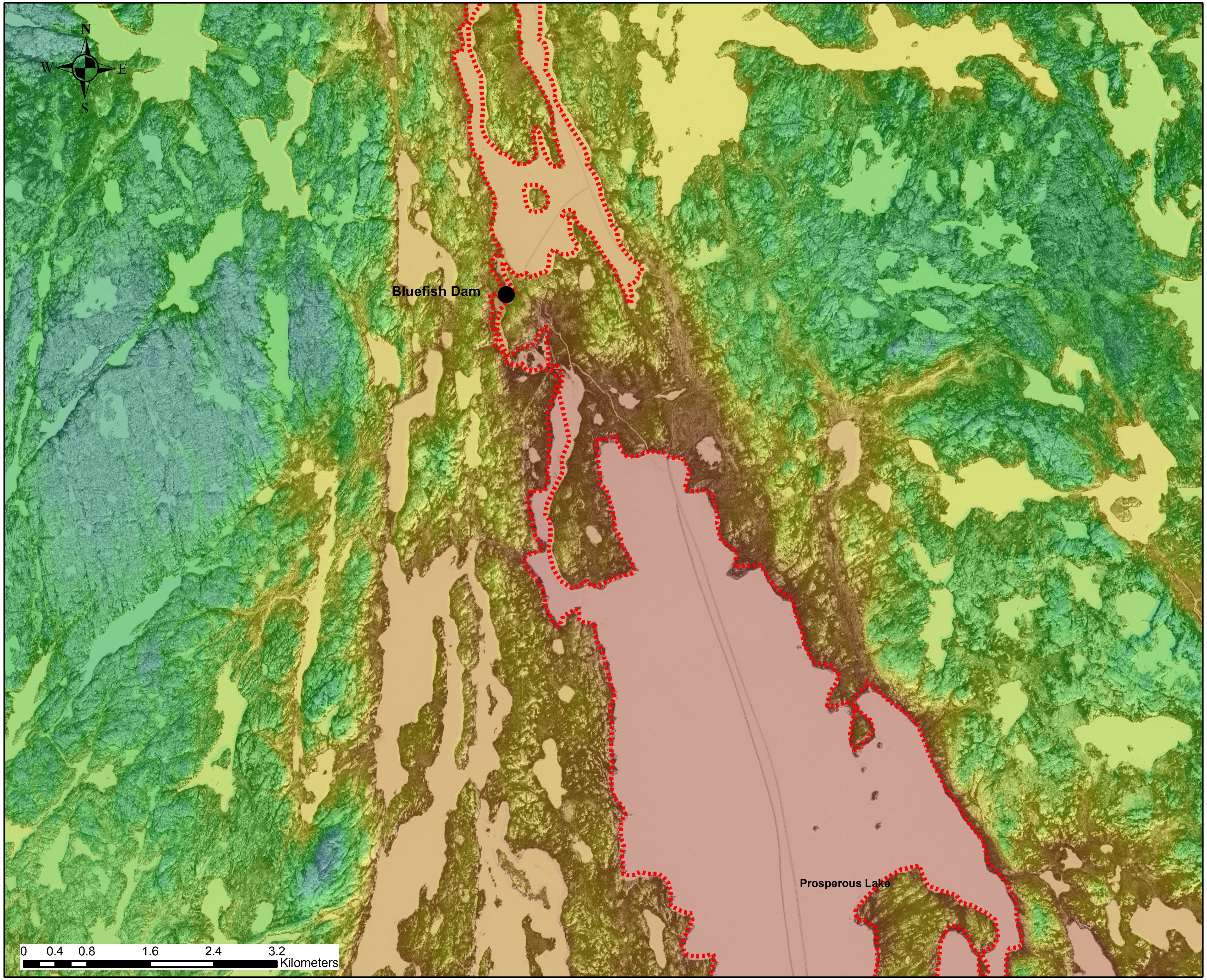
Sequence No.	02 of 09

Serv. char.	Project	Wbs	Disc.	Type	Drawing No.	Rev.
	159100263	120	HY		02	

References

10 cm 5 4 3 2 1 0



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Sheet1$ Events

Duncan IDF-Dambreak

Elevation

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- 156.6 - 160.4
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- 183.7 - 189.4
- 189.5 - 193.2
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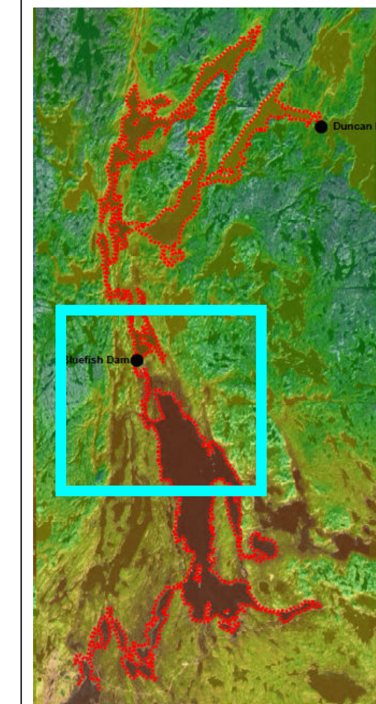
- 210.7 - 214.5
- 214.6 - 220.3
- 220.4 - 224.1
- 224.2 - 228
- 228.1 - 233.8
- 233.9 - 239.6
- 239.7 - 243.5
- 243.6 - 247.3
- 247.4 - 251.2
- 251.3 - 255.1
- 255.2 - 260.9
- 261 - 266.7
- 266.8 - 270.5
- 270.6 - 274.4
- 274.5 - 280.2

Note: At this scale, the flooding limits of the three studied scenarios are overlapped, and only one flooding limit is shown.



Client
Northwest Territories Power Corporation

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Bluefish Hydro Comprehensive Dam Safety Review

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Discipline Hydrotechnical
Scale As shown
Date 2016-12-06

Project Manager Ammar Taha, P.Eng, Ph.D.

Sequence No. 03 of 09

Serv. char.	Project	Wbs	Disc.	Type	Drawing No.	Rev.
	159100263	120	HY		03	

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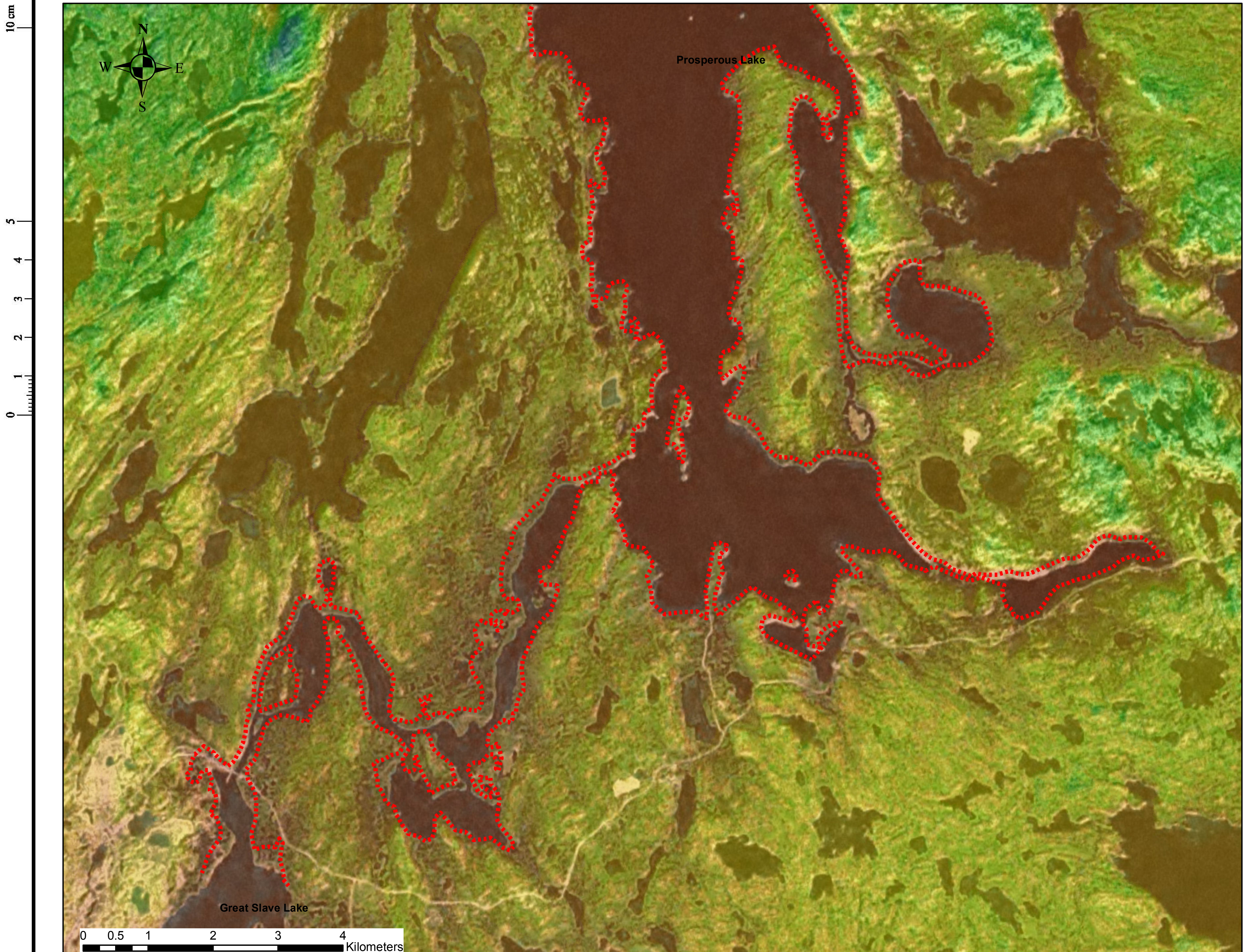

Legend

Sheet1$ Events

Duncan IDF-Dambreak

Elevation

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- 174 - 179.7
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- 183.7 - 189.4
- 189.5 - 193.2
- 193.3 - 197.1
- 197.2 - 202.9
- 203 - 206.8
- 206.9 - 210.6
- 210.7 - 214.5
- 214.6 - 220.3
- 220.4 - 224.1
- 224.2 - 228
- 228.1 - 233.8
- 233.9 - 239.6
- 239.7 - 243.5
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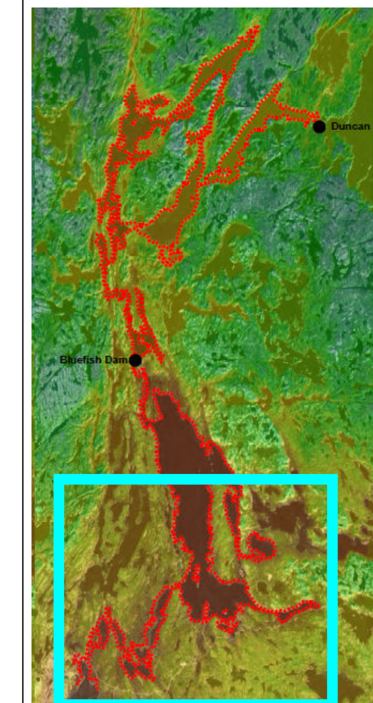
- 247.4 - 251.2
- 251.3 - 255.1
- 255.2 - 260.9
- 261 - 266.7
- 266.8 - 270.5
- 270.6 - 274.4
- 274.5 - 280.2

Note: At this scale, the flooding limits of the three studied scenarios are overlapped, and only one flooding limit is shown.



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Scale As shown
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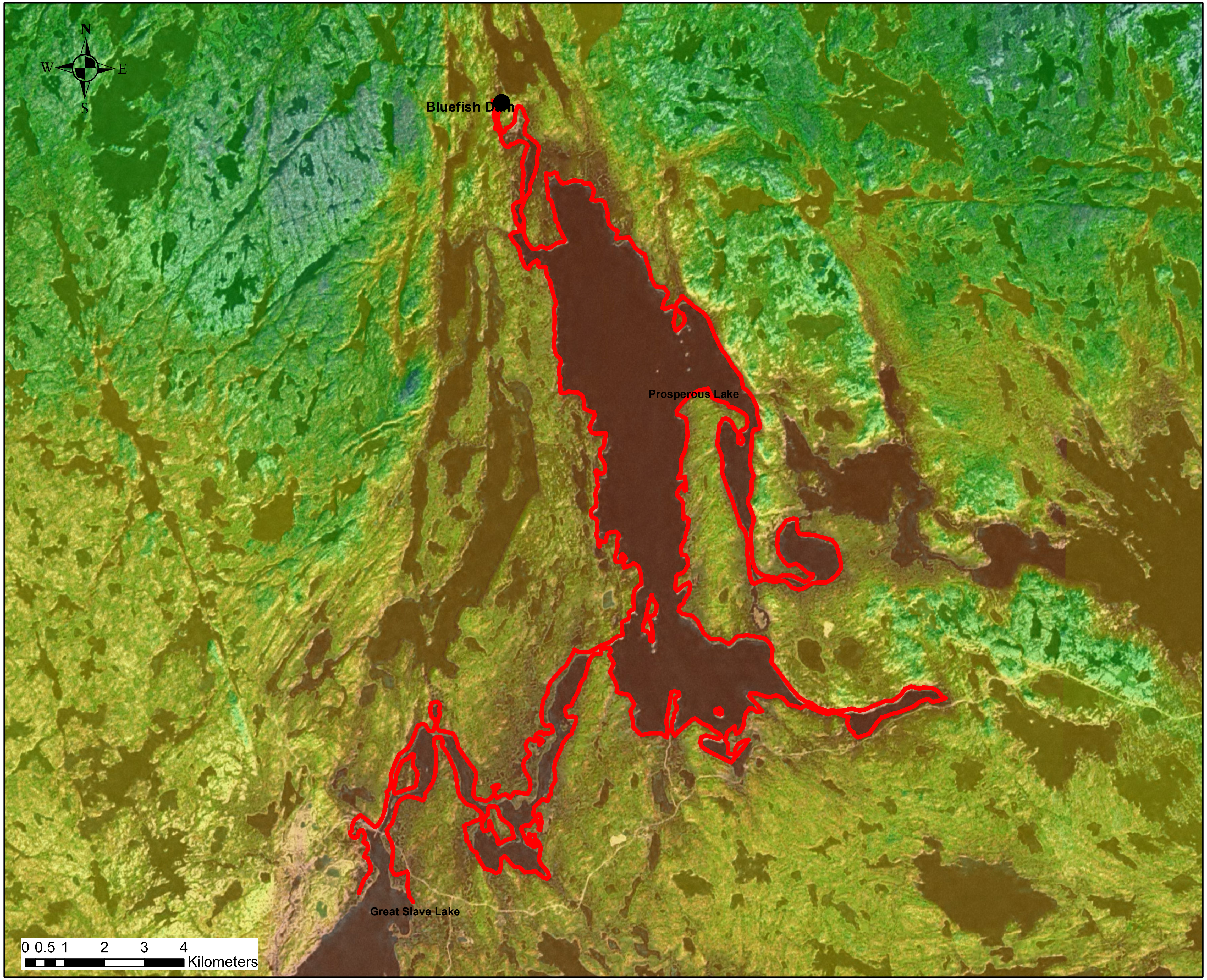
Serv. char.	Project	Wbs	Disc.	Type	Drawing No.	Rev.
	159100263	120	HY		04	

References



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Bluefish IDF-Dambreak

Elevation

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- 174 - 179.7
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- 183.7 - 189.4
- 189.5 - 193.2
- 193.3 - 197.1
- 197.2 - 202.9
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- 206.9 - 210.6
- 210.7 - 214.5
- 214.6 - 220.3
- 220.4 - 224.1
- 224.2 - 228
- 228.1 - 233.8
- 233.9 - 239.6
- 239.7 - 243.5
- 243.6 - 247.3
- 247.4 - 251.2
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- 255.2 - 260.9
- 261 - 266.7
- 266.8 - 270.5
- 270.6 - 274.4
- 274.5 - 280.2

Note: At this scale, the flooding limits of the three studied scenarios are overlapped, and only one flooding limit is shown.

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Date 2016-12-06

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Sequence No. 05 of 09

Serv. char.	Project	Wbs	Disc.	Type	Drawing No.	Rev.
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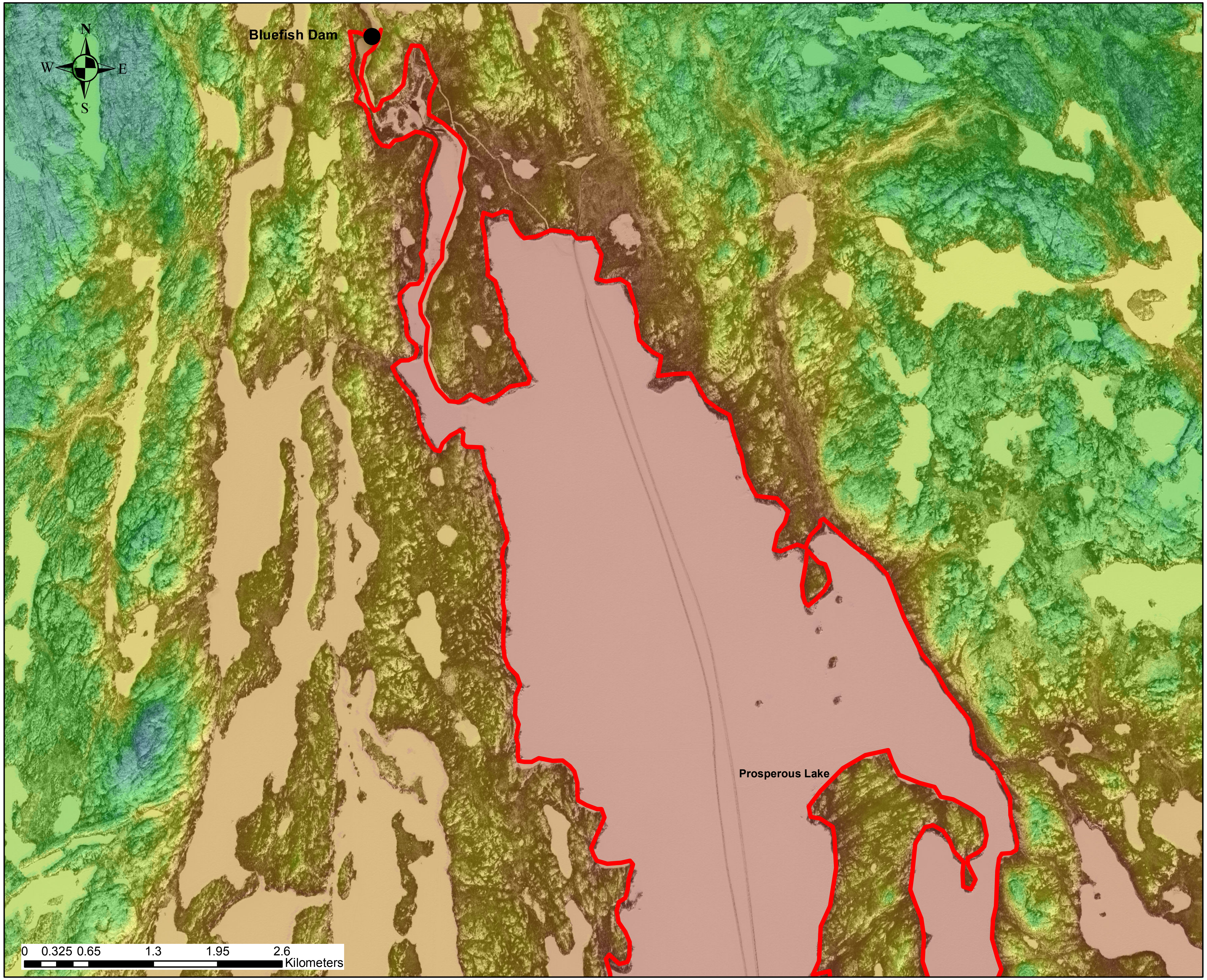

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Bluefish IDF-Dambreak

Elevation

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- 174 - 179.7
- 179.8 - 183.6
- 183.7 - 189.4
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- 197.2 - 202.9
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- 206.9 - 210.6
- 210.7 - 214.5
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- 224.2 - 228
- 228.1 - 233.8
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- 239.7 - 243.5
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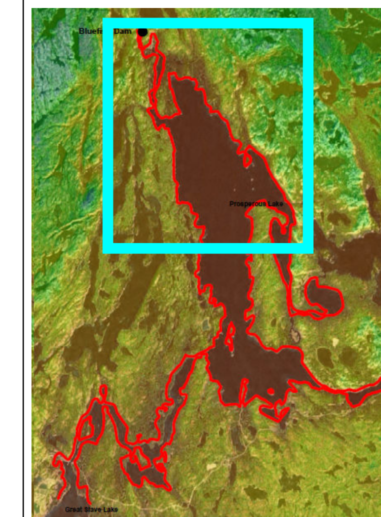
Note: At this scale, the flooding limits of the three studied scenarios are overlapped, and only one flooding limit is shown.



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Sequence No. 06 of 09

Serv. char.	Project	Wbs	Disc.	Type	Drawing No.	Rev.
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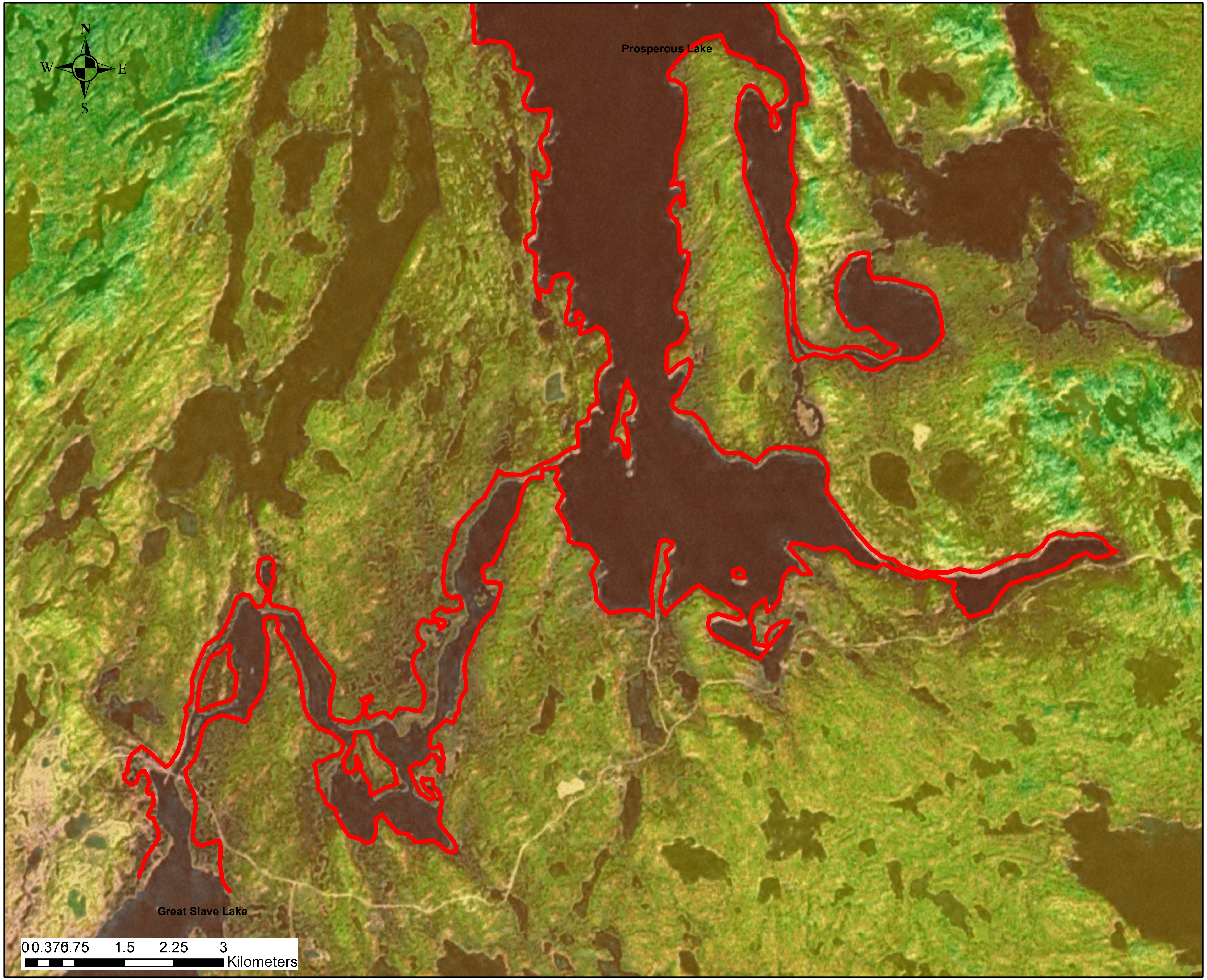

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Bluefish IDF-Dambreak

Elevation

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- 174 - 179.7
- 179.8 - 183.6
- 183.7 - 189.4
- 189.5 - 193.2
- 193.3 - 197.1
- 197.2 - 202.9
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- 261 - 266.7
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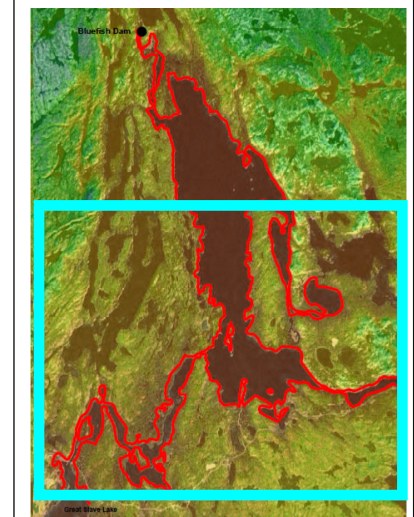
Note: At this scale, the flooding limits of the three studied scenarios are overlapped, and only one flooding limit is shown.



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Northwest Territories Power Corporation

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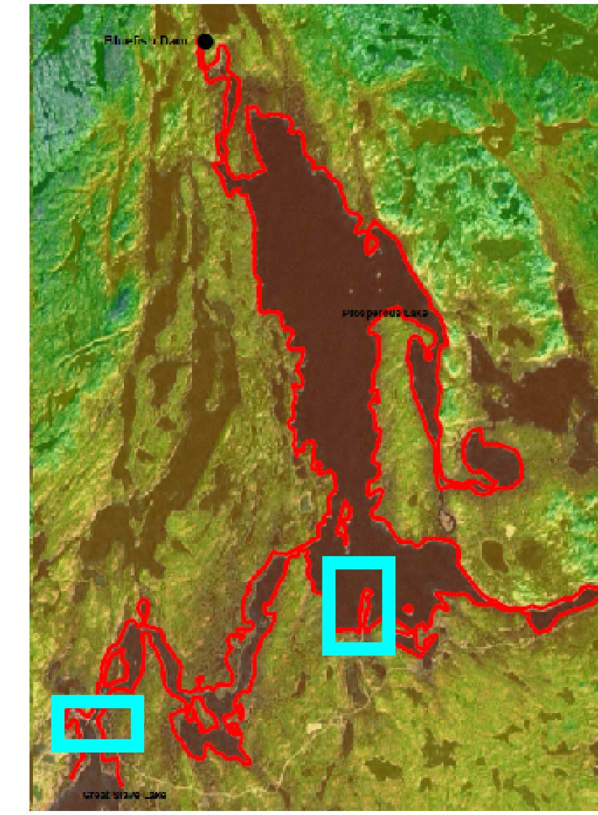
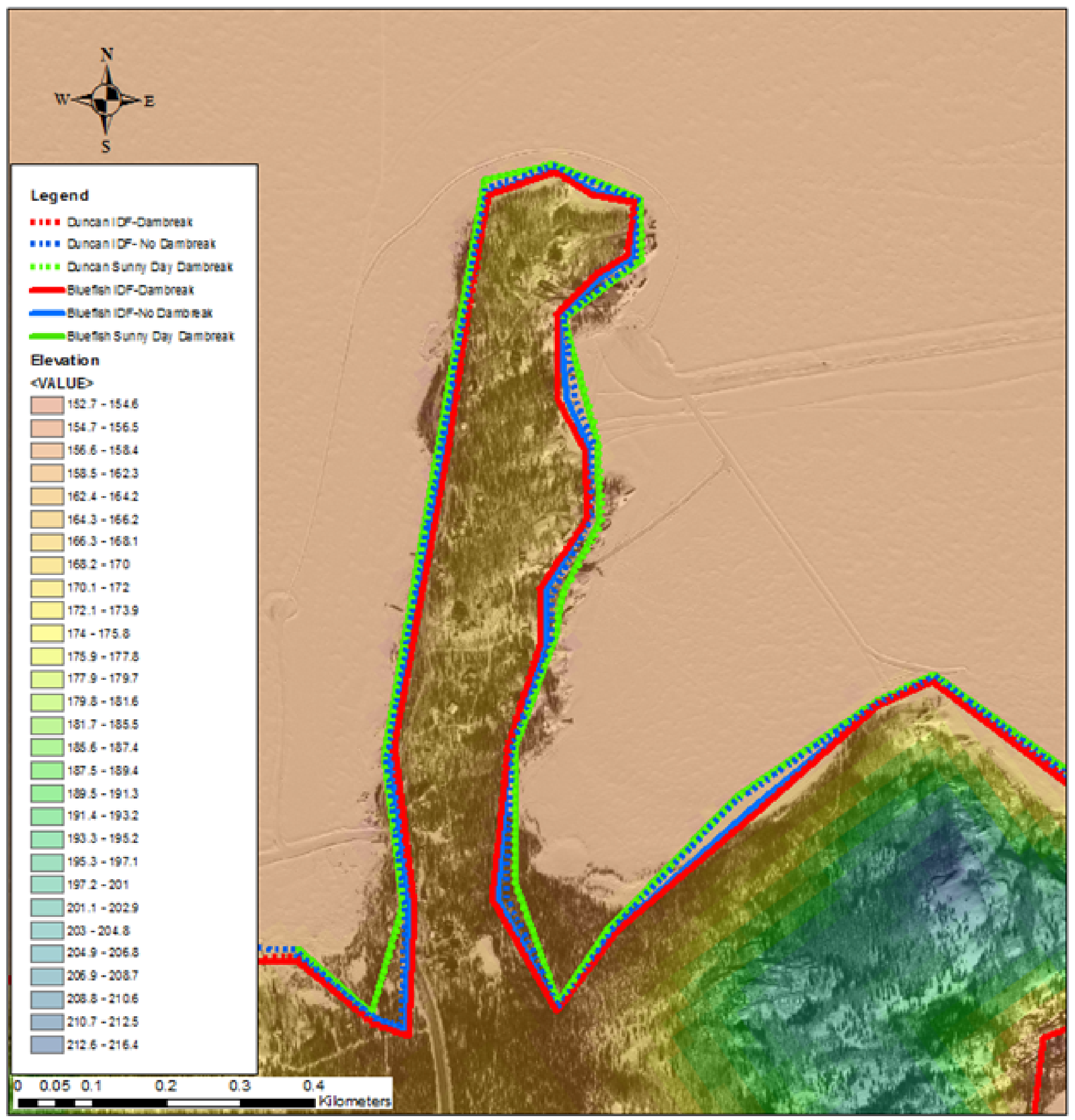
Sequence No. 07 of 09

Serv. char.	Project	Wbs	Disc.	Type	Drawing No.	Rev.
	159100263	120	HY		07	

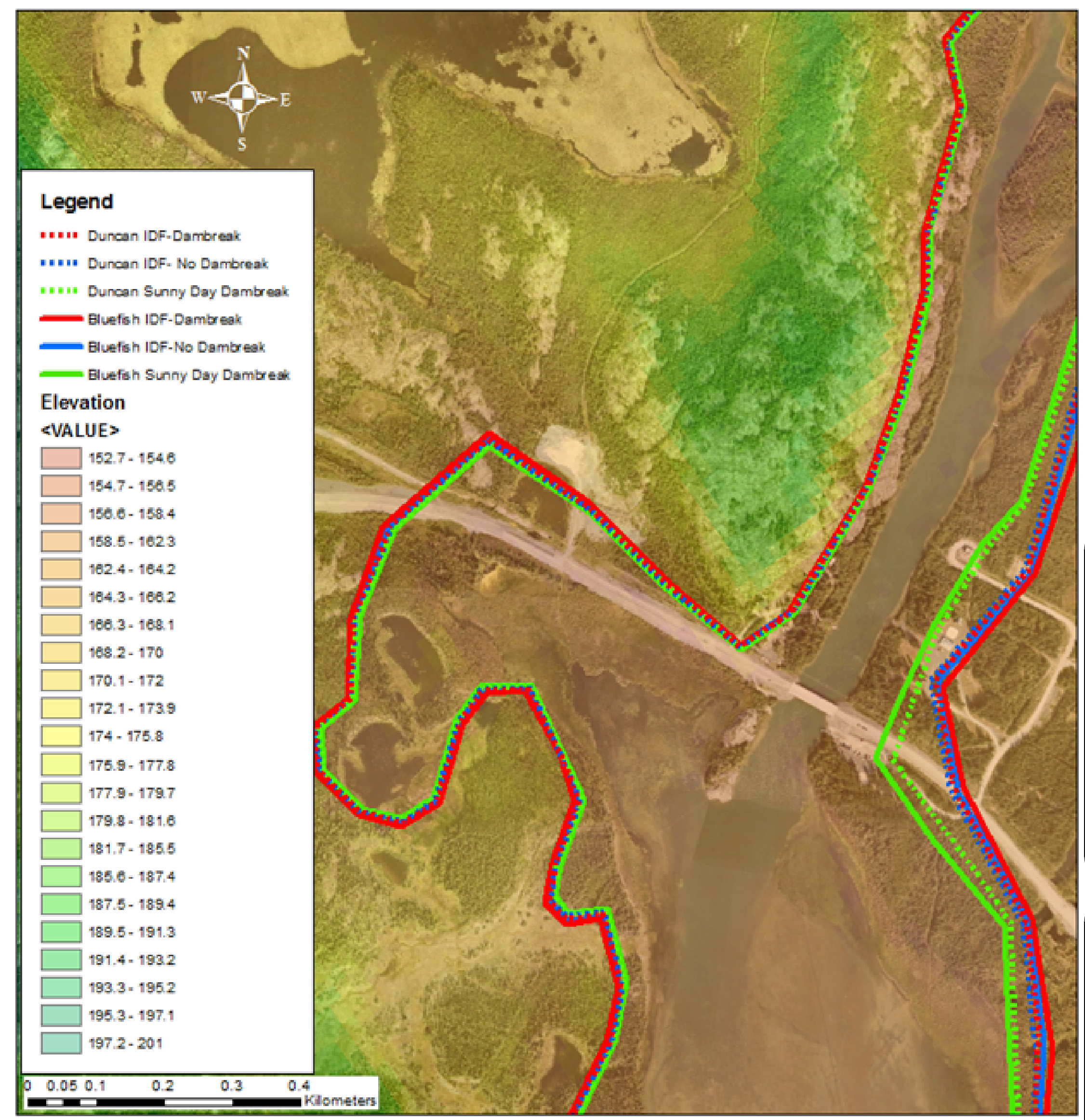
References



Cassidy Point (Prosperous Lake)



Ingraham Trail Bridge



References

Client
Northwest Territories Power Corporation

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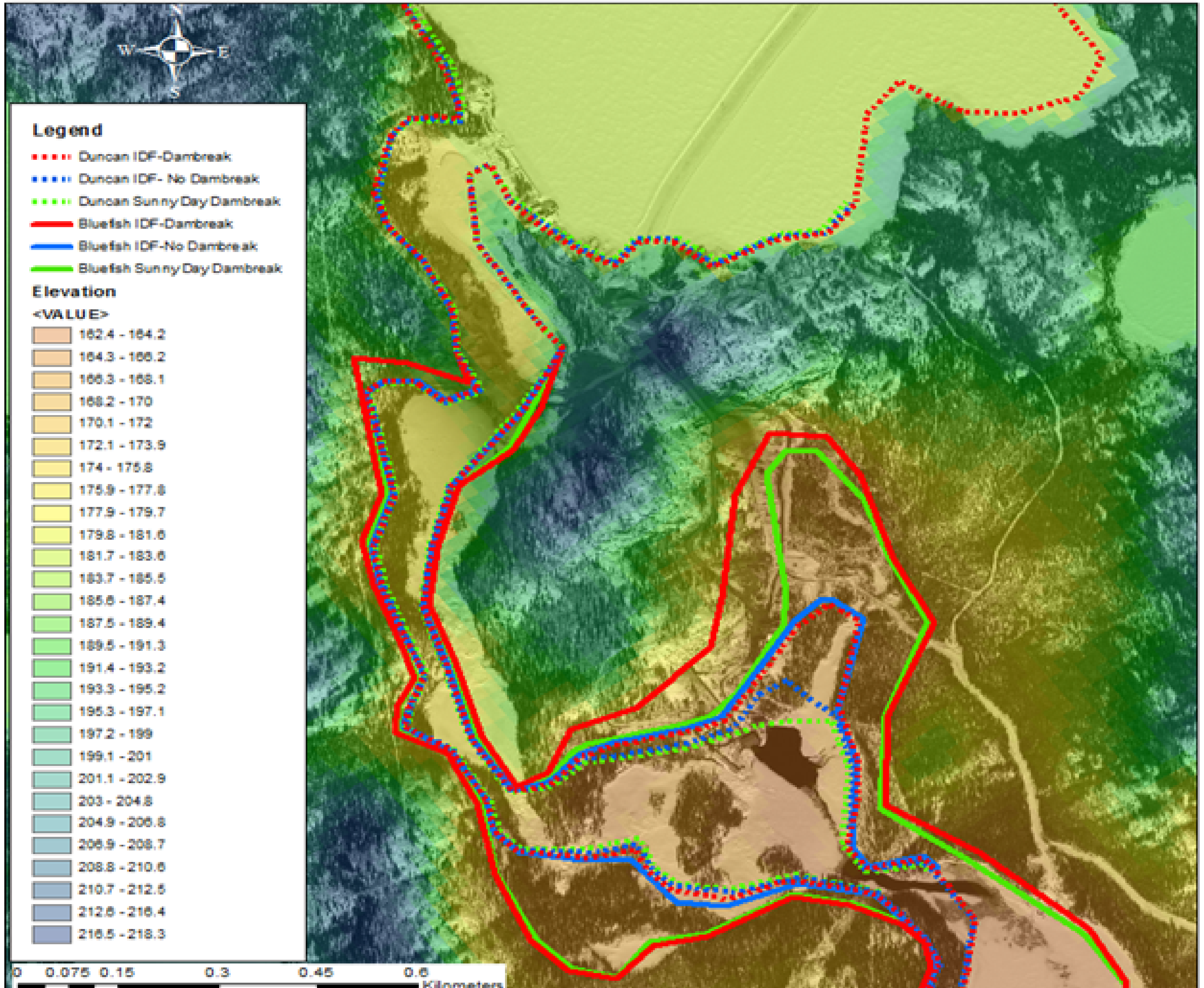
Project Manager: Ammar Taha, P.Eng, Ph.D.

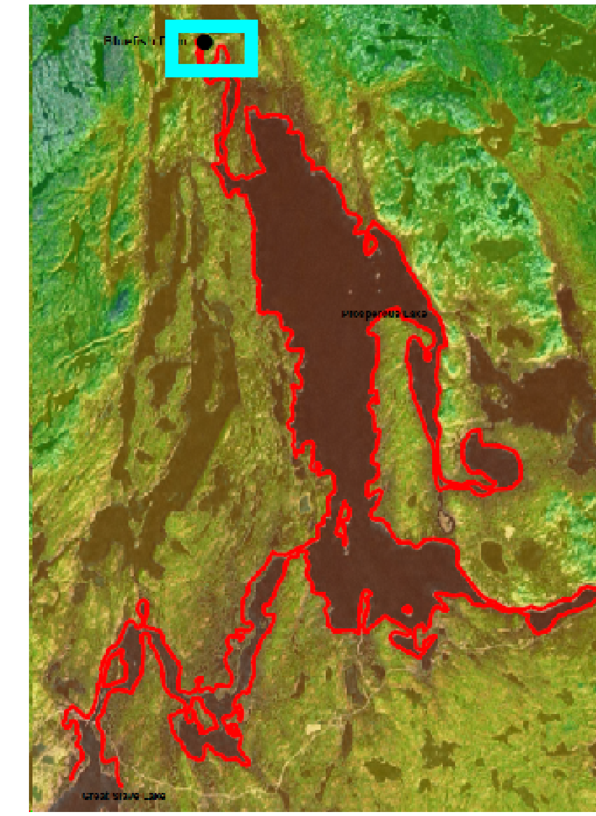
Sequence No. 08 of 09

Serv. char.	Project	Wbs	Disc.	Type	Drawing No.	Rev.
	159100263	120	HY		08	

10 cm 5 4 3 2 1 0

NTPC Buildings





Client	Northwest Territories Power Corporation
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Title	Dam Inundation Mapping

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Discipline	Hydrotechnical
Scale	As shown
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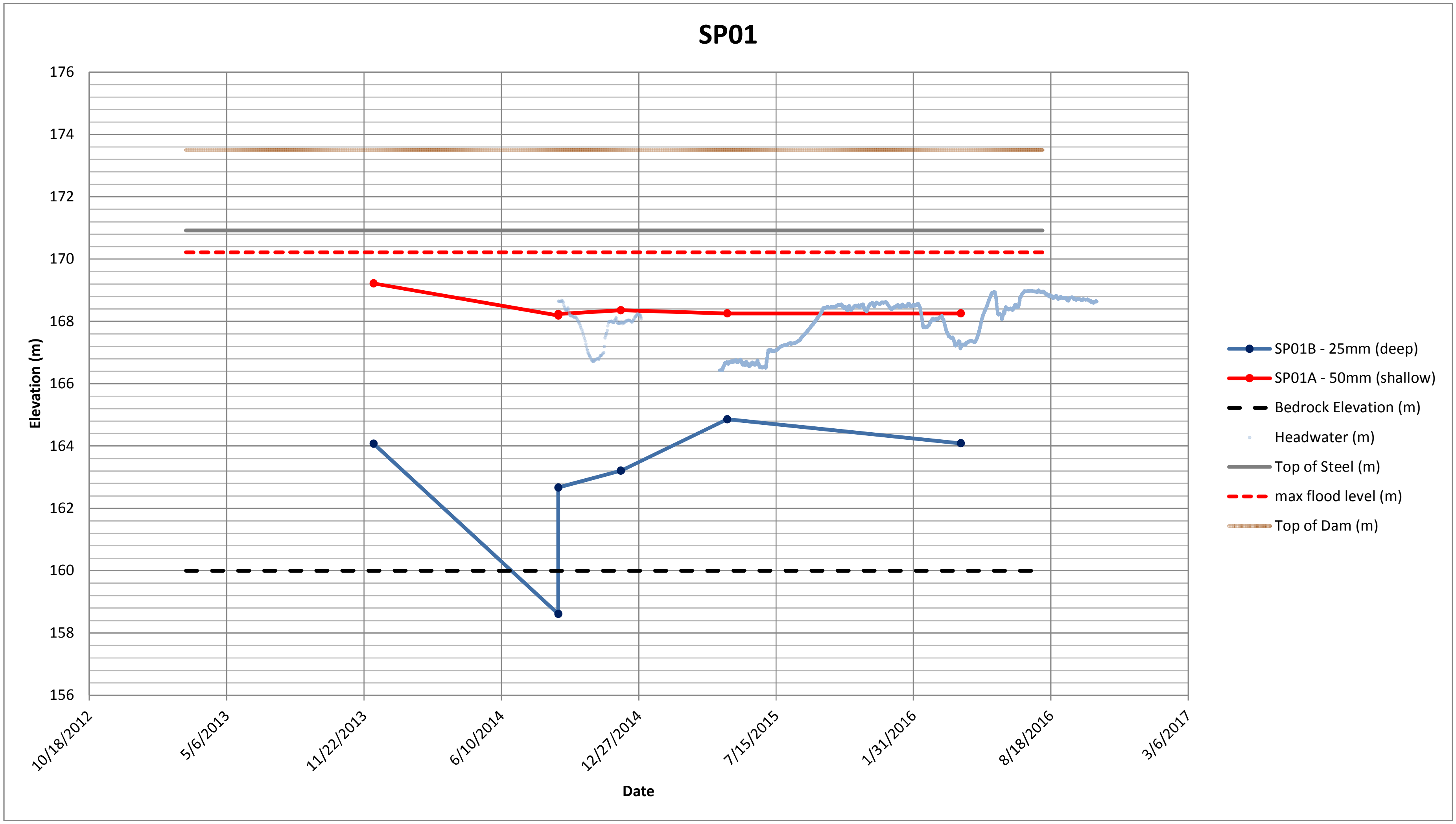
Project Manager	Ammar Taha, P.Eng, Ph.D.
Sequence No.	09 of 09

Serv. char.	Project	Wbs	Disc.	Type	Drawing No.	Rev.
	159100263	120	HY		09	

References

APPENDIX D:
PIEZOMETER MONITORING DATA



SP01
176
174
172
170
168
166
164
162
160
158
156
Elevation (m)
10/18/2012
5/6/2013
11/22/2013
6/10/2014
12/27/2014
7/15/2015
1/31/2016
8/18/2016
3/6/2017
Date
SP01B - 25mm (deep)
SP01A - 50mm (shallow)
Bedrock Elevation (m)
Headwater (m)
Top of Steel (m)
max flood level (m)
Top of Dam (m)

Figure 1

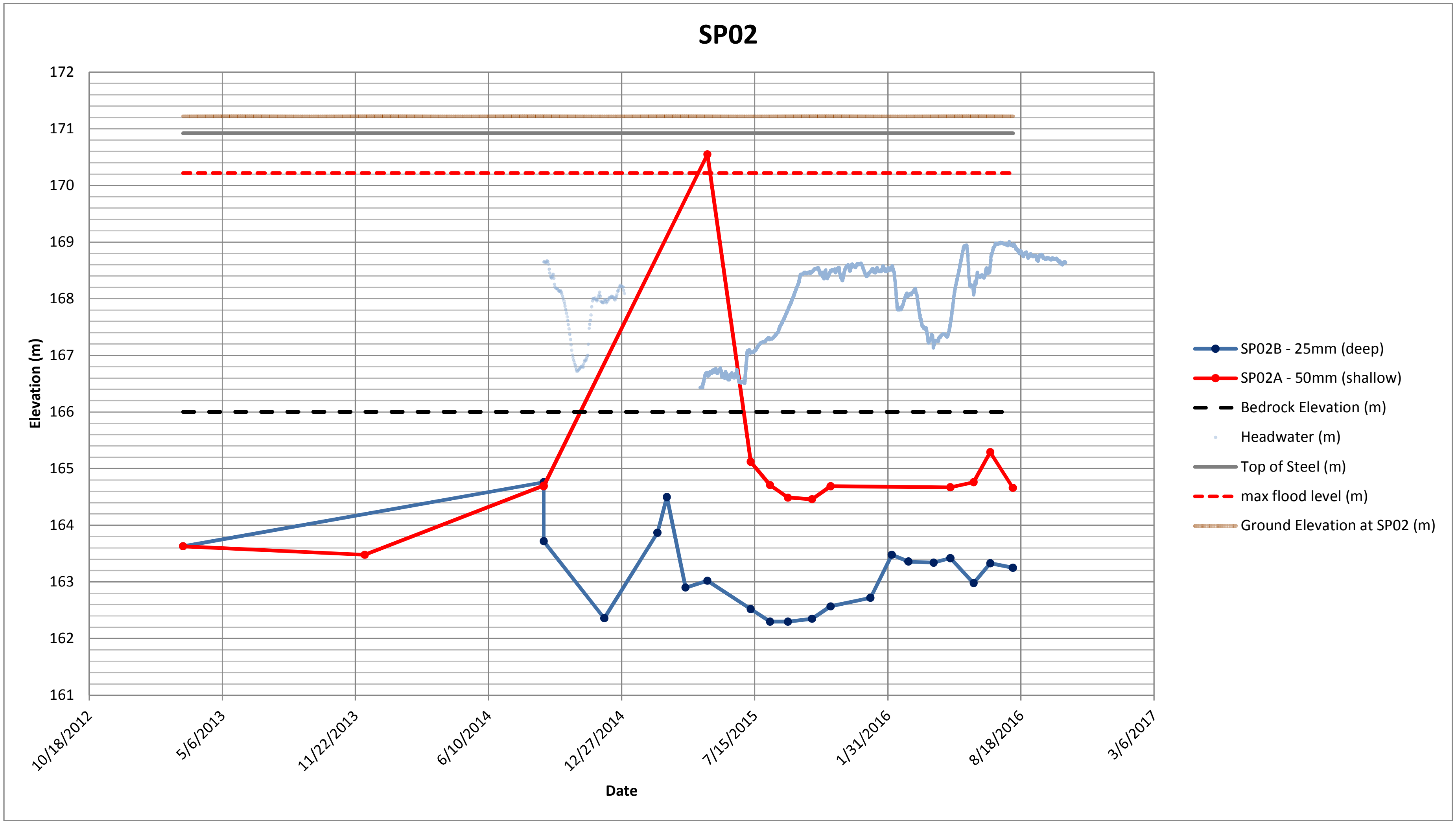
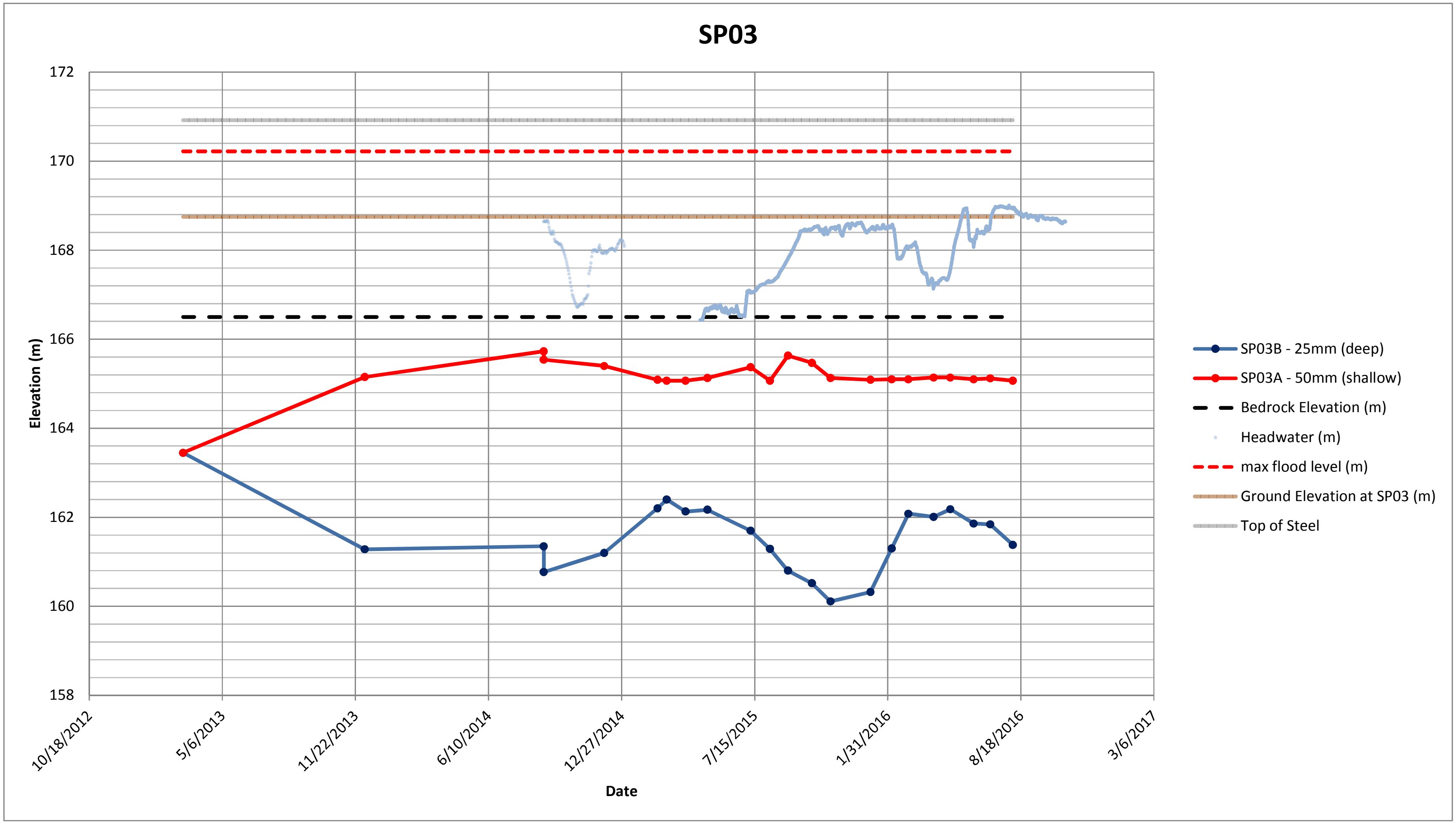
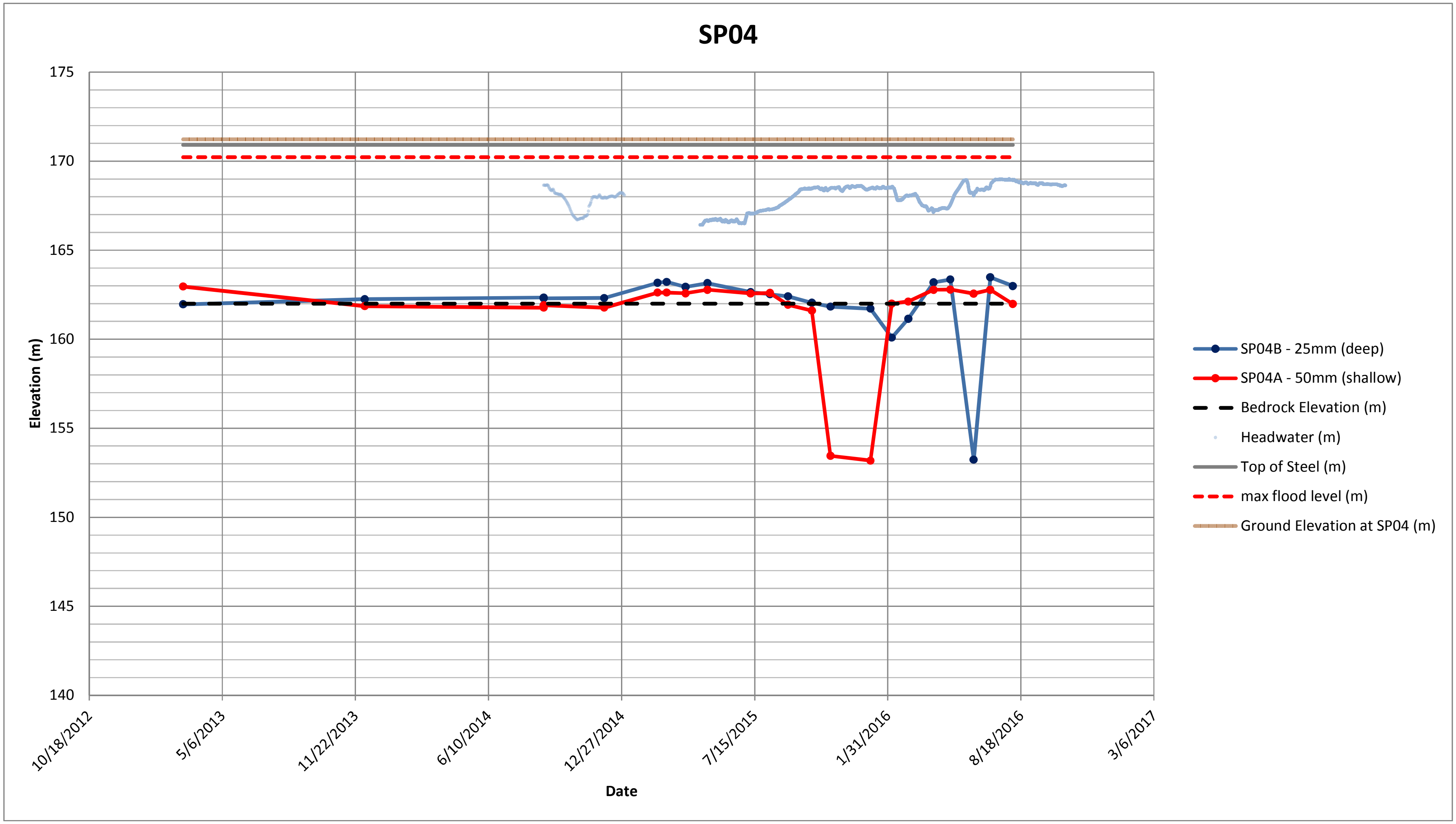

SP02
172
171
170
169
168
167
166
165
164
163
162
161
Elevation (m)
10/18/2012
5/6/2013
11/22/2013
6/10/2014
12/27/2014
7/15/2015
1/31/2016
8/18/2016
3/6/2017
Date
SP02B - 25mm (deep)
SP02A - 50mm (shallow)
Bedrock Elevation (m)
Headwater (m)
Top of Steel (m)
max flood level (m)
Ground Elevation at SP02 (m)

Figure 2



SP03
172
170
168
166
164
162
160
158
Elevation (m)
10/18/2012
5/6/2013
11/22/2013
6/10/2014
12/27/2014
7/15/2015
1/31/2016
8/18/2016
3/6/2017
Date
SP03B - 25mm (deep)
SP03A - 50mm (shallow)
Bedrock Elevation (m)
Headwater (m)
max flood level (m)
Ground Elevation at SP03 (m)
Top of Steel

Figure 3



SP04
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170
165
160
155
150
145
140
Elevation (m)
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5/6/2013
11/22/2013
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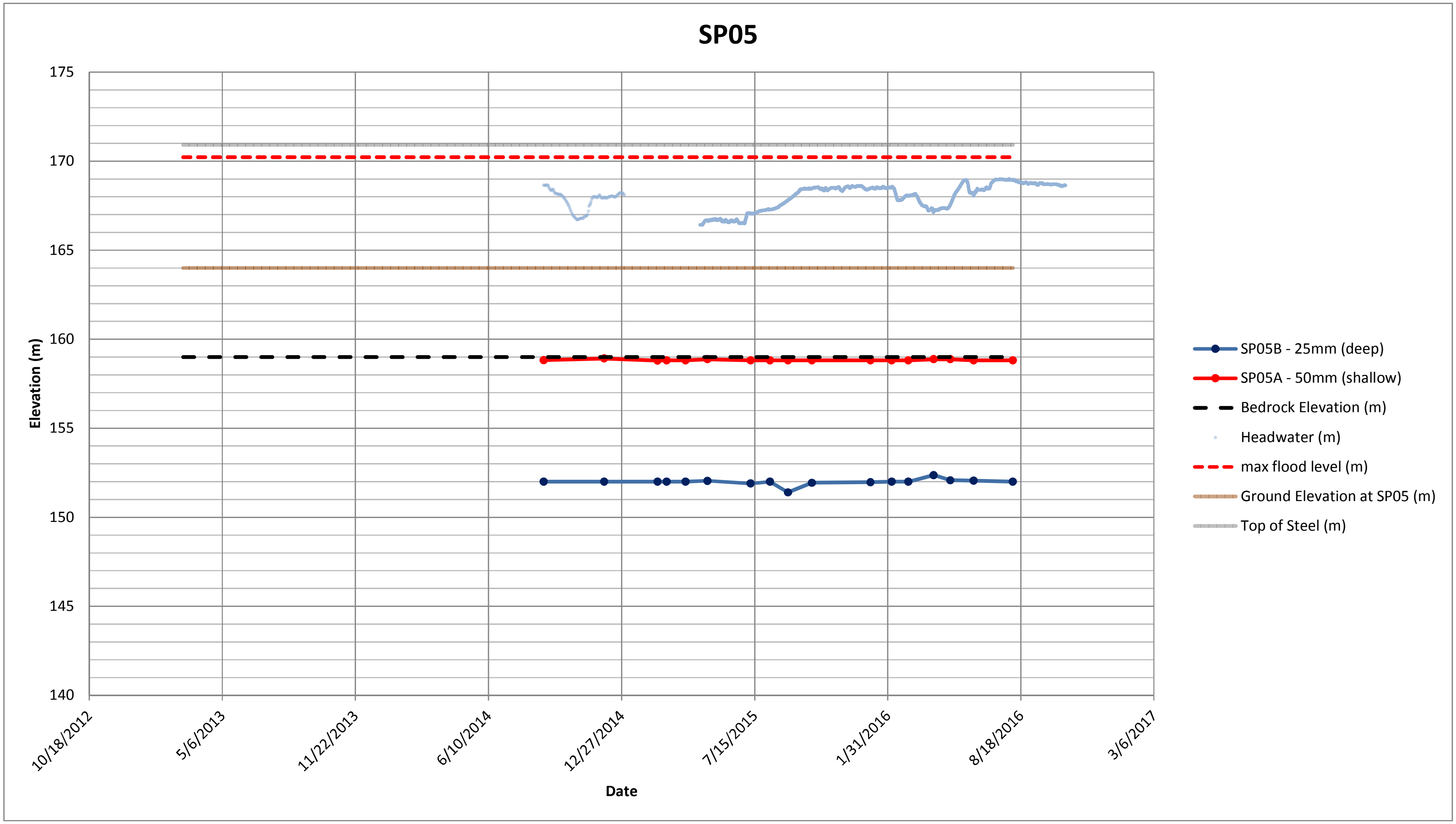
12/27/2014
7/15/2015
1/31/2016
8/18/2016
3/6/2017
Date
SP04B - 25mm (deep)
SP04A - 50mm (shallow)
Bedrock Elevation (m)
Headwater (m)
Top of Steel (m)
max flood level (m)
Ground Elevation at SP04 (m)

Figure 4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160
155
150
145
140
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11/22/2013
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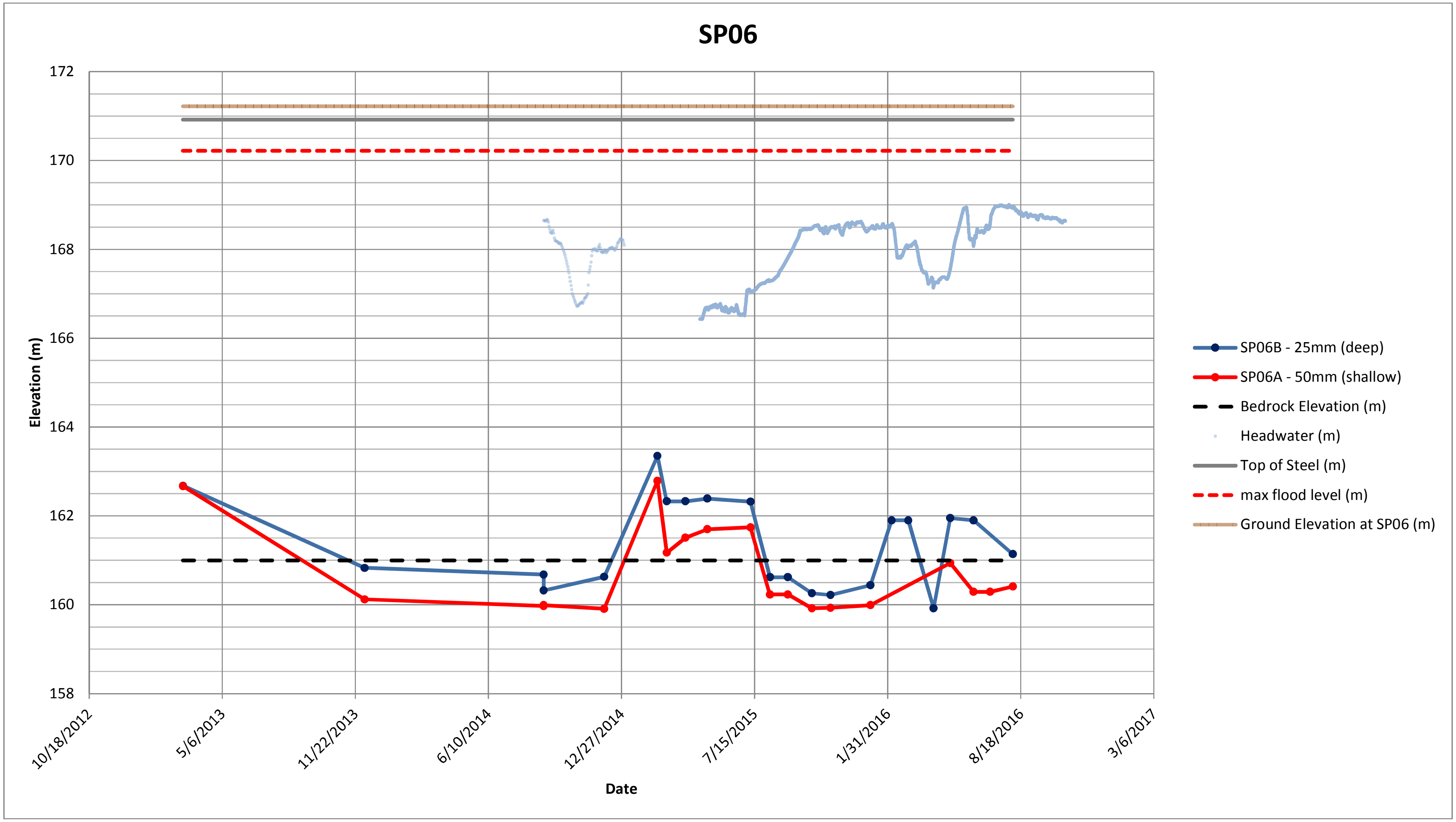
7/15/2015
1/31/2016
8/18/2016
3/6/2017
Date
SP05B - 25mm (deep)
SP05A - 50mm (shallow)
Bedrock Elevation (m)
Headwater (m)
max flood level (m)
Ground Elevation at SP05 (m)
Top of Steel (m)

Figure 5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164
162
160
158
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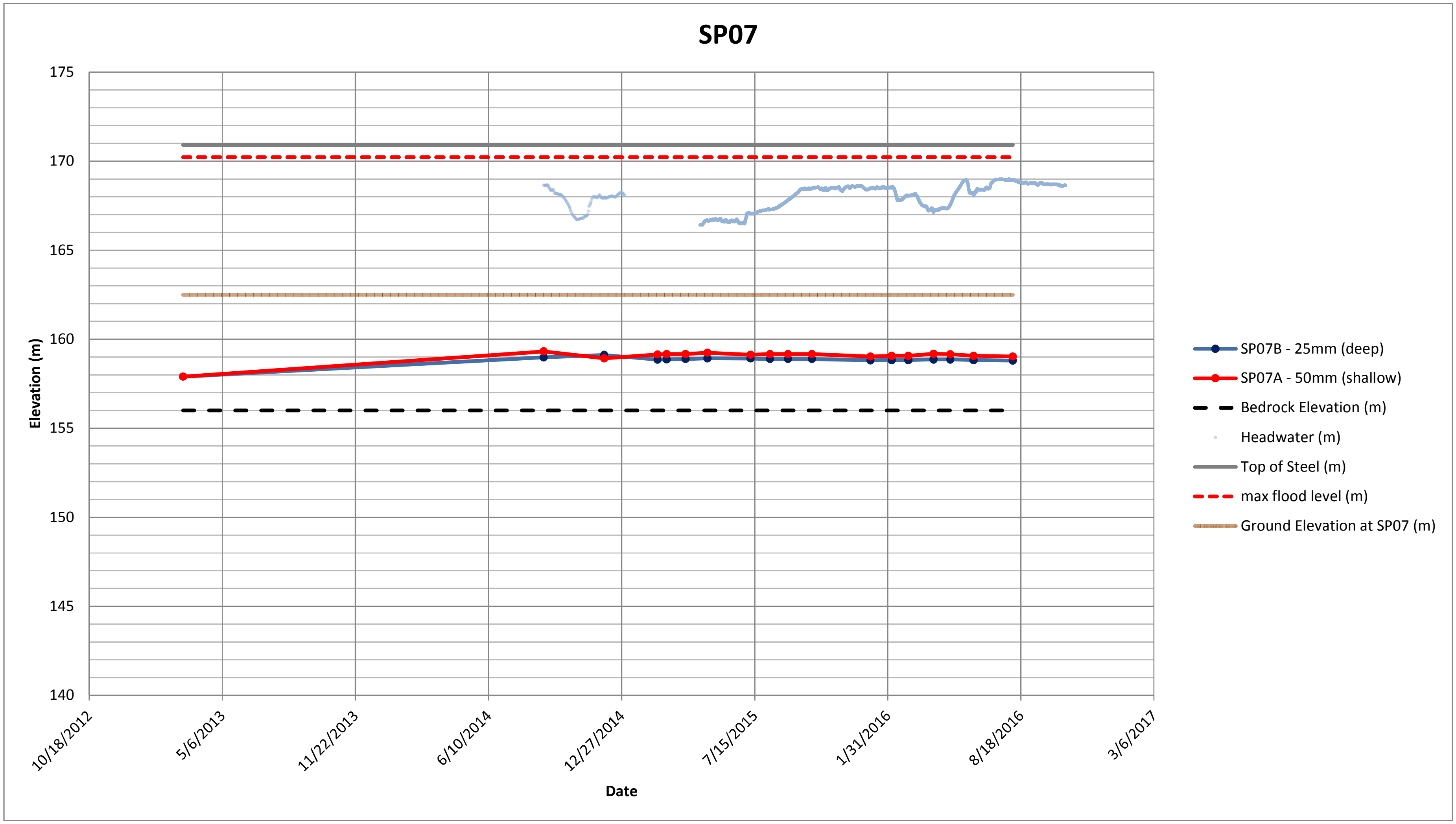
11/22/2013
6/10/2014
12/27/2014
7/15/2015
1/31/2016
8/18/2016
3/6/2017
Date
SP06B - 25mm (deep)
SP06A - 50mm (shallow)
Bedrock Elevation (m)
Headwater (m)
Top of Steel (m)
max flood level (m)
Ground Elevation at SP06 (m)

Figure 6



SP07
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160
155
150
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140
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11/22/2013
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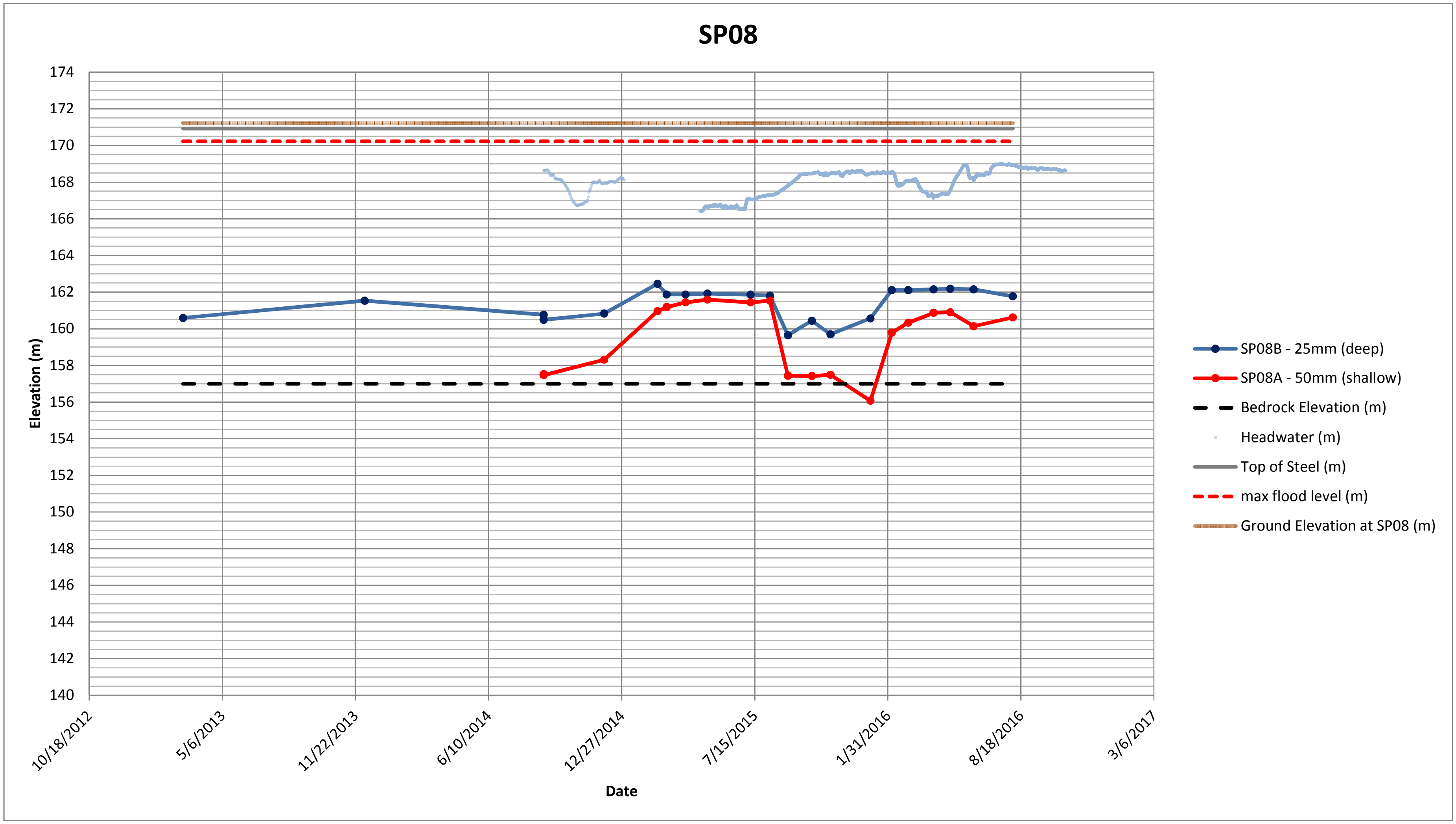
12/27/2014
7/15/2015
1/31/2016
8/18/2016
3/6/2017
Date
SP07B - 25mm (deep)
SP07A - 50mm (shallow)
Bedrock Elevation (m)
Headwater (m)
Top of Steel (m)
max flood level (m)
Ground Elevation at SP07 (m)

Figure 7



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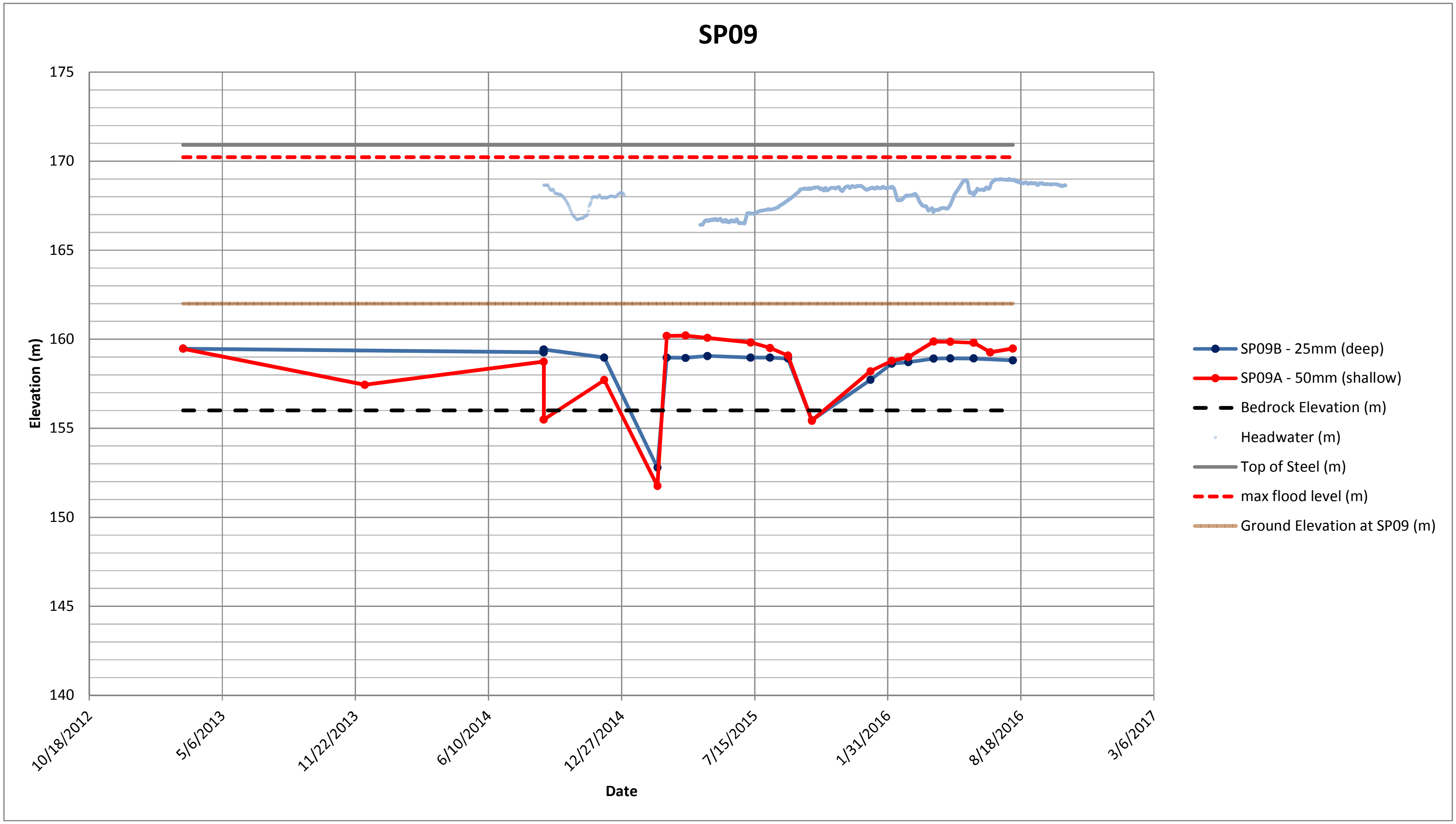
168
166
164
162
160
158
156
154
152
150
148
146
144
142
140
Elevation (m)
10/18/2012
5/6/2013
11/22/2013
6/10/2014
12/27/2014
7/15/2015
1/31/2016
8/18/2016
3/6/2017
Date
SP08B - 25mm (deep)
SP08A - 50mm (shallow)
Bedrock Elevation (m)
Headwater (m)
Top of Steel (m)
max flood level (m)
Ground Elevation at SP08 (m)

Figure 8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160
155
150
145
140
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11/22/2013
6/10/2014
12/27/2014
7/15/2015
1/31/2016
8/18/2016
3/6/2017
Date
SP09B - 25mm (deep)
SP09A - 50mm (shallow)
Bedrock Elevation (m)
Headwater (m)
Top of Steel (m)
max flood level (m)
Ground Elevation at SP09 (m)

Figure 9

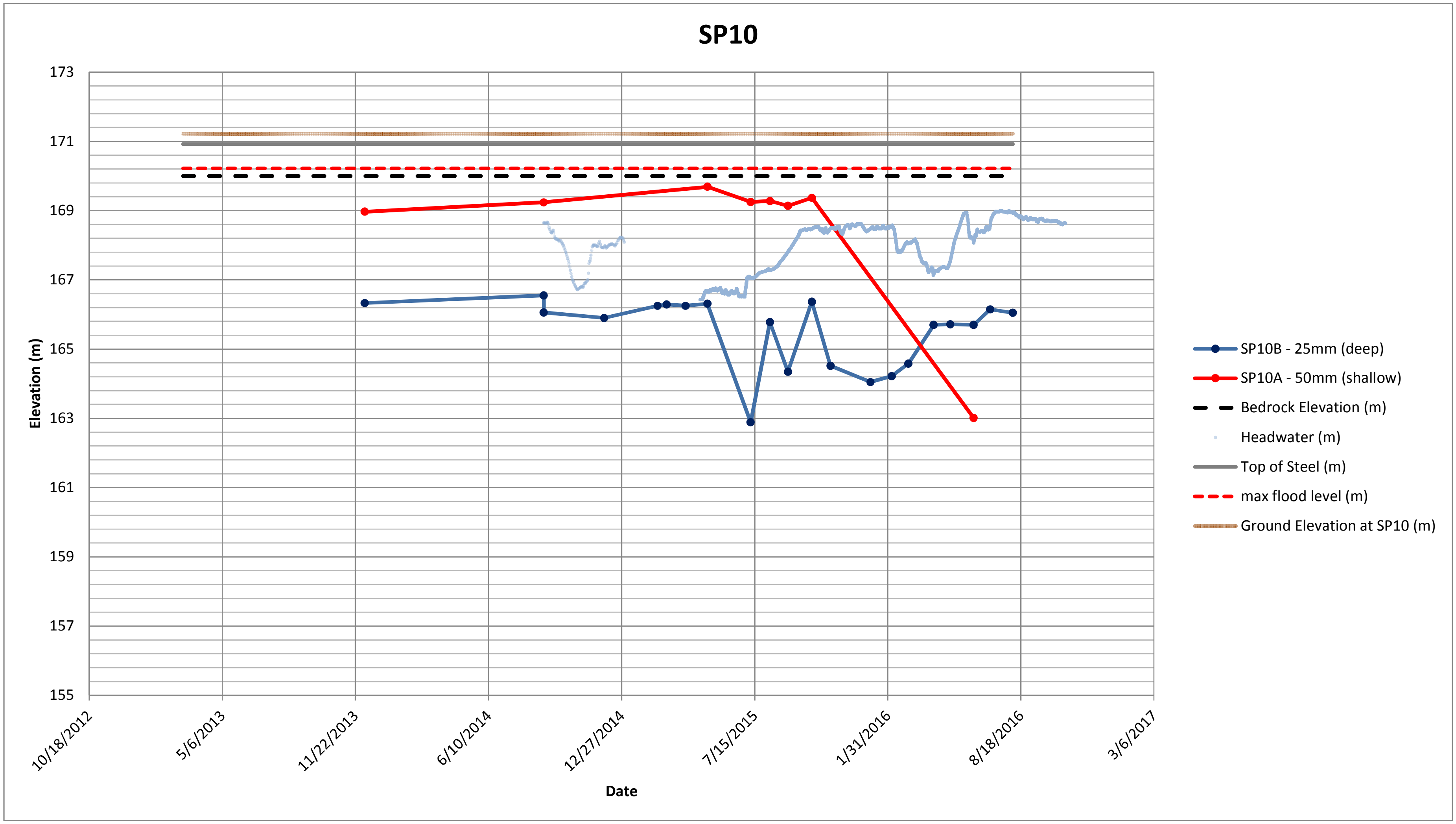
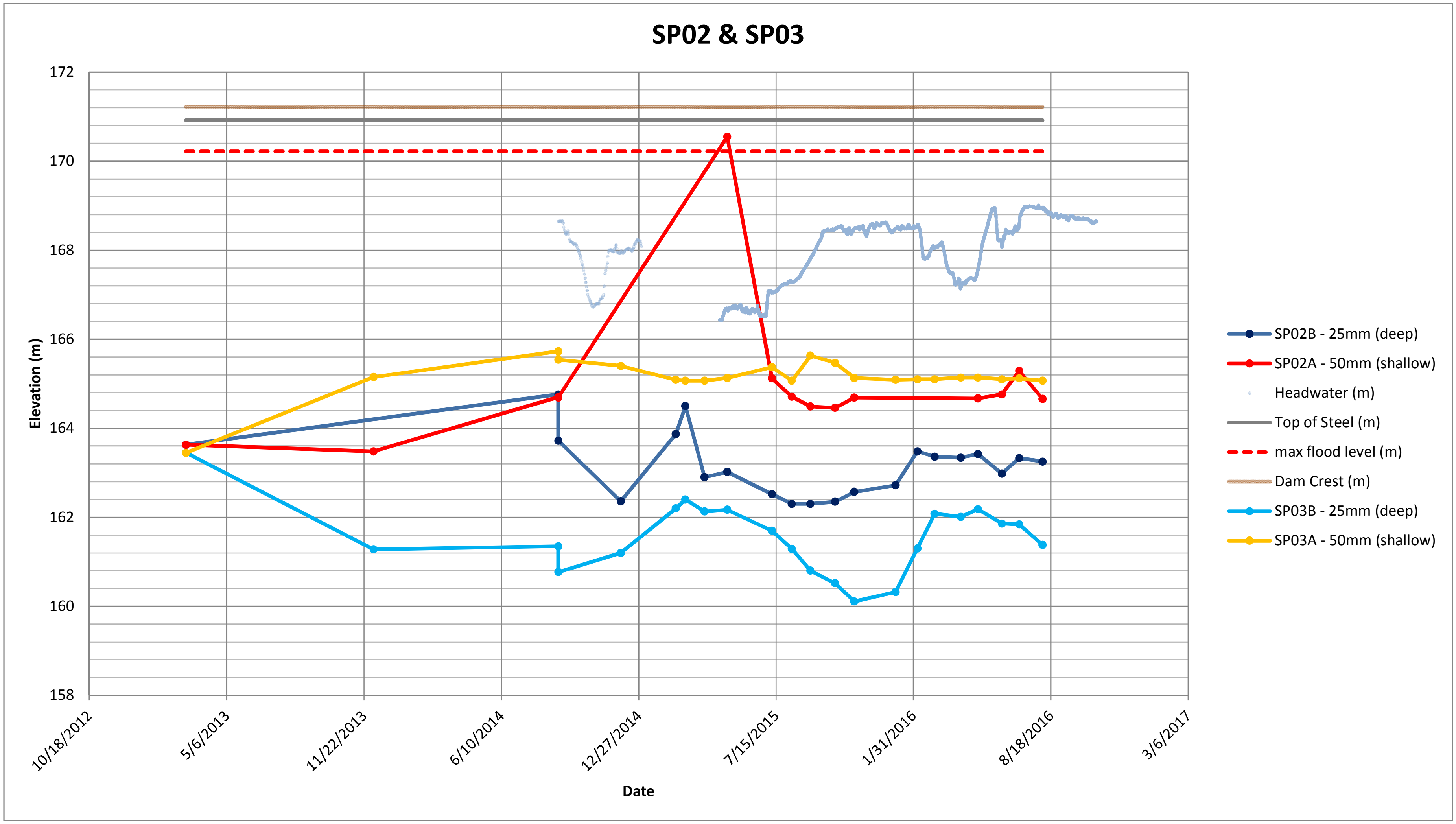
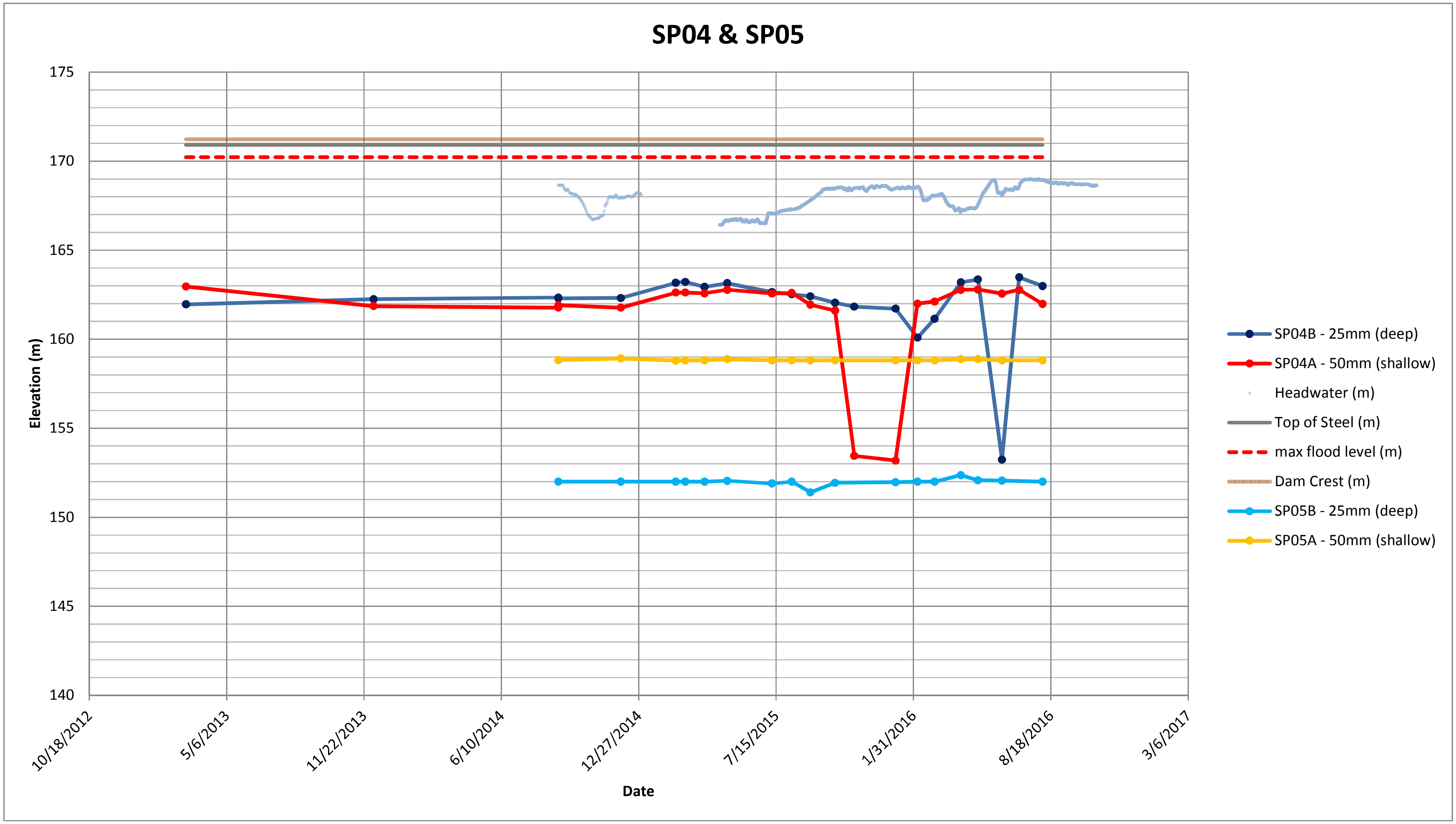

SP10
173
171
169
167
165
163
161
159
157
155
Elevation (m)
10/18/2012
5/6/2013
11/22/2013
6/10/2014
12/27/2014
7/15/2015
1/31/2016
8/18/2016
3/6/2017
Date
SP10B - 25mm (deep)
SP10A - 50mm (shallow)
Bedrock Elevation (m)
Headwater (m)
Top of Steel (m)
max flood level (m)
Ground Elevation at SP10 (m)

Figure 10



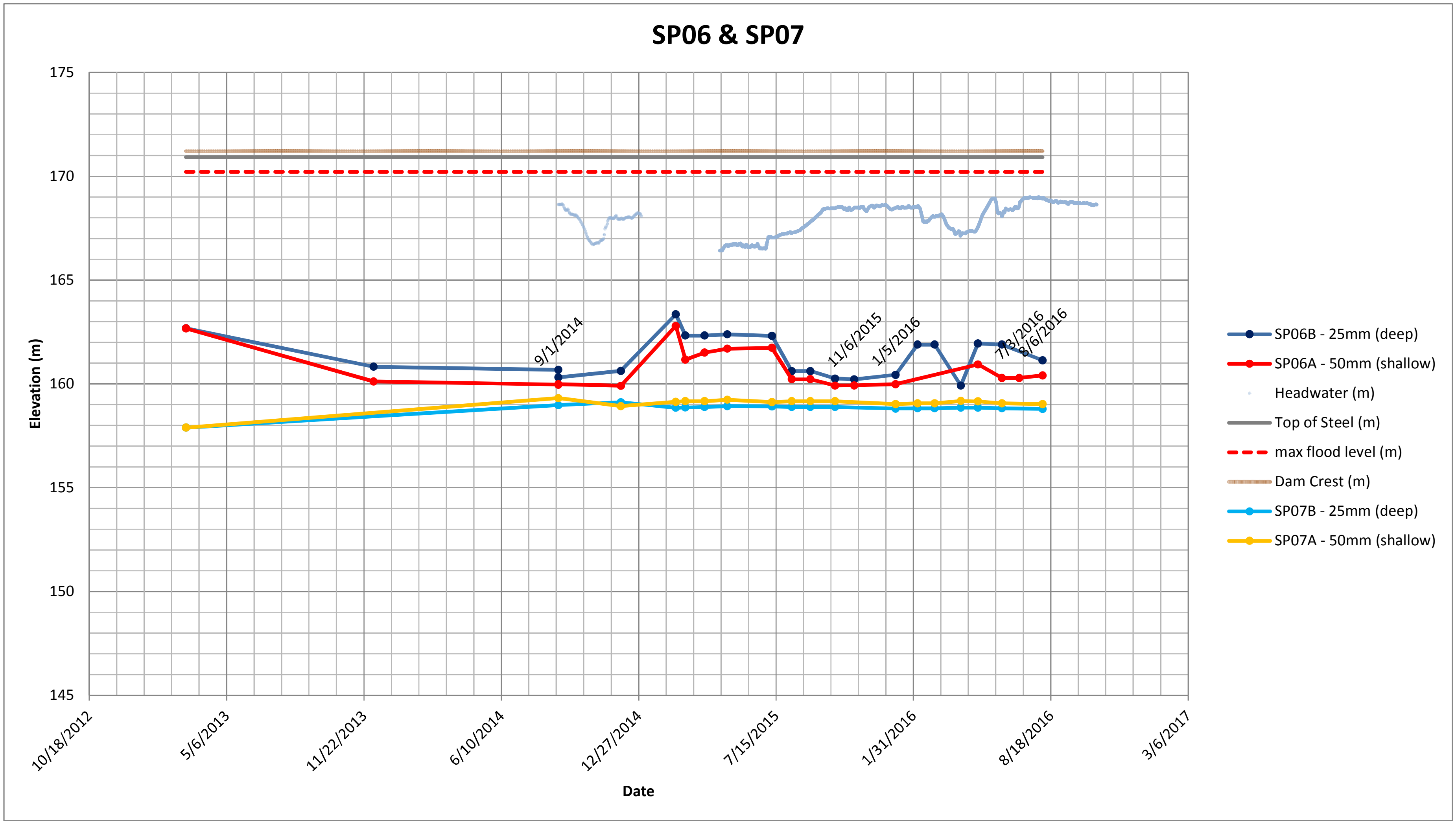
SP02 & SP03
172
170
168
166
164
162
160
158
Elevation (m)
10/18/2012
5/6/2013
11/22/2013
6/10/2014
12/27/2014
7/15/2015
1/31/2016
8/18/2016
3/6/2017
Date
SP02B - 25mm (deep)
SP02A - 50mm (shallow)
Headwater (m)
Top of Steel (m)
max flood level (m)
Dam Crest (m)
SP03B - 25mm (deep)
SP03A - 50mm (shallow)

Figure 11



SP04 & SP05
175
170
165
160
155
150
145
140
Elevation (m)
10/18/2012
5/6/2013
11/22/2013
6/10/2014
12/27/2014
7/15/2015
1/31/2016
8/18/2016
3/6/2017
Date
SP04B - 25mm (deep)
SP04A - 50mm (shallow)
Headwater (m)
Top of Steel (m)
max flood level (m)
Dam Crest (m)
SP05B - 25mm (deep)
SP05A - 50mm (shallow)

Figure 12



SP06 & SP07
Elevation (m)
175
170
165
160
155
150
145
10/18/2012
5/6/2013
11/22/2013
6/10/2014
12/27/2014
7/15/2015
1/31/2016
8/18/2016
3/6/2017
Date
9/1/2014
11/6/2015
1/5/2016
7/13/2016
8/6/2016
SP06B - 25mm (deep)
SP06A - 50mm (shallow)
Headwater (m)
Top of Steel (m)
max flood level (m)
Dam Crest (m)
SP07B - 25mm (deep)
SP07A - 50mm (shallow)

Figure 13

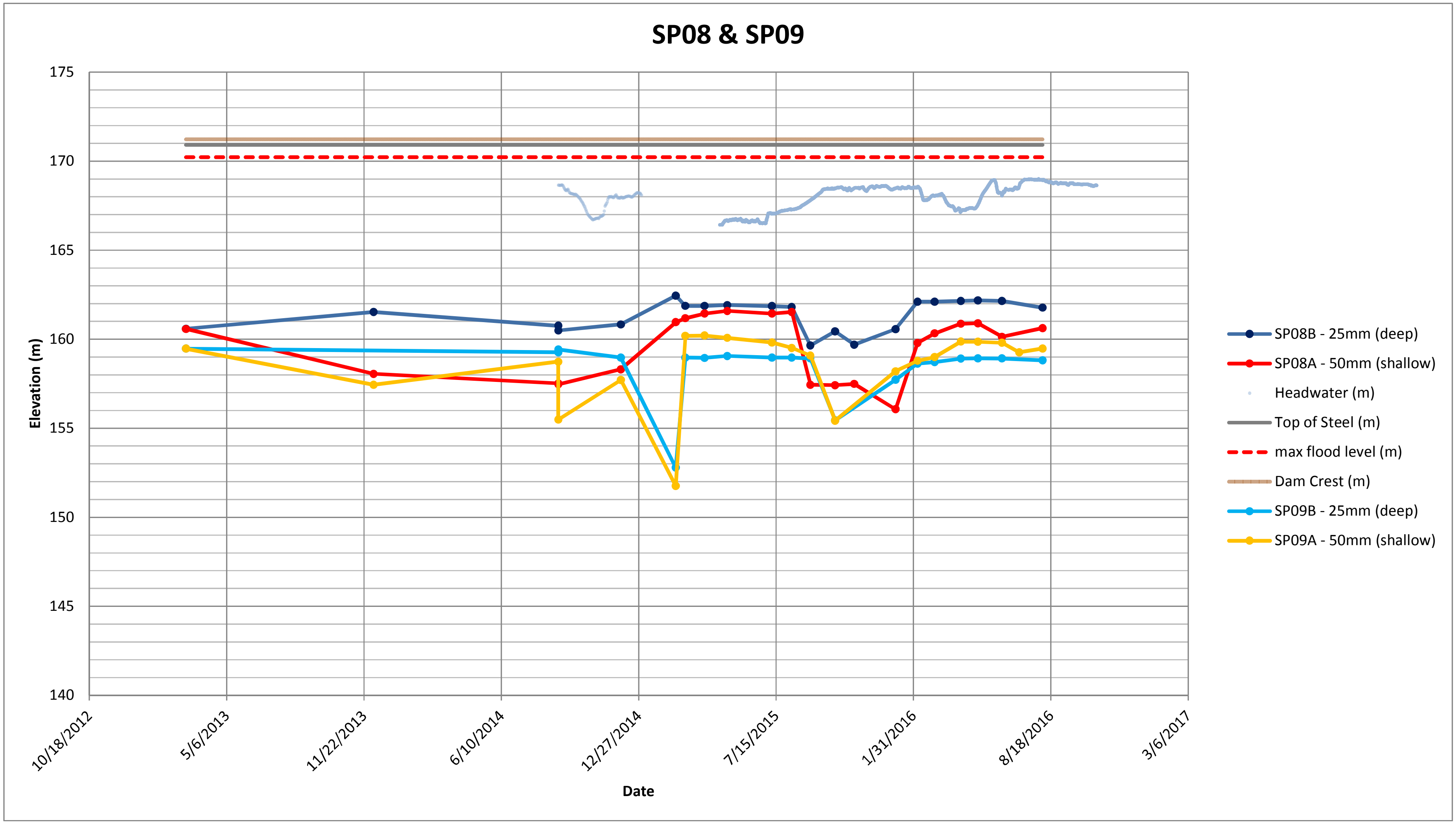

SP08 & SP09
175
170
165
160
155
150
145
140
Elevation (m)
10/18/2012
5/6/2013
11/22/2013
6/10/2014
12/27/2014
7/15/2015
1/31/2016
8/18/2016
3/6/2017
Date
SP08B - 25mm (deep)
SP08A - 50mm (shallow)
Headwater (m)
Top of Steel (m)
max flood level (m)
Dam Crest (m)
SP09B - 25mm (deep)
SP09A - 50mm (shallow)

Figure 14

APPENDIX E: THERMISTOR CONNECTION CABLE COST QUOTATION

From:	Hayley Croteau
To:	Pineau, Joel
Cc:	Nasser Nia
Subject:	RE: Thermistor strings - Bluefish Dam - Northwest Territories
Date:	Thursday, October 13, 2016 3:00:28 PM

Hi Joel,

I would estimate 2 weeks from receipt of order. Do you happen to have a photo of the connector just to confirm the one that was used?

Regards,

RST Instruments Ltd., *per*
Hayley Croteau, P.Eng.
Manager Sales
Tel: 604.540.1100 ext 218
Fax: 604.540.1005
Email: hcroteau@rstinstruments.com
Web: www.rstinstruments.com

From: Pineau, Joel [mailto:Joel.Pineau@stantec.com]
Sent: October-13-16 2:11 PM
To: Hayley Croteau
Subject: RE: Thermistor strings - Bluefish Dam - Northwest Territories

Thanks for your help Hayley.

Can you provide an estimate for the readout box and the fly lead?

Joel Pineau, P.Eng
Geotechnical Engineer
Team Leader
Stantec
500-4730 Kingsway Burnaby BC V5H 0C6
Phone: 604-678-3078
Cell: 778-228-9704
Fax: 604-436-3752
joel.pineau@stantec.com

From: Hayley Croteau [mailto:hcroteau@rstinstruments.com]
Sent: Thursday, October 13, 2016 11:25 AM
To: Pineau, Joel <Joel.Pineau@stantec.com>
Cc: Nasser Nia <NNia@rstinstruments.com>
Subject: RE: Thermistor strings - Bluefish Dam - Northwest Territories

Hi Joel,

We sold these goods to McCaw Drilling and Blasting who must have been a contractor on that project at the time. I don't know if maybe they still have the readout unit.

Nasser, can you work on looking into the details of the corrosion system?

Joel, also each coupon had a cable attached to it so I suspect they were suspended down the PVC. If there is no cable there, perhaps they were removed at some point?

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Hayley Croteau, P.Eng.
Manager Sales
Tel: 604.540.1100 ext 218
Fax: 604.540.1005
Email: hcroteau@rstinstruments.com
Web: www.rstinstruments.com

From: Pineau, Joel [mailto:Joel.Pineau@stantec.com]
Sent: October-13-16 10:43 AM
To: Hayley Croteau
Subject: Re: Thermistor strings - Bluefish Dam - Northwest Territories

I'm not sure I understand the corrosion system and how it is intended to be operated.

The well covers at the locations I suspect are for this system are empty save for a 2 pvc pipe,going into the ground.

Can you see if we can track down someone within rst with more knowledge?

Joel

On Oct 13, 2016, at 10:49 AM, Hayley Croteau <hcroteau@rstinstruments.com> wrote:

> Hi Joel,
>
> Please see the attached schematic. We supplied these cables (there were 6 total) with 19 pin connector on the end plus a TH2016 thermistor readout and fly lead (19 pin M x 19 pin F with 1.5m cable to extend the length of the thermistor string out of the stick out to the readout box). Is the readout and fly lead available? If not, we still have these products in our standard product line.
>
> We don't have any standard corrosion monitoring solutions but it looks like we provided a custom solution for this project. We supplied 15 direct burial coupons with connectors for cathodic potential monitoring along with a reference electrode for permanent burial. These were supplied with 150m of cable on a reel and a handheld

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I wasn't involved in this project (it was sold around the time I started with RST) so I don't know more about the system than that. Is this enough to get you started? Otherwise we could dig into it further with staff who were involved at that time.

I have cc'd Nasser Nia since I will be on a business trip starting tomorrow and not quite as available as usual.

Regards,

<image001.jpg> RST Instruments Ltd., *per*
Hayley Croteau, P.Eng.
Manager Sales
<image002.gif> Tel: 604.540.1100 ext 218
<image003.gif> Fax: 604.540.1005
<image004.gif> Email: hcroteau@rstinstruments.com
<image005.gif> Web: www.rstinstruments.com

From: Pineau, Joel [mailto:Joel.Pineau@stantec.com]
Sent: October-12-16 4:16 PM
To: Hayley Croteau
Subject: Thermistor strings - Bluefish Dam - Northwest Territories

Hi Hayley,

Working on another dam in the northwest territories. It is a new dam, the Bluefish dam, located just north of Yellowknife. The dam was designed by EBA and is owned and operated by the Northwest Territories Power Corporation. The dam was built in 2013 and they have installed several thermistor strings.

The thermistor strings have never been monitored. They are RST cables. See attached for a photo with an ID #. Can you check you records and see if you provided a dial gauge to anyone for these cables? Have the schematics available such that a dial gauge could purchase and used?

Also, they are RST stick ups (3) on the upslope side of the dam. I believe they are for corrosion monitoring of the stainless steel membrane, but they are just empty pipes. What type of corrosion monitoring systems does RST have? How would they work?

Any help is much appreciated!

Thanks,

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Team Leader
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joel.pineau@stantec.com

<THW0123A_WOQ024782.pdf.secure>

STANTEC CONSULTING LTD.
JOEL PINEAU
SUITE 500 - 4730 KINGSWAY
BURNABY, BC V5H 0C6

QUOTE

No.	**114868**
Date	13-Oct-2016
Customer ID	JACQ06/12531
Contact	Nasser Nia
E-Mail	nnia@rstinstruments.com
Page	1 / 2

Telefax (604) 436-3752

mail & email: accountspayable@stantec.com

Your inquiry: 114868- TH2016 AND FLYLEAD

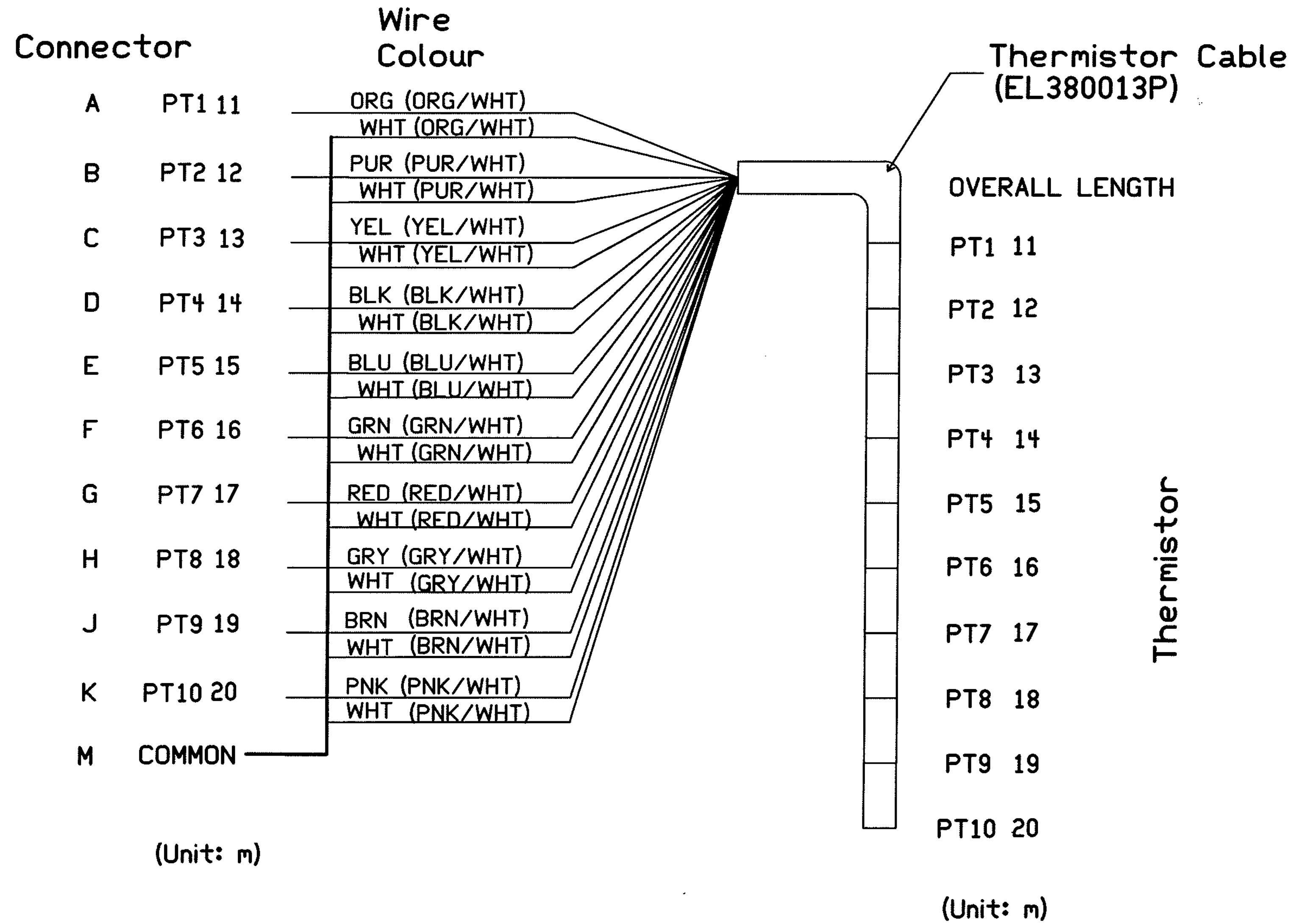
Pos	Item Description	Qty	Unit	Price CAD	Value CAD
1	 **TH2016B** THERMISTOR READOUT/LOGGER 16 CHANNEL C/W CAL. SHEET w/ USB CABLE AND SOFTWARE/MANUAL CD	**1**	**EA**	2,200.00	2,200.00
1.1	 **CUSB2-AM506** CABLE, USB A-MINI B 5PIN 6ft	**1**	**EA**		
1.2	 **MIG0280** RESOURCE DVD - data file: users manual only	**1**	**EA**		
1.3	 **MIG0283** MICROFIBER CLOTH	**1**	**EA**		
2	**TH2016-JB-F1** 19 PIN x 19 PIN x 1.5m FLY LEAD FOR TH2016 TH2016 TO TH STRING – M TO F	**1**	**EA**	390.00	390.00

Value of Goods			2,590.00
Net Amount			**2,590.00**
7.00	PST	2,590.00	181.30
5.00	GST	2,590.00	129.50
Total Value			**2,900.80**

Terms of Payment	Net 30 days
Terms of Delivery	FOB
Carrier	COLLECT - Customer to specify carrier

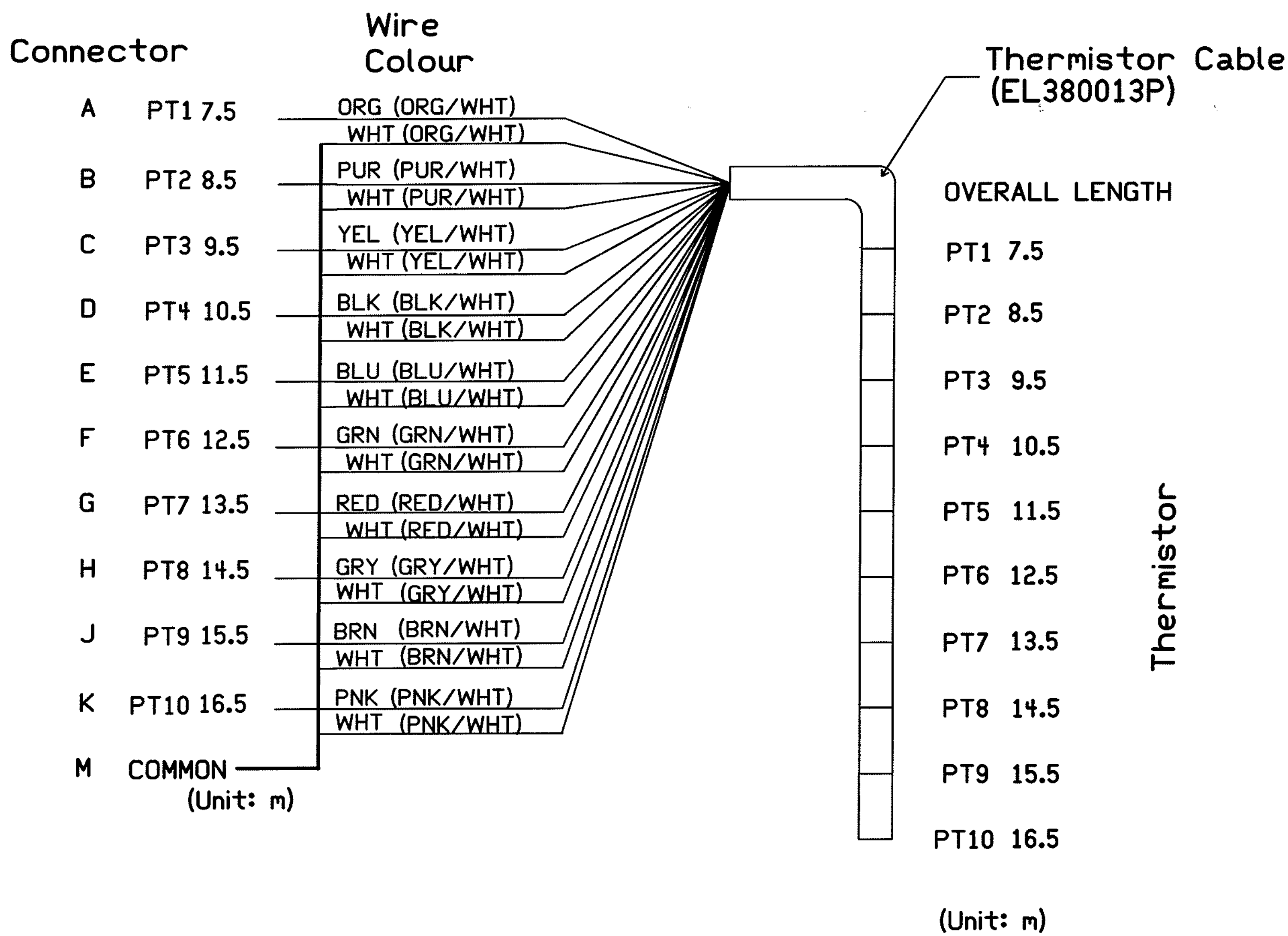
ESTIMATED DELIVERY: 2 WEEKS ARO

Subject to RST Instruments Sales Terms and Conditions
http://www.rstinstruments.com/Standard-Terms-Conditions.html



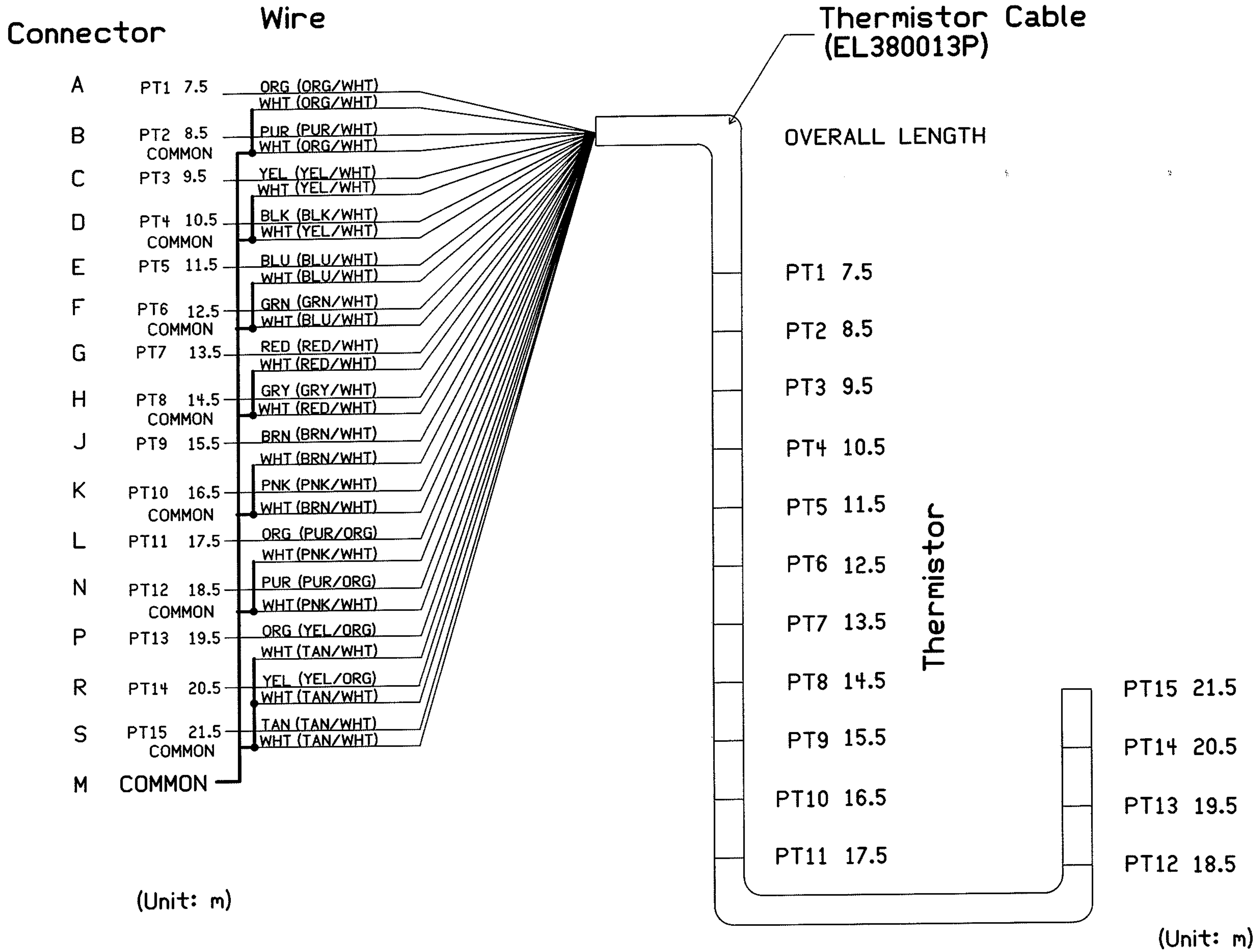
S/N: TS3415

Co:	RST INSTRUMENTS LTD		
Title:	THERMISTOR CABLE		
J/N:	THW0123/WOQ024782	Revision:	A
Author:	WY	Size:	A
Date:	2012/10/26	Sheet	1 of 5



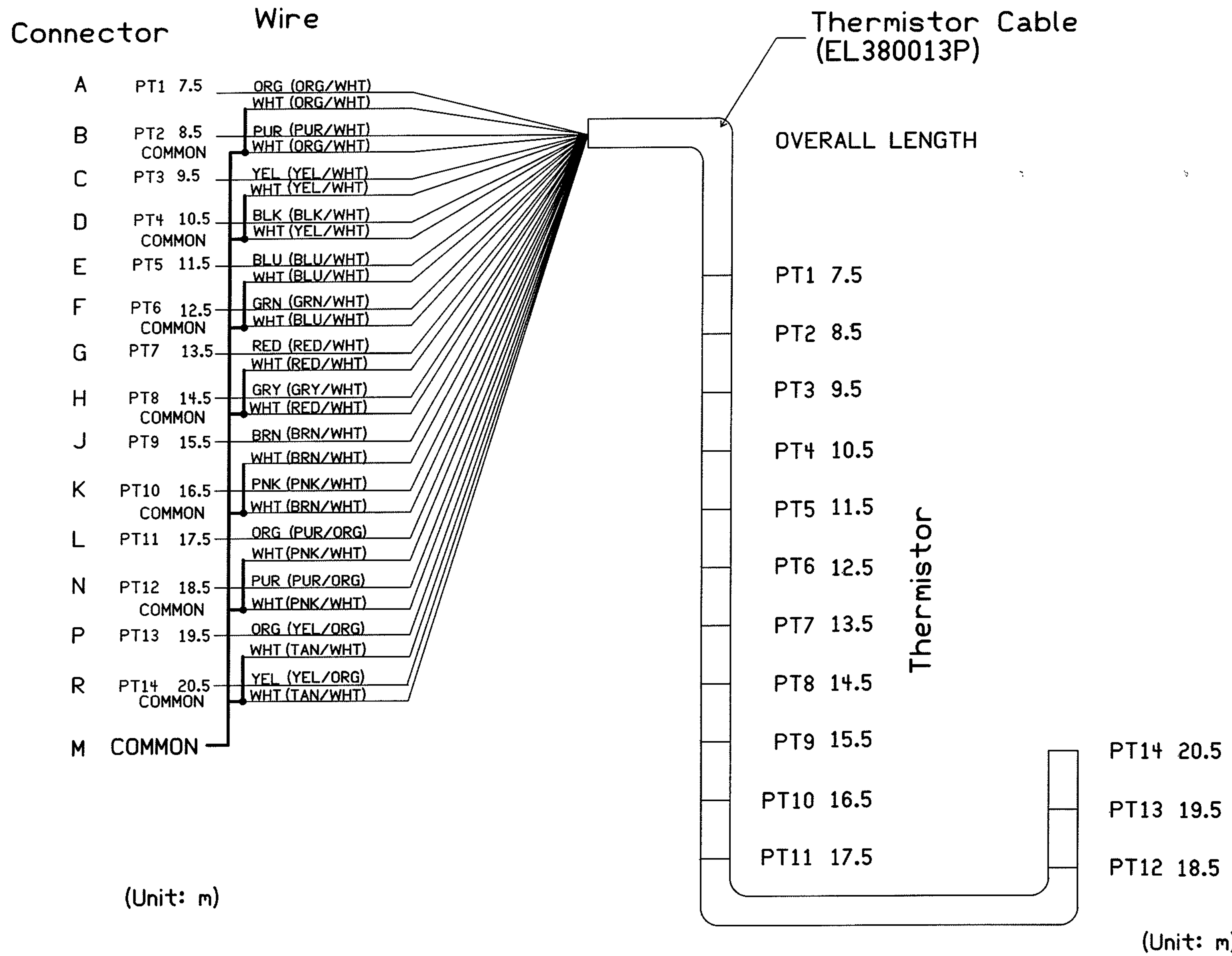
S/N: TS3416

Co:	RST INSTRUMENTS LTD		
Title:	THERMISTOR CABLE		
J/N:	THW0123/WOQ024782	Revision:	A
Author:	WY	Size:	A
Date:	2012/10/26	Sheet	2 of 5



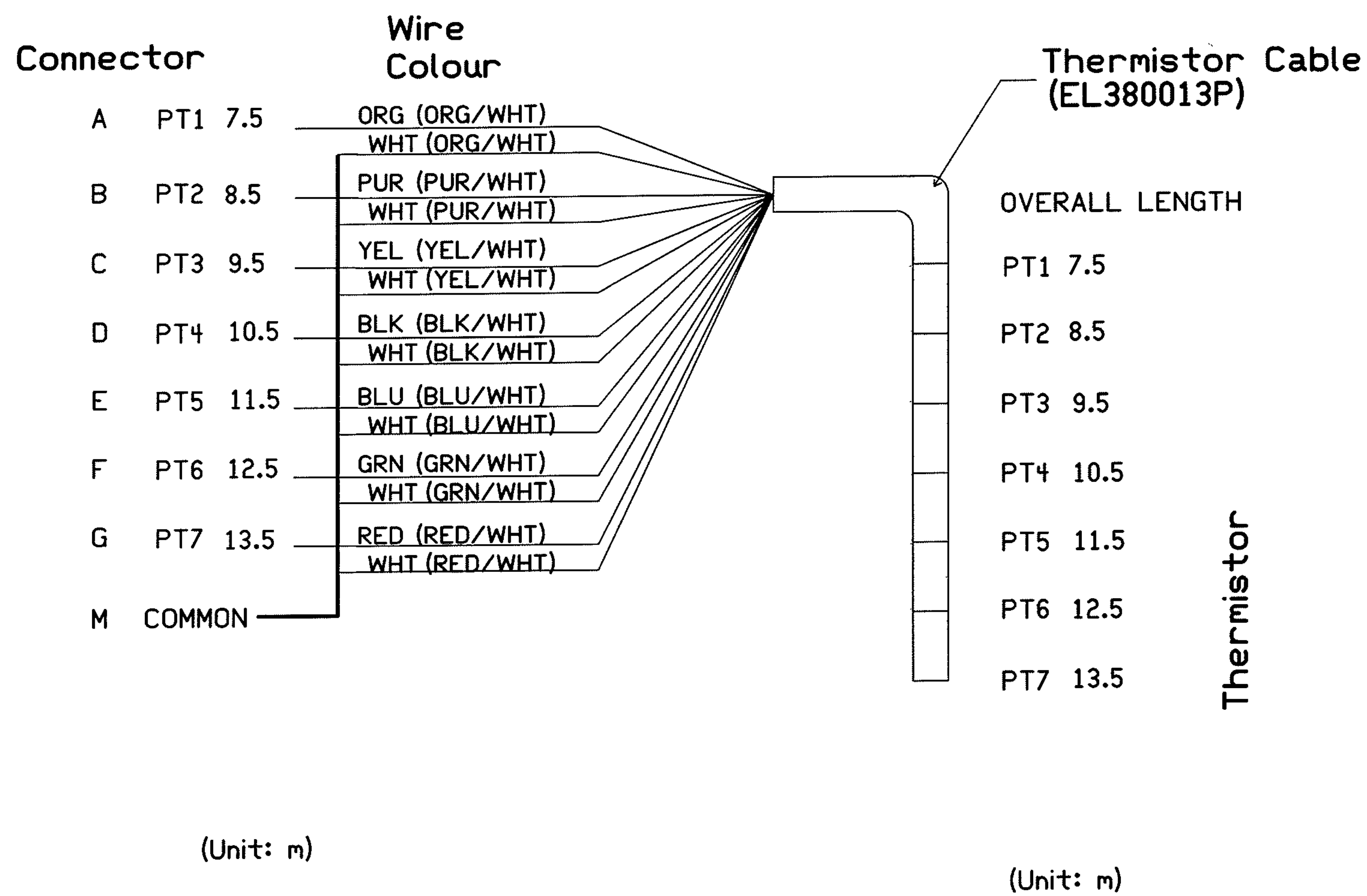
Co:	RST INSTRUMENTS LTD		
Title:	THERMISTOR CABLE		
J/N:	THW0119/WOQ024384	Revision:	A
Author:	WY	Size:	A
Date:	2012/10/26	Sheet 3 of 5	

TS3417



TS3418 - TS3419

Co:	RST INSTRUMENTS LTD		
Title:	THERMISTOR CABLE		
J/N:	THW0119/WOQ024384	Revision:	A
Author:	WY	Size:	A
Date:	2012/10/26	Sheet 3 of 5	



S/N: TS3420

Co:	RST INSTRUMENTS LTD
Title:	THERMISTOR CABLE
J/N:	THW0123/WOQ024782 Revision: A
Author:	WY Size: A
Date:	2012/10/26 Sheet 5 of 5

APPENDIX F:
CORROSION MONITORING
SYSTEM E-MAILS

Pineau, Joel

From: Nasser Nia <NNia@rstinstruments.com>
Sent: Thursday, October 13, 2016 3:48 PM
To: Pineau, Joel
Cc: Hayley Croteau
Subject: RE: Thermistor strings - Bluefish Dam - Northwest Territories
Attachments: 1224_001.pdf; MIS0054A.PDF

Hi Joel ,

I am preparing a quote for the thermistor readout TH2016B and its flylead and will submit to you as soon as possible .

In the meantime I talked to my supervisor Rob who was involved on the corrosion monitor job . He did some digging in his outlook and we found something that shows how they ended up quoting and ordering the coupons early 2011, reference points , cables and voltmeters . Please read through the emails and let us know what you have at site , supposedly the 15 coupons have to be buried in dirt and the reference electrode should be installed at upstream select fill .

RST Instruments Ltd., *per*
Nasser Nia
Sales Engineer
Tel: 604.540.1100 ext 243
Cell: 604.352.4501
Fax: 604.540.1005
Email: nnia@rstinstruments.com
Web: www.rstinstruments.com

Hi Chris

So I have finally got something for you on the stainless coupons.

Coupons would be made 3” x 8” racetrack shaped plates of ¼ 304L. The cutout would be by abrasive water jet, so no heat affected zone would be produced. At the center of the top radius, a 0.06”D stainless wire would be (tiny) TIG welded to the plate. That wire would in turn be crimp butt-spliced to 12 AWG copper 600V insulated wire. All atypical metal (weld HAZ, filler, SS wire, crimp, copper) would be encapsulated in high dielectric resin in a ¾” Schedule 40 PVC potting chamber to provide strength, prevent galvanic action, and permit PVC conduit to be used to protect the wire in borehole backfill if required. The wire length would be made to order. 3 wire marks (up to 10 chars, one each end, one spare) would be provided with each coupon to control ID.

A third-party cathodic industry IonX20 Cu/CuSO4 10.5" x 1.5"D permanent (20 year) reference soil electrode could be provided, complete with standard 25' 12AWG wire. It is expected that this unit would be placed in the upstream select fill.

Given the scale of the site and the puny length of typical DMM leads, it might be convenient to trench the cables from the borehole collars to a central terminal box. We could provide a 8 x 8 x 6" NEMA4x fiberglass box with mounting plate, conduit entry, panel, DIN rail and 12 screw terminals.

I hope that this is of some help to you in planning the project.

Cheers

From: Rob Taylor
Sent: April-18-11 4:09 PM
To: 'Grapel, Chris'
Subject: RE: Update on corrosion monitoring instrumentation

Hi Chris

I enclose a rough concept (not to scale) sketch. It shows a DMM measuring from the reference electrode to a coupon. It also shows a metallic bond on the SS304L membrane as another measurement point of interest, either as an alternate reference or with respect to the reference electrode.

On the locations of the:

- Borehole installed coupons
- Reference electrode
- Membrane bond

we would prefer to defer to your corrosion expert, who has specified the system. The reference electrode should be located below the minimum water table and frost line.

On reading the potentials, I expect that all points would be read as a DC voltage with respect to the reference electrode. A consistent convention with the leads should be used, with the minus (black) probe connected to reference electrode, the positive (red) probe connected to the coupon or membrane bond. The measurement should include the sign of the data.

The measurements would be made using a battery-powered DMM on the DC volts terminals. The readings would likely be on the order of +/- 100-500 mV. I suggest a 3 ½ digit DMM with fixed ranges including 20V, 2V, and 200 mV would be suitable. Ideally, a basic meter (0.1% DC accuracy, >20 Mohm input impedance) from a reputable manufacturer (Fluke, Beckman, Amprobe etc) would be purchased for the job, so that all readings would be taken with the same unit, and in the case of loss or damage, could be replaced with an identical unit without interchangeability artefact. Initial readings could be taken using all of the above ranges, deferring the decision on which to use in the future until all points were installed and measured. Note that portable DMMs have LCD displays which function poorly below minus 10C, and may be damaged by low temperature (-40C) storage. The operation at low temperature issue may be handled by keeping the DMM in an inner parka pocket between readings.

The DMM probe wires are typically 1 m long. The coupon borehole plan locations would probably be much more than a meter from the reference electrode. This span will have to be wired, either permanently or temporarily during measurements. If the temporary approach is taken, the connection area on each wire should be protected from oxidation when not in use, and every effort to make good connections on bright copper. A small waterproof box located above grade would be helpful. The temporary connection cable should be flexible at worst-case temperatures, be insulated, could be stored on a reel, and be fitted with an alligator clip for connection convenience (similar to an aircraft fuel grounding setup).

Alternately, permanent wire extensions could be routed in buried conduit, either individually or shared, to a central enclosure near the reference electrode, and the enclosure fitted with terminals or even a rotary switch to facilitate readings. This would be a highly recommended if:

1. Frequent readings are to be taken
2. The path between measurement points and reference electrode is obstructed
3. The borehole collars are subject to equipment or animal damage

I hope these concepts fit your requirements; let me know if we need to revise.

Cheers

RST Instruments Ltd., *per*
Robert Taylor PEng
President
Tel: 604.540.1100 ext. 206
Fax: 604.540.1005
Email: rtaylor@rstinstruments.com
Web: www.rstinstruments.com

From: Grapel, Chris [mailto:CGrapel@eba.ca]
Sent: April-18-11 12:07 PM
To: Rob Taylor
Subject: Update on corrosion monitoring instrumentation

Rob,

I will need to start wrapping this up. When we last emailed I requested a schematic and an explanation on how the corrosion monitoring instrumentation would work. Can you send this to me please?

Chris

Chris Gräpel, M.Eng., P.Eng. | **Principal Specialist**
p. 780.451.2130 516 | **f.** 780.454.5688
cgrapel@eba.ca

From: Hayley Croteau
Sent: Thursday, October 13, 2016 3:00 PM
To: Pineau, Joel
Cc: Nasser Nia
Subject: RE: Thermistor strings - Bluefish Dam - Northwest Territories

Hi Joel,

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Stantec
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joel.pineau@stantec.com

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Hayley Croteau, P.Eng.
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<image002.gif> Tel: 604.540.1100 ext 218
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<image004.gif> Email:

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Cell: 778-228-9704
Fax: 604-436-3752
joel.pineau@stantec.com

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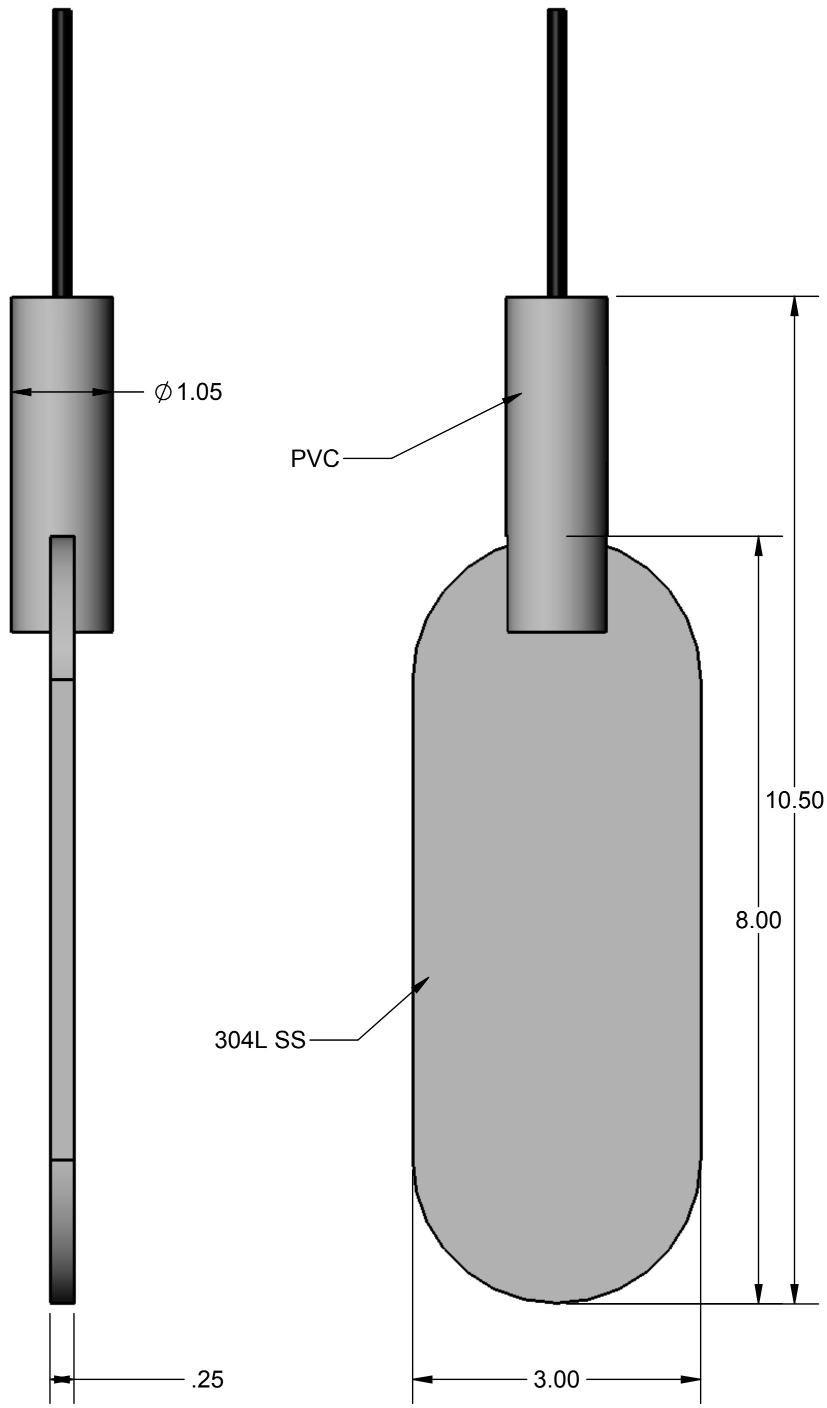


NOTE:
1. MATERIAL: SUB ASM

x.x ±.050"
x.xx ±.010"
x.xxx ±.005"
ang. ±.5°

Revision Table

rst INSTRUMENTS

COUPONS

SALES DRAWING

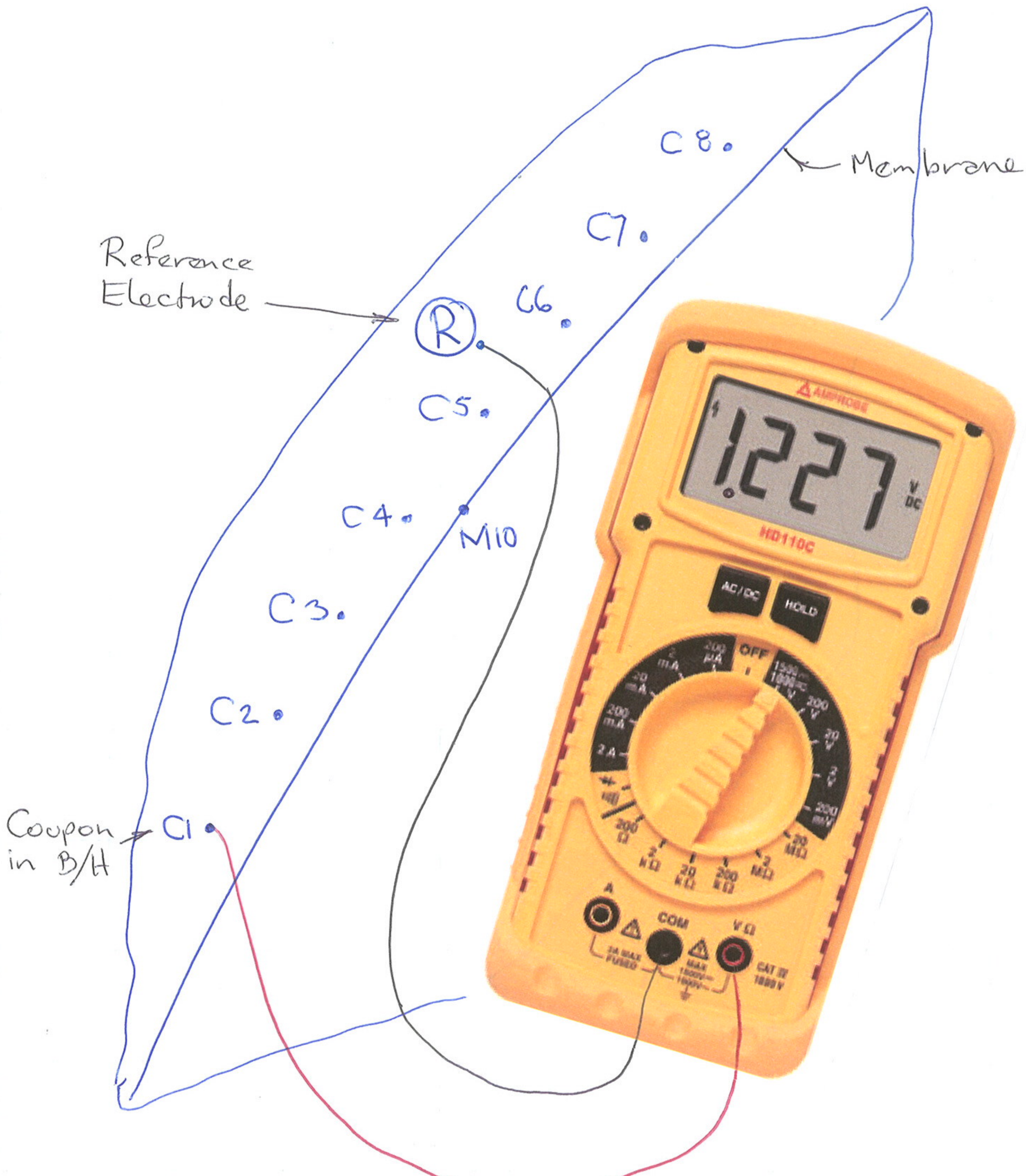
SCALE: 1:2	DWG #: MIS0054A		REV: A
DATE: 15MAR-2011	CHK'D	APPRV'D	DRAWN BY: TW

rst INSTRUMENTS

PROJECT EDA SS 304 Coupons
REF No.

SUBJECT
DATE 2011/04/18

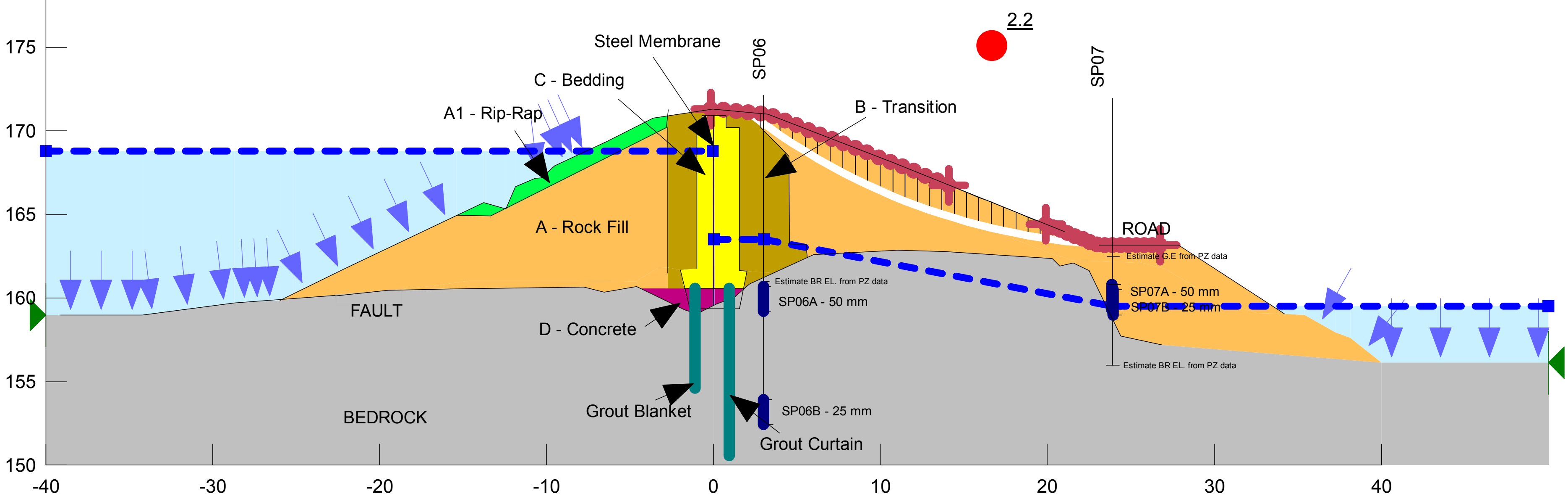
NAME CONCEPTUAL HOOKUP
PAGE OF



APPENDIX G:
SLOPE STABILITY

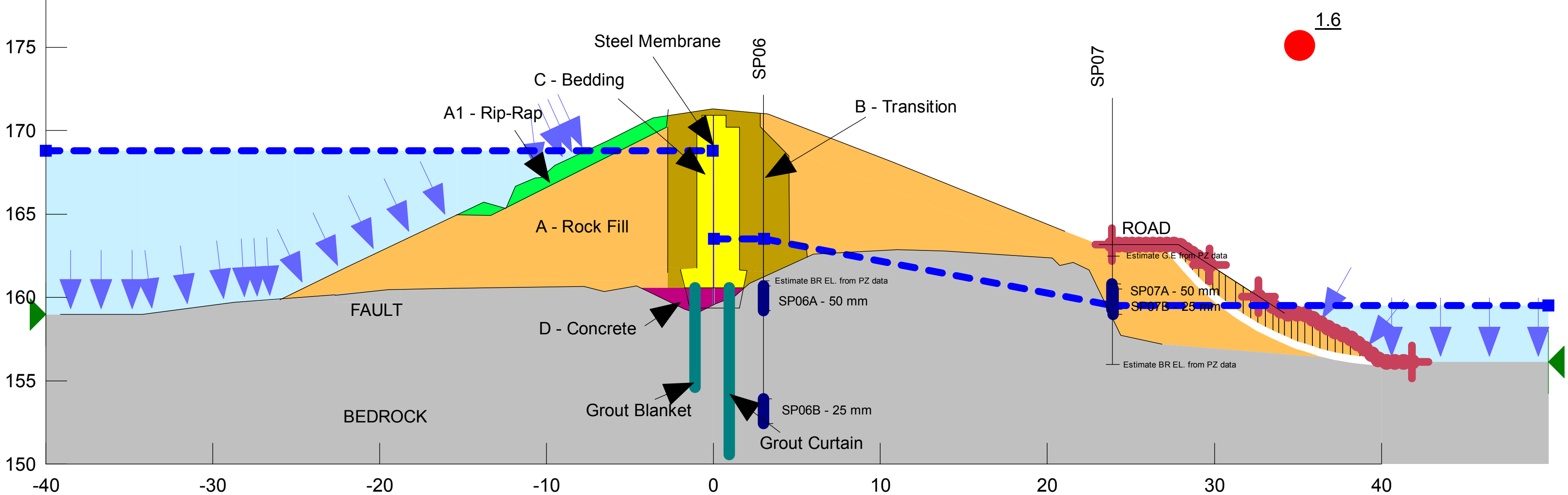
Bluefish Dam - Slope Stability Analysis
Station: 0+160
Name: 1. PZ readings = average
Case 1 Main

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	A - Rock Fill 1.0 m Minus	Mohr-Coulomb	22	0	40
	A1 - Rip-Rap 0.5 to 1.0 m	Mohr-Coulomb	22	0	40
	B - Transition, 200 mm Minus	Mohr-Coulomb	22	0	40
	C - Bedding, 20 mm minus	Mohr-Coulomb	22	0	35
	D - Concrete, Key Trench Backfill	Bedrock (Impenetrable)			
	Bedrock	Bedrock (Impenetrable)			
	Steel Membrane	Bedrock (Impenetrable)			
	A - Rock Fill 1.0 m Minus (downslope)	Mohr-Coulomb	22	0	40
	B - Transition, 200 mm Minus (downslope)	Mohr-Coulomb	22	0	40
	C - Bedding, 20 mm minus (downslope)	Mohr-Coulomb	22	0	35
	Bedrock (downslope)	Bedrock (Impenetrable)			



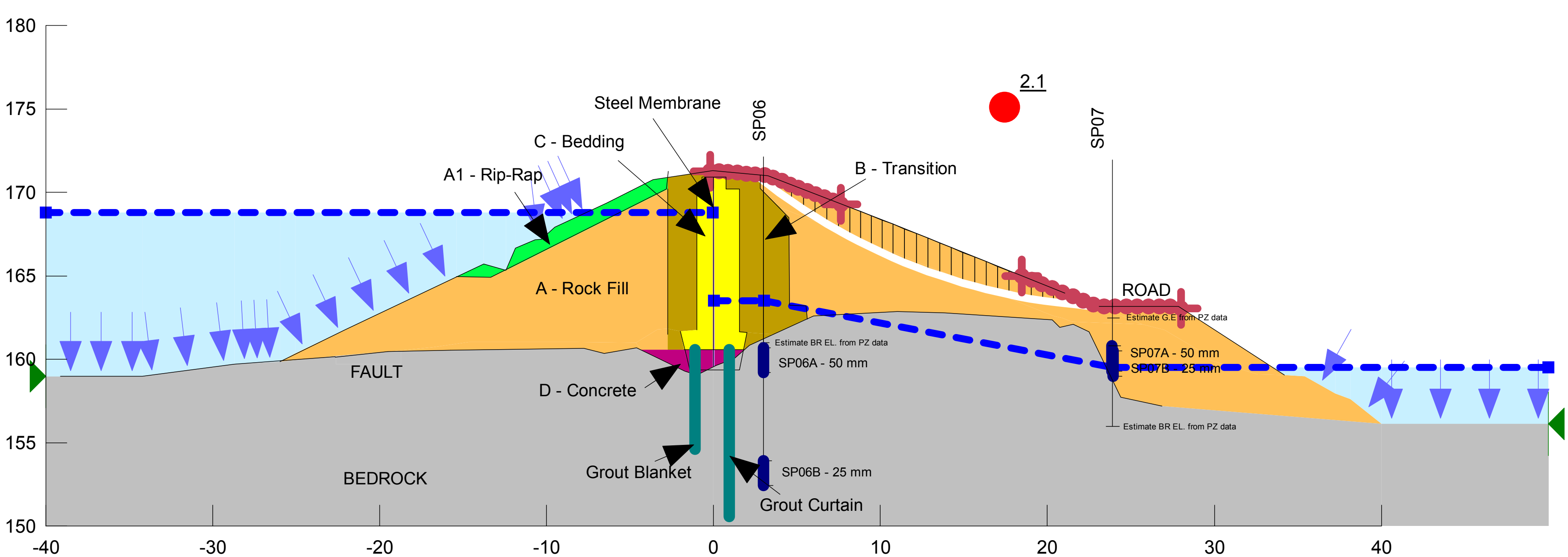
Bluefish Dam - Slope Stability Analysis
Station: 0+160
Name: 1. TOE - PZ readings = average
Case 1 Toe

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	A - Rock Fill 1.0 m Minus	Mohr-Coulomb	22	0	40
	A1 - Rip-Rap 0.5 to 1.0 m	Mohr-Coulomb	22	0	40
	B - Transition, 200 mm Minus	Mohr-Coulomb	22	0	40
	C - Bedding, 20 mm minus	Mohr-Coulomb	22	0	35
	D - Concrete, Key Trench Backfill	Bedrock (Impenetrable)			
	Bedrock	Bedrock (Impenetrable)			
	Steel Membrane	Bedrock (Impenetrable)			
	A - Rock Fill 1.0 m Minus (downslope)	Mohr-Coulomb	22	0	40
	B - Transition, 200 mm Minus (downslope)	Mohr-Coulomb	22	0	40
	C - Bedding, 20 mm minus (downslope)	Mohr-Coulomb	22	0	35
	Bedrock (downslope)	Bedrock (Impenetrable)			



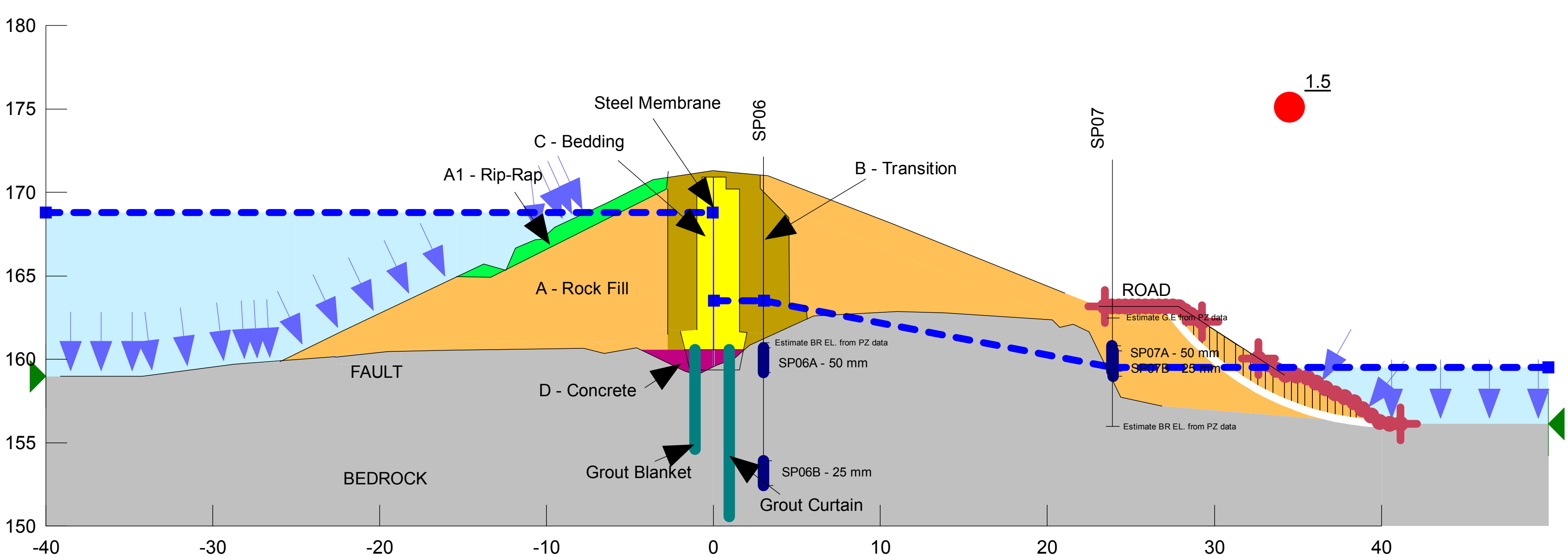
Bluefish Dam - Slope Stability Analysis
Station: 0+160
Name: 2. PZ readings - Seismic - kh = 0.014g
Case 2 Main

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	A - Rock Fill 1.0 m Minus	Mohr-Coulomb	22	0	40
	A1 - Rip-Rap 0.5 to 1.0 m	Mohr-Coulomb	22	0	40
	B - Transition, 200 mm Minus	Mohr-Coulomb	22	0	40
	C - Bedding, 20 mm minus	Mohr-Coulomb	22	0	35
	D - Concrete, Key Trench Backfill	Bedrock (Impenetrable)			
	Bedrock	Bedrock (Impenetrable)			
	Steel Membrane	Bedrock (Impenetrable)			
	A - Rock Fill 1.0 m Minus (downslope)	Mohr-Coulomb	22	0	40
	B - Transition, 200 mm Minus (downslope)	Mohr-Coulomb	22	0	40
	C - Bedding, 20 mm minus (downslope)	Mohr-Coulomb	22	0	35
	Bedrock (downslope)	Bedrock (Impenetrable)			



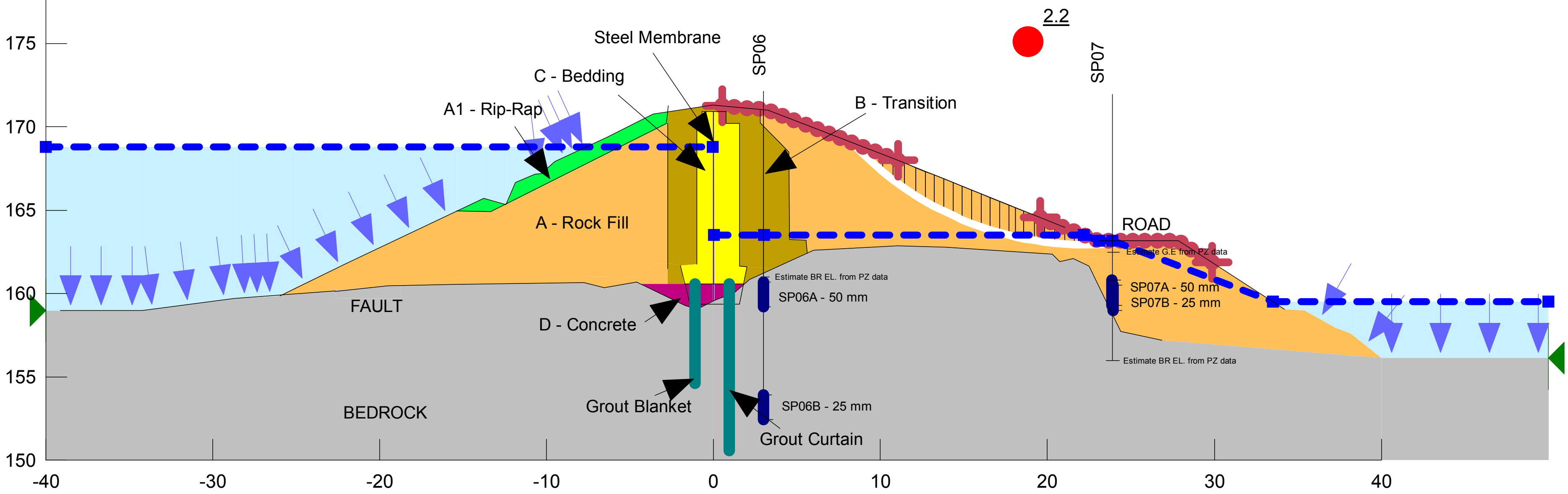
Bluefish Dam - Slope Stability Analysis
Station: 0+160
Name: 2. TOE - PZ readings - Seismic - kh = 0.014g
Case 2 Toe

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	A - Rock Fill 1.0 m Minus	Mohr-Coulomb	22	0	40
	A1 - Rip-Rap 0.5 to 1.0 m	Mohr-Coulomb	22	0	40
	B - Transition, 200 mm Minus	Mohr-Coulomb	22	0	40
	C - Bedding, 20 mm minus	Mohr-Coulomb	22	0	35
	D - Concrete, Key Trench Backfill	Bedrock (Impenetrable)			
	Bedrock	Bedrock (Impenetrable)			
	Steel Membrane	Bedrock (Impenetrable)			
	A - Rock Fill 1.0 m Minus (downslope)	Mohr-Coulomb	22	0	40
	B - Transition, 200 mm Minus (downslope)	Mohr-Coulomb	22	0	40
	C - Bedding, 20 mm minus (downslope)	Mohr-Coulomb	22	0	35
	Bedrock (downslope)	Bedrock (Impenetrable)			



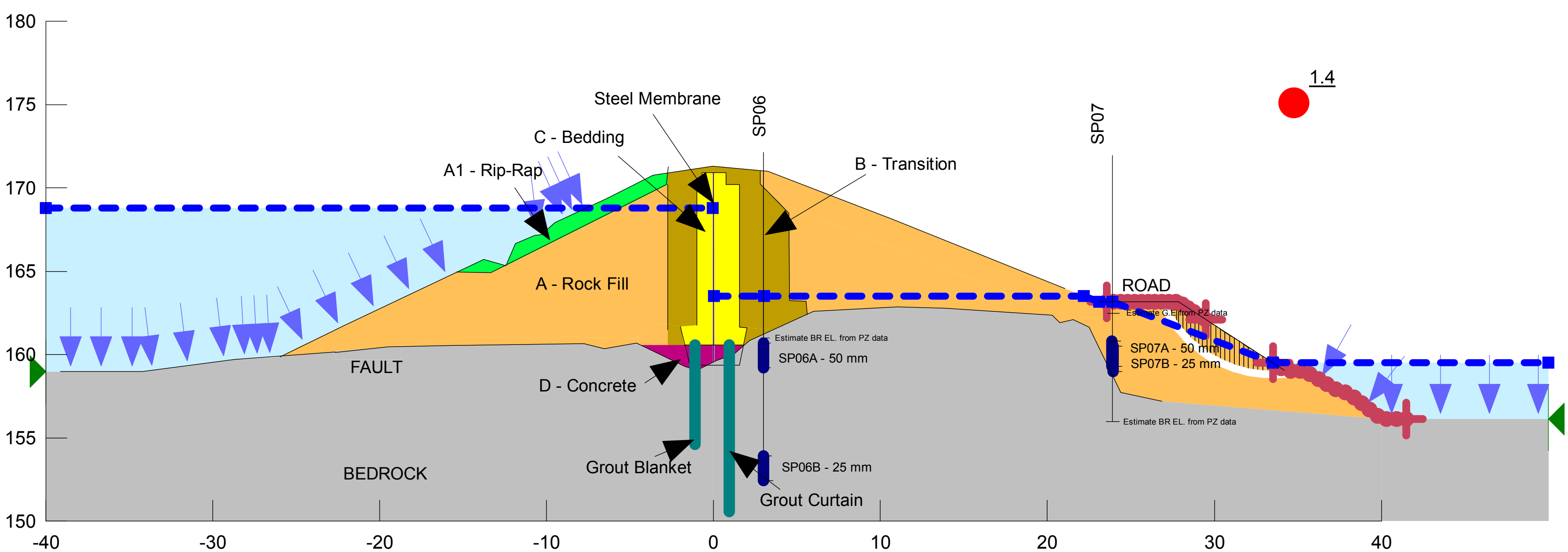
Bluefish Dam - Slope Stability Analysis
Station: 0+160
Name: 3. Ice formation - PZ = high
Case 3 Main

Color	Name	Model	Unit Weight (kN/m^3)	Cohesion' (kPa)	Phi' (°)
	A - Rock Fill 1.0 m Minus	Mohr-Coulomb	22	0	40
	A1 - Rip-Rap 0.5 to 1.0 m	Mohr-Coulomb	22	0	40
	B - Transition, 200 mm Minus	Mohr-Coulomb	22	0	40
	C - Bedding, 20 mm minus	Mohr-Coulomb	22	0	35
	D - Concrete, Key Trench Backfill	Bedrock (Impenetrable)			
	Bedrock	Bedrock (Impenetrable)			
	Steel Membrane	Bedrock (Impenetrable)			
	A - Rock Fill 1.0 m Minus (downslope)	Mohr-Coulomb	22	0	40
	B - Transition, 200 mm Minus (downslope)	Mohr-Coulomb	22	0	40
	C - Bedding, 20 mm minus (downslope)	Mohr-Coulomb	22	0	35
	Bedrock (downslope)	Bedrock (Impenetrable)			



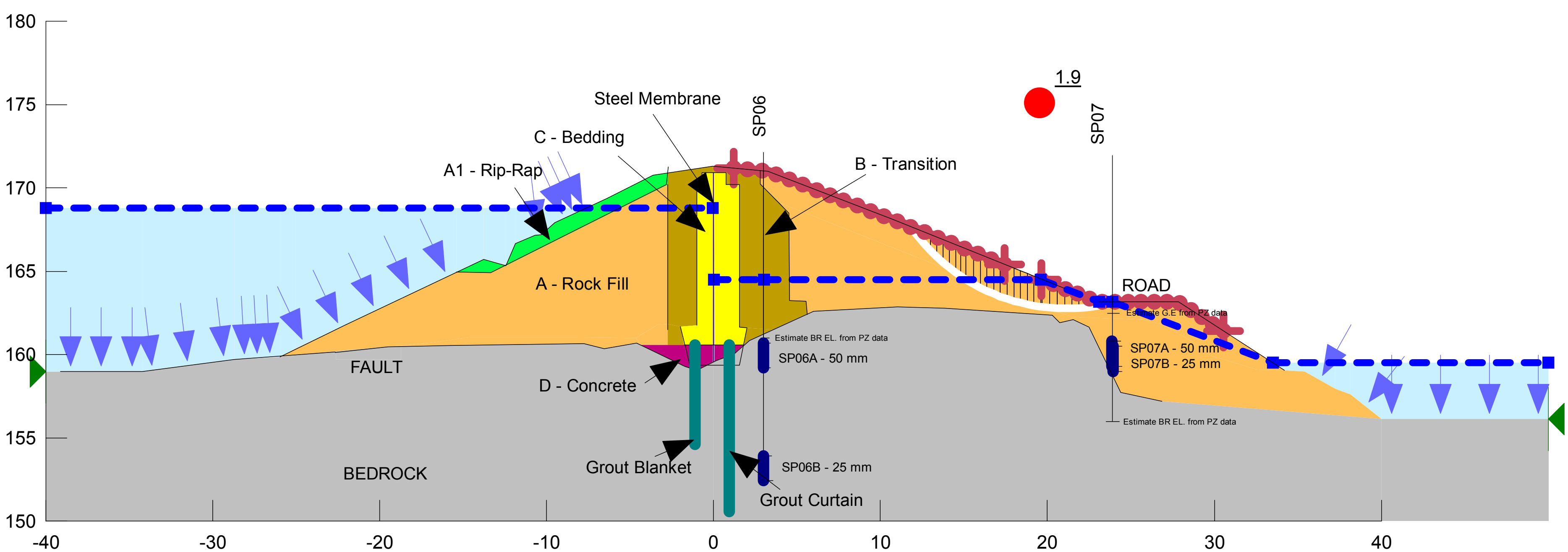
Bluefish Dam - Slope Stability Analysis
Station: 0+160
Name: 3. TOE Ice formation - PZ = high
Case 3 Toe

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	A - Rock Fill 1.0 m Minus	Mohr-Coulomb	22	0	40
	A1 - Rip-Rap 0.5 to 1.0 m	Mohr-Coulomb	22	0	40
	B - Transition, 200 mm Minus	Mohr-Coulomb	22	0	40
	C - Bedding, 20 mm minus	Mohr-Coulomb	22	0	35
	D - Concrete, Key Trench Backfill	Bedrock (Impenetrable)			
	Bedrock	Bedrock (Impenetrable)			
	Steel Membrane	Bedrock (Impenetrable)			
	A - Rock Fill 1.0 m Minus (downslope)	Mohr-Coulomb	22	0	40
	B - Transition, 200 mm Minus (downslope)	Mohr-Coulomb	22	0	40
	C - Bedding, 20 mm minus (downslope)	Mohr-Coulomb	22	0	35
	Bedrock (downslope)	Bedrock (Impenetrable)			



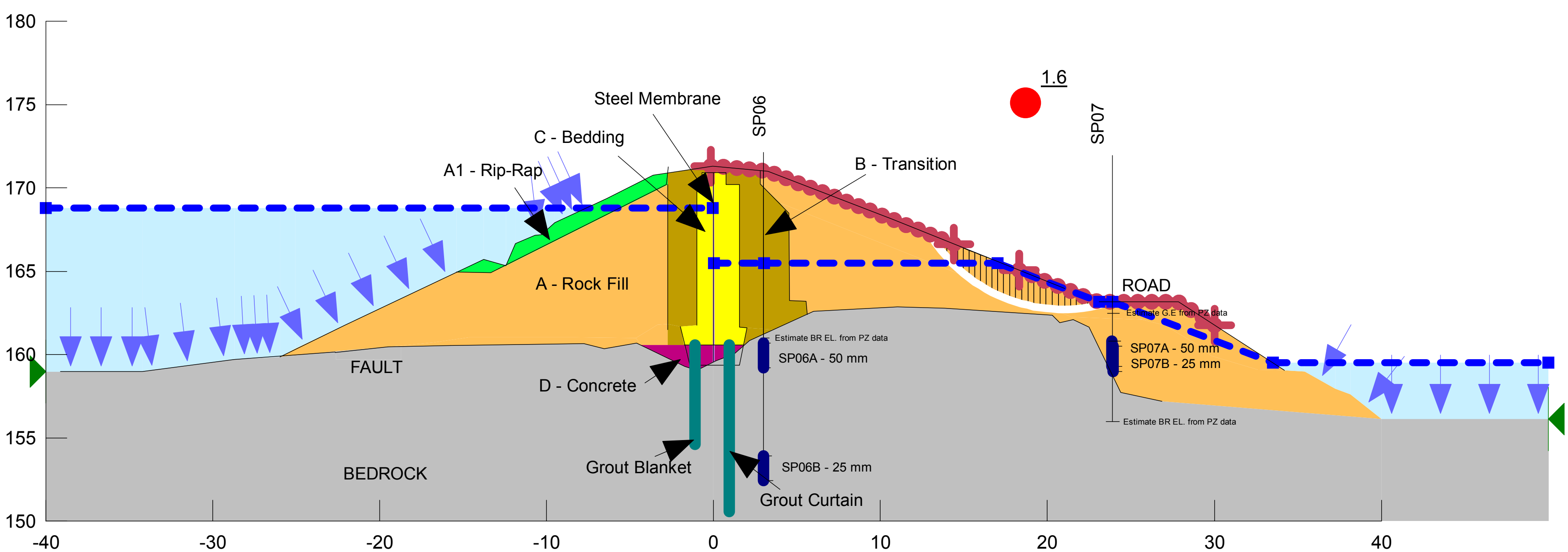
Bluefish Dam - Slope Stability Analysis
Station: 0+160
Name: Ice formation - PZ + 1.0 m
Case 3a Main

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	A - Rock Fill 1.0 m Minus	Mohr-Coulomb	22	0	40
	A1 - Rip-Rap 0.5 to 1.0 m	Mohr-Coulomb	22	0	40
	B - Transition, 200 mm Minus	Mohr-Coulomb	22	0	40
	C - Bedding, 20 mm minus	Mohr-Coulomb	22	0	35
	D - Concrete, Key Trench Backfill	Bedrock (Impenetrable)			
	Bedrock	Bedrock (Impenetrable)			
	Steel Membrane	Bedrock (Impenetrable)			
	A - Rock Fill 1.0 m Minus (downslope)	Mohr-Coulomb	22	0	40
	B - Transition, 200 mm Minus (downslope)	Mohr-Coulomb	22	0	40
	C - Bedding, 20 mm minus (downslope)	Mohr-Coulomb	22	0	35
	Bedrock (downslope)	Bedrock (Impenetrable)			



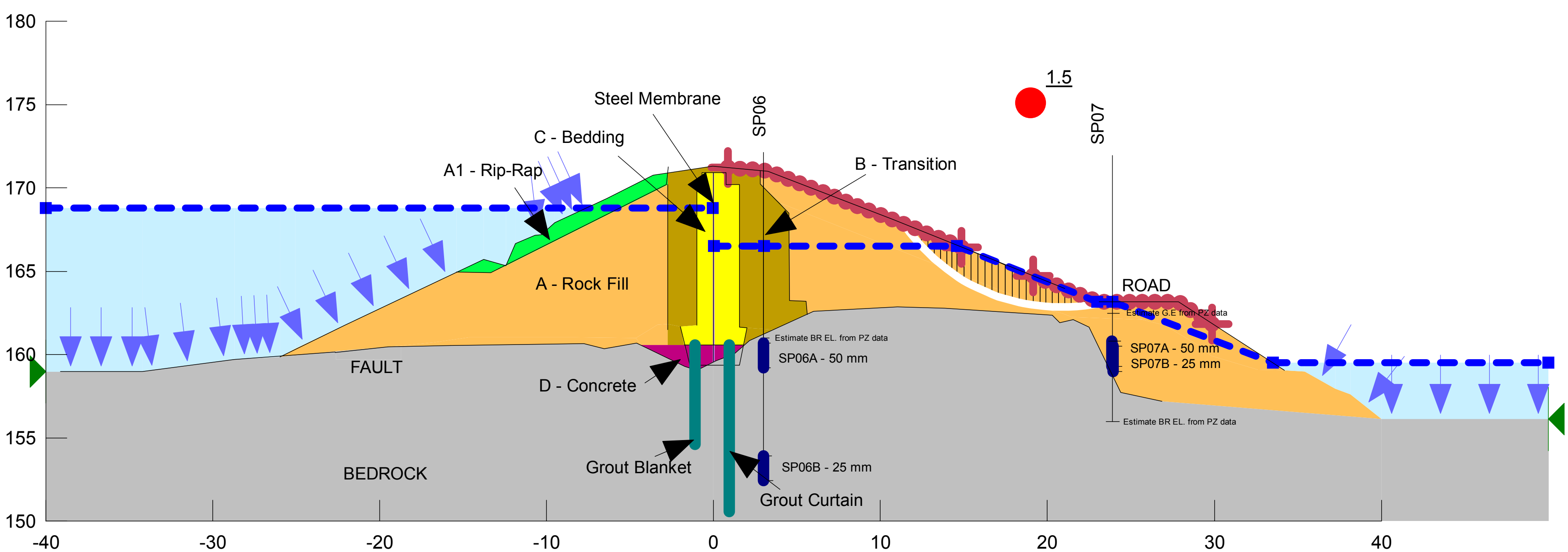
Bluefish Dam - Slope Stability Analysis
Station: 0+160
Name: Ice formation - PZ + 2.0 m
Case 3b Main

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	A - Rock Fill 1.0 m Minus	Mohr-Coulomb	22	0	40
	A1 - Rip-Rap 0.5 to 1.0 m	Mohr-Coulomb	22	0	40
	B - Transition, 200 mm Minus	Mohr-Coulomb	22	0	40
	C - Bedding, 20 mm minus	Mohr-Coulomb	22	0	35
	D - Concrete, Key Trench Backfill	Bedrock (Impenetrable)			
	Bedrock	Bedrock (Impenetrable)			
	Steel Membrane	Bedrock (Impenetrable)			
	A - Rock Fill 1.0 m Minus (downslope)	Mohr-Coulomb	22	0	40
	B - Transition, 200 mm Minus (downslope)	Mohr-Coulomb	22	0	40
	C - Bedding, 20 mm minus (downslope)	Mohr-Coulomb	22	0	35
	Bedrock (downslope)	Bedrock (Impenetrable)			



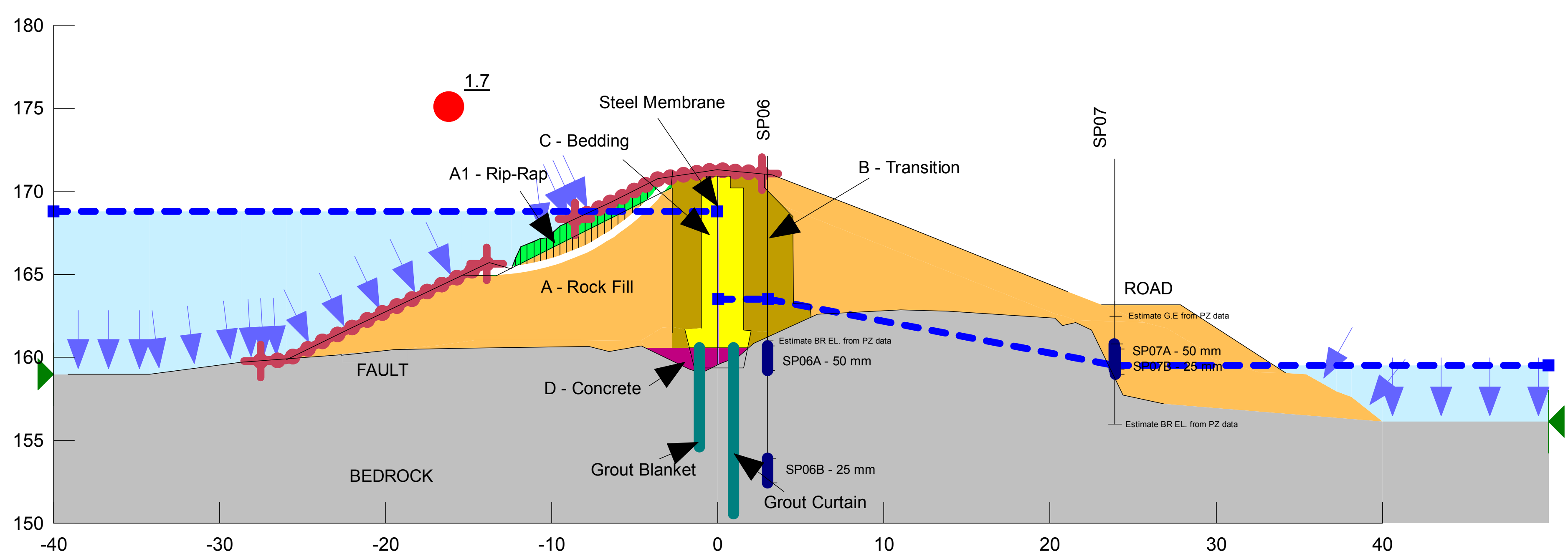
Bluefish Dam - Slope Stability Analysis
Station: 0+160
Name: Ice formation - PZ + 3.0 m
Case 3c Main

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	A - Rock Fill 1.0 m Minus	Mohr-Coulomb	22	0	40
	A1 - Rip-Rap 0.5 to 1.0 m	Mohr-Coulomb	22	0	40
	B - Transition, 200 mm Minus	Mohr-Coulomb	22	0	40
	C - Bedding, 20 mm minus	Mohr-Coulomb	22	0	35
	D - Concrete, Key Trench Backfill	Bedrock (Impenetrable)			
	Bedrock	Bedrock (Impenetrable)			
	Steel Membrane	Bedrock (Impenetrable)			
	A - Rock Fill 1.0 m Minus (downslope)	Mohr-Coulomb	22	0	40
	B - Transition, 200 mm Minus (downslope)	Mohr-Coulomb	22	0	40
	C - Bedding, 20 mm minus (downslope)	Mohr-Coulomb	22	0	35
	Bedrock (downslope)	Bedrock (Impenetrable)			



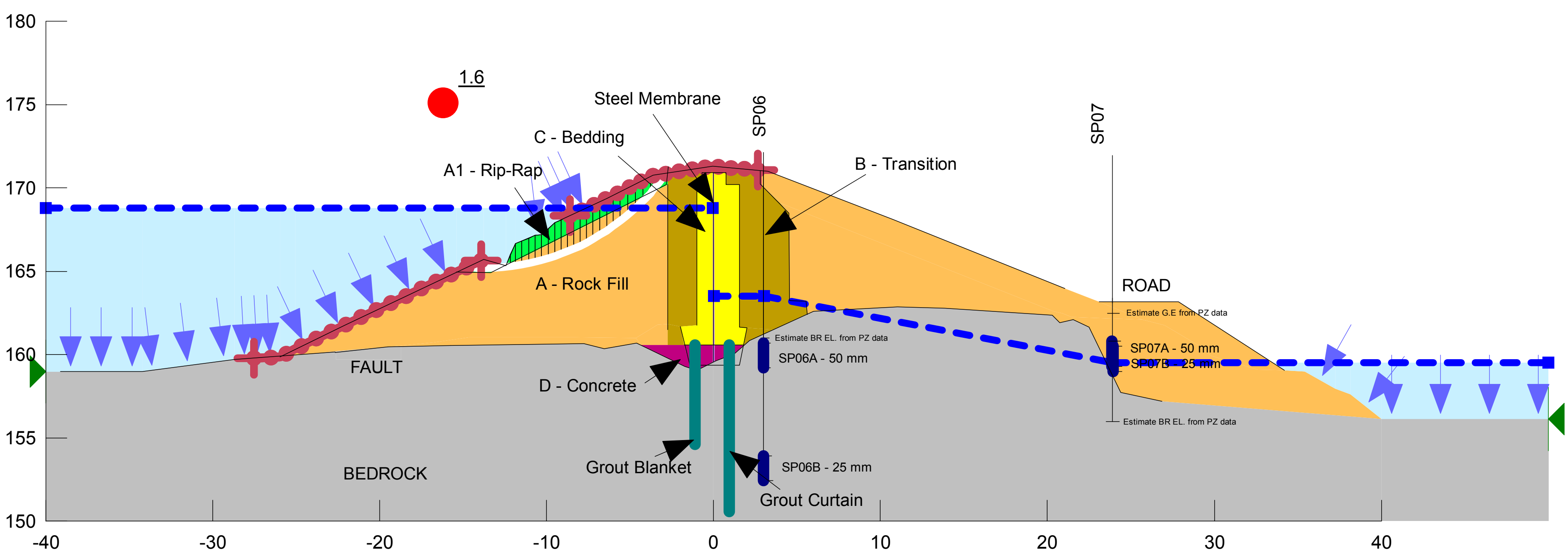
Bluefish Dam - Slope Stability Analysis
Station: 0+160
Name: 4. UPSTREAM - Base case - normal water level
Case 4

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	A - Rock Fill 1.0 m Minus	Mohr-Coulomb	22	0	40
	A1 - Rip-Rap 0.5 to 1.0 m	Mohr-Coulomb	22	0	40
	B - Transition, 200 mm Minus	Mohr-Coulomb	22	0	40
	C - Bedding, 20 mm minus	Mohr-Coulomb	22	0	35
	D - Concrete, Key Trench Backfill	Bedrock (Impenetrable)			
	Bedrock	Bedrock (Impenetrable)			
	Steel Membrane	Bedrock (Impenetrable)			
	A - Rock Fill 1.0 m Minus (downslope)	Mohr-Coulomb	22	0	40
	B - Transition, 200 mm Minus (downslope)	Mohr-Coulomb	22	0	40
	C - Bedding, 20 mm minus (downslope)	Mohr-Coulomb	22	0	35
	Bedrock (downslope)	Bedrock (Impenetrable)			



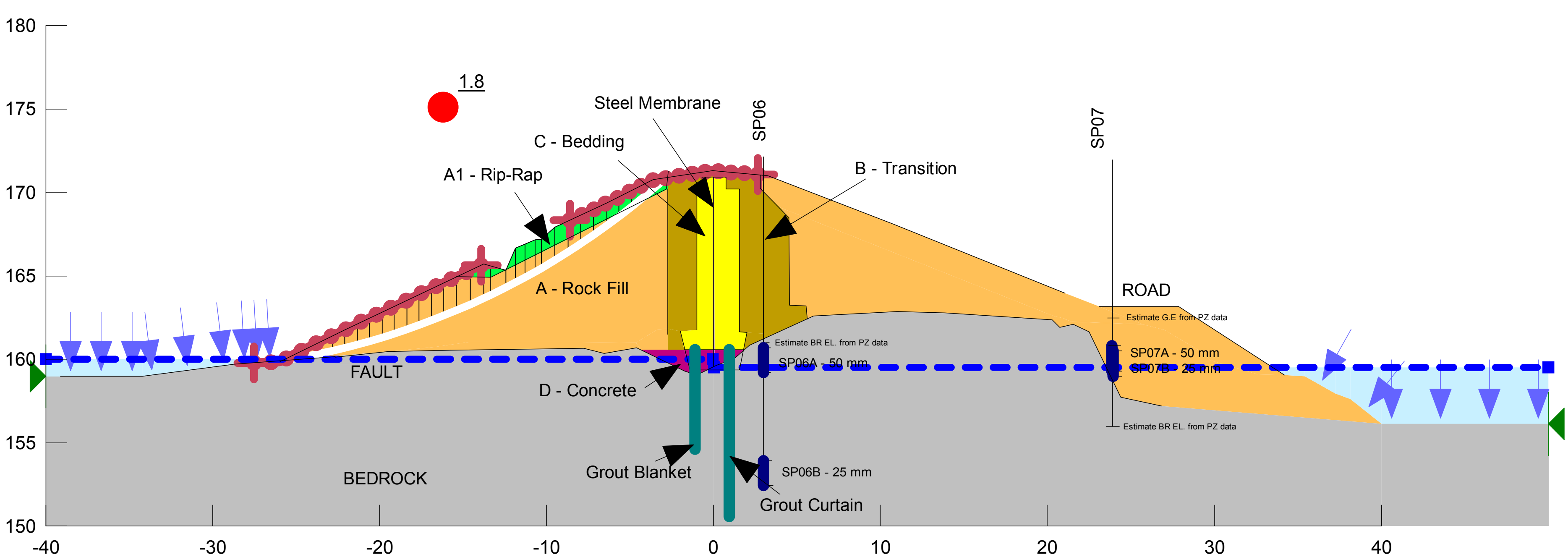
Bluefish Dam - Slope Stability Analysis
Station: 0+160
Name: 5. UPSTREAM - Seismic - kh = 0.014g - normal water level
Case 5

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	A - Rock Fill 1.0 m Minus	Mohr-Coulomb	22	0	40
	A1 - Rip-Rap 0.5 to 1.0 m	Mohr-Coulomb	22	0	40
	B - Transition, 200 mm Minus	Mohr-Coulomb	22	0	40
	C - Bedding, 20 mm minus	Mohr-Coulomb	22	0	35
	D - Concrete, Key Trench Backfill	Bedrock (Impenetrable)			
	Bedrock	Bedrock (Impenetrable)			
	Steel Membrane	Bedrock (Impenetrable)			
	A - Rock Fill 1.0 m Minus (downslope)	Mohr-Coulomb	22	0	40
	B - Transition, 200 mm Minus (downslope)	Mohr-Coulomb	22	0	40
	C - Bedding, 20 mm minus (downslope)	Mohr-Coulomb	22	0	35
	Bedrock (downslope)	Bedrock (Impenetrable)			



Bluefish Dam - Slope Stability Analysis
Station: 0+160
Name: 6. UPSTREAM - low water level
Case 6

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	A - Rock Fill 1.0 m Minus	Mohr-Coulomb	22	0	40
	A1 - Rip-Rap 0.5 to 1.0 m	Mohr-Coulomb	22	0	40
	B - Transition, 200 mm Minus	Mohr-Coulomb	22	0	40
	C - Bedding, 20 mm minus	Mohr-Coulomb	22	0	35
	D - Concrete, Key Trench Backfill	Bedrock (Impenetrable)			
	Bedrock	Bedrock (Impenetrable)			
	Steel Membrane	Bedrock (Impenetrable)			
	A - Rock Fill 1.0 m Minus (downslope)	Mohr-Coulomb	22	0	40
	B - Transition, 200 mm Minus (downslope)	Mohr-Coulomb	22	0	40
	C - Bedding, 20 mm minus (downslope)	Mohr-Coulomb	22	0	35
	Bedrock (downslope)	Bedrock (Impenetrable)			



Bluefish Hydro Comprehensive Dam Safety Review

Northwest Territories Power Corporation
December 2016
Project: 159100263

Stantec