APPENDIX K

Hydrotechnical Assessment of the Iron Arm Causeway

Stantec

Memo

To:	Georgi Doundarov Labec Century Iron Ore Inc.	From:	Sundar Premasiri & Sheldon Smith Markham
File:	121511139	Date:	January 27, 2015

Reference: Hydrotechnical Assessment of the Iron Arm Causeway

1.0 Introduction

A causeway is proposed across Iron Arm as part of the mine haul road to be constructed for the Joyce Lake Direct Shipping Iron Ore Project. Based on the current design (BBA, 2014), the causeway will be approximately 1.1 km long and will contain two 8 m span bridges to allow flow across the causeway, as shown in **Figure 1** below. A hydrotechnical assessment was conducted to assess the water levels and flow velocities in the vicinity of the causeway crossings. Wave conditions, including wave run up and wind set up conditions, were also assessed. This memo details the methodology, results, and recommendations from the completed assessment.

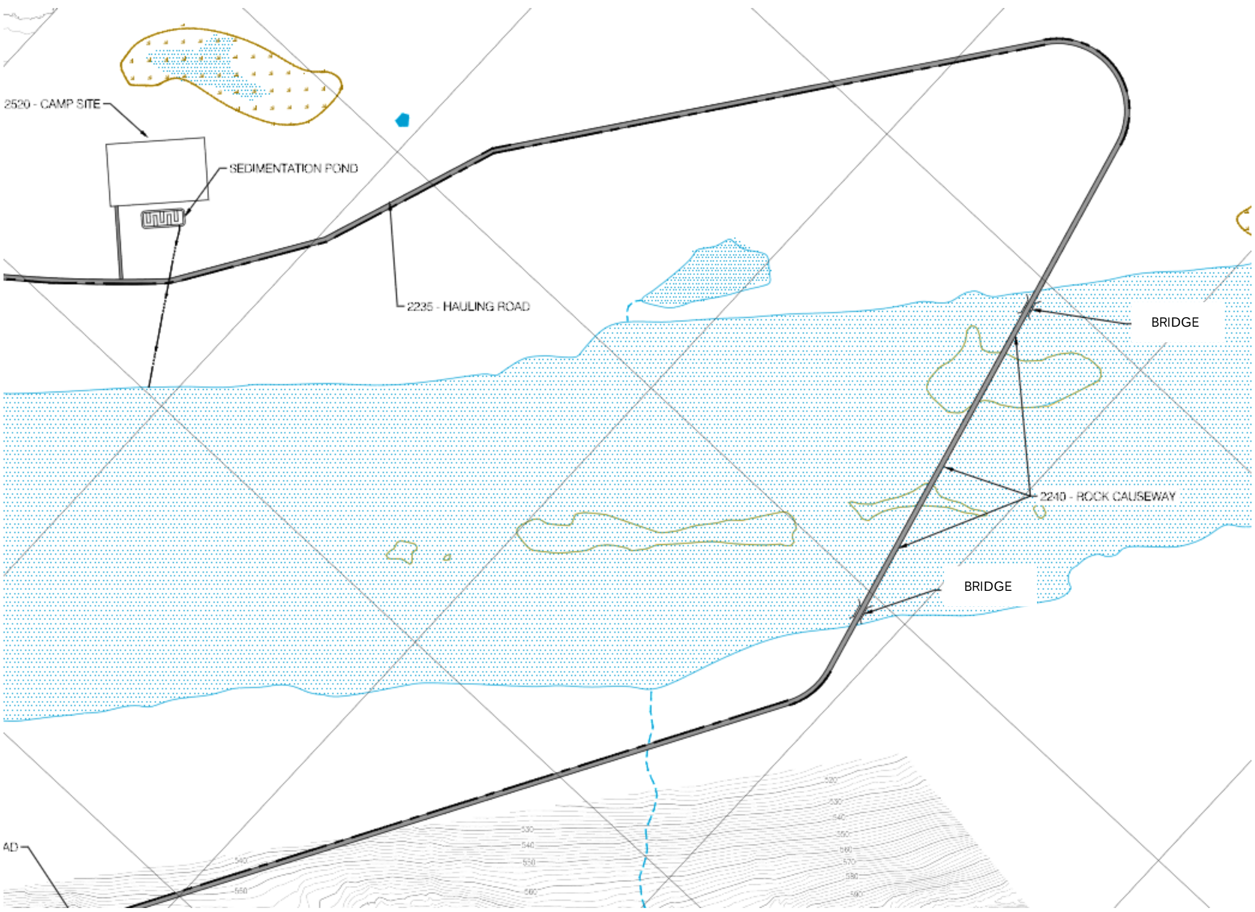

Figure 1 Planview of the Proposed Iron Arm Causeway (BBA, 2014)

Reference: Hydrotechnical Assessment of the Iron Arm Causeway

2.0 Tasks

The hydrotechnical assessment involved the following steps:

- Determine hydraulic characteristics (channel geometry, slope and roughness) at the causeway based on available bathymetry information and the proposed causeway design drawing (BBA, 2014);
- Determine design peak flows at the causeway crossing at Iron Arm using Environment Canada Hydrometric Data;
- Assess the hydraulic conditions and impacts at the causeway crossing using the HEC-RAS hydraulic model (USACE, 2010);
- Assess the potential wave conditions at the causeway during extreme winds; and,
- Assess the freeboard requirements and recommend causeway and bridge height.

3.0 Hydraulic Design Criteria for the Causeway Bridges

The following was considered in assessing the hydraulic performance of the bridges:

- Potential for overtopping or damage to the bridge during floods;
- Potential for upstream flooding due to the conveyance constrictions; and,
- Potential for scouring within the bridge waterway due to excessive velocity and shear stress.

Key design criteria are discussed in the following sections.

3.1.1 Design Flow Frequency

The design flow frequency selected for the causeway bridges is the 1:25 year flood flow. This is consistent with Environmental Guidelines for Water Crossings (Government of Newfoundland and Labrador, 1992).

3.1.2 Bridge Height

The bridge soffit elevation is determined by the design high water level plus an appropriate freeboard or clearance. The following factors are relevant when considering clearance:

- The maximum expected height of waves;
- Ice run-up on piers and abutments, and projection of ice floes above high water level;
- Projection of logs and other floating debris; and,

Reference: Hydrotechnical Assessment of the Iron Arm Causeway

- Statutory navigation requirements.

3.1.3 Scour/ Erosion Protection

Higher velocities at the bridge openings may cause scour and erosion. In addition, waves may cause erosion of the embankment. If required, appropriately sized protection should be used on the channel bed, bridge toe and embankment.

3.1.4 Ice Jamming Considerations

Freeze-up can produce a mass of ice on large water channels such as Iron Arm. Break-up of ice may result in ice jams and ice forces on the causeway. The resulting ice jam may cause the following type of problems:

- Increased scour at waterway constrictions;
- Flooding upstream of an ice jam and aggravated channel scour downstream resulting in damage to land and property;
- Damage to stream crossings due to ice abrasion;
- Impact of ice forces on bridges, abutments and piers which could result in structural damage or destruction;
- Channel icing which may reduce the conveyance capacity of a water crossing, resulting in upstream flooding; and,
- Surges of flow from sudden release of jams may aggravate these problems.

3.1.5 Navigation Requirements

Attikamagen Lake is not a “scheduled water” under the *Navigation Protection Act* (2014). Due to the remote location of the lake it is also not expected to have frequent users. However, passage across the causeway should be maintained through sufficient clearance at the bridges.

3.1.6 Fish Passage Requirements

The fish habitat assessment determined that provisions for fish passage during the open water season are required at the proposed causeway. An initial review has indicated that Northern Pike and Lake Trout are two important fish species to assess in Attikamagen Lake.

The following are relevant recommendations related to fish passage from *Guidelines for Protection for Freshwater Fish Habitat in Newfoundland and Labrador* (DFO, 1998):

- Bridges should be located on straight sections of a stream, where the stream channel is narrow, having low banks and firm, non-erodible soils;

Reference: Hydrotechnical Assessment of the Iron Arm Causeway

- Concrete aprons under bridges are not recommended since fish passage can be impeded at low flows;
- Instream piers should be aligned with the stream flow;
- Fill material for bridges should not be taken from stream beds, banks or riparian areas; and
- Instream work should be scheduled to avoid potential adverse impacts on spawning activities, spawning habitat, egg incubation, and fish migration.

4.0 Hydraulic Assessment

The proposed causeway crosses Iron Arm, a long arm also forming the outlet bay on Attikamagen Lake. The catchment area at Iron Arm outlet is approximately 1598 km^2. The Attikamagen Lake watershed is a large lake system, which is expected to have a significant controlling influence on the flows in the Iron Arm outlet. Therefore, design peak flows in the Iron Arm outlet were estimated using the data from Environment Canada Hydrometric Station 03PB001 on Naskaupi River at Fremont Lake. Flows at the Naskaupi River at Fremont Lake are significantly controlled by the lakes as illustrated by the regional flow frequency analysis presented in **Figure 2**.

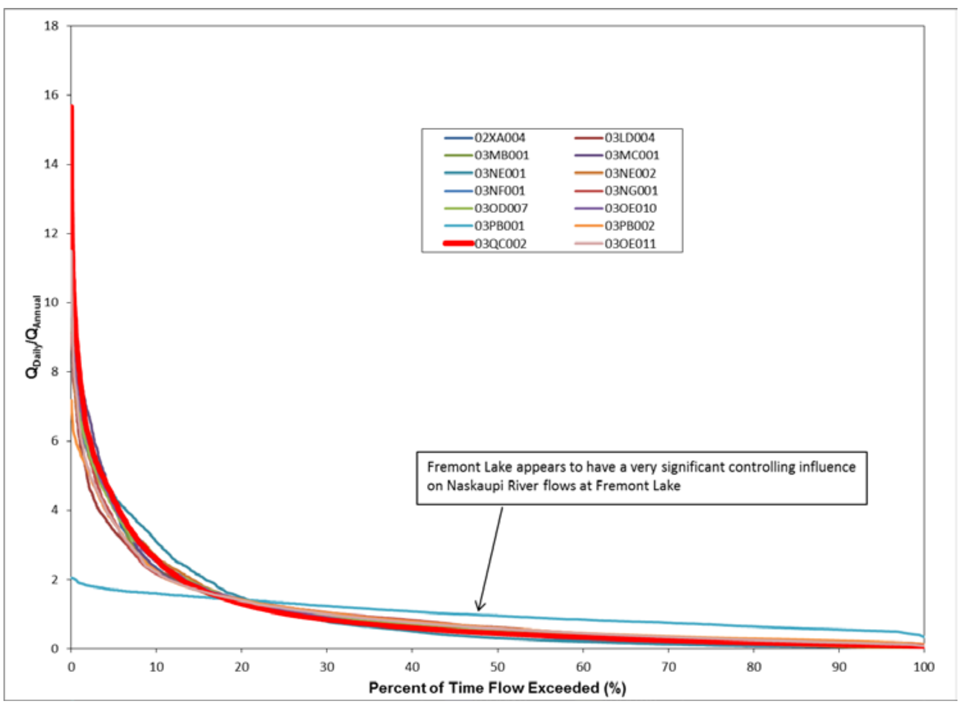

Figure 2 Period-of-Record Flow Duration Curves for Selected Hydrometric Stations

Flood flows at Iron Arm outlet were estimated by prorating the flood flows from the Naskaupi River station using the log-proration method (Equation 1). The catchment area at station 03PB001 on Naskaupi River is 8990 km^2.

Reference: Hydrotechnical Assessment of the Iron Arm Causeway

Equation 1:

$$\frac{Log(A_1)}{Log(A_2)} = \frac{Log(Q_1)}{Log(Q_2)}$$

Where:

Q_1 = known peak flow (m^3/s) from gauged system

Q_2 = unknown peak flow (m^3/s)from ungauged system

A_1 = catchment area Q_1 (km^2)

A_2 = catchment area Q_2 (km^2)

Table 1 provides the estimated flood flows at Naskaupi River Hydrometric Station and Iron Arm outlet.

Table 1 Flood Flows at Iron Arm

Return Period	Flood Flows Naskaupi River (m^3/s)	Flood Flows Iron Arm (m^3/s)
Mean Annual Flow	219	79
10 Year	444	140
25 Year	481	149
100 Year	540	164

Two bridges are proposed on the causeway, one close to the south side and one close to the north side. A HEC-RAS hydraulic model was used to assess the hydraulic conditions at the bridge crossings. The following inputs were required for the HEC-RAS hydraulic model:

- Channel cross section details at the crossing, upstream of the crossing and downstream of the crossing;
- Bridge details (i.e. bridge opening dimensions, embankment details);
- Channel and floodplain roughness; and,
- Design flood conditions.

Channel cross section details at the bridge crossing were estimated based on available bathymetry information provided by Labec Centruy Iron Ore. This information was also used to characterize the upstream and downstream channel cross sections. Bathymetry data was converted from depth to

Reference: Hydrotechnical Assessment of the Iron Arm Causeway

elevation by assuming that 0 depth is equivalent to 469 mAMSL elevation. This assumption should be field verified and elevations included in this assessment should be adjusted accordingly.

The bridge and causeway details were based on the preliminary design provided by BBA Inc. and presented in **Figure 3**. The bridges were assumed to have 8 m spans based on correspondence with Labec Century Iron Ore. Manning's n values of 0.03 and 0.08 were selected for Iron Arm channel and floodplain, respectively.

As indicated in **Figure 3**, the causeway will be designed using aggregate rock fill to the high water level. The aggregate rock is expected allow significant seepage through the causeway due to the large rock size and associated porosity (approximately 50%). A preliminary seepage rate of 30 m^3/s was estimated assuming a hydraulic conductivity of 1 X 10^2 cm/s and a head difference of 0.5 m. The seepage estimate should be updated during the detailed design phase. HEC-RAS is not able to model seepage across the causeway directly; therefore, seepage flow was modelled as an opening sized to allow the 30 m^3/s flow.

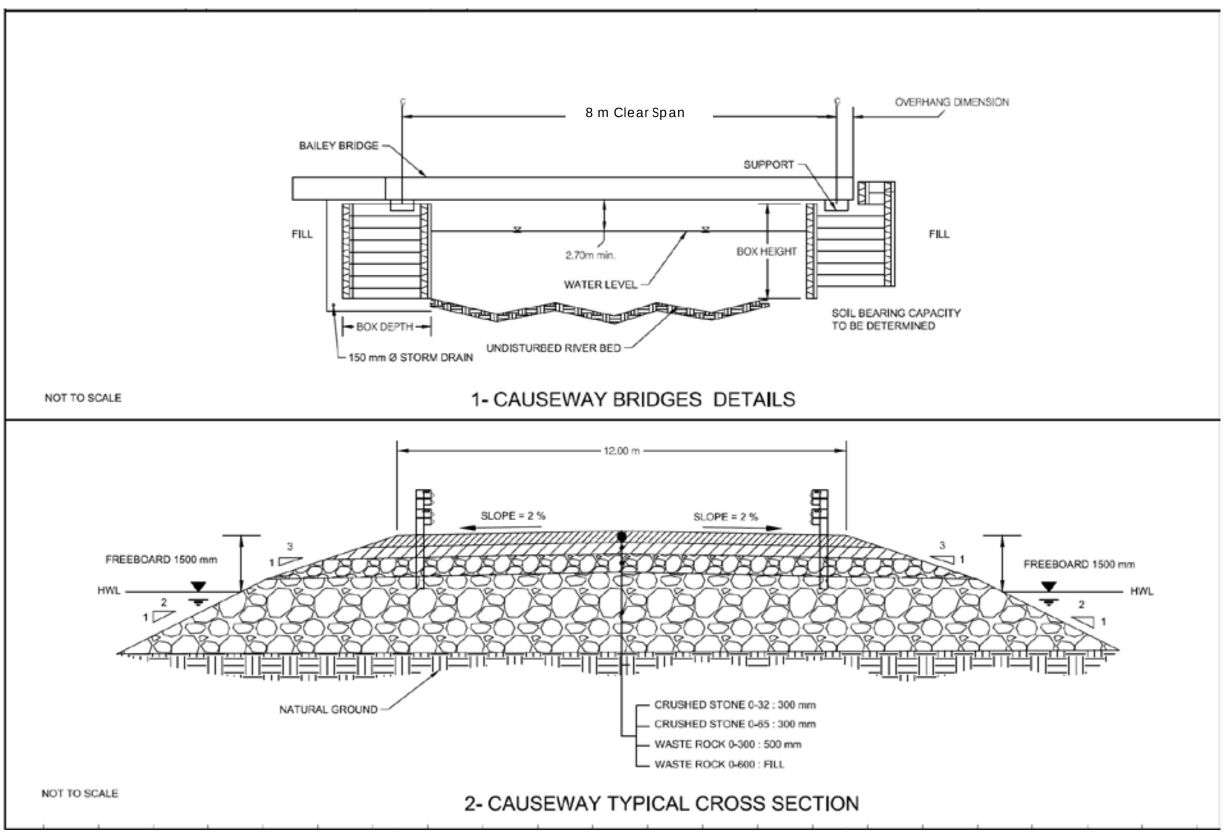

Figure 3 Proposed Bridge Crossing Details

Hydraulic conditions at the causeway crossing were simulated using the HEC-RAS model for the mean flow and flood flows presented in Table 1. As no water level data is available for Iron Arm, it was assumed that the downstream water elevation was 0.25 m above the normal water level during

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the flood events, or approximately 469.25 mAMSL. The sensitivity of the downstream water level was assessed to determine if it affected the modelled water level and flow velocity at the crossing.

Tables 2 presents the predicted water levels and flow velocities at the bridge crossings for the mean annual flow, 1:10 Year, 1:25 Year and 1:100 Year flood conditions, respectively.

Table 2 Predicted Water Levels and Velocities at Bridge Crossing

Return Period (year)	Water Level* (m)			Average Flow Velocity at Bridge Openings (m/s)
	Maximum Upstream	Bridge Crossing	Downstream	
Mean Annual Flow	469.2	469.0	469.00	1.62
10 Year	469.7	469.4	469.25	2.62
25 Year	469.8	469.4	469.25	2.80
100 Year	470.0	469.5	469.25	3.05

*Note: All elevations are based on an assumed 469 mAMSL normal water level (0 m depth in the bathymetric data)

Figures 4 shows the water level profile at the causeway for the design flood event (1:25 year return period) and **Figure 5** compares water level for a range of flood events. **Figure 6** shows the design flood water level profile for various downstream water level conditions, ranging from 468 to 470 mAMSL and indicates that the downstream water level conditions does not significantly influence the upstream water levels in the range from 468 mAMSL to 469.5 mAMSL.

Reference: Hydrotechnical Assessment of the Iron Arm Causeway

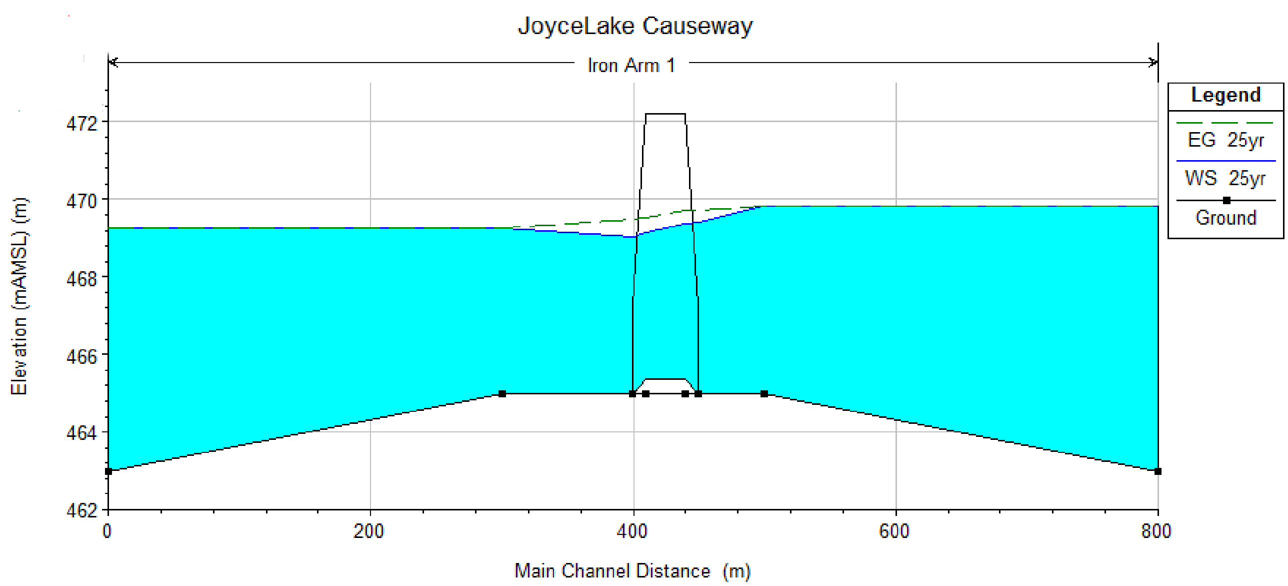

Figure 4 Water Profile at Causeway – 1:25 Year Flood Flow (Design Flood)

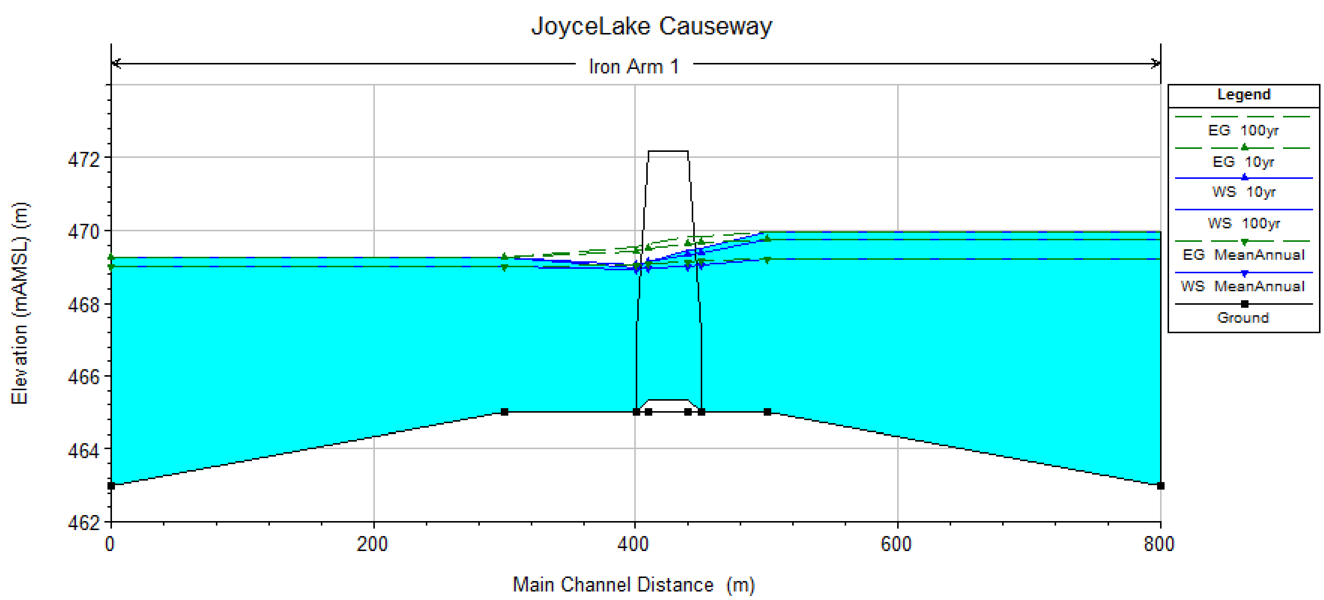

Figure 5 Water Profiles at Causeway – Mean Flow, 1:10 and 1:100 Year Flood Flow

Reference: Hydrotechnical Assessment of the Iron Arm Causeway

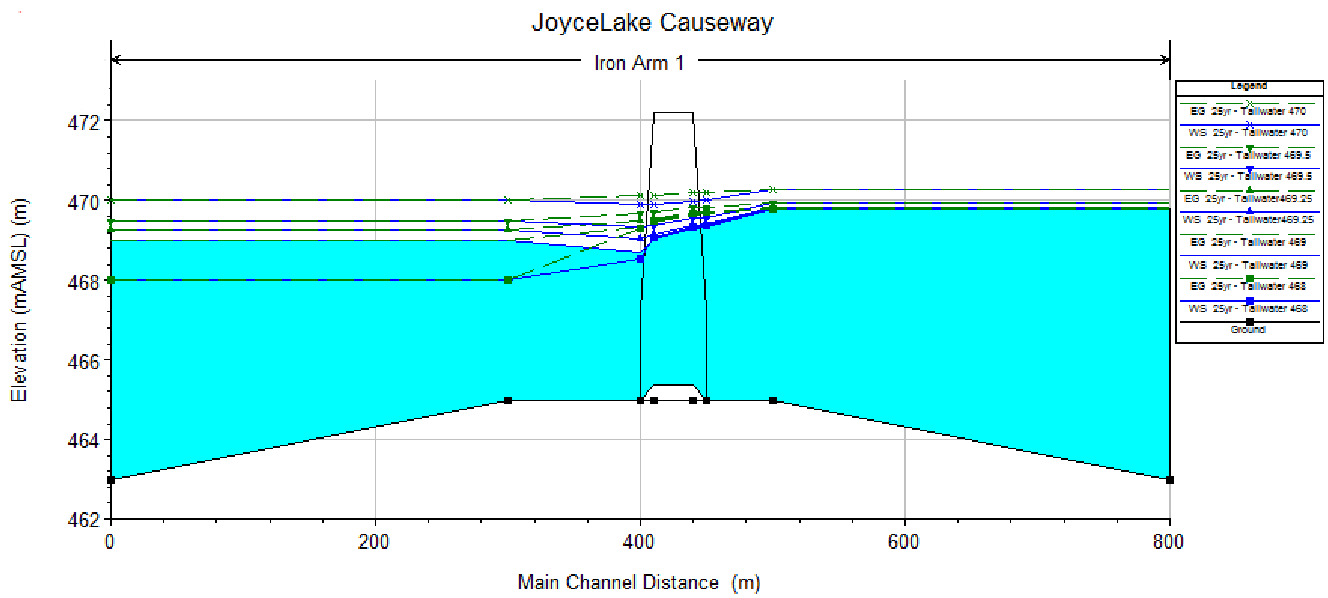

Figure 6 Water Profiles at Causeway – Various Downstream Water Level Conditions

The hydraulic assessment indicates that:

- The causeway will have some damming effect during flood events, raising the water level upstream. During the 1:25 Year design flood event, a maximum water level of 469.8 m was modelled upstream of the causeway crossing (Table 2). This is 0.55 m above the assumed flood level (469.25 mAMSL) and 0.8 m above the assumed normal water level. The estimated water levels are considered within the natural water level variations for the study area;

- As shown in **Figure 6**, it was found that an increase or decrease of 0.25 m in the assumed downstream water level had only a minor effect on the modelled water levels at the causeway; and,

- The flow velocities at the bridge crossings range from 1.62 m/s for mean annual flow conditions to 2.80 m/s and 3.05 m/s for 1:25 Year and 1:100 Year flood conditions.

5.0 Ice Conditions and Jamming Effects

The lacustrine ice climate in the project study area, including Attikamagen Lake, is detailed in a separate memo prepared by Stantec (2013). The memo describes ice formation, thickness, break-up and movement. As detailed in the memo, lakes in the study area are considered to be snow-covered lakes having a coefficient of ice growth of 19.5. Freeze-over occurs around November 1 in study area lakes and the mean maximum ice thickness is expected to range from 125 cm to 150 cm. Therefore, to allow for ice coverage, an additional clearance of 1.5 m above the normal water level is required. The ice-free condition occurs in the study area lakes around June 1.

6.0 Fish Passage Requirements

Fish passage requirements will be assessed for Northern Pike and Lake Trout as the aquatics assessment has indicated that these species are important to assess in Attikamagen Lake. To determine fish passage requirements flow velocity can be compared to fish swim speed and fatigue time. It is expected that mean flow conditions best represent the fish passage requirements at the causeway as the Iron Arm channel downstream of the causeway provides an extensive staging area for fish to wait during a flood event.

The Department of Fisheries and Oceans (DFO) Draft Fish Swimming Performance User Guide (2014) presents fatigue curves, which were used in this analysis. The DFO guide groups species of fish based on similar characteristics and presents fatigue curves for each group. The Northern Pike are represented by the Pike group and Lake Trout are represented by the Salmon and Walleye group. Based on the completed hydraulics assessment, the mean flow velocity in the bridge openings is approximately 1.6 m/s. Assuming a downstream to upstream passage length of 20 m, the DFO guide curves indicate that Northern Pike greater than 500 mm long and Lake Trout greater than 200 mm long could pass through the bridges.

7.0 Wave Assessment

An assessment was completed to determine the design wave heights at the causeway location. The design wave height was assumed to be the wave generated by a 1:25 year wind speed along the direction of the channel.

7.1 Wind Frequency Analysis

Long term wind data from the Schefferville Airport climate station was used to characterize wind conditions at Iron Arm. Wind data from 1953 to 2009 was analyzed to determine the 25 Year return period wind speed. Only wind data in the northwest or southeast direction was considered as it is expected that winds along the channel directions will generate the largest waves due to the long fetch length. A frequency analysis was carried out using a Gumbel distribution (Attachment 1). The 1:25 year wind speed in the northwest direction (towards NW) was estimated to be 55 km/h, or 15.3 m/s. The 1:25 year wind speed in the southeast direction (towards SE) was estimated to be 73 km/h, or 20.2 m/s.

7.2 Wave Assessment

The generation of wind waves over water is dependent on the length of the open water along the wind direction (fetch), the depth of the water, the wind speed, and the duration of the wind. The longest possible fetch length was estimated to be 11.5 km for winds from the northwest direction and 11.3 km for winds from the southeast direction. The average depth was estimated to be 6 m based on bathymetry data in the vicinity of the causeway. The 1:25 year wind speeds in the northwest and southeast directions will be used as the design wind speeds in each direction. The duration is assumed to be unlimited.

Wind setup, significant wave height, significant wave period and wave run up were calculated based on the approach presented in the Coastal Engineering Manual (CEM) by the U.S. Army Corps of Engineers (2008). The results are in Table 3 below and calculations are included in Attachment 2.

Table 3 Wave Assessment Summary

Wind Direction	Design Wind Speed (km/h)	Fetch Length (km)	Average Depth (m)	Max. Wind Setup (m)	Significant Wave Height (m)	Significant Wave Period (s)	Max. Wave Height (m)	Max. Wave Run Up (m)
NW	73	11.5	6	0.16	1.5	3.7	2.7	2.0
SE	55	11.3	6	0.09	1.0	3.3	1.9	2.0

The wind set up is the vertical rise in the still water level on the leeward side of a lake caused by wind stresses on the surface of the water. As shown in Table 3 above, the wind set up was calculated as approximate 16 cm due to the northwest direction design wind and 9 cm due to the southeast direction design wind.

The significant wave height is the mean wave height for the highest third of all waves and the significant wave period is the mean period for the highest third of all waves. These values can be used to estimate the required bridge clearance, causeway freeboard and are also used to determine the wave run up. As presented in Table 3, the 1:25 year wind is estimated to produce a significant wave height of 1.5 m and 1.0 m in the southeast and northwest directions, respectively. Based on these significant wave heights the maximum wave heights were estimated to be approximately 2.7 m and 1.9 m.

The wave run up is the vertical height above the water level to which waves will travel up an embankment. The 1:25 year wind calculated previously was used to determine the wave run up for the causeway. This will indicate the potential for overtopping due to run up. A maximum wave run up of 2 m was estimated based on a 2% exceedance probability.

8.0 Erosion Protection

The required rock fill sizing to prevent erosion from the design wave was estimated using the method outlined in the CEM (2008). It was assumed that the rock fill would consist of a rough angular stone with a specific gravity of 2.65. The estimated minimum D_{50} for the causeway rock fill is 750 mm.

In addition to the potential for erosion due to waves, the estimated flow velocities at the bridge crossings may cause scour on the channel bed and erosion at the toe of the bridges. The use of bed and toe protection is recommended. As indicated in Table 2 (Section 4), the average flow velocity at the bridge openings is 2.8 m/s during the 1 in 25 year flood event. The design recommendations in the National Cooperative Highway Research Program (NCHRP) report *Countermeasures to Protect Bridge Piers from Scour* (2007) were used to determine the required riprap sizing. Based on the

Reference: Hydrotechnical Assessment of the Iron Arm Causeway

estimated average velocity of 2.8 m/s, the minimum D_{50} for the bed and toe protection is 700 mm. It is recommended that the same material as the causeway is used, with a D_{50} of 750 mm.

Riprap placement is critical to ensure effective erosion and scour protection. It is recommended that riprap is placed in accordance with the NCHRP 2007 report and the *Transport Association of Canad (TAC) Guide to Bridge Hydraulics* (2001).

9.0 Clearance Requirements

Based on the above assessment, the clearance requirements for the bridges and the causeway are summarized in the table below. The design high water level is assumed to be the 1:25 year flood water level of 469.8 mAMSL.

Table 4 Minimum Clearance

	½ Maximum Wave Height (m)	Wave Run Up (m)	Freeboard (m)	Minimum Clearance Above Design High Water Level (m)
Bridge	1.4	N/A	0.5	**1.9**
Causeway	N/A	2.0	0.5	**2.5**

As noted in Table 4, a minimum clearance of approximately 2 m above the high water level is required for the bridges. However, as the bridges will not be below the causeway, a clearance of 2.5 m is recommended. The current design clearance for the causeway is only 1.5 m above high water level. It is recommended that this clearance is increased to 2.5 m to allow for wave run up and freeboard.

10.0 Limitations

The hydrotechnical assessment is based on limited data available at time of the assessment. The following limitations should be considered when interpreting the results presented herein:

- The HEC-RAS model is one-dimensional hydraulic model and primarily developed for riverine hydraulic analysis. No recorded water levels with associated flow rates in Iron Arm are available to calibrate the model. A two-dimensional hydrodynamic model is more appropriate to assess the hydraulic conditions at the causeway crossings;

- Iron Arm bathymetry data is not available downstream of the causeway crossing. Therefore, cross section details of the causeway crossing downstream were based on the causeway crossing details;

- The historic high water levels at the causeway crossing location are unknown as only very short term water level data is available;

- Seepage was estimated based on simplified laminar flow calculations, however, due to the size of the waste rock the flow is expected to be partly turbulent; and,
- Wind conditions over the Iron Arm are estimated based on the wind conditions at the Schefferville Airport climate station and wind conditions at the site may be different from the Schefferville Airport wind conditions.

11.0 Conclusions and Recommendations

The following conclusions are made based on the hydrotechnical assessment:

- The design high water level is 0.8 m above the normal water level based on the 1:25 year flood. The normal water level and flood water level must be field verified to verify the elevations;
- A clearance of 2.5 m above the high water level is recommended for both the bridges and the causeway;
- The clearance provided should also allow passage by small craft by users of the lake;
- To resist erosion from waves it is recommended that the rock fill has a minimum D_{50} of 750 mm;
- The estimated flow velocities at the bridge crossings may cause scour and erosion on the channel bed and at toe of the bridges. Use of riprap bed and toe protection with a minimum D_{50} of 750 mm is recommended;
- Based on the modelled mean flow velocity the causeway is not expected to present a fish passage limitation for Northern Pike greater than 500 mm long and Lake Trout greater than 200 mm long; and,
- Preliminary modeling indicated that the causeway will have some damming effect during flood events, raising the water level upstream by 0.55 m above the estimated flood water level. The extent of damming should be verified during future assessments to determine potential effects on the camps/residences upstream of the causeway crossing.

It is recommended that:

- The hydraulic assessment of the causeway should be updated to a two-dimensional hydrodynamic model during the detailed design stage in order to more accurately model the hydraulic effects of the proposed causeway;
- Bathymetry data downstream of the causeway crossing should be collected and a more detailed seepage analysis should be completed to update the hydraulic model; and,

- A hydrometric monitoring program should be implemented to collect water levels and flow rates in Iron Arm. Collected water level and flow rate data can be used to calibrate the hydraulic model and verify elevations.

12.0 Closing

We trust the above memo meets your current needs for this project. Should you have any questions or comments please contact the undersigned.

Sincerely,

STANTEC CONSULTING LTD.

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Attachments: References
Attachment 1 – Wind Frequency Analysis
Attachment 2 – Wind Generated Wave Calculations

References

BBA, 2014. Site Plan – Layout. Joyce Lake and Area DSO Project. Issued For Information: November 7, 2014.

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Reference: Hydrotechnical Assessment of the Iron Arm Causeway

ATTACHMENT 1 – Wind Frequency Analysis Figures

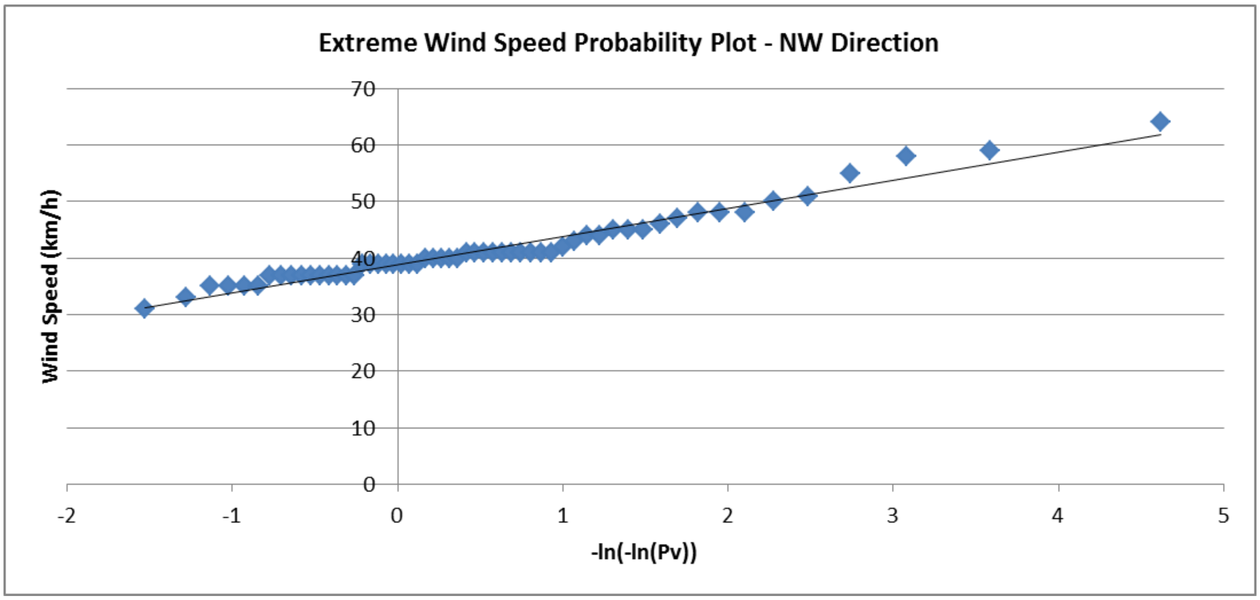

Figure A-1 Extreme Wind Speed Probability Plot - NW Direction

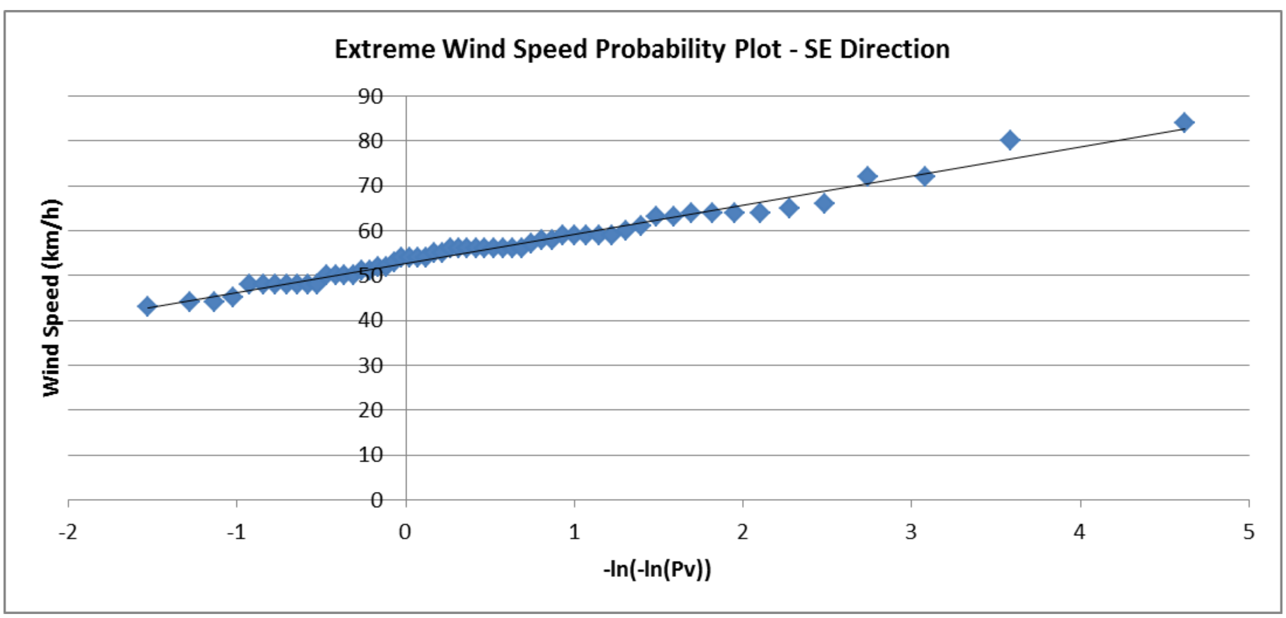

Figure A-2 Extreme Wind Speed Probability Plot - SE Direction

Reference: Hydrotechnical Assessment of the Iron Arm Causeway

ATTACHMENT 2 – Wave Assessment Calculations

Wave height and period were calculated using the method presented in the Coastal Engineering Manual (USACE, 2008) for fetch-limited waves:

$$t_{x,u} = 77.23 \left(\frac{X^{0.64}}{u^{0.34} g^{0.33}}\right) \qquad \text{Eqn 2-1}$$

$$\frac{g\,H_{mo}}{u_*^2} = 4.13 \times 10^{-2} \left(\frac{gX}{u_*^2}\right)^{1/2} \qquad \text{Eqn 2-2}$$

$$\frac{g\,T_p}{u_*} = 0.651 \left(\frac{gX}{u_*^2}\right)^{1/3} \qquad \text{Eqn 2-3}$$

$$C_D = \frac{u_*^2}{U_{10}} \qquad \text{Eqn 2-4}$$

$$C_D = 0.001\,(1.1 + 0.035\,U_{10}) \qquad \text{Eqn 2-5}$$

Where $t_{x,u}$ = time for waves crossing a fetch to become fetch limited
X = straight line fetch distance over which wind blows (m)
H_{mo} = significant wave height (m)
T_p = wave period (s)
C_D = drag coefficient
U_* = frictional velocity (m/s)
U_{10} = wind speed at 10 m elevation (m/s)
U = friction velocity (m/s)
G = gravitational acceleration (9.81 m/s^2)

Table 2-1 Wave Calculation SUmmary

X	Direction	U_{10}	H_{mo}	T_p	H_{max}
m		m/s	m	sec	m
11500	SE	20.4	1.5	3.7	2.7
11300	NW	15.3	1.0	3.3	1.9

APPENDIX L

Membrane Bioreactor Wastewater Treatment System

BUDGET PROPOSAL 1502268R0
38 Cubic Meters/Day
Joyce Lake Project

newterra MicroClear™ MEMBRANE BIOREACTOR WASTEWATER TREATMENT SYSTEM

Submitted To:

BBA

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November 27, 2014

At newterra we understand that our performance will have a direct impact on your success in your project. We are extremely committed to ensuring that you are successful. This means that if we do not live up to your expectations, we will do whatever it may take to resolve an issue immediately.

newterra ltd.
200 555 11th Ave SW, Calgary, AB, T2R 1P6
(800) 420-4056 / www.newterra.com

ADVANTAGES OF NEWTERRA MBR SYSTEM:

The **newterra** MBR system employs membrane biological reactor (MBR) technology with submerged **MicroClear**TM membranes. The system is designed to be the simplest, most operator-friendly flat plate membrane technology available in the market. The **newterra** MBR system produces ultra-clean water (solids free effluent) which effectively meets any water standards for discharge and reuse.

The **newterra** MBR system is a packaged wastewater treatment plant with modular design features. The system comes complete with containerized screen or primary clarifier, equalization tank, aeration tank and membrane tanks. The plant is housed inside modified high-cube shipping containers or prefabricated buildings - completely pre-assembled, pre-piped, pre-wired and pre-tested, ready for a quick site installation and start-up. The advantages that the **newterra** MBR system offers include:

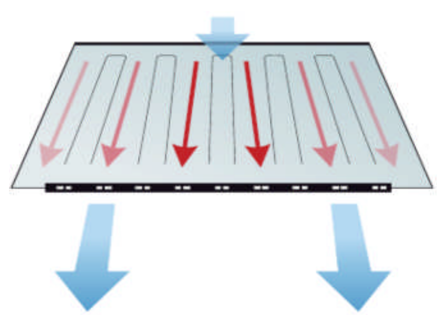
- Absolute physical barrier for contaminants
- Short delivery period;
- Factory assembled and tested;
- Minimal construction work on site;
- Easy to relocate;
- Reliable and low maintenance system;
- Superior effluent quality that is suitable for reuse;
- Compact footprint;
- Minimal noise and odourless operation;
- Backflushable flat plate membrane system;
- Low transmembrane pressure system – only 0.1 to 0.2 bar vacuum required;
- Excellent membrane structure life;

UNIQUE FEATURES OF **MICROCLEAR**TM MEMBRANES:

newterra MicroClearTM membranes provide the following unique features:

- Low electric power consumption - filtrate is drawn through and out of the filter by a slightly negative pressure (vacuum) of only 0.07 – 0.1 bar (1 to 2.9 psi)
- Membrane sheet-to-backing sheet welding by laser – perfect welding, ensures no ingress of dirty wastewater into the clean permeate

Laser-welded Flat Plate Membrane during Pressure Test



FSDTM (full surface distribution)

- UF membranes with a molecular weight cut-off of 150k Dalton, equivalent to a pore size of 0.04 µm, leaving out any bacteria (1 – 2 µm), parasites (5 – 50 µm), with a bacteria removal of 99.9999% and virus removal of 99.99%
- Cleaning during operation by cyclic backflushing
- Patented special design of backing sheet surface – thus no need for a gauze between the membrane and backing sheets to prevent adhesion
- FSD™ (full surface distribution) – full membrane surface utilization for permeate collection by multiple outflow points, thus no short-circuiting and even flux distribution
- Easily expandable with modular design

Design Parameters:

	Design Value	Unit
Per capita design flow	250	L/p/d
Number of persons on site	150	people
Average daily flow (ADF)	38	m^3/d
Peak hourly flow (assumed)	400	L/p/d
Overall time for peak to occur	5 hours	
Maximum number of peak events per day	2 times	
Mixed liquor suspended solids	1%	
Minimum inlet temperature	8	°C
Site power	Three-phase, 480V, 60Hz	
System Area Classification	According to NFPA 820, 2012 Edition	
Ambient temperatures	max: 37 °C, min: -40 °C	
Elevation	< 500 m	

Influent Wastewater Characteristics and Effluent Quality:

Parameter	Unit	Influent Wastewater Characteristics	Effluent Quality
pH	s.u	6 - 9	7 - 9
FOG	mg/L	< 30	-
BOD_5	mg/L	400	< 5
COD	mg/L		

TSS	mg/L	350	< 1
TDS	mg/L	< 1,200	-
TKN	mg/L	70	-
NO3-N	mg/L		
TAN	mg/L	65	-
TN	mg/L		
TP	mg/L	10	-
Fecal Coliform	CFU/100ml	-	< 200*
E-Coli	CFU/100ml		
Total Coliform	CFU/100ml		
Alkalinity (assumed)	mg/L as $CaCO_3$	> 200	-

* After UV disinfection

PROHIBITED ITEMS:

- A complete list of prohibited chemicals is included in the membrane maintenance manual.
- Grinder pumps should not be used upstream of the **newterra** system as they can cause particles which are too small for the inlet screen to effectively capture which can increase required system maintenance.

SCOPE OF SUPPLY:

Inlet Filter Module

- Insulated and heated screen room
- Two automatic cleaning perforated plate 2 mm screens
    - Stainless steel construction
- Screen discharge pump tank:
    - High level alarm switch
    - Pump control switch
    - Discharge pumps

Equalization Tank Module

- Level transmitter
- Temperature transmitter
- Immersion heater
- Air diffusers
- Discharge pumps
- Air blower

Anoxic Tank Module

- Air diffusers
- Air blower

Aeration Tank Module

- Level transmitter
- High level alarm switch
- Temperature transmitter
- Immersion heater
- Fine bubble air diffusers
- Discharge pumps
- pH transmitter
- Dissolved oxygen transmitter
- Air blowers with VFD control
- Foam suppression system

Membrane Tank Module

Two membrane tanks for full redundancy

- Access door for ease of membrane removal (Patent Pending)
- Sample port for MLSS testing
- Viewing window
- Pump control switch
- MicroClear™ submerged flat sheet membrane module with
    - Full surface distribution
    - Medium bubble scouring
    - Laser sheet welding

- High level alarm switch
- Sludge wasting pump
- Overflow return to aeration tank

Membrane Aeration Blower Module

Each membrane train to include:

- Compressed air blower
- Pressure gauge
- Low pressure alarm switch

Permeate Extraction Module

Each membrane train to include:

- Vacuum transmitter
- Vacuum gauge
- Permeate extraction system with back pulsing capabilities
- Check valve
- Water flow meter

Ultraviolet Disinfection Module

- UV lights piped in series for redundancy
- UV light operation alarms

Sludge Holding Module

- Level transmitter
- High level alarm
- Air blower and diffusers
- Decanting pump
- Vac truck connection

System Enclosures – 40' Modified Shipping Containers

cMET certified, built to CEC standards with all wiring complete and all equipment pre-piped factory tested and mounted in enclosure.

Two used, high-cube modified shipping containers. Each container has the following standard features:

- Exterior paint
- Lifting eyes on upper corners
- Insulated walls and ceiling
- Insulated floor
- Aluminum checker plate ceiling in control rooms
- Welded steel man door(s) with safety window and crashbar
- Barn-style rear double doors
- Grating under HDPE tanks
- Lighting
- Ventilation fans

- Passive vent louvers with hoods
- Emergency stop switch
- Low temperature alarm switch
- Duplex 15 Amp GFI receptacle for heat trace inlet and discharge

Control System Module:

Schneider PLC based control panel with the following standard features:

- cMET certification
- NEMA 12 lockable panel enclosure
- Primary circuit protection
- Main power block
- Branch circuit protection with circuit breakers for motors
- Motor starters with overload protection
- Branch circuit protection with circuit breakers for powered devices
- PLC control system
- 24 VDC IS power supply
- Intrinsically safe barriers for switches in classified areas
- Variable frequency drives where required
- Dry contacts to allow interlock with system inlet pumps
- Wired and installed
- Factory tested prior to shipping

Outside cover of panel to contain the following:

- System ready light
- Red alarm indicator light
- Programmable touch screen with:
  - Colour P&ID display
  - Display of measurements recorded from any transmitters present in system
  - System on/off control
  - Safety control over all valves and motors with timed delay when in Hand position
  - Timers for solenoid valves and motors present in system
  - Alarm indicators with reset function
  - Run indicators for system components
  - USB port for datalogging download (USB key included)
  - Alarm reset button
- Emergency stop button

Operation and Maintenance Manual:

- Two hard copies and one electronic provided

BUDGET PRICING:

Budget Equipment Purchase Cost:	$493,000.00
Estimated Equipment Freight to Site: • Includes freight of system to Sept –îles, Québec	$20,000.00
Sales Tax on Equipment:	Not Included
Total System Cost:	$513,000.00

INSTALLATION / COMMISSIONING / TRAINING:

- CAD $1,200.00/day per technician plus expenses for travel, meals and accommodation

CURRENCY:

- All prices are quoted in CAN dollars.

PAYMENT TERMS:

- 25% due net 30 days from order
- 25% due net 30 days from approved drawings
- 50% due net 30 days from notice of readiness to ship

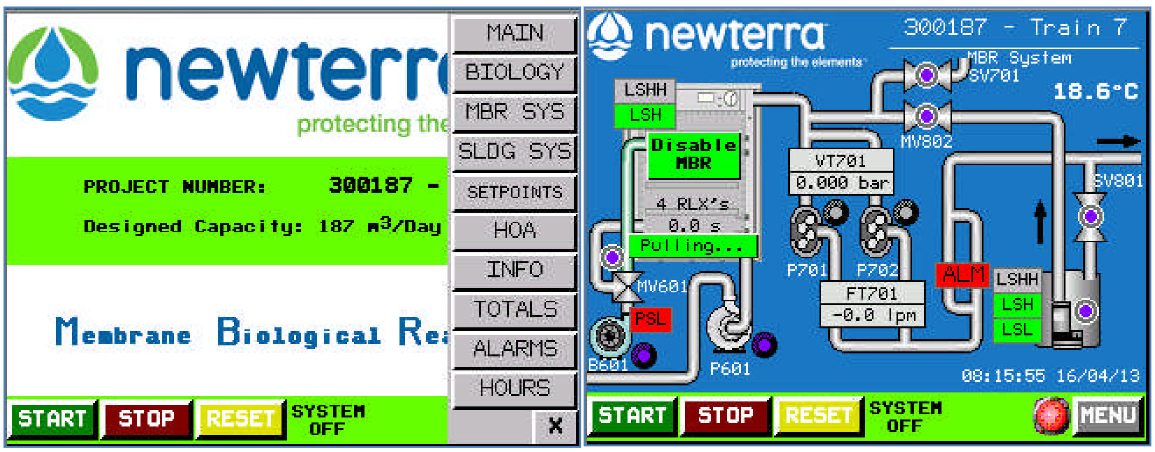
CLIENT'S SCOPE OF SUPPLY AND WORK:

- Delivery of raw sewage to the **newterra** MBR STP;
- Permitting;
- Grease trap to control entry of oil and greasy material to the **newterra** MBR. Fat, oil and grease levels entering the newterra MBR system must be less than 30 mg/L to ensure the treatment system functions as designed and to prevent damage to the membranes;
- Pilings or firm, level base for the containers;
- External access stairs, walkways, skirting, etc.;
- Piping hookups to and from the **newterra** MBR;
- Electrical power supply to our electrical panel, lightning, grounding, etc. ;
- Potable water supply to the plant site for plant hydraulic test during startup;
- Seed sludge;
- Wastewater testing;
- Chemicals supply and storage;
- Treated effluent and waste sludge disposal;
- Anything not mentioned in "Scope of Supply" above.

OPTIONAL TELEMETRY CONTROL AND REMOTE ACCESS:

One-time hardware cost *(site internet provided): Hardware: Industrial Router	$ 2,150.00
One-time hardware cost *(site internet NOT provided): Hardware: Industrial Router & Modem	$ 2,960.00
Annual telemetry service contract:	$ 1,825/year

newterra SITE-LINK is a customized software program and hardware configuration which provides a real-time link to a treatment system via cellular modem or customer supplied internet connection using advanced VPN technology. An annual Telemetry Service Agreement with **newterra** is required which includes all costs associated with the service.



newterra Site-Link comes with the following customizable features:

- Customized P&ID layout with system status
- Start/Stop/Reset of system
- Manual control of all system components
- Data logging downloads in .csv format†
- Daily system status reports (E-Monitor)
- Alarm history including current alarm status
- Hour meters for applicable equipment
- Customization of all system set points†
- Live and historical trending
- Immediate text & email on alarm (E-Alarm)

†certain restrictions apply

The basic system requires that the customer provide a standard computer network cable to the control panel. If the customer's computer network is accessible to the internet, this system can also be monitored from any internet enabled computer. Static IP is not required but is recommended and must be provided by customer.

This system is not available if customer supplied internet connection or cellular service is not available at the site. During internet outages, reports cannot be sent and system status cannot be monitored remotely.

newterra ltd.
200 555 11th Ave SW, Calgary, AB, T2R 1P6
(800) 420-4056 / www.newterra.com

APPENDIX M

Hydraulic Assessment of the Proposed Bridge at Gilling River

Stantec **Memo**

To:	Georgi Doundarov Labec Century Iron Ore Inc.	From:	Sundar Premasiri & Sheldon Smith Markham
File:	121511139	Date:	December 4, 2014

Reference: Hydraulic Assessment of the Proposed Bridge at Gilling River

1.0 Introduction

The following includes a hydraulic assessment of the proposed bridge at Gilling River crossing of the proposed mine haul road to be constructed as part of the Joyce Lake Direct Shipping Iron Ore Project. The methodology, approach, data used and assessment results are provided below.

2.0 Methodology

The hydraulic assessment involved the following steps:

- Determine hydraulic characteristics (channel geometry, slope and roughness) at the bridge crossing, upstream and downstream of the bridge crossing based on available survey information and field observation made as part of the Fish and Fish Habitat Baseline Study (WSP, 2013) and the proposed bridge design drawing (BBA, 2014);
- Determine the bridge details from the proposed bridge design drawings (BBA, 2014);
- Determine design peak flows at the bridge crossing sites using the regional hydrologic relationships between peak flows and watershed area developed as part of the Surface Water Baseline Study (Stantec, 2013);
- Determine the hydraulic conditions at the bridge crossing using the HEC-RAS hydraulic model (USACE, 2010);
- Assess the hydraulic impacts using the results from the hydraulic modeling; and
- Assess the fish passage requirements.

2.1 Hydraulic Design Criteria for the Bridge Crossings

The engineering design of any bridge crossing must address the hydraulic performance of the culvert during low and high flow conditions. The following should be considered:

- Potential for damage to the bridge during floods;
- Potential for upstream flooding due to the channel constrictions; and
- Potential for scouring within the bridge waterway due to excessive velocity and shear stress.

Key design criteria are discussed below.

2.1.1 Design Flow Frequency

The design flow frequency selected for the bridge crossing is the 1:25 year flood flows. This is consistent with Environmental Guidelines for Water Crossings (NL Water Resources Management Design, Water Investigations Section 1992).

2.1.2 Bridge Height

The bridge soffit elevation is determined by the design high water level plus an appropriate freeboard or clearance. The following factors are relevant when considering clearance:

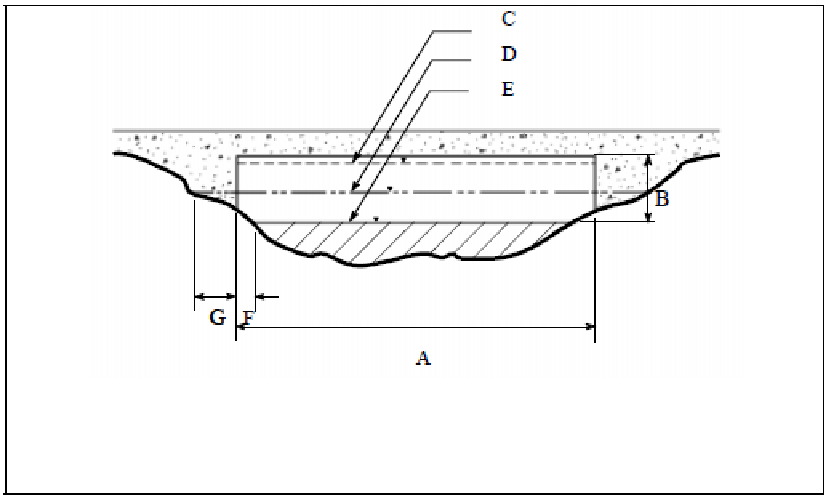
- The maximum expected height of waves;
- Ice run-up on piers and abutments, and projection of ice floes above high water level;
- Superelevation of the water surface at tight bends in high-velocity streams;
- Projection of logs and other floating debris; and
- Statutory navigation requirements.

2.1.3 Bridge Length

The length of the bridge should be such that the opening is able to pass the maximum flows without endangering the bridge or appurtenances by scour, without causing major maintenance problems, without causing unacceptable backwater effects upstream and without causing currents, waves, or turbulence unacceptable to navigation. It should be possible to pass expected quantities of ice, logs, and other debris without endangering the structure or adjacent property as a result of jams and accumulations. The required bridge length are illustrated in Figure 1

Reference: Hydraulic Assessment of the Proposed Bridge at Gilling River

Figure 1 Typical Bridge Dimensions (NL Water Resources Management Design, 1992)



A -	Length =	normal stream width + (2 x 0.5 m), or, 1:10 year stream width - 10%
B -	Height =	sufficient to pass design flow along with waves, ice and debris, without contacting the bridge
C -	Maximum Design Flow	
D -	1:10 year high water level	
E -	Normal water level	
F -	Abutment Placement =	set back 0.5 m from normal water's edge
G -	Permissible Flow Constriction =	total flow constrictions of no more than 10% of the 1:10 year flow width

2.1.4 Scour/ Erosion Protection

Riprap shall be used for protecting the bank slopes and bridge end fills of abutments. Toe protection shall be provided to prevent undermining of slope revetments in accordance with the *TAC (Transport Association of Canada) Guide to Bridge Hydraulics* (2001).

2.1.5 Ice Jamming Consideration

Stream freeze-up produces a mass of ice on a river. Break-up of river ice may result in ice jams and ice forces on water crossings. The resulting ice jam may cause the following type of problems:

- Increased scour at waterway constrictions;

Reference: Hydraulic Assessment of the Proposed Bridge at Gilling River

- Flooding upstream of an ice jam and aggravated channel scour downstream resulting in damage to land and property;
- Damage to stream crossings due to ice abrasion;
- Impact of ice forces on bridges, abutments and piers which could result in structural damage or destruction;
- Channel icing which may reduce the conveyance capacity of a water crossing, resulting in upstream flooding; and
- Surges of flow from sudden release of jams may aggravate these problems.

The following should be considered in during the design of water crossings:

- Each stream crossing site should be assessed to determine whether a site under consideration is prone to significant ice problems and its suitability for a stream crossing;
- For sites potentially subjected to ice runs, the following locations will be avoided for a stream crossing:
  - the outside of a meander bend; and
  - near a location historically known for ice jams.
- Design high ice conditions at a water crossing site should be considered in the design of water crossing.

2.1.6 Fish Passage Requirements

The fish habitat assessment determined that provisions for fish passage during the open water season are required at the proposed bridge crossings. According to *Practitioners Guide to Fish Passage for DFO Habitat Management Staff* (DFO, 2007), a 3-day delay during a 1 in 10 year flow event ($3DQ_{10}$) is a threshold commonly used for establishing design criteria for watercourse crossings.

Guidelines for Protection for Freshwater Fish Habitat in Newfoundland and Labrador (DFO, 1998) provides the following recommendations related to fish passage at bridge crossing locations:

- Bridges should be located on straight sections of a stream, where the stream channel is narrow, having low banks and firm, non-erodible soils;
- Concrete aprons under bridges are not recommended since fish passage can be impeded at low flows;

Reference: Hydraulic Assessment of the Proposed Bridge at Gilling River

- Bridge abutments should be located outside the wetted perimeter of the stream;
- Instream piers should be aligned with the stream flow;
- Fill material for bridges should not be taken from stream beds, banks or riparian areas; and
- Instream work should be scheduled to avoid potential adverse impacts on spawning activities, spawning habitat, egg incubation, and fish migration.

3.0 Hydraulic Assessment

The proposed bridge crossing is located on the Gilling River. The catchment area at the bridge crossing location is approximately 102 km^2. Flood flows at the bridge location are estimated using the regional relationship for the catchment area of 102 km^2 (Table 1).

Table 1 Flood Flows at Bridge Crossing Locations

Return Period (year)	Flood Flows (m3/s)
Mean Annual Flow	2.33
10 Year	25.0
25 Year	27.4
100 Year	30.9

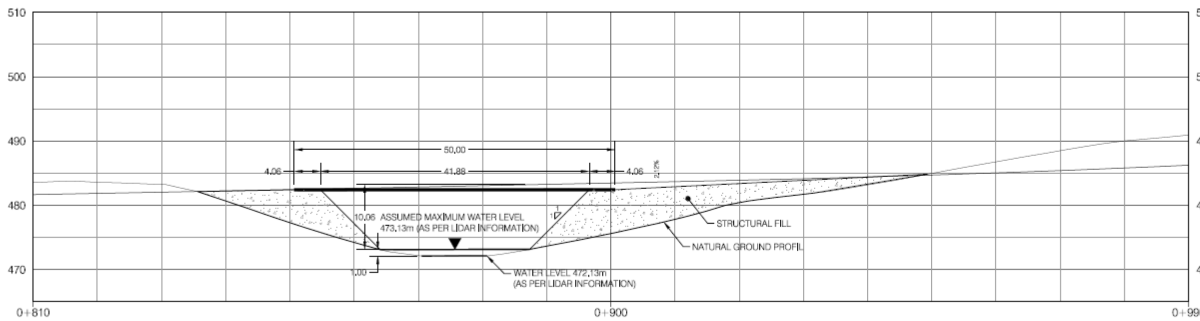
The proposed bridge crossing details are shown in Figure 2. HEC-RAS hydraulic model was used to assess the hydraulic conditions at the bridge crossing. The following inputs are required for the HEC-RAS hydraulic model:

- Channel cross section details at the crossing, upstream of the crossing and downstream of the crossing;
- Bridge details (i.e. bridge opening dimensions, embankment details);
- Channel and floodplain roughness; and
- Design flood conditions.

The channel cross section details upstream and downstream of the bridge crossing are not available. Therefore, channel cross section details at the bridge crossing was used to characterize the upstream and downstream channel cross sections. Channel slope is assumed to be 0.5 %. Manning's n of 0.035 for channel roughness and Manning's n of 0.08 for the floodplain roughness were used for the hydraulic modeling.

Reference: Hydraulic Assessment of the Proposed Bridge at Gilling River

Figure 2 Proposed Bridge Crossing Details



Tables 2 presents the predicted water levels and flow velocity at the bridge crossing for a range of flood events. Figures 3 to 6 shows the water level at the bridge crossings for mean annual flow, 1:10 Year, 1:25 Year and 1:100 Year flood conditions, respectively. Hydraulic assessment indicates that

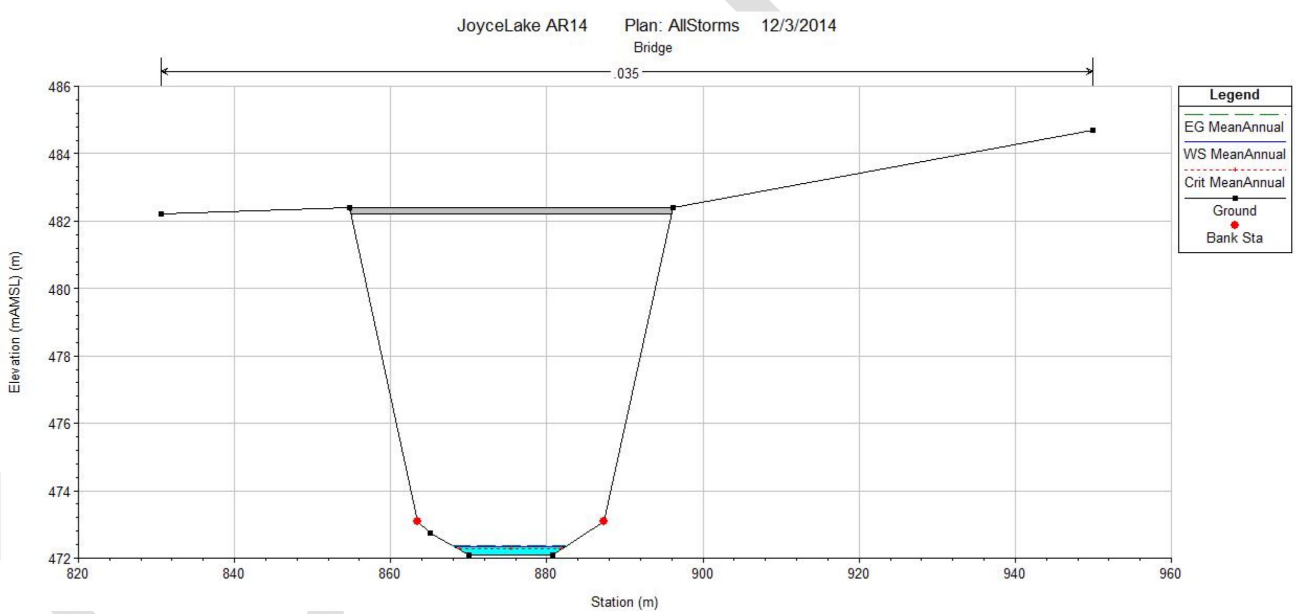
- the bridge can pass the design flood without adverse upstream flooding impacts;
- the available freeboard/clearance is 9.29 m for 1:100 Year flood event and can pass floating debris and ice without any adverse impacts;
- the bridge abutments are located more than 0.5 m away from the normal water's edge;
- the 1:10 Year water level is contained within the natural channel at the bridge crossing; and
- the flow velocities at the bridge crossing range from 0.81 m/s for mean annual flow conditions to 1.75 m/s for 1:100 Year flood conditions.

Reference: Hydraulic Assessment of the Proposed Bridge at Gilling River

Table 2 Predicted Water Levels and Velocities at Bridge Crossing

Return Period (year)	Water Level (m)			Soffitt Elevation	Average Flow Velocity (m/s)
	Upstream	Bridge Crossing	Downstream		
Mean Annual Flow	472.38	472.35	472.25	482.40	0.81
10 Year	473.05	473.01	472.91		1.64
25 Year	473.09	473.05	472.96		1.69
100 Year	473.15	473.11	473.02		1.75

Figure 3 Water Level at Bridge Crossing – Mean Annual Flow



Reference: Hydraulic Assessment of the Proposed Bridge at Gilling River

Figure 4 Water Level at Bridge Crossing – 1:10 Year Flood Flow

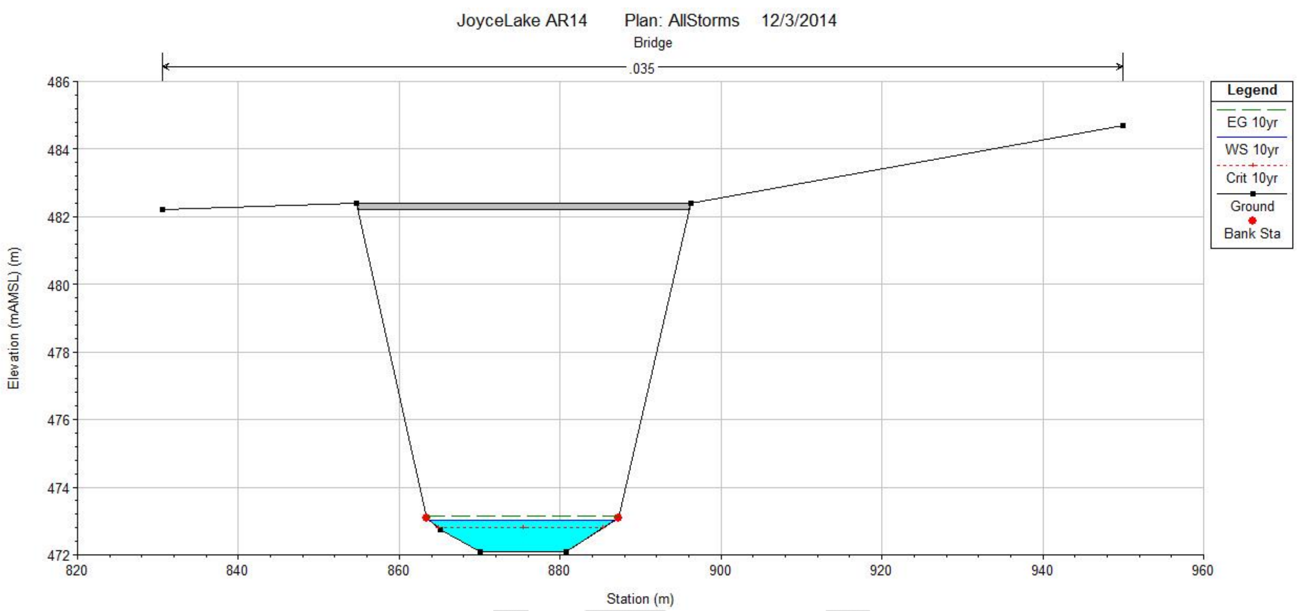
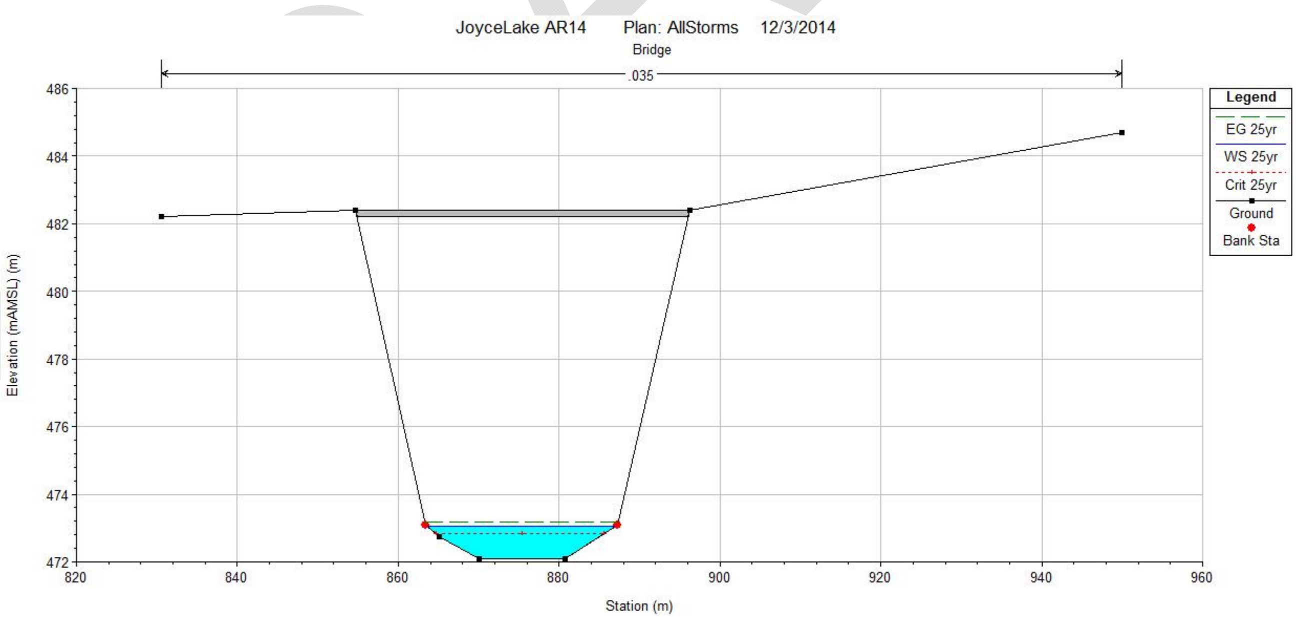
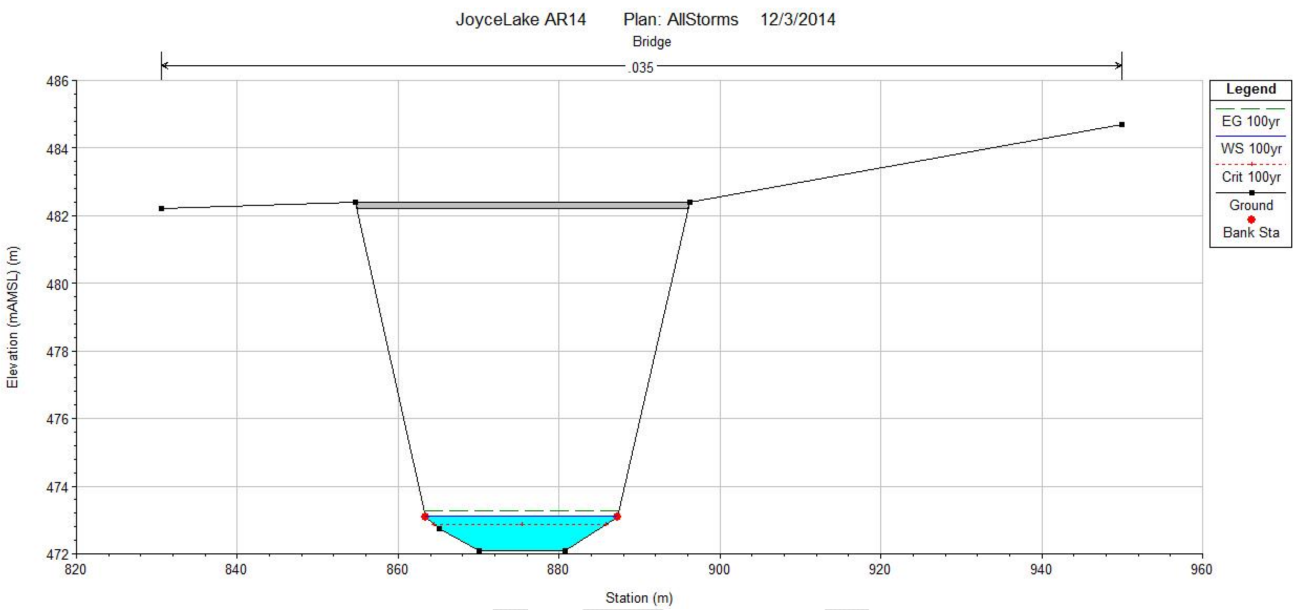


Figure 5 Water Level at Bridge Crossing – 1:25 Year Flood Flow



Reference: Hydraulic Assessment of the Proposed Bridge at Gilling River

Figure 6 Water Level at Bridge Crossing – 1:100 Year Flood Flow



Approximately 9 m of clearance is available between the 1:100 Year water level and the soffit of the bridge. Hydraulic conditions (flow depth and velocity) at the bridge crossing have not been altered up to the 1:10 year flood events by the proposed construction of bridge at Gilling River. Therefore, the proposed bridge crossing meets the fish passage requirements. The hydraulic assessment of the bridge crossing at the Gilling River should be updated based on detailed site survey information at the bridge crossing during the detailed design stage.

STANTEC CONSULTING LTD.

DRAFT

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Reference: Hydraulic Assessment of the Proposed Bridge at Gilling River

Attachment:

c. Angelo Grandillo - BBA
Ken Lam - Century
Dana Feltham - Stantec
Colleen Leeder - Stantec

APPENDIX N

Stream Crossing Design

Memo

To:	Georgi Doundarov Labec Century Iron Ore Inc.	From:	Sundar Premasiri & Sheldon Smith Markham
File:	121511139	Date:	November 17, 2014

Reference: Stream Crossing Design

1.0 Introduction

Water crossing design was prepared for each the 14 watercourses crossed by the proposed mine haul road to be constructed as part of the Joyce Lake Direct Shipping Iron Ore Project. The methodology, approach, and data used are described below and typical concept drawings of the proposed crossing designs are provided below.

2.0 Methodology

The crossing design process involved the following steps:

- Determine hydraulic characteristics (channel geometry, slope and roughness) at each water crossing based on available survey information and field observations made as part of the Fish and Fish Habitat Baseline Study (WSP, 2013);
- Determine design peak flows at the water crossing sites using the regional hydrologic relationships between peak flows and watershed area developed as part of the Surface Water Baseline Study (Stantec, 2013);
- For sites with no fish habitat, select a culvert size based entirely on hydraulic criteria;
- For sites with confirmed or potential fish habitat, determine whether or not a culvert crossing could be designed to meet requirements for fish passage;
- If fish passage requirements cannot be met with a culvert crossing, select an alternative design involving a “clearspan” structure.

The following general approach was adopted for culvert crossing design:

- A single culvert will be used whenever flow is mainly confined to a single well defined channel under normal flow conditions;
- Multiple culverts will be considered at sites where poorly-defined channel exist in fens or wetland areas that are being crossed by the proposed access road to ensure that the natural drainage through these areas is adequately maintained; and
- A minimum culvert size of 600 mm will be used to reduce the potential blockage due to ice, sediment, beaver activities and vegetation.

2.1 Hydraulic Design Criteria for Culvert Crossings

The engineering design of any culvert crossing must address the hydraulic performance of the culvert during low and high flow conditions. The following should be considered:

- Potential for damage to the culvert and/or roadway during floods;
- Potential for upstream flooding due to headwater ponding; and
- Potential for downstream scour/erosion due to excessive outlet velocities.

The culverts will be designed according to the *Canadian Highway Bridge Design Code*. *Handbook of Steel Drainage & Highway Construction Products* (American Iron and Steel Institute, 2002) which provides general guidance for corrugated steel pipe design. Key design criteria are discussed below.

2.1.1 Design Flow Frequency

The design flow frequency selected for this project is the 1:25 year flood flows. This is consistent with Environmental Guidelines for Water Crossings (NL Water Resources Management Division, Water Investigation Section, 1992).

2.1.2 Headwater Depth

Culverts were sized to accommodate the design flow with headwater depths (HW) no greater than the crown elevation at the inlet end of the pipe (i.e., the ratio of headwater depth to pipe diameter (D) should not exceed 1.0). This criteria minimizes ponding (flooding) upstream of the crossing, avoids potential problems associated with uplift pressures at the culvert inlet and reduces the likelihood of the crossing being overtopped during flood events exceeding the design flow.

2.1.3 Headwater Freeboard

The 1:100 year flood flow was used to check the available freeboard (i.e. the vertical distance between the upstream pool elevation and the top of roadway elevation). In each water crossing it will be confirmed that the proposed top of roadway elevation provides sufficient freeboard to prevent overtopping of the roadway during passage of a 1:100 year flood flow. Thus, the possibility of the crossing being overtopped during its lifetime and resulting in washouts is low.

2.1.4 Scour/Erosion Protection

The need to provide erosion protection to resist bed scour or bank erosion at culvert inlets and outlets should never be overlooked when designing culvert crossings. Whether or not erosion protection is required depends on the expected flow velocities and on the erodibility of the materials comprising the streambed and banks. For the crossing site being considered, the native material forming the streambed and banks varies from organic material to alluvium containing a mix of sand, gravel and cobbles. The coarser the material, the more resistant to erosion it will be. Inlet and outlet erosion protection shall be provided based on inlet and outlet velocities (Appendix A) and stream bed and bank material at the water crossings.

2.1.5 Minimum Cover

A minimum cover (i.e., vertical distance between the obvert of the culvert and crown of the roadway) is required to prevent potential bending or crushing of the pipe due to the effect of dead and live loads. The American Association of State Highway and Transportation Officials (AASHTO) specifies the minimum cover for steel culverts as being: (span/8) or 300 mm, whichever is greater. The exceptions to this rule are long span culverts, which are governed by special design consideration.

The Canadian Highway Bridge Design Code (CHBD) specifies minimum cover as being the larger of:

$(D_h/6)*(D_h/D_v)^{0.5}$ or $0.6*(D_h/D_v)^2$ metres, with a minimum of 0.6 m

Where D_h = Span (metres)

D_v = Rise (metres)

Consistent with CHBD, a minimum cover of 600 mm is recommended. This should be reviewed if loads larger than allowed highway loading are anticipated. However, minimum cover may exceed 600 mm at locations where other criteria such as HW depth and 100 year freeboard require. The above minimum cover criteria are based on hydraulic considerations and do not take into account dead and live load forces. Dead and live load forces and the associated minimum cover requirements are to be provided and integrated in to design by others.

2.2 Ice Jamming Consideration

Stream freeze-up produces a mass of ice on a river. Break-up of river ice may result in ice jams and ice forces on water crossings. The resulting ice jam may cause the following type of problems:

- Increased scour at waterway constrictions;
- Flooding upstream of an ice jam and aggravated channel scour downstream resulting in damage to land and properties;
- Damage to stream crossings due to ice abrasion;
- Impact of ice forces on bridges, abutments and piers which could result in structural damage or destruction;

- Channel icing which may reduce the conveyance capacity of a water crossing, resulting in upstream flooding; and

- Surges of flow from sudden release of jams may aggravate these problems.

The following should be considered in during the design of water crossings:

- Each stream crossing site should be assessed to determine whether a site under consideration is prone to significant ice problems and its suitability for a stream crossing;

- For sites potentially subjected to ice runs, the following locations will be avoided for a stream crossing:

    - the outside of a meander bend; and

    - near a location historically known for ice jams.

- Design high ice conditions at water crossing site should be considered in the design of water crossing.

2.3 Fish Passage Requirements

The fish habitat assessment determined that provisions for fish passage during the open water season is required at 9 of the 14 water crossing sites. In designing a culvert for the fish passage the objective is to mimic the environment of the natural stream as closely as possible. Factors to be considered include flow depth, width and velocity, as well as the provision of appropriate substrate within the culvert. In general, it has been found that “arch” or “elliptical” shaped culvert sections will mimic the stream channel better than a standard circular culvert section and are preferred by regulators. When fish passage is a concern, it is common practice to “depress” the culvert invert below the natural stream bed profile to encourage sedimentation and thereby provide an opportunity for a substrate layer to form within the culvert barrel.

Guidelines for Protection of Freshwater Fish Habitat in Newfoundland and Labrador (DFO, 1998) provides the following guidelines related to the fish passage at culvert installations:

- Sufficient depth of flow and appropriate water velocities for the fish species and size of the fish at the site/area should be provided in culvert installations. Swimming performance of some fish species, relative to fish passage, is provided in Gervais and Katopodis. (2014);

- Open bottom/bottomless arch culverts are the preferred type of culvert installation. These culverts maintain the natural bottom substrate and hydraulic capacity of the watercourse when footings are installed outside the wetted perimeter of the stream;

- To allow fish passage, cylindrical culverts should have a minimum diameter of 1000 mm;

- Cylindrical culverts up to 2000 mm in diameter should be countersunk a depth of 300 mm below the streambed elevation. Culverts having a diameter equal to or exceeding 2000 mm should be countersunk a minimum of 15% of the diameter below the streambed elevation;

- For multiple culvert installations, the culvert intended to provide fish passage should be placed in the deepest part of the channel and be countersunk to the required depth. The remaining culvert(s) should be placed 300 mm above the invert of the fish passage culvert;

- A minimum water depth of 200 mm should be provided throughout the culvert length. To maintain this water depth at low flow period an entrance/downstream pool can be constructed. The invert of the pool outlet should be at an elevation that maintains a minimum of 200 mm of water depth up to the inlet or upstream end of the culvert; and

- Depending on site-specific conditions (e.g. steep slopes, long crossings, constructed streams resulting in high water velocities, etc.), baffles/weirs may need to be installed in the fish passage culverts. Baffles/weirs can provide an adequate depth of flow and reduce the water velocity in the culvert in order to facilitate fish passage.

Reference: Stream Crossing Design

3.0 PROPOSED WATER CROSSING DESIGNS

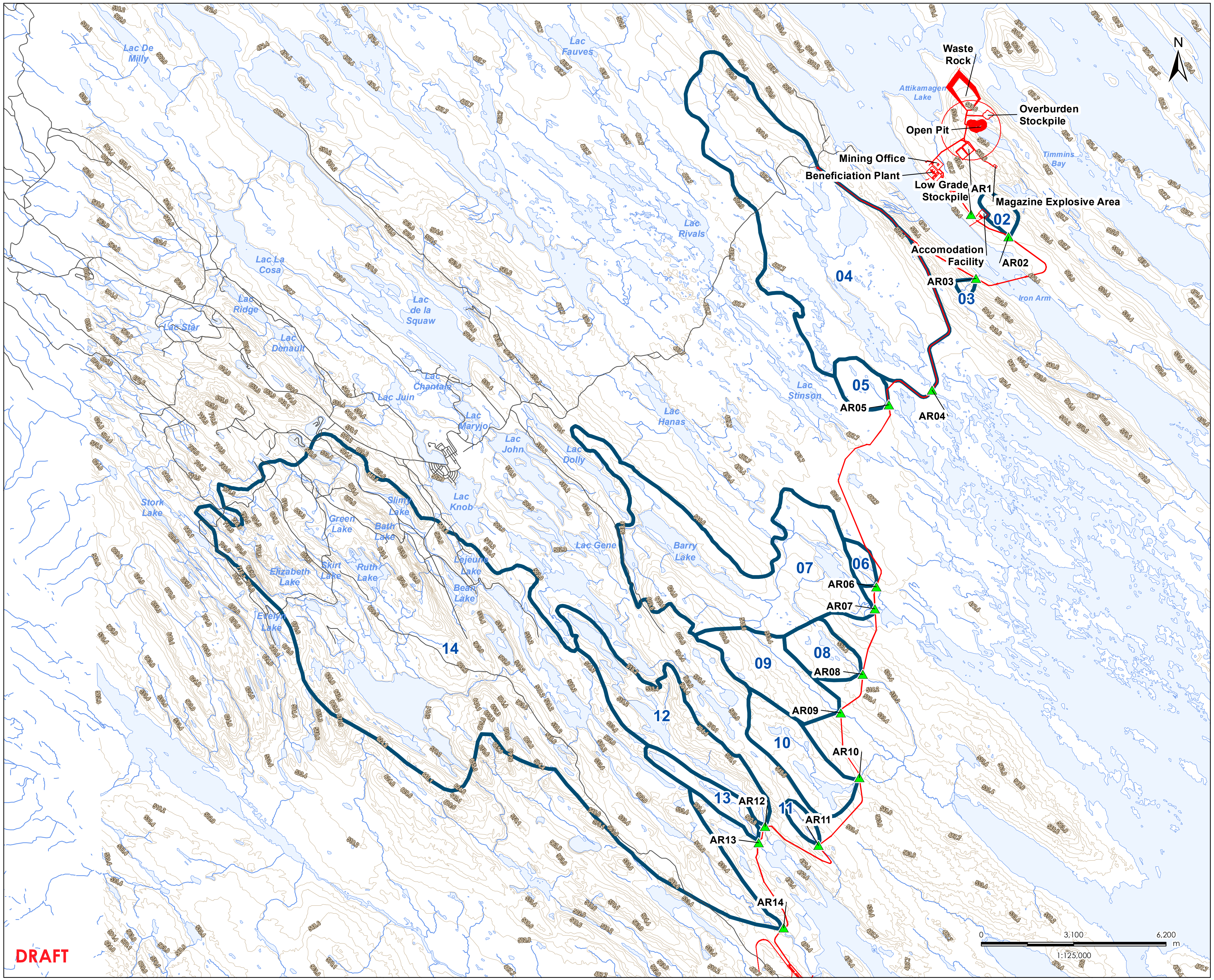
The mine haul road will cross 14 watercourses and the location of the water crossings are shown in Figure 1. Table 1 provides the drainage area at each water crossing, channel width, design flood flows. The channel width and fish habitat information at each crossing locations are based on the field survey conducted by the WSP (2013). The water crossing at the Gilling River (AR14) will be designed as bridge crossing to accommodate a wider channel and high design flood flows. The bridge crossing design at the Gilling River will be done by others. Water crossing AR1 will be affected by the camp site sediment pond outlet. Therefore, water crossing AR1 will be designed once sediment pond design is finalized.

HY-8 Version 7.3 (U.S. Department of Transportation, August 18, 2014) was used to size the culverts. The typical haul road cross section is illustrated in Figure 2 (BBA, 2014). The following information was assumed to size the culverts:

- Culvert slope is 0.5%;
- Access road width including shoulder is 16.0 m;
- Access road side slope is 2H:1V; and
- Tailwater depth was estimated from the channel cross section details.

Table 2 provides preliminary design information for haul road water crossings. Detailed water crossing hydraulic conditions are provided in Appendix A. Figures 3 and 4 provide conceptual design of water crossings for non-fish bearing streams and fish bearing streams respectively. The preliminary culvert design details should be updated based on the following during the detailed design stage:

- Detailed site survey information at water crossings (channel slope, bathymetry survey, stream bed and bank conditions, etc.);
- Special design consideration must be given to fish bearing streams, culvert embedment and fish passage;
- Special design consideration must be given to ice jam and ice blockage; and
- Minimum cover based on the fill material and the anticipated haul road live and dead loads.



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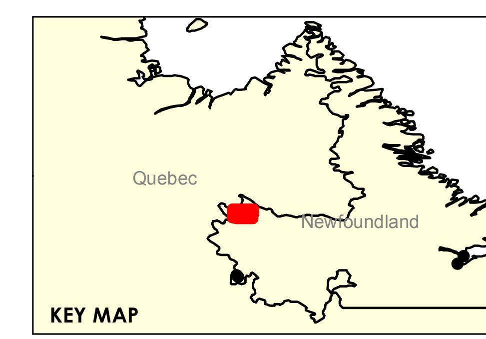
Legend

- Access Road Crossing
- Proposed Project Features
- Existing Road
- Contour (m)
- Watercourse
- Watershed Boundary
- Waterbody



Notes

1. Coordinate System: NAD 1983 UTM Zone 19N
2. Base features produced under license with the Ontario Ministry of Natural Resources © Queen's Printer for Ontario, 2013.

November 2014
121511139

Client/Project

Labec Century Iron Ore Inc.
Joyce Lake Direct Shipping Iron Ore Project

Figure No.
1

DRAFT

Title

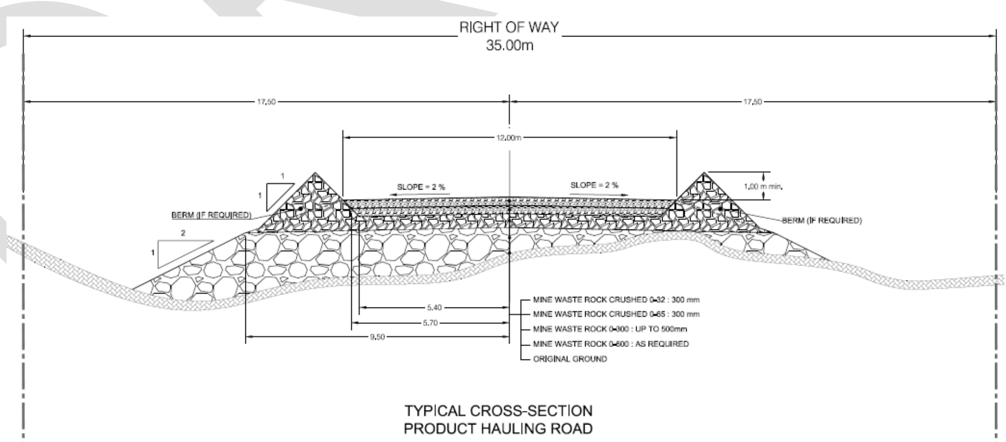
Haul Road Water Crossings

Reference: Stream Crossing Design

Table 1 Water Crossing Data

Water Crossing ID	Drainage Area (km^2)	Channel Width (m)	Design Flood (m^3/s)		Fish Habitat Present
			1:25 Year	1:100 Year	
AR2	1.10	Not available	0.41	0.44	Not available
AR3	0.310	Not available	0.130	0.140	Not available
AR4	41.4	20.0	11.9	13.3	Confirmed
AR5	2.25	0.750	0.800	0.870	No
AR6	1.04	0.500	0.390	0.420	No
AR7	27.1	6.00	8.02	8.93	Potential
AR8	3.37	1.50	1.17	1.27	Potential
AR9	7.09	2.75	2.32	2.55	Potential
AR10	6.59	3.50	2.17	2.38	Confirmed
AR11	0.830	1.50	0.320	0.340	Potential
AR12	12.0	3.00	3.77	4.16	Potential
AR13	2.69	1.00	0.950	1.03	Potential
AR14	102.1	15.0	27.4	30.9	Confirmed

Figure 2 Haul Road Typical Cross-Section Road



Reference: Stream Crossing Design

Table 3 Water Crossing Design Summary

Crossing ID	Fish Passage Required	Culvert Details					Min. Cover (mm)	Inlet and Outlet Protection Required
		TYPE	Shape	Size (mm)	Length (m)	Embedment Depth (mm)		
AR2	No	CSP	Circular	900	22	0	600	Yes
AR3	No	CSP	Circular	600	21	0	600	Yes
AR4	Yes	CSP	Open Bottom Arch	6400 x 2100	31	-	1,000	Yes
AR5	No	CSP	Circular	1,200	24	0	600	Yes
AR6	No	CSP	Circular	900	22	0	600	Yes
AR7	Yes	CSP	Open Bottom Arch	4500 x 2000	29	-	700	Yes
AR8	Yes	CSP	Circular	1,400	24	210	600	Yes
AR9	Yes	CSP	Circular	2,000	27	300	600	Yes
AR10	Yes	CSP	Circular	2,000	27	300	600	Yes
AR11	Yes	CSP	Circular	1,000	24	150	600	Yes
AR12	Yes	CSP	Circular	2,400	28	360	600	Yes
AR13	Yes	CSP	Circular	1,400	24	210	600	Yes
AR14	Yes	Bridge	-	-	-	-	-	-

Reference: Stream Crossing Design

Figure 3 Conceptual Design of Water Crossing – Non-Fish Bearing Stream

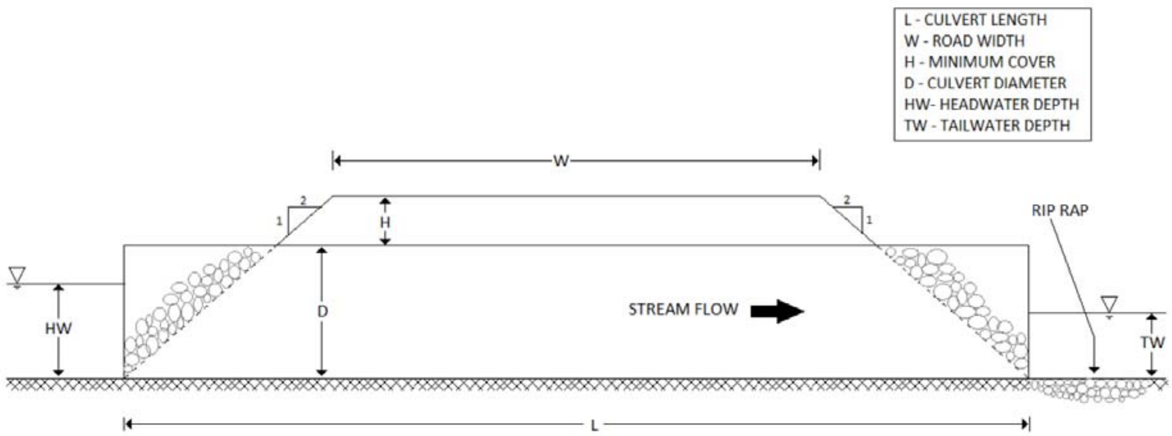
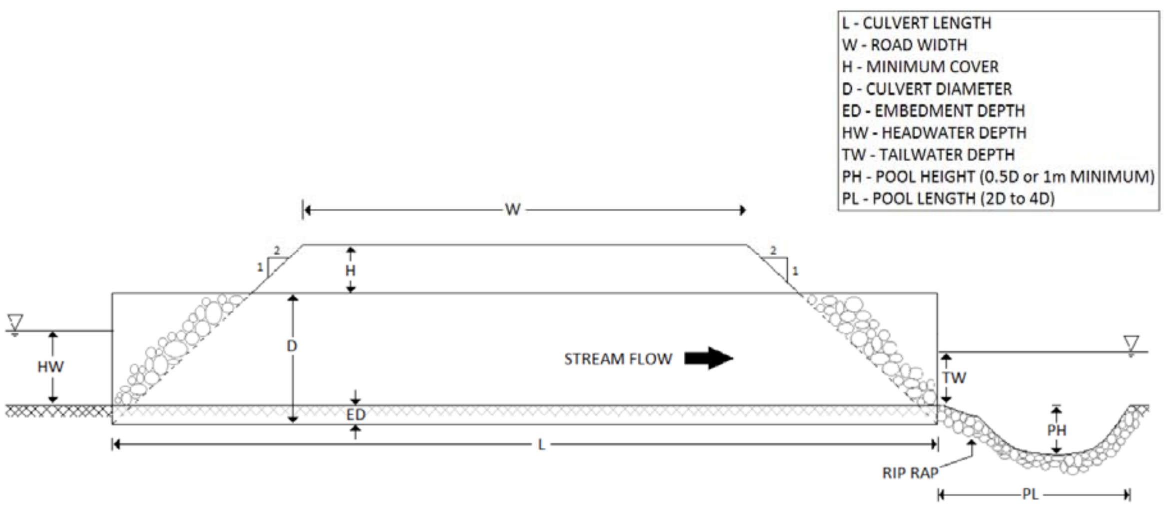


Figure 4 Conceptual Design of Water Crossing – Fish Bearing Stream



Reference: Stream Crossing Design

STANTEC CONSULTING LTD.

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Attachment: Table A.1 Water Crossing Hydraulic Conditions

c.

Project Name:	**Joyce Lake Direct Shipping Iron Ore Project**
Job Number:	**121511139.800.012**
Subject:	**Water Crossing Design**
Date Updated:	**14-Nov-14**
Updated By:	**Jordan Atherton**

Table A1: Water Crossing Hydraulic Information

Crossing ID	Drainage Area (km2)	Design Flood Flow (m3/s)		Fish Passage	Culvert Information				Hydraulic Information				Freeboard (m)
					Shape	Size (mm)	Length (m)	Embedment Depth (mm)	Inlet Depth (m)		Outlet Velocity (m/s)		
		1:25 Year	1:100 Year						1:25 Year	1:100 Year	1:25 Year	1:100 Year	1:100 Year
AR2	1.10	0.41	0.44	No	Circular Corrugated Steel	900	22	0	0.62	0.66	1.41	1.46	0.84
AR3	0.31	0.13	0.14	No	Circular Corrugated Steel	600	21	0	0.40	0.44	0.7	0.75	0.76
AR4	41.43	11.88	13.29	Yes	Arch, Open Bottom Corrugated Steel	Span: 6400.8; Rise: 2108.2	31	0	1.43	1.55	2.78	2.87	1.40
AR5	2.25	0.80	0.87	No	Circular Corrugated Steel	1200	24	0	0.80	0.86	1.28	1.34	0.94
AR6	1.04	0.39	0.42	No	Circular Corrugated Steel	900	22	0	0.61	0.66	1.03	1.09	0.84
AR7	27.08	8.02	8.93	Yes	Arch, Open Bottom Corrugated Steel	Span: 4572; Rise: 2006.6	29	0	1.32	1.42	2.65	2.76	1.15
AR8	3.37	1.17	1.27	Yes	Circular Corrugated Steel	1400	24	210	1.05	1.11	2.01	2.08	0.89
AR9	7.1	2.32	2.55	Yes	Circular Corrugated Steel	2000	27	300	1.35	1.42	2.35	2.25	1.18
AR10	6.6	2.17	2.38	Yes	Circular Corrugated Steel	2000	27	300	1.31	1.38	2.2	2.28	1.22
AR11	0.83	0.32	0.34	Yes	Circular Corrugated Steel	1000	24	150	0.60	0.63	1.47	1.41	0.97
AR12	12.0	3.77	4.16	Yes	Circular Corrugated Steel	2400	28	360	1.63	1.72	2.58	2.49	1.28
AR13	2.7	0.95	1.03	Yes	Circular Corrugated Steel	1400	24	210	0.94	1.00	1.88	1.95	1.00