FEASIBILITY PLAN FOR REMOVEABLE CONTROL STRUCTURES IN THE PEACE-ATHABASCA DELTA

BIG EGG LAKE WATER CONTROL STRUCTURE

FINAL REPORT

Prepared for:

SLR Consulting (Canada) Ltd.

10 March 2020

NHC Ref. No. 1005166

northwest hydraulic consultants
water resource specialists

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Prepared for:

SLR Consulting (Canada) Ltd.
Calgary, Alberta

Prepared by:

Northwest Hydraulic Consultants Ltd.
Edmonton, Alberta

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nhc

Prepared by:

PROFESSIONAL ENGINEER
MICHAEL BRAYALL
ALBERTA
10 March 2020

Michael Brayall, MSc, PEng
Project Engineer

Reviewed by:

PROFESSIONAL ENGINEER
P.G. VanDerVinne
ALBERTA
Mar 10/20

PERMIT TO PRACTICE
NORTHWEST HYDRAULIC CONSULTANTS LTD.
Signature
Date 10 Mar 2020
PERMIT NUMBER: P 654
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

Gary Van Der Vinne, MSc, PEng
Principal

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EXECUTIVE SUMMARY

The objectives of the study was to provide a feasibility plan to support decision making related to options for a removable control structure on Big Egg Lake. Several studies have been conducted on Big Egg Lake regarding the feasibility of a control structure to return water levels to those experiences prior to regulation of flows on the Peace River. Historically, there have been two structures that have existed on the lake, but currently the water level is only controlled by the natural sill elevation. The scope of work of the project included detailed bathymetric survey of the Athabasca River and the East Connection Channel to Big Egg Lake, discharge and water level measurements, numerical hydraulic modelling, hydrotechnical assessment of water levels on the Athabasca River and Big Egg Lake, an assessment of various water level control options, and a cost estimate for the recommended option.

Local knowledge gathering sessions were an integral component of the study to better understand the history and effectiveness of water level control on Big Egg Lake. Knowledge holders from the Athabasca Chipewyan First Nation, the Mikisew Cree First Nation, and the Fort Chipewyan Métis Local 125 provided valuable information about changing water levels in the Peace-Athabasca delta and the effect on wildlife and vegetation. Specifically, a goal of improving muskrat habitat was identified and a target minimum water depth of 8 ft was identified by the knowledge holders. Strong support was received for the water level control structure to be located at the East Connection Channel.

Detailed bathymetric surveys were completed in early October including a measurement of the discharge and water level on the Athabasca River. A hydraulic model of the Athabasca River was developed to simulate the water level on the Athabasca River at the proposed location of the water control structure. The stage-discharge relationship was developed using the hydraulic model and historical water level and discharge measurements from Water Survey of Canada stations.

A simulation of historical Athabasca River water levels at the East Connection Channel of Big Egg Lake found that the current spill elevation of about 211.0 m was exceeded about 80% of the time for the discharge and water elevation conditions between 1971 and 2016. An assessment of satellite imagery for the June to September period of several years was conducted. The analysis of the satellite imagery showed no discernable variation in the water level of Big Egg Lake throughout a given year.

Depth and frequency criteria were developed to determine the appropriate sill elevation of the control structure. A sill elevation of about 211.5 m was recommended to achieve a depth of 8 ft; however, a lower sill elevation of 211.0 m would maximize the frequency of inundation.

Numerous alternatives were considered for the water control structure for Big Egg Lake as assessed using a range of criteria. The recommended alternative for the water level control structure is stop logs in conjunction with a sheet pile wall. Stop logs were selected due to the relative simplicity of installation and removal along with a low operation and maintenance cost. The structure would be comprised of three 2000 mm wide stop log structure bays in between sheet pile walls up to an elevation of 211.5 m. A safety berm along both sides of the structure with a crest elevation of 212.4 m will prevent high water levels from damaging the structure. A channel will need to be excavated with a length of about 300 m

connecting the structure to the southern boundary of Big Egg Lake. The construction cost estimate for the structure is $446,200.

CREDITS AND ACKNOWLEDGEMENTS

The project team gratefully acknowledges the local knowledge shared by members of the Indigenous communities of Fort Chipewyan. We would also like to thank the representatives from Parks Canada, Environment and Climate Change Canada, and Public Services and Procurement Canada for initiating this project and providing available background information and documentation. Additional background information and technical input provided by Alberta Environment and Parks is also appreciated. We would also like to thank Mel Hamilton from SLR Consulting (Canada) Ltd. for managing this project and engaging Northwest Hydraulic Consultants Ltd. as a subconsulting partner for this work.

Key members of the project team and their roles are:

- Robyn Andrishak – Team Lead
- Michael Brayall – Report author
- Gary Van Der Vinne – Senior Advisor and technical reviewer of this report
- Ken Roy and Kate Neigel – Field survey crew
- Joshua Mueller and Rebecca Himsl – Engineering support

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1 INTRODUCTION

Northwest Hydraulic Consultants (NHC) was retained by SRL Consulting to provide a feasibility plan to support decision-making related to options for removable control structures at two locations in the Peace-Athabasca Delta (PAD).The two locations under consideration were selected by Fort Chipewyan Indigenous communities and are described below:

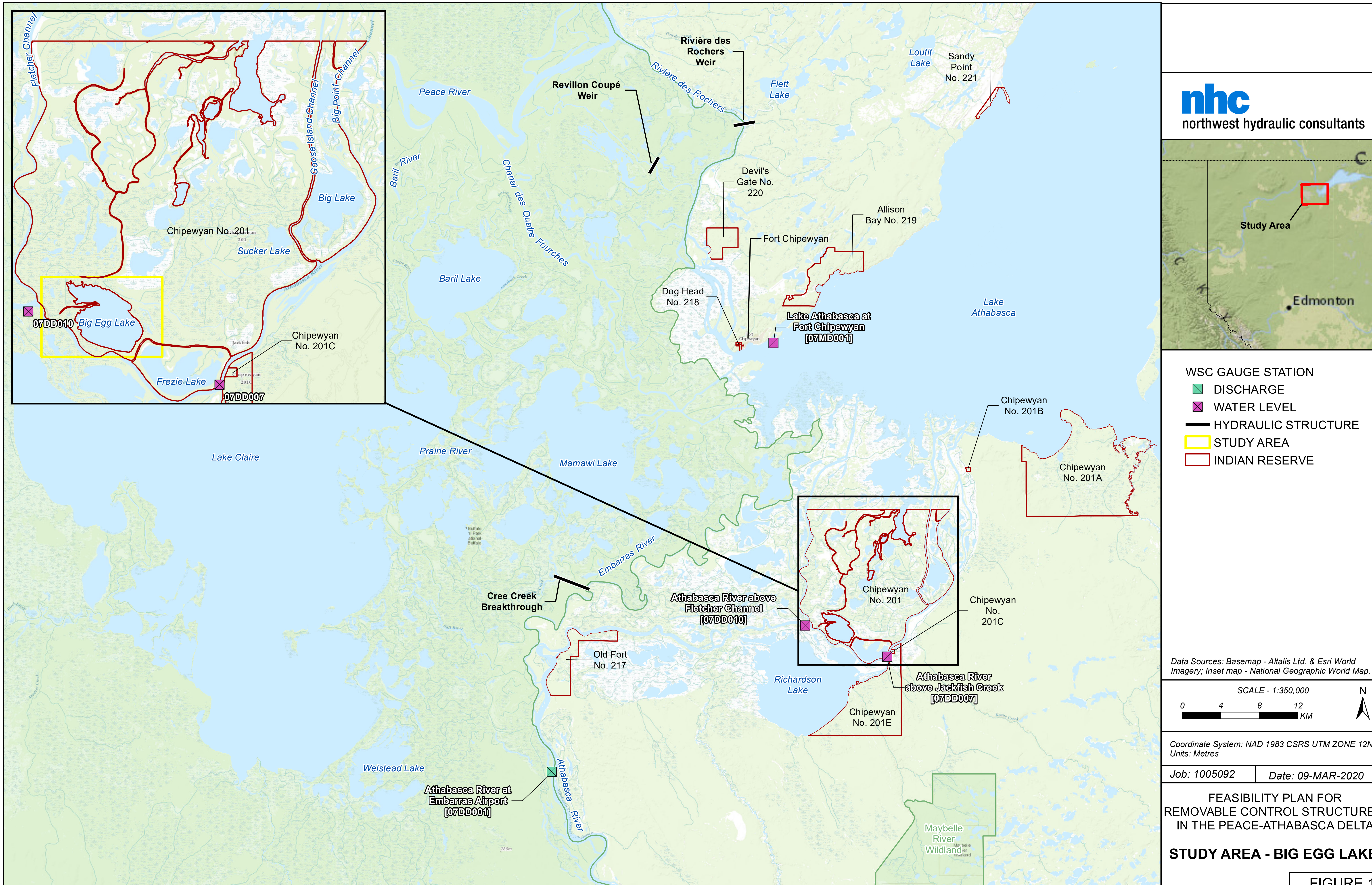
1) Dog Camp which is located on the west arm of the Chenal Des Quatre Fourches.
2) Big Egg Lake near the community of Jackfish on the Athabasca Chipewyan First Nation Jackfish reserve (I.R. 201).

This report presents the feasibility plan for the Big Egg Lake site (**Figure 1**). Results for the feasibility plan for Dog Camp are provided under separate cover (NHC 2020).

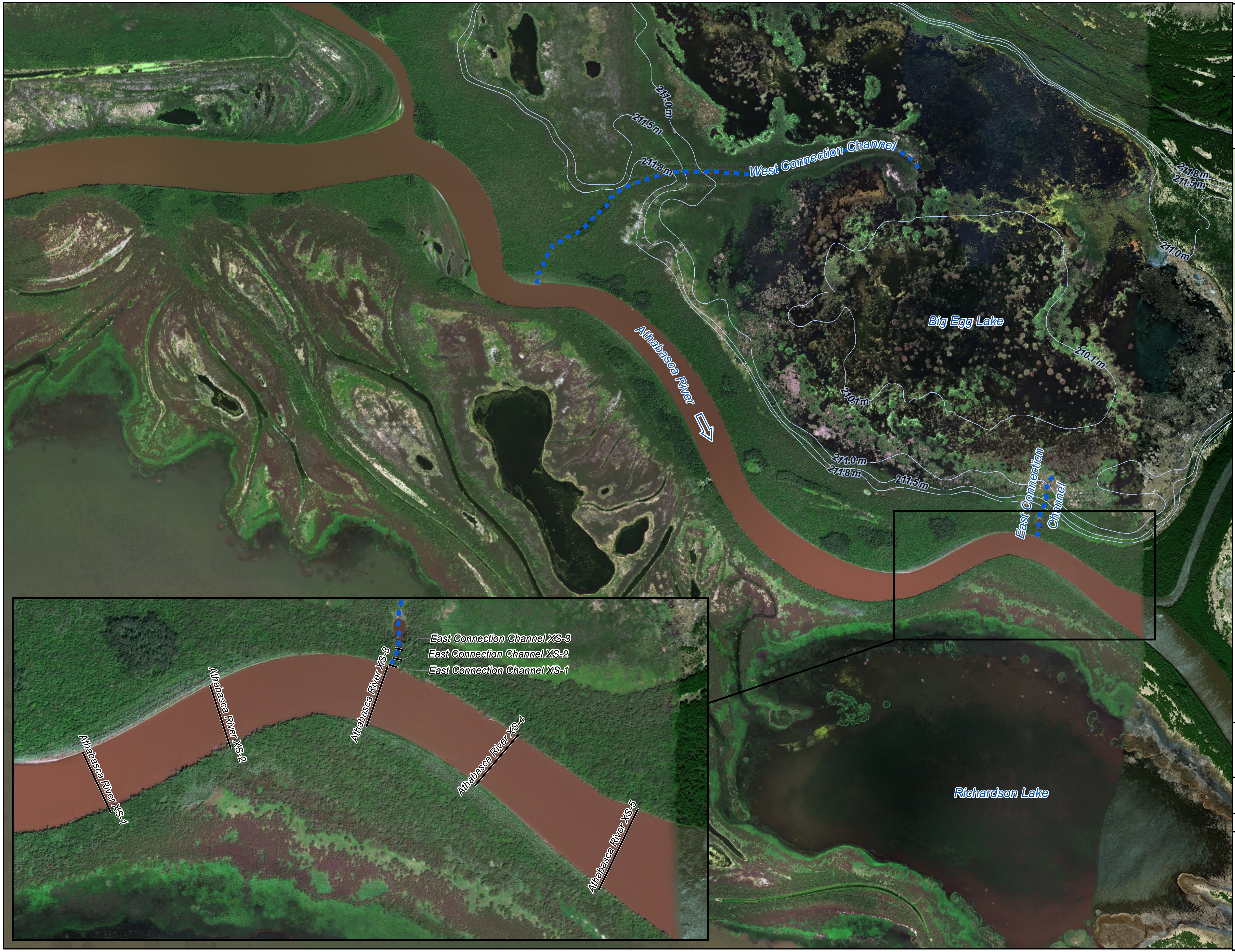
1.1 Background

Big Egg Lake is a perched lake located along the north bank of the Athabasca River. A perched lake is defined as a permanent lake in which the water elevation is higher than adjacent water bodies. Perched lakes within the PAD are generally surrounded by natural levees that isolate the lakes from the connected system of rivers and lakes. Precipitation is generally less than evaporation, so water levels within the perched lakes are recharged only from floods events in the connected system of rivers and lakes.

Numerous studies have been conducted regarding the use of a control structure to regulate water levels on Big Egg Lake in an effort to return water levels to conditions experienced prior to regulation of the discharge on the Peace River. The studies were conducted under a much larger body of work referred to as the Peace-Athabasca Delta Technical Studies (PADTS). Historically, there have been two paths through which water has preferentially flowed into Big Egg Lake; the West Connection Channel East Connection Channel (**Figure 2**). The West Connection Channel is the older of the two paths, but was not maintained and filled with sediment in the 1970s. The East Connection Channel was excavated in the late 1970s or early 1980s and had a weir structure on it at one time that has since deteriorated. A study was conducted in 1987 and found that it was technically feasible to construct control structures on Big Egg Lake to provide desired water levels for muskrat habitat (W-E-R 1987). An additional study designed a structure for the West Connection Channel but it was not implemented (PADTS 1994).



Fletcher Channel
Goose Island Channel
Big Point Channel
Big Lake
Chipewyan No. 201
Sucker Lake
Athabasca River
07DD010
Big Egg Lake
Chipewyan No. 201C
Frezie Lake
07DD007
Peace River
Baril River
Chenal des Quatre Fourches
Baril Lake
Revillon Coupé Weir
Rivière des Rochers Weir
Rivière des Rochers
Flett Lake
Loutit Lake
Sandy Point No. 221
Devil's Gate No. 220
Allison Bay No. 219
Fort Chipewyan
Dog Head No. 218
Lake Athabasca at Fort Chipewyan [07MD001]
Lake Athabasca
Chipewyan No. 201B
Chipewyan No. 201A
Lake Claire
Prairie River
Mamawi Lake
Embarras River
Cree Creek Breakthrough
Athabasca River above Fletcher Channel [07DD010]
Chipewyan No. 201
Chipewyan No. 201C
Old Fort No. 217
Richardson Lake
Athabasca River above Jackfish Creek [07DD007]
Chipewyan No. 201E
Welstead Lake
Athabasca River at Embarras Airport [07DD001]
Athabasca River
Maybelle River Wildland
nhc
northwest hydraulic consultants
Study Area
Edmonton
WSC GAUGE STATION
DISCHARGE
WATER LEVEL
HYDRAULIC STRUCTURE
STUDY AREA
INDIAN RESERVE
Data Sources: Basemap - Altalis Ltd. & Esri World Imagery; Inset map - National Geographic World Map.
SCALE - 1:350,000
0 4 8 12 KM
N
Coordinate System: NAD 1983 CSRS UTM ZONE 12N
Units: Metres
Job: 1005092
Date: 09-MAR-2020
FEASIBILITY PLAN FOR REMOVABLE CONTROL STRUCTURES IN THE PEACE-ATHABASCA DELTA
STUDY AREA - BIG EGG LAKE
FIGURE 1



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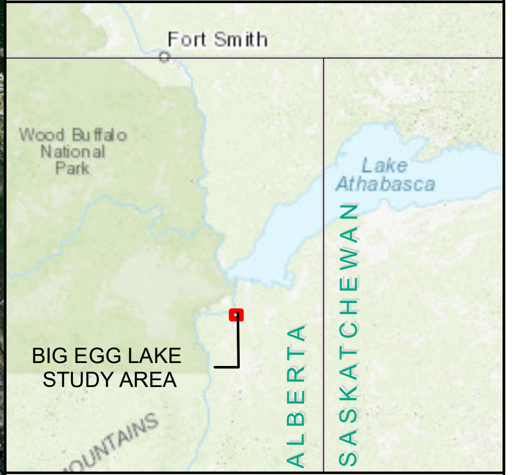


CONNECTION CHANNEL
KEY ELEVATION CONTOUR
MODEL CROSS SECTION

Data Sources: Basemap - Altalis Ltd. & Esri World Imagery; Inset map - National Geographic World Map.

SCALE - 1:20,000
0 200 400 800 M
N

Coordinate System: NAD 1983 CSRS UTM ZONE 12N
Units: Metres

Job: 1005092 | Date: 26-FEB-2020

FEASIBILITY PLAN FOR REMOVABLE CONTROL STRUCTURES IN THE PEACE-ATHABASCA DELTA

LOCATION PLAN - BIG EGG LAKE

FIGURE 2

REH_\\mainfile-edm\P-drive_Projects (Active)\1005092 PAD Weir Surveys\90 GIS\1005092_REH_OAD_BigEggLake_Location.mxd

1.2 Report Outline

The objective of this study is to provide a feasibility plan to support decision making related to possible water control structure options for Big Egg Lake. The water level of Big Egg Lake is limited by the maximum water level in the Athabasca River at the East Connection Channel, the capacity of the East Connection Channel and size of Big Egg Lake. Historical water levels in the river are not available at this location, so a hydraulic assessment of the Athabasca River was required to estimate water levels in the river at the East Connection Channel. The scope of work and chosen approach to complete the project objective is summarized as follows.

Data Collection – Site specific data was collected to assess historical and current conditions at Big Egg Lake. Data collection included engagement with First Nations and Métis knowledge holders and other stakeholders, a site inspection and cross section survey of the Athabasca River and channel connecting it to Big Egg Lake at the proposed location, and compiling hydrometric, geospatial, and satellite imagery.

Hydraulic Assessment of the Athabasca River – An assessment of historical discharge and levels on the Athabasca River and water levels of Lake Athabasca was conducted to develop a stage-discharge rating curve relationship in the river at the East Connection Channel to Big Egg Lake. A hydraulic model of the Athabasca River at the East Connection Channel was developed from the cross-section survey data and historical hydrometric data upstream and downstream of the site. The stage-discharge rating curves generated by the hydraulic model were used in the Hydrotechnical Assessment of Big Egg Lake to quantify historical water levels in Big Egg Lake and predict changes in water level at Big Egg Lake with a water control structure in place.

Hydrotechnical Assessment of Big Egg Lake – A simulation of water levels on Big Egg Lake was conducted to understand the frequency of flow into Big Egg Lake under existing conditions and optimize the elevation of the proposed control structure and to determine the potential benefit that the control structure could provide. The water levels were simulated using the stage-discharge rating curve relationships developed in the Hydraulic Assessment of the Athabasca River. Geospatial data was used to estimate the surface area and volume of Big Egg Lake during the simulation.

Alternative Evaluation – A high level assessment of alternatives for the control structure was completed and an alternative was selected which best satisfied the assessment criteria.

Feasibility Level Design – A feasibility level design of the selected alternative along with a cost estimate was developed to facilitate decision making regarding the implementation of the control structure.

2 DATA COLLECTION

2.1 Local Knowledge Gathering

Local knowledge and traditional use information for the PAD was collected during the Knowledge Gathering Sessions carried out on 17-19 September 2019 in Fort Chipewyan, Alberta. Knowledge holders of the Athabasca Chipewyan First Nation (ACFN), the Mikisew Cree First Nation (MCFN), and the Fort Chipewyan Métis Local 125 (FCML) provided valuable information about water level variations in the PAD and how this affected the wildlife and vegetation. Separate Knowledge Gathering Sessions held with each of the three groups are documented in reports by Lifeways of Canada Limited. In addition, Open House Sessions carried out on 18 and 19 September were used to engage with the local community about the work being undertaken. The following is a summary of information provided in these Knowledge Gathering Sessions that was relevant to this study.

Historically, large floods replenished the perched basins, inland lakes, and other backcountry areas in the PAD, Peace River, and Athabasca River areas. This flooding was primarily due to ice jam formation on the Peace and Athabasca rivers in the spring time. The Peace River used to jam at the 30th baseline downstream of the confluence of the Riviere des Rochers and water from the Peace River would inundate the delta (MCFN, 2019). On the Athabasca River, ice jams would occur most frequently at Big Eddy and Devils Elbow (MCFN, 2019).

Flooding from spring ice jams is not the only major source of water in the PAD. Seasonal runoff from rivers such as the Birch, McIvor, and Athabasca Rivers are also important to the maintenance of water levels in the PAD (MCFN, 2019). Summer runoff in the Athabasca River also provides high water (ACFN, 2019). Also, both ACFN and MCFN knowledge holders indicated that when Lake Athabasca levels were high, strong northeast winds would push water from Lake Athabasca into Lake Mamawi causing summer flooding (ACFN, 2019 and MCFN, 2019).

After a flood occurred, the water levels in the perched basins would drop slowly over time so the frequency of flooding was important to ensure that adequate water levels were maintained. One MCFN knowledge holder stated that there was “flooding every three to seven years” (MCFN, 2019). Another MCFN knowledge holder stated “that '96 flood ……… just flooded the whole Peace-Athabasca Delta, and we had water like in the back country for at least six years after that” (MCFN, 2019). AFCN knowledge holders indicated that, in recent years, flooding has been less frequent and water levels are lower and attributed the changes to the operation of the Bennet Dam (ACFN, 2019).

Lower water levels and less frequent flooding of perched lakes cause changes to wildlife and vegetation. ACFN knowledge holders indicated that there used to be lots of muskrats when water levels were higher and that muskrats need more water than is currently available in some lakes (ACFN, 2019). Muskrat populations typically rebound in the second year following a replenishing flood as the first year is needed for the recovery of muskrat food resources. One MCFN knowledge holder stated that “two years after a highwater event, then the muskrat comes back” (MCFN, 2019). A FCML knowledge holder indicated that lower water levels have also allowed a lot of thistle to grow (FCML, 2019) and an MCFN knowledge holder stated: “Now all the basins that used to have muskrats and everything, it's all filled with willows and grass.” Flooding was cited by both ACFN and FCML knowledge holders as being needed to help clear out unwanted vegetation.

Low water levels have also made traditional use of the landscape more difficult. ACFN knowledge holders indicated that shallow channels are not allowing boat passage, which affects the ability of users to access cabins, hunting areas, and to move through their traditional territory and that the growth of willows in the shallow areas has also inhibited navigation (ACFN, 2019). An FCML knowledge holder indicated that the increase in willows also make trapping more difficult, with the traps getting tangled in the willows when muskrats are caught in them (FCML, 2019).

Increased water levels are required to restore muskrat populations and help clear out the willows and bulrushes. ACFN knowledge holders indicated that muskrat populations are healthy when a water depth of about 8 ft occurs in Big Egg Lake; however, currently, there are more beaver than muskrat present which indicates that the lake level is too low (ACFN, 2019). They also indicated that willows and bulrushes are also growing in the shallower water and this vegetation would be cleaned out if water levels were higher (ACFN, 2019).

Historically, water flowed into Big Egg Lake from the Athabasca River when spring ice jams or summer floods generated high enough water levels. ACFN knowledge holders indicated that flooding in Big Egg Lake was mostly caused by spring ice jams on the Athabasca River; however, high flows on the Athabasca River could affect water levels in Big Egg Lake as well (ACFN, 2019).

Big Egg Lake is connected to other lakes farther from the Athabasca River. ACFN knowledge holders indicated that when water from the Athabasca River filled Big Egg Lake, the water subsequently flowed to the north into Sucker Lake, Willow Island Lake, and then as far north as Flour Bay (ACFN, 2019).

The original inflow location near the west end of the lake had become ineffective, so a trench was excavated by the ACFN in the late 1970’s or early 1980’s connecting Big Egg Lake to the Athabasca River to the east of the original inflow location (AFCN, 2019). ACFN knowledge holders indicated that, originally, this trench had a wooden weir on it to control flow in and out of the lake, but the weir no longer exists (ACFN, 2019). This trench is still functioning to divert water into Big Egg Lake, and better conditions in 2019 in the area of Big Egg Lake were attributed by ACFN knowledge holders to the existence of the trench (ACFN, 2019). It was indicated that if water flowed into Big Egg Lake via the trenches that have been excavated along the south side of the lake, that the water would remain in the lake and would not drain out through other trenches (ACFN, 2019).

AFCN knowledge holders unequivocally supported the eastern trench location as the best site to locate a removable control structure. One knowledge holder also indicated that use of artificial ice dams using ice booms or spray ice to increase local water levels in the Athabasca River would not be an effective option (ACFN, 2019).

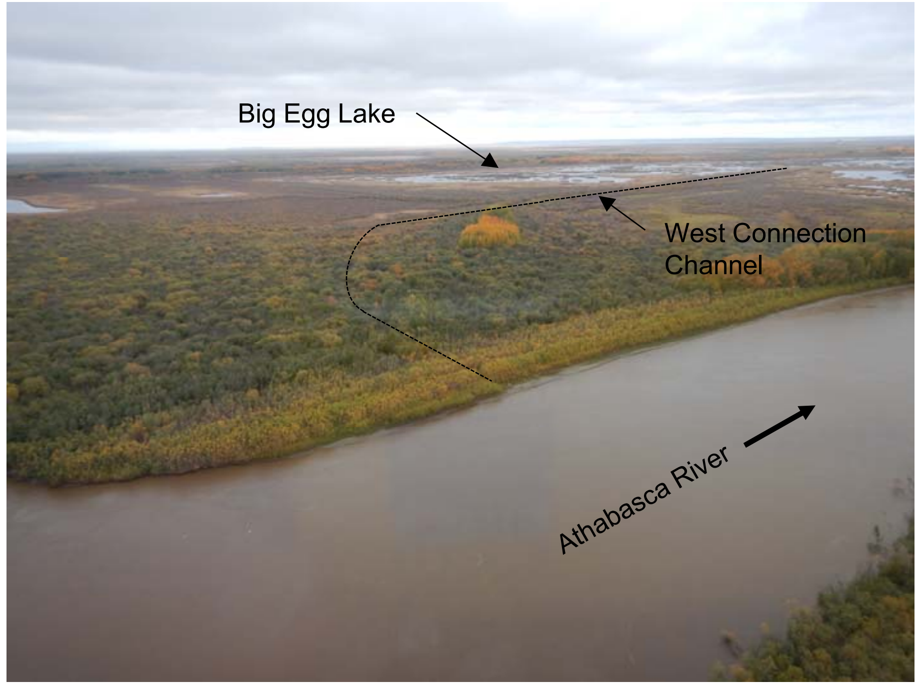
2.2 Site Inspection

NHC conducted an inspection of the proposed Big Egg Lake site by helicopter on 20 September 2019 to assess the current level of connectedness of the East and West Connection Channels to the Athabasca River (**Figure 2**). During this site inspection, photographs were taken of the West and East Connection Channels and of the lake itself. The locations of nearby cabins on the Athabasca River were also investigated. A summary of key photographs taken during the site inspection and the site survey are shown in **Figure 3**.

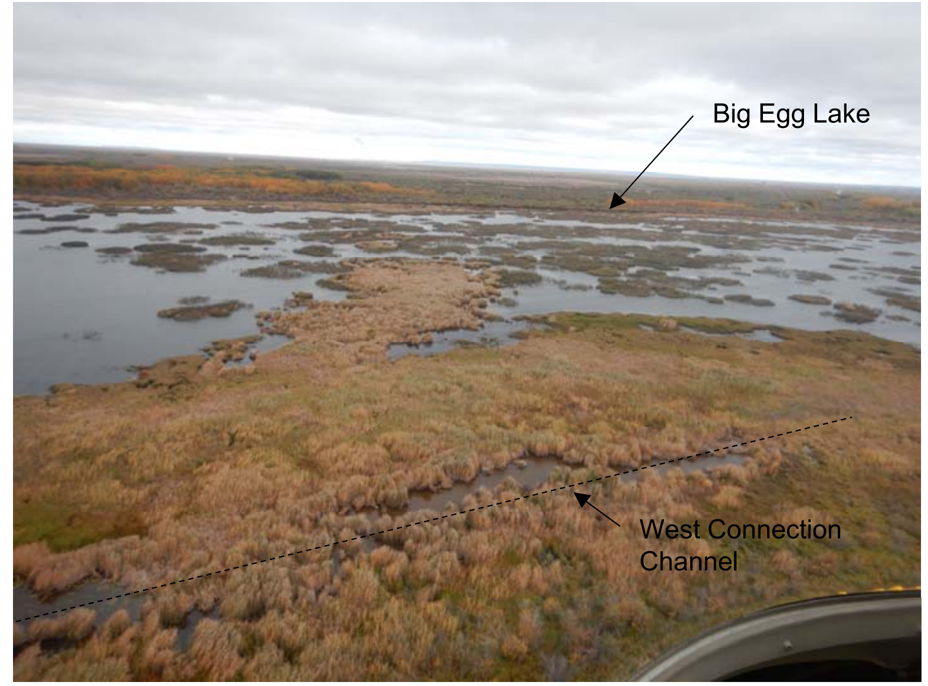
The West Connection Channel is shown in **Figure 3a**. The entrance and the length of the channel is overgrown with vegetation and poorly defined. **Figure 3b** shows the connection of the West Connection Channel with Big Egg Lake. The entrance to the East Connection Channel is shown in **Figure 3c**. On the day of the site inspection the water level was high enough in the Athabasca River to wet the East Connection Channel to the wetted area set back from the banks of the Athabasca River. The average water level at WSC Station 07DD007 (Athabasca River above Jackfish Creek) during the site inspection was 210.686 m. **Figure 3d** shows the East Connection Channel and the wetted area from the air. On the day of the site inspection, it appeared that the water level was high enough in the wetted area for water to flow through the vegetation towards Big Egg Lake. **Figure 3e** shows the East Connection Channel during the site survey. The water level in the Athabasca River had receded and the connection channel was no longer carrying water toward Big Egg Lake. The average water level at WSC Station 07DD007 during the site survey was 210.311 m. The wetted area is shown from the ground during the site survey in **Figure 3f**. Debris accumulation within the channel was evident from the photos taken from the site survey. The photographs show that the East Connection Channel is much less obstructed by vegetation than the West Connection Channel. The East Connection Channel still carries water towards Big Egg Lake during high water events and provides a better connection from the river to the lake than the West Connection Channel.

2.3 Site Survey

A survey was conducted on 8 October 2019 of the Athabasca River channel and the East Connection Channel to Big Egg Lake in order to obtain cross-sectional data to build a HEC-RAS model to inform the hydraulic modelling (**Section 3.2**). The survey extended about 600 m upstream and downstream of the connection channel on the Athabasca River and about 50 m north from the bank of the Athabasca river along the connection channel. Five cross sections were surveyed on the Athabasca River and three cross sections were surveyed on the East Connection Channel. The locations of the cross sections are shown in **Figure 2**.

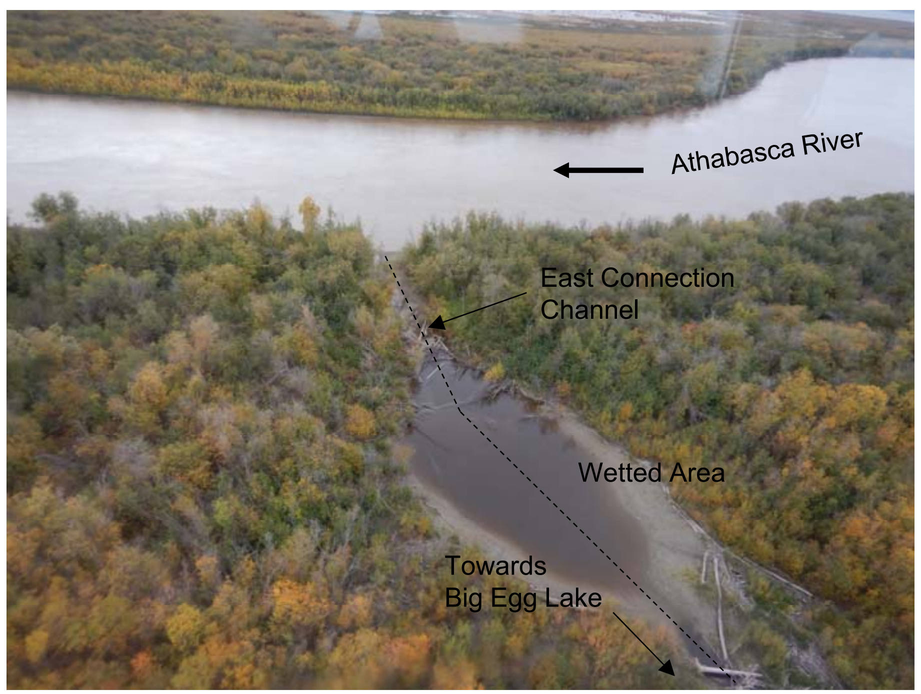


a) Looking north at the West Connection Channel to Big Egg Lake. (Photo Date: 20SEP2019)



b) Looking north at the northern portion of Big Egg Lake. (Photo Date 20SEP2019)

c) Looking at the entrance of the East Connection Channel from the Athabasca River. (Photo Date 20SEP2019)



d) Looking south at the East Connection Channel and the wetted area inside the banks of the Athabasca River. (Photo Date 20SEP2019)

e) Looking towards the Athabasca River along the East Connection Channel. (Photo Date 8OCT2019)

f) Looking north at the wetted area along the East Connection Channel. (Photo Date 8OCT2019)

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SCALE – AS SHOWN

Coordinate System:
Units: As Shown

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FEASIBILITY PLAN FOR REMOVABLE CONTROL STRUCTURE IN THE PEACE ATHABASCA DELTA
BIG EGG LAKE FEASIBILITY PLAN

SITE INSPECTION PHOTOS

FIGURE 3

The submerged, deep water portions of channel cross sections upstream and downstream of the weirs were surveyed using an Odom Hydrotrac single-frequency digital echo sounder and Trimble R10/R8 real-time kinematic (RTK) survey-grade GPS. Near shore, shallow water and bank portions of cross sections were surveyed on foot using RTK GPS. Standard survey methods and procedures for river bathymetric surveys in Alberta were employed, including establishing suitable temporary benchmarks and referencing existing survey control markers where they exist.

Coordinate system information for all survey data collected and reported is described as follows:

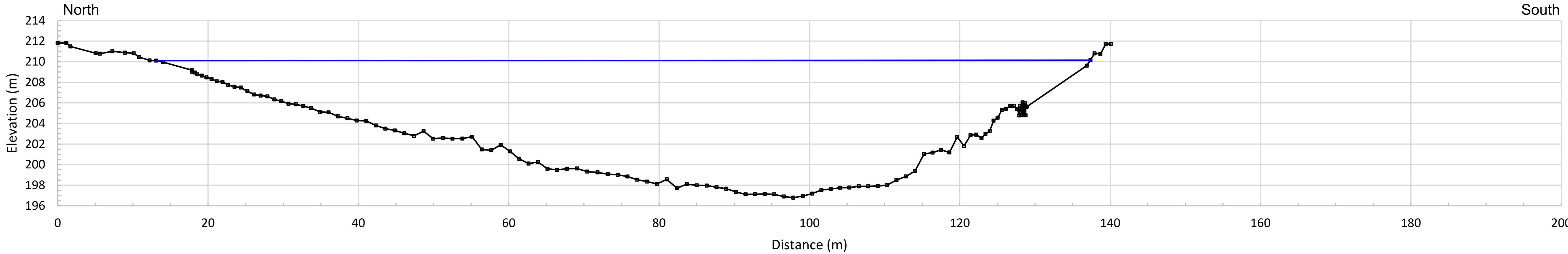
- Horizontal coordinate system: Universal Transverse Mercator Zone 12N
- Horizontal datum: North American Datum 1983 (Canada)
- Vertical datum: Canadian Geodetic Vertical Datum 2013
- Geoid: Canada CGG2013A

Local benchmarks at hydrometric gauging stations were surveyed to facilitate comparison and adjustments to water level data recorded by Water Survey of Canada (WSC) so that all elevations are referenced to a common datum. Table 1 summarizes control point coordinates at local benchmarks established in the study area.

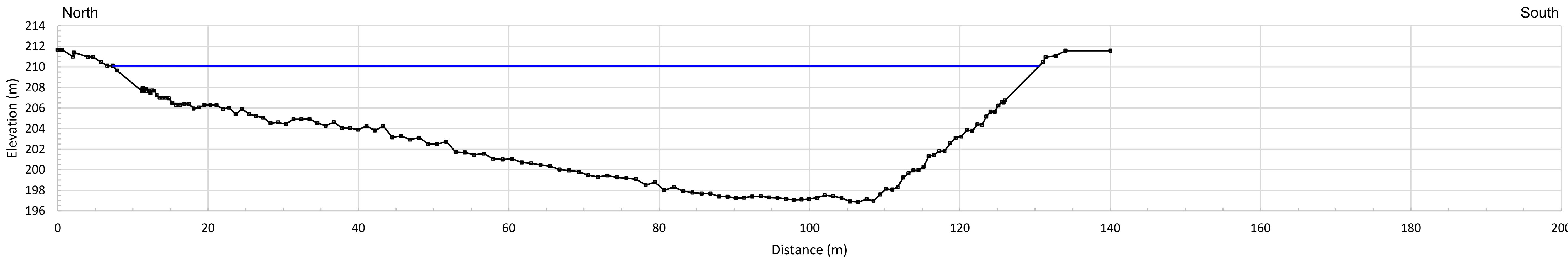
Table 1 Summary of network adjusted control point coordinates

Survey ID	Location	Northing (m)	Easting (m)	Elevation (m)
1	Rochers Weir	6531241.710	489638.792	212.557
104	Fort Chipewyan	6513157.848	494147.394	248.444
200	Dog Camp	6501172.866	481643.724	211.378
300	Cree Creek	6482261.901	471923.868	212.015
3000	Below Rochers Weir	6532224.191	487748.826	215.856
400	Big Egg Lake	6476791.674	500172.001	210.474
500	Revillon Coupé Weir	6530295.462	475637.119	209.159
100	Fort Chipewyan	6508182.786	491225.838	218.917

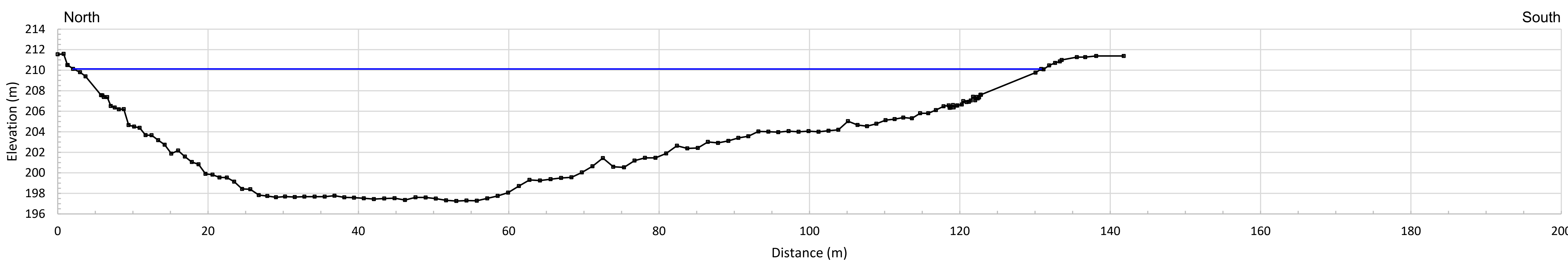
The surveyed cross sections of the Athabasca River are shown in **Figure 4** and **Figure 5**. The slope of the water surface on the day of the survey was about 0.000024 with an average water elevation of 210.11 m. The channel shape is generally quite similar for cross sections one through four with a minimum elevation of about 197 m (maximum depth of about 13 m) and a wetted top width of between 120 m and 130 m. The fifth cross section is wider and shallower with a wetted top width of about 170 m and a minimum elevation of about 201 m (maximum depth of about 9 m). The top of bank elevation along the north bank varies between about 211.5 m and 211.8 m.



a) Athabasca River Cross Section 1



b) Athabasca River Cross Section 2



c) Athabasca River Cross Section 3

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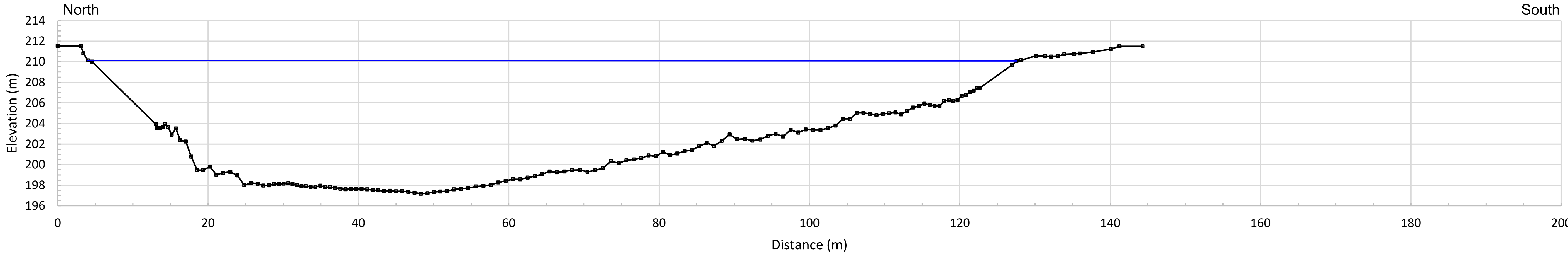
Coordinate System:
Units: As Shown

Job: 1005166 | *Date: 27-FEB-2020*

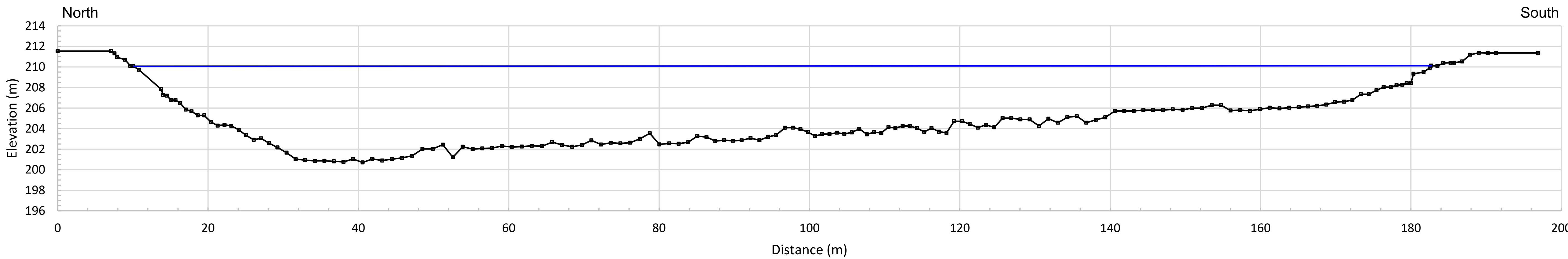
FEASIBILITY PLAN FOR REMOVABLE CONTROL STRUCTURE IN THE PEACE ATHABASCA DELTA BIG EGG LAKE FEASIBILITY PLAN

ATHABASCA RIVER SURVEY CROSS SECTIONS SHEET 1

FIGURE 4



a) Athabasca River Cross Section 4



b) Athabasca River Cross Section 5

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ATHABASCA RIVER SURVEY CROSS SECTIONS SHEET 2

FIGURE 5

The surveyed cross sections of the East Connection Channel are shown in **Figure 6**. The top of bank elevation of both the west and east banks was about 211.2 m. The minimum elevation varied from 210.2 m at cross section one to about 209.8 m at cross section three. No water flowed through the East Connection Channel during the site survey. The water elevation was 210.61 m in the wetted area at the northern extents of the site survey. This suggests that the highest elevation along the connection channel between the Athabasca River and the wetted area was above 210.6 m.

2.4 Hydrometric Data

Water Survey of Canada has periodically operated gauging stations at numerous sites on the Athabasca River and Lake Athabasca measuring the discharge and the water level. The gauging station records are important for understanding the hydraulic relationship between the multitude of channels through the delta. A summary of the measurement records at key gauging stations for understanding the hydraulic conditions at Big Egg Lake is provided in **Table 2** and their locations are shown on **Figure 1**.

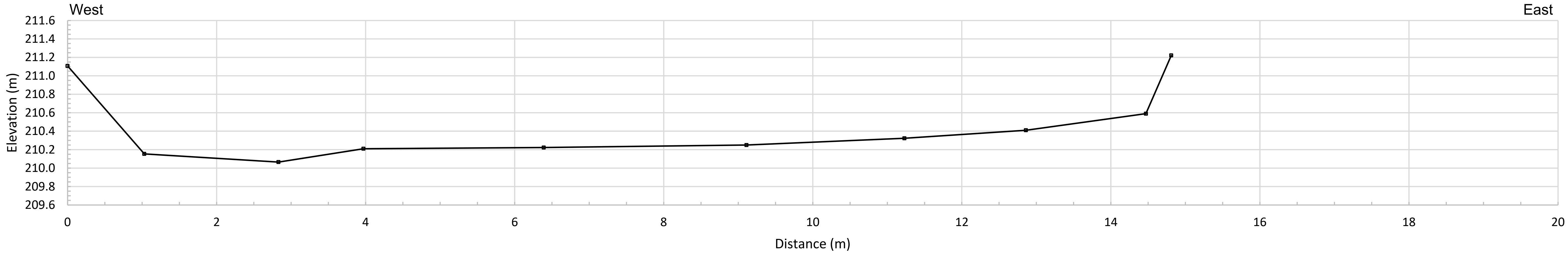
Table 2 Key hydrometric stations on the Athabasca River in the Delta

Type	Station No.	Station Name	Period of Record
Discharge	07DD001	Athabasca River at Embarras Airport	1971-1984, 2014-2018, 2019[1]
Water Level	07DD010	Athabasca River above Fletcher Channel	1975-1981, 1983-1985
	07DD007	Athabasca River above Jackfish Creek	1971, 1975-2016, 2017-2019[1]
	07MD001	Lake Athabasca at Fort Chipewyan	1931, 1934-1944, 1947-1956, 1960-2016, 2017-2019[1]

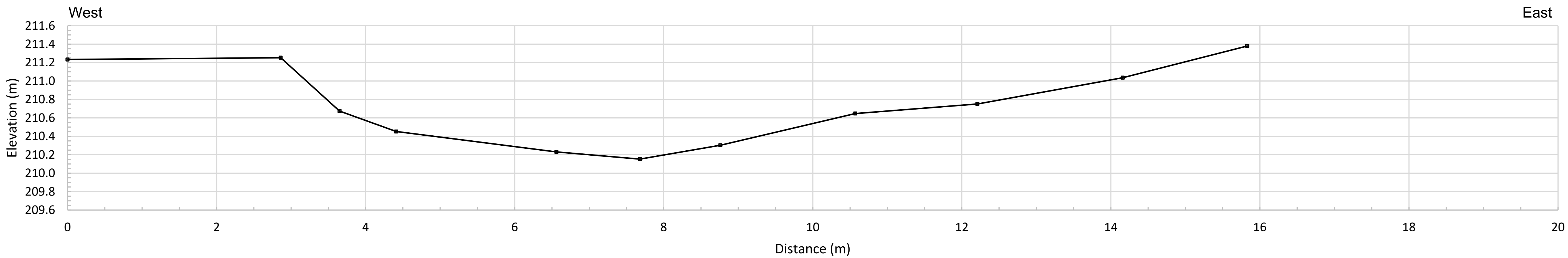
[1] Preliminary data obtained from Alberta Environment and Parks.

2.5 Geospatial Data

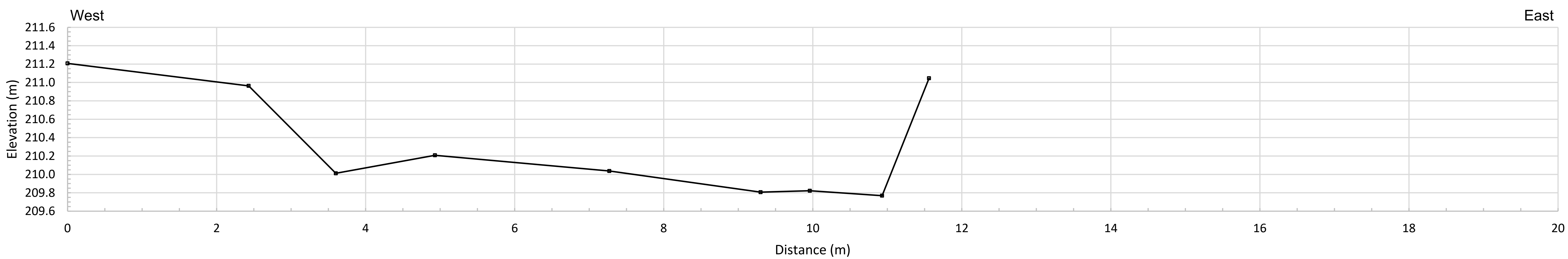
Geospatial data of the study area was obtained to provide elevation data for the feasibility study. The data included the Canadian Digital Surface Model (CDSM) obtained from the Government of Canada as well as LiDAR at the Dog Camp site. The CDSM is a dataset compiled by Natural Resources Canada and captures the elevation off vegetation rather than ground level at approximately 20 m spacing. Data was obtained over the full extent of the delta. The elevation of the CDSM was adjusted up by 1.65 m to generally match the elevation of the LiDAR and the survey data at the Dog Camp site and it was assumed that the same adjustment was appropriate at Big Egg Lake.



a) East Connection Channel Cross Section 1



b) East Connection Channel Cross Section 2



c) East Connection Channel Cross Section 3

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EAST CONNECTION CHANNEL SURVEY CROSS SECTIONS

FIGURE 6

2.6 Satellite Imagery

Satellite imagery was obtained to analyse the historical inundation extents of Big Egg Lake. Imagery was obtained from Google Earth, Digital Global via ESRI ArcGIS World Imagery, the Copernicus Sentinel-2 Satellite operated by European Space Agency (ESA), and Landsat Satellite from United States Geological Survey (USGS). The satellite imagery obtained for the study is summarized in **Table 3**. The Landsat Satellite imagery was the only dataset that was georeferenced so only this imagery could be used to quantify the water level variation throughout the year.

Table 3 Summary of Satellite Imagery

Source	Date
Google Earth	28 August 2007
Copernicus Sentinel-2 Satellite	23 August 2016
	19 June 2017
	5 August 2017
	20 August 2017
	29 September 2017
	16 June 2018
	26 July 2018
	20 August 2018
	22 September 2018
Landsat Satellite	21 June 2013
	14 July 2013
	8 August 2013
	16 September 2013
	8 June 2014
	26 July 2014
	3 September 2014
	28 September 2014
Digital Global	29 May 2011
	15 August 2014
	27 June 2016

3 HYDRAULIC ASSESSMENT OF ATHABASCA RIVER

The Athabasca River flows northwards into the PAD and diverges into several channels as the water flows towards Lake Athabasca. The Embarras River and Fletcher Channel divert water from the Athabasca River upstream of Big Egg Lake. Downstream of Big Egg Lake, the Athabasca River splits into the Goose Island Channel and the Big Point Channel (**Figure 1**). The water level at Big Egg Lake is a function of both the discharge on the Athabasca River and the water level on Lake Athabasca.

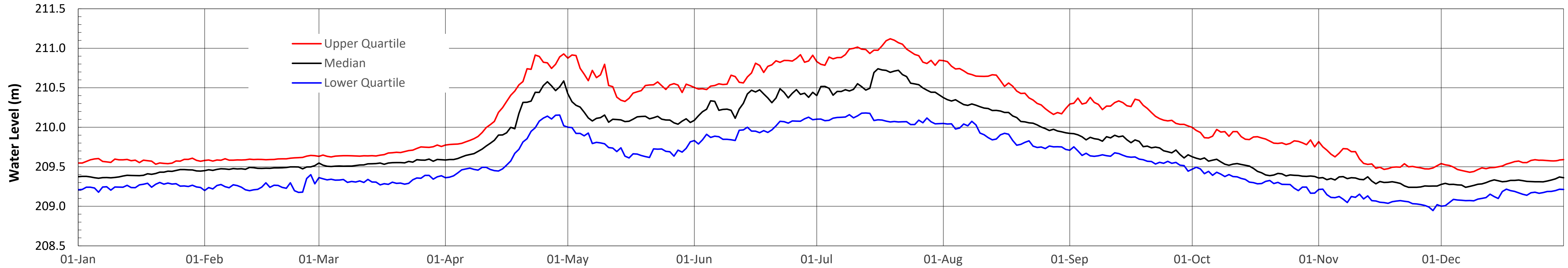
Development of stage-discharge relationships at the proposed site of the control structure at Big Egg Lake is important for understanding how the water level regime at Big Egg Lake varies with both the discharge on the Athabasca River and the water level on Lake Athabasca. The stage-discharge relationship was required to quantify historical water levels at Big Egg Lake and could be used to predict future water levels due to changes in the discharge of the Athabasca River and the water level of Lake Athabasca.

3.1 Historical Flows and Levels

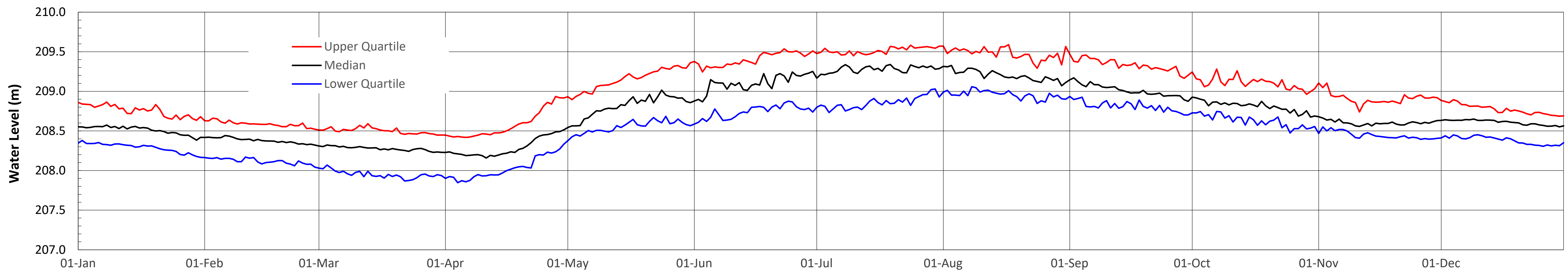
Measurements were reviewed at the gauges operated by WSC to determine the historical ranges of discharge and water level. The discharge entering the PAD via the Athabasca River is measured at WSC Station 07DD001 (Athabasca River at Embarras Airport). The water level gauge at WSC Station 07DD007 (Athabasca River above Jackfish Creek) is most representative of the water level at Big Egg Lake. It is located about 6 km downstream of the proposed location of the control structure. The water level at WSC Station 07MD001 (Lake Athabasca at Fort Chipewyan) provides the water level at the confluence of the Athabasca River with Lake Athabasca.

The variation in the daily water level of the Athabasca River above Jackfish Creek throughout the year is shown in **Figure 7a**. The figure shows that the maximum water levels occur in the middle of July each year but high water levels are also common around the end of April. The annual maximum of the median water levels under open water and ice covered conditions are about 210.7 m on 16 July and 210.6 m on 30 April. High water levels in June, July, and August are the result of open water floods on the Athabasca River in conjunction with high water levels on Lake Athabasca, while the high water levels in April and May occur due to the breakup of the river ice.

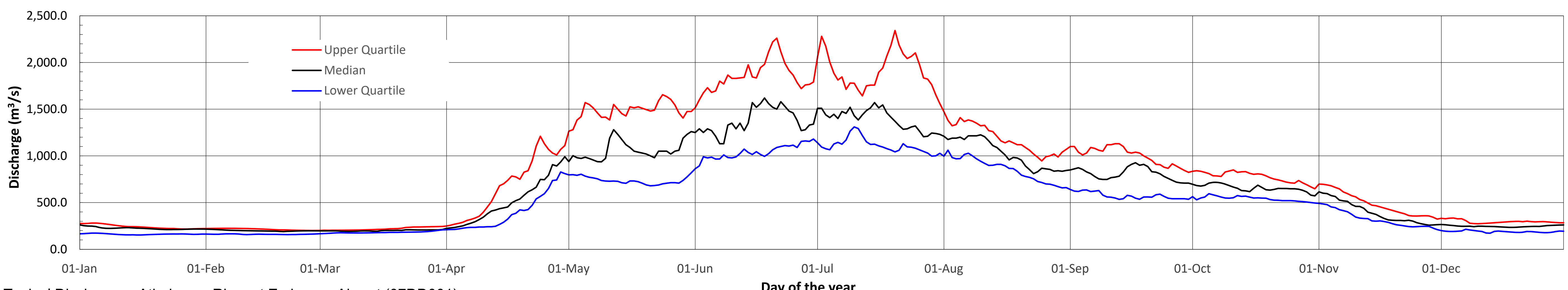
The annual maximum water level and the day of the year that it occurred over the 46 years of record are provided in **Table 4**. In total, 20 of the annual maximum water levels occurred during river ice breakup with the remaining 26 maximum water levels occurring under open water conditions. River ice breakup was defined as before 1 June. The average annual maximum water level was 211.18 m. The standard deviation of these annual maximum water levels is 0.54 m.



a) Typical Water Levels – Athabasca River above Jackfish Creek (07DD007)



b) Typical Water Levels – Lake Athabasca at Fort Chipewyan (07MD001)



c) Typical Discharge – Athabasca River at Embarras Airport (07DD001)

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FEASIBILITY PLAN FOR REMOVABLE CONTROL STRUCTURE IN THE PEACE ATHABASCA DELTA BIG EGG LAKE FEASIBILITY PLAN

SUMMARY OF TYPICAL ANNUAL MEASUREMENTS AT WSC HYDROMETRIC STATIONS

FIGURE 7

Table 4 Record of Annual Maximum Water Levels at WSC Station 07DD007, Athabasca River above Jackfish Creek

Year	Maximum Water Level (m)	Date	Condition
1971	212.065	20 July	Open water
1975	211.382	1 May	River ice breakup
1976	211.178	21 April	River ice breakup
1977	211.324	9 June	Open water
1978	211.373	2 May	River ice breakup
1979	211.656	12 May	River ice breakup
1980	211.043	12 June	Open water
1981	210.727	1 May	River ice breakup
1982	211.109	12 July	Open water
1983	210.942	4 August	Open water
1984	210.567	8 June	Open water
1985	211.363	1 May	River ice breakup
1986	211.762	31 July	Open water
1987	210.918	21 April	River ice breakup
1988	211.140	20 July	Open water
1989	211.157	11 August	Open water
1990	211.533	22 June	Open water
1991	211.306	20 June	Open water
1992	210.640	25 April	River ice breakup
1993	210.400	31 July	Open water
1994	211.549	23 April	River ice breakup
1995	211.140	14 August	Open water
1996	211.649	14 August	Open water
1997	212.104	1 May	River ice breakup
1998	210.838	14 July	Open water
1999	210.802	15 July	Open water
2000	210.721	1 August	Open water
2001	211.175	5 August	Open water
2002	210.826	11 May	River ice breakup
2003	210.837	30 June	Open water
2004	210.802	29 April	River ice breakup
2005	211.429	6 July	Open water
2006	210.616	18 April	River ice breakup

Table 4 Record of Annual Maximum Water Levels at WSC Station 07DD007, Athabasca River above Jackfish Creek (continued)

Year	Maximum Water Level	Date	Condition
2007	211.544	16 May	River ice breakup
2008	210.969	12 May	River ice breakup
2009	210.830	17 July	Open water
2010	210.107	29 May	River ice breakup
2011	211.719	18 July	Open water
2012	211.454	1 August	Open water
2013	211.800	30 June	Open water
2014	211.356	4 May	River ice breakup
2015	210.231	11 April	River ice breakup
2016	210.407	23 April	River ice breakup
2017	211.397[1]	17 June	Open water
2018	213.096[1]	9 May	River ice breakup
2019	211.408[1]	5 July	Open water

[1] Preliminary data obtained from Alberta Environment and Parks.

The water level on Lake Athabasca affects the relationship between discharge and water level at Big Egg Lake and therefore there is not a unique rating curve at the site. **Figure 7b** presents the variation in the water level of Lake Athabasca throughout the year since 1976. The median water level is at a minimum of about 208.2 m in early April and reaches a maximum of about 209.3 m in the middle of July. The maximum water level on record was 210.8 m in 1997, which is an outlier relative to the rest of the dataset. The high water level in 1997 was due to significantly higher than average discharge throughout the summer on the Peace River.

It is important to understand how the discharge entering the PAD varies throughout the year.
The average daily discharge entering the PAD via the Athabasca River throughout the year is shown in **Figure 7c**. The median discharge is highest in the middle of June but remains very high towards the end of July with the largest peak events occurring in July. The discharge in the Athabasca River in the reach along Big Egg Lake is not measured but knowing the discharge entering the PAD via the Athabasca River gives an indication of the magnitude in the Big Egg Lake reach. Discharge that enters the PAD via the Athabasca River is split into the Embarras River, the Fletcher Channel, the Goose Island Channel, and the Big Island Channel.

3.2 Hydraulic Modelling

A hydraulic model of the river reach was developed from the survey data of the Athabasca River to simulate water levels in the river. The domain of the hydraulic model extended from 600 m downstream to 600 m upstream of the proposed location of the connecting channel.

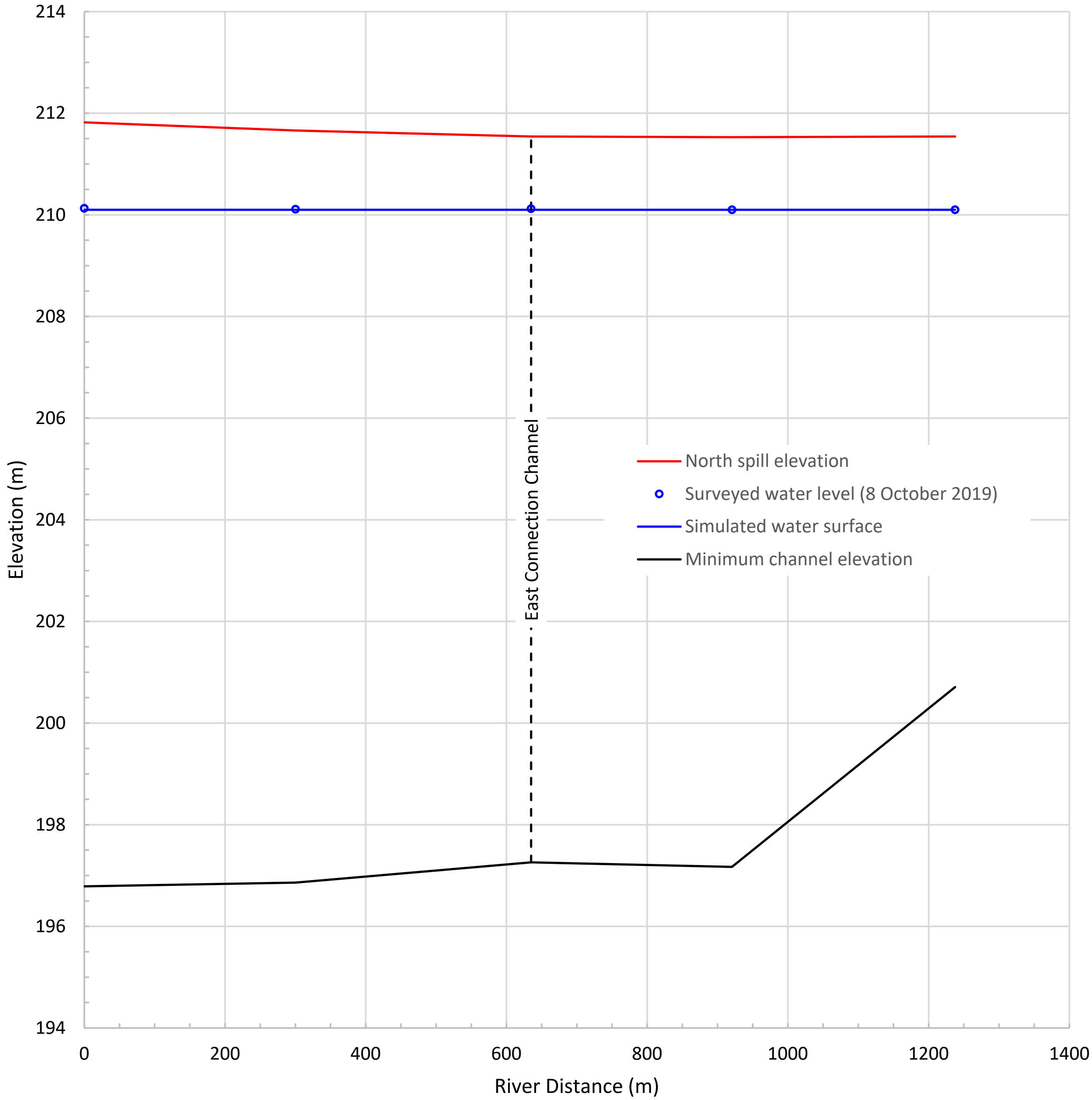
The discharge was measured during the survey was 633 m^3/s. The simulated water surface profile using this measured discharge is compared to the measured water levels in **Figure 8**. The water surface slope was essentially flat during the survey, so calibration of the Manning roughness was not possible using the survey data. Instead, a Manning roughness of 0.010 was adopted for the channel based on the observed bed material characteristics.

3.3 Stage-Discharge Rating Curves

The hydraulic model of the river was used to generate the stage-discharge relationship at Big Egg Lake for various Lake Athabasca water levels. The hydraulic model requires boundary conditions at inflow and outflow boundaries of the model. The inflow boundary condition is the discharge of the Athabasca River at Big Egg Lake and the outflow boundary condition is the water level at this boundary. The inflow discharge was taken as a percentage of the discharge of the Athabasca River at Embarras Airport. The outflow water level is a function of both the discharge in the channel and the water level of Lake Athabasca. Determining relationships at both model boundaries was necessary to define the stage-discharge relationships at Big Egg Lake.

Discharge measurements are not available for the Athabasca River at Big Egg Lake so a relationship was obtained from previous work. Work completed as part of the Peace-Athabasca Delta Technical Studies (DeBoer, Garner, and Winhold, 1994) determined a relationship between the discharge on the Athabasca River at Embarras Airport and discharges on the Embarras River, in the Fletcher Channel, in the Goose Island Channel, and in the Big Point Channel. The relationships were determined from a linear regression analysis of concurrent discharge measurements between 1971 and 1992. Figures in the report comparing the linear regression to the measurements show errors in the regression as a large as ±50%. These large errors occur because the discharges in the Fletcher Channel, Goose Island Channel, and the Big Point Channel are also dependent on the Lake Athabasca water level. The discharge on the Athabasca River at Big Egg Lake was determined by adding together the discharges in the Goose Island and the Big Point Channels.

Water levels at the downstream boundary of the hydraulic model were established from the water level gauge on the Athabasca River above Jackfish Creek, located about 6 km downstream of the proposed control structure at Big Egg Lake. Water levels on the Athabasca River above Jackfish Creek vary with both discharge in the channel and the water level of Lake Athabasca.



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FEASIBILITY PLAN FOR REMOVABLE CONTROL STRUCTURE IN THE PEACE ATHABASCA DELTA BIG EGG LAKE FEASIBILITY PLAN

SIMULATED SURVEY WATER SURFACE PROFILE ALONG ATHABASCA RIVER AT BIG EGG LAKE

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FIGURE 8

The following steps were undertaken to develop stage-discharge rating curves at Big Egg Lake.

- Discharge measurements from the Athabasca River at Big Egg Lake are not available so the discharge from the Athabasca River at Embarras Airport was used instead. The travel time between the gauge at Embarras Airport and Jackfish was determined by comparing the time between distinct peaks in the hydrographs. Well defined peaks generally had a travel time of about one day while peaks that were less well defined generally approached two days in travel time. A shift of one day was applied between to the discharge at Embarras Airport and water level measurements above Jackfish Creek because the well-defined peaks provide a better correlation between the discharge and water level.

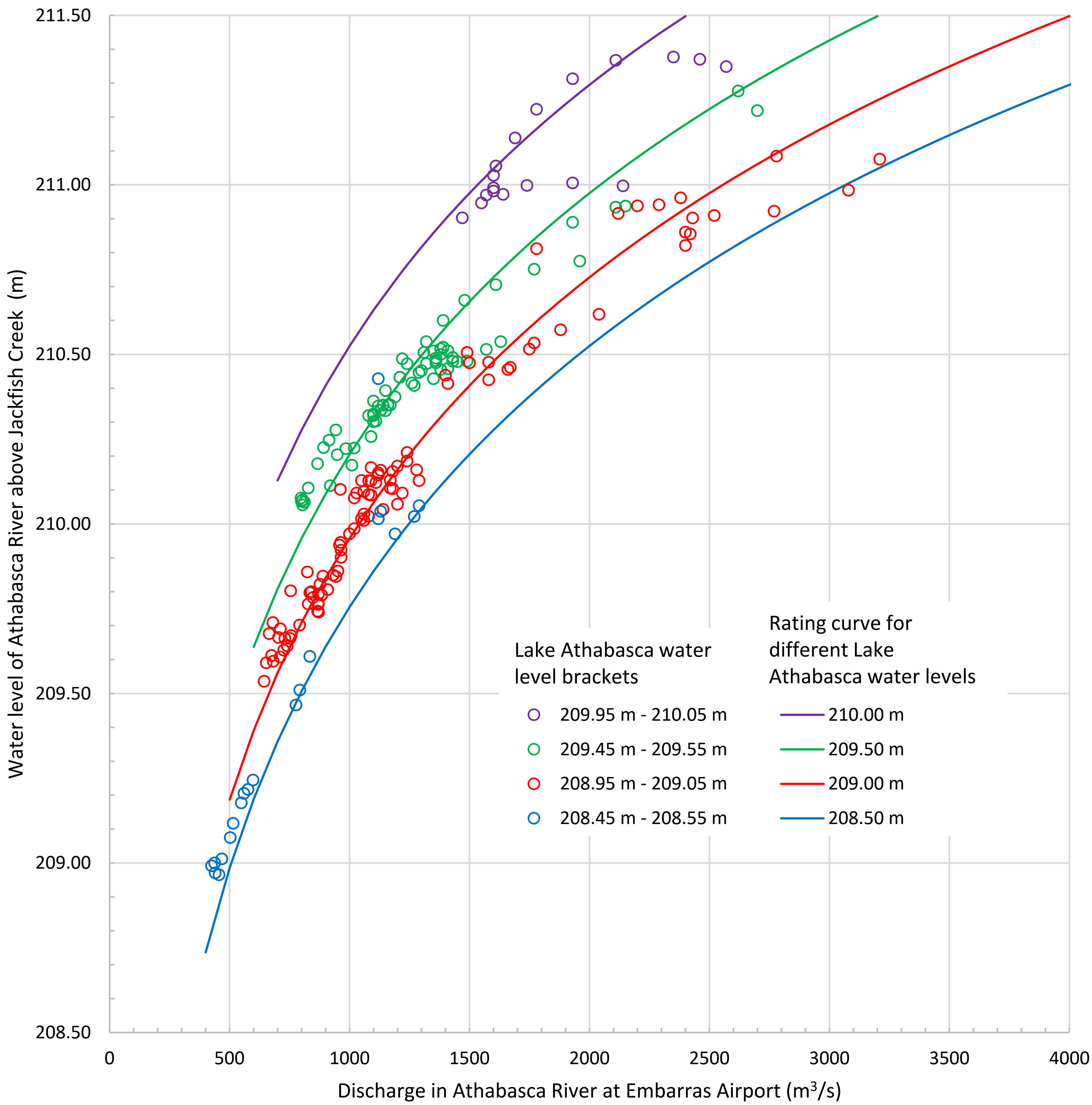
- To isolate changes in the water level above Jackfish Creek due to the discharge instead of changes caused by Lake Athabasca water levels, discharge-water level pairs were divided into brackets of 0.1 m variation in the Lake Athabasca water level. Pairs were available for eleven years in total (1971, 1975 – 1984). Lake Athabasca water levels varied from about 208.5 m to 210.0 m over the periods of available discharge-water level pairs. Unique rating curves were developed for each bracket. It was found that the shape of the rating curve was relatively constant over the range of Lake Athabasca water levels. An equation to estimate the water level on the Athabasca River above Jackfish Creek as a function of the Athabasca River discharge at Embarras Airport and Lake Athabasca water level was developed as follows (Eqn 1):

$$WL_{AthaJF} = \frac{1}{0.9}\ln\left(\frac{Q_{AthaEM}}{211.5 - WL_{LAtha}}\right) + 203.3$$

Where	WL_{AthaJF} =	Water level on the Athabasca River above Jackfish Creek (m); must be greater than WL_{LAtha}
	Q_{AthaEM} =	Discharge in the Athabasca River at Embarras Airport (m^3/s)
	WL_{LAtha} =	Lake Athabasca water level (m); must be less than 211.5 m

  The limitation for use of the equation is that for small discharges, the calculated water level will be less than the water level on Lake Athabasca. This was assumed to not be possible so these data were not included.

- **Figure 9** compares the rating curve equation to the measured gauge data for selected Lake Athabasca water level brackets. The equation generally underpredicts water levels on average by about 0.15 m for discharges less than about 1,000 m^3/s with a maximum underprediction of 0.3 m around 500 m^3/s. Above 1,000 m^3/s, the equation has an error of about ±0.2 m. Several outliers can be seen on the plots in **Figure 9** which are not included in the error estimate of the relationship. It is believed the outliers are due to wind setup of Lake Athabasca which the model does not account for. The rating curve equations were extrapolated beyond the measured gauge data to simulate the water levels for conditions that did not occur during the limited measurement record.



Notes:

1. Rating curves were developed for Lake Athabasca water level brackets from 208.5 m to 210.0 m with 0.1 m between brackets. Only selected water level brackets are shown in the figure to illustrate the variation in the rating curve for different Lake Athabasca water levels.
2. Concurrent record of the discharge in the Athabasca River at Embarras Airport and the water level of the Athabasca River above Jackfish Creek were available in 1971 and between 1975 and 1984.

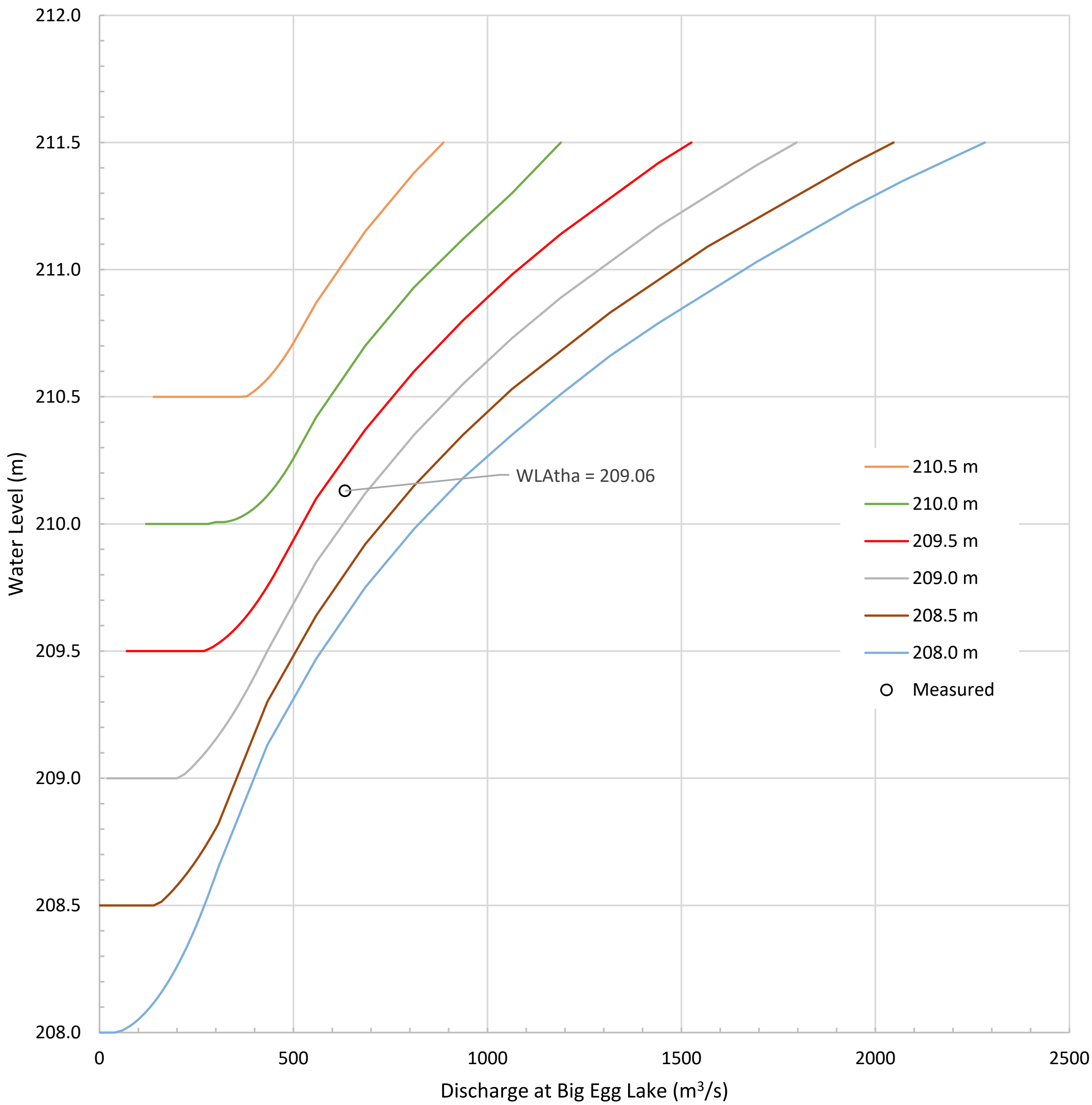
	SCALE – AS SHOWN	*FEASIBILITY PLAN FOR REMOVABLE CONTROL STRUCTURE IN THE PEACE ATHABASCA DELTA BIG EGG LAKE FEASIBILITY PLAN*
nhc northwest hydraulic consultants	Coordinate System: Units: As Shown	*RATING CURVE FOR ATHABASCA RIVER ABOVE JACKFISH CREEK FOR VARIOUS LAKE ATHABASCA LEVELS*
	Job: 1005166 *Date: 27-FEB-2020*	*FIGURE 9*

- The rating curve equation established for the Athabasca River above Jackfish Creek was transferred to Big Egg Lake using the river slope. The downstream boundary of the HEC-RAS model is located 5.1 km upstream of the WSC gauge above Jackfish Creek. The water surface slope was established by reviewing the water level difference between the concurrent WSC gauge records above Jackfish Creek and above Fletcher Channel. The channel distance between the two WSC gauges is about 10.7 km. The water level difference was found to depend on the Athabasca River discharge. The water level difference varied from about 0.15 m for a discharge around 500 m^3/s up to about 0.70 m for a discharge around 2,500 m^3/s. The water level difference at the downstream boundary of the HEC-RAS model was assumed to be proportional to the distance from Jackfish Creek. The equation to determine the water level at Big Egg Lake is as follows (Eqn 2):

$$WL_{BEL} = WL_{AthaJF} + \frac{5.1}{10.7}(0.00029Q_{AthaEM} + 0.01)$$

Where WL_{BEL} = Water level on the Athabasca River at Big Egg Lake (m)
Q_{AthaEM} = Discharge in the Athabasca River at Embarras Airport (m^3/s)
WL_{AthaJF} = Water level on the Athabasca River above Jackfish Creek (m)

The hydraulic model was used to simulate rating curves at Big Egg Lake, using the Equations 1 and 2 to establish the water levels at the downstream boundary. The simulated rating curves at Big Egg Lake for various Lake Athabasca water levels are provided in **Figure 10**. The measured discharge and water level from the site survey compared to the simulated rating curves are within 0.1 m of the simulated rating curve for the corresponding Lake Athabasca water level.



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FEASIBILITY PLAN FOR REMOVABLE CONTROL STRUCTURE IN THE PEACE ATHABASCA DELTA BIG EGG LAKE FEASIBILITY PLAN

SIMULATED RATING CURVES AT BIG EGG LAKE FOR VARIOUS LAKE ATHABASCA LEVELS

FIGURE 10

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4 HYDROTECHNICAL ASSESSMENT OF BIG EGG LAKE

A hydrotechnical assessment of the water level in Big Egg Lake was completed to assess existing conditions and to determine changes to the water level regime with a control structure in place.

4.1 Modelling Approach

A continuous simulation of the water level of Big Egg Lake was conducted over the time that water level data is available at the WSC Station 07DD007, Athabasca River above Jackfish Creek. This provided over 40 years of simulation after the start of regulation of discharge on the Peace River. The model was developed with the following assumptions:

- The water level at Big Egg Lake for each day was determined by increasing the water level at the WSC gauge based on the discharge-slope relationship presented in **Section 3.3**. In 1974, a large gap in the discharge record was filled in by assuming the discharge to be the average daily discharge determined in Section 3.1 and shown in **Figure 7c**. For small gaps in the discharge record, a linear interpolation was used to fill in missing data.

- Flow into and out of Big Egg Lake from the Athabasca River only occurs over the water control structure. This assumption is conservative as the elevation of the landscape along the southern boundary of the lake is of similar elevation and other entry points would be activated during some high water events.

- The peak annual water level in Big Egg Lake in any given year was limited by the peak water level on the Athabasca River and the geometry of the water control structure.

- The discharge across the water control structure was modelled using a standard weir equation and was a function of the water level difference between the Athabasca River and Big Egg Lake each day.

- The minimum water level in Big Egg Lake at the end of the summer (after drawdown) was controlled by the height of the water control structure and the assumed losses due to evaporation.

- Water levels in Big Egg Lake were controlled by flows over the structure. This assumption will increase the drawdown time relative to actual conditions, where according to local knowledge holders, some water will flow out of Big Egg Lake towards Lake Athabasca through connected areas and channels (ACFN, 2019).

- Seepage losses and groundwater flows are negligible into/out of Big Egg Lake. According to Nielsen (1972) Big Egg Lake is a perched basin with negligible groundwater contribution through the natural surrounding levees Local knowledge holders also indicated that flooded areas could retain water for up to 6 years after a large flood (MCFN, 2019). Monitoring of Big Egg Lake water levels is required to quantify seepage rates.

- The CDSM provides a reasonably accurate representation of landscape around Big Egg Lake.

The model was used to simulate conditions for a water control structure with crest elevations of varying from 210.7 m to 211.5 m.

4.2 Big Egg Lake Characteristics

Under current conditions, inflow and outflow from Big Egg Lake into the Athabasca River occurs first through the East Connection Channel along the southern boundary of the lake. The connection channel does not connect directly to the main body of Big Egg Lake but instead to a small wetted area set back about 50 m from the north bank of the river. The minimum elevation of the connection channel was surveyed to be about 210.6 m. When water levels exceed the banks of the wetted area, water flows through the vegetation into Big Egg Lake through a series of poorly defined channels. The top of bank elevation of the wetted area was not surveyed; but, based on photos taken during the survey and comparing it to the surveyed water level in the wetted area, the top of bank elevation was estimated to be 211.0 m. Local knowledge holders indicated that if water flowed into Big Egg Lake via the trenches along the south side of the lake that the water would not flow out through other trenches around the lake (ACFN, 2019). This suggests that the East Connection Channel is the lowest sill elevation around the lake. Outflow also occurs from the lake for higher water level elevations towards the east through a vegetated area. The CDSM suggests that the spill elevation for the eastward flow is about 211.8 m (**Figure 15**). Local knowledge holders indicate that water that flows out of Big Egg Lake to the east generally flows towards Sucker Lake and back into the Goose Island Channel (ACFN, 2019) (**Figure 1**).

Big Egg Lake is generally broken up into a north and south portions which are of similar area. The elevation-area-volume relationship was determine for the lake from the CDSM elevation data (**Table 5**). The minimum elevation of the lake based in the CDSM is 209.1 m. Based on this elevation, the water elevation required to achieve a depth of 8 ft (2.44 m) to improve muskrat habitat (AFCN 2019) is about 211.5 m. As well, being able to retain high water levels for several years could result in killing off the increased willow and other plant growth that has developed during drier seasons (ACFN, 2019). The north and south portions of the lake are divided by high ground through the middle of the lake with an elevation of about 210.1 m. Since the elevation-area-volume relationship was utilized to simulate the water levels at the connecting channel along the southern edge of the lake, it was assumed the southern portion of the lake was separate from the north portion and would fill first.

Table 5 Relationship between Water Elevation, Surface Area, and Volume of Big Egg Lake

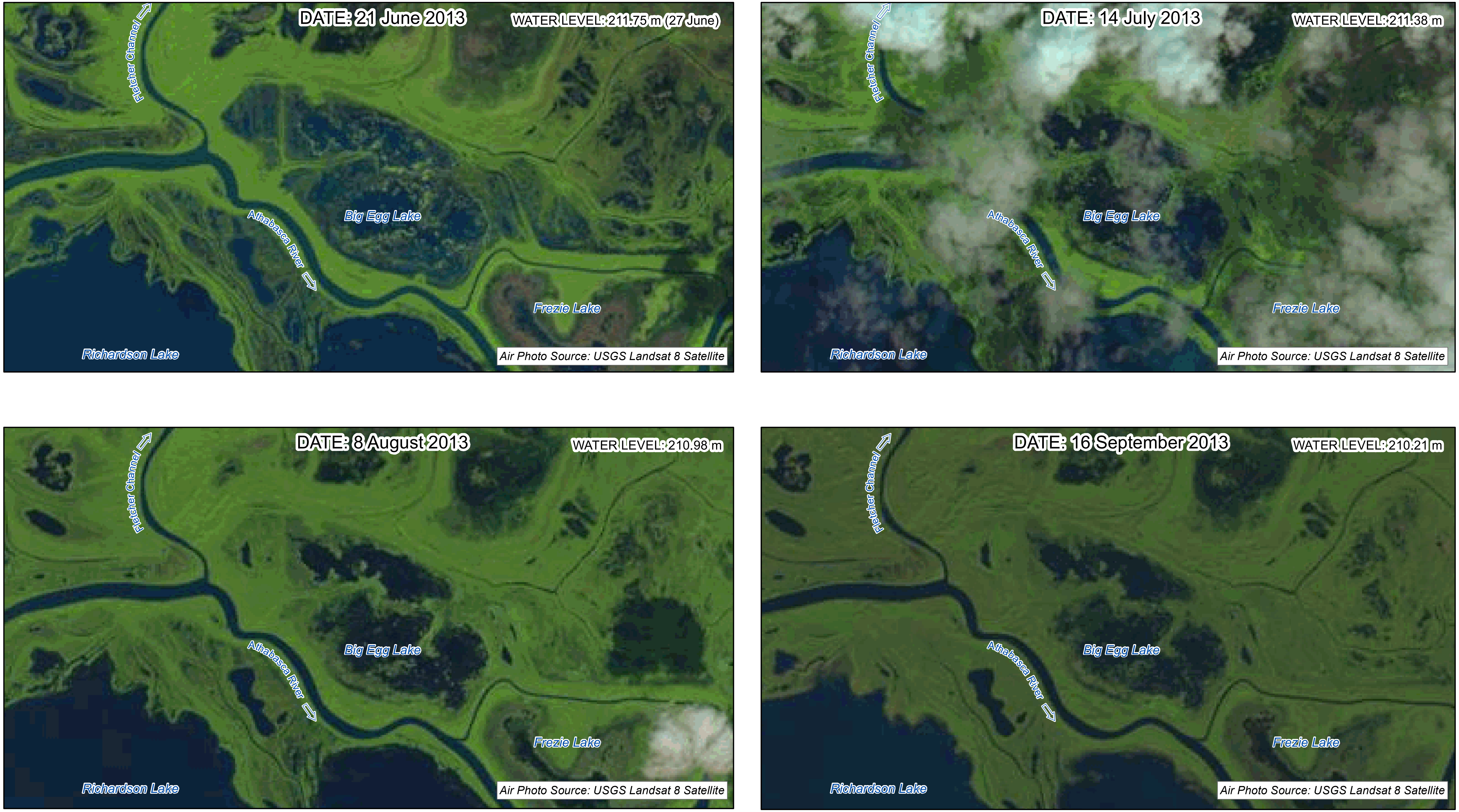
Water Elevation (m)	Surface Area (ha)	Volume (1,000 m^3)	Max Depth (m)
209.2	105	104	0.1
209.4	110	320	0.3
209.6	113	543	0.5
209.8	119	773	0.7
210.0	129	1,020	0.9
210.2	371	2,960	1.1
210.4	467	3,790	1.3
210.6	560	4,790	1.5
210.8	620	5,940	1.7
211.0	712	7,270	1.9
211.2	830	8,940	2.1
211.4	876	10,600	2.3
211.6	912	12,400	2.5

An assessment of the satellite imagery from 2013, 2014, 2017, and 2018 was undertaken to attempt to determine how the inundation extents of Big Egg Lake varies throughout the year. Images from 2013, 2014, 2017, and 2018 are compared in **Figure 11**, **Figure 12**, **Figure 13**, and **Figure 14**, respectively. The maximum water level on the Athabasca River above Jackfish Creek (**Table 4**) was relatively high in each of the years with satellite imagery.

The satellite imagery in 2013 and 2014 suggests that the extents of the water level is highest in June and decreases throughout the summer. Due to the low resolution of the satellite imagery, it is difficult to discern between the water's edge and the growth of vegetation that occurs along the fringe of the lake throughout the summer. The quality of the satellite imagery is much higher in 2017 and 2018. The extent of water is similar throughout the year in both 2017 and 2018. The only discernable difference occurs around the East Connection Channel in 2017. In June, the extent of the water is connected to wetted portion of the East Connection Channel and the extent of water moves away from the East Connection Channel throughout the summer. No concrete conclusions regarding the variation in the water level of Big Egg Lake throughout the year was made from the analysis of the satellite imagery.

4.3 Precipitation and Evaporation

Precipitation and evaporation have minimal effect on the water levels of Big Egg Lake. Therefore, precipitation and evaporation was simulated using regional averages as opposed to daily measurements. In general, drawdown of the lake is expected each year as evaporation from the lake exceeds the annual precipitation on average. An annual water deficit of 80 mm/year was used to estimate average precipitation and evaporation in the simulation of the lake water balance (Golder, 2012).



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Water level recorded at WSC Station 07DD007 (Athabasca River above Jackfish Creek)

SCALE 1:60,000

0 300 600 1,200 1,800 2,400 3,000 m

N

Coordinate System: NAD 1983 UTM ZONE 12N
Units: Metres

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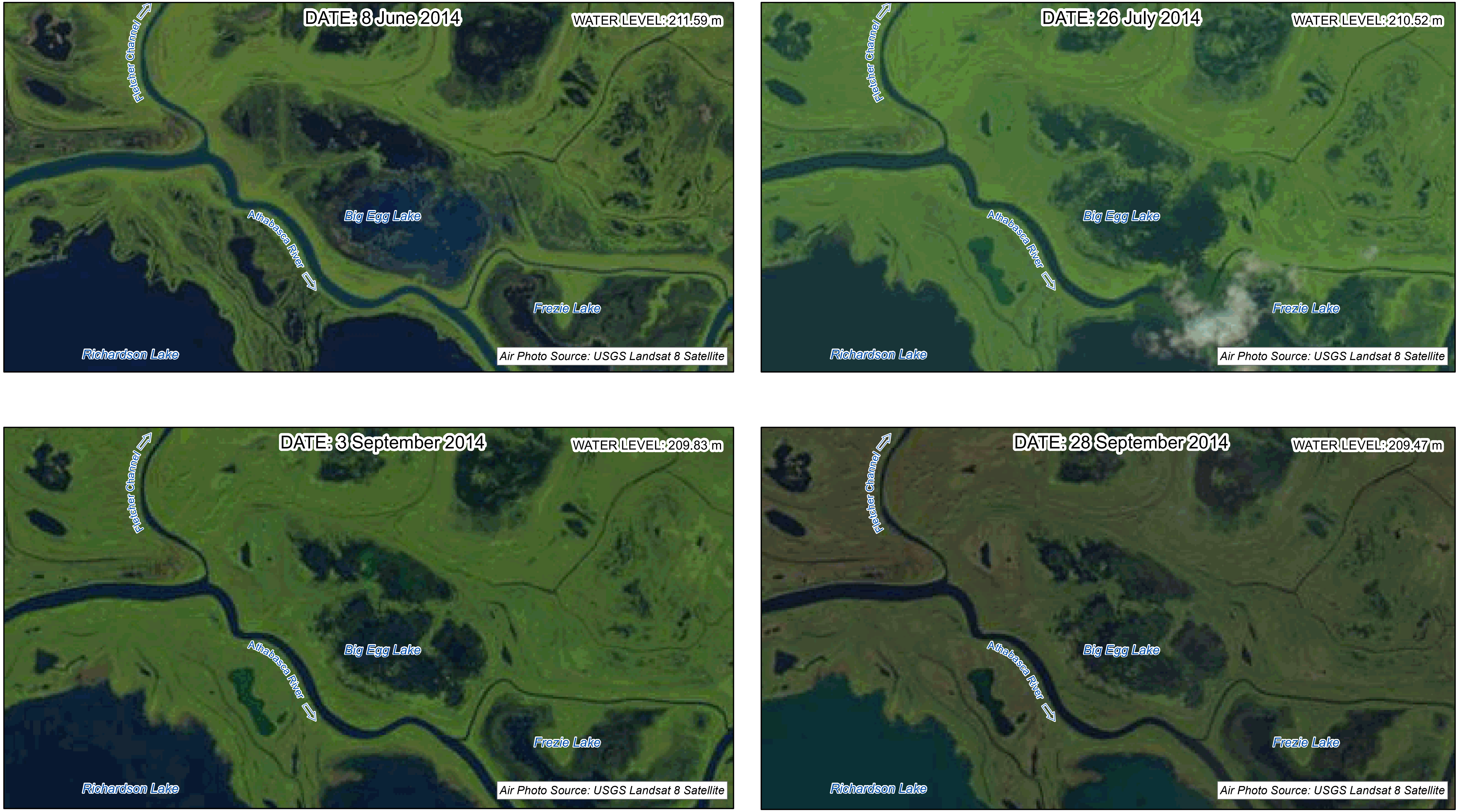
FEASIBILITY PLAN FOR REMOVABLE CONTROL STRUCTURES IN THE PEACE-ATHABASCA DELTA

2013 BIG EGG LAKE HISTORICAL AIR PHOTO ANALYSIS

FIGURE 11

REH, Path: P:_Projects (Active)\1005092 PAD Weir Surveys\90 GIS\Figure 11_Air_Photo_Anlaysis_2013_JPM.mxd



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Water level recorded at WSC Station 07DD007 (Athabasca River above Jackfish Creek)

SCALE 1:60,000

0 300 600 1,200 1,800 2,400 3,000 m

N

Coordinate System: NAD 1983 UTM ZONE 12N
Units: Metres

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FEASIBILITY PLAN FOR REMOVABLE CONTROL STRUCTURES IN THE PEACE-ATHABASCA DELTA

2014 BIG EGG LAKE HISTORICAL AIR PHOTO ANALYSIS

FIGURE 12

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Water level recorded at WSC Station 07DD007 (Athabasca River above Jackfish Creek)

SCALE 1:4,700

0 100 200 m

N

Coordinate System: NAD 1983 UTM ZONE 12N
Units: Metres

Job: 1005092 | 27-FEB-2020

FEASIBILITY PLAN FOR
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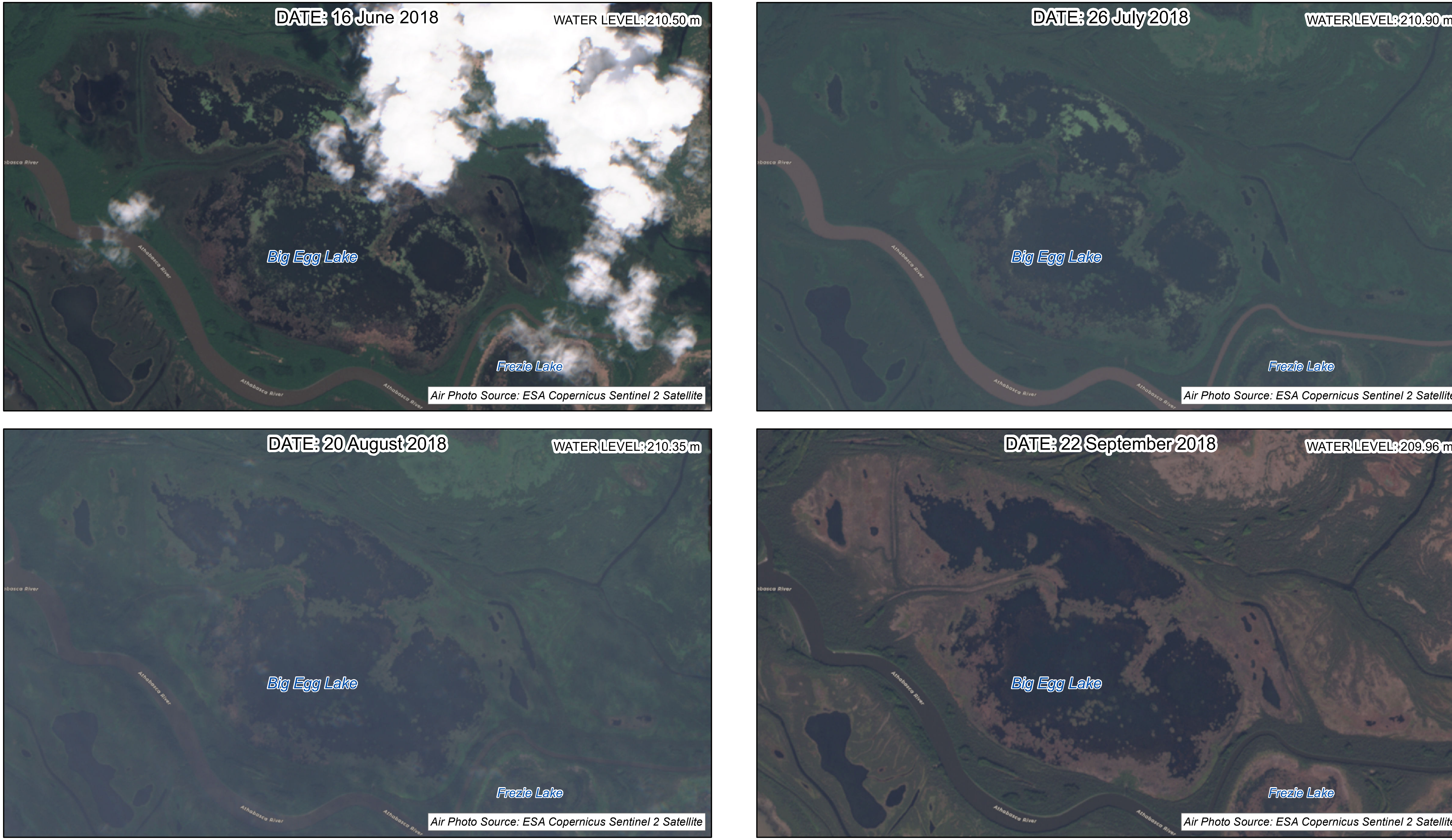
IN THE PEACE-ATHABASCA DELTA

2017 BIG EGG LAKE
HISTORICAL AIR PHOTO ANALYSIS

FIGURE 13

REH, Path: P:_Projects (Active)\1005092 PAD Weir Surveys\90 GIS\Figure 13_Air_Photo_Analysis_2017_JPM.mxd



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Water level recorded at WSC Station 07DD007 (Athabasca River above Jackfish Creek)

SCALE 1:4,700

0 100 200 m

N

Coordinate System: NAD 1983 UTM ZONE 12N
Units: Metres

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FEASIBILITY PLAN FOR
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IN THE PEACE-ATHABASCA DELTA

2018 BIG EGG LAKE
HISTORICAL AIR PHOTO ANALYSIS

FIGURE 14

REH, Path: P:_Projects (Active)\1005092 PAD Weir Surveys\90 GIS\Figure 14_Air_Photo_Anlaysis_2018_JPM.mxd

4.4 Existing Inflow and Outflow

The calculated water level at Big Egg Lake was compared to the top of bank elevation of the wetted area to determine how often water flowed from the Athabasca River into the lake under current conditions. For 22 of the 43 years of simulation, the top of bank elevation was not exceeded, which is 51% of the years simulated. The average maximum annual water level was 211.4 m which is only 0.1 m below the top of bank elevation of the wetted area along the East Connection Channel. The longest duration of overtopping was 81 days in 1997 and 66 days in 1996 which were both outliers in relation to the current conditions. The median duration of overtopping was 8 days. It is important to also look at successive years without overtopping as inundation of a perched lake can result in the water level being high for numerous seasons. The longest time between overtopping events was seven years between 1998 and 2004. The average time between overtopping events was just over two years.

4.5 Lake Water Level Analysis

A comparison of the variation in frequency and duration of flooding for different sill elevations was assessed over 1971 to 2016. The results are summarized in **Table 6**.

Table 6 Overtopping Frequency for Various Sill Elevations

Sill Elevation (m)	Years without overtopping	Median duration of overtopping (days)	Average time between overtopping events (year)	Average/Maximum Withdrawal Discharge (m^3/s)
211.5	22	8	2.4	0.8/1.8
211.4	22	11	2.4	1.0/2.1
211.3	18	16	2.0	1.0/2.8
211.2	17	23	1.9	1.1/3.2
211.1	15	33	1.7	1.2/3.5
211.0	8	26	1.1	1.1/3.3
210.9	6	34	1.1	1.3/3.2
210.8	3	38	1	1.3/3.6
210.7	2	48	1	1.5/4.1

A comparison of the different sill elevations shows that the frequency of overtopping increases steadily with lower sill elevations until a sill elevation of about 211.0 m. For sill elevations lower than 211.0 m, the increase in frequency is minimal when compared to the higher sill elevations. The duration over which the sill elevation is exceeded each year also increases with lower sill elevations until a sill elevation of about 211.0 m. The analysis also showed that withdrawal discharge is less than 5 m^3/s for all of the sill elevations. The discharge on the Athabasca River at Big Egg Lake between May and the end of August is generally between 700 m^3/s and 1000 m^3/s. The withdrawal into Big Egg Lake represents less than 1% of the total flow so the withdrawal of water into Big Egg Lake will not affect water levels downstream of the control structure.

Inundation extents for key water levels is compared in the **Figure 15**. The key water levels are:

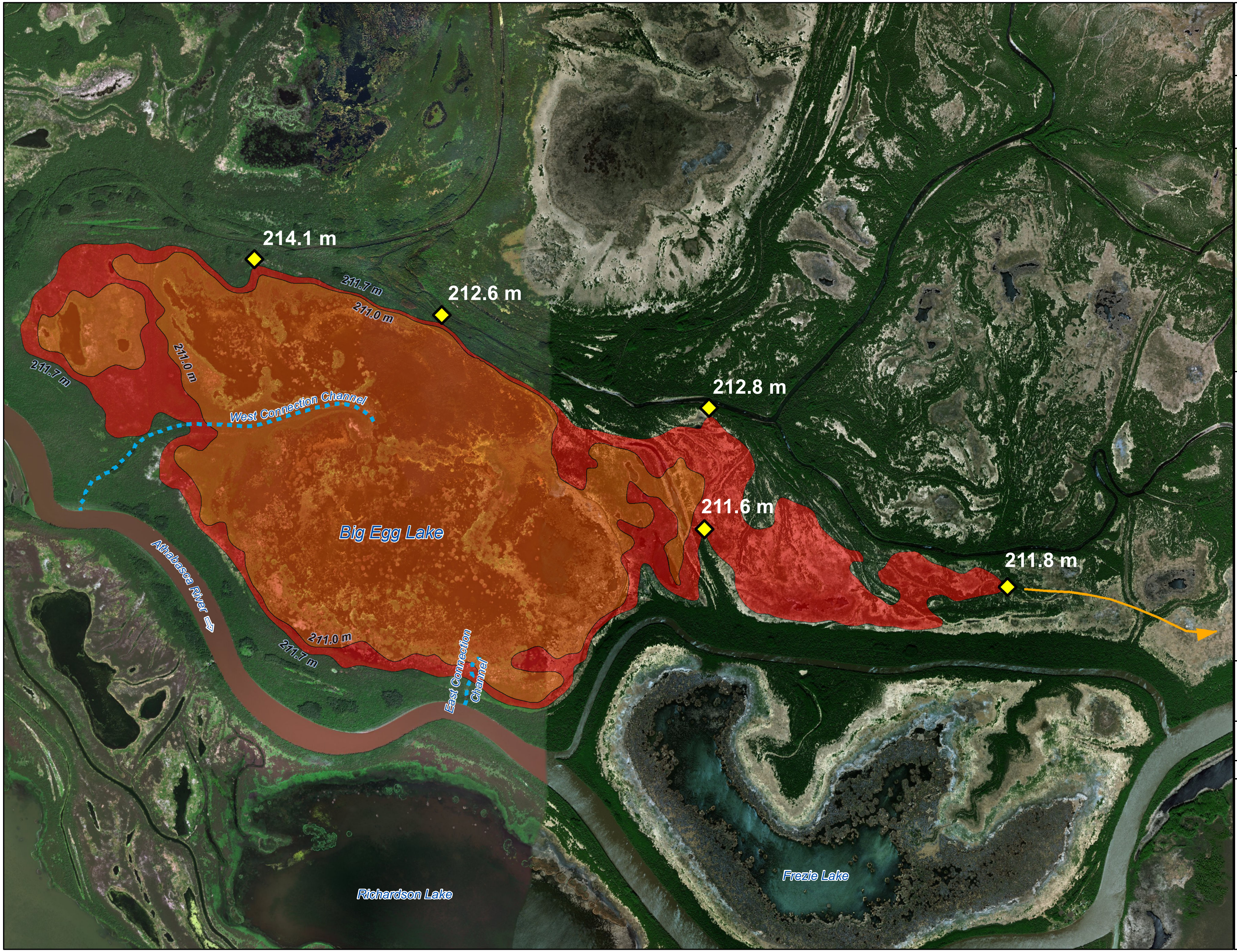
- 211.7 m – The maximum inundation extents based on the CDSM before water spills towards the east;
- 211.0 m – The estimated current sill elevation

4.6 Sill Elevation

Two criteria were selected to define the sill elevation.

Frequency Criteria – To maximize the frequency of recharge the sill elevation should be set at 211.0 m. For the water level and discharge conditions that occurred between 1971 and 2016, this would result in recharge of the lake four out of every five years. A sill elevation of 211.0 m is similar to the estimated sill elevation of the existing East Connection Channel. A sill elevation of 211.0 m would produce a water level of about 1.9 m in Big Egg Lake. The benefit of establishing the sill elevation using the control structure in comparison to the natural sill is that the sill elevation can be adjusted to change the frequency of flooding. Furthermore, the existing sill elevation may change with further erosion or sedimentation, so a structure would provide better control of the selected sill elevation.

Depth Criteria – The recommended depth of water based on information provided by local knowledge holders is 8 ft (2.4 m) which requires a sill elevation of 211.5 m. For the water level and discharge conditions that occurred between 1971 and 2016, this would result in recharge of the lake every two to three years.



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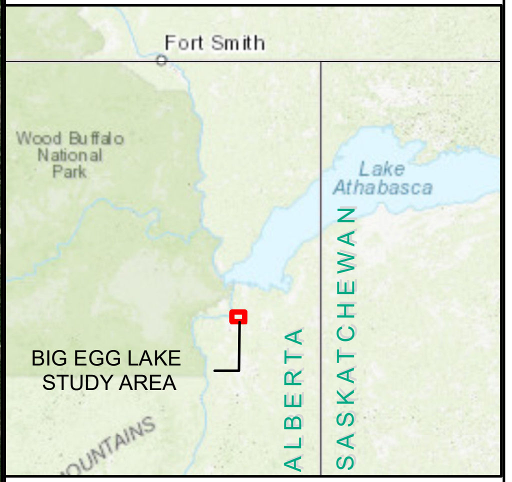


211.7 m
211.0 m
Approximate Elevations Shown
Eastward Flow
Connection Channel

Data Sources: Basemap - Altalis Ltd. & Esri World Imagery; Inset map - National Geographic World Map.

SCALE - 1:26,000
0 200 400 800 M
N

Coordinate System: NAD 1983 CSRS UTM ZONE 12N
Units: Metres

Job: 1005092 | *Date: 09-MAR-2020*

FEASIBILITY PLAN FOR REMOVABLE CONTROL STRUCTURES IN THE PEACE-ATHABASCA DELTA

COMPARISON OF BIG EGG LAKE INUNDATION EXTENTS FOR KEY ELEVATIONS

FIGURE 15

REH, P:_Projects (Active)\1005092 PAD Weir Surveys\90 GIS\Figure 15_BigEggLake_MaxInundation_JPM.mxd

5 ALTERNATIVE EVALUATION

Numerous alternatives were considered for the water control structure for Big Egg Lake. The following section discusses the structure alternatives that were considered, the criteria used to compare the alternatives, and the preferred alternative for Big Egg Lake.

5.1 Structure Alternatives

The feasibility of several types of water control structures were evaluated for Big Egg Lake. These included both removable temporary structures and more permanent structures. A summary of the alternatives considered is provided below.

AquaDam

An AquaDam is a temporary water-filled barrier which can control and divert water. It consists of two flexible watertight inner tubes, side by side, contained within a woven outer sleeve. The inner tubes are filled with water, giving form to the AquaDam, and creating a temporary, highly-effective water barrier. (AquaDam, 2020)

These structures are frequently used to dewater instream construction areas or may be deployed as temporary dikes to protect buildings in flood prone areas.

Geotubes

Geotubes consist of a permeable geotextile membrane filled with a slurry of sediment-laden water. The solid contents of the tube are retained and consolidated to form a contained barrier that can serve as a temporary dike in certain applications.

Excavation is required to remove the geotube bags and their contents when no longer needed.

Portadam

Portadams are portable cofferdams consisting of a metal frame supporting a water-tight barrier. This type of structure is widely used for temporary flood protection and construction site dewatering applications.

This option has a height limitation of approximately 3 m and is intended to have water on only one side.

Cofferdam

Traditional cofferdams consist of either an earth fill or steel enclosure built within a waterbody. These are typically used to isolate and dewater an instream construction site.

Rockfill/Earth Embankment

A rockfill or earth embankment is similar to a cofferdam; however, it does not provide a complete enclosure and may span a river channel to completely or partially block the flow of water.

Embankments are often used as one component of a water control structure, such as the bypass channel embankment shown here at the Riviere des Rochers boat passage tramway.

Rubber Dam

A rubber dam acts as an adjustable weir. The rubber bladder is anchored to a concrete foundation and inflated with water or air, depending on site conditions and design considerations.

The crest height of the rubber dam is typically controlled automatically based on established operating rules. Mechanical and electrical components are required to inflate and deflate the rubber dam. When completely deflated, the bladder rests on the base of the structure.

Stop Logs

A stop log structure is effectively a variable height flood gate that is manually operated by installing or removing timber beams in a series of slots. The process of adding and removing the beams may be mechanically-assisted by a hoist. Upstream water levels can be controlled by adding or removing stop logs.

Stop logs are commonly used in combination with other types of water control structures to isolate components, such as gates, so that maintenance can be performed.

Gated Sluiceway

Sluice gates are used to control the release of water from a reservoir and are commonly used in irrigation works and dams. A sluiceway typically provides several gates that can be operated independently and in parallel. Operation of the gates can be manual or automated. These types of structures are highly robust and capable of withstanding debris and ice impact forces.

5.2 Assessment Criteria and Results

A range of criteria was developed to assess the selected structure alternatives for the range of expected operating conditions. The criteria generally assessed the difficulty of installation and operation at the proposed site, the cost and availability of required materials, and the effectiveness at achieving water level targets. The assessment criteria and results for each structure alternative are provided in **Table 7**.

5.3 Recommended Option

A recommended structure alternative was selected based on the assessment criteria and results presented in **Table 7**. Based on the assessment criteria, the structure alternatives most likely to effectively increase the frequency of flooding of Big Egg Lake were stop logs and a gated sluiceway. It was important that the recommended structure alternative be able to withstand impacts from debris (observed in the East Connection Channel during the site survey) and ice rubble that could move towards the structure during high water events. Both stop logs and a gated sluiceway would be resistant to impacts from debris and ice in the East Connection Channel. Both alternatives were preferred over the others because they were generally quite sturdy, were resistant to both ice and debris impacts, and relatively easy to operate and maintain. Stop logs are recommended over the gated sluiceway due to the lower installation and maintenance costs.

Table 7 **Assessment Criteria to Evaluate the Water Level Control Structure at Big Egg Lake**

Assessment Criteria / Considerations	Type of Structure								
	Aquadam	Geotubes	Portadam	Cofferdam	Rubber Dam	Stop logs	Rockfill/Earth Embankment	Gated Sluiceway	Remarks
Installation/removal frequency	Annual	1-5 years	Annual	1-5 years	> 10 years	1-5 years	Semi-Permanent	Semi-Permanent	Geotubes may be left in place over winter but materials will degrade over time.
Length of service (life of materials)	10 years	5 years	25 years	> 10-years	25 years	> 20 years	> 50 years	> 30 years	Length of service for temporary structres will vary depending on care and maintenance.
Availability of materials	Regional Suppliers	Regional Suppliers	Rental only	Suppliers/ Contractors	Regional Suppliers	Part local	Part Local	Custom Built	All options can be sourced. Portadams appear to be supplied on a rental basis only.
Suitable for span and height required	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	All possible structures are feasible for the connecting channel
Relative ease of installation	Simple	Simple	Moderate	Moderate	Moderate	Simple	Moderate	Complex	Based on type of equipment and skills necessary to install the structure.
Relative ease of removal	Simple	Simple	Simple	Moderate	Moderate	Simple	Moderate	Complex	Based on type of equipment and skills necessary to remove the structure.
Can be installed and removed at appropriate times	Yes	Maybe	Yes	Maybe	Yes	Yes	Yes	Yes	May not be feasible to remove Geotubes during highwater to drawdown the lakes.
Relative supply and install cost	Low	Low	Moderate	Moderate	High	Low	Moderate	High	Rubber dams require mechanical and electrical components.
Relative operation and maintenance cost	Moderate	Moderate	Moderate	Moderate	High	Low	Low	Moderate	Options that require annual installation and removal will cost more over time.
Adjustable flow control during season	No	No	No	No	Yes	Yes	No	Yes	Ability to adjust outflows through season may be important to mitigate negative impacts.
Resistance to debris impacts	No	No	No	Yes	Somewhat	Yes	Yes	Yes	Site visit showed that woody debris will be pushed into the connecting channel
Resistance to ice forces	No	No	No	Yes	Yes	Yes	Yes	Yes	Ice forces will be generated in connecting channel as ice is pushed into the channel during breakup
Allows Sediment into Lake	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	All options will allow and retain sediment in the lake; maintenance of connecting channel will be required
Overall feasibility (Will it achieve objectives?)	Likely	Likely	Very unlikely	Likely	Likely	Very Likely	Likely	Very Likely	Stop logs are recommended over Gated Sluiceway due to low install and maintenance costs

6 FEASIBILITY LEVEL DESIGN

A feasibility level design of a stop log structure was developed to inform a decision on whether to proceed with funding detail design and construction. The design includes the general arrangement of the structure, the recommended sill levels, operation and maintenance considerations, and construction cost estimates.

6.1 General Arrangement

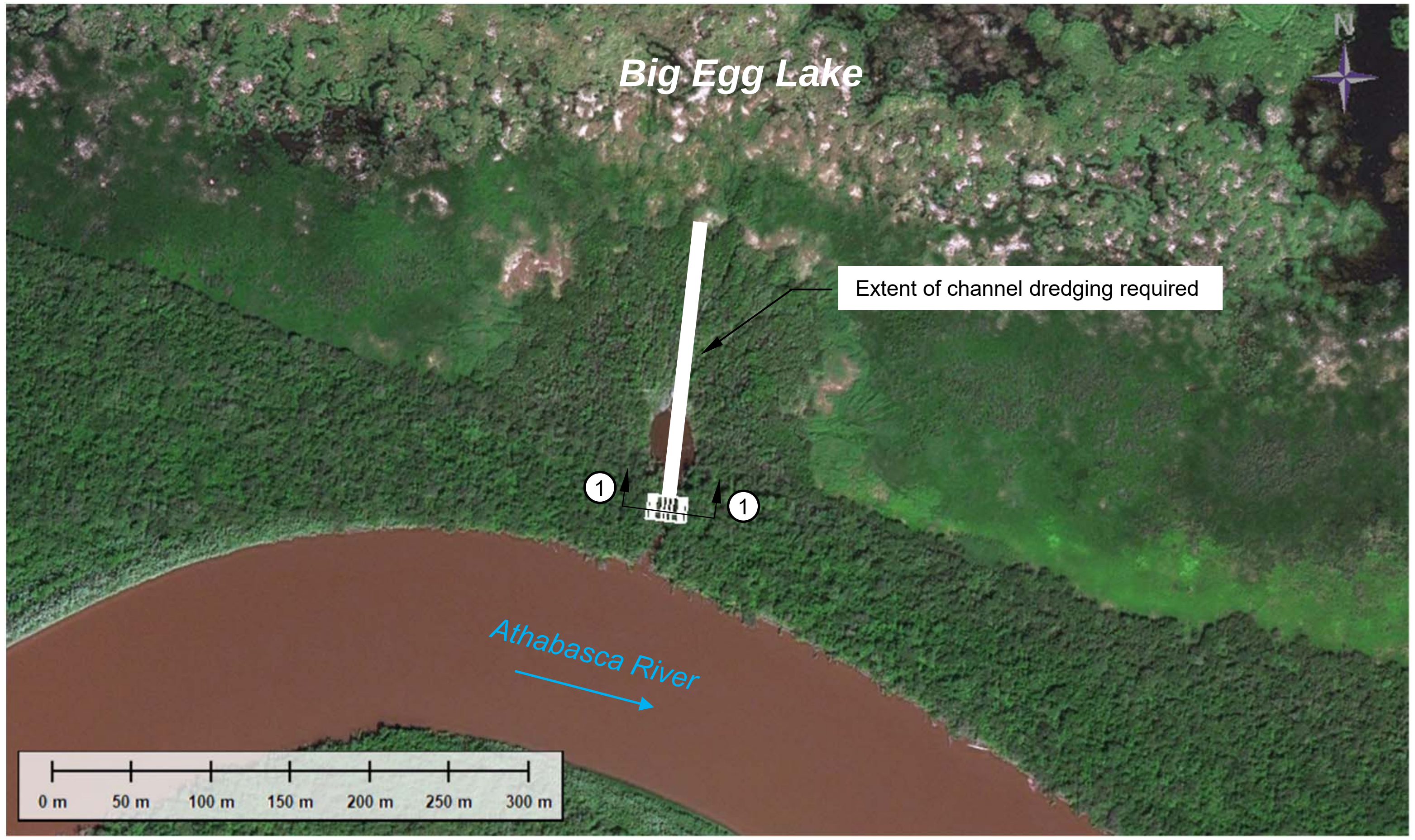
The plan and general arrangement of the structure is shown in **Figure 16**. The structure will be set back 50 m from the bank of the Athabasca River near the point where the existing wetted area opens up. The structure will consist of three bays in which stop logs will be inserted to set the sill elevation. The width of the structure was selected to fit within the existing width of the connecting channel. The bays will be flanked on either side by steel sheet pile walls. Sheet pile walls consist of sheets of steel that interlock together that are driven into the ground with a piledriver. Safety berms will be built up on either side of the structure above the natural bank elevation and extend away from the structure on both sides to divert high water levels away from the structure. A sheet pile wall should also be installed under the stop logs flush with the channel bed to minimize seepage underneath the structure. Class I riprap should line the channel and the banks on both sides of the structure to prevent erosion. The riprap lined channel will extend into the existing wetted area. A walkway will pass above the structure between the two safety berms to facilitate installation and removal of the stop logs. A description of the different parts of the structure and key dimensions are summarized in **Table 8**. A channel will need to be excavated to connect flow from the stop log structure to the main body of Big Egg Lake. The dimensions of the connection channel are also summarized in **Table 8**.

Table 8 Description of Various Aspects of the Water Control Structure

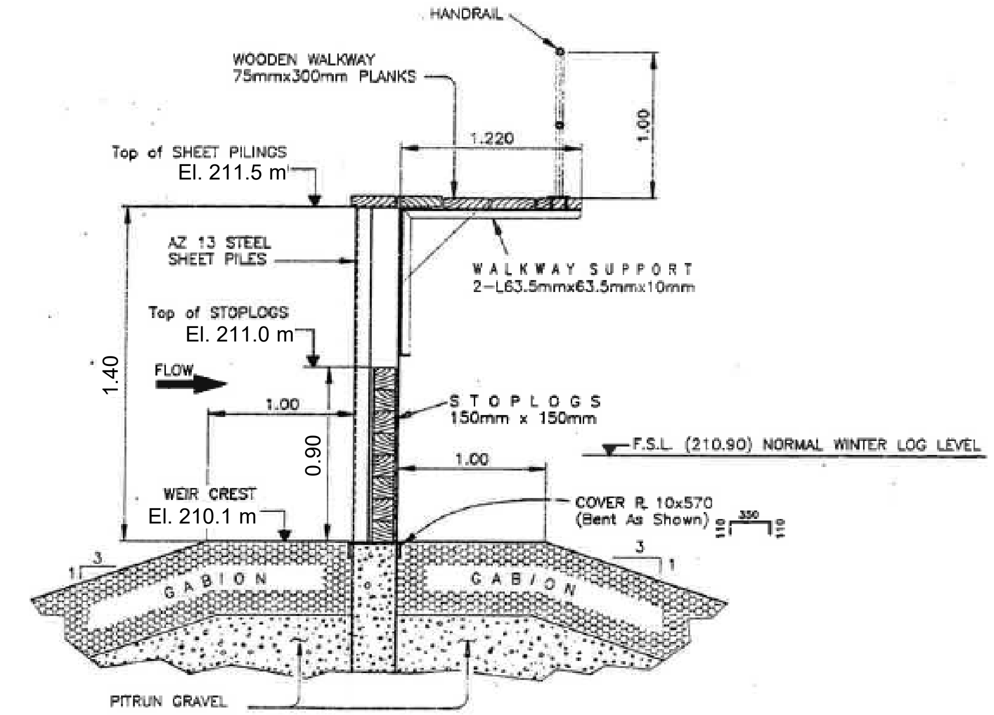
Design Feature	Description
Stop Logs	• The stop logs will have the dimensions of 2,000 mm long by 150 mm deep by 150 mm tall. • The number of stop logs required depends on the criteria selected for the sill elevation. A total of 18 stop logs will be required to raise the sill elevation up to an elevation of 211.0 m. To achieve the higher sill elevation of about 211.5 m, 9 additional stop logs will be required. It is recommended that additional stops logs be stored at the site to further adjust the sill elevation to optimize operating of the structure. • Lifting hooks will be installed in the top of the logs to facilitate installation and removal with two people

Table 8 Description of Various Aspects of the Water Control Structure (continued)

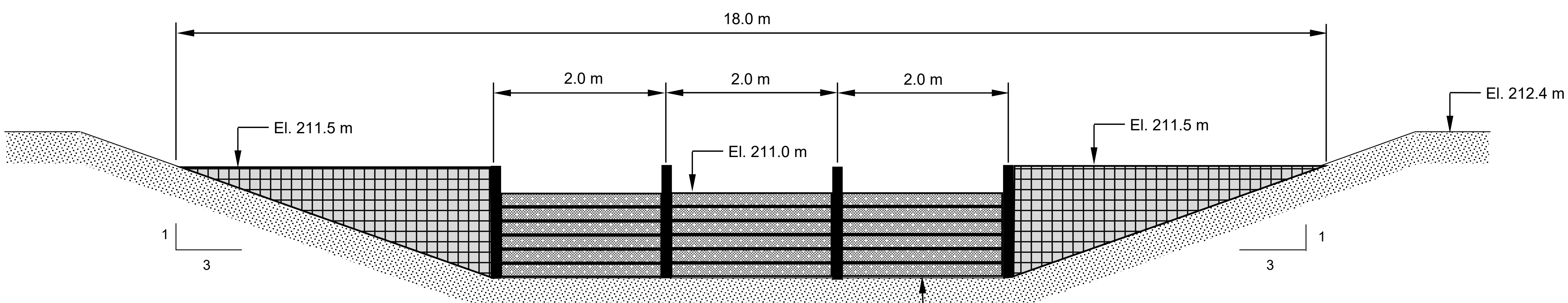
Design Feature	Description
Safety Berm	• The safety berm should have a top elevation of 212.4 m which provides 0.3 m freeboard above the 1997 peak water level at the WSC gauge above Jackfish Creek. • The safety berm should extend 5.0 m towards the Athabasca River and 10.0 m towards Big Egg Lake to direct high water levels away from the structure
Sheet Pile Wall	• The top of the sheet pile wall will vary within the bays and adjacent to the bays. Within the bays, the top of the sheet pile wall will be 210.1 m, flush with the existing channel, to facilitate draw down of the lake if required. Adjacent to bays, the top of the sheet pile will be 212.4 m. • The sheet pile walls should extend at least 1 m into the safety berm to minimize seepage around the structure. • If possible, the sheet piles should be installed to refusal depth. A borehole analyses is recommended during detailed design of the structure to refine the required depth of the sheet pile wall.
Stop Log Structure Channel	• The channel should have a bottom width of 6.0 m and 3H:1V side slopes rising up to the top of the safety berms at an elevation of 212.4 m. • The elevation of the bottom of the channel should be similar to the existing connection channel which is nominally 210.1 m. The bottom and the sides of the channel should be lined with Class I riprap (D_{50} = 300 mm) with a thickness of 0.5 m. The riprap should extend a distance of 5.0 m towards the Athabasca River and 10.0 m towards Big Egg Lake.
Connection Channel	• The connection channel will be about 300 m in length and should have a bottom elevation of 210.3 m or less to ensure that flow in the channel does not effect the performance of the weir. The channel should have a minimum slope of 0.00030 m/m. It is recommended that the channel have a bottom width of 6.0 m and 2H:1V side slopes rising up to the top of bank elevation. • It is recommended that further refinement of the bottom elevation, slope, and dimensions of the connection channel be undertaken during detailed design to assess flow velocities in the channel and the potential for sedimentation and shifting of the channel alignment. • The top of bank elevation of the connection channel should be built at least 0.3 m above the existing ground to contain flow within the channel and reduce sedimentation.



PLAN VIEW



CENTRE LINE SECTION DETAIL
(NOTE 1)



SECTION 1

CONCEPTUAL – NOT FOR CONSTRUCTION

Notes:

1. ADAPTED FROM BIG EGG LAKE CONTROL STRUCTURE REPORT (ALBERTA ENVIRONMENTAL PROTECTION, 1994)

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NOT TO SCALE

Coordinate System:
Units: As Shown

Job: 1005166

Date: 13-JAN-2020

FEASIBILITY PLAN FOR REMOVABLE CONTROL STRUCTURE IN THE PEACE ATHABASCA DELTA BIG EGG LAKE FEASIBILITY PLAN

PLAN AND GENERAL ARRANGEMENT FOR STOP LOG STRUCTURE

FIGURE 16

6.2 Operation and Maintenance

Maintenance will be required periodically on the structure and the channel to ensure effective and long term operation of the structure. The main maintenance activity required is removal of deposited sediment around structure and in the length of constructed channel on either side of the structure. Deposition along the base of the stop logs as well as in the channel between the structure and Big Egg Lake will have the largest effect on the operation of the structure. It is expected that sediment deposition at the exit of the channel into Big Egg Lake may also form a delta in Big Egg Lake. Removal of vegetation in the vicinity of the structure will also be required to reduce seepage through the structure and safety berm.

An operational consideration that may need to be considered is the possibility of the channel between the banks of the Athabasca River and the control structure filling with rubble ice during river ice breakup in the spring. This could potentially result in a reduction of the discharge passing over the control structure limiting the filling of Big Egg Lake. A possibility to prevent ice rubble from entering the channel would be to install several bollards across the opening of the channel in order to prevent large pieces of ice rubble from entering the channel. Further analysis should be undertaken during detailed design of the structure.

6.3 Estimated Construction Costs

The estimated construction costs for the stop log structure is provided in **Table 9**. It is assumed that site preparation, hauling of materials, and construction of the structure can be undertaken during the winter when the East Connection Channel will likely be dry.

Table 9 Estimated construction cost for Big Egg Lake Structure

Item	Estimated Quantity	Unit Price	Total
Mobilization	Lump sum	$55,000	$55,000
Care of Water	Lump sum	$30,000	$30,000
Clearing	Lump sum	$5,000	$5,000
Excavation and Backfill	4000 m^3	$8.00	$32,000
Rock Riprap	500 m^3	$125	$62,500
Steel Sheet Pilings	250 m^3	$420	$105,000
Stop logs	30 units	$110	$3,300
Miscellaneous Items	Lump sum	$20,000	$20,000
Detailed Engineering Design	Lump sum	$50,000	$50,000
Construction Supervision	Lump sum	$20,000	$20,000
Environmental Permitting and Monitoring	Lump sum	$25,000	$25,000
Contingency (15%)	Lump sum	$61,170	$61,200
		Total Construction Cost	**$469,000**

7 SUMMARY AND CONCLUSIONS

The data collected from the site survey and the hydrometric data from WSC gauging stations was analysed to develop stage-discharge rating curve relationships at the proposed Big Egg Lake site. The stage-discharge relationship depends on both the water level of Lake Athabasca and the discharge on the Athabasca River. Additional uncertainty in the rating curve relationship results from water level variation on Lake Athabasca due to wind affects.

The developed rating curve relationships were used to determine how often water flows from the Athabasca River into Big Egg Lake for the current estimated natural sill elevation of 211.0 m. The current sill elevation for the East Connection Channel was exceeded about 80% of the time based on the Athabasca River discharge and Lake Athabasca water level between 1971 and 2016. An assessment of satellite imagery from June to September in several years was conducted to determine how the inundation extent of Big Egg Lake varied throughout the year. No concrete conclusion could be determined from the analysis of the satellite imagery.

Depth and frequency criteria were developed to determine a sill elevation for the control structure. Assuming that the elevation data in the CDSM is accurate for the bottom elevation of Big Egg Lake, a sill elevation of about 211.5 m was recommended to achieve a depth of 8 ft. If it is more important to maximize the frequency of inundation, then a sill elevation of 211.0 m should be adopted. The recommended control structure consists of stop logs in conjunction with a sheet pile wall. Stop logs were selected due to the relative simplicity of installation and removal along with a low operation and maintenance cost.

A feasibility level design of a stop log structure was developed to inform a decision on whether to proceed with funding detail design and construction. The structure would be comprised of three 2000 mm wide stop log structure bays in between sheet pile walls up to an elevation of 211.5 m. A safety berm along both sides of the structure with a crest elevation of 212.4 m will prevent high water levels from damaging the structure. A channel will need to be excavated with a length of about 300 m connecting the structure to the southern boundary of Big Egg Lake. The channel should have a bottom elevation at least as low as the sill elevation of the stop log structure and have a bottom width of 6.0 m. The top of bank of the connection channel should rise 0.3 m above the elevation of the natural ground to prioritize flow in the channel and reduce sediment accumulation. The construction cost estimate for the structure is $446,200.

The simulation of water level on Big Egg Lake for various sill elevations showed the importance of accurate elevation data around the lake on flows into and out of the lake. The CDSM utilized for the study is of poor resolution and does not necessarily capture the minimum elevation along the perimeter of Big Egg Lake. It is recommended that high resolution LiDAR be obtained for the lake and surrounding landscape to ensure that the potential water levels determined in this analysis are actually achievable. The wetted portion of the lake should also be surveyed to better understand how the depth varies throughout the lake.

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Appendix A
Study Terms of Reference

Public Services and Procurement Canada | Services publics et Approvisionnement Canada

Canada

Respect • Integrity • Excellence • Leadership

Serving GOVERNMENT, Serving CANADIANS.

Terms of Reference
For
Feasibility Plan for Removable Control Structures in the Peace-Athabasca Delta

R.106569.001

Prepared by

Public Services and Procurement Canada

Western Region

September 2019

Amendment #1

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Glossary of Terms

ECCC	Environment and Climate Change Canada
PAD	Peace-Athabasca Delta
PADIC	Peace-Athabasca Delta Implementation Committee
PADTS	Peace-Athabasca Delta Technical Studies
PADPG	Peace-Athabasca Delta Project Group
PFRA	Prairie Farm Rehabilitation Administration
PSPC	Public Services and Procurement Canada
WBNP	Wood Buffalo National Park
WHC	World Heritage Committee
EFH	Environmental Flows and Hydrology
ACFN	Athabasca Chipewyan First Nation
MCFN	Mikisew Cree First Nation
FCML125	Fort Chipewyan Metis Local 125

Definitions:

The term ‘temporary control structures’ means that the hydraulic control structures are non-permanent, such that they can be removed and preferably re-installed.

The Task Team is composed of representatives from three local Indigenous communities (ACFN, FCML125, and MCFN), and federal government departments including Parks Canada and ECCC with local and technical knowledge of the area that will guide and inform this work.

Amendment 1 – September 2019

As part of **Section 4.2 – Engagement with, and involvement of, local Indigenous communities**, the Consultant will provide catering for the Open Houses on September 18 & 19 and the three Indigenous Knowledge Sessions on September 17, 18 and 19, 2019. The Consultant proposal from August 2019 included catering services for these sessions. Due to the requests by the local Indigenous communities, dinner (e.g., bannock and stew) with refreshments is now being provided during the Open House on September 18, 2019 and a larger than initially estimated number of persons are now attending (from 60 to 100 persons), and will increase the catering budget. Catering for the second Open House on September 19th and the three Indigenous Knowledge Sessions will serve refreshments and light snacks.

Additional work is also required under Section 4.2 to complete the development and revision of the Knowledge Sharing agreements with the three Indigenous communities (Athabasca Chipewyan First Nation, Mikisew Cree Frist Nation and Fort Chipewyan Metis) and project administration for material/poster production and revisions.

For the Indigenous Knowledge Sessions under Section 4.2.3, an increase in budget is required as additional land users and Elders are expected at the Mikisew Creen First Nation session and increased sub-contract rate for the Athabasca Chipewyan First Nation session.

- MCFN knowledge gathering session- expecting to have 14 participants @ $300 each (that is 4 more participants than budgeted for) = $4,200.
- ACFN knowledge gathering session, expecting ~10 participants @ a fee of $500 per participant (this is of course above the $300 fee per participant budgeted) = $5,000
- FCML125 knowledge gathering session- expecting to have 10 participants @ $300 each = $3,000.

As indicated in **Section 6.7 – Method of Payment**, any consultant fees and disbursements for the community engagement activities and field work including contractor time, materials, and Indigenous subcontractors related to this Project (R.106569.001) will be invoiced and charged to the "Riviere des Rochers Little Rapid Weir & Revillon Coupé Structure Survey – 2019" (R.106570.001).

1. Context

Public Services and Procurement Canada (PSPC; formerly Public Works and Government Services Canada (PWGSC)) on behalf of Environment and Climate Change Canada (ECCC) has a requirement for environmental professional services from a qualified firm with the capability and expertise to successfully complete environmental services as outlined in this document.

The Peace-Athabasca Delta (PAD), located largely in Wood Buffalo National Park (WBNP), consists of a complex interconnected network of lakes and channels and interspersed perched basins. Three Indigenous communities (Athabasca Chipewyan First Nation (ACFN), Fort Chipewyan Metis local 125 (FCM125), and Mikisew Cree First Nation (MCFN)) make their home in and around Fort Chipewyan and the PAD is "their home, their grocery store, their classroom, their medicine cabinet, their church, their highway, their photo album, and the place where their happiest memories live." (p. EX-03, Independent Environmental Consultants 2018). This work is to provide the members of these communities, the province of Alberta and the Wood Buffalo National Park

(WBNP) managers with the information that they require to make an informed decision on what option or options to pursue in further detail for water control structure(s) in the PAD to achieve their desired hydrology-related outcomes. Their traditional and present-day knowledge of the land is critical information to guide this plan and these Indigenous and Parks Canada partners are committed to supporting this work with ECCC.

It is important for the Consultant to recognize and appreciate this context, illustrate cultural sensitivity at all times, meaningfully incorporate the provided knowledge and expertise as is within scope, and respect that this undertaking is to support the Fort Chipewyan community and that they are, and have been, the experts in their own home for time immemorial.

Historically, naturally variable climatic conditions periodically caused the PAD to flood, maintaining water levels, and refreshing the perched basins. As a result of natural deltaic aggradation, climate change, and regulation, hydrological and hydraulic conditions have changed such that flooding in the PAD is reduced, temporal variability of water levels has changed and the perched basins are not regularly rejuvenated (Peters, 2003, Peters et al. 2006, Beltaos 2018). This has impacted the ecological integrity of the PAD and the ability of the local Indigenous peoples to travel using the waterways and to meaningfully practice their Aboriginal and Treaty Rights.

This region has had a history of flow interventions. It will be necessary for the Consultant to become knowledgeable on the hydrology of the PAD, and hydrologic conditions necessary for ecological and cultural sustainability in order to understand what is feasible, and what has and has not worked in the past and why. A list of references is provided for background.

In 2014, the MCFN petitioned the World Heritage Committee (WHC) to request that the WBNP World Heritage Site be included on the List of World Heritage in Danger. At the request of the World Heritage Committee, the Government of Canada, with input and collaboration from provincial and territorial governments, Indigenous communities, and stakeholders, produced an Action Plan[1] to ensure that Wood Buffalo National Park World Heritage Site is safeguarded for current and future generations.

This work directly addresses portions of the Environmental Flows and Hydrology (EFH) actions EFH 56 and 57 from the Action Plan, and will be the basis for actions EFH 58 and 59. It will also inform actions related to artificial ice dam installation (EFH 31-36).

[1] https://www.pc.gc.ca/en/pn-np/nt/woodbuffalo/info/action

<table>
<tr><td colspan="4">GOAL: Strategically-placed short- and/or long-term water management control structure(s) within the PAD create a local hydrological regime that supports the ecological functioning and Indigenous use in identified target areas</td></tr>
<tr><th colspan="2">Actions</th><th>Lead</th><th>Timeline</th></tr>
<tr><th colspan="4">Small-scale and/or temporary control structures</th></tr>
<tr><td colspan="2">EFH56: Assemble and review overview of the existing data and information related to past, current, or potential control structures in the PAD:
• state of the weirs currently in place;
• alternatives considered, rationale for chosen options, design criteria, and effectiveness of the weirs currently in place (including past modelling exercises).
• new alternatives that were not considered or available at time of construction (e.g., inflatable rubber dams);
• previous weir/dam experiments in the PAD (e.g., ice dam at Dog Camp and small trench/weirs on perched basins in Athabasca Delta); and
• Weirs and dams that have been considered in the past but not implemented and why not (e.g., Big Egg Lake).</td><td>FPTI Committee</td><td>Targeted Completion: Summer 2019</td></tr>
<tr><td colspan="2">EFH57: Obtain new information related to possible short-term or small-scale options to improve the hydrological regime in the PAD</td><td>FPTI Committee</td><td>2019-2020</td></tr>
<tr><td rowspan="3">Implementation Detail</td><td>Employ a contractor to assess the effectiveness of the two existing weirs (Rivière des Rochers and Revillon Coupé) and identify any maintenance required to ensure that the weirs operate as originally designed.</td><td>PCA (Coupé weir) / AB (Rochers weir)</td><td>2019-2020</td></tr>
<tr><td>Undertake a feasibility assessment on the potential use of one or more temporary control structures to meet specific water level objectives in the Lake Claire and Mamawi Lake area of the Peace–Athabasca Delta, including simple modelling of potential outcomes.</td><td>ECCC</td><td>Targeted Completion March 2020</td></tr>
<tr><td>Consult with Indigenous partners and potentially affected parties</td><td>Indigenous partners / AB / PCA</td><td>2019-2020</td></tr>
<tr><td colspan="2">EFH58: Pending feasibility assessment results and consultation with local communities, select the most appropriate action and complete the full design for one or more pilot control structures.
• Determine appropriate Indigenous and hydro-ecological indicators and monitor for the effects of the control structure(s).
• Learning from monitoring of implementation results, adjust timing and length of installation and/or site of installation.</td><td>FPTI Committee</td><td>2020-2021</td></tr>
<tr><td colspan="2">EFH59: Install one or more pilot control structures and/or repair existing weirs, as designed.</td><td>PCA and/or AB</td><td>2021-2024</td></tr>
</table>

Action 57 considers 'temporary control structures', which are the target of this work. For clarity, the use of the word '**temporary'** means that the hydraulic control structures are intended to be non-permanent, such that they can be removed and ideally re-installed. Removal includes either if they are not producing the desired results or if the recommended operation schedule includes seasonal installation. The effectiveness of these structures will be monitored to inform longer-term options.

2. Objectives

The Consultant is to provide a feasibility plan as described herein to support decision-making related to options for removable control structures generally, and at two specific locations in the PAD to achieve desired outcomes, accounting for climate and flow pressures.

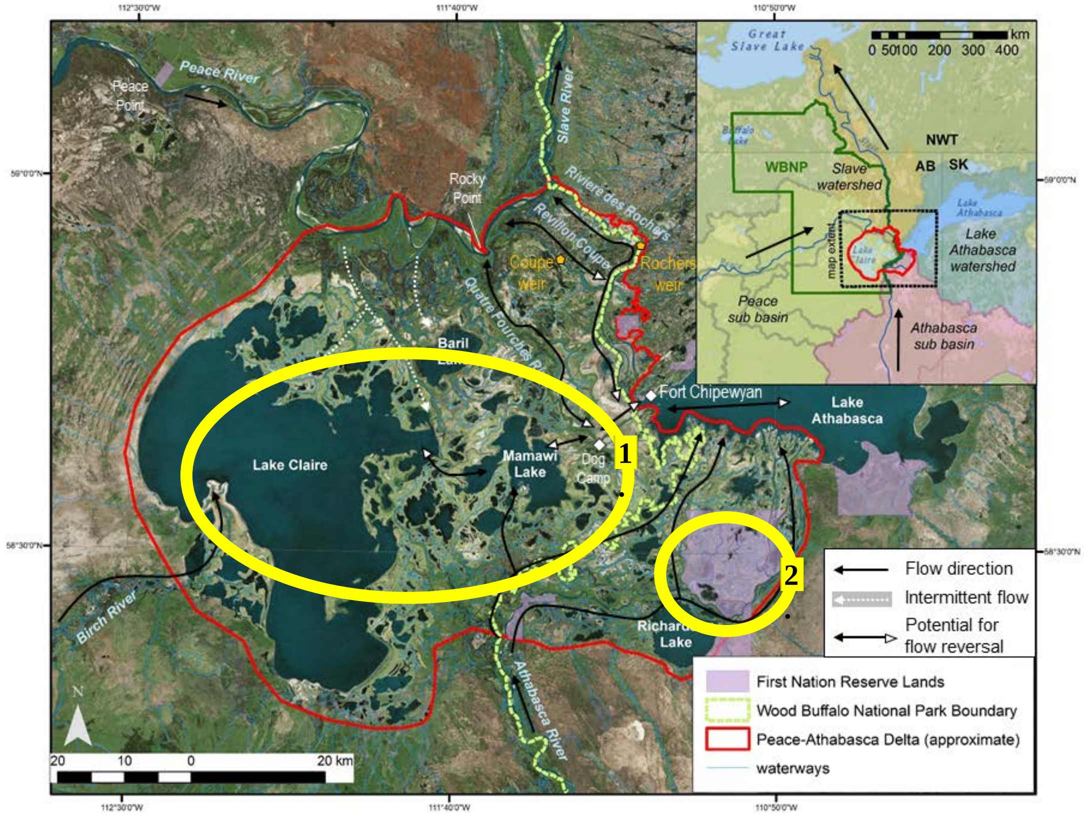


Figure 1. Peace Athabasca Delta (From Action Plan 2019). Yellow circles identify the general locations of the two areas of interest: 1. Mamawi Lake and connected Lake Claire (via assessment of a possible structure at Dog Camp and whether or not an associated structure at Cree Creek is needed to support water drainage and achieve low fall water levels) and 2. On the ACFN Jackfish reserve.

This feasibility plan will investigate the use of temporary control structures in the PAD to achieve desired water levels in two general locations selected by the Fort Chipewyan Indigenous communities (Figure 1). The Dog Camp and Big Egg Lake sites have been previously investigated for temporary or permanent water control structures.

1. Mamawi Lake and connected Lake Claire.
   a. This will include consideration for a structure on the west arm of the Quatre Fourches River at **Dog Camp**, and
   b. If required to achieve objectives, an associated structure at the **Cree Creek** diversion.
2. on the ACFN Jackfish reserve (I.R. 201).
   a. At the connection between **Big Egg Lake** and the Athabasca River.

3. Background

3.1 Peace Athabasca Delta water dynamics

The complex hydrology of the PAD is captured in the Golder (2012) reference provided and also at a high level in the Lake Athabasca section of the Atlas of Alberta Lakes (available online: http://albertalakes.ualberta.ca/?page=lake&region=1&lake=18). An excerpt is included in Annex E, and is further summarized below:

The Peace Athabasca Delta (PAD), is a complex and dynamic system, with inflows from the Peace, Athabasca, and Birch Rivers, connection to Lake Athabasca, and outflow to the Slave River (Figure 1). Lake Athabasca is drained primarily by Rivière des Rochers and its distributary, Revillon Coupé, with a smaller outflow through Chenal des Quatre Fourches (Atlas of Alberta Lakes). The drainage is primarily northward to the Peace River and then the Slave River, but when the Peace River is very high during spring or summer flooding, its elevation can exceed that of Lake Athabasca and cause flow reversals in these channels (Figure 1).

In 1982, the Embarras River breakthrough occurred, connecting the Embarras River directly to Mamawi Lake via Cree Creek and then Mamawi Creek. While this breakthrough increased water flow into Mamawi Lake, it also carries high levels of sediment and the Mamawi Creek delta has grown considerably since that time. While the additional water to the Delta lakes and the additional navigational route are considered desirable by the PAD communities, the increase in sediment deposition is likely an impediment to navigation. This additional inflow may cause the Mamawi Lake area to drain more slowly in the fall than it would have, prior to the breakthrough. The Implementation Committee and Biological Sub-committee in the 1986 PFRA Quatre Fourches study indicated that this delay in the recession of fall water levels was undesirable.

The PAD is comprised of open drainage (interconnected lakes and streams) and perched basins. Perched basins are separated from groundwater and are higher than the surrounding water table so they rely on flooding to be recharged. The aim of this study is to investigate whether there are feasible, removable options that could be installed to support flooding of perched basins or other wetlands and lakes that are not recharged annually.

3.1 Historic, Existing and Proposed Control Structures

Annex F contains detailed summaries of the past and existing control structures in the PAD. Figure 2 and Table 1 summarize the past and current water control structure locations.

Installation of the W.A.C. Bennett Dam in the 1960s influenced Peace River flows and in 1971 the governments of Canada, Alberta, and Saskatchewan established the Peace-Athabasca Delta Project Group (PADPG) to evaluate methods to raise water levels in the delta lakes and in Lake Athabasca. On recommendation by PADPG, the three signed an agreement and subsequently formed the PAD Implementation Committee (PADIC).

In 1971, a temporary rockfill dam was built on the Quatre Fourches near Mamawi Lake (“Dog Camp”), but it was damaged by flooding in 1974 and removed in 1975. During 1975 and 1976, permanent control structures were built on the Revillon Coupé and Rivière des Rochers. These permanent structures remain today, but their current state and functionality is unknown. This is being addressed through the linked contract “Rivière des Rochers Little Rapid Weir &Revillon Coupé Structure Survey” (R.106570.001).

Assessment in the 1980s (PADIC 1987) concluded that the weirs did not reproduce natural conditions, but nearly restored peak summer water levels and counteracted many of the hydrological changes from regulation of the Peace River.

However, the weirs did not influence flooding of the perched basins, nor did they restore the natural fluctuations of the delta lakes.

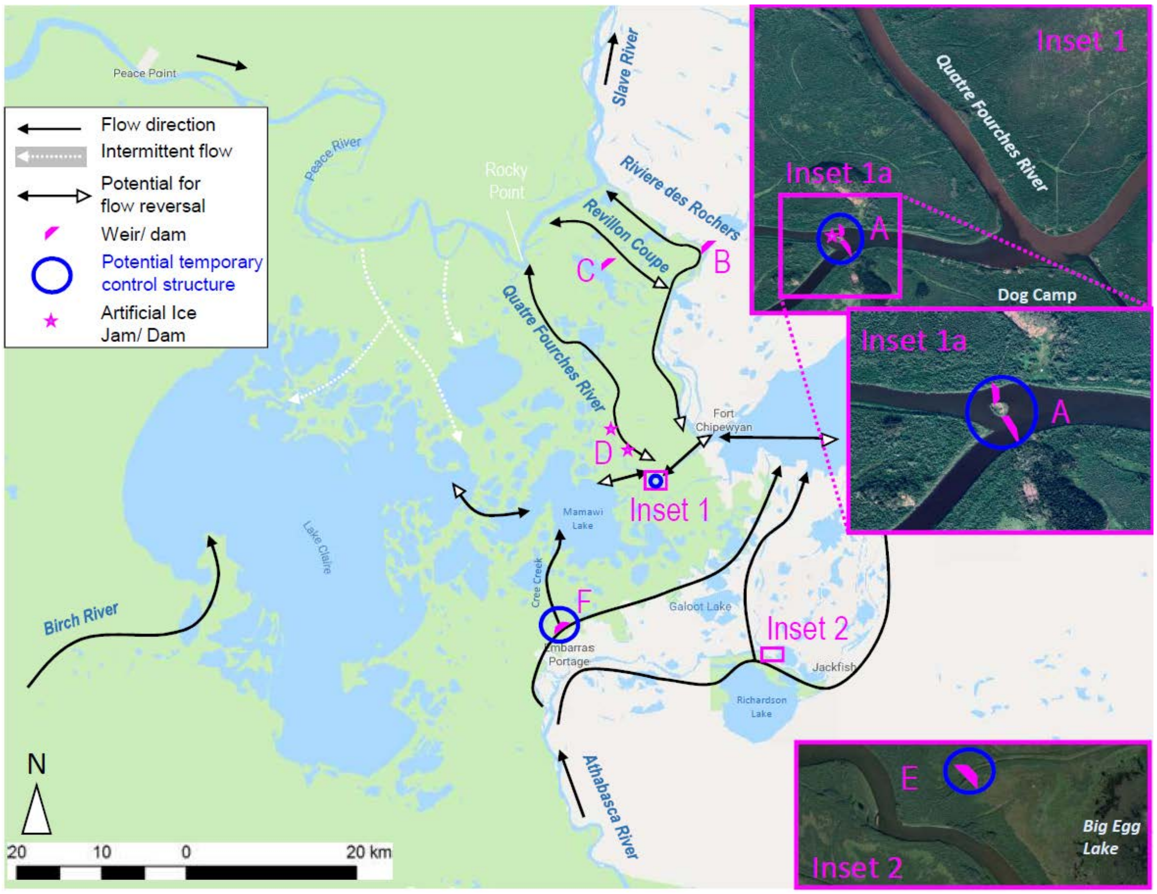


Figure 2. Summary history of water management in the PAD including proposed temporary control structure locations. A) west arm of Quatre Fourches (Dog Camp Location): previous location of rockfill dam (1971-1974, proposed gated control structure (1987), artificial ice dam (1995), and current proposed location of temporary control structure. B) Permanent rock weir at Riviere des Rochers (1975-present). C) Permanent rock weir at Revillon Coupé (1976-present). D) Historical artificial ice jams (1992-1993). E) Current proposed Big Egg Lake control structure on ACFN Reserve land F) Potential temporary control structure on Cree Creek.

Table 1: **Summary of Existing and Proposed Control Structures in the Peace Athabasca Delta. Letters for the location indicate their symbol as shown in Figure 2**

Location (Jurisdiction)	Structure	Purpose/Notes
A. West arm Quatre Fourches at **Dog Camp**	• 1971-1974 Rockfill dam	Rockfill dam removed in 1975.

(Federal-Parks Canada)	• 1986 Proposal - gated control structure (studied but not constructed) • 1994-1995 Artificial Ice Dam **• Current Proposal – Temporary control structures**	1995 Ice dam was unsuccessful. **Assess use of temporary control structures to be installed and removed periodically to provide seasonal flooding and drawdown in the vicinity of Mamawi Lake and Lake Claire.**
B. **Riviere des Rochers**: (Alberta)	• 1975/76 Submerged outflow weir with boat bypass and a tramway	To restore water levels in Lake Athabasca and the PAD. A gated control structure was studied but not constructed. There is a tramway to haul boats over a berm on an adjacent bypass channel, which works intermittently. An associated assessment will establish the current effectiveness of the Rochers and Coupé weirs.
C. **Revillon Coupé** (Federal-Parks Canada)	• 1976 Submerged outflow weir	To restore water levels in Lake Athabasca and the PAD. An associated assessment will establish the current effectiveness of the Rochers and Coupé weirs.
D. North arm Quatre Fourches (Federal-Parks Canada)	• 1992-1993 – Artificial Ice Jams	Ice jams were unsuccessful.
E**. Big Egg Lake on ACFN Jackfish reserve:** (Indigenous reserve lands; Alberta)	1987 & 1990s – adjustable control structure (studied but not constructed) **• Current Proposal – Temporary control structures**	Engineering pilot design for a permanent structure investigated in 1987 and then produced in 1994 to facilitate wetland restoration, but not implemented. Located on ACFN reserve, Athabasca River portion of PAD. **Assess use of temporary control structures to be installed and removed periodically to provide temporary flooding of the Big Egg Lake perched basin.**
F. Cree Creek (Federal)	**• Current proposal – Temporary control structures if necessary to support Dog Camp (an independent structure here is not envisioned).** No feasibility-level designs.	In the 1980s, concern was raised that additional inflow from the Athabasca River via Cree Creek and Mamawi Creek to Mamawi Lake would delay fall drainage and reduce habitat for waterfowl and wildlife. This may not be a concern today, but the increased sedimentation into Mamawi Lake is a concern for navigation. **Assess the use of a temporary control structure (likely in summer/fall) to assist in drainage of the PAD (and/or increase flow on the Embarras), if a control structure is implemented at Dog Camp. No feasibility-level designs.**

4. Scope of Work

This scope of work outlines the steps to be taken to achieve the objectives in Section 2. The overarching outputs of this work are:

- **General Feasibility.** Evaluation of the general feasibility and logistical considerations of using various available types of temporary (i.e. non-permanent; removable) hydraulic control structures within the PAD, including ice dams, given the dynamic hydrology and harsh winter climate. Provide a general assessment of why assessed types would or would not be feasible. For those that are feasible, provide cost estimates, installation, maintenance, and removal requirements, and anticipated longevity.
- **Location-specific data**. Collect detailed data (survey, bathymetry, photos) at the denoted locations and create a theoretical stage-discharge curve. Estimate the maximum achievable water level and areal extent of induced flooding and the time to drain to minimum water levels from any installation, plus estimate the flows to consider at each site.
- **Options assessment**. Comparison of the effectiveness of different product types, configurations and locations (e.g. Dog Camp alone vs Dog Camp with Cree Creek structure) under foreseeable operating conditions for the Mamawi Creek and the Jackfish Reserve location. Provide recommended options to move forward to feasibility-level design, not to exceed a total of 6 designs.
- **Feasibility-level designs.** Unless no feasible options exist, provide one or more technical feasibility level designs for the recommended configurations for <u>each</u> the (1) Dog Camp location and (2) Big Egg Lake, on the ACFN Jackfish reserve, optimizing low cost, durability, and ease of installation that provide a high likelihood of achieving the desired water level outcomes.
- **Inclusion of Indigenous engagement and knowledge.** Engage with the Fort Chipewyan community and the task team (see definition) to understand desired outcomes, specific areas of interest with respect to water levels, insights on historical floods, and to gain direction on structures that should undergo a feasibility assessment.

Detailed guidance on scope of work:

4.1 Desktop literature review and general assessment of potential applicability of different temporary control structure types for this dynamic, cold-weather delta

4.1.1 The Consultant will **review literature noted in Appendix E** to understand the current and historical timing and duration of flooding and hydrological regime of the Lake Claire/Mamawi Lake basin and the Big Egg Lake Jackfish Reserve area, including current and past control structures. Key documents are identified as required, further references are provided for additional information.

4.1.2 **Investigate the availability of temporary control structures and assess the potential for implementation in the dynamic, cold-weather environment of the PAD**. This may include, but is not limited to, coffer dams, rubber dams, portadams, and aquadams/ geotubes that can be filled with water or sediment. Other options to temporarily control flows include the construction of ice jams or ice dams.

4.1.2.1 Investigate the supply and availability of temporary control structures that may be useful for this application and document and compare their costs, characteristics, properties, benefits, etc. as well as their installation requirements, and any associated products and best practices required for sediment control during installation and removal. Include considerations for ability to withstand forces of nature present in cold regions such as ice and potential flows and identify any potential products that could be employed to help mitigate these factors. Considering the conditions at the proposed locations, provide a reasonable estimate of life spans of the structures and whether they could be re-used for more than one deployment.

4.1.2.2 Investigate the overall feasibility of installation of artificial ice dams, state of the art techniques, best practices, weather conditions required for their success, seasonal timing of their construction, availability of equipment and related costs.

4.1.2.3 Provide a brief summary of the types of control structures investigated, potential combinations (such as stacked geotubes and aquadams vs. one large aquadam), including why the options would or would not be recommended for general application in the PAD[2].

4.2 Engagement with, and involvement of, local Indigenous communities.

4.2.1 **The Consultant will communicate with the task team**, supported by ECCC and PSPC, throughout the life of the contract, at a mutually acceptable frequency. The task team, including Parks Canada, will provide information to the Consultant on how to identify and establish Indigenous subcontractors.

4.2.2 **The Consultant will engage with and present a PowerPoint presentation to community members in Fort Chipewyan for 2 community open-houses prior to field work on September 18 and 19** to inform the community about the work that they are undertaking and to learn from community members their desired outcomes, specific areas of interest with respect to water levels, insights on historical floods, and recommendations on structures that should undergo a feasibility assessment.

4.2.3 **The Consultant will participate in three knowledge gathering sessions as soon as possible considering the community and Consultant's availability;** one with each of the three PAD Indigenous communities. **The Consultant will subcontract local experts and Elders to share local knowledge at knowledge gathering sessions and meaningfully**

[2] ECCC has been in contact with certain suppliers and can provide information garnered to date on options discussed specific to the study area.

incorporate this information into the work, to the extent possible within the scope. The Consultant will provide a record of any notes, maps, or other products produced during these meetings to the respective community for validation and make any corrections prior to finalization. A data sharing agreement may be required, at the knowledge holder and community's discretion, to be finalized at least one week prior to the session. These expert (elders and/or land users) meetings are intended to provide:

- Site-specific pertinent local knowledge, such as specific locations to consider when assessing achievable water levels and information on how past and current control structures have influenced water levels; and
- Effects and timing of past open-water flood events in the (1) Mamawi Lake and connected Lake Claire and (2) Big Egg Lake and connected area, including key areas that were (or were not) flooded. This includes the rate of drainage and any impacts observed on plants or wildlife.
- Number of persons/day: Maximum of 10 persons/day

Current Western science related to elevation and topography data and mapping in the Peace-Athabasca Delta has not been completed. The Consultant will review historic flooding events as displayed on satellite imagery and coarse-level DEMs and outdated hydrological models that are no longer readily useable due to changes within the Peace-Athabasca Delta and with technology. The local knowledge provided by experts/elders who are local land users is critical as they can provide detailed information and observations that was observed at the time of historic flooding.

4.2.4 The Consultant will be **available in-person to address technical questions about the final report during a presentation by Parks Canada to the community in Fort Chipewyan.**

4.3 Conduct site investigations to collect site-specific data for design of temporary control structures

4.3.1 The Consultant will **conduct site assessment during the open-water season at the 3 identified locations (Dog Camp and Cree Creek; Big Egg Lake near community of Jackfish)**.

4.3.1.1 Perform an one day initial site reconnaissance trip by helicopter in conjunction with the community open house to gain an overview of each site, assess safety, and determine an a approach for collecting the required survey information during the field program. Aerial transportation will be provided by Parks Canada in kind.

4.3.1.2 Two boats will be required. Boat #1: boat and driver will be provided by Parks Canada or the Government of Alberta in kind. Boat #2: Facilitated by Canada (PSPC and/or Parks Canada), subcontract a local Indigenous person(s) or company with local knowledge of the area and of traditional sites of importance to serve as a boat guide to avoid navigational hazards when accessing the sites, and to provide on-the-ground and site-specific pertinent additional local knowledge, such as specific locations to consider when assessing achievable water levels (Section 4.4.1). The subcontractor**(s)** may also be used to supply and drive the boat to site. An Indigenous guide will also be required for Boat #1.

4.3.1.3 Collect detailed survey data, bathymetry data, and photos sufficient to assess the locations for implementation of the temporary control structures investigated in section 4.1.2, including information required to inform options for boat and fish passage.

4.3.1.3 Collect stage-discharge measurements at each site.

4.3.1.4 If possible, within time and budgetary constraints, survey for the base elevation of nearby structures to support an estimate of impacts to nearby property.

4.3.1.5 Provide the Preliminary e-mail report of field results, per the schedule.

4.4 Determine maximum possible areal extent of flooding

The work to be performed should be based on literature reviewed, surveyed data and Indigenous knowledge from site visits and knowledge gathering sessions, and taking into account the best available digital elevation data, geospatial data of historical open-water flooding (such as 1935 max historical, 1996) and associated water levels.

4.4.1 Based on the geography/ topography of the study areas, provide a reasonable estimate of the **maximum achievable water levels for the spring peak from implementation** of (a) temporary control structure(s) at the (1) Mamawi Lake and connected Lake Claire, and (2) Big Egg Lake and connected area. Show the areal extent of this maximum estimated flooding on a map.

4.4.2 Based on the geography/ topography of the study areas, provide a reasonable estimate of the **time it would take to drain water to minimum water levels in the fall after achievement of the maximum spring water level** at Mamawi Lake and connected Lake Claire from implementation of (1) a temporary control structure at Dog Camp and (2) a temporary control structure at Dog Camp plus a secondary structure at Cree Creek that limits inflow. Show a time-series of the areal extent of draining on a map under both scenarios.

4.4.3 **Include estimates of the influence on downstream flows/volumes** to be expected from holding back water and then releasing water, such that the impact to the Slave River are or can be inferred.

4.5 Evaluate the effectiveness of the temporary control structure options

4.5.1 **Estimate the flows to consider** when evaluating the effectiveness of the temporary control structures at withstanding conditions and at elevating water levels (for example, by conducting a frequency duration analysis of river flows, and determining the 5-year, 10-year and 100-year return flows). If possible, consider the additional influence of a strategic release of water from the Bennett dam, such as occurred in spring 1996.

To inform the estimate of flows, create a theoretical stage-discharge curve for example, by collecting discharge data and comparing them to the existing/ historical stations.

4.5.2 **Investigate and compare the effectiveness of different product types, configurations and locations of temporary control structures at holding back water under foreseeable operating conditions in the two areas.** For each scenario/configuration evaluated, present the maximum water level achievable plus reasonable estimates of the range of water levels and areal extents anticipated based on flows estimated in section 4.5.1.

a. Options for the **Mamawi Lake and connected Lake Claire** area include, but are not limited to:

   i. North section of Dog Camp structure: Installation of a temporary control structure at Dog Camp between the island and the north bank of the river (Figure 3);

   ii. North and south section of Dog Camp weir: Installation of a temporary control structure at Dog Camp between the island and the north bank of the river, and between the island and the south shore. (Figure 3);

   iii. Evaluate the influence, if any, of an additional structure at Cree Creek at Embarras River location (Figure 4) on the rate of fall drainage and the optimal configuration to achieve drainage objectives, should a structure be recommended. Include consideration of the influence on sedimentation rate into the Mamawi delta.

b. **Big Egg Lake** (ACFN Jackfish reserve):

   a. Investigate options for a temporary control structure(s) to retain water in Big Egg Lake to achieve the water level objectives for this site. This would include, but is not limited to, the natural levee low point between the restricted basin, Big Egg Lake, and the Athabasca River that was previously investigated for a permanent control structure (see PADTS, 1994 for specific location and previous work), (Figure 1, Figure 5).

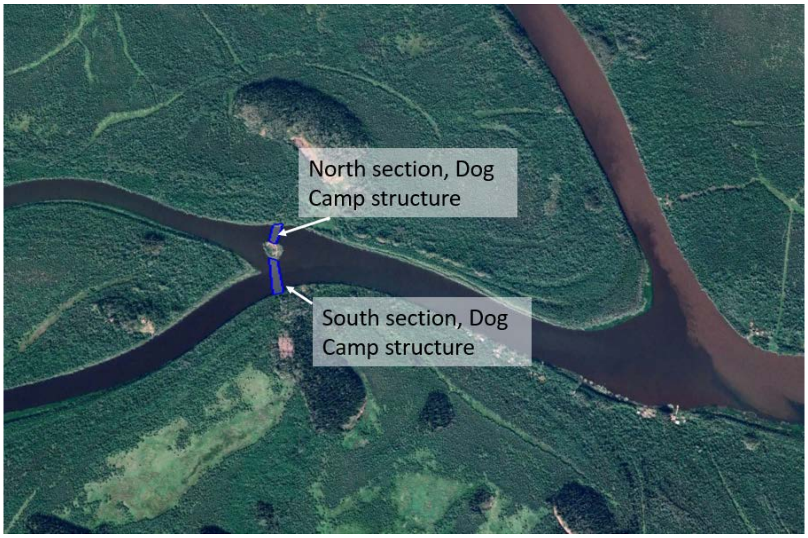


Figure 3. **Dog Camp weir configuration options, including north and south sections.**

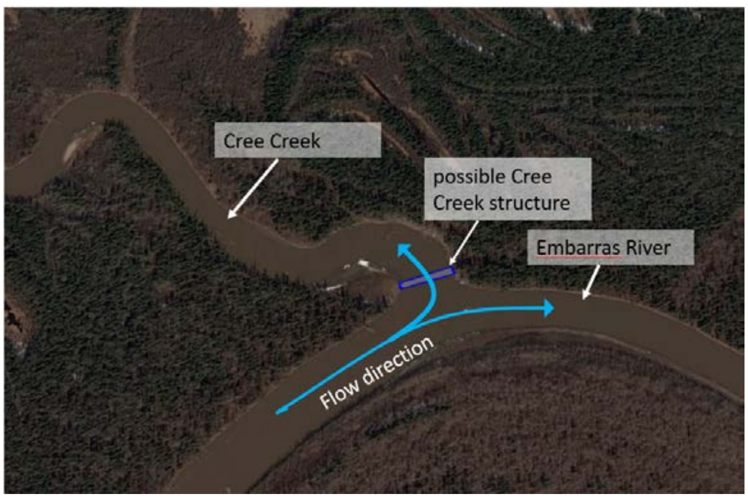


Figure 4. Possible Cree Creek structure location.

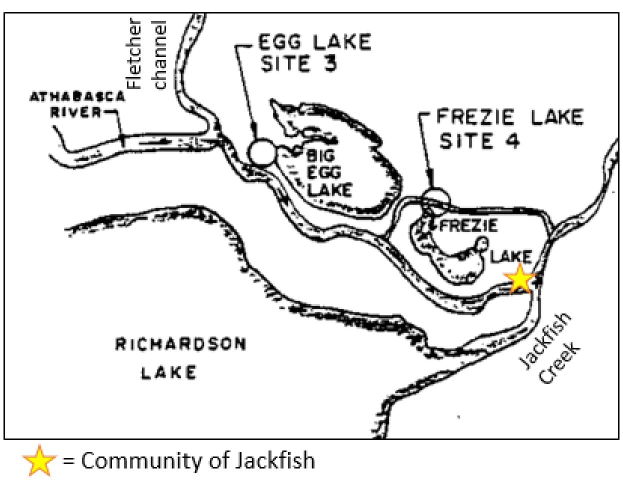


Figure 5. **Possible Jackfish Reserve structure locations from 1987 W-E-R report.**

4.5.3 **Provide the assessments of these scenarios/configurations in a written report to ECCC/PSPC to inform the decision on which should be selected to move to feasibility-level design.** This represents the submission of findings to date, draft results of scenarios for evaluating the effectiveness of the temporary control structures, and draft recommended structures and configurations in the schedule, below.

4.5.3.1 Provide the results both in detailed technical form, sufficient that results could be reproduced, and in the form of maps and possibly graphs, suitable to explain the results to non-technical audiences.

4.5.3.2 **Identify one or more of the most promising location(s), configuration, and type of control structure** for the (1) Mamawi Lake and connected Lake Claire [Dog Camp site], and (2) Big Egg Lake. Include consideration of optimizing low cost, maximizing durability and ease of installation (and removal, if appropriate), while ensuring functionality.

4.5.3.3 Provide ECCC with recommendations on which configurations should be considered to go to feasibility-level design. Within 2 weeks of receipt of this submission, ECCC will confirm which configurations to move to feasibility-level design phase.

4.6 Prepare technical feasibility level designs

4.6.1 **Prepare technical feasibility level design(s)** of the selected structure(s), including boat and fish passage(s). The level of detail provided should be adequate to inform a decision on whether to proceed with funding detailed design and construction. Designs should include, but are not limited to:

- **Drawings to indicate location, configuration, type, sizing (structure dimensions)**
- **site preparation, foundation, and if required, anchoring requirements**
- **recommended season(s) of deployment and removal (and rough installation/ removal schedule), and anticipated maintenance schedule**. Also assess site accessibility for installation work and ongoing operations, public safety and environmental impact considerations related to construction of temporary control structures
- **cost estimates for each design**, including materials, transportation to site, person hours for all installation and removal and operation.
- **potential impact of the proposed temporary water level increases on areas upstream and estimate downstream impacts both while water is being held back and when it is released (including an estimate of influence of flows on the Slave River, if applicable)**.

4.7 Produce a comprehensive feasibility plan report, and attend final presentation

4.7.1 **Document the feasibility plan process, input and results** (including feasibility plans and any results previously provided, as appropriate) **in a comprehensive report** that can be used as the basis for the detailed design/implementation phase of this project. The results from the Indigenous community sessions may be submitted separately, as determined during the course of the contract.

4.7.2 **Present draft report** the WBNP Environmental Flows and Hydrology Working Group for review and comment prior to finalization. Be available to answer questions either in-person in Edmonton or via webex.

4.7.3 **Attend, in-person, the Parks Canada presentation of the final report** (and the final report from the linked contract) **in Fort Chipewyan** and be available to answer technical questions related to the final report.

5. Scheduling and Reporting

5.1 Schedule

The Consultant will provide a detailed schedule for completion of contracted goals in order to meet the project timeline in their proposal submission. This schedule should include major project milestones such as a date for a Project Kick-off Meeting and a date for completion of field related activities.

The Consultant shall maintain the project schedule that is agreed upon with the PSPC Project Manager at the project initiation. The schedule will be in accordance with any necessary modifications agreed upon with the PSPC Project Manager.

The project schedule will adhere to the following milestone completion dates for this project:

Item	Timeline
Submission of Proposal	Within 10 days from receipt of Statement of Work
Kick-Off Meeting	Within one week of contract award
Submit Health & Safety Plan	1 week prior to travel
Submission of draft presentation material for Fort Chipewyan Community Meeting	At least 4 working days prior to Fort Chipewyan Community Meeting
Submission of final presentation material for Fort Chipewyan Community Meeting	At least 1 working day prior to Fort Chipewyan Community Meeting
Three (3) targeted knowledge gathering sessions in Fort Chipewyan, 1 per community	To be completed as early as possible, at the convenience of the communities. All notes, maps, records, etc. to be provided to the community for verification within 2 weeks of the session.
Community Open house presentations in Fort Chipewyan, Alberta	PowerPoint Presentation to the Fort Chipewyan community prior to site visit (field work). September 18 and 19, 2019. Same trip as the initial site reconnaissance visit.

Completion of Field Activities	The site visit (field work) must occur during open-water season (commencing no later than October 7, 2019).
Preliminary e-mail report of Field Results	Within 1 week of site visit, but no later than October 21, 2019
Submission of findings to date, draft results of scenarios for evaluating the effectiveness of the temporary control structures, and draft recommended structures and configurations (submission by email)	No later than November 8, 2019.
Mid-point Meeting to discuss draft results, and confirm proposed options to go to feasibility-level design	No later than November 15, 2019
Submission of Draft Report	January 6, 2020
Draft presentation of findings/ recommended structures to PSPC, ECCC, Task Team, and FPTI Committee in Edmonton or via webex	January 27, 2020
Submission of Feasibility Final Report	3 weeks following receipt of PSPC draft report review comments, but no later than February 17, 2020.
Attendance at Parks Canada meeting in Fort Chipewyan to answer technical questions related to the final report	Targeted February/March 2020.
Project Close-out Date/Final Invoice	Within 1 week of Parks Canada presentation in Fort Chipewyan and receipt of final report but no later than March 20, 2020.

Regarding the schedule, the Consultant is advised that a four (4) week period shall be included in the timetable at the end of the draft report submission to allow PSPC and ECCC to review and provide comments on the report, and to discuss any project adjustments. Once comments are received on the draft report, the Consultant must finalize the report and submit the report within three weeks.

A final report will incorporate PSPC/ECCC comments on the draft report. The Consultant will provide a spreadsheet with the final report identifying how every PSPC/ECCC comment has been addressed.

5.2 Project Management

A competent project manager on staff with the Consultant will be assigned to effectively manage this project on behalf of PSPC/ECCC. The project manager will oversee the communications, schedule control, and the overall quality of work.

The project manager will maintain regular contact with and submit progress updates to the PSPC project manager throughout the duration of the project including project status, budget updates and any factors which may influence the schedule, budget or deliverables.

The contact information for the PSPC project manager for this work is as follows:

Leslie Yasul
Senior Environmental Specialist
Public Services & Procurement Canada – Environmental Services & Contaminated Sites Management, Western Region
(780) 893-8665
leslie.yasul@pwgsc-tpsgc.gc.ca

The contact information for the ECCC project manager for this work is as follows:

Theresa Braat
Manager, Analysis, Relationships and Indigenous Affairs
Environment and Climate Change Canada
780-951-8610
Theresa.Braat@canada.ca

Lieserl Woods
Water Resources Specialist, Environmental Services
Environment and Climate Change Canada
(780) 951-8855
Lieserl.woods@canada.ca

5.3 Communication

A 1-hour project kick-off meeting is mandatory for the Consultant to attend and must be completed prior to the Consultant mobilizing to site. The meeting will discuss health and safety, schedule, logistics and issues for the field work. The *Consultant is responsible for taking meeting minutes and submitting the minutes to PSPC within 48 hours of the meeting.*

The Consultant shall maintain communications with the PSPC Project Manager throughout the contract. Copies of all correspondence shall be sent to them.

During the project the Consultant must provide updates to the PSPC project manager via email at least every two weeks including:
1. When the site visit travel is booked and for what dates.
2. Daily updates during field activities.
3. Weekly updates detailing the status of the project scope, schedule and budget will also be required. The Excel file for weekly updates will be emailed upon project award.
4. Within 1-week of completing the site visit provide an update on data results and how the project is progressing; and,
5. When any issues are encountered that may affect the project deliverables, schedule or contract budget.

A contact will be provided to the Consultant for them to use in the event that the PSPC project manager is unavailable during the field activities, if issues are encountered in the field and further direction and/or information is required. However, all other communication shall be directed to the PSPC Project Manager.

The Consultant's assigned project manager shall be responsible for the scheduled execution of the contract and coordination with the PSPC Project Manager. Changes to the designated project manager may be made only with prior approval from PSPC. The project manager shall have the experience and capability to be responsible for the overall supervision of work and serve as liaison between the Consultant and the PSPC Project Manager for all work required under this contract, unless alternate arrangements are agreed upon by both parties.

5.4 Reporting

Draft and final reports, incorporating any comments by PSPC PM, PCA and ECCC shall be issued no later than indicated in project schedule.

Draft Report:

- One electronic copy of the draft report in text recognized, non-password protected (unsecured) Portable Document Format (pdf).
- **Note: The draft report shall be submitted as if it were the Final report.** If PSPC determines that the report does not meet the objectives outlined in the TOR, the Consultant will be responsible for revising the draft report until it is satisfactory with no additional costs incurred to the Crown. Justification for any draft report comments that cannot or will not be addressed by the Consultant in the Final report must be provided to in writing and discussed to the satisfaction of PSPC prior to submission of the Final report.

Submit to PSPC Project Manager electronically along with the Comment Tracking Table (Appendix D) to identify questions for PSPC and the Client and to demonstrate how comments from PSPC and the Client were addressed.

5.5 Deliverables

- A start-up meeting will be held between PSPC/ECCC and the Consultant within one week of the issuance of the task authorization. The Consultant will provide the work plan submitted in their proposal for review at this meeting. The work plan should include a matrix illustrating the number of days/hours planned for each member of their team. They will also review all tasks related to the execution of the project, indicate the individuals who will be conducting the work and agree on milestone dates and deliverables.

- A written report of the field program initial results will be provided and presented to PSPC/ECCC.

- Reporting on each of the Indigenous knowledge sessions as described in the scope of work.

- A written report of the options assessment, results to date, and recommendations to proceed to feasibility-level design will be provided to ECCC prior to proceeding to feasibility-level design.

- Project deliverables will include one electronic copy of the draft report and 11 USB sticks of the resultant Final report, and one electronic copy of the final presentation to the FPTI Committee and Task Team. The Final copy will be sent electronically to the Project Manager over secure FTP. The final report(s) and products from the Indigenous knowledge gathering sessions will be provided as one electronic copy. The inclusion or not, of these reports in the final report will be determined prior to finalization of the draft report.

  The Consultant will provide PSPC/ECCC with the following documentation in English:
  - 14 USB sticks of the summary report, and final report in Microsoft Word and PDF formats;
  - A full listing and provision of reference materials/bibliography and data sources;
  - All pictures, aerial photographs, datasets and electronic worksheets/models developed to support the analysis in their native format in the table below

Report Component	*Requested Native File Type*
Pictures	.jpeg
Video	Files compatible with Windows Media Player
Figures	.jpeg and/or Adobe .pdf
Tables	Microsoft Excel - .xls
Maps	1. Shapefiles suitable for use in ArcGIS such as .shp, .shx,.dbf; and 2. CAD files such as .dwg (for MSC)
Report text	Microsoft Word - .doc

5.6 Health and Safety

The Consultant shall be responsible for making all employees, other Consultants and subcontractors and anyone at the site aware of safety hazards, and shall ensure the health and safety of all personnel at the site. Accordingly, for all site assessments a Health and Safety Plan shall be developed one week prior to the site visit, and then implemented by the Consultant during the field activities.

The Consultant shall ensure that all relevant safety policies, guidelines, and emergency response actions are reviewed with site personnel and that the Health and Safety Plan is easily accessible to staff during all field activities.

6. Special Requirements

6.1 Consultant Services and Responsibilities

The Consultant shall perform all work required to for this project. All work shall be performed in an environmentally acceptable manner conforming to existing applicable Federal and Provincial regulations and guidelines. The Consultant shall furnish all services, labor, materials, supplies, and equipment required to conduct the scope of work.

The Consultant shall have responsibility for the complete effort specified in the contract.

The Consultant is responsible for the professional quality, technical accuracy and timely completion and submission of all deliverables, services or commodities required to be provided under the contract.

The Consultant shall, without additional compensation, correct or revise any errors, omissions, or other deficiencies in its deliverables and other services. The approval of deliverables furnished under this contract shall not in any way relieve the Consultant of responsibility for the technical adequacy of its work.

The review, approval, acceptance or payment for any of the services shall not be construed as a waiver of any rights that TC/PSPC may have arising out of the Consultant's performance of this contract.

6.2 Confidentiality

It is understood and agreed that the Consultant shall, during and after the effective period of this contract, treat as confidential and not divulge, unless authorized in writing by the PSPC Project Manager, any information obtained in the course of the performance of the ensuing contract. Refer any queries regarding this project from the public, news media or other to the PSPC Project Manager.

6.3 Ownership of Material

Without affecting any existing intellectual property rights or relating to information or data supplied by Canada for purposes of the contract, copyright in anything conceived, developed, or produced as part of the Work under the contract will belong to the Crown.

To be explicit, all Traditional Knowledge and Traditional Use Information provided for the purposes of this work remains the exclusive intellectual property of the indigenous communities that provided it and that delivery or disclosure of Traditional Knowledge and Traditional Use Information will give the Crown no right or interest in the Traditional Knowledge and Traditional Use Information.

The Statement of Limitations in the Final report shall not contradict PSPC General Conditions.

6.4 Data Confidentiality

All financial, statistical, personnel and/or technical data supplied by PSPC/ECCC to the Consultant are confidential. The Consultant is required to use reasonable care to protect the confidentiality of such data. Any use, sale or offering of this data in any form by the Consultant, or any individual or entity in the Consultant's charge or employ, will be considered a violation of this contract and may result in termination.

6.5 News Releases

The Consultant is not permitted to issue news releases or speak to the Media pertaining to any aspect of the services being provided under this contract without prior written consent of PSPC and ECCC.

6.6 Budget Updates and Contract Amendments

At the completion of the project once the final invoice is received and processed, the Consultant shall submit an amended TAPF for the site to reflect project actuals.

6.7 Method of Payment

All invoices must be submitted to the PSPC Project Manager on a monthly basis. The final invoice shall be submitted on the same date as the final report.

The consultant is required to fulfill all responsibilities required to receive payment for the work. This includes the completion of a statutory declaration form. The statutory declaration form shall be signed on or after the date of the final invoice and shall be submitted on the same date as the final report and final invoice. The statutory declaration form is provided to the Consultant as part of the ToR package (Appendix D).

It is the responsibility of the Consultant to retain and provide receipts for all disbursements if requested. These receipts are to be included in the monthly invoice immediately following the travel. All travel shall be invoiced as per the Federal Travel Directive: http://www.njc-cnm.gc.ca/directive/d10/v10/s90/en#s90-tc-tm

Note: Consultant fees for the feasibility-level drawings and any consultant fees, travel and disbursements for the community engagement activities and field work including contractor time, materials, and Indigenous subcontractors related to this Project (R.106569.001) will be invoiced and charged to the "Riviere des Rochers Little Rapid Weir & Revillon Coupé Structure Survey – 2019" (R.106570.001). The intent is that field work and community meetings for both projects would occur concurrently.

6.8 Project Close Out

As per the Standing Offer Agreement, the Consultant is required to complete a Statutory Declaration form at completion of the task authorization. A copy of the form has been appended in Appendix B to the TOR.

7. Submission of Proposal

Proposals are to be forwarded to the PSPC Project Manager via email (.pdf format) as follows:

PSPC Project Manager

Leslie Yasul
Senior Environmental Specialist, Western Region
leslie.yasul@pwgsc-tpsgc.gc.ca / Tel: 780-893-8665

The project proposal shall be received no later than **August 2, 2019.**

The proposal will include the following information:

- Project scope and objectives.
- A description of the Consultant's overall approach that will ensure the objectives of the project will be satisfied cost effectively.
- Proposed project schedule presented in a table and Gantt chart format. The schedule must include critical path(s) and a timeline for all milestones, tasks, deliverables, meetings, travel, etc. The project schedule should be provided in a template that allows updating throughout the project.
- The proposed methodology to be used to meet the requirements as described above.
- The personnel to be assigned to the project including name, qualifications and experience and their individual roles and responsibilities within the project. There shall be no substitutions to the project team unless written approval to do so is granted by the PSPC Project Manager before the substitution is used.
- Work to be subcontracted must be specified at the time of the proposal. Background information such as company profile and past working relationship must be provided.
- The Consultant shall prepare a cost estimate and timetable outlining the relative cost and timing for all project tasks. The budget shall be organized as estimated fees and disbursements on a task basis using unit rates in accordance with the existing standing offer agreement. Three cost estimate tables are required as follows:
  - Table 1 - A total cost estimate for completing the entire project must be provided divided into tasks.
  - Table 2 – A cost estimate for all travel disbursements.
  - Table 3 – A cost estimate for all other disbursements
- The cost estimate shall include the Consultant fees and travel disbursements for the community engagement activities and field work related to the Feasibility Plan for Temporary Control Structures on Mamawi Lake in the Peace-Athasbaca Delta (R.106569.001) since the intent is that field work and community meetings for both projects would occur within the same trip. See that project's Terms of Reference for further details.
- **Note:** The *Task Authorization Proposal Form* (TAPF) will be forwarded to Consultant to be completed once the proposal and budget tables have been accepted.
- Price back-up documentation for disbursement items for which the total value exceeds $5,000.00 (GST included) must be provided with the TAPF.

It is the responsibility of the Consultant to retain and provide receipts for all disbursements if requested.

7.1 Coordination with the "Feasibility Plan for Removable Control Structures on Mamawi Lake in the Peace-Athabasca Delta" project

The contract for the "Rivière des Rochers Little Rapid Weir & Revillon Coupé Structure Survey" (R.106570.001) will be awarded concurrently with this contract to the same Consultant who must be capable of fulfilling requirements stipulated in each contract. Proposals should be submitted bearing this in mind. All field work, consultations and community meetings in Fort Chipewyan should be scheduled coincidentally to minimize costs, at the convenience of the communities.

8. List of Appendices

Appendix A - Weekly Update Reporting Form (To be submitted to PSPC on a weekly basis)

Appendix B – Statutory Declaration Form (To be notarized and submitted to PSPC with the final invoice)

Appendix C – Task Authorization Proposal Form (To be submitted to PSPC with the proposal package)

Appendix D – Comment Tracking table (to be submitted with any revisions to the report)

Appendix E – References (Available on BIM360 Site)

Appendix F – Details on past and current water control structures

Appendix E. References

<u>Required for Review:</u>

1. Golder. 2012. Jack Pine Mountain Expansion Project Appendix 3.4 Peace-Athabasca Delta Assessment.
    - Section 3.0 (Hydrology) pp.6-20 includes flow statistics, water level, differences in flow statistics pre- and post-Bennett dam, changes from water withdrawals on water level on the Athabasca River delta and more.
    - Attachment A includes hydrological baseline information

2. Aiken, B. and Sapach, R. 1994. Northern River Basin Study Project Report No. 43, Hydraulic Modelling of the Peace-Athabasca Delta: Under Modified and Natural Flow Conditions. Report. Published by the Norther River Basin Study, Edmonton, Alberta.

3. Candler, Craig and Rachel Olson, Steve DeRoy and the Firelight Group Research Firelight Group Research Cooperative, with the Mikisew Cree First Nation, 2010. As Long As The Rivers Flow: Athabasca River Use, Knowledge and Change, MCFN Community Report, August 16, 2010.
    - Indigenous navigation routes in the PAD, instances of lost access, cultural importance of the PAD.

4. Peace-Athabasca Delta Implementation Committee (PADIC) 1987c. McPhail, G.D. 1986. Peace-Athabasca water management works evaluation, final report. Appendix C. Ancillary Studies. *A technical feasibility study of the Quatre Fourches control structure in the Peace-Athabasca Delta*. Report.
    - Feasibility study for a control structure at the Dog Camp location. Not implemented.

5. Peace-Athabasca Delta Technical Studies (PADTS). 1994. Big Egg Lake Control Structure Project. Task H.1 – Alternative Remediation. Alberta Environmental Protection. Edmonton, AB.
    - Control structure study for Big Egg Lake on the Jackfish reserve. Not implemented.

6. Fort Chipewyan Indian Reserve No. 201 Water Management Control Structures Feasibility Report. 1987.
    - Feasibility report for permanent control structures in the Jackfish reserve for several locations.
7. Chipewyan IR 201 Big Egg Lake Site Specifications 1995.
    - Schedule D provides detailed drawings that reference Big Egg Lake in the ACFN Jackfish reserve 201. Not implemented.

Provided as references:

There is a considerable amount of published information on water management in the PAD. While most of this information is not explicitly germane to the work described herein, it is assumed that high-level background data are contained in the following documents, to be provided to the Consultant. In their proposal, the Consultant shall provide a list of any additional information that they will require to be provided prior to commencement of the assignment.

1. Beltaos. 2018. The 2014 ice-jam flood of the Peace-Athabasca Delta: Insights from numerical modelling. *Cold Regions Science and Technology* **155**, 367-380.

2. Independent Environmental Consultants. 2018. FINAL REPORT: Strategic Environmental Assessment of Wood Buffalo National Park. Markham, ON.

3. Peace-Athabasca Delta Implementation Committee (PADIC) 1987c. Garner, L. A., & Fonstad G. D. 1986. Peace-Athabasca water management works evaluation, final report. PADIC, under the Peace-Athabasca Implementation Agreement. Appendix C. Ancillary Studies. *Assessment of Creed Creek diversion*. Report. Alberta Department of the Environment, Water Resources Management Services, Technical Services Division, River Engineering Branch.

4. Peace-Athabasca Delta Implementation Committee (PADIC). 1987a. Peace-Athabasca Delta Water Management Works Evaluation – Final Report – A report prepared under the Peace-Athabasca Delta Implementation Agreement. Canada, AB and SK.

5. Peace-Athabasca Delta Implementation Committee (PADIC). 1987b. Peace-Athabasca Delta Water Management Works Evaluation – Appendix A – Hydrological Assessment. Canada, AB and SK.

6. Peace–Athabasca Delta Project Group (PADPG). 1973. Peace–Athabasca Delta Project, technical report and appendices. Vol. 1, Hydrological Investigations; Vol. 2, Ecological Investigations.

7. Peace-Athabasca Delta Technical Studies newsletter. 1995.

8. Peace-Athabasca Delta Technical Studies (PADTS), Peterson, M. 1993. Artificial Ice Jam 1992-93 Field Report – Task F.3 – Artificial Ice Strategies. Parks Canada, Fort Chipewyan, AB.

9. Peace-Athabasca Delta Technical Studies (PADTS), Wilson, E. 1995. Artificial Ice Dam 1994-95 Field Report – Task F.3 – Artificial Ice Strategies. Parks Canada. Ft. Chipewyan, AB.

10. Peace-Athabasca Delta Technical Studies (PADTS). 1996. Final Report. Parks Canada. Ft. Chipewyan, AB.

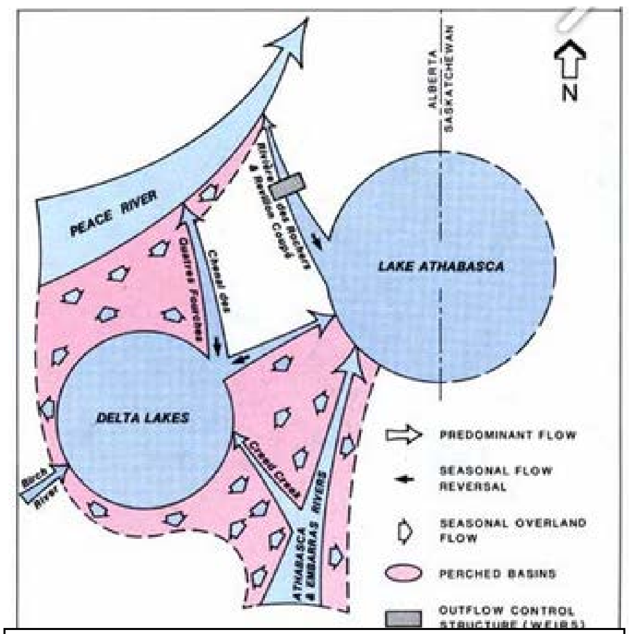
11. Peters, D. 2003. Controls on the Persistence of Water in Perched Basins of the Peace-Athabasca Delta. PhD. Thesis. Trent University. Ontario, Canada.

12. Peters, D. Prowse, T.D., Pietroniro, A., Leconte, R. 2006. Flood hydrology of the Peace-Athabasca Delta, northern Canada. *Hydrological Processes* **20**, 4073-4096.

13. Townsend, G. H. 1982. On Selecting a Control Structure for the Peace-Athabasca Delta. Canadian Wildlife Service, Western and Northern Region.

Excerpt from Lake Athabasca section of the Atlas of Alberta Lakes (available online: http://albertalakes.ualberta.ca/?page=lake&region=1&lake=18)

"Lake Athabasca is drained by Rivière des Rochers and its distributary, Revillon Coupé, which carry most of the outflow. Smaller volumes flow from the lake through Chenal des Quatre Fourches. These three rivers join the Peace River to form the Slave River.



Reproduced from the Atlas of Alberta Lakes Figure 1 of Lake Athabasca section.

Mamawi Lake, to the west of Lake Athabasca, is also drained by Chenal des Quatre Fourches. The volume of water leaving Lake Athabasca via Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches is partly dependent on the water level in the Peace River. The predominant direction of streamflow in the three channels is northward, toward the Peace River (Figure 1). During spring or summer flooding, however, flow reversals in the channels can occur when the elevation of the Peace River exceeds the elevation of Lake Athabasca. This results in reversed flows in Rivière des Rochers, Revillon Coupé and Chenal des Quatre Fourches. As well, flow reversals can occur between Lake Athabasca and the delta lakes. At these times, strong easterly winds cause water from Lake Athabasca to flow west into the southwestern arm of Chenal des Quatre Fourches and then into the delta lakes rather than north into the Peace River (PADIC 1987). When inflow from the Athabasca River to Lake Athabasca is high during spring and summer, an estimated 80% to 90% of the lake's outflowing water originates from the Athabasca River (Neill et al. 1981). During fall and winter, more of the outflow originates from the main body of the lake.

The drainage network of the delta is made up of open drainage and perched basins. The open drainage network is an interconnected system of lakes and streams. Its extent is related to water levels in the delta. Perched basins, which have surface levels higher than the surrounding water table, are located between the open-water drainages. They are separated from groundwater by impermeable beds, so their existence depends on flooding. The topography of the delta is quite flat, so minor changes in water levels can cause either extensive flooding or drought (PADIC 1987): In the mid-1960s, the Government of British Columbia created Williston Lake by constructing the W.A.C. Bennett Dam on the Peace River. The resulting low water levels downstream threatened the ecological balance in the Peace-Athabasca Delta when annual floods did not occur. In 1971, the governments of Canada, Alberta and Saskatchewan established the Peace-Athabasca Delta Project Group to evaluate methods of raising water levels in Lake Athabasca and the delta lakes (PADPG 1973). In the fall of 1971, a temporary rockfill dam was constructed on the southwestern arm of the Chenal des Quatre Fourches, near Mamawi Lake. On recommendation of the Peace-Athabasca Delta Project Group, the three governments signed the Peace-Athabasca Delta Implementation Agreement. The agreement gave high priority to conservation of the Peace-Athabasca Delta and the governments agreed to jointly construct control structures on Rivière des Rochers and Revillon Coupé.

In 1974, the temporary control structure on Chenal des Quatre Fourches was severely damaged by flooding. It was removed in 1975, and during 1975 and 1976, permanent control structures were built on Revillon Coupé and Rivière des Rochers (PADIC 1987). In order to allow movement of boats past the weir on Rivière des Rochers, a tramway was built in 1976 and upgraded in 1986. The tramway operates during the open-water season and is maintained by Alberta Environment. The success of the two weirs in restoring water levels in the delta and the effect of the weirs on the delta's biological community were evaluated during 1983 and 1984 by the Peace-Athabasca Delta Implementation Committee (1987). It was concluded that, although the weirs did not reproduce natural conditions, they had nearly restored peak summer water levels in the delta and had successfully counteracted many of the hydrological changes in the delta caused by regulation of the Peace River by the Bennett Dam. The weirs did not affect water levels in the Peace River, so the perched basins that relied on flooding from the Peace River were lost. “

Appendix F. Detailed scope of work for guidance

F.1 Details of past studies and water management actions at Dog Camp (Quatre Fourches)

West Arm of Quatre Fourches Rockfill Dam:

- Extremely low water levels were experienced in the Peace Athabasca Delta in the 3 years immediately following 1967 as the Williston Lake reservoir was filled, raising concerns about environmental effects of the Bennett Dam on the PAD, and leading to establishment in January 1971 of the Peace-Athabasca Delta Project Group (PADPG), a joint Canada-Alberta-Saskatchewan government committee. The committee was authorized to study the water level regime and associated problems, and to propose mitigating measures. The PADPG published its findings in 1973. The main findings were that regulation of the Peace River was causing a lower water level regime in the PAD, and that this was detrimental to the local bio-physical environment, with adverse effects on the socio-economic condition of the local people. The final recommendation was for two structures: a weir on the Rivière des Rochers and a control structure on the Revillon Coupé.
- As a preliminary measure, a temporary rockfill dam was built in the fall of 1971 on the West Arm of the Quatre Fourches River, which serves as the outlet of Mamawi Lake. The purpose of the dam was to raise the water levels in Lake Claire and Mamawi Lake and to refresh the adjacent perched basins.
- The West Arm of Quatre Fourches rockfill dam was an interim solution to the problem of low water levels. The effect of this dam, combined with the exceptional floods of 1972 and 1974, resulted in the highest water levels experienced on the Mamawi lake and Lake Clairesince construction of the Bennett Dam. In its 1973 assessment of the structure, the PADPG concluded that this type of structure was not suitable as a permanent solution because it would only control water levels in 60% of the PAD, and should be removed. It was predicted that this structure would reduce the flushing action required to maintain the chemical quality of the Delta lakes and would form a barrier to fish spawning migration. It would neither duplicate the timing and amplitude of the natural PAD water regime nor alleviate low water levels in Lake Athabasca, in the ACFN Reserve and in the marshes outside of Wood Buffalo National Park.
- The structure was severely damaged during a flood in early May 1974. In the fall of 1975/winter 1976, following completion of permanent weirs on Rivière des Rochers and Revillon Coupé, this structure was removed. Despite limitations to regulation at the Mamawi Lake outlet, the site was considered for a permanent gated control structure subsequent to the PADPG studies.
- Townsend (1982) highlighted the importance of seasonal fluctuations of water levels in the PAD to maintain its flora and fauna, especially the abrupt spring flooding and rapid drawdown of water levels in the fall. When the West Arm of the Quatre Fourches River was blocked off, resulting in prolonged summer and fall flooding, negative impacts resulted on meadow communities, emergent aquatic vegetation at lower elevations, and to muskrat through their dependence on aquatic emergent for food. If the meadows remain flooded during freeze-up, they become unavailable for foraging by bison in winter. Water level fluctuations are equally important for staging habitat for waterfowl.

- The submerged rockfill weirs on Rivière des Rochers and Revillon Coupé are still in place, and while they have generally restored peak annual water levels on the large delta lakes, they have also raised mean and minimum water levels, and attenuated the ecologically-dependent seasonal water level fluctuations (PADIC 1987).

West Arm of Quatre Fourches Gated Control Structure Feasibility Study:

- In 1984, the Fort Chipewyan Hunters and Trappers Association expressed concerns to the PADIC about the drying up of the perched basins surrounding Lake Claire and Mamawi Lake. PADIC in turn requested Agriculture Canada, Prairie Farm Rehabilitation Administration (PFRA) to examine the technical feasibility of constructing a permanent gated control structure on the outlet channel of Mamawi Lake.
- The purpose of the structure was to manage water levels in Lake Claire and Mamawi Lake to their natural hydrological regimes. Recharging these lakes to their natural regime would recharge the perched basins surrounding these lakes. The study included a review of background information, a feasibility level design and cost estimate, and an evaluation of the impacts of the structure on the water levels of the Delta lakes (PFRA, 1986).
- While the Rochers and Coupe weirs increased water levels in Mamawi Lake compared to having on the Bennett dam in place, the fluctuations are not as great as under natural conditions (Figure F1). As noted above, the weirs also do not function to flood the perched basins, which was the concern raised at the time, and which remains today.
- As noted in the Peace-Athabasca Delta Technical Studies Final Report (1996), the design was never implemented as it was determined that while such a structure could restore peak water levels in Lake Claire and Mamawi Lake, it could not restore the equally important low fall and winter water levels because of the effects of the existing Revillon Coupé and Rivière des Rochers weirs.
- The final PADIC summary report (1987a) concluded that "If the capacity of Creed Creek continues to increase as it presently appears to be doing, the comparative water level simulation showed that a control structure on the Quatre Fourches Channel would not restore the hydrologic regime of the Delta Lakes to natural conditions as the outlet channel of Mamawi Lake appears to have insufficient capacity to release the additional water [...] Any control structure which further delays the outflow would only increase the difference between the existing and natural hydrologic regime. […] The effectiveness of any gated control structure built on the Quatre Fourches outlet channel of Mamawi Lake would be determined by operation of the gates. If the structure is built in the future, a model will have to be developed to predict water levels so that the control structure can be operated to achieve desired target levels."

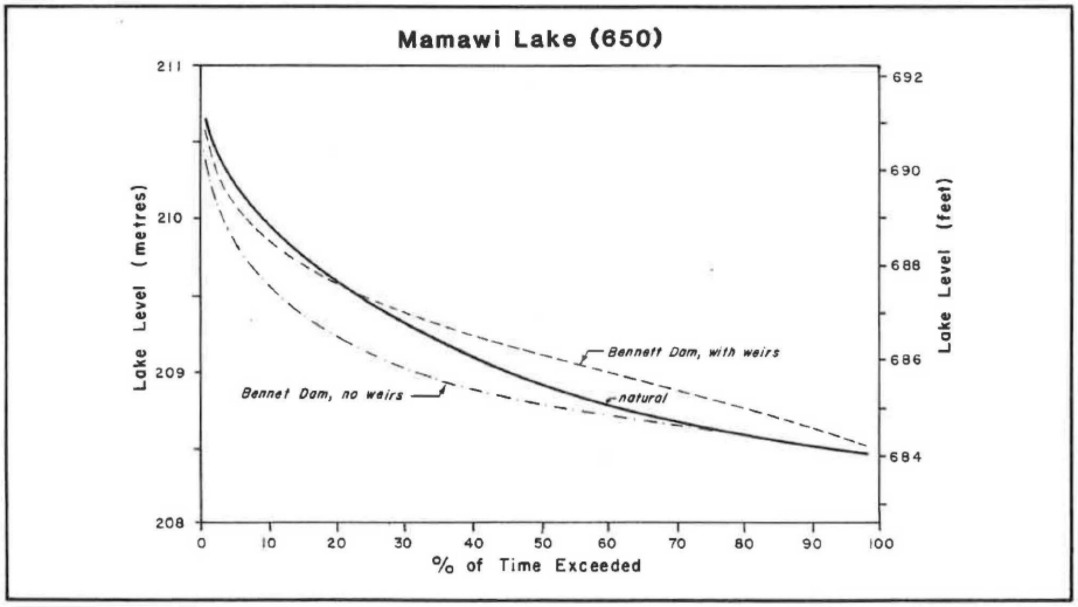


Figure F1. Mamawi Lake water level frequency-duration curves (PFRA, 1986). Note how the natural condition has the steepest curve, reflecting greater variability in seasonal fluctuations.

<u>Temporary Ice Dams on West Arm Quatre Fourches</u>:

- In the effort to raise water levels in Lake Athabasca, ice dams were first investigated to block the Rivière des Rochers at Little Rapids by using cryopiles to create an ice mass in January and keeping it frozen until after break-up. Field tests were conducted in 1972 (PADPG 1973), however that method was not considered feasible and not pursued.
- in 1993 the Governments of Canada and Alberta, BC Hydro and Power Authority, the Mikisew Cree First Nation, the Athabasca Chipewyan First Nation, and the Fort Chipewyan Metis Association signed a Memorandum of Understanding to establish Peace-Athabasca Delta Technical Studies to study the effects of regulation and climate variability on river flows and hydrological processes of the PAD, particularly related to flooding of perched basins.
- The initial testing of inducing artificial ice jamming was done on the north branch of the Quatre Fourches River in the winter of 1993. A late start to building up ice and a thermal break-up of ice in the spring resulted in no significant ice jamming (Peterson 1993).
- One of the experiments stemming from this research included a temporary ice dam that was constructed at Dog Camp in the winter of 1994-1995. The objective of this seasonal ice dam was to restrict the exit of the spring flow that enters Mamawi Lake from the Athabasca River, the Birch River and other minor tributaries and to elevate water levels in Mamawi Lake and Lake Claire. This would then increase the probability of flooding the basins that are hydraulically connected with these lakes (Wilson, 1995).
- Ultimately, the ice dam was unsuccessful at producing a flood due to a mild winter, low water levels, and minimal spring runoff, resulting in a thermal break-up of the ice; no further attempts to create temporary ice dams ensued (Wilson, 1995).

F.2 Details of past study at Big Egg Lake on the ACFN Jackfish Reserve

- Water control structures have been investigated several times for the Big Egg Lake on ACFN reserve 201 (Jackfish reserve). Although the Big Egg Lake control structure went to fairly detailed design, it was not implemented. The original investigation in 1987 (W-E-R Engineering Report) includes the Big Egg Lake site; the 1994 PAD Technical Study focuses on the Big Egg Lake site. The Chipewyan IR 201 Big Egg Lake Site Specifications schedule D provides drawings for Big Egg Lake site, plus an updated cost estimate at the time.

F.3 Hydraulic Models of the Delta Lakes

- Currently, due to changes in the delta and technology, there is no readily usable hydrodynamic model to simulate water levels in this portion of the PAD; however historical satellite images of past flooding are available and so are coarse-level DEMs such as the SRTM data available for download from the USGS with an approximate 30m x 30 m horizontal resolution and a 1 – 10m vertical resolution. Indigenous knowledge will be a key component in understanding past flooding impacts.
- Two previous hydrodynamic models of the PAD exist. The 1972 Stanley model, which treats the delta lakes and channels with Lake Athabasca as a single water body, informed the selection and design of the Rivière des Rochers and Révillon Coupe weirs. The other model was the PAD Implementation Committee’s 1-D hydrodynamic model, which described varied water levels in the PAD’s network of lakes and channels, with and without the Rivière des Rochers and Révillon Coupe control structures, and assessed the effects of these structures on water levels in the PAD (PADIC 1987a, 1987b).
- As part of the PFRA’s Technical Feasibility Study of the Quatre Fourches Control Structures (PFRA 1986), PFRA modified the 1-D PADIC model to simulate storage in perched basins and to simulate the 1982 breakthrough diversion of Embarrass River water to Lake Mamawi through Creed Creek (PADIC 1987b).