NORTHWEST TERRITORIES
POWER
CORPORATION
Empowering Communities

Health, Safety, & Environment, 4 Capital Drive, Hay River, NT X0E 1G2

~~February 25, 2019~~

Tyree Mullaney, EP
Regulatory Officer
Mackenzie Valley Land and Water Board
7th Floor, 4922 48th St, PO Box 2130
Yellowknife, NT | X1A 2P6
tyree@mvlwb.com

Water Licence Renewal Application for the Jackfish Lake Generating Station in Yellowknife, NT

Hello Tyree,

The Northwest Territories Power Corporation (NTPC) owns and operates the Jackfish Generating Facility, located on the northeast shore of Jackfish Lake in Yellowknife, Northwest Territories. The facility contributes power to the North Slave electrical system when required. It consists of three separate plants: the CAT plant, E.M.D. plant, and K plant. Each plant has an engine cooling system that uses water from Jackfish Lake.

The cooling systems for each plant and their use of water from Jackfish Lake are regulated under the Type A Water Licence N1L1-1632, which is held with the Mackenzie Valley Land and Water Board (MVLWB). This water licence was issued in 1995 and expires on December 31, 2019.

In order to maintain compliance NTPC has prepared the following application package to renew the Water Licence for the Jackfish Lake Generating Facility, which is located within Lot 1054, Reserve Number R657T.

This application package is comprised of:

1. MVLWB Water Licence Application form
2. Copy of Reserve Number R657T
3. Jackfish Lake Generating Facility- General Site Diagrams and GIS Data
4. Jackfish Lake Generating Facility- Cooling System Detailed Blueprints
5. Jackfish Lake Generating Facility- Engagement Plan
6. Jackfish Lake Generating Facility- Engagement Log
7. Jackfish Lake Generating Facility- Operations, Maintenance and Surveillance Manual
8. Jackfish Lake Generating Facility- Spill Contingency Plan
9. Jackfish Lake Generating Facility- Waste Management Plan
10. Jackfish Lake Generating Facility- Public Safety and Awareness Plan

Health, Safety, & Environment, 4 Capital Drive, Hay River, NT X0E 1G2

February 25, 2019

11. Jackfish Lake Generating Facility- Conceptual Abandonment and Restoration Plan
12. Hydro Electric Development Questionnaire
13. Jackfish Lake 2018 Environmental Monitoring Report
14. Jackfish Lake Generating Facility- 2018 Discharge Quality Report
15. Proposed Draft Water Licence Conditions

The full application package has been uploaded as an FTP submission on the Online Review System for the MVLWB. If you have any questions regarding this application or if there is any further information we can provide please contact me at (867) 874 - 5314 or email mmiller@ntpc.com.

Sincerely,

Matthew Miller, M.Sc., P.Eng.
Senior Environmental Licensing Specialist
Northwest Territories Power Corporation

Mackenzie Valley Land and Water Board
7th Floor - 4922 48th Street, PO Box 2130
Yellowknife, NT. X1A 2P6
867-669-0506
867-873-6610
mvlwb.com

Water Licence Application Form

(Subsection 6(1) of the Northwest Territories Water Regulations)

APPLICATION/LICENCE NO: MV2019L1-00**

(Amendment or Renewal only)

1. NAME AND MAILING ADDRESS OF APPLICANT

Applicant's Name	Northwest Territories Power Corporation		
Mailing Address	4 Capital Drive, Hay River, NT		
Community	Hay River		
Prov/Terr	NT	Postal Code	X0E 1G2
Telephone	867-874-5314	Fax	
Email	mmiler@ntpc.com	Other	

2. ADDRESS OF HEAD OFFICE IN CANADA IF INCORPORATED

Mailing Address	Same as above		
Community			
Prov/Terr		Postal Code	
Telephone		Fax	

3. LOCATION OF UNDERTAKING

(Describe and attach a map, indicating watercourses and location of any proposed waste deposits)

See attached Figures 1.1 and 1.2.

Longitude 114° 23'00" W Latitude 62° 28'10" N

4. DESCRIPTION OF UNDERTAKING

(Describe and attach plans)

The NTPC owns and operates the Jackfish diesel generating facility, which is located on the northeast shore of Jackfish Lake in Yellowknife, Northwest Territories (NT). The Jackfish facility contributes power to the North Slave electrical system, when required, and is comprised of three separate plants: the CAT plant, E.M.D. plant, and K plant. Each plant has an engine cooling system that uses water from Jackfish

5. TYPES OF UNDERTAKING

Power

The Jackfish Facility is a back-up power generating facility for the North Slave Electrical System.

6. WATER USE

Other (describe)

Cooling of the CAT plant, E.M.D. plant, and K plant. Water returned to source.

7. QUANTITY OF WATER INVOLVED

(Litres per second, litres per day or cubic metres per year, including both quantity to be used and quality to be returned to source)

Less than 50,000 cubic meters per day

8. WASTE DEPOSITED

(Quantity, quality, treatment and disposal)

9. OTHER PERSONS OR PROPERTIES AFFECTED BY THIS UNDERTAKING

(Give name, mailing address and location; attach list if necessary)

See attached
Jackfish Lake Generating Facility- Engagement Plan
Jackfish Lake Generating Facility- Engagement Log
Jackfish Lake Generating Facility- Public Safety and Awareness Plan

10. PREDICTED ENVIRONMENTAL IMPACTS OF UNDERTAKING AND PROPOSED MITIGATION

See attached
Jackfish Lake Generating Facility- Spill Contingency Plan
Jackfish Lake Generating Facility- Waste Management Plan
Jackfish Lake 2018 Environmental Monitoring Report
Jackfish Lake Generating Facility- 2018 Discharge Quality Report
Jackfish Lake Generating Facility- OMS Manual

11. CONTRACTOR AND SUB-CONTRACTORS

(Names, addresses and functions)

N/A

12. STUDIES UNDERTAKEN TO DATE

(Attach list if necessary)

See attached
Jackfish Lake 2018 Environmental Monitoring Report
Jackfish Lake Generating Facility- 2018 Discharge Quality Report

13. PROPOSED TIME SCHEDULE

Start Date: 01-Jan-2020

Completion Date: 12/31/40

Matthew Miller
Name (Print)

Senior Environmental Licensing Sp
Title (Print)

Matthew Miller Digitally signed by Matthew Miller DN: cn=Matthew Miller, o=NTPC, ou, email=mmiller@ntpc.com, c=CA Date: 2019.02.25 21:21:23 -07'00'
Signature

25-Feb-2019
Date

FOR OFFICE USE ONLY

Application Fee	Amount:		Receipt No.:	
Water Use Deposit	Amount:		Receipt No.:	

Please make all cheques payable to the Receiver General for Canada.

Hydro-electric Development Questionnaire to Accompany Water License Applications to the Mackenzie Valley Land and Water Board

Mackenzie Valley Land and Water Board
7th Floor - 4910 50th Avenue
P.O. Box 2130
YELLOWKNIFE NT X1A 2P6
Phone (867) 669-0506
FAX (867) 873-6610

Regulating the use of land and waters and the deposit of waste, and enabling residents to participate in the management of resources to provide optimum benefit to the residents of the settlement areas and of the Mackenzie Valley and to all Canadians.

May 2007

The purpose of this questionnaire is to solicit supplemental information from an applicant to support his/her application for a water licence (or renewal). It is anticipated that the completion of this questionnaire will reduce delays arising from the Board having to solicit additional information after an application has already been submitted. This information will also be useful during the pre-screening of your application, which must be undertaken prior to development and approval of a water licence to determine if the project needs to be referred to the Mackenzie Valley Environmental Impact Review Board.

The applicant should complete the questionnaire to the best of his/her ability, recognizing that some questions may not be relevant to the project under consideration. For questions that do not relate to his/her operation, the applicant is requested to indicate “N/A” (Not Applicable).

If any questions arise while completing the questionnaire, the applicant may wish to contact the Mackenzie Valley Land and Water Board at (867) 669-0506.

Table of Contents **Page**

PLEASE PRINT OR TYPE YOUR RESPONSES

NOTES:

If space is insufficient for any of the responses on this questionnaire, use the back of the sheet or an attachment.

A number of sections in the questionnaire solicit information on water quality and waste management which must be provided in accordance with specific policies and guidelines: the Board's *Water and Effluent Quality Management Policy*; the Board's *Guidelines for Developing a Waste Management Plan*; and INAC's *Guidelines for Spill Contingency Planning*. The Board's policies and guidelines are accessible at www.mvlwb.com or by calling the Board. INAC's *Guidelines for Spill Contingency Planning* are available at http://www.ainc-inac.gc.ca/ai/scr/nt/pdf/SCP-EUD-eng.pdf). Please provide separate plans and/or reports to address these information requirements as part of the completed application package. Reference the relevant title(s) of the plans and/or reports in the body of the questionnaire.

SECTION 1 – GENERAL

Date: **February 18, 2019**

1.1 Applicant **Northwest Territories Power Corporation**
(company, corporation, owner) (telephone no.)

4 Capital Drive, Hay River, NT X0E 1G2
(postal address)

Property Name: **Jackfish Lake Generating Facility**

Closest Community: **Yellowknife**

Latitude/Longitude: **62° 28'10.19 N/114° 22'52.54**

1.2 Environmental Contact: **Matthew Miller**
(name)

1-867-874-5314
(telephone no.)

Senior Environmental Licensing Specialist
(title)

1.3 Attach two detailed maps identifying the project site in relation to local geographical features. Maps should be drawn at a scale of 1:50, 000.

Map 1 – Showing the location of the Site in relation to neighbouring roads, lands, and waterbodies, including:

- Lake, stream and river locations, including but not limitied to the tertiary watershed boundary in which proposed project is found, and location of property boundaries.

Map 2 – Map of the proposed project, this should include:

- Location of powerhouses, dams, water conduits, water impoundments and other works and structures as applicable to the proposed project;
- Area to be flooded, if any, by the proposed project;
- Access road location to the project site, and;
- Anticipated transmission line route from Site to grid.

SECTION 2 –STREAM FLOW INFORMATION

2.1 Provide the following Stream Flow information:

Maximum Annual Flow (m^3/s): **N/A**

Minimum Annual Flow (m^3/s): **N/A**

Mean Annual Flow (m^3/s): **N/A**

Source of Stream Flow information (gauge number):

N/A

Length of Stream Flow Record: **N/A**

Estimate the peak instantaneous 100, 20 and 2 year flood: **N/A**

Provide methodology for calculation. If more space is required, please attach a separate sheet.

Not applicable as water is used for cooling and returned to source lake.

SECTION 3 – POWER PRODUCTION

3.1 Type of Project – Please check appropriate boxes:

*a) Peaking **X**	*b) Intermediate	*c) Run-of-River	*d) Pumped Storage
*e) Attended **X**	*f) Unattended	*g) Interconnected **X**	*h) Embedded Energy

**a) Peaking: Inflows can be stored and then released at peak energy demands*

**b) Intermediate: Run of River facility with peaking capabilities*

**c) Run-of-River: Little or no upstream storage capacity*

**d) Pumped Storage: Water pumped to storage reservoir, usually during off-peak periods*

**e) Attended: Individual on site to operate*

**f) Unattended: Remotely accessed (e.g. operated by a computer)*

*** Energy production expected in an average year of flow*

**g) Interconnected: Requires connection to the grid*

**h) Embedded Energy: Local distribution - energy for off-grid use*

3.2 Describe Type of Operation Strategy, including river and reservoir management: (if any)

NTPC owns and operates the Jackfish Lake Generating Facility, which is located on the northeast shore of Jackfish Lake in Yellowknife, Northwest Territories (NT). The Jackfish facility uses diesel generators to contribute power to the North Slave electrical system, when required, and is comprised of three separate plants: the CAT plant, E.M.D. plant, and K plant. Each plant has an engine cooling system that uses water from Jackfish Lake in a closed loop system.

3.3 Capacity:

(a) Estimate Project Site Capacity	(b) Estimate Average Annual Production*	(c) Firm Capacity
25.4 MW	**__5-150___GWH**	**25.4 MW**

3.4 Head:

(a) Natural Head	(b) Proposed Developable Head
N/A (m)	**N/A (m)**

3.5 Drainage Area

(a) Drainage Area	(b) Area to be flooded
N/A km^2	**N/A km^2**

3.6 Conceptual Design Flow Rate **N/A m/s^3**

SECTION 4 – ENVIRONMENTAL MONITORING PROGRAM

4.1 Has any baseline data been collected for the main waterbodies in the area prior to development?

Yes _________ No **Yes – Jackfish Lake Baseline Environmental Monitoring (Existing Conditions) Report collected in 2018**

4.2 If "Yes", include all data gathered on the physical, biotic and chemical characteristics at each sampling location. Identify sampling locations on a map.

See – Jackfish Lake Baseline Environmental Monitoring (Existing Conditions) Report collected in 2018

4.3 Provide an inventory of hazardous materials on the property and storage locations. (attach separate map)

See Attached Spill Contingency Plan for Jackfish Lake Generating Facility

4.4 Attach the present or proposed contingency plan which describes course of action, mitigative measures and equipment available for use in the event of system failures and spills of hazardous materials.

See Attached Spill Contingency Plan for Jackfish Lake Generating Facility

4.5 If applicable, provide a brief overview of the conceptual abandonment and restoration plan for the site.

See Attached Conceptual Abandonment and Restoration Plan for Jackfish Lake Generating Facility

SECTION 5 – PRESCREENING

In addition to providing sufficient technical and related information for licensing to proceed, applicants must provide adequate descriptive information to ensure that an initial pre-screening decision can be made prior to a project proceeding for regulatory approvals.

Your application and other project details, such as this questionnaire, will be sent out for review to First Nations, local aboriginal groups, communities, and territorial and federal government agencies. Their comments (e.g., regarding the significance of project impacts) are considered before a decision is made to allow the project to proceed.

5.1 Has this project ever undergone an initial environmental review, including previous owners?

Yes **X** By whom/when **Northwest Territories Water Board/ 1995 – Licence N1L1-1632-**

NTPC does not have copies of the application documents

No ______________ Unknown ____________________________

5.2 Has any baseline data collection and evaluation been undertaken with respect to the various biophysical components of the environment potentially affected by the project (e.g., wildlife, soils, air quality), in addition to water related information requested in this questionnaire?

Yes Jackfish Lake Baseline Environmental Monitoring Report (Existing Conditions) collected in 2018

No _______ Unknown ____

5.3 Has any meteorological data been collected at or near the site? (e.g., precipitation, evaporation, snow, wind)

Yes X______ No _______**Yellowknife Airport meteorological station**

5.4 If "Yes", please include data and attach copies of reports or cite titles, authors and dates.

Yellowknife Airport – Climate.weather.gc.ca

5.5 If "No", are such studies being planned? Briefly describe the proposals.

5.6 Has authorization been obtained or sought form the Department of Fisheries and Oceans for proposed project activities?

Yes ______ **No X____ Conversations with DFO are ongoing**

5.7 Has a socio-economic impact assessment or evaluation of this project been undertaken? (This would include a review of any public concerns, land, water and cultural uses of the area, compensation, local employment opportunities, etc.)

Yes X____ No ______ Unknown ______

5.9 If "Yes", please describe the proposal briefly.

NTPC has been engaged with stakeholders and regulators throughout the operation of the facility. Recently NTPC has also engaged with all stakeholders in the region regarding the water licence renewal. Multiple emails were sent to all stakeholders which were followed by phone calls to receive feedback on the application. NTPC received feedback from all stakeholders and met with key stakeholders in person for a more in-depth conversation. NTPC also advertised the renewal to the public through newspaper and social media advertisements. The details of this thorough engagement process are outlined in the Jackfish Lake Generating Facility Engagement Plan and Engagement Log.

5.10 Has this project ever undergone an initial environmental review, including previous owners?

Yes X By whom/when **Various environmental assessment have taken place since the facility began operating included as part of obtaining Northwest Territories Water Board Licence N1L1-1632 in 1995 NTPC does not have copies of the application documents**

No ______________ Unknown ____

5.11 Has any baseline data collection and evaluation been undertaken with respect to the various biophysical components of the environment potentially affected by the project (e.g., wildlife, soils, air quality), in addition to water related information requested in this questionnaire?

Yes X Jackfish Lake Baseline Environmental Monitoring Report (Existing Conditions) collected in 2018

No _______ Unknown ____

5.12 Has any meteorological data been collected at or near the site? (e.g., precipitation, evaporation, snow, wind)

Yes X______ No ________**Yellowknife Airport meteorological station**

5.13 If "Yes", please include data and attach copies of reports or cite titles, authors and dates.

Yellowknife Airport – Climate.weather.gc.ca

5.14 If "No", are such studies being planned? Briefly describe the proposals.

N/A

5.16 Has authorization been obtained or sought form the Department of Fisheries and Oceans for dewatering or using any waterbodies for containment of waste?

Yes ______ No **N/A**

5.17 Please attach an outline briefly describing any options or alternatives considered or rejected for the various mine components outlined in this questionnaire (e.g., mill site, water supply sources, locations for ore and waste piles).

N/A

5.18 Has a socio-economic impact assessment or evaluation of this project been undertaken? (This would include a review of any public concerns, land, water and cultural uses of the area, implications of land claims, compensation, local employment opportunities, etc.)

Yes X No ______ Unknown ______

5.19 If "Yes", please describe the proposal briefly.

NTPC has been engaged with stakeholders and regulators throughout the operation of the facility. Recently NTPC has also engaged with all stakeholders in the region regarding the water licence renewal. Multiple emails were sent to all stakeholders which were followed by phone calls to receive feedback on the application. NTPC received feedback from all stakeholders and met with key stakeholders in person for a more in-depth conversation. NTPC also advertised the renewal to the public through newspaper and social media advertisements. The details of this thorough engagement process are outlined in the Jackfish Lake Generating Facility Engagement Plan and Engagement Log.

SECTION 6 – LIST OF ATTACHMENTS

	Reference to Question #	Title	Number of pages
1.	4.3: 4.4	Spill Contingency Plan_	
2.	4.5	Conceptual Abandonment and Restoration Plan	
3.	4.1; 4.2: 5.2; 5.11	Environmental Monitoring Report	
4.	Waste Management Plan__		
5.		Public Safety Plan___________	
6.		Operations and Maintenance Plan_	
7.		Effluent Quality Conditions____	
8.	5.19	Engagement Plan___________	
9.	5.19	Engagement Log____________	

Prepared by: **Matthew Miller**_________________________

Title: **Senior Environmental Licensing Specialist** _

Completion Date: **February 16, 2019**______________________

Northwest
Territories Municipal and Community Affairs

105-Q85J/8-1054

May 3, 2005

NWT Power Corporation
4 Capital Drive
HAY RIVER, NT X0E 1G2

To Whom It May Concern:

Lot 1054, Quad 85J/8, Plan 2696
Jackfish Power Plant – Yellowknife, NT

Please be advised that we have consolidated three previous reserve numbers into one. The following reserve numbers have been deleted R041T, R361T and R362T.

The new Reserve number is R657T for the above noted lot.

I trust the above is satisfactory. If you have and questions, please contact the undersigned at 920-8082.

Sincerely,

Robin Sproule
Robin Sproule
Senior Lands Officer
North Slave Regional Office

ATLAS
Government of
Northwest Territories

Jackfish Lake NTPC Reserve

Legend
- Block Land Transfer Boundaries
- Municipal Boundaries
- Obsolete Sketches
- Surveyed Parcels
- Surveyed Easements
- Surface Land Withdrawal

Scale 1: 2,000

50 metres

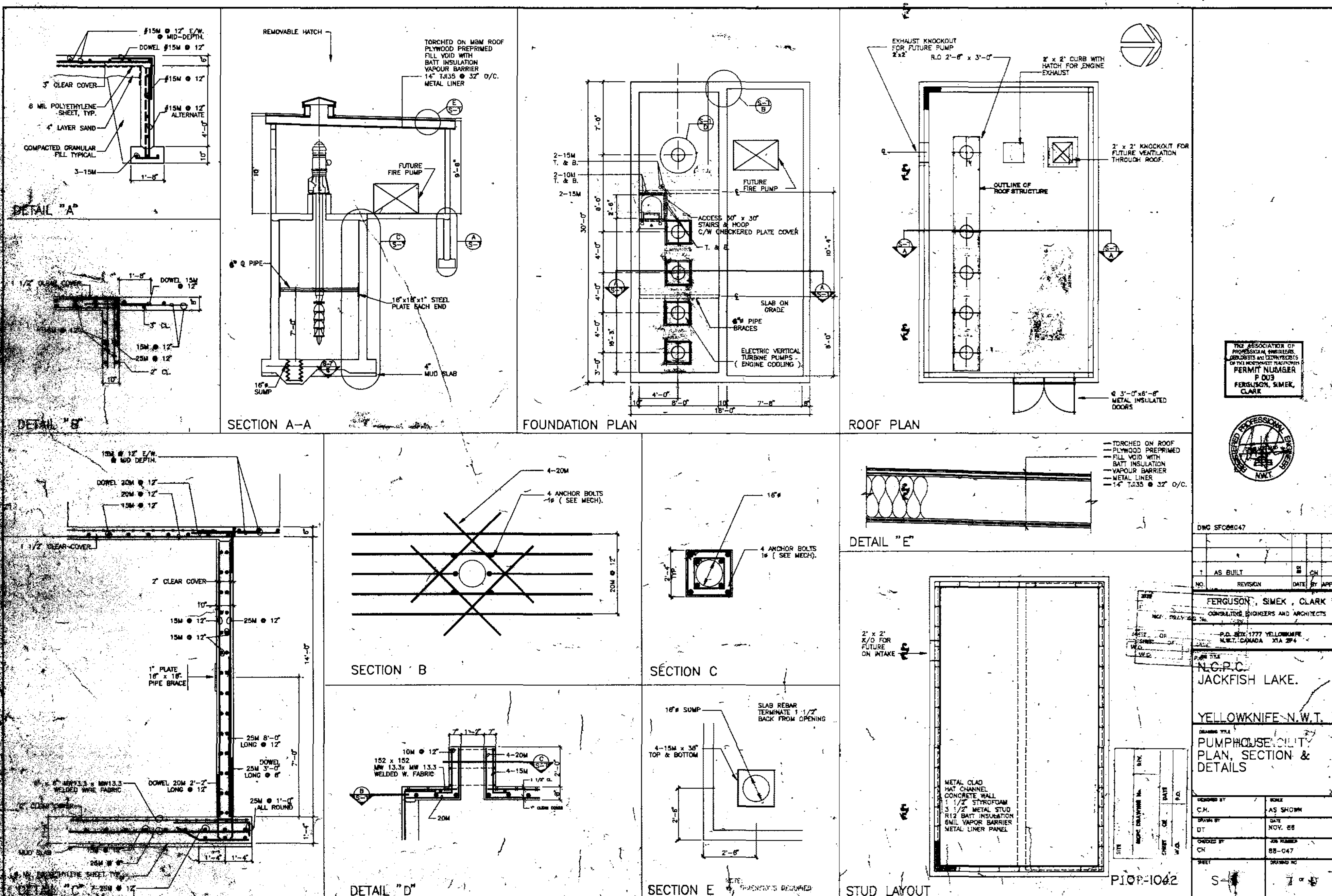
February 5, 2019

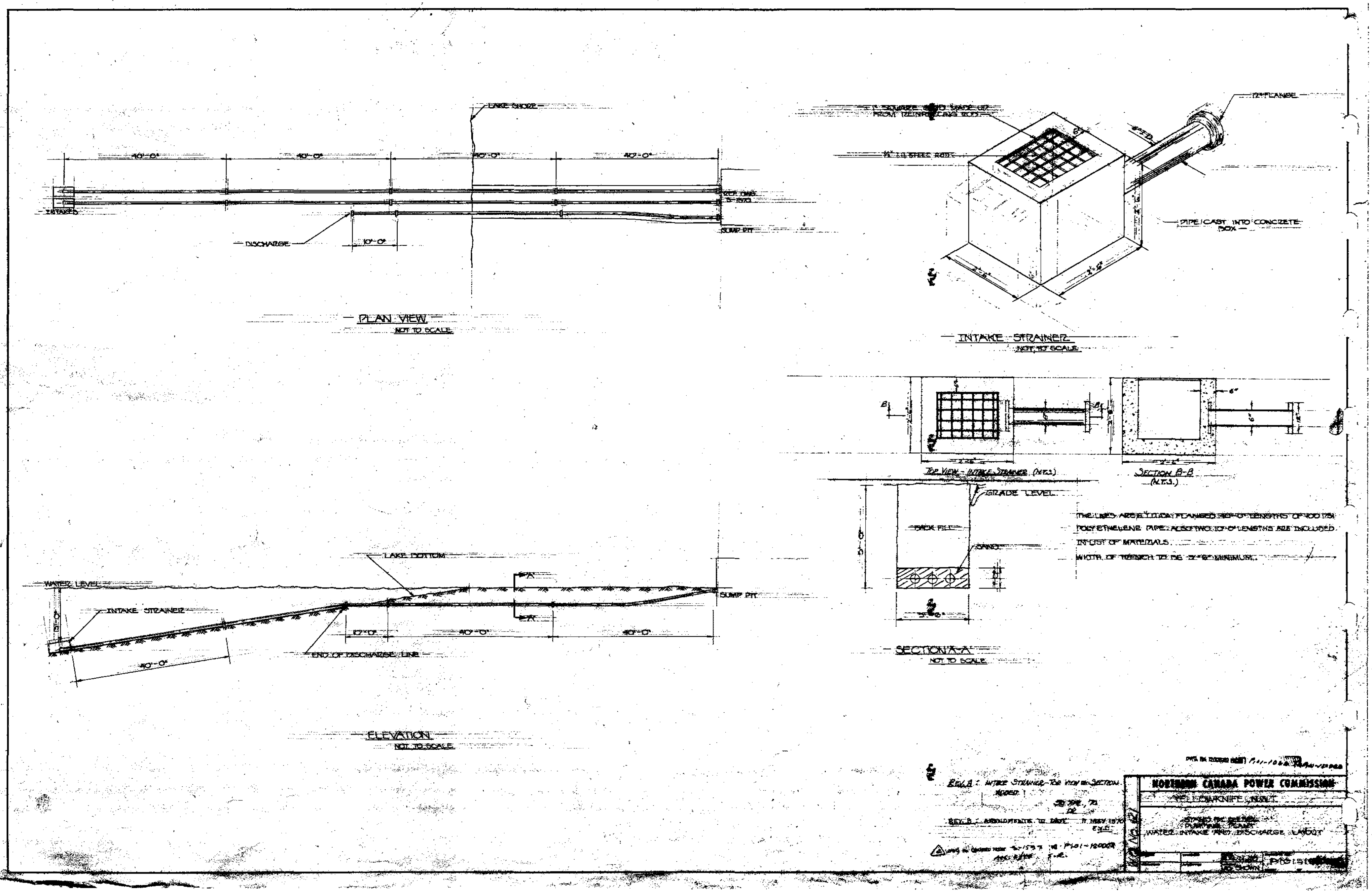
UTM Zone: 11

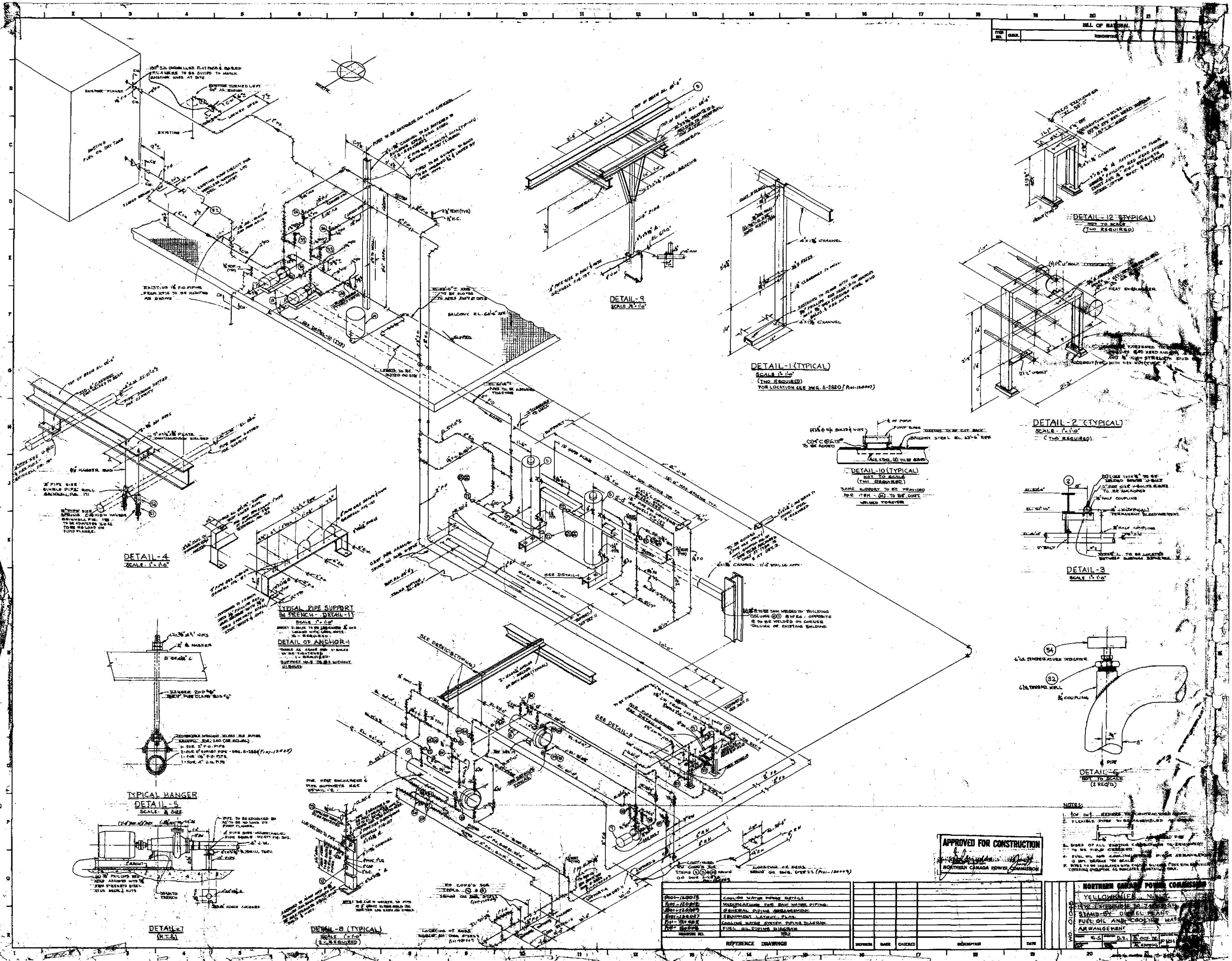
NORTHWEST TERRITORIES
POWER
CORPORATION
Empowering Communities

COOLING SYSTEM DETAILED BLUEPRINTS

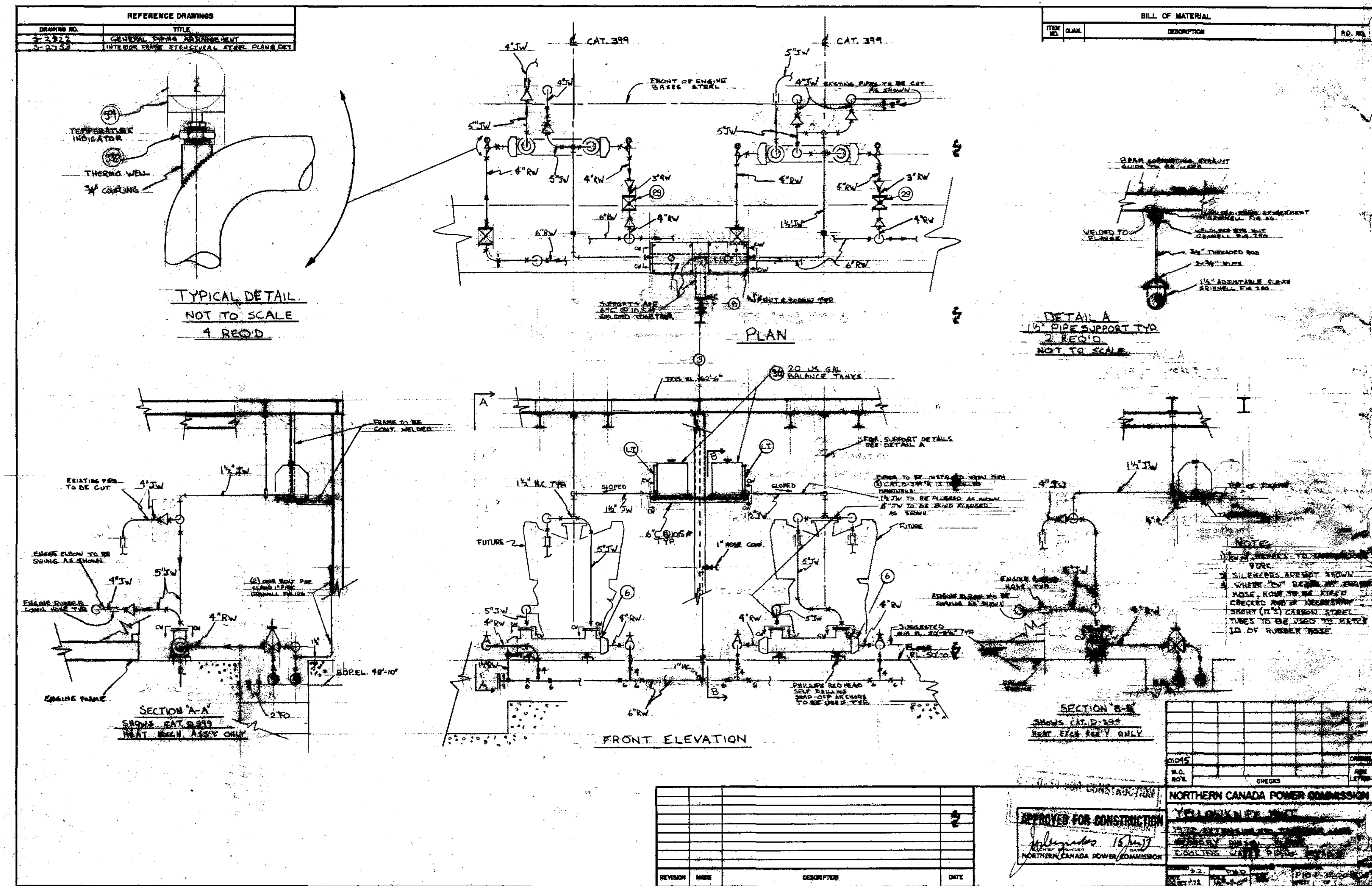
JACKFISH LAKE
GENERATING FACILITY, NWT
PLANT #120
YEELOWKNIFE, NORTHWEST TERRITORIES


DETAIL "A"
DETAIL "B"
SECTION A-A
FOUNDATION PLAN
ROOF PLAN
DETAIL "C"
SECTION B
SECTION C
DETAIL "E"
DETAIL "D"
SECTION E
STUD LAYOUT
REMOVABLE HATCH
TORCHED ON M&M ROOF
PLYWOOD PREPRIMED
FILL VOID WITH
BATT INSULATION
VAPOUR BARRIER
14" TJI35 @ 32" O/C.
METAL LINER
FUTURE FIRE PUMP
16"x16"x1" STEEL PLATE EACH END
4" MUD SLAB
16"ø SUMP
ACCESS 30" x 30" STAIRS & HOOP C/W CHECKERED PLATE COVER
SLAB ON GRADE
ELECTRIC VERTICAL TURBINE PUMPS (ENGINE COOLING)
EXHAUST KNOCKOUT FOR FUTURE PUMP
2' x 2' CURB WITH HATCH FOR ENGINE EXHAUST
2' x 2' KNOCKOUT FOR FUTURE VENTILATION THROUGH ROOF.
OUTLINE OF ROOF STRUCTURE
3'-0"x6'-8" METAL INSULATED DOORS
4-20M
4 ANCHOR BOLTS 1ø (SEE MECH).
SLAB REBAR TERMINATE 1 1/2" BACK FROM OPENING
METAL CLAD
HAT CHANNEL
CONCRETE WALL
1 1/2" STYROFOAM
3 1/2" METAL STUD
R12 BATT INSULATION
6MIL VAPOR BARRIER
METAL LINER PANEL
P1OP-1042
THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF THE NORTHWEST TERRITORIES
PERMIT NUMBER P 003
FERGUSON, SIMEK, CLARK
REGISTERED PROFESSIONAL ENGINEER N.W.T.
DWG SFC88047
1 AS BUILT
FERGUSON , SIMEK , CLARK
CONSULTING ENGINEERS AND ARCHITECTS
P.O. BOX 1777 YELLOWKNIFE N.W.T. CANADA X1A 2P4
N.C.P.C.
JACKFISH LAKE.
YELLOWKNIFE N.W.T.
PUMPHOUSE FACILITY
PLAN, SECTION &
DETAILS
C.H.
AS SHOWN
DT
NOV. 88
CH
88-047
S-1

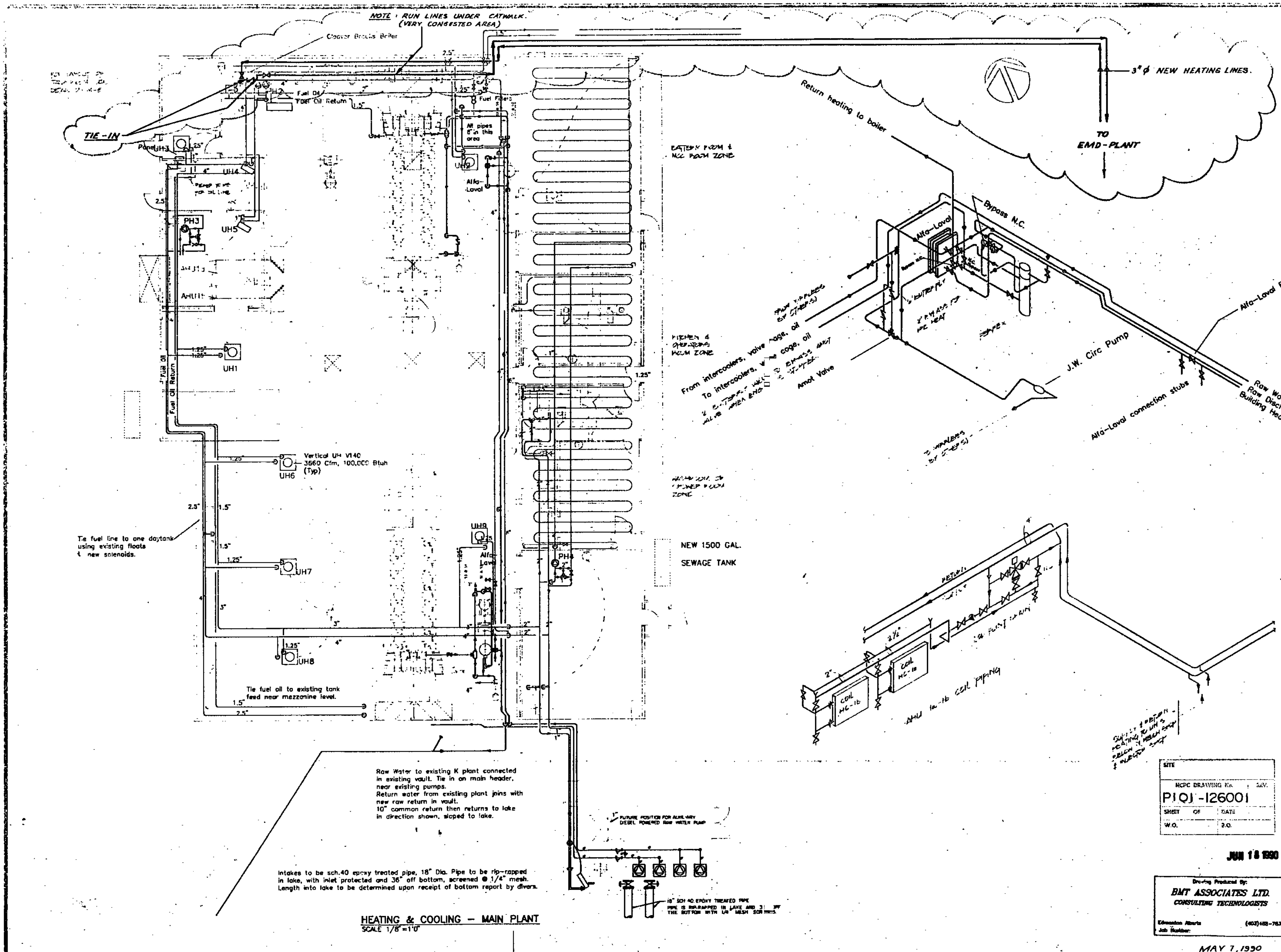

LAKE SHORE
40'-0"
INTAKE
DISCHARGE
10'-0"
SUMP PIT
PLAN VIEW
NOT TO SCALE
12" FLANGE
1/2" I.D. STEEL ROD
PIPE CAST INTO CONCRETE BOX
INTAKE STRAINER
NOT TO SCALE
TOP VIEW - INTAKE STRAINER (N.T.S.)
SECTION B-B
(N.T.S.)
GRADE LEVEL
BACK FILL
SAND
SECTION 'A-A'
NOT TO SCALE
WIDTH OF TRENCH TO BE 3'-6" MINIMUM.
IN LIST OF MATERIALS.
LAKE BOTTOM
WATER LEVEL
INTAKE STRAINER
END OF DISCHARGE LINE
ELEVATION
NOT TO SCALE
REV. A: INTAKE STRAINER - TOP VIEW & SECTION ADDED
REV. B: AMENDMENTS TO DATE 11 MAY 1970
NORTHERN CANADA POWER COMMISSION
YELLOWKNIFE, N.W.T.
WATER INTAKE AND DISCHARGE LAYOUT
AS SHOWN



BILL OF MATERIAL
DETAIL-9
SCALE 3/4"=1'-0"
DETAIL-1 (TYPICAL)
SCALE 1"=1'-0"
(TWO REQUIRED)
FOR LOCATION SEE DWG. S-2820 (P101-120007)
DETAIL-12 (TYPICAL)
NOT TO SCALE
(TWO REQUIRED)
DETAIL-2 (TYPICAL)
SCALE 1"=1'-0"
(TWO REQUIRED)
DETAIL-10 (TYPICAL)
NOT TO SCALE
(TWO REQUIRED)
DETAIL-3
SCALE 1"=1'-0"
DETAIL-4
SCALE 1"=1'-0"
TYPICAL PIPE SUPPORT IN TRENCH - DETAIL-11
SCALE 1"=1'-0"
DETAIL OF ANCHOR-1
TYPICAL HANGER
DETAIL-5
DETAIL-6
NOT TO SCALE
(2 REQ'D)
DETAIL-7
(N.T.S.)
DETAIL-8 (TYPICAL)
SCALE 1"=1'-0"
(2-REQUIRED)
BALCONY EL. 62'-6" REF.
EXISTING FUEL OIL DAY TANK
HEAT EXCHANGER
NOTES:
APPROVED FOR CONSTRUCTION
NORTHERN CANADA POWER COMMISSION
COOLING WATER PIPING DETAILS
MODIFICATIONS FOR RAW WATER PIPING.
GENERAL PIPING ARRANGEMENT.
EQUIPMENT LAYOUT. PLAN.
COOLING WATER SYSTEM PIPING DIAGRAM.
FUEL OIL PIPING DIAGRAM.
DRAWING NO.
TITLE
REFERENCE DRAWINGS
REVISION
MADE
CHECKED
DESCRIPTION
DATE
NORTHERN CANADA POWER COMMISSION
YELLOWKNIFE, N.W.T.
EXTENSION TO
STAND-BY DIESEL PLANT
FUEL OIL AND COOLING WATER
ARRANGEMENT
W.O. 01045



REFERENCE DRAWINGS
DRAWING NO.
TITLE
GENERAL PIPING ARRANGEMENT
INTERIOR FRAME STRUCTURAL STEEL PLAN & DET.
TEMPERATURE INDICATOR
THERMO WELL
3/4" COUPLING
TYPICAL DETAIL.
NOT TO SCALE
4 REQ'D
CAT. 399
FRONT OF ENGINE BASES STEEL
EXISTING PIPES TO BE CUT AS SHOWN
PLAN
BILL OF MATERIAL
ITEM NO.
QUAN.
DESCRIPTION
P.O. NO.
WELDED TO FLANGE
3/8" THREADED ROD
1½" ADJUSTABLE CLEVIS GRINNELL FIG. 260
DETAIL A
1½" PIPE SUPPORT TYP.
2 REQ'D
NOT TO SCALE
20 US. GAL. BALANCE TANKS
FRAME TO BE CONT. WELDED
FOR SUPPORT DETAILS SEE DETAIL A
EXISTING PIPE TO BE CUT
ENGINE ELBOW TO BE SWING AS SHOWN
ENGINE RUBBER CONN. HOSE TYP.
ENGINE FRAME
SECTION "A-A"
SHOWS CAT. D399
HEAT EXCH. ASS'Y ONLY
SLOPED
FUTURE
1" HOSE CONN.
PHILLIPS RED HEAD SELF DRILLING SNAP-OFF ANCHORS TO BE USED TYP.
FRONT ELEVATION
SECTION "B-B"
SHOWS CAT. D-399
HEAT EXCH ASS'Y ONLY
NOTE:
SILENCERS ARE NOT SHOWN.
CHECKS
NORTHERN CANADA POWER COMMISSION
REVISION
DESCRIPTION
DATE
APPROVED FOR CONSTRUCTION
CHIEF ENGINEER
NORTHERN CANADA POWER COMMISSION



NCPC DRAWING No. P1QJ-126001

JUN 18 1990

Drawing Produced By: BMT ASSOCIATES LTD. CONSULTING TECHNOLOGISTS

MAY 7, 1990

JACKFISH POWER PL[illegible] EXPANSION YELLOWKNI[illegible]

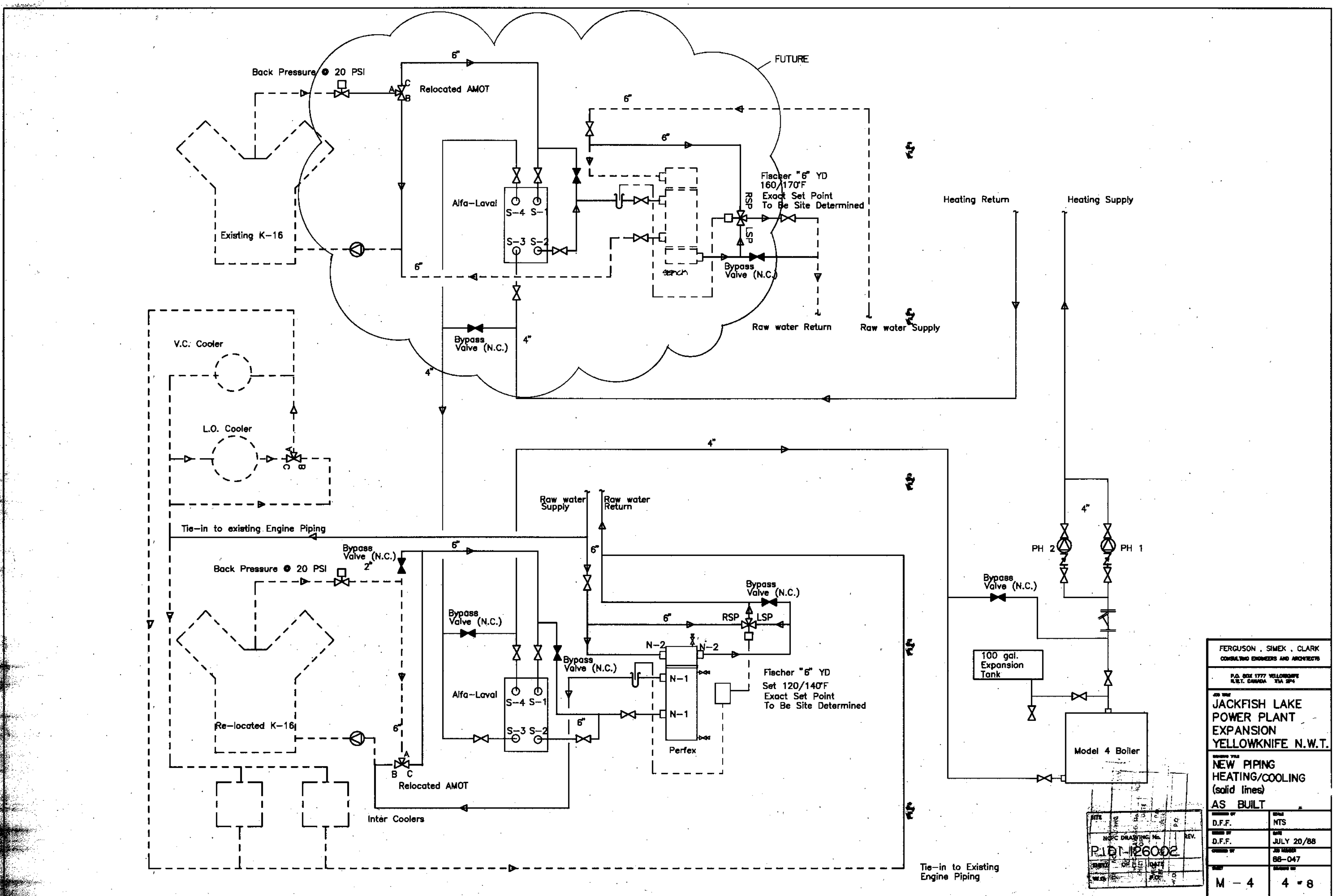
HEATING & MAIN PLA[illegible]

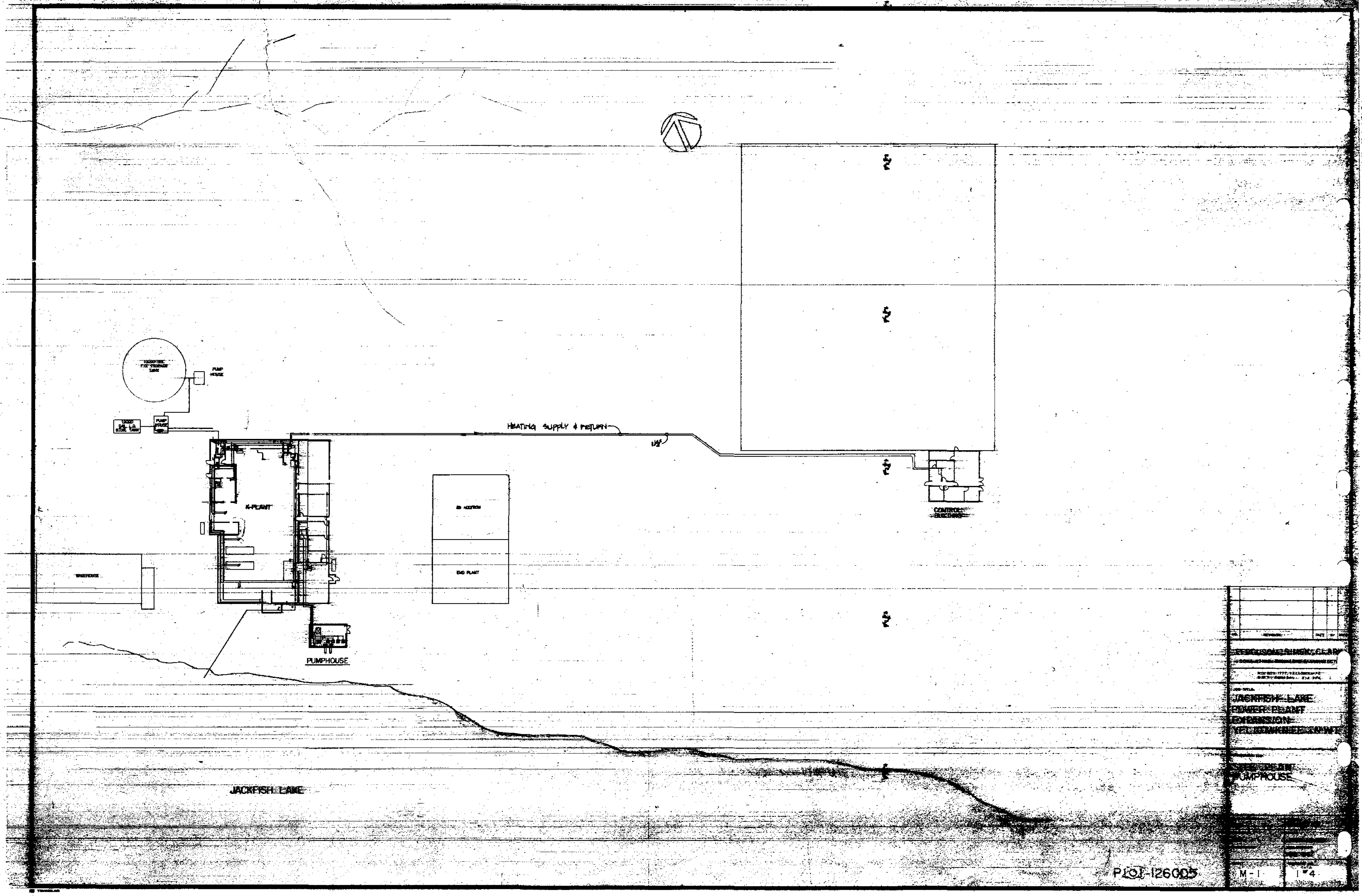
AS BUILT

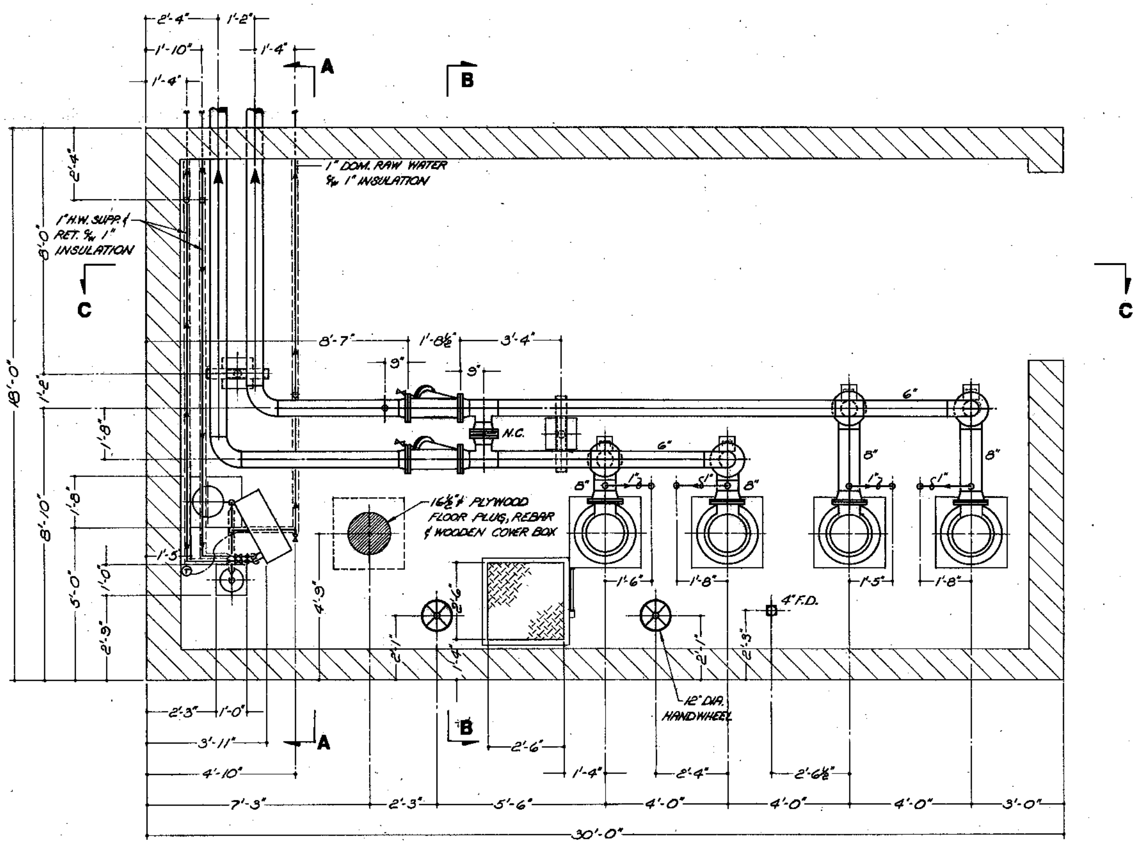
DESIGNED BY DF

DRAWN BY RB

3 of 8


FUTURE
Back Pressure @ 20 PSI
Relocated AMOT
6"
Existing K-16
Alfa-Laval
S-4 S-1
S-3 S-2
Fischer "6" YD
160/170°F
Exact Set Point
To Be Site Determined
RSP
LSP
Bypass Valve (N.C.)
Raw water Return
Raw water Supply
Heating Return
Heating Supply
4"
V.C. Cooler
L.O. Cooler
Tie-in to existing Engine Piping
Raw water Supply
Raw water Return
Back Pressure @ 20 PSI
Re-located K-16
Inter Coolers
N-2
N-1
Perfex
Fischer "6" YD
Set 120/140°F
Exact Set Point
To Be Site Determined
PH 2
PH 1
100 gal. Expansion Tank
Model 4 Boiler
Tie-in to Existing Engine Piping
FERGUSON . SIMEK . CLARK
JACKFISH LAKE POWER PLANT EXPANSION YELLOWKNIFE N.W.T.
NEW PIPING HEATING/COOLING (solid lines)
AS BUILT
D.F.F.
NTS
D.F.F.
JULY 20/88
88-047
M - 4
4 - 8
NCPC DRAWING No.
P-1-01-126002


HEATING SUPPLY & RETURN
K-PLANT
PUMPHOUSE
JACKFISH LAKE
PUMPHOUSE
M-1



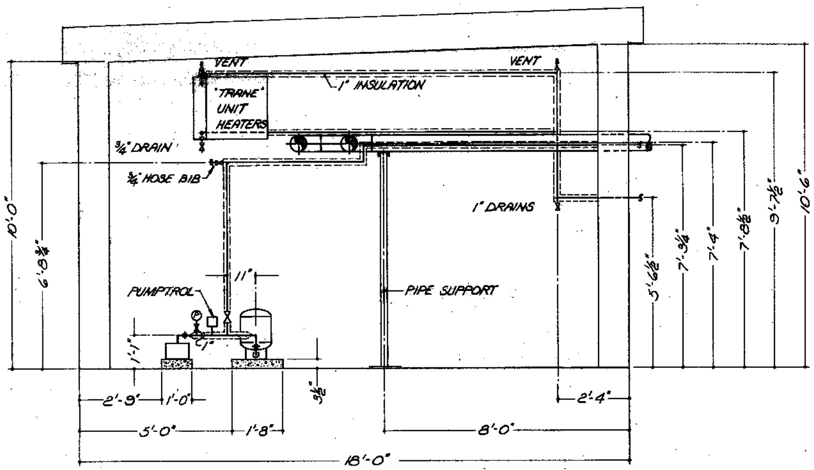
HOWAT Construction (1985) Ltd.
P.O. BOX 2807, YELLOWKNIFE, N.W.T. X1A 2P9

JACKFISH LAKE POWER PLANT

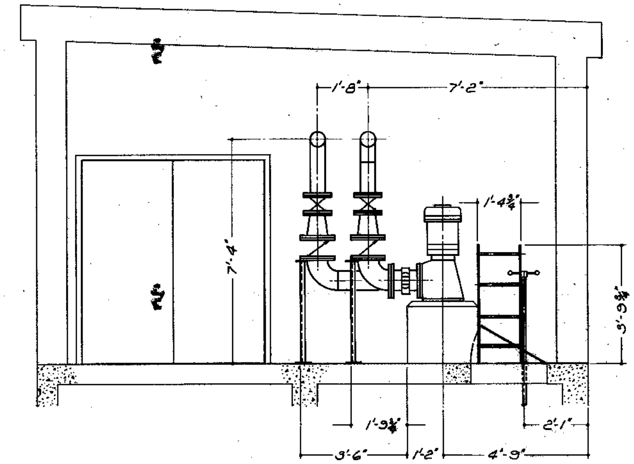
PUMPHOUSE

SCALE	DWG.	SHEET
⅛"=1'-0"	M-2	2 OF 4

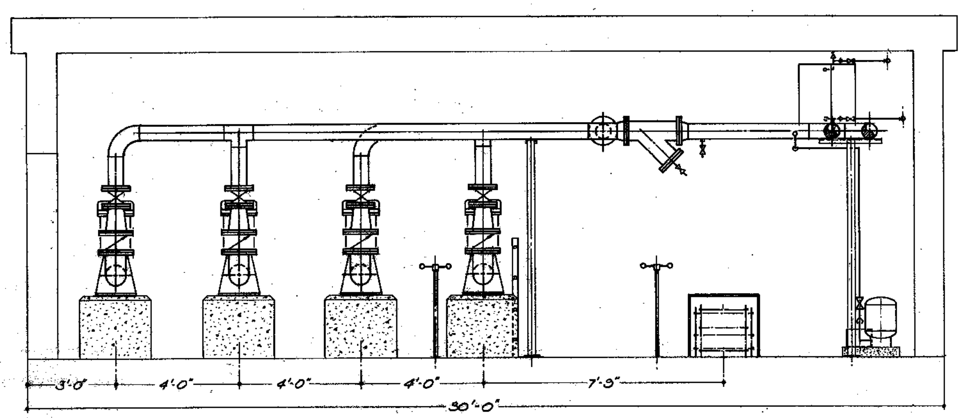
P2G2-126006



SECTION 'A-A'



SECTION 'B-B'



SECTION 'C-C'

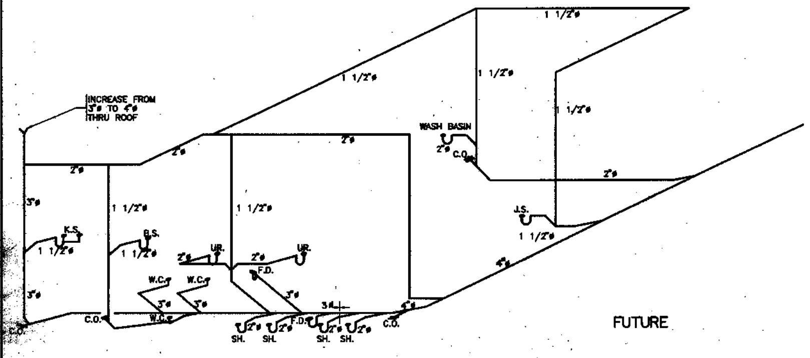
P262-1260D7

HOVAT Construction (1985) Ltd.
P.O. BOX 2807, YELLOWKNIFE, N.W.T. X1A 2P8

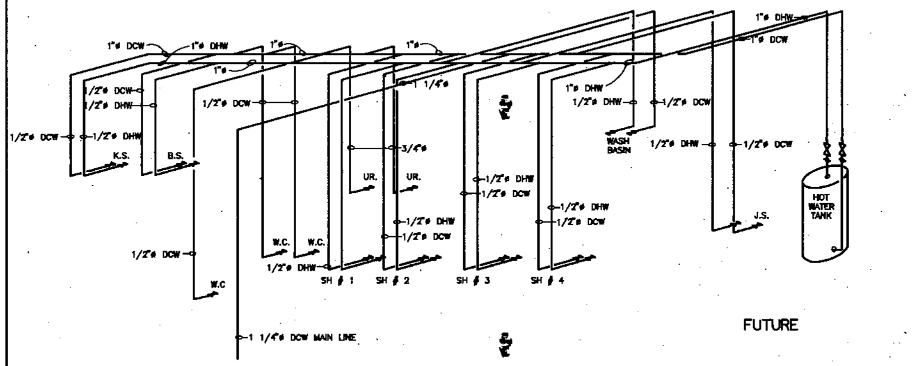
JACKFISH LAKE POWER PLANT

PUMPHOUSE

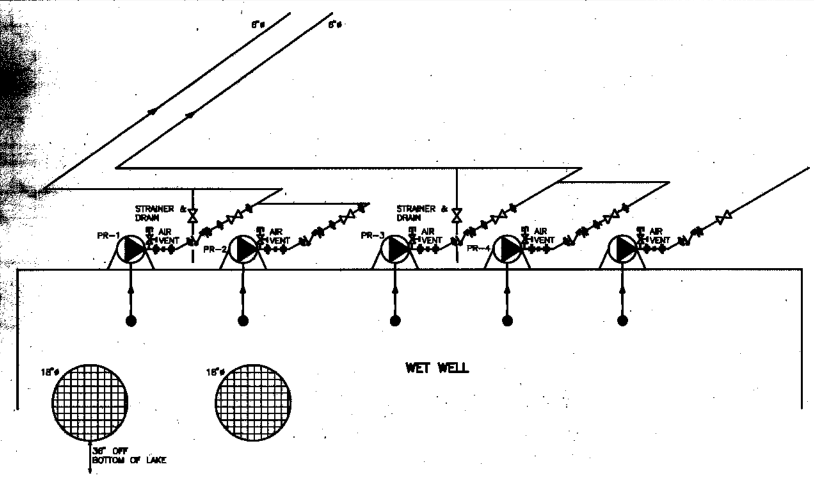
SCALE	DWG.	SHEET
1/8"=1'-0"	M-3	3 OF 4



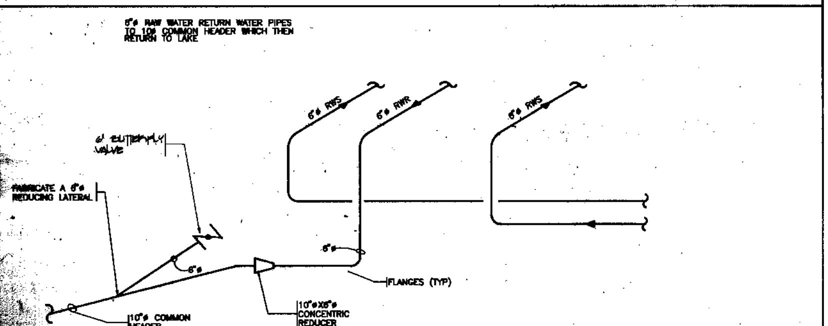
PLUMBING IN SLAB & VENTING (K-PLANT)



DOMESTIC COLD & HOT WATER FIXTURES SUPPLIES (K-PLANT)



RAW WATER PUMPS & PIPING FROM NEW PUMP HOUSE (K-PLANT)



RAW WATER TO 10"ø COMMON HEADER TO LAKE

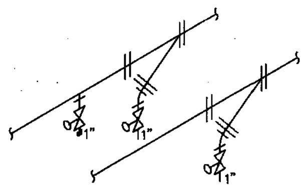
FERGUSON, SIMEK, CLARK
CONSULTING ENGINEERS AND ARCHITECTS
P.O. BOX 1777 YELLOWKNIFE N.W.T. CANADA X1A 2P4

JACKFISH LAKE POWER PLANT EXPANSION YELLOWKNIFE N.W.T.

PUMPHOUSE & K-PLANT SCHEMATICS
AS BUILT

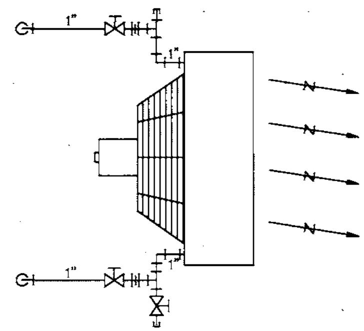
D.B.	NTS
R.H.	JULY 21/88
	88-047
M-2	2 - 3

P10K-126008



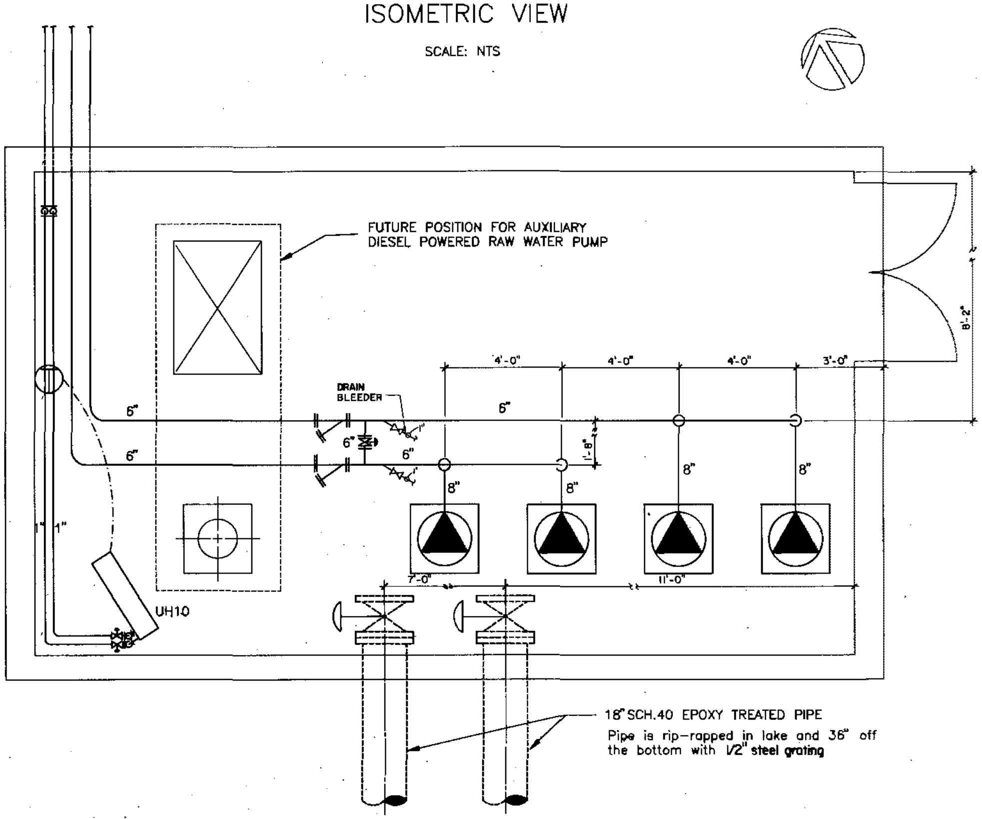
RAW WATER STRAINERS ISOMETRIC VIEW

SCALE: NTS



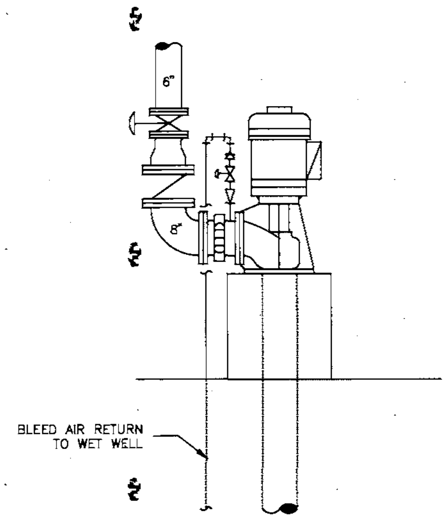
UNIT HEATER (UH10) PIPING SCHEMATIC

SCALE: NTS



PUMP HOUSE PLAN VIEW

SCALE: 1/2"=1'0"



RAW WATER PUMP SCHEMATIC

SCALE: NTS

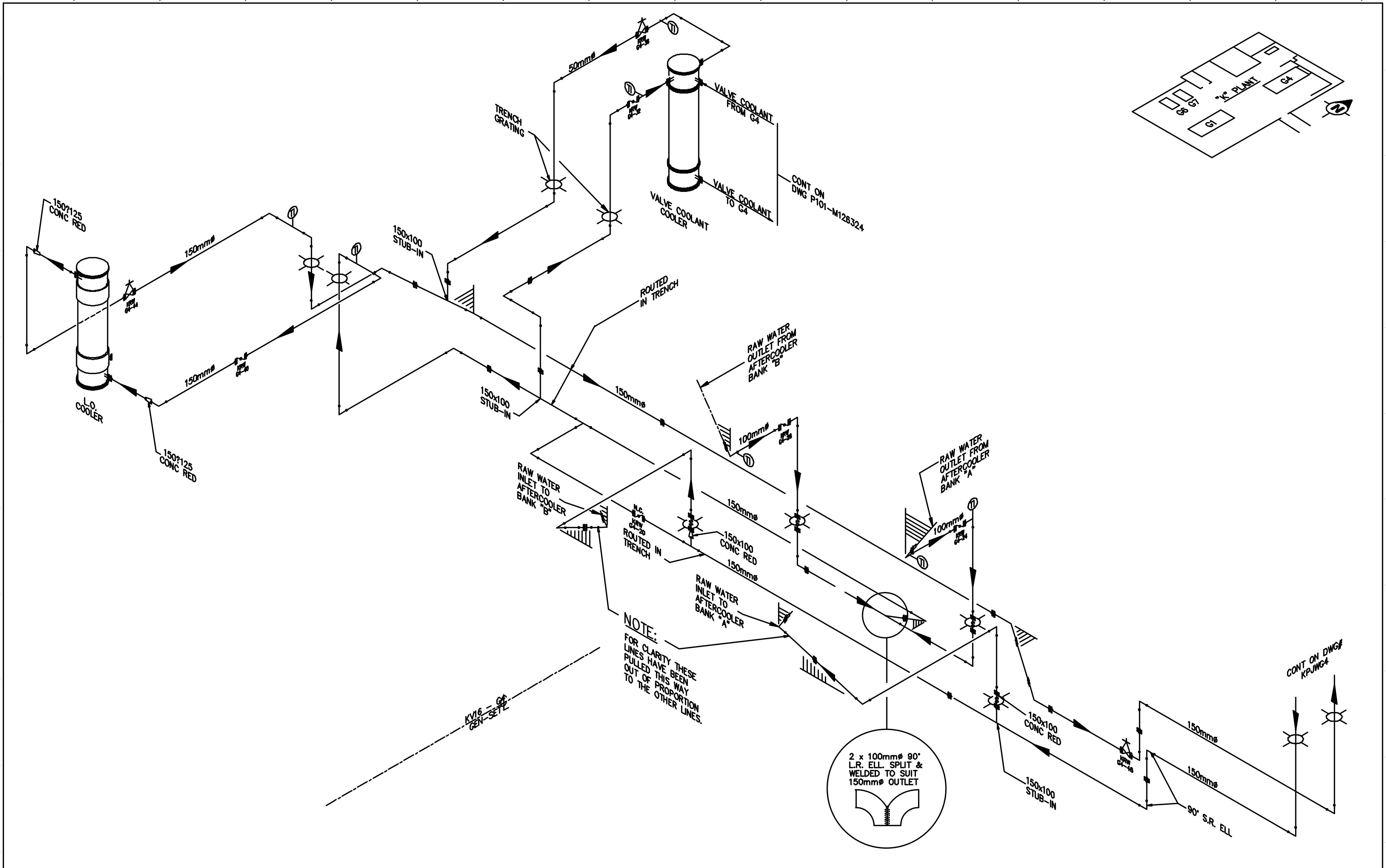
FERGUSON, SIMEK, CLARK
CONSULTING ENGINEERS AND ARCHITECTS
P.O. BOX 1777 YELLOWKNIFE
N.W.T. CANADA X1A 2P4

JACKFISH LAKE POWER PLANT EXPANSION YELLOWKNIFE N.W.T.

PUMP HOUSE AS BUILTS

D.F.F.	AS SHOWN
D.F.F.-R.B.-S.R.	JANUARY 05/89
	88-047
M-3	3 - 3

PLOC 126009



		B	VALVE NUMBERS REVISED		R.L.	12/00								AS BUILT 2000	12/00
P101–M126324	J.W. PIPING – KV16 G4	A	AS BUILT AS PER FIELD INFO PROVIDED	901–8310	F.L.	04/97	S.E.S.								
DRAWING NO.	TITLE	0	ORIGINAL	525–94	R.LAYCOCK	APR.27/94									
REFERENCE DRAWINGS		REVISION LETTER	REVISION	WORK ORDER	NAME	DATE	CHECKED BY	DESIGNED BY	CIVIL	MECH	ELEC	T & D	P & C	STATUS OF DRAWING	DATE
					DRAWN BY				APPROVED FOR CONSTRUCTION BY						

LOCATION
JACKFISH LAKE
YELLOWKNIFE N.W.T.

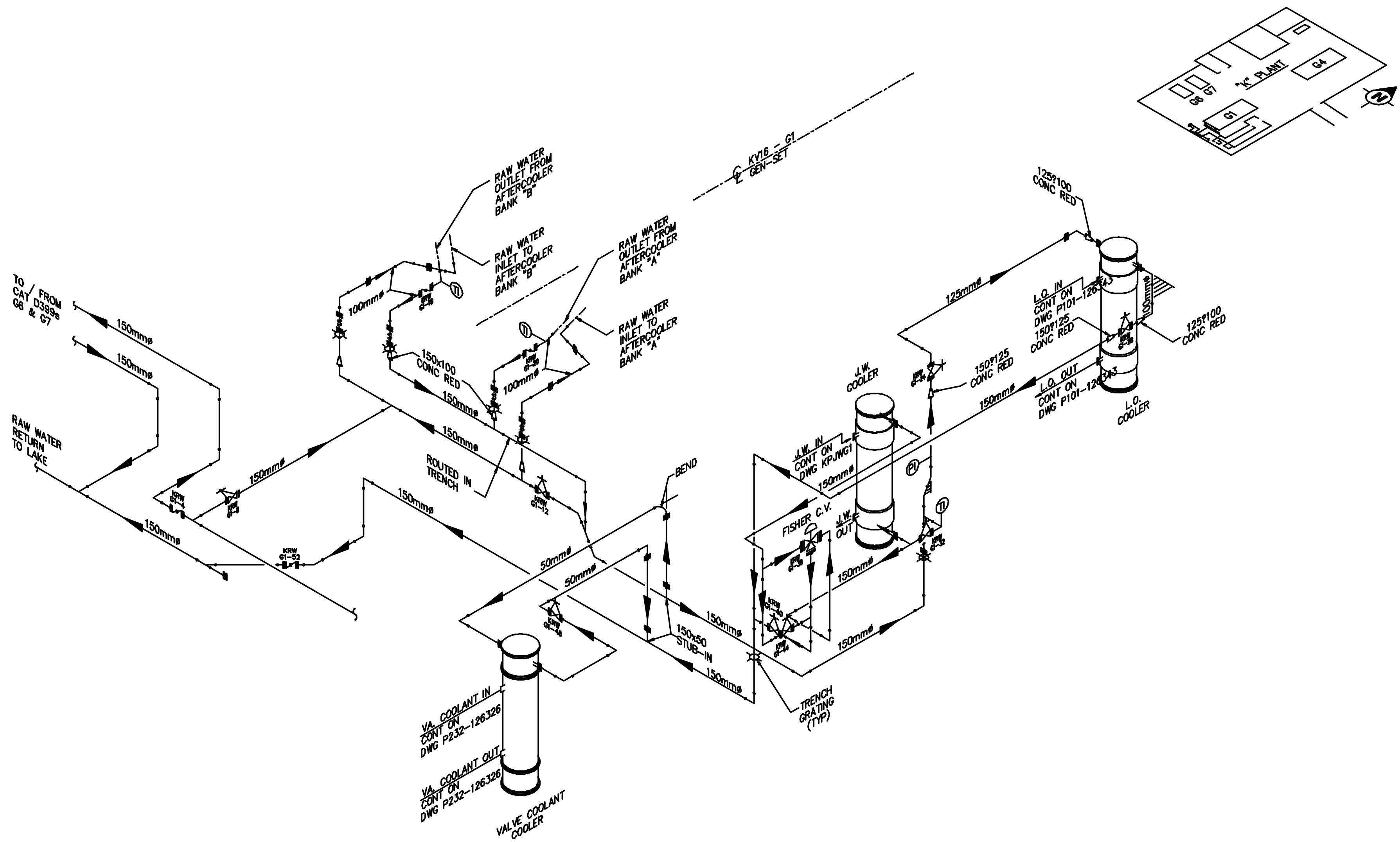
NORTHWEST TERRITORIES POWER CORPORATION

PLANT

TITLE
DIESEL PLANT No.1 (KV16)
RAW WATER SYSTEM
NORTH END of BUILDING – KV16–G4
SYSTEM ISOMETRIC

SCALE NTS | SHEET 1 OF 1 | DRAWING NO. P101–M126321 | REV. B

AUTOCAD FILE: \P101/M126321.DWG PLOT SCALE: 1:1



		B	VALVE NUMBERS REVISED		R.L.	12/00								AS BUILT 2000	12/00	
		A	AS BUILT AS PER FIELD INFO PROVIDED	901-6310	F.L.	04/97	S.E.S.									
DRAWING NO.	TITLE	0	ORIGINAL	525-94	R. LAYCOCK	MAY 3/94										
REFERENCE DRAWINGS		REVISION LETTER	REVISION	WORK ORDER	NAME (DRAWN BY)	DATE (DRAWN BY)	CHECKED BY	DESIGNED BY	CIVIL	MECH	ELEC	T & D	P & C	STATUS OF DRAWING	DATE	

LOCATION
JACKFISH LAKE
YELLOWKNIFE N.W.T.

NORTHWEST TERRITORIES POWER CORPORATION

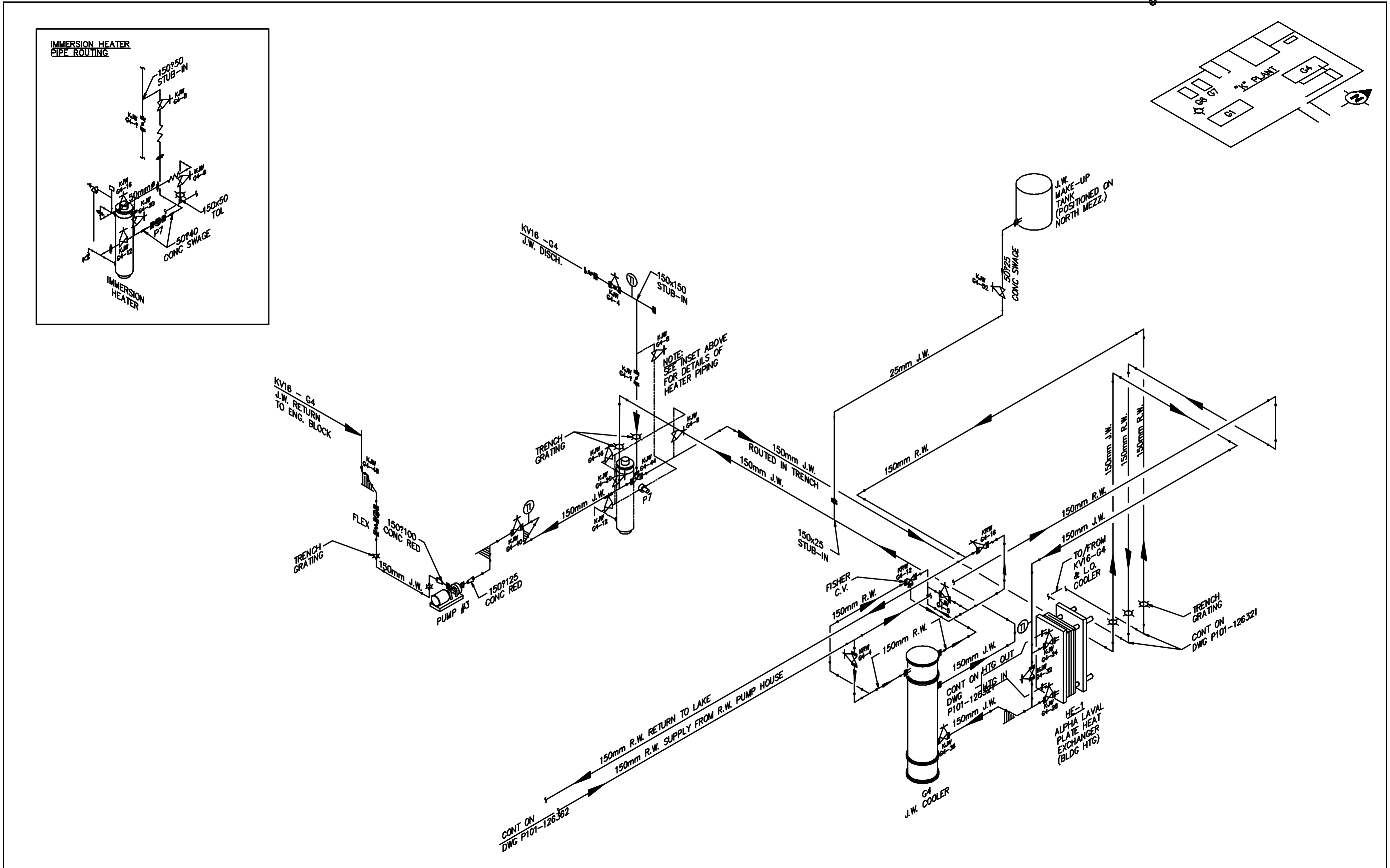
PLANT

TITLE
DIESEL PLANT No.1 (KV16)
RAW WATER SYSTEM
SOUTH END of BUILDING – KV16 G1
SYSTEM ISOMETRIC

APPROVED FOR CONSTRUCTION BY

SCALE NTS | SHEET 1 OF 1 | DRAWING NO. P101–M126322 | REV. B

AUTOCAD FILE: \P101\M126322.DWG PLOT SCALE: 1:1



		B	VALVE NUMBERS REVISED		R.L.	12/00		
P101 – M126321	RAW WATER – KV16 G4	A	AS BUILT AS PER FIELD INFO PROVIDED	901-8310	F.L.	04/97	S.E.S.	
DRAWING NO.	TITLE	0	ORIGINAL	525-94	R. LAYCOCK	MAY.12/94		
REFERENCE DRAWINGS		REVISION LETTER	REVISION	WORK ORDER	NAME / DRAWN BY	DATE	CHECKED BY	DESIGNED BY

CIVIL	MECH	ELEC	T & D	P & C	STATUS OF DRAWING	DATE
					AS BUILT 2000	12/00
APPROVED FOR CONSTRUCTION BY						

LOCATION: JACKFISH LAKE YELLOWKNIFE N.W.T.

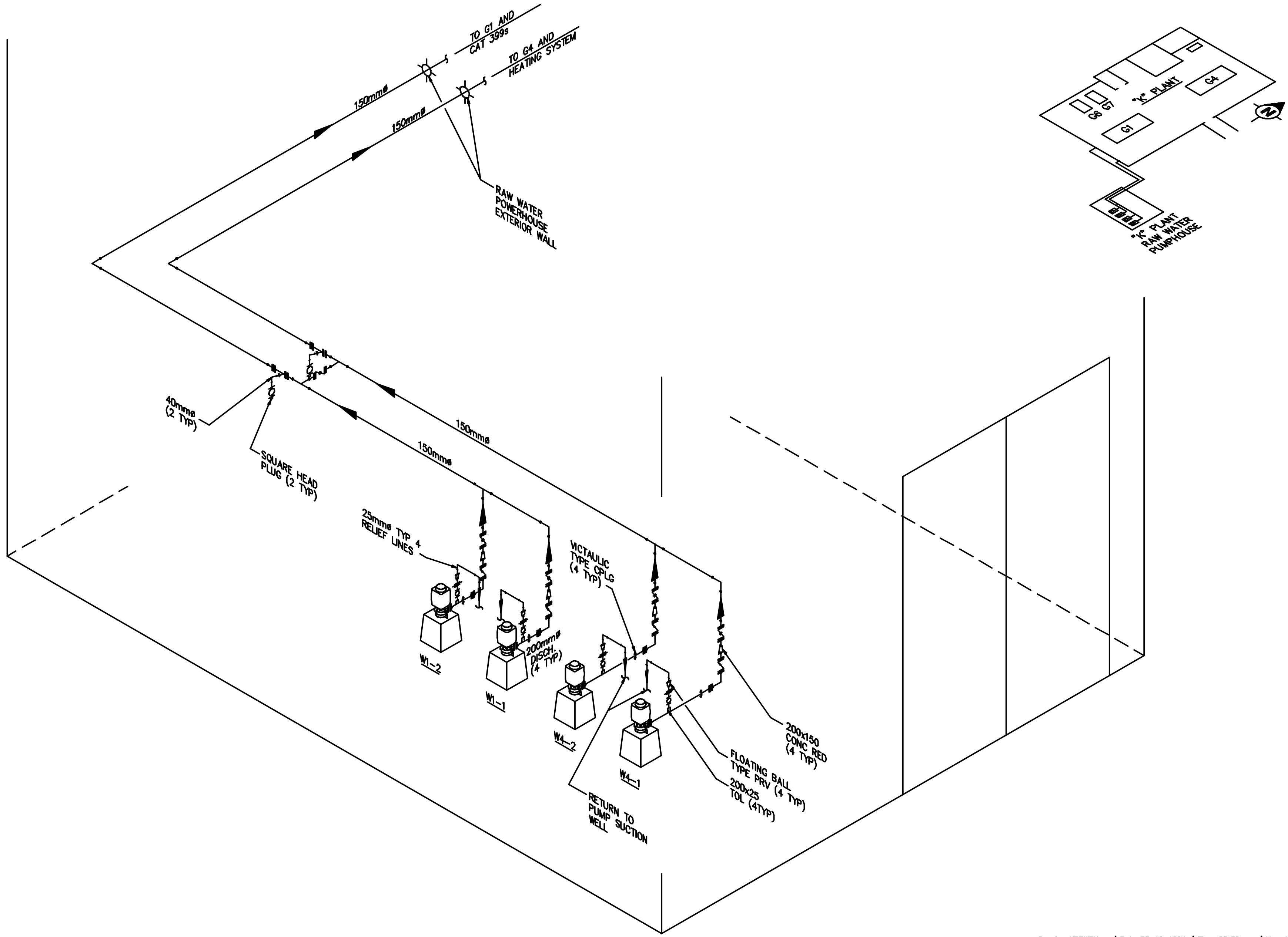
NORTHWEST TERRITORIES POWER CORPORATION

PLANT

TITLE: DIESEL PLANT No.1 (KV16) J.W. PIPING – KV16 G4 SYSTEMS ISOMETRIC (RELATED R.W. LINES ALSO INDICATED)

SCALE: NTS | SHEET 1 OF 1 | DRAWING NO. P101–M126324 | REV. B

AUTOCAD FILE: \P101\M126324.DWG PLOT SCALE: 1:1



Drawing: KPRWPH / Date: 05-10-1994 / Time: 09:59 / User ID: RL

DRAWING NO.	TITLE	REVISION LETTER	REVISION	WORK ORDER	NAME (DRAWN BY)	DATE (DRAWN BY)	CHECKED BY	DESIGNED BY
		0	ORIGINAL	525/94	R.LAYCOCK	MAY.8/94		

REFERENCE DRAWINGS

APPROVED FOR CONSTRUCTION BY: CIVIL | MECH | ELEC | T & D | P & C

STATUS OF DRAWING | DATE

LOCATION: JACKFISH LAKE YELLOWKNIFE N.W.T.

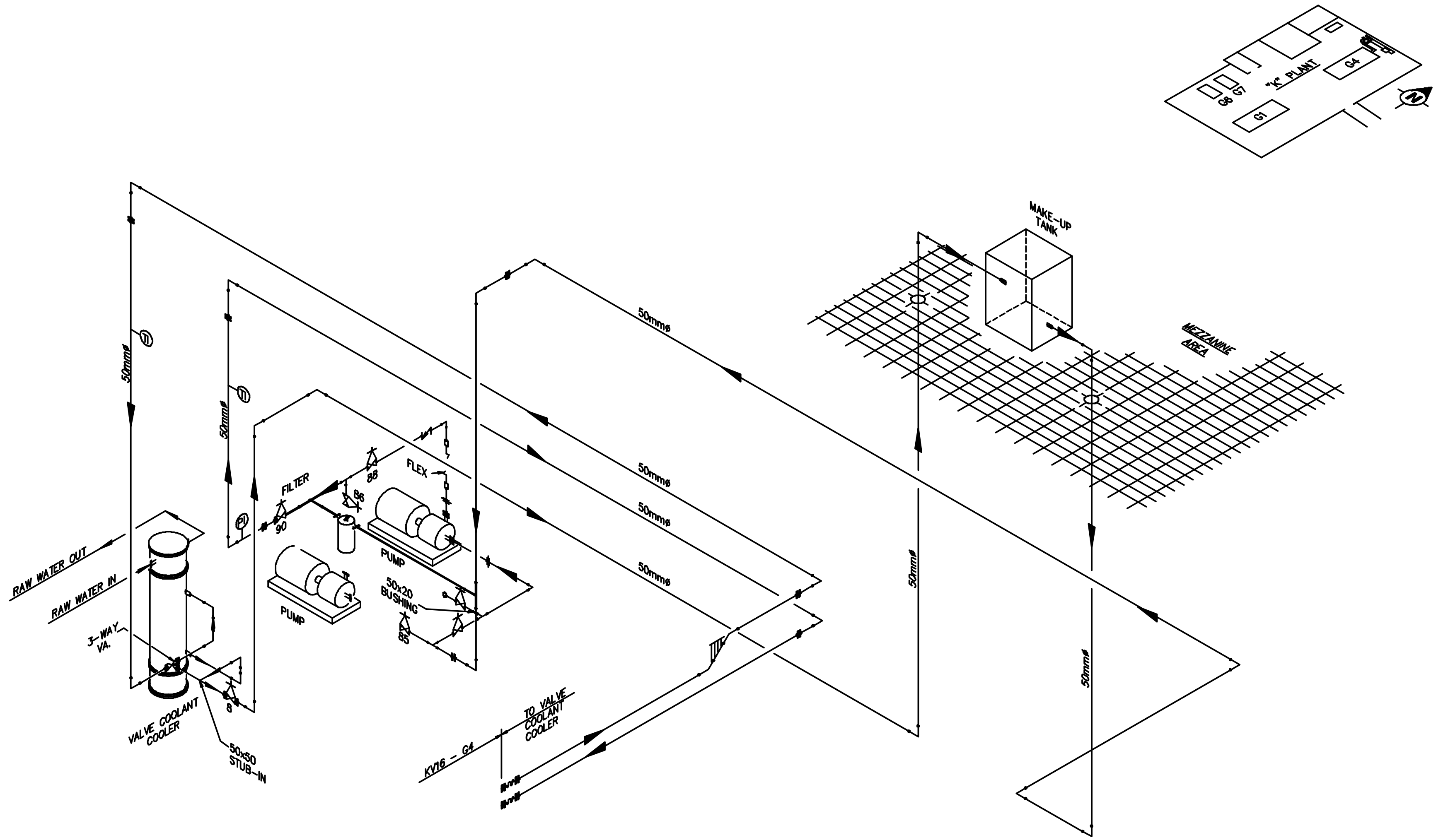
NORTHWEST TERRITORIES POWER CORPORATION

PLANT: 01

TITLE: "K" PLANT RAW WATER SYSTEM RAW WATER PUMP HOUSE SYSTEM ISOMETRIC

SCALE: NTS | SHEET 1 OF 1 | DRAWING NO. P101-M126325 | REV. 0

AUTOCAD FILE: \P101\M126325.DWG PLOT SCALE: 1:1



Drawing No.	Title	Revision Letter	Revision	Work Order	Drawn By Name	Drawn By Date	Checked By	Designed By	Status of Drawing	Date
P101 – M126321	R.W. SYSTEM KV16 G4	A	REV'D AS PER INFO. PROVIDED - REPLACED TITLEBLOCK	901.6140	S.E.S.	01.05				
		0	ORIGINAL	–	R.LAYCOCK	05.94			AS BUILT	01.05

REFERENCE DRAWINGS

PROFESSIONAL STAMP

PERMIT STAMP

LOCATION: JACKFISH LAKE YK, NT.

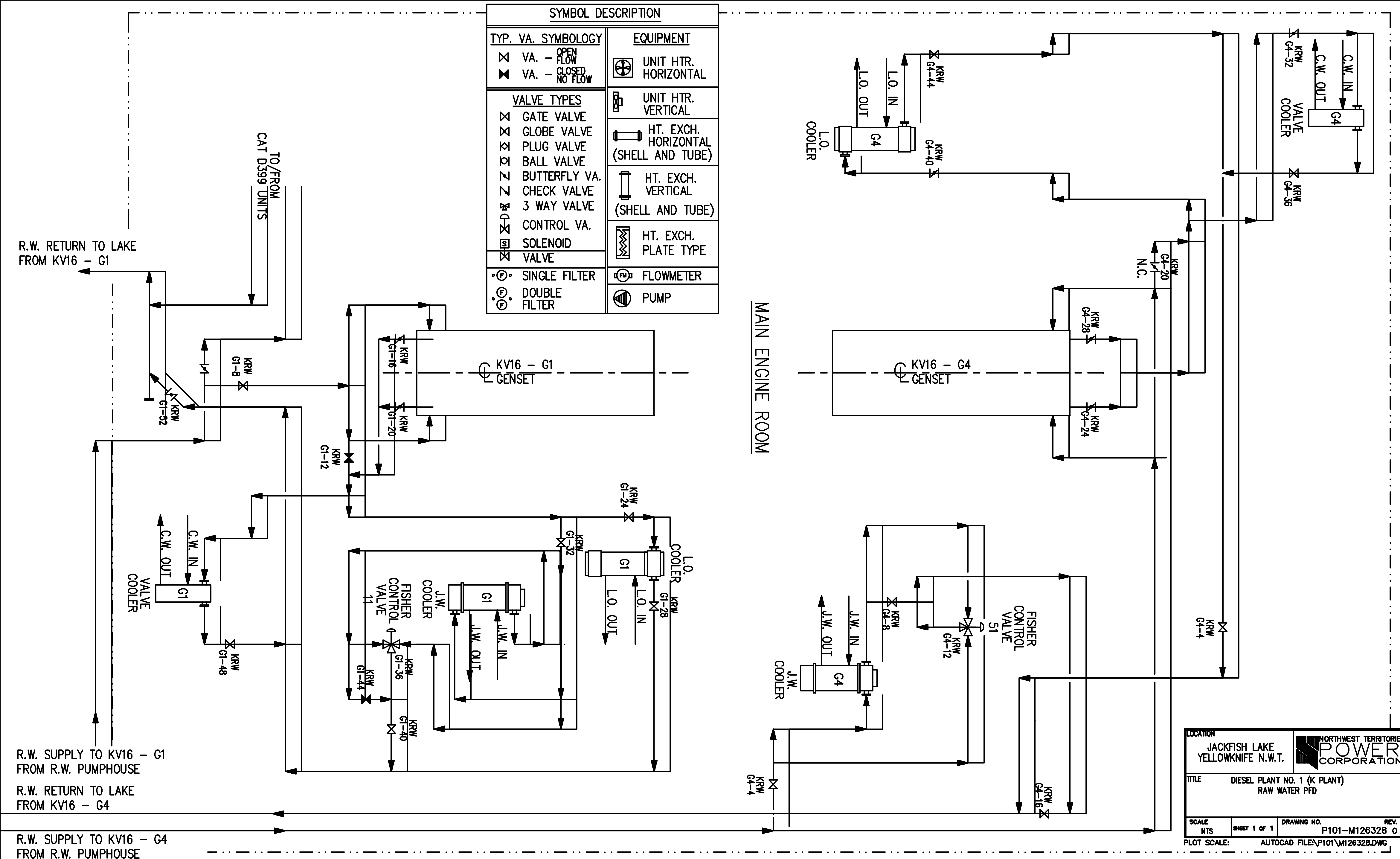
NORTHWEST TERRITORIES POWER CORPORATION

TITLE: DIESEL PLANT NO. 1 (K PLANT) KV16 G4 – VALVE COOLER COOLANT ROUTING SYSTEM ISOMETRIC

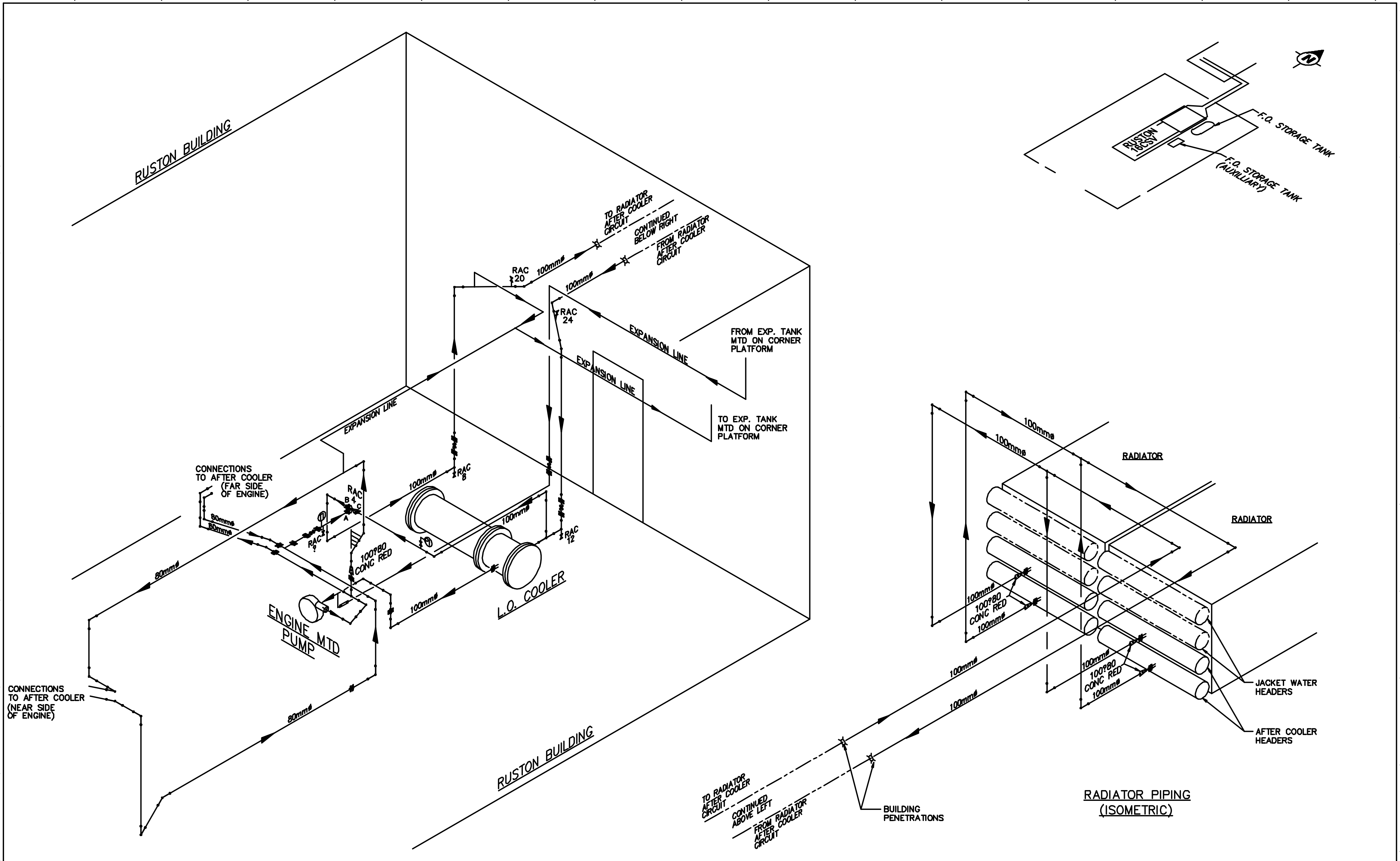
SCALE	SHEET	DRAWING NO.	REV.
NTS	SHEET 1 OF 1	P101–M126327	A

AUTOCAD FILE: \P101\M126327.DWG

PLOT SCALE: 1 : 1



"K" PLANT – RAW WATER – FLOW SHEET



Drawing: RJWHT1 / Date: 12-14-2000 / Time: 10:22 / User ID: e

DRAWING NO.	TITLE	REVISION LETTER	REVISION	WORK ORDER	DRAWN BY NAME	DRAWN BY DATE	CHECKED BY	DESIGNED BY	STATUS OF DRAWING	DATE
		0	ORIGINAL		R.LAYCOCK	DEC.13 / 0			AS BUILT – 2000	FEB/00
REFERENCE DRAWINGS										

APPROVED FOR CONSTRUCTION BY: CIVIL | MECH | ELEC | T & D | P & C

LOCATION: JACKFISH LAKE YELLOWKNIFE N.W.T.

PLANT: 01

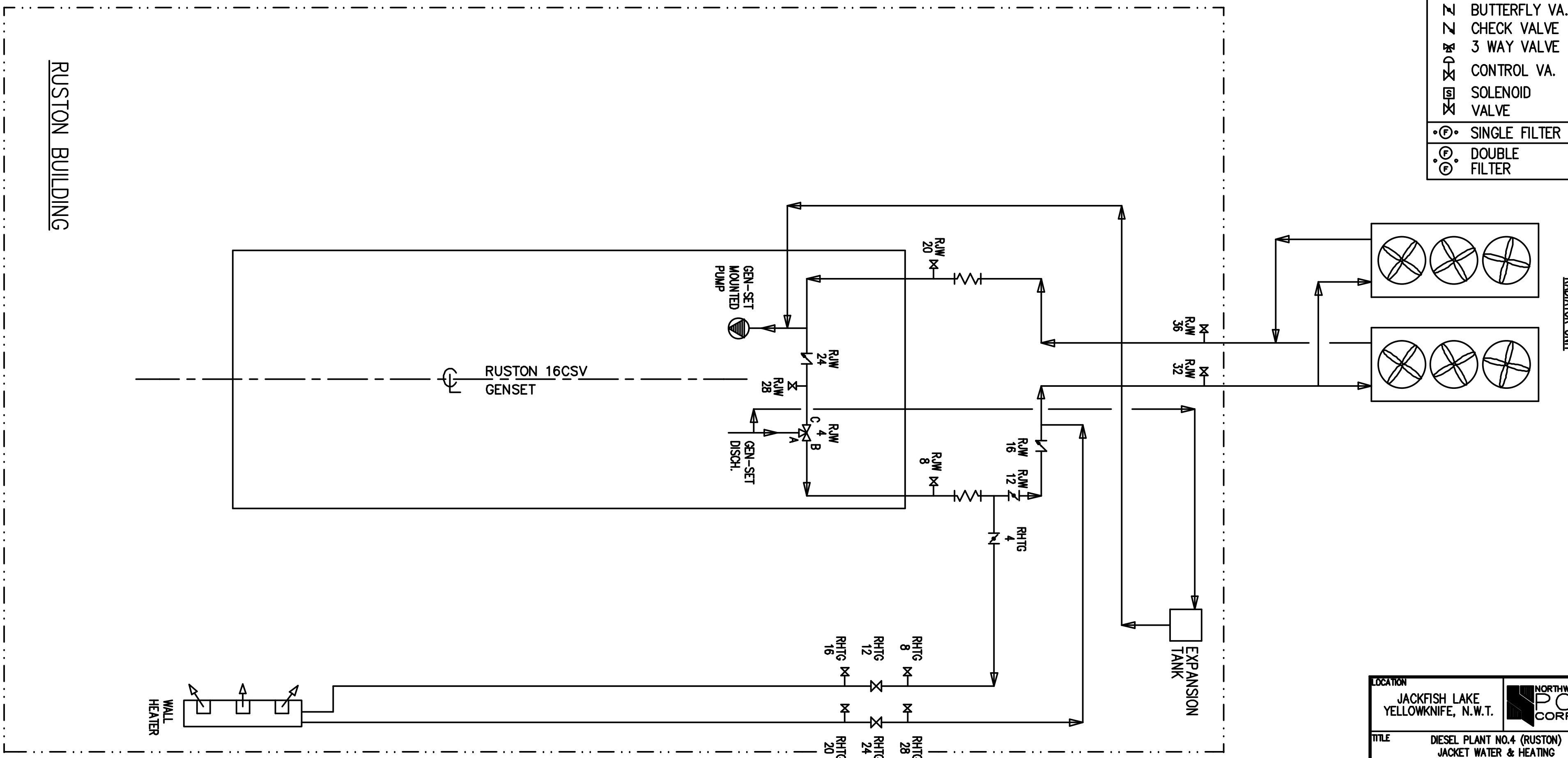
TITLE: RUSTON PLANT AFTER COOLER COOLING SYSTEM SYSTEM ISOMETRIC

NORTHWEST TERRITORIES POWER CORPORATION

SCALE: NTS | SHEET 1 OF 1 | DRAWING NO. P105–M126322 | REV. 0

AUTOCAD FILE: \P105\M126322.DWG PLOT SCALE: 1 : 1

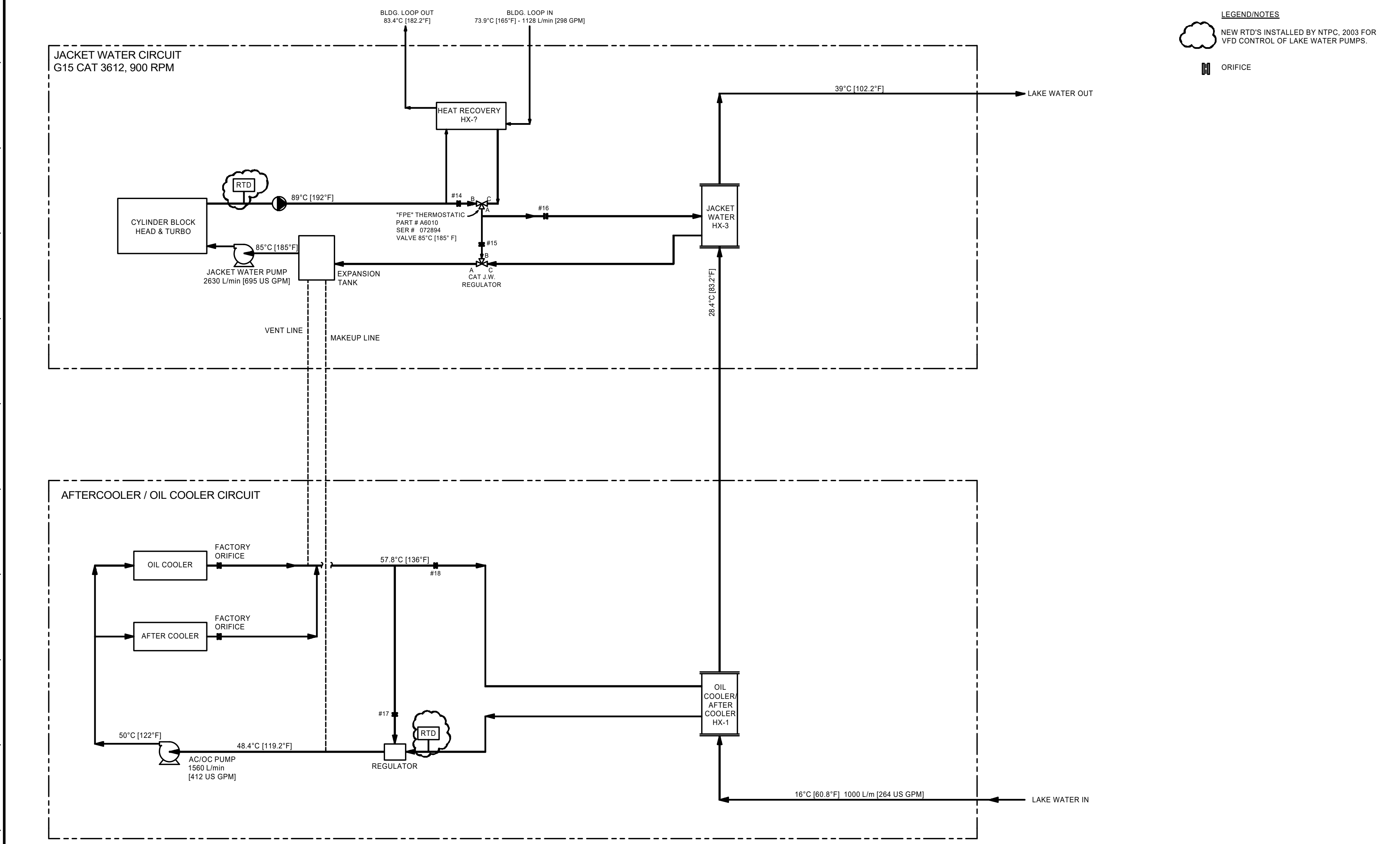
SYMBOL DESCRIPTION	
TYP. VA. SYMBOLOGY	**EQUIPMENT**
VA. – OPEN FLOW	UNIT HTR. HORIZONTAL
VA. – CLOSED NO FLOW	
VALVE TYPES	UNIT HTR. VERTICAL
GATE VALVE	HT. EXCH. HORIZONTAL (SHELL AND TUBE)
GLOBE VALVE	
PLUG VALVE	
BALL VALVE	HT. EXCH. VERTICAL (SHELL AND TUBE)
BUTTERFLY VA.	
CHECK VALVE	
3 WAY VALVE	
CONTROL VA.	HT. EXCH. PLATE TYPE
SOLENOID VALVE	
SINGLE FILTER	FLOWMETER
DOUBLE FILTER	PUMP



LOCATION	
JACKFISH LAKE YELLOWKNIFE, N.W.T.	NORTHWEST TERRITORIES POWER CORPORATION
TITLE	DIESEL PLANT NO.4 (RUSTON) JACKET WATER & HEATING PFD
SCALE NTS	SHEET 1 OF 1
DRAWING NO. P105–M126360	REV. 0

PLOT SCALE: AUTOCAD FILE:\P105\M126360.DWG

RUSTON PLANT – JACKET WATER & HEATING – FLOW SHEET



DRAWING NO.	TITLE	0	ORIGINAL	101.5364	S.E.S.	11/02	W.T.	W.T.	ISSUED FOR CONSTRUCTION	01/03
REFERENCE DRAWINGS		REVISION LETTER	REVISION	WORK ORDER	NAME (DRAWN BY)	DATE (DRAWN BY)	CHECKED BY	DESIGNED BY	STATUS OF DRAWING	DATE

PROFESSIONAL STAMP

PERMIT STAMP

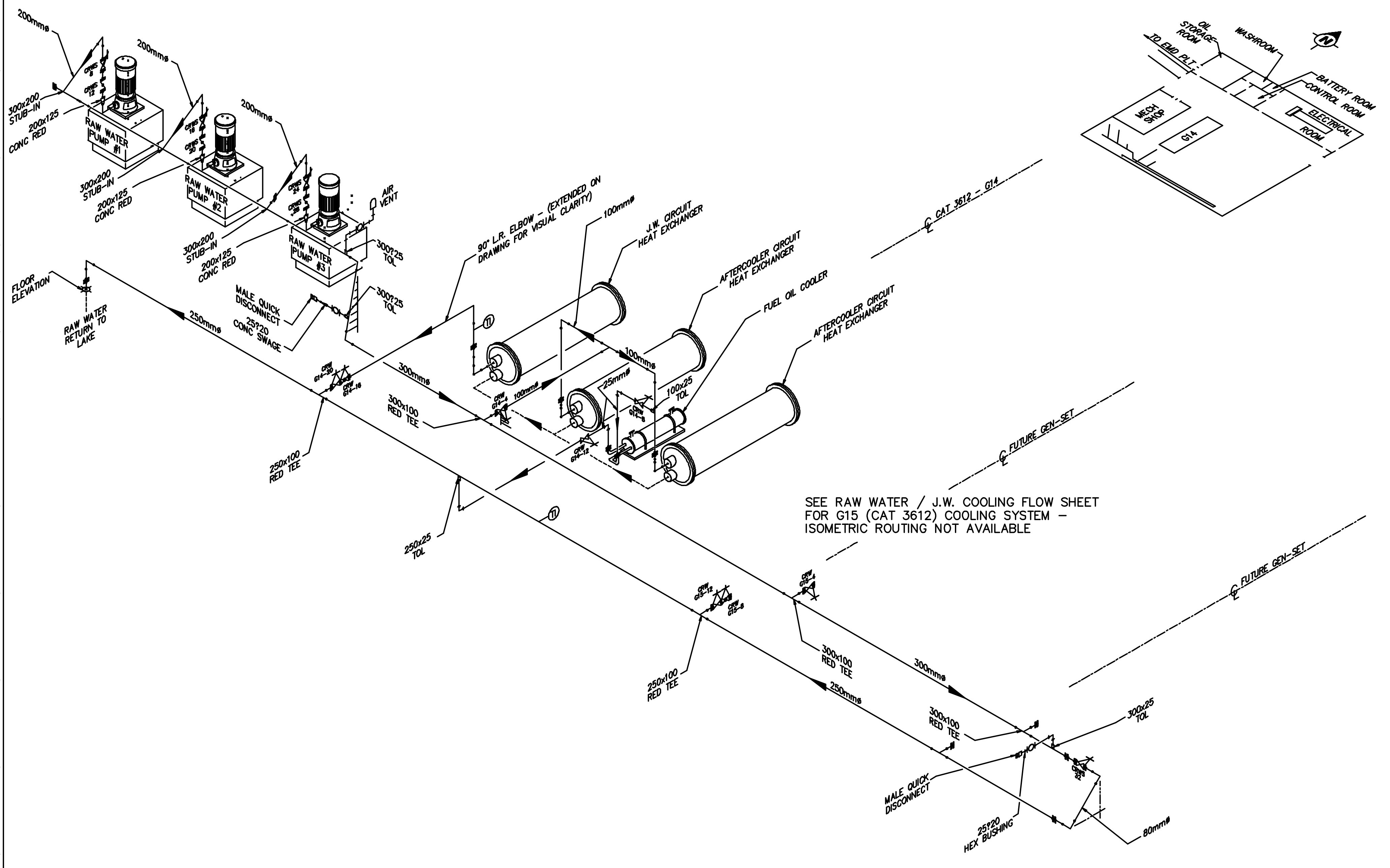
LOCATION: JACKFISH LAKE, YK N.W.T.

NORTHWEST TERRITORIES POWER CORPORATION

TITLE: INSTALL VFD – 2003 CONSTRUCTION
1992 DIESEL PLANT NO. 3 (CAT)
G15 – COOLING SYSTEM SCHEMATIC

SCALE: NTS | SHEET 1 OF 1 | DRAWING NO. H-P231-5364-M04 | REV. 0

AUTOCAD FILE: \PROJECTS\PLANTS\P231\5364M04   PLOT SCALE: 1 : 1



		B	VALVE NUMBERS REVISED		R.L.	12/00								AS BUILT 2000	12/00
		A	AS BUILT AS PER FIELD INFO PROVIDED	901-6310	F.L.	04/97	S.E.S.								
DRAWING NO.	TITLE	0	ORIGINAL	525-94	R.LAYCOCK	JUNE.20/94									
REFERENCE DRAWINGS		REVISION LETTER	REVISION	WORK ORDER	NAME	DATE	CHECKED BY	DESIGNED BY	CIVIL	MECH	ELEC	T & D	P & C	STATUS OF DRAWING	DATE
					DRAWN BY				APPROVED FOR CONSTRUCTION BY						

LOCATION: JACKFISH LAKE YELLOWKNIFE N.W.T.

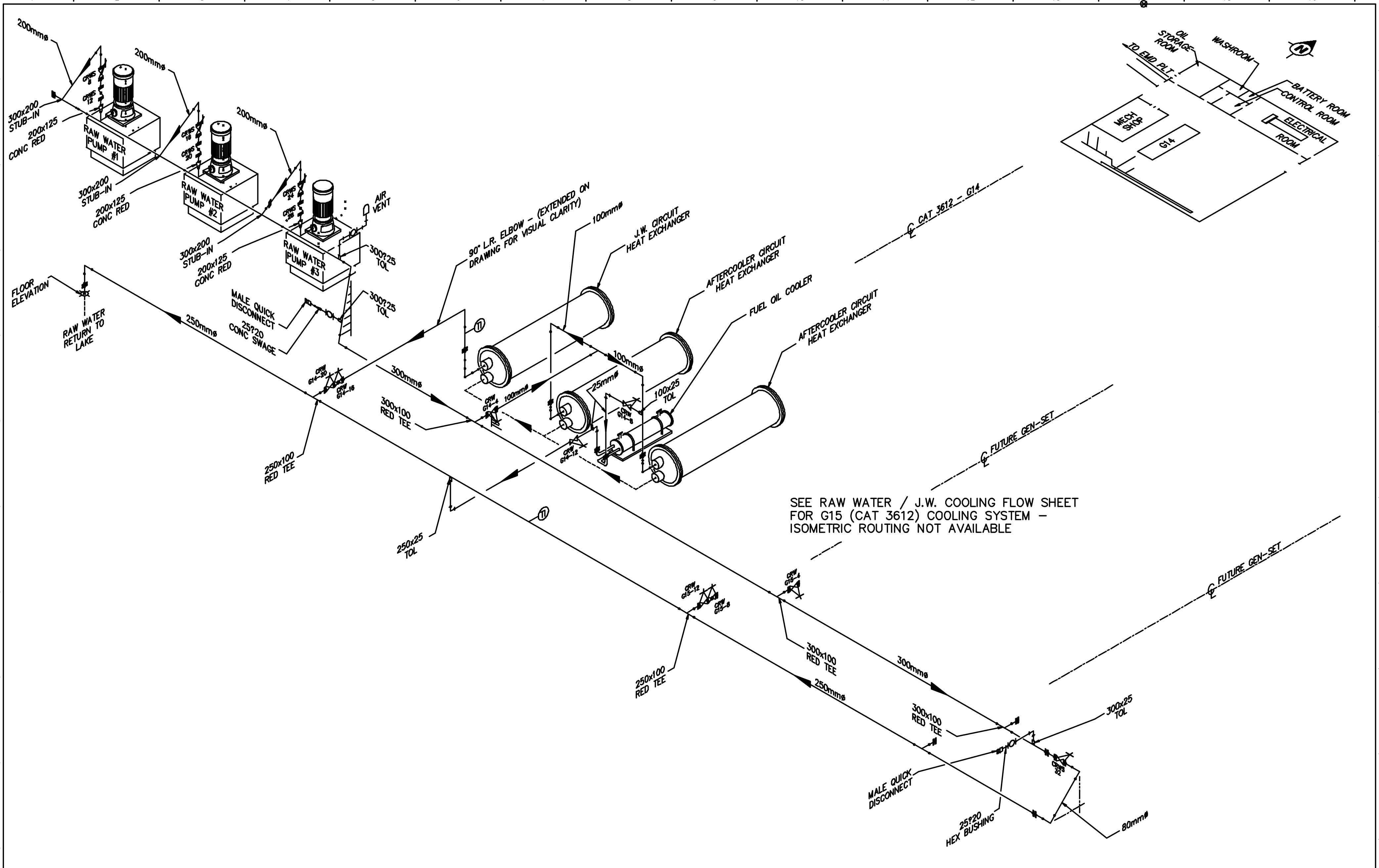
NORTHWEST TERRITORIES POWER CORPORATION

PLANT

TITLE: DIESEL PLANT #3 RAW WATER SYSTEM PUMPING AND DISTRIBUTION ROUTING SYSTEM ISOMETRIC

SCALE: NTS | SHEET 1 OF 1 | DRAWING NO. P231 - 126323 | REV. B

AUTOCAD FILE: P231/126323 PLOT SCALE: 1:1



		B	VALVE NUMBERS REVISED		R.L.	12/00								AS BUILT 2000	12/00
		A	AS BUILT AS PER FIELD INFO PROVIDED	901-6310	F.L.	04/97	S.E.S.								
DRAWING NO.	TITLE	0	ORIGINAL	525-94	R.LAYCOCK	JUNE.20/94									
REFERENCE DRAWINGS		REVISION LETTER	REVISION	WORK ORDER	NAME	DATE	CHECKED BY	DESIGNED BY	CIVIL	MECH	ELEC	T & D	P & C	STATUS OF DRAWING	DATE
					DRAWN BY				APPROVED FOR CONSTRUCTION BY						

LOCATION
JACKFISH LAKE
YELLOWKNIFE N.W.T.

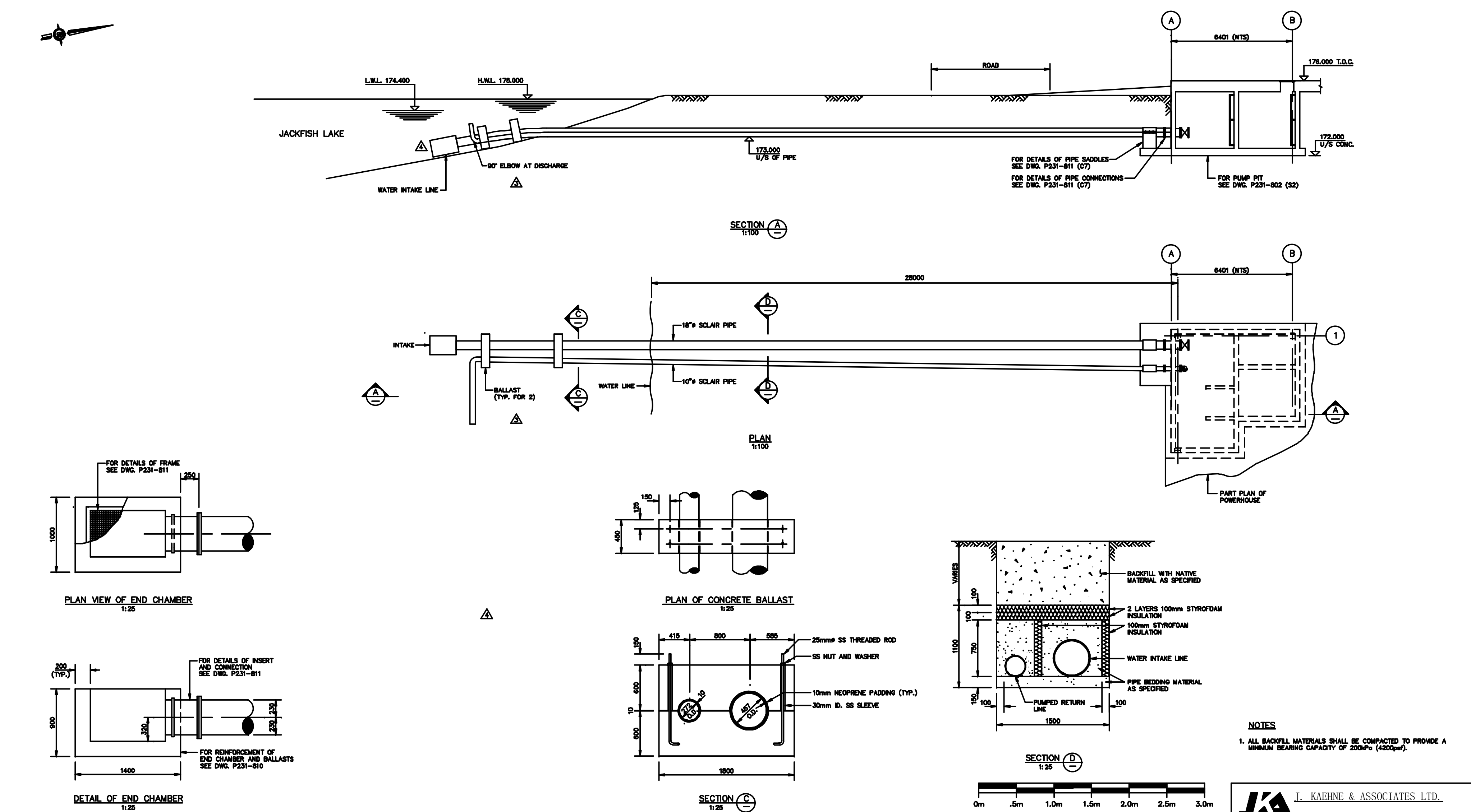
NORTHWEST TERRITORIES POWER CORPORATION

PLANT

TITLE
DIESEL PLANT #3
RAW WATER SYSTEM
PUMPING AND DISTRIBUTION ROUTING
SYSTEM ISOMETRIC

SCALE NTS | SHEET 1 OF 1 | DRAWING NO. P231 - 126323 | REV. B

AUTOCAD FILE: P231/126323 PLOT SCALE: 1:1



NOTES

1. ALL BACKFILL MATERIALS SHALL BE COMPACTED TO PROVIDE A MINIMUM BEARING CAPACITY OF 200kPa (4200psf).

0m .5m 1.0m 1.5m 2.0m 2.5m 3.0m
SCALE: 1:25

J. KAEHNE & ASSOCIATES LTD.
VANCOUVER, BRITISH COLUMBIA, CANADA

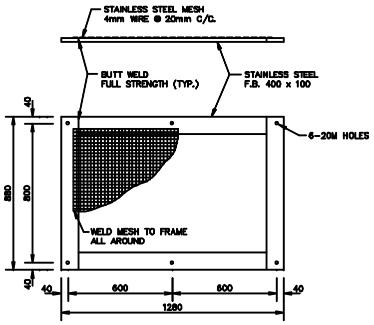
LOCATION: JACKFISH LAKE YELLOWKNIFE
PLANT: P-231
NORTHWEST TERRITORIES POWER CORPORATION
TITLE: JACKFISH LAKE DIESEL PLANT No.3 COOLING WATER INTAKE SYSTEM LAYOUT AND DETAILS SHEET 1

DRAWING NO.	TITLE	REVISION LETTER	REVISION	WORK ORDER	DRAWN BY NAME	DRAWN BY DATE	CHECKED BY	DESIGNED BY	CIVIL	MECH	ELEC	T & D	P & C	STATUS OF DRAWING	DATE
		5	AS BUILT – SHORTENED COOLING WATER INTAKE		JTS	95 01 20		P.E.						AS BUILT	95 01 20
		4	MODIFICATIONS TO COOLING WATER INTAKE	101-5159	D.G.	94 07 21	D.P.	D.P.						FOR APPROVAL	
		3	SHORTENED COOLING WATER INTAKE; DELETED SECTION B		K.C.	93 02 27	D.P.	J.W.						AS BUILT	93 02 27
P231-C0811 (C7)	COOLING WATER INTAKE – MISCELLANEOUS DETAILS	2	GENERAL		K.C.	92 04 30	D.P.	J.W.						FOR CONSTRUCTION	92 04 30
P231-C0802 (S2)	PUMP PITS – LAYOUT SHEET 1	1			K.C.	92 04 01	D.P.	J.W.						FOR REFERENCE	92 04 01
		0	ORIGINAL	01-5-049	K.C.	91 12 19	D.P.	J.W.						FOR BID PURPOSES ONLY	92 02 20

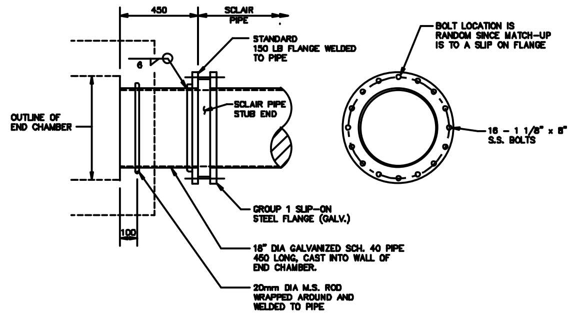
REFERENCE DRAWINGS — APPROVED FOR CONSTRUCTION BY

SCALE: AS NOTED — SHEET 1 OF 1 — DRAWING NO. P231-C0801 — REV. 5

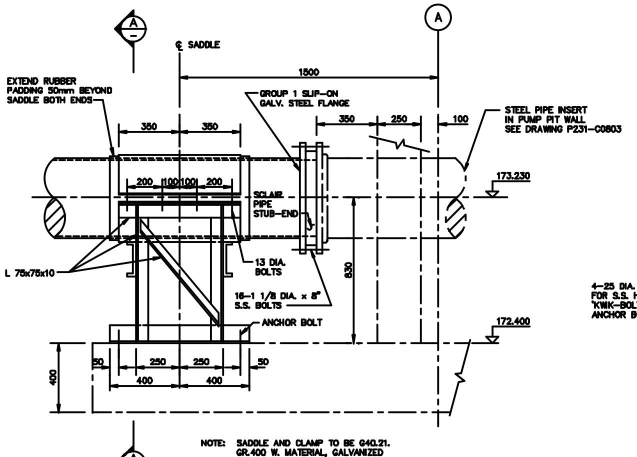
AUTOCAD FILE: \P231\C0801.DWG 95 01 31 12:00 MW



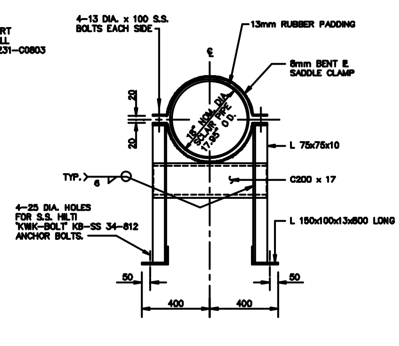
COOLING WATER INTAKE
END CHAMBER COVER
1:15



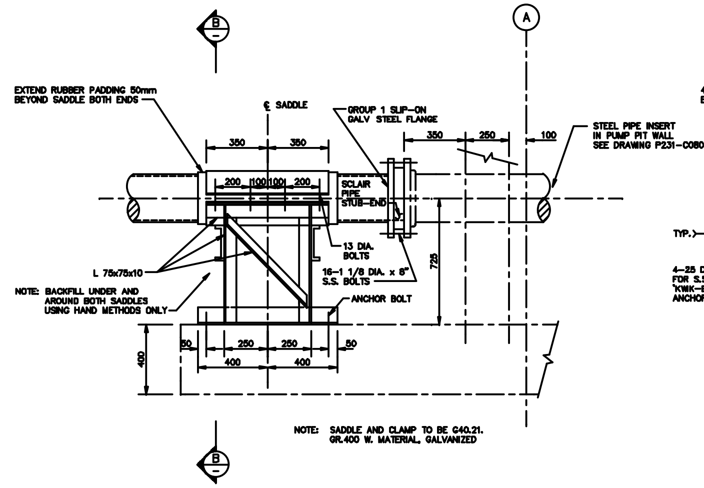
CONNECTION OF SCLAIR PIPE
TO END CHAMBER
1:15



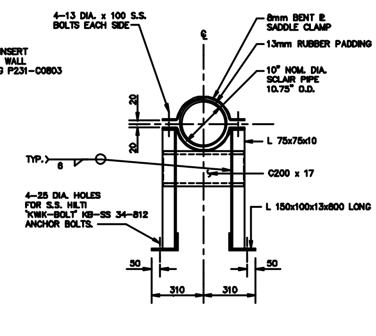
SADDLE FOR 18" DIA. SCLAIR PIPE
1:15



SECTION A
1:15



SADDLE FOR 10" DIA. SCLAIR PIPE
1:15



SECTION B
1:15

NOTES:

1. HOT DIP GALVANIZING SHALL CONFORM TO CSA. G164-M81 AND SHALL BE AT THE RATE OF 2.0 oz. per sq. ft.

J. KAEHNE & ASSOCIATES LTD.
VANCOUVER, BRITISH COLUMBIA, CANADA

LOCATION: JACKFISH LAKE YELLOWKNIFE
PLANT: P-231

NORTHWEST TERRITORIES POWER CORPORATION

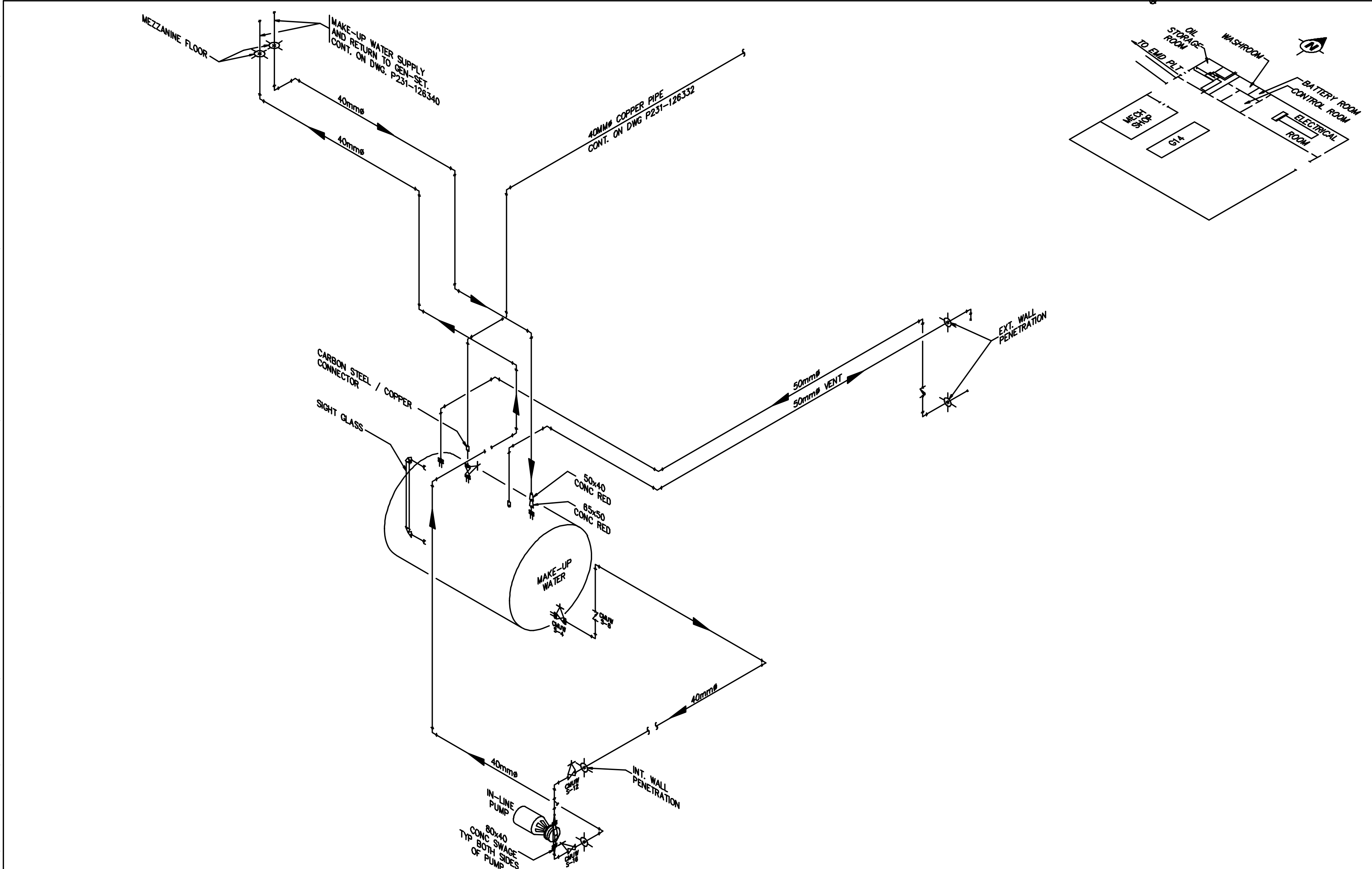
TITLE: JACKFISH LAKE DIESEL PLANT No.3
COOLING WATER INTAKE
MISCELLANEOUS DETAILS

DRAWING NO.	TITLE	REVISION LETTER	REVISION	WORK ORDER	NAME	DATE	CHECKED BY	DESIGNED BY	STATUS OF DRAWING	DATE
		3	GENERAL		K.C.	93 02 27	D.P.	J.W.	AS BUILT	93 02 27
		2	GENERAL		K.C.	92 04 30	D.P.	J.W.	FOR CONSTRUCTION	92 04 30
P231-C0803 (S3)	PUMP PITS - LAYOUT AND MISCELLANEOUS DETAILS	1			K.C.	92 04 01	D.P.	J.W.	FOR REFERENCE	92 04 01
		0	ORIGINAL	01-5-045	G.T.	92 02 18	D.P.	J.W.	FOR BID PURPOSES ONLY	92 02 20

REFERENCE DRAWINGS | DRAWN BY | APPROVED FOR CONSTRUCTION BY: CIVIL, MECH, ELEC, T & D, P & C

SCALE 1:15 | SHEET 1 OF 1 | DRAWING NO. P231-C0811 | REV. 3

AUTOCAD FILE: \P231\C0811.DWG 93 03 03 11:45 KC | C7



		B	VALVE NUMBERS REVISED		R.L.	12/00								AS BUILT 2000	12/00
P231-126340	MAKE-UP WATER DISTRIBUTION	A	AS BUILT AS PER FIELD INFO PROVIDED	901-6310	F.L.	04/97	S.E.S.								
DRAWING NO.	TITLE	0	ORIGINAL	525/94	R.LAYCOCK	JUNE.16/94									
REFERENCE DRAWINGS		REVISION LETTER	REVISION	WORK ORDER	NAME	DATE	CHECKED BY	DESIGNED BY	CIVIL	MECH	ELEC	T & D	P & C	STATUS OF DRAWING	DATE
					DRAWN BY				APPROVED FOR CONSTRUCTION BY						

LOCATION
JACKFISH LAKE
YELLOWKNIFE N.W.T.

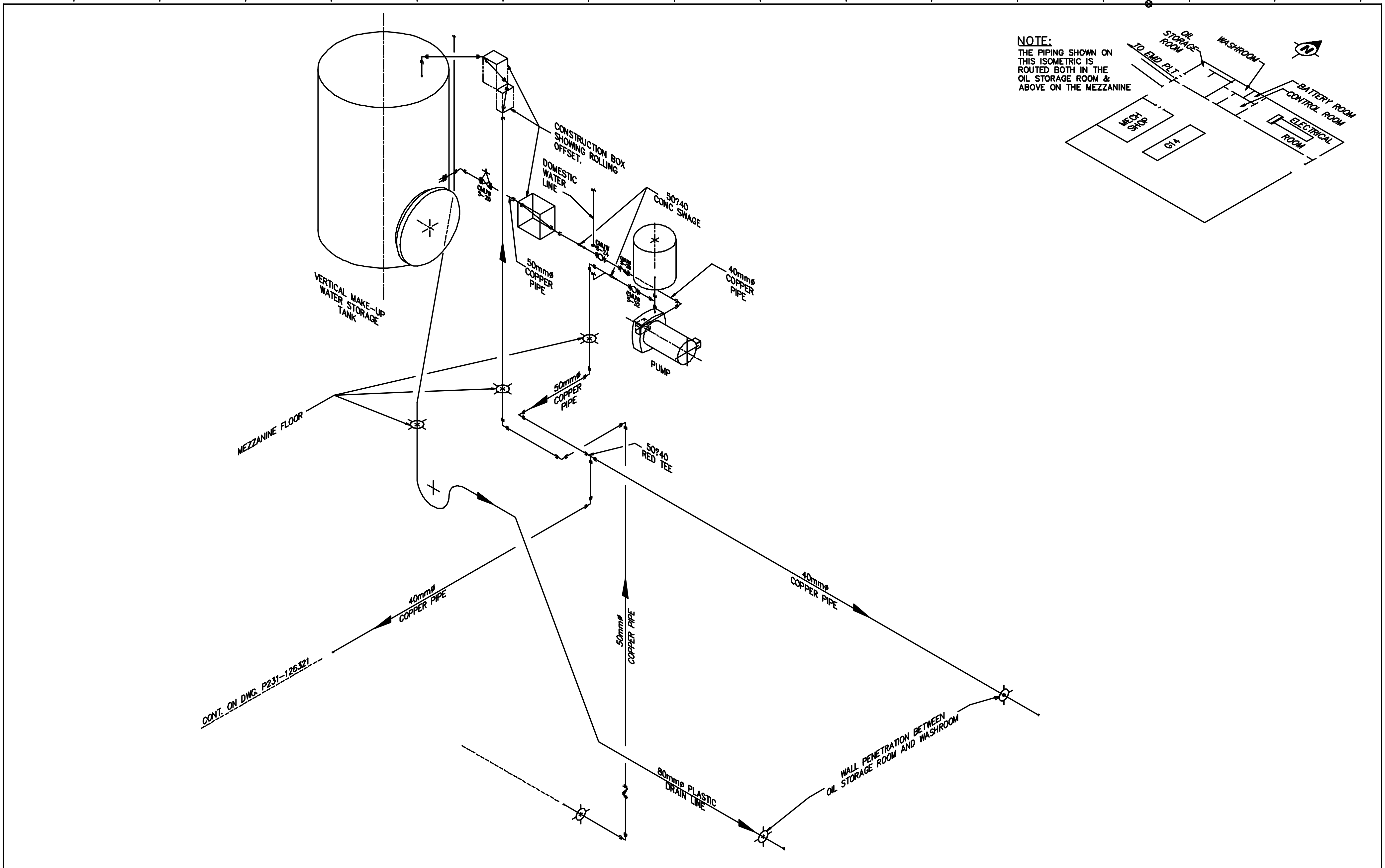
NORTHWEST TERRITORIES POWER CORPORATION

PLANT

TITLE
DIESEL PLANT #3
MAKE-UP WATER SYSTEM
STORAGE TANK AND DISTRIBUTION VALVING
SYSTEM ISOMTERIC

SCALE NTS | SHEET 1 OF 1 | DRAWING NO. P231-126321 | REV. B

AUTOCAD FILE: P231/126321 PLOT SCALE: 1:1



DRAWING NO.	TITLE	REVISION LETTER	REVISION	WORK ORDER	DRAWN BY NAME	DRAWN BY DATE	CHECKED BY	DESIGNED BY	STATUS OF DRAWING	DATE
P231-126340	MAKE-UP WATER DIST. TO CAT 3612-G14	B	VALVE NUMBERS REVISED		R.L.	12/00			AS BUILT 2000	12/00
P231-126321	MAKE-UP WATER TANK & DIST. VALVING	A	AS BUILT AS PER FIELD INFO PROVIDED	901-6310	F.L.	04/97	S.E.S.			
		0	ORIGINAL	525-94	R.LAYCOCK	JUNE.20/94				
REFERENCE DRAWINGS										

APPROVED FOR CONSTRUCTION BY: CIVIL | MECH | ELEC | T & D | P & C

LOCATION: JACKFISH LAKE YELLOWKNIFE N.W.T.

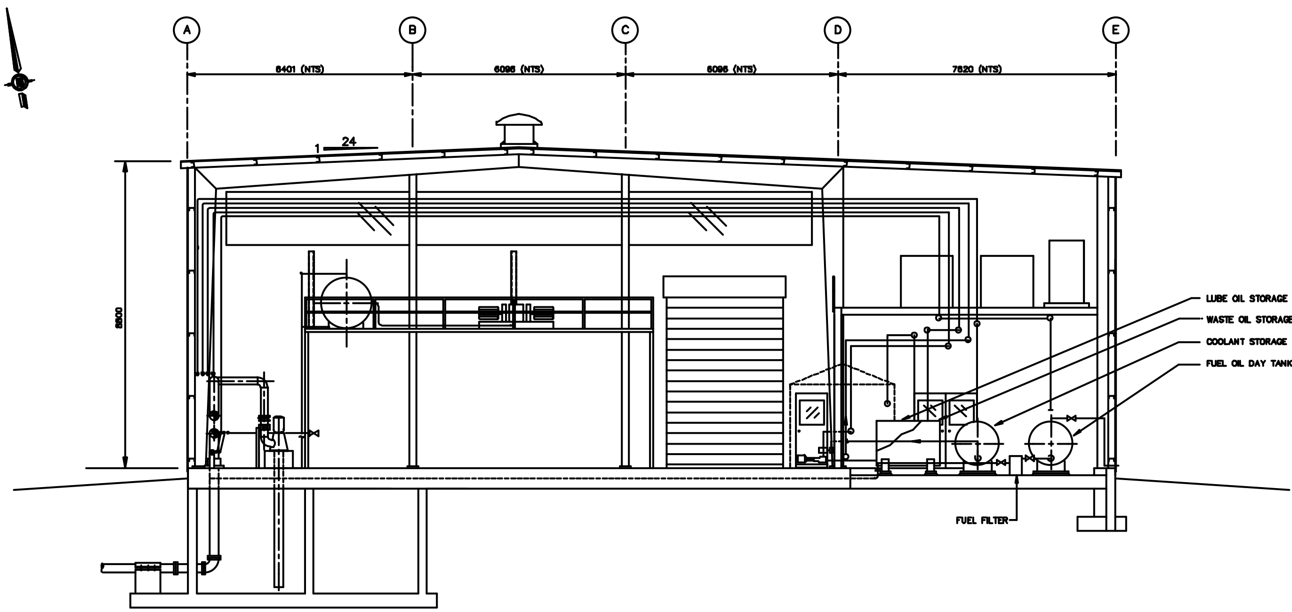
NORTHWEST TERRITORIES POWER CORPORATION

PLANT

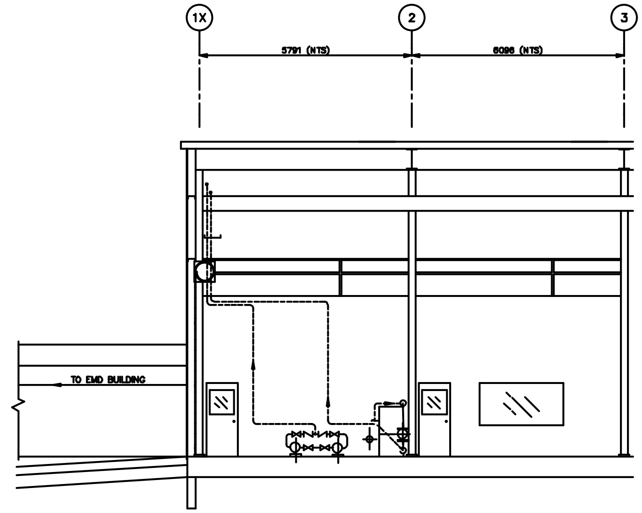
TITLE: DIESEL PLANT #3
MAKE-UP WATER SYSTEM
WATER STORAGE & INITIAL DISTRIBUTION
SYSTEM ISOMETRIC

SCALE: NTS | SHEET 1 OF 1 | DRAWING NO. P231 – 126322 | REV. B

AUTOCAD FILE: P231/126322 PLOT SCALE: 1:1



SECTION A/M7
N.T.S.



SECTION B/M7
N.T.S.

0m 2.0m 4.0m 6.0m 8.0m 10.0m
SCALE: 1:75

REVISION LETTER	REVISION	WORK ORDER	DRAWN BY NAME	DRAWN BY DATE	CHECKED BY	DESIGNED BY	CIVIL	MECH	ELEC	T & D	P & C	STATUS OF DRAWING	DATE
2	AS PER CONTRACTOR'S MARK-UP		K.C.	93 03 11	D.P.	L.J.F.						AS BUILT	93 03 11
1	STATION LUBE OIL TANK, TRANSFER PUMP AND PIPING DELETED.		K.C.	92 08 06	D.P.	P.E.		D.P.				FOR CONSTRUCTION	92 08 07
0	ORIGINAL	01-5-049	K.C.	92 04 03	D.P.	J.W.						FOR BID PURPOSES ONLY	92 05 19

REFERENCE DRAWINGS: DRAWING NO. | TITLE

J. KAEHNE & ASSOCIATES LTD.
VANCOUVER, BRITISH COLUMBIA, CANADA

LOCATION: JACKFISH LAKE YELLOWKNIFE
PLANT: P-231

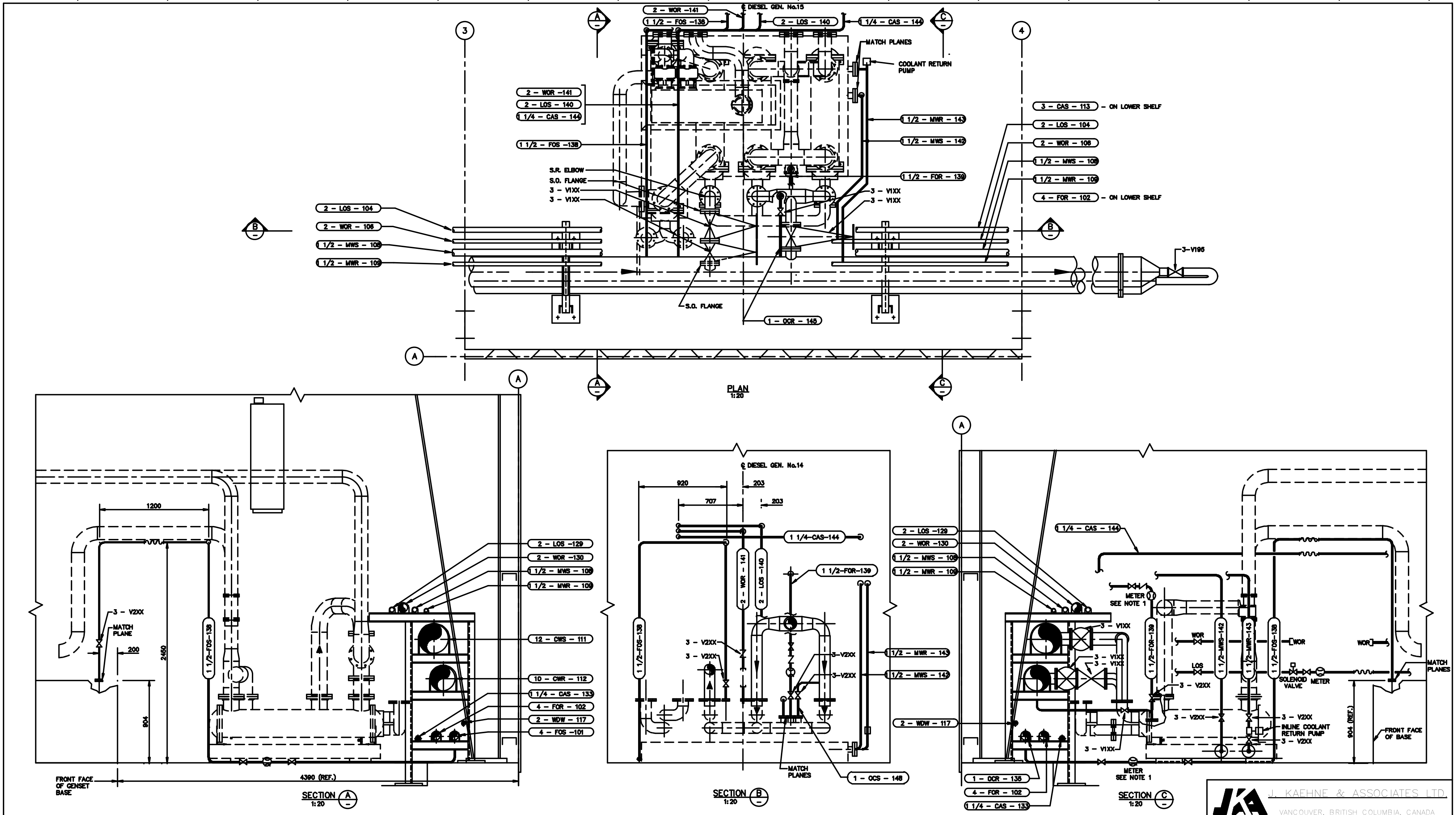
NORTHWEST TERRITORIES POWER CORPORATION

TITLE: JACKFISH LAKE DIESEL PLANT No.3
GENERAL ARRANGEMENT
SECTIONS AND DETAILS

SCALE: N.T.S. | SHEET 1 OF 2 | DRAWING NO. P231-156302 | REV. 2

AUTOCAD FILE: P231\156302 93 04 05 10:45 KC

M9



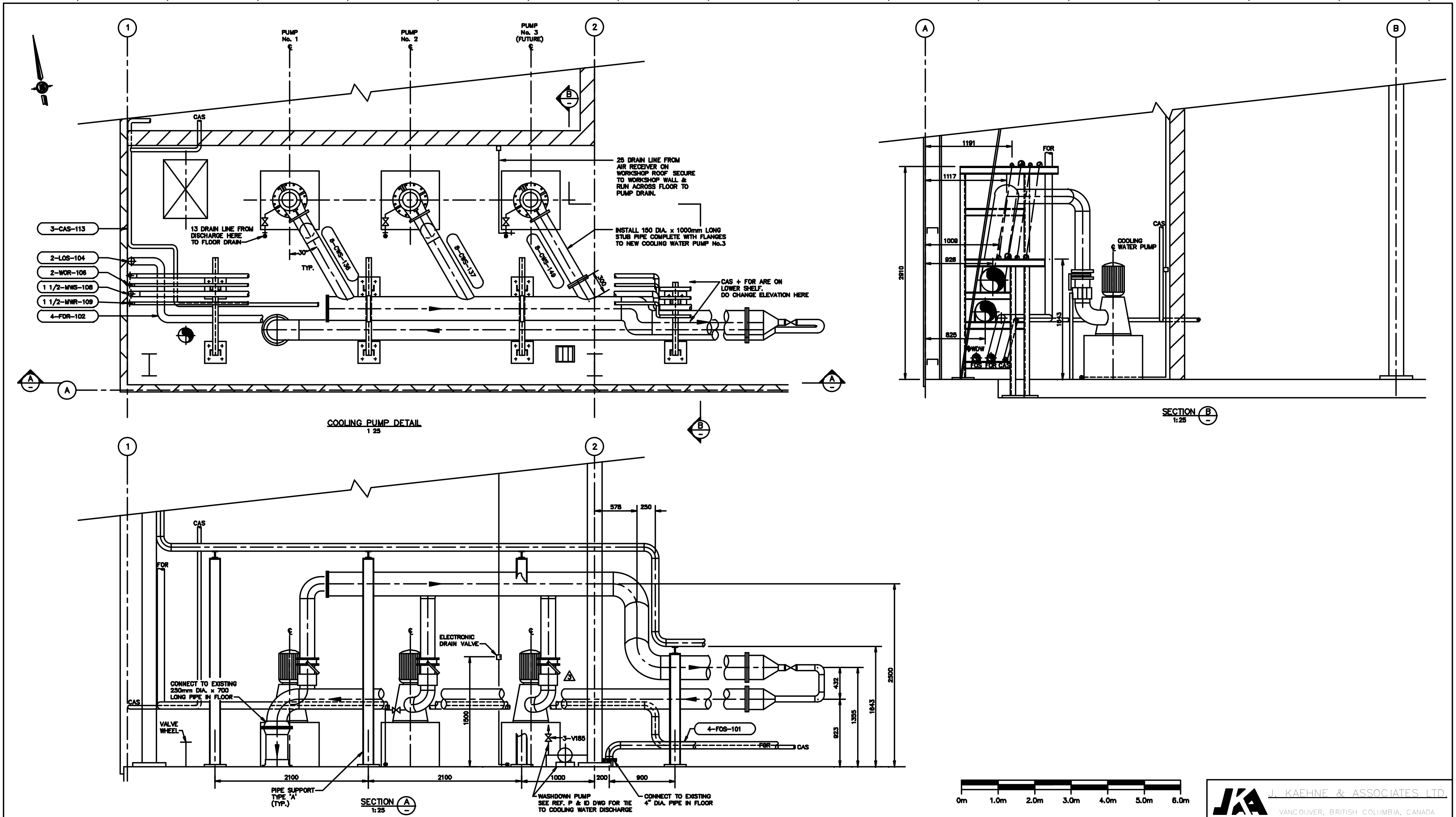
J. KAEHNE & ASSOCIATES LTD.
VANCOUVER, BRITISH COLUMBIA, CANADA

DRAWING NO.	TITLE	REVISION LETTER	REVISION	WORK ORDER	NAME	DATE	CHECKED BY	DESIGNED BY	CIVIL	MECH	ELEC	T & D	P & C	STATUS OF DRAWING	DATE
		4	AS BUILT – G15 INSTALLED		JTS	95 01 19		P.E.						AS BUILT	95 01 19
		3	DRAWING REVISED FOR G15 PIPING	101-5159	D.G.	94 07 22	D.P.	D.P.		D.P.	P.E.			FOR REFERENCE	
		2	AS PER CONTRACTOR'S MARK-UP		K.C.	93 03 11	D.P.	M.B.		D.P.	P.E.			AS BUILT	93 03 11
		1	PIPE SUPP. BRACKETS, WATER COOLING RTRN TO INCL FLANGES & ELBOW REV'D. 3-V195 & PIPING ADDED	01-5-049	K.C.	92 06 07	D.P.	M.B.		D.P.	P.E.			FOR CONSTRUCTION	92 06 07
		0	ORIGINAL	01-5-049	K.C.	92 04 08	D.P.	D.A.						FOR BID PURPOSES ONLY	92 05 19

REFERENCE DRAWINGS — DRAWN BY — APPROVED FOR CONSTRUCTION BY

LOCATION: JACKFISH LAKE YELLOWKNIFE
PLANT: P-231
NORTHWEST TERRITORIES POWER CORPORATION
TITLE: JACKFISH LAKE DIESEL PLANT No.3 GENSET CONNECTION PIPING DETAILS
SCALE: N.T.S.
SHEET 1 OF 3
DRAWING NO. P231-156304
REV. 4

AUTOCAD FILE: P231\156304 95 01 19 8:30 JTS



		4	AS BUILT – G15 INSTALLED		JTS	95 01 19		P.E.						AS BUILT	95 01 19
		3	ADDITION OF COOLING PUMP No.3	101–5159	D.G.	94 07 22	D.P.	D.P.		D.P.	P.E.			FOR REFERENCE	
		2	AS PER CONTRACTOR'S MARK–UP	01–5–049	K.C.	92 08 06	D.P.	M.B.		D.P.	P.E.			AS BUILT	93 03 11
P231–156250A	PROCESS AND INSTRUMENTATION DIAGRAM	1	REV. COOLING WATER RTN. SHOW TIE–IN TO WASHDN PMP & PIPE SUPP. ADDED COOLING WATER BYPASS	01–5–049	K.C.	92 08 06	D.P.	M.B.		D.P.	P.E.			FOR CONSTRUCTION	92 08 07
DRAWING NO.	TITLE	0	ORIGINAL	01–5–049	K.C.	92 04 21	D.P.	D.A.						FOR BID PURPOSES ONLY	92 05 19
REFERENCE DRAWINGS		REVISION LETTER	REVISION	WORK ORDER	NAME (DRAWN BY)	DATE (DRAWN BY)	CHECKED BY	DESIGNED BY	CIVIL (APPROVED FOR CONSTRUCTION BY)	MECH	ELEC	T & D	P & C	STATUS OF DRAWING	DATE

J. KAEHNE & ASSOCIATES LTD.
VANCOUVER, BRITISH COLUMBIA, CANADA

LOCATION: JACKFISH LAKE YELLOWKNIFE

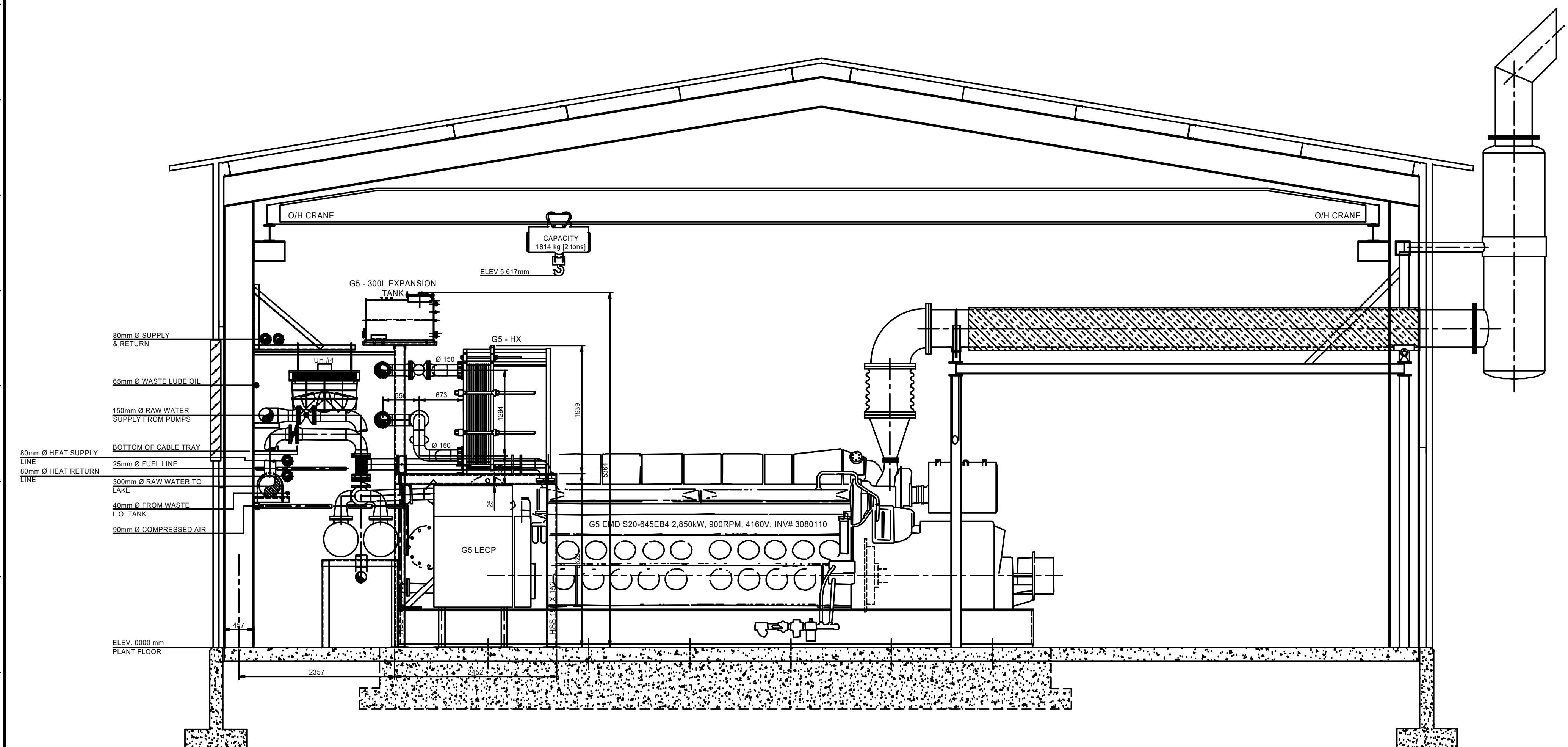
PLANT: P–231

NORTHWEST TERRITORIES POWER CORPORATION

TITLE: JACKFISH LAKE DIESEL PLANT No.3
COOLING WATER PUMPS
PIPING DETAILS

SCALE	SHEET	DRAWING NO.	REV.
N.T.S.	SHEET 1 OF 1	P231–156305	4

AUTOCAD FILE: P231\156305 95 01 27 17:00 MW



SECTION A / M01
SCALE: 1 : 30

DRAWING NO.	TITLE	REVISION LETTER	REVISION	WORK ORDER	DRAWN BY NAME	DRAWN BY DATE	CHECKED BY	DESIGNED BY	STATUS OF DRAWING	DATE
		0	ORIGINAL	101.5395	S.E.S.	01/04	W.T.		CONCEPTUAL	02/04

REFERENCE DRAWINGS

PROFESSIONAL STAMP

PERMIT STAMP

LOCATION
JACKFISH LAKE, YK. NT.

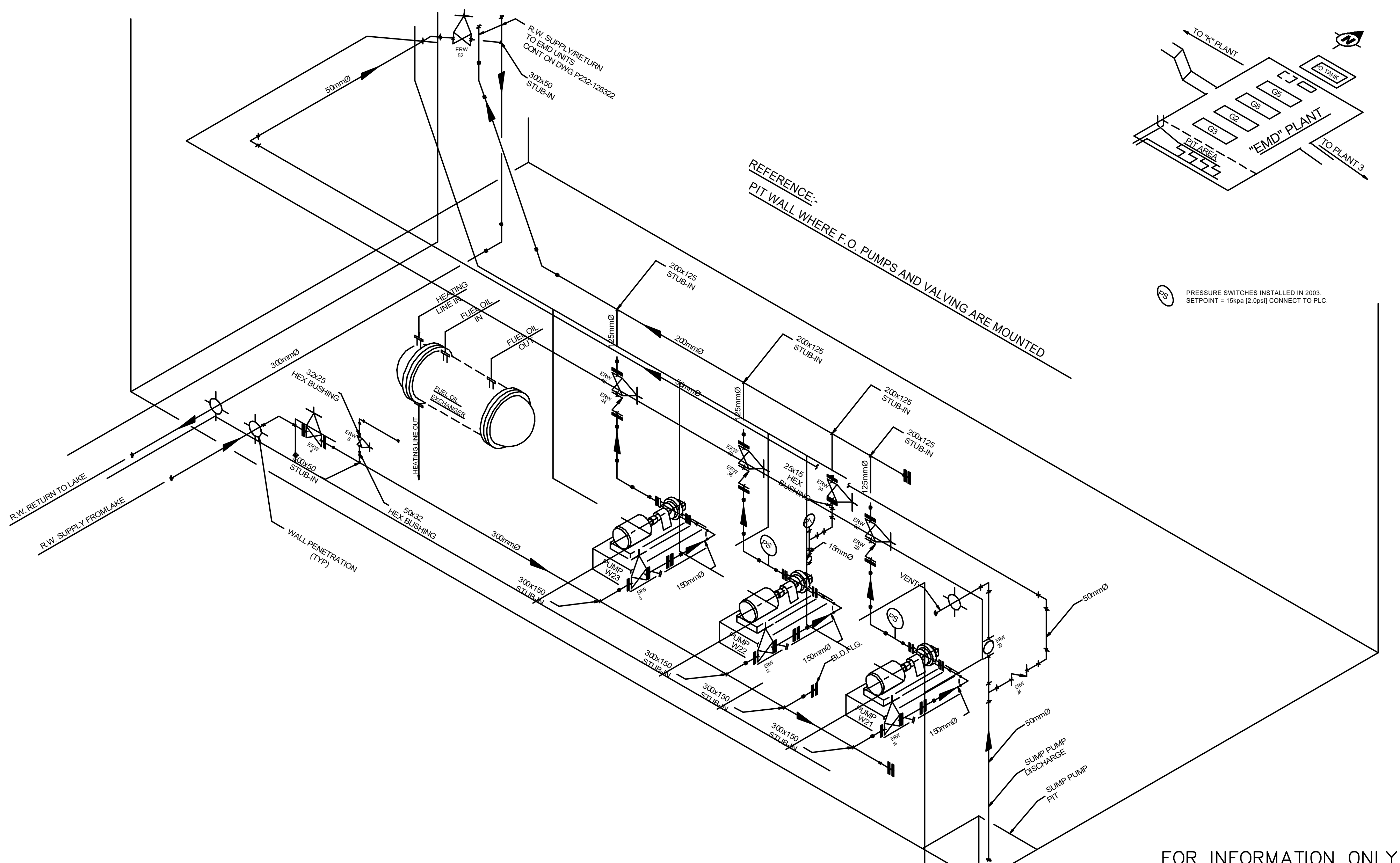
NORTHWEST TERRITORIES POWER CORPORATION

TITLE 1974 DIESEL PLANT NO. 2 (EMD)–2004 CONSTRUCTION HEAT AND COOLING SYSTEM UPGRADE SECTION

SCALE	SHEET	DRAWING NO.	REV.
1 : 30	SHEET 1 OF 1	H-P232-5395-SK08	0

AUTOCAD FILE: P-232-5395SK08.dwg

PLOT SCALE: 1 : 30



FOR INFORMATION ONLY

THIS AREA IS LOCATED IN THE PIT AT THE "SOUTH" END OF THE BUILDING

DRAWING NO.	TITLE	REVISION LETTER	REVISION	WORK ORDER	NAME (DRAWN BY)	DATE (DRAWN BY)	CHECKED BY	DESIGNED BY	STATUS OF DRAWING	DATE
		B	VALVE NUMBERS REVISED		R.L.	12/00			AS BUILT 2000	12/00
P232 - 126322	R.W. DISCH. TO EMD UNITS	A	AS BUILT AS PER FIELD INFO PROVIDED	901-6310	F.L.	04/97	S.E.S.			
		0	ORIGINAL	525-94	R.LAYCOCK	MAY 31/94				
REFERENCE DRAWINGS										

PROFESSIONAL STAMP

PERMIT STAMP

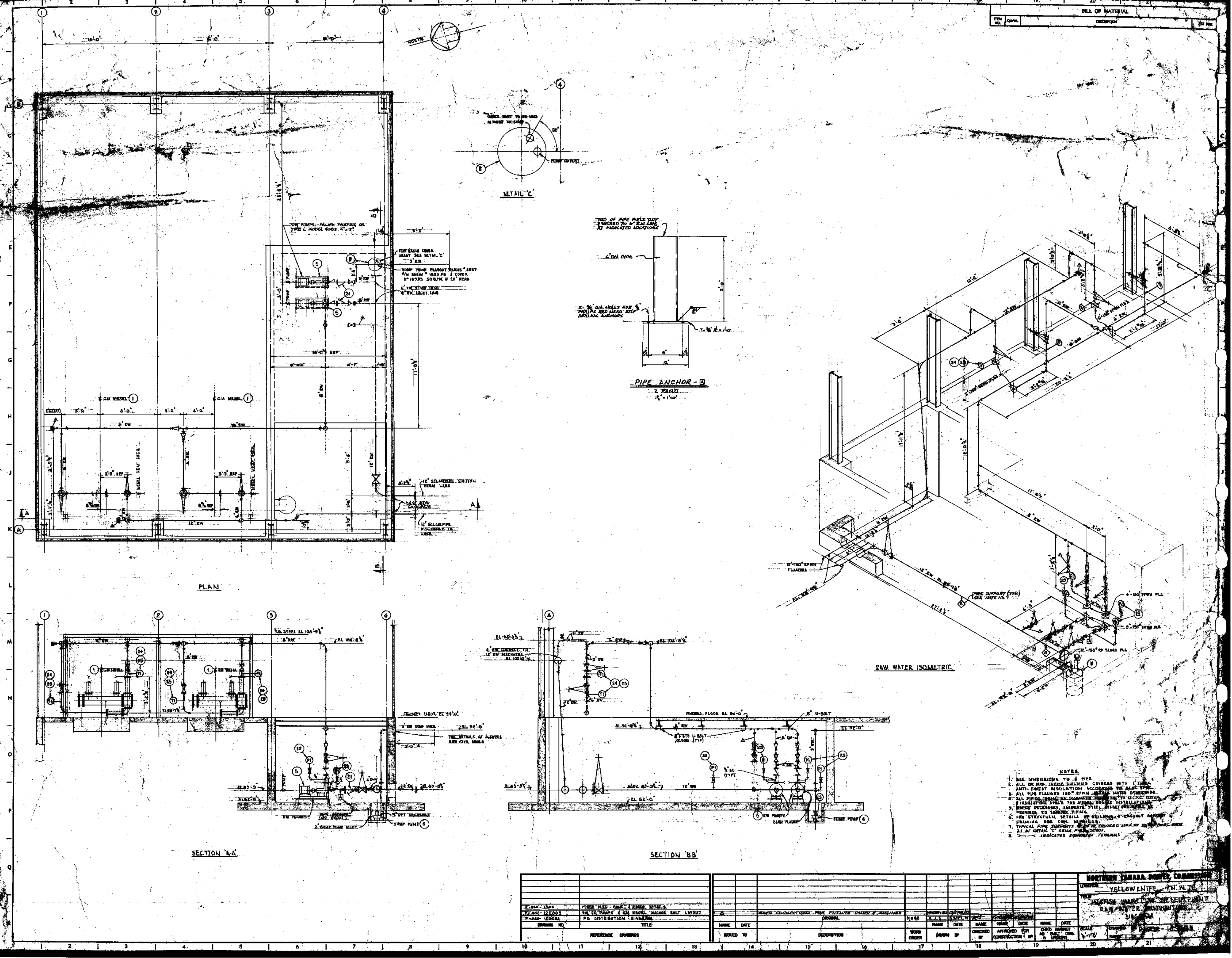
LOCATION
JACKFISH LAKE, YK
N.W.T.

NORTHWEST TERRITORIES POWER CORPORATION

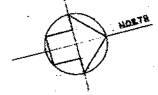
TITLE
1974 DIESELPLANT (EMD)
RAW WATER SYSTEM
PUMP SECTION AND DISCHARGE PIPE ROUTING
SYSTEM ISOMETRIC

SCALE	SHEET	DRAWING NO.	REV.
NTS	SHEET 1 OF 1	P232-126323	B

AUTOCAD FILE: \DOCUMENT\PROJECTS\PLANTS\P232_02\126323 PLOT SCALE: 1 : 1

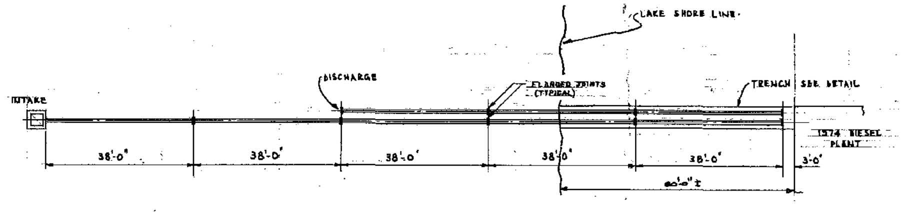


PLAN
DETAIL 'C'
PIPE ANCHOR - A
RAW WATER ISOMETRIC
SECTION 'AA'
SECTION 'BB'
NOTES.
1. ALL DIMENSIONS TO ℄ PIPE
2. ALL ... INSIDE BUILDING COVERED WITH 1" THICK ANTI-SWEAT INSULATION ACCORDING TO ... SPEC.
3. ALL PIPE FLANGES 150# RFWN, UNLESS NOTED OTHERWISE.
4. ALL PIPING ... TO N.C.P.C. PIPING & INSULATION SPEC'S FOR DIESEL ENGINE INSTALLATIONS.
5. WHERE NECESSARY, ADEQUATE STEEL STRUCTURE SHALL BE PROVIDED TO SUPPORT PIPING.
6. FOR STRUCTURAL DETAILS OF BUILDING & EXHAUST ... & FRAMING SEE CIVIL DRAWINGS.
7. TYPICAL PIPE SUPPORTS ... PROVIDED SIMILAR ... AS IN DETAIL 'C' DRWG. P-...-12600I.
8. ⟩—⟨ INDICATES EQUIPMENT TERMINALS
P-...-1604 FLOOR PLAN - CONC. & ... DETAILS
P-...-125005 ... PUMPS & ... DIESEL ... BOLT LAYOUT
P-...-12600I F.O. DISTRIBUTION DIAGRAM
DRAWING NO.
TITLE
REFERENCE DRAWINGS
ADDED CONNECTIONS FOR FUTURE PUMP & ENGINES
ORIGINAL
NAME
DATE
ISSUED TO
DESCRIPTION
WORK ORDER
DRAWN BY
CHECKED BY
APPROVED FOR CONSTRUCTION BY
CHKD AGAINST AS BUILT DWG. & UPDATED
NORTHERN CANADA POWER COMMISSION
LOCATION YELLOWKNIFE N.W.T.
TITLE JACKFISH ... DIESEL PLANT RAW WATER DISTRIBUTION DIAGRAM
SCALE
DRAWING NO.
SHEET

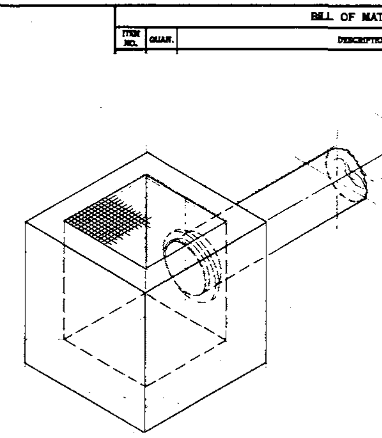


BILL OF MATERIAL

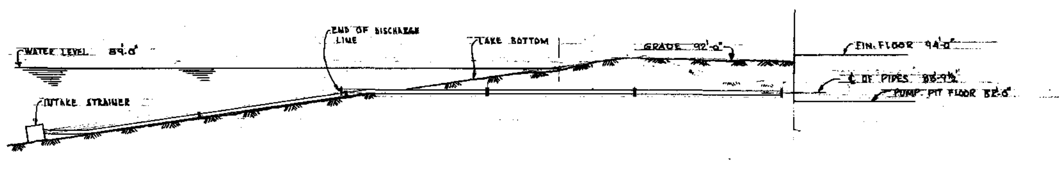
ITEM NO.	QUAN.	DESCRIPTION	P.O. NO.



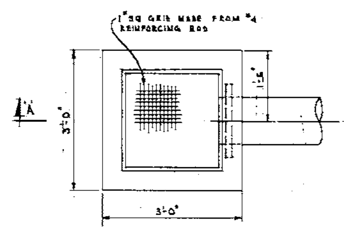
PLAN VIEW
1/16" = 1'-0"



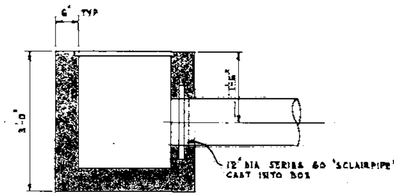
INTAKE STRAINER
3/4" = 1'-0"



ELEVATION
1/16" = 1'-0"



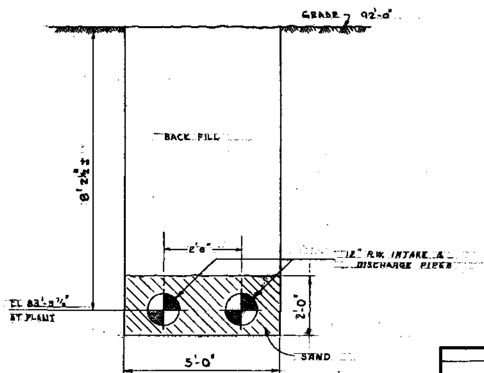
PLAN - INTAKE STRAINER
3/4" = 1'-0"



SECTION 'A-A'
3/4" = 1'-0"

NOTES

1. ALL LINES ARE 12" DIA. SERIES 60 'SCLAIRPIPE' FLANGED 38'-0" LENGTHS.
2. TRENCH TO BE 5'-0" WIDE WITH MAX COVER OF 10'-0" OVER PIPE.
3. FLANGES TO MATCH 150# ANSI R.F. FLANGES.
4. 'SCLAIRPIPE' TO BE FITTED FLANGE TO FLANGE.



TRENCH DETAILS
NTS

DRAWING NO.	TITLE
P-7832-125003	R.W. DISTRIBUTION DIAGRAM

REFERENCE DRAWINGS

ISSUED TO NAME	DATE	DESCRIPTION	WORK ORDER	DRAWN BY NAME	DATE	CHECKED BY NAME	APPROVED FOR CONSTRUCTION BY NAME	DATE	CHKD AGAINST AS BUILT DWG. & UPDATED NAME	DATE
KNC	Nov. 14 74	Rev. A - ELEVATIONS INDICATED WHERE REQ'D.	01062	S.S.	Nov. 14 74	G.G.	[illegible]			
		ORIGINAL	01062	A.J.B	3 SEPT 74	[illegible]	[illegible]	15/10/74		

NORTHERN CANADA POWER COMMISSION

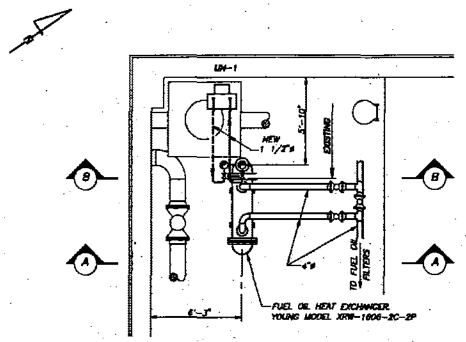
LOCATION: YELLOWKNIFE N.W.T.

TITLE: JACKFISH LAKE 1974 DIESEL PLANT RAW WATER INTAKE & DISCHARGE PIPING LAYOUT

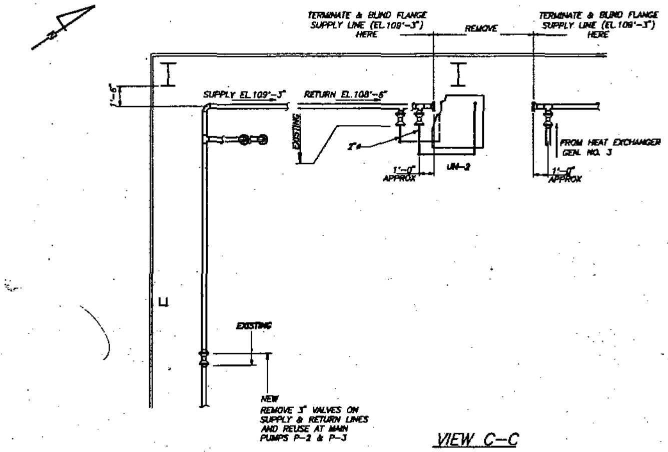
SCALE: AS NOTED

DRAWING NO. P7832 - 125004

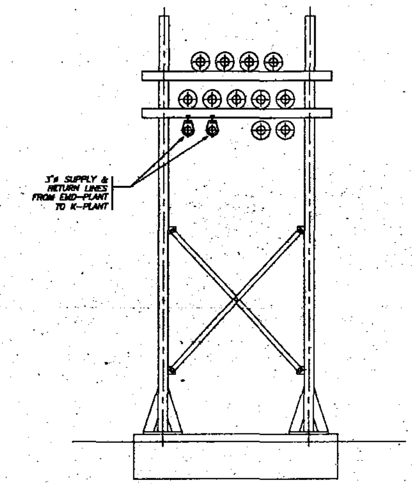
SHEET 1 OF 1



PLAN OF PIT AREA
(BELOW EL. 100'-0")
(SHOWING AS BUILT LAYOUT OF HEATING PIPING)

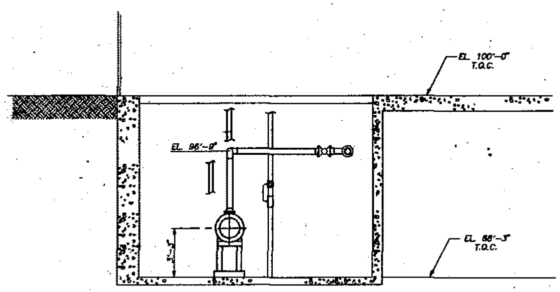


VIEW C–C
(EL. 109'-3")

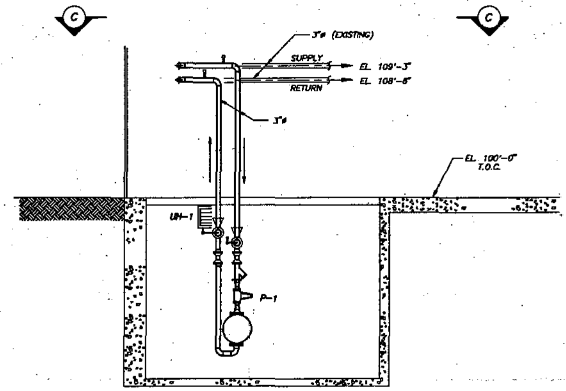


SECTION (A-A / M-1)

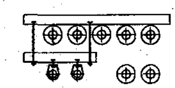
TYP. EXIST. PIPERACK ELEVATION
N.T.S.



SECTION A–A



SECTION B–B



TYP. INTERMEDIATE PIPE SUPPORT DETAIL
N.T.S.

SITE		
NTPC DRAWING No.		REV.
SHEET OF		DATE
W.O.		P.O.

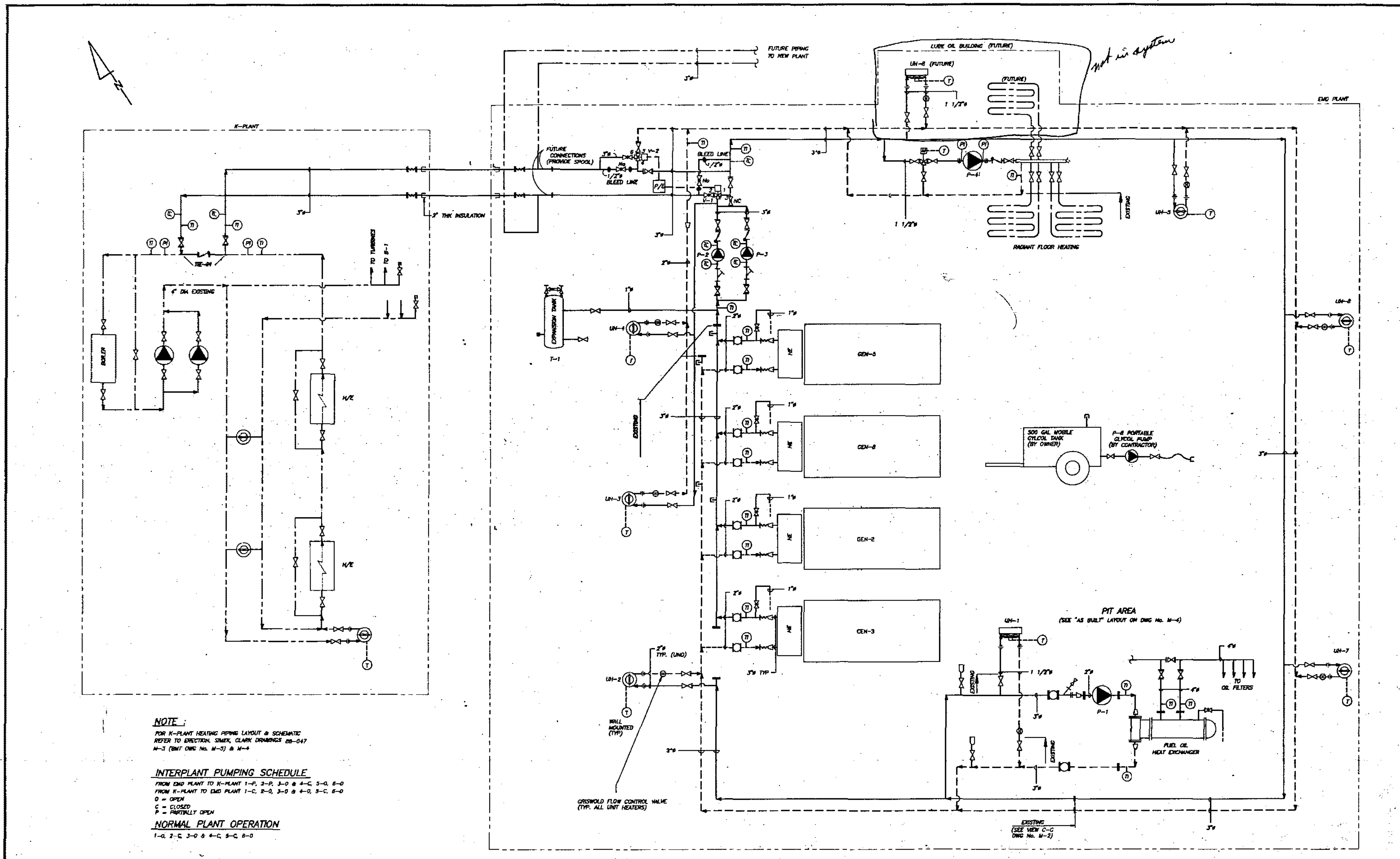
JUN 18 1990

NO.	REVISION	DATE

BMT ASSOCIATES LTD.
CONSULTING TECHNOLOGISTS
EDMONTON ALBERTA

IAN M. DRINNAN
consulting mechanical engineer
YELLOWKNIFE N.W.T.

DRAWN	CHECKED	SCALE	CLIENT : NORTHWEST TERRITORIES POWER CORPORATION
K.N.	T.W.B.	1/4"=1'-0"	PROJECT : JACKFISH LAKE POWER PLANT
APPROVED	DATE	PROJECT NO. 89226	TITLE : EMD PLANT SECTIONS & DETAILS
			DRAWING NO. : P232-126000



NOTE :

FOR K-PLANT HEATING PIPING LAYOUT & SCHEMATIC REFER TO ERECTION, SIMEK, CLARK DRAWINGS 88-047 M-3 (BMT DWG No. M-3) & M-4

INTERPLANT PUMPING SCHEDULE

FROM EMD PLANT TO K-PLANT 1-P, 2-P, 3-O & 4-C, 5-O, 6-O
FROM K-PLANT TO EMD PLANT 1-C, 2-O, 3-O & 4-O, 5-C, 6-O
O = OPEN
C = CLOSED
P = PARTIALLY OPEN

NORMAL PLANT OPERATION

1-O, 2-C, 3-O & 4-C, 5-C, 6-O

JUN 18 1998

NO.	REVISION	DATE

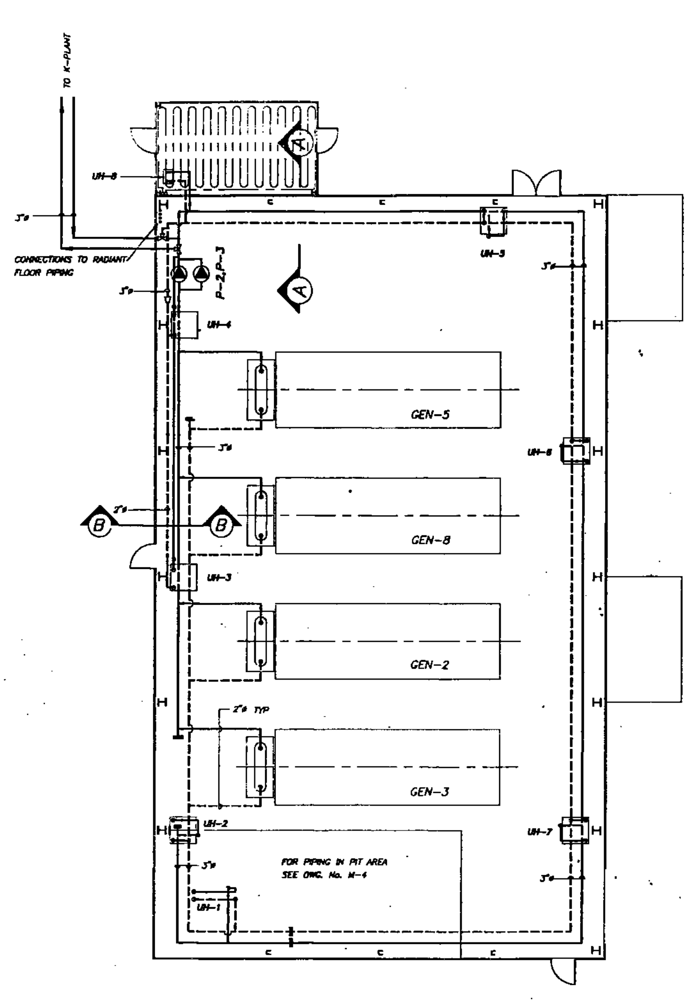
BMT ASSOCIATES LTD.
CONSULTING TECHNOLOGISTS
EDMONTON ALBERTA

IAN M. DRINNAN
consulting mechanical engineer
YELLOWKNIFE N.W.T.

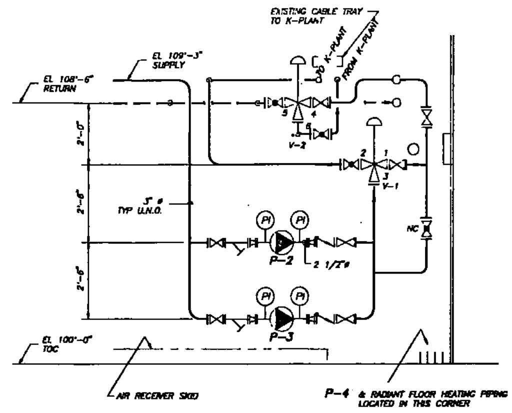
NCPC DRAWING No. | REV.
SHEET OF | DATE
W.O. | P.O.

DRAWN	CHECKED	SCALE
K.N.	T.W.B.	NONE
APPROVED	DATE	PROJECT NO. 89228 89263

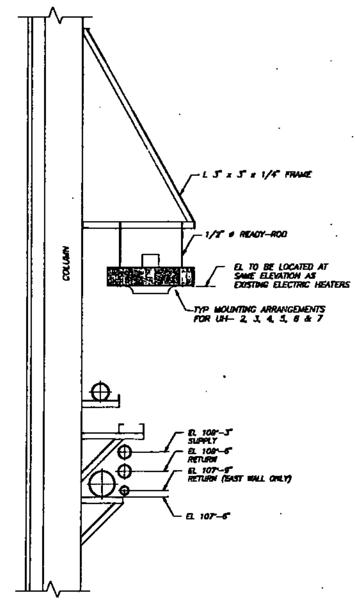
CLIENT : NORTHWEST TERRITORIES POWER CORPORATION
PROJECT : JACKFISH LAKE POWER PLANT
TITLE : EMD PLANT HEATING SCHEMATIC
DRAWING NO. : P232-126001



PIPING LAYOUT
SCALE : 1/8" = 1'- 0"



SECTION A–A
SCALE : 1/2" = 1'- 0"



SECTION B–B
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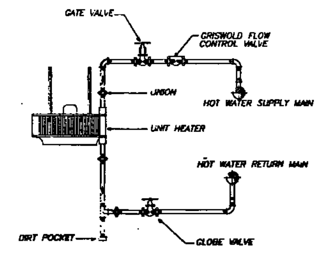
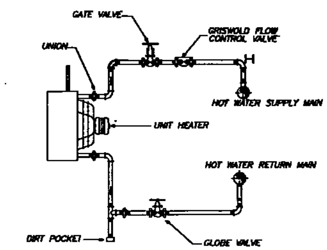


VERTICAL UNIT HEATER PIPING DETAIL
UH -2,3,4,5,6 & 7



HORIZONTAL UNIT HEATER PIPING DETAIL
UH -1, UH - 8

89226 EQUIPMENT SCHEDULE

P-1 FULL OIL HEAT EXCHANGER PUMP (EXISTING)
GRUNDFOS SERIES 200 TYPE UMC 50-80
20 USGPM @ 6' TDH, 208/3/60

P-2 & P-3 HEATING PUMPS
GRUNDFOS SERIES L TYPE 2.5 LM6
150 USGPM @ 40' TDH, 6.9" IMPELLOR
MOTOR 3 HP, 1750 RPM 600/3/60

P-4 RADIANT FLOOR HEATING PUMP
GRUNDFOS MODEL UP 26-64 F
5 USGPM @ 20' TDH
MOTOR 1/12 HP, 115/1/60

P-8 PORTABLE GLYCOL PUMP
12-15 USGPM, 110V c/w CABLE, HOSE & FITTINGS
MOUNTING TO SUIT MOBILE GLYCOL TANK (BY OWNER)

UNIT HEATERS

UH-1 TRANE MODEL 70-S 38 MBH, 0.5 GPM
MOTOR 1/8 HP,1150 RPM 115/1/60

UH-2, 3, 4, 5, 6 & 7 UNIT HEATERS
TRANE MODEL 500 P 288 MBH, 20 GPM
MOTOR 1-1/2 HP,1120 RPM 600/3/60

T-1 EXPANSION TANK
AMTROL "EXTROL" SX-90V PRE PRESSURIZED EXPANSION TANK
44 GAL, SIZE 22"ø x 33" HIGH

CONTROL VALVES

V-1 3-WAY CONTROL VALVE
DEZURIK PERMASEAL 3-WAY PLUG VALVE
ARRANGEMENT Z3 c/w DOUBLE ACTING
PNEUMATIC ACTUATOR

V-2 3-WAY CONTROL VALVE
DEZURIK PERMASEAL 3-WAY PLUG VALVE
ARRANGEMENT Y3 c/w DOUBLE ACTING
PNEUMATIC OPERATOR

HEATING MEDIUM

50/50 PROPYLENE GLYCOL

90263 EQUIPMENT SCHEDULE LUBE OIL DAY TANK EXTENSION

UH-8 UNIT HEATER
TRANE MODEL 70-S, 38 MBH, 0.5 GPM
MOTOR 1/8 HP,1150 RPM 115/1/60

RH-1 RADIANT HEATING
3/4" DIA. KITEK ORANGE (BY SCEPTER) @ 12" CENTRES

JUN 18 1990

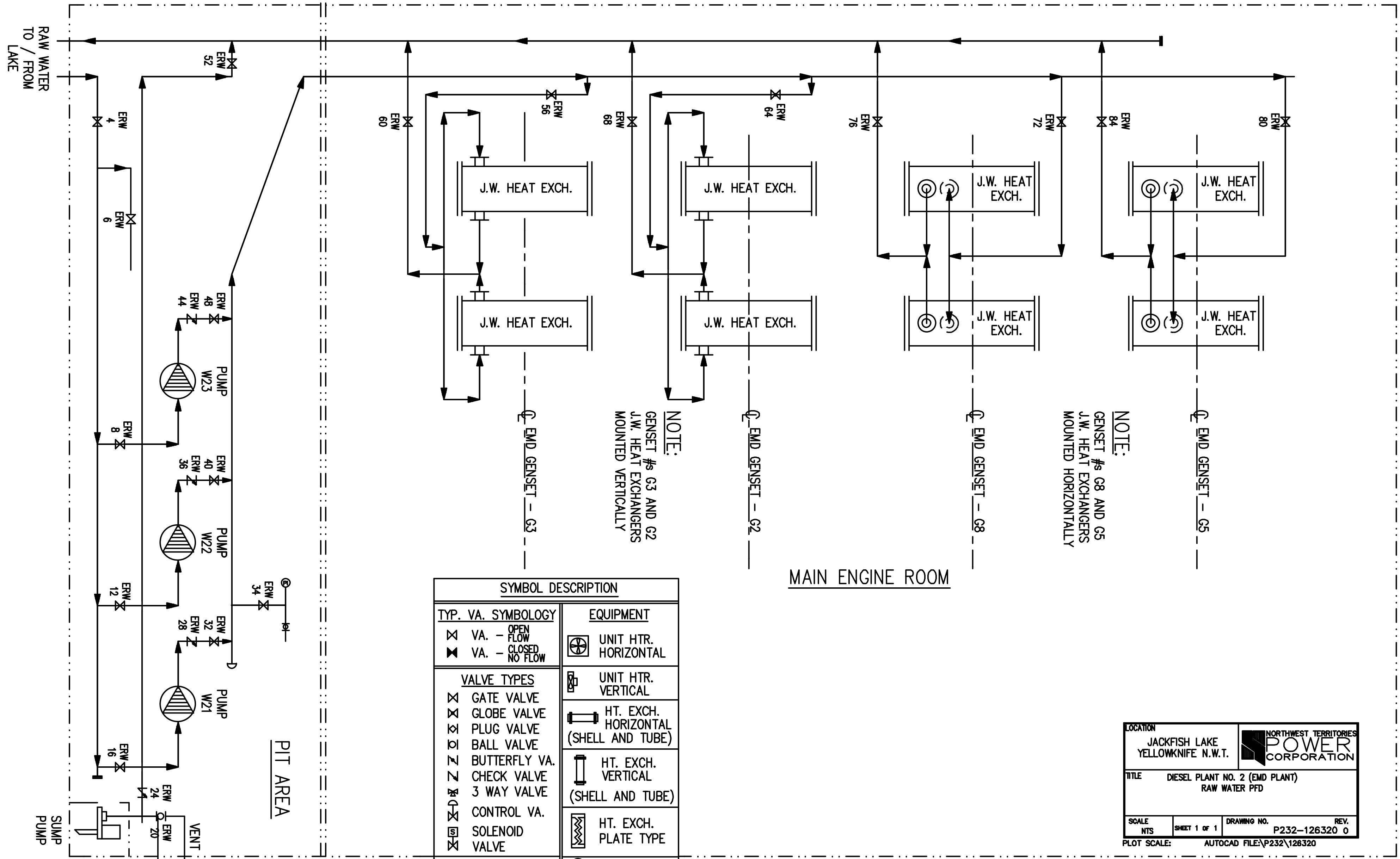
SITE		
NCPC DRAWING No.		REV.
SHEET OF		DATE
W.O.		P.O.

NO.	REVISION	DATE

BMT ASSOCIATES LTD.
CONSULTING TECHNOLOGISTS
EDMONTON ALBERTA

IAN M. DRINNAN
consulting mechanical engineer
YELLOWKNIFE N.W.T.

DRAWN	CHECKED	SCALE	
MAURICE	T.W.B.	AS SHOWN	CLIENT : NORTHWEST TERRITORIES POWER CORPORATION
APPROVED	DATE	PROJECT NO. 89226 90263	PROJECT : JACKFISH LAKE POWER PLANT
			TITLE : EMD PLANT HEATING PIPING LAYOUT
			DRAWING NO. : P232-126002

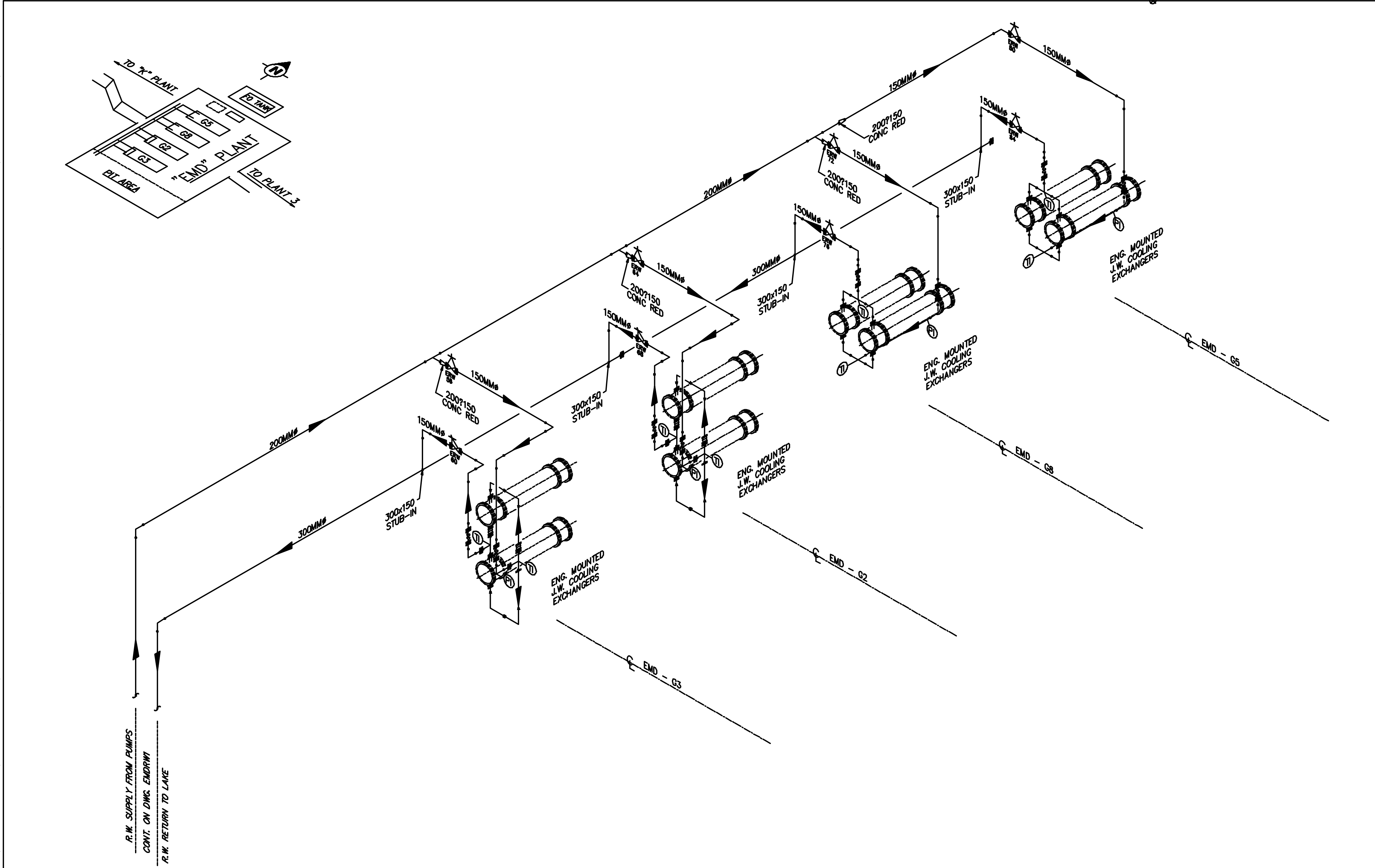


E.M.D. PLANT – RAW WATER – FLOW SHEET

SYMBOL DESCRIPTION

TYP. VA. SYMBOLOGY	EQUIPMENT
VA. – OPEN FLOW	UNIT HTR. HORIZONTAL
VA. – CLOSED NO FLOW	UNIT HTR. VERTICAL
VALVE TYPES	HT. EXCH. HORIZONTAL (SHELL AND TUBE)
GATE VALVE	HT. EXCH. VERTICAL (SHELL AND TUBE)
GLOBE VALVE	HT. EXCH. PLATE TYPE
PLUG VALVE	FLOWMETER
BALL VALVE	PUMP
BUTTERFLY VA.	
CHECK VALVE	
3 WAY VALVE	
CONTROL VA.	
SOLENOID VALVE	
SINGLE FILTER	
DOUBLE FILTER	

LOCATION: JACKFISH LAKE YELLOWKNIFE N.W.T.	NORTHWEST TERRITORIES POWER CORPORATION
TITLE: DIESEL PLANT NO. 2 (EMD PLANT) RAW WATER PFD	
SCALE: NTS — SHEET 1 OF 1	DRAWING NO. P232–126320 — REV. 0
PLOT SCALE:	AUTOCAD FILE:\P232\126320



		B	VALVE NUMBERS REVISED		R.L.	12/00		AS BUILT 2000	12/00	
P232–126325	RAW WATER – PUMP AREA	A	AS BUILT AS PER FIELD INFO PROVIDED	901–6310	F.L.	04/97	S.E.S.			
DRAWING NO.	TITLE	0	ORIGINAL	525–94	R.LAYCOCK	JUNE.2/94				
REFERENCE DRAWINGS		REVISION LETTER	REVISION	WORK ORDER	NAME / DRAWN BY	DATE	CHECKED BY	STATUS OF DRAWING	DATE	

LOCATION: JACKFISH LAKE YELLOWKNIFE N.W.T.

NORTHWEST TERRITORIES POWER CORPORATION

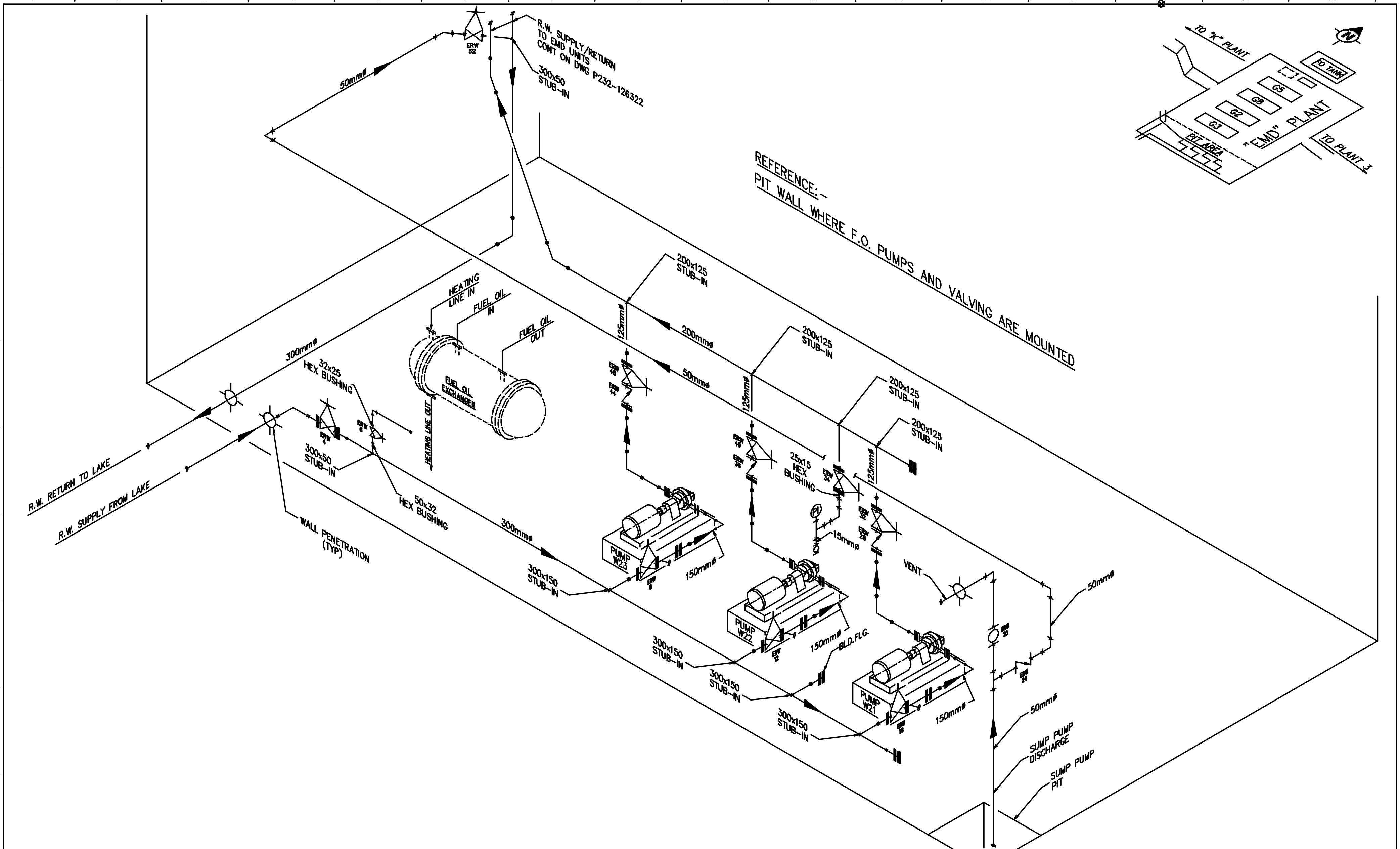
PLANT

TITLE: 1974 DIESEL PLANT (EMD) RAW WATER SYSTEM R.W. ROUTING TO EMD UNITS SYSTEM ISOMETRIC

DESIGNED BY | CIVIL | MECH | ELEC | I & D | P & C — APPROVED FOR CONSTRUCTION BY

SCALE: NTS | SHEET 1 OF 1 | DRAWING NO. P232 – 126322 | REV. B

AUTOCAD FILE: P232/126322 PLOT SCALE: 1:1



THIS AREA IS LOCATED IN THE PIT AT THE "SOUTH" END OF THE BUILDING

DRAWING NO.	TITLE	REVISION LETTER	REVISION	WORK ORDER	NAME (DRAWN BY)	DATE (DRAWN BY)	CHECKED BY	DESIGNED BY	STATUS OF DRAWING	DATE
		B	VALVE NUMBERS REVISED		R.L.	12/00			AS BUILT 2000	12/00
P232 – 126322	R.W. DISCH. TO EMD UNITS	A	AS BUILT AS PER FIELD INFO PROVIDED	901-6310	F.L.	04/97	S.E.S.			
		0	ORIGINAL	525-94	R.LAYCOCK	MAY.31/94				

REFERENCE DRAWINGS — APPROVED FOR CONSTRUCTION BY: CIVIL, MECH, ELEC, T & D, P & C

LOCATION: JACKFISH LAKE YELLOWKNIFE N.W.T.

NORTHWEST TERRITORIES POWER CORPORATION

PLANT

TITLE: 1974 DIESEL PLANT (EMD) RAW WATER SYSTEM PUMP SUCTION AND DISCHARGE PIPE ROUTING SYSTEM ISOMETRIC

SCALE: NTS | SHEET 1 OF 1 | DRAWING NO. P232 – 126323 | REV. B

AUTOCAD FILE: P232/126323 PLOT SCALE: 1:1

NORTHWEST TERRITORIES POWER CORPORATION

Empowering Communities

OPERATIONS, MAINTENANCE AND SURVEILLANCE MANUAL

JACKFISH LAKE
GENERATING FACILITY, NWT
PLANT #120
YELLOWKNIFE, NORTHWEST TERRITORIES

February 2019

DOCUMENT MAINTENANCE AND CONTROL

This document will be reviewed annually by the Plant Operations Manager and updated as required. Changes in phone numbers, names of individuals, etc. that do not affect the intent of the plan are to be made as required.

DOCUMENT HISTORY				
Revision #	**Revised Section(s)**	**Description of Revision**	**Prepared by**	**Issue Date**
0	N/A	First Version	NTPC	Feb 2019

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1 GENERAL

1.1 DESCRIPTION OF FACILITIES

Yellowknife is located on the west shore of Yellowknife Bay on the north arm of Great Slave Lake (Figure 1). The Jackfish Lake Generating Facility (the Jackfish Facility) is located at the north end of Yellowknife on the north shore of Jackfish Lake (formerly known as Stock Lake) and is surrounded by chain-link fencing (Figure 2).

The arrangement of buildings from east to west along the south side of the property is as follows: the office building, Cat Plant, EMD Plant, K-Plant (the three plants are joined by covered walkways), the warehouse, and the line shop. There is a water pump house located south of the K-Plant, a fuel pump house north of the K-Plant, and a storage shed northeast of the line shop. On the north side of the property from east to west sits the substation, the Ruston Plant, a drum storage berm, the tank farm, and five modular gen-sets with a fuel storage tank and control building (Figure 3).

The K-plant built in 1969 and extended in 1988 contains two Mirrlees KV-16 gen-sets rated at 5000 kilowatts (kW) each; only one is in service at this time. The EMD Plant (Photo 1) built in 1974 and extended in 1988 contains four EMD's (Electro-Motive Division of GM); two E-series gen-sets rated at 2500 kW each and two F-series gen-sets rated at 2850 kW each. The Cat plant built in 1993 contains two Caterpillar 3612 gen-sets rated at 2700 kW.

Figure 1: Regional Project Location

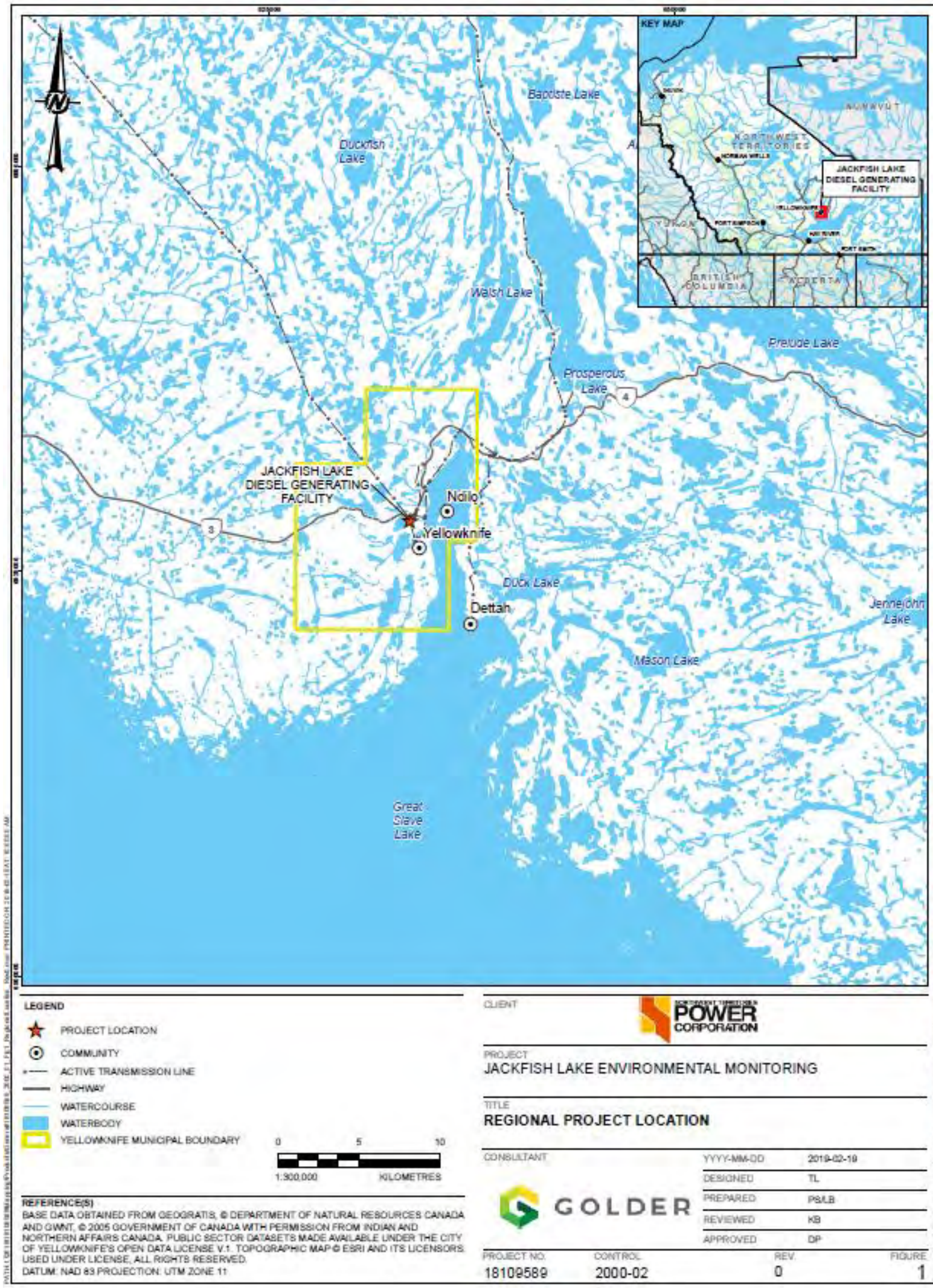


Figure 2: Location of Jackfish Diesel Generating Facility

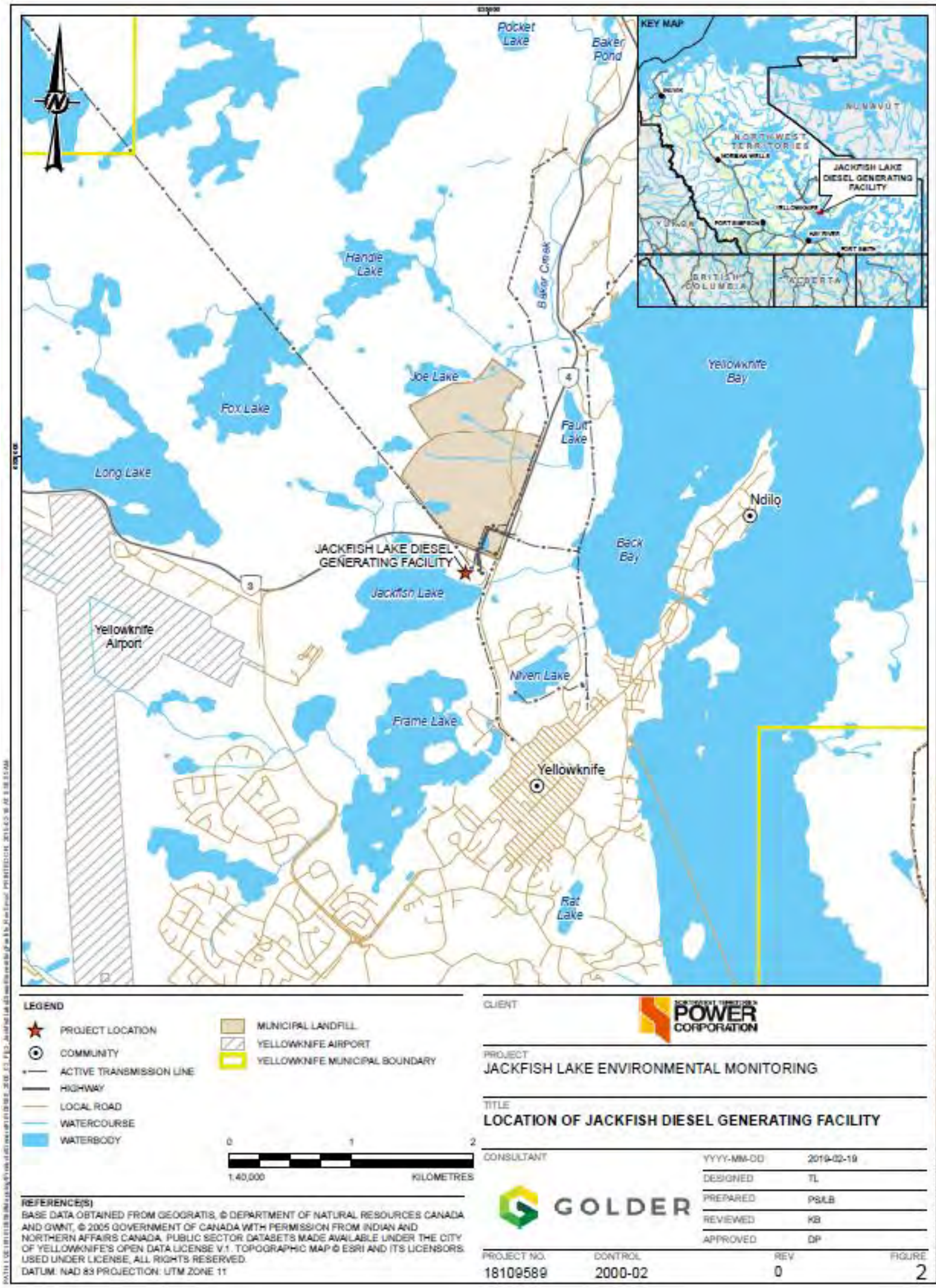


Figure 3: Jackfish Diesel Generating Facility

Photo 1: EMD Plant

The Jackfish Facility is an important component of the North Slave Power System which is the sole supplier of electricity to the communities of Yellowknife, Behchokǫ̀, Ndilo, and Dettah (Figure 4).

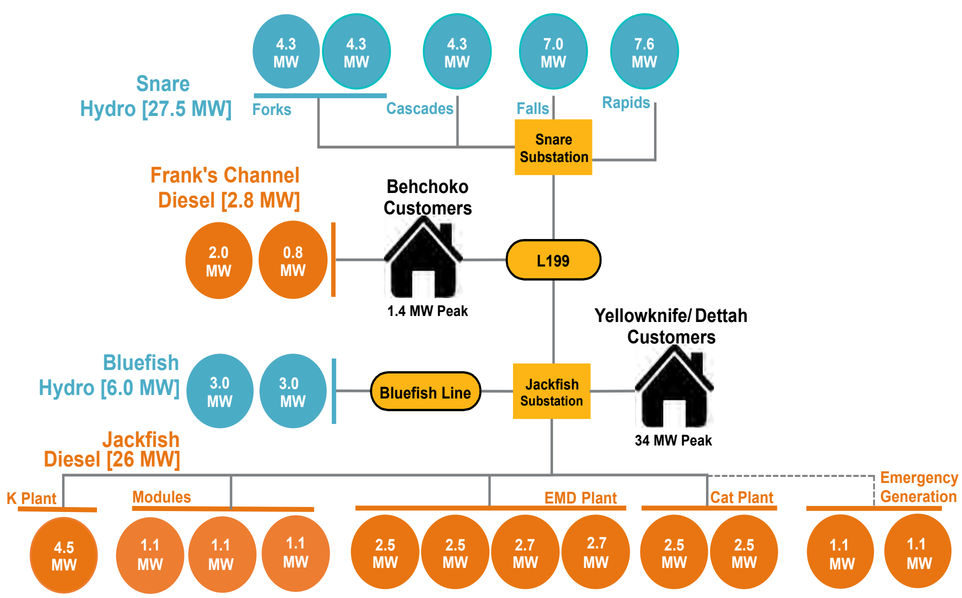


Figure 4: North Slave Power System Diagram

Historically, and recommended by the Northwest Territories (NWT) Public Utilities Board, the Jackfish Facility has been developed so the total installed diesel generating capacity can provide power to the communities in the event of a failure of the L199 transmission line from the Snare Hydro System (Table 1). The diesel generating capacity was sequentially increased until the construction of the 4300 kW Snare Cascades Hydro Plant in 1996 (Table 2). The closure of Con Mine in 2003 and Giant Mine in 2004 and resulting drop in the system load has made further expansion unlikely.

Table 1: North Slave System Generation Maximum Continuous Capacity

System	Plant and Unit	Continuous Capacity (kW)
Snare Hydro	Snare Rapids	7600
	Snare Falls	7000
	Snare Cascades	4300
	Snare Forks #1	4300
	Snare Forks #2	4300
	Total Snare Hydro	**27,500 kW**
Bluefish Hydro	Bluefish G1	3000
	Bluefish G2	3000
	Total Bluefish Hydro	**6,000 kW**
Jackfish Diesel	Mirrlees KV16 (G1)	4500
	Mirrlees KV16 (G4)	0
	EMD S20-645 (G2)	2500
	EMD S20-645 (G3)	2500
	EMD S20-645 (G5)	2700
	EMD S20-645 (G8)	2700
	CAT 3612 (G14)	2500
	CAT 3612 (G15)	2500
	Cummins (G20)	1100
	Cummins (G22)	1100
	Cummins (G25)	1100
	MTU (EM9)	1100
	MTU (EM10)	1100
	Total Jackfish Diesel	**25,400 kW**
Behchokǫ̀ Diesel	Behchokǫ̀ G5	2000
	Behchokǫ̀ G1	800
	Total Behchokǫ̀ Diesel	**2,800 kW**
	Yellowknife Peak Demand	34,000 kW
	Behchokǫ̀ Peak	1,400 kW

Note: EM9 and EM10 to be replaced by two Cummins units of the same capacity.

Table 2: Jackfish Diesel Generating Units in Service

UNIT	MANUFACTURER	MODEL	YEAR	Theoretical kW	Continuous Generation kW	Raw Water Cooling
G1	Mirrlees	KV16	1971	5000	4500	YES
G2	EMD	S20-645E4B	1974	2500	2500	YES
G3	EMD	S20-645-E4B	1974	2500	2500	YES
G5	EMD	S20-645-F4B	1993	2800	2700	YES
G8	EMD	S20-645-F4B	1988	2800	2700	YES
G14	CAT	3612	1993	2700	2500	YES
G15	CAT	3612	1997	2700	2500	YES
G20	Cummins	QSK50-G4	2017	1150	1100	NO
G22	Cummins	QSK50-G4	2017	1150	1100	NO
G23	Cummins	QSK50-G4	2017	1150	1100	NO
EM9	MTU	16V4000G03	2016	1150	1100	NO
EM10	MTU	16V4000	2015	1150	1100	NO

Note: EM9 and EM10 to be replaced in the future by two Cummins units of the same capacity.

2 OPERATION

2.1 OPERATING PRINCIPLES

The Jackfish Facility is a standby plant for the North Slave System. Hydroelectric power, while expensive in capital, is very economic to operate compared to diesel generation. Diesel generating units at Jackfish are therefore only utilized for the following conditions:

Instantaneous loss of hydro supply (Outage). This could be caused by a temporary issue such as lightning strike, failed insulator, or broken conductor on the transmission line, or a hydro unit(s) unplanned shutdown.

Shortage of hydro generating capacity. This occurs when the total system (customers) load exceeds the total available generating capacity of the hydro units. This generally occurs during the winter but may occur due to maintenance on the hydro components.

Diminished hydro supply. Due to low water inflows this may exist for a short duration due to a late spring runoff or for a longer term due to extended drought conditions in the Snare and/or Yellowknife River basins.

2.2 ACTUAL OPERATION

Actual system generation throughout various conditions is shown in Figure 4.

When Jackfish Facility needs to generate due to an instantaneous loss of hydro supply it is generally of short duration and is not significant on a monthly basis. The vast majority of electrical generation comes from Snare or Bluefish Hydro.

A shortage of hydro generating capacity can be seen in the winter months of the normal water year of 2015-2016 and a hydro unit overhaul in July of 2015 (Figure 5).

Diminished hydro supply can be seen in the drought period of 2014-2015 (Figure 5). Considerable diesel generation was required, particularly in the summer, to save water in the reservoirs required for the winter peak demand months.

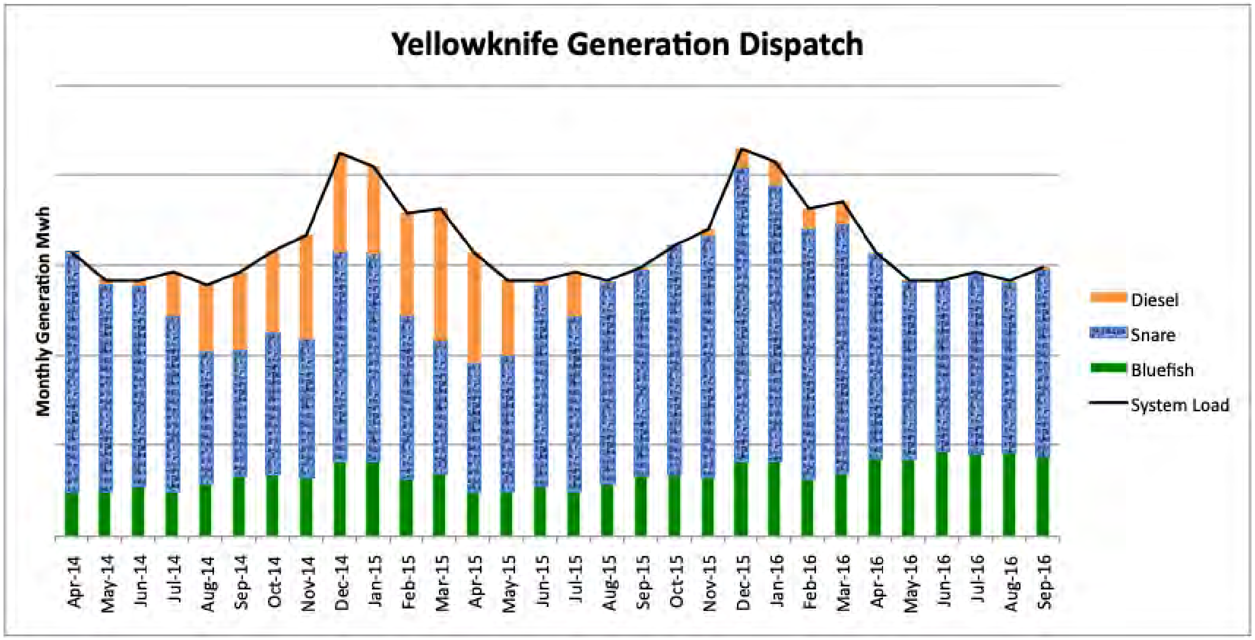


Figure 5: Yellowknife Generation Dispatch

2.3 DIESEL FORECASTING

Forecast Diesel Generation is the remainder of the Forecast System Load minus the Forecast Hydro Generation. This includes a shortage of capacity due to system load peaking in the winter and potential hydro from available reservoir storage and forecast inflows.

The forecasting process is a dynamic process that involves a series of forecasts, updates and adjustments during the year. The process uses some knowledge of hydrologic conditions and the manner in which runoff travels through the Snare River and Yellowknife River basins.

- STEP 1: The first forecast is based on an estimated annual runoff derived from the **April** snow surveys conducted on the Snare River and Yellowknife River basins.
- STEP 2: The next occasion to update the forecast occurs when the spring peak is observed at the Indin River gauge. This peak occurs, typically in **mid-June**, and is a good predictor of the eventual peak flow that will be observed at the Snare Ghost gauge, upstream of the Big Spruce Reservoir. This information is then used to forecast the spring peak flow at Snare Ghost. The resulting update forecast is then used to revise the reservoir-operating plan, the monthly water allocations and plant operations are adjusted accordingly.
- STEP 3: The next occasion to update the forecast occurs when the spring peak is observed at Snare Ghost gauge, normally during the period **mid– to late July**. The forecast is updated based on the observed peak and the recession (falling limb) of the annual hydrograph is adjusted to fit. The inflow hydrograph, water management plan and power plant operations are then updated.
- STEP 4: The fourth step involves monitoring the recession of the annual hydrograph, for the remainder of the year. The initial rate of recession until freeze up, typically in **mid-October**, varies somewhat from year to year. During this period, the performance of the forecast is reviewed and adjusted, normally at monthly intervals.

- STEP 5: After October 15, precipitation measured at Indin River, Snare Rapids and Yellowknife is normally in the form of snow and is a precursor of conditions in the coming year. Snow accumulations estimated for these stations give an indication of the future conditions and forewarning of possible problems.

2.4 OPERATIONAL RESPONSIBILITIES

Staffing levels at Jackfish Facility vary due to the rotation of staff to the Snare and Bluefish hydro plants and North Slave Communities. There are Mechanics, Electricians, and Millwrights as a resource for preventive maintenance, trouble shooting, and emergency repair. In general, there are eight Hydro Plant Operators skilled at operating the Jackfish Facility, although this number may fluctuate according to diesel demand. These operators also rotate through a days on / days off schedule to the Snare and Bluefish hydro systems. Their working hours at Jackfish Facility are scheduled depending on the current role of that plant to the system. An additional and critical role of the operators are supporting inspections for Health and Safety in addition to maintenance tasks identified by the central maintenance system.

There are five System Operators that monitor the North Slave System via SCADA (System Control and Data Acquisition) over a 24/7 shift in addition to 26 other communities.

2.4.1 Plant Operators

Reporting Structure

The Hydro Plant Operators report to the Plant Operations Manager in Yellowknife who reports directly to the Hydro Divisional Director. For technical assistance, there is the Mechanical Services Manager, Electrical Services Manager and System Control Manager in Yellowknife who may provide input and support staff.

Duties of Plant Operators

At a minimum, the Plant Operator does a visual inspection of the entire facility at least once a day. This includes a walk around of each unit, a check of sumps, raw water pumps, tank farm and modules. When Diesel Units are being operated the Plant Operator’s duties increase to observing and recording generating data, temperatures and pressures on the units and auxiliary equipment. The Plant Operator also performs or assists in maintenance.

2.4.2 System Operators

Reporting Structure

The System Operators report to the System Control Manager in Yellowknife who reports directly to the Hydro Divisional Director. For technical assistance, there is the Mechanical Services Manager, Electrical Services Manager, Transmission and Distribution Manager, and Plant Operations Manager in Yellowknife that may provide input and support staff.

Duties of System Operators

The System Operator monitors and controls the various components of the North Slave System to ensure safe, efficient, and reliable power generation. The System Operator directs the dispatch of diesel generating units, based on short- and long-term operating schedules. This may be performed by the Plant Operator or remotely through SCADA. Some high-level monitoring of information and alarms of the Jackfish Facility and units are also performed with SCADA.

2.5 DIESEL GENERATING UNIT COOLING SYSTEMS

The three main plants use Jackfish Lake water (raw water) to circulate cooling between the internal plant heat exchangers and back out to Jackfish Lake (Table 3, Figure 6). Jacket Water is the term used for the internal “closed loop” system for engine cooling which contains a corrosion inhibitor called Powercool 3000 (mixture of 95% water to 5% powercool). The five modular gen-sets use antifreeze for cooling and are not connected to Jackfish Lake for cooling requirements. All pumps are 3-phase, 600 volts. Maximum flow rate is 7,619 imperial gallons per minute, or 34.6 m^3 per minute and 49,882 m^3 per day.

Table 3: Jackfish Facility Raw Water Pumps

K-Plant Vertical 2 Stage Pumps				
PUMP	**HP**	**RPM**	**GPM US**	**GPM IMP**
W1-1	50	1800	1500	1245
W1-2	20	1800	910	755
W4-1	50	1800	1500	1245
W4-2	20	1800	910	755
EMD Plant Horizontal Double Suction Pumps				
PUMP	**HP**	**RPM**	**GPM US**	**GPM IMP**
W2-1	30	1800	840	697
W2-2	30	1800	840	697
W2-3	30	1200	560	465
Cat Plant Vertical Single Stage Pumps				
PUMP	**HP**	**RPM**	**GPM US**	**GPM IMP**
1	15	1750	1060	880
2	7.5	1750	530	440
3	7.5	1750	530	440

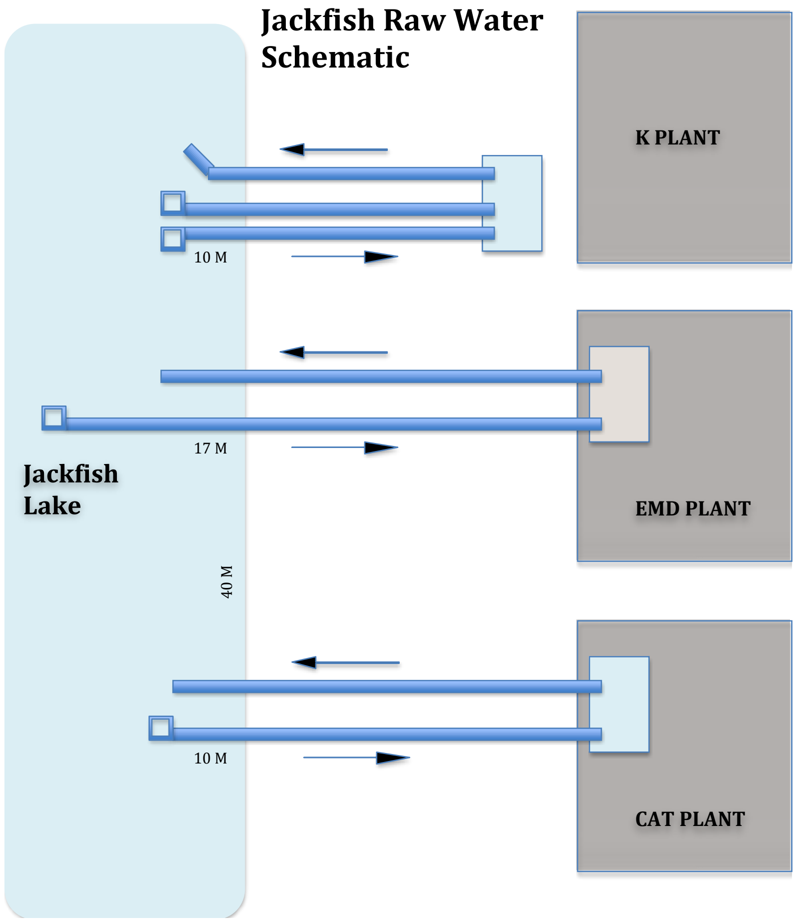


Figure 6: Jackfish Raw Water Schematic

2.5.1 K-Plant Raw Water System

2.5.1.1 Description

The K-Plant raw water system consists of two screened unpressurized intake pipes that allow water from Jackfish Lake to flow into a large covered well enclosed in a pumphouse building (Figure 7, Photo 2). Water can be pumped from the well by any combination of four vertical 2-stage pumps, 2-50 horsepower (HP) and 2-20HP, to the K-Plant powerhouse. In the Powerhouse the raw water flows through sheet and tube heat exchangers for distinct (isolated) Jacket Water, Oil, Fuel, and Turbocharger Air systems. The raw water returns to Jackfish Lake via a common gravity pipe.

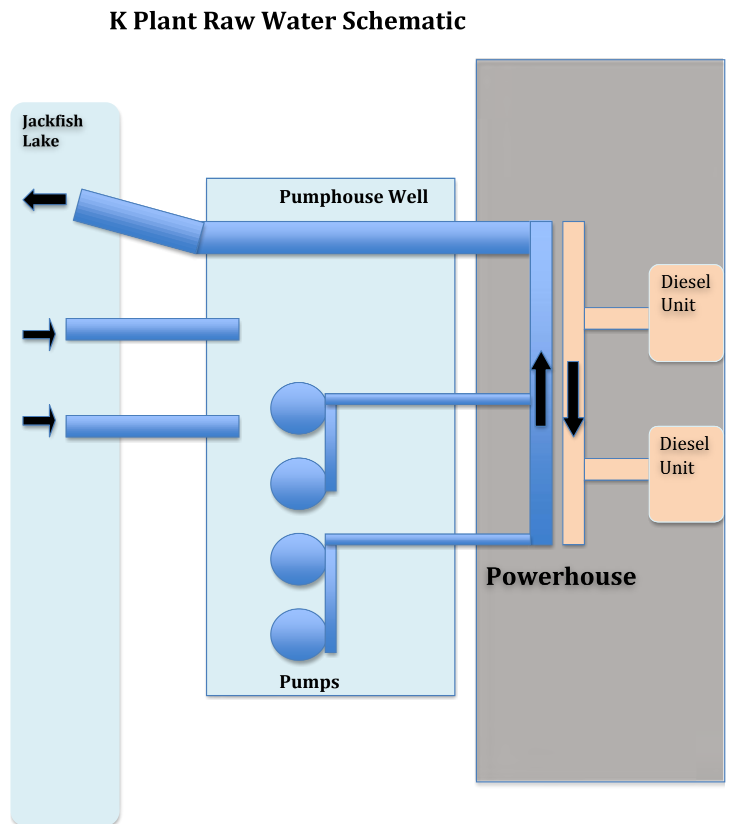


Figure 7: K-Plant Raw Water Schematic

Photo 2: K-Plant Raw Water Pumphouse

2.5.1.2 Normal Operation

The K-Plant raw water system was designed and constructed to supply cooling water to 2 KV-16 Major Generating units. In recent years one unit has been taken out of service so the system is currently overbuilt. Two pumps are normally running continuously to keep the supply and return pipes from freezing in the winter. In summer one pump is running continuously to allow for prompt unit startup in outage conditions. Jacket Water, Oil, and Fuel are not pumped through the heat exchangers (Photo 3) unless the corresponding pumps are manually turned on, generally upon unit startup.

Photo 3: K-Plant Sheet and Tube Oil Heat Exchanger

2.5.2 EMD Plant Raw Water System

2.5.2.1 Description

Unlike the K-Plant the EMD Plant raw water system draws water directly from the lake via a screened and valved, 12-inch intake pipe (Figure 8). From the intake pipe three 30-HP horizontal pumps are installed in parallel to a 12-inch outlet manifold (Photo 4). This system is located in a dry sump below the powerhouse floor. The outlet manifold rises and extends the length of the powerhouse where it is circulated through the main heat exchangers of each of the four generating units. The EMDs are self-contained beyond this heat exchanger so there are no additional heat exchangers on the raw water system. The raw water returns to Jackfish Lake via a common gravity pipe.

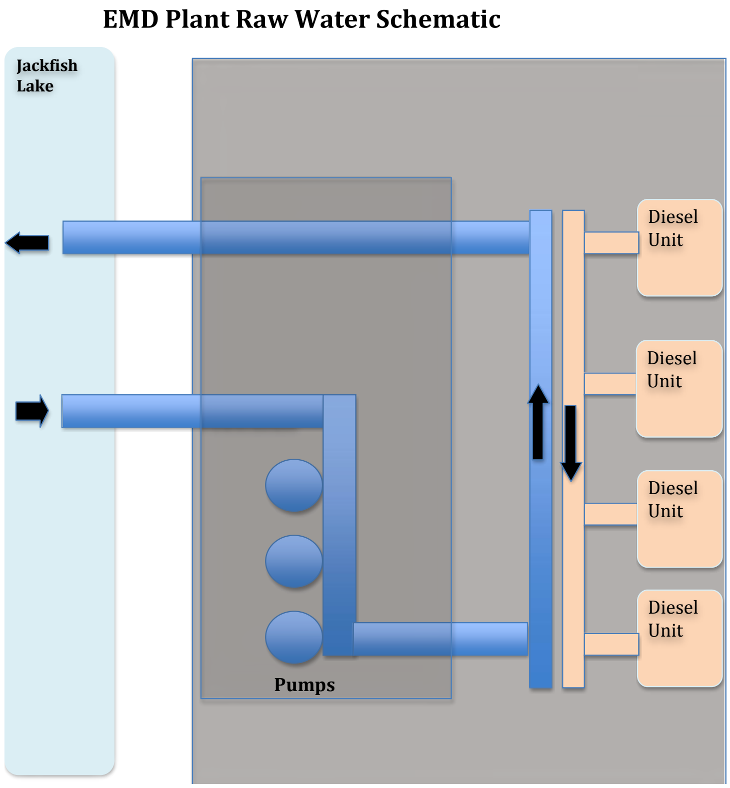


Figure 8: EMD Plant Raw Water Schematic

Photo 4: EMD Plant Raw Water Pumps

2.5.2.2 Normal Operation

For the EMD Plant two raw water pumps are normally running continuously in order to keep the supply and return pipes from freezing in the winter. In summer one pump is running continuously to allow for prompt unit startup in outage conditions. A second pump is started if additional cooling is needed. The third pump is for maintenance of the other pumps.

2.5.3 CAT Plant Raw Water System

2.5.3.1 Description

The CAT Plant has a well system similar to the K-Plant but has the well located inside the powerhouse (Figure 9). The well has a screened 12- inch pipe from Jackfish Lake to the well that can be isolated. There are two 7.5HP and one 15HP single stage horizontal pumps connected to a 12-inch supply manifold (Photo 5). The supply manifold extends across the plant where the two units connect with the respective Jacket Water, Oil, Fuel and Turbocharger heat exchangers. Jacket Water, Oil, and Fuel are not pumped through the heat exchangers unless the corresponding pumps are automatically turned on by the PLC for each unit.

The raw water returns to Jackfish Lake via a 10-inch common gravity pipe.

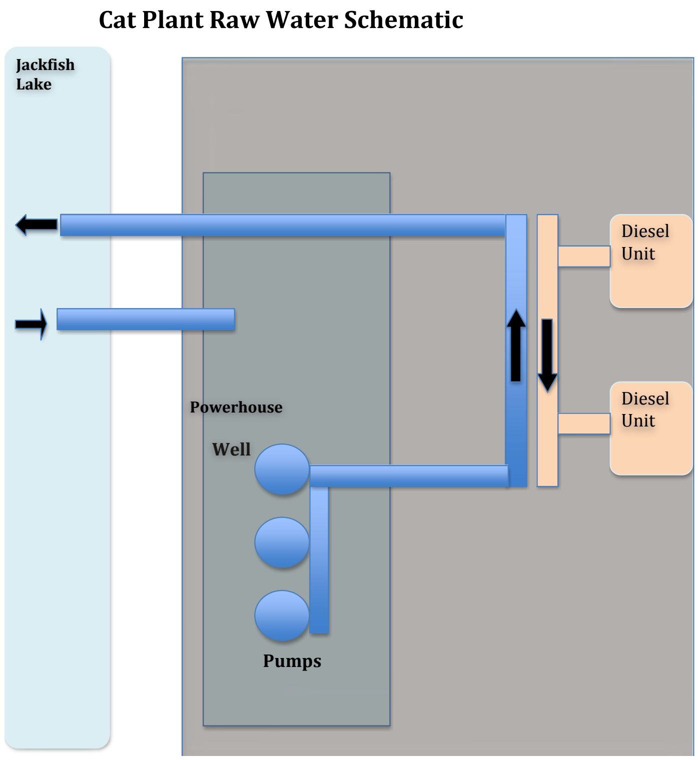


Figure 9: Cat Plant Raw Water Schematic

Photo 5: CAT Plant Raw Water Pumps

2.5.3.2 Normal Operation

The CAT Plant has one raw water pump continuously running to keep the supply and return pipes from freezing in the winter. In summer one pump is running continuously to allow for prompt unit startup in outage conditions. The second pump is automatically started if needed for cooling purposes when both units are running. The third pump is for maintenance of the other pumps

2.6 OTHER SYSTEMS

2.6.1 Heat Recovery System

There are Plate Type Heat Exchangers that capture waste heat off the Jacket Water of the KV-16 Unit 1, EMD Units 5 and 8, and CAT Unit 15 (Photo 6). This system is used as needed to heat the other Diesel Plants as well as the Administration Building and Warehouse.

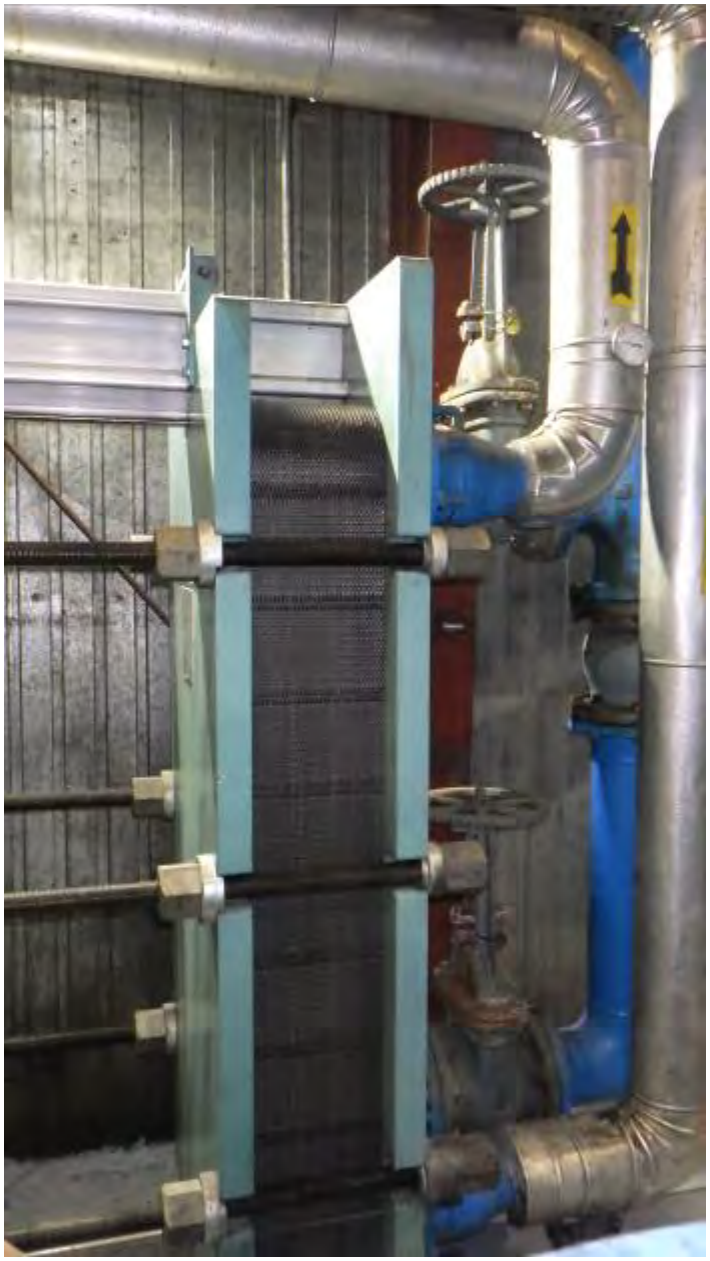


Photo 6: K-Plant Plate Heat Exchanger

2.6.2 Sumps

The K-Plant drains to a sump that has a level alarm and is manually pumped out through an oil/water separator if needed.

The EMD Plant has a lower sump within the raw water pump sump that has a level alarm with an oil/water separator installed in the discharge line (Photo 7). Discharge to a surface container is manual only.

Photo 7: EMD Plant Sump

The CAT Plant drains through an oil/water separator to a water sump that is pumped out through a manual operation.

3 MAINTENANCE

3.1 MAINTENANCE RESPONSIBILITIES

The Electrical Services Manager and Mechanical Service Manager are responsible for the planning and implementation of maintenance. Maintenance of the diesel generating units is planned in coordination with plant and system operation, These Managers report to the Hydro Operations Director. The Plant Operators, Electricians, Mechanics, Millwrights and contractors, depending on the work to be done, perform the maintenance on these facilities. The Maintenance staff are knowledgeable in all facets of power generation, and beyond servicing the Jackfish Facility, supply crucial support to Snare Hydro, Bluefish Hydro, and isolated North Slave communities of Behchokǫ̀, Whatì, Gamètì, and Lutsel K'e. Staff also maintain vehicles, heavy equipment, and the Transmission and Distribution system.

3.2 MAINTENANCE PROGRAMS

The diesel generating units have extensive maintenance programs for both electrical and mechanical components predominantly based on engine hours using a Computerized Maintenance Management System. The Mirrlees, EMD and Caterpillar engines have both common and unique specialized tools, overhaul schedules, and required skillsets. In addition, there are regular inspections and maintenance performed on plant auxiliaries, heating systems including waste heat, structures, and the many critical substations throughout the system.

4 SURVEILLANCE

4.1 PLANT CHECKS

When the Jackfish Facility and respective plants are in standby operation mode there is a daily visual check by a Plant Operator throughout the plants and grounds for proper operation and abnormalities (Appendix A). Any incidents are documented in the Incident Report (Appendix B).

4.2 HOURLY READINGS

When a diesel unit is in operation, logs sheets are completed hourly by the plant operator (Appendix C). They are specific to a particular unit and, among other details, record the temperature and pressure of the Raw Water System as well as the Jacket Water, Fuel, Oil, and Turbocharger cooling systems (Photo 8). Discrepancies observed are noted and may result in communication to maintenance department or the unit being taken through a controlled shutdown and replaced with alternative generation.

Photo 8: Raw Water Pressure and Temperature Gauges

4.3 WILDLIFE

The Jackfish Facility is surrounded by municipal and industrial developments. As illustrated in Figure 2, the Jackfish Facility is bound by the Yellowknife municipal landfill, Giant Mine, Highway 3, Highway 4, the Yellowknife Airport, the Niven Lake housing development, and Yellowknife city centre. As such, the potential for impacts to wildlife is limited. Continual operation of the Jackfish Facility for over 40 years have confirmed this.

Species at Risk
Species at risk that may interact with the Jackfish Facility (i.e., species with overlapping range that may venture into city limits) include bank swallow, barn swallow, Harris' sparrow, horned grebe, olive-sided flycatcher, rusty blackbird and short-eared owl. No mammal, plant, fish or insect species are anticipated. The most likely impact to these species at risk will be disturbance of nests if they attempt to nest on Jackfish Facility structures. These species are small enough that mortality through electrocution (caused by simultaneous contact with charged and grounded electrical current) is not anticipated.

Potential Wildlife Impacts
Potential impacts to wildlife and wildlife habitat from developments include:

- direct habitat loss
- indirect habitat loss
- wildlife mortality or injury

Direct habitat loss refers to the disturbance and immediate loss of wildlife habitat within the Project physical footprint, for example from new infrastructure. As the Jackfish Facility is contained within a fence and is surrounded by other infrastructure and disturbances, further direct habitat loss due to Jackfish Facility operations is not anticipated.

Indirect habitat loss describes changes to wildlife movement and behavior due to Project activities (such as the noise from landing aircraft, operation of drilling equipment, odours or human presence). Indirect habitat loss can occur even where vegetation and other habitat features remain intact. These changes are typically negative, causing wildlife avoidance, but can also be positive for some species that are attracted to camps. As the Jackfish Facility is contained within a fence, and as it is surrounded by other infrastructure and disturbances, and most activity is contained within a fence or enclosed buildings, further indirect habitat loss is not anticipated.

Wildlife mortality or injury can result from accidents caused during deterrent or removal of problem wildlife to protect worker safety. Considering the physical hazards, possible presence of food attractants, and electrical infrastructure at Jackfish Facility, wildlife injury or mortality is possible and has occurred. This category includes disturbance or destruction of nests, which may occur when birds nest on structures within the Jackfish Facility.

The anticipated impacts to wildlife, and the associated mitigation implemented for each is outlined in Table 4.

Table 4: Mitigation for Anticipated Impacts to Wildlife

Potential Impact	**Mitigation**	**Monitoring**
Contamination of terrestrial environment from spills	Spill Contingency Plan outlines mitigation and procedures to reduce risk of spills, and actions to follow in the event of a spill	Daily Safety Inspection (Appendix A) Prevent and respond to all spills as per the Spill Contingency Plan
Attractants from office waste	Food scraps and other household waste from the Administration Building are stored	Daily Safety Inspection

	inside and in wildlife-proof containers when outside	Feeding of wildlife is prohibited Implement the Waste Management Plan
Electrocution of birds from sub-station	Sonic bird scare devices (Phoenix Wailer MkIII, supplemented by Bird-X UltrasonX and Bird-X Super BirdXPeller Pro) Spikes? Other physical deterrents or barriers?	Daily Safety Inspection Isolate electrical hazards where possible
Greenhouse gas and particulate emissions	Diesel generation is an expensive alternative to hydro, and engaged only when there is instantaneous loss of hydro power, shortage of hydro generating capacity, or diminished hydro supply.	Diesel use is documented
Physical hazards	Chain-link fence surrounds the Sub Station Gated entrance to the facilities	Daily Safety Inspection

5 REPORTING

5.1 MONTHLY READINGS AND ANNUAL REPORTING

Every month the hour meters are read and recorded for each raw water pump. The number of hours operated multiplied by the flow capacity of the pump results in the amount of water pumped through the raw water system. The water usage for the pumps and cooling systems is reported to the Mackenzie Valley Land and Water Board in quarterly reports and an annual report all of which are available on the online registry (https://mvlwb.com/registry).

5.2 WILDLIFE REPORTING

Results from the daily check of plant and grounds will be documented…
Wildlife incidents refer to a range of possible occurrences at the Project, including:

- human-wildlife interactions that present a risk to either people or animals
- wildlife-caused damage to property or delay in operations
- wildlife deterrent actions
- wildlife injury or mortality
- wildlife found dead, even if from natural causes
- birds nesting on Project infrastructure or equipment

All incidents will be documented using the Incident Report form (Appendix X), and will be reported immediately to the Government of the Northwest Territories Department of Environment and Natural Resources at 867-873-7181.

6 CONTACT NUMBERS

Plant Operator/ System Operator shall report to:	
Manager, Plant Operations- Robert Sunderland	867-669-3338 (O)
	(H)
	867-445-1841 (cell)
Manager, Electrical Services- Robert Burgin	867-669-3308 (O)
	867-766-3328 (H)
	867-444-8424 (cell)
Manager, Mechanical Services- Sergio Catlyn	867-669-3326 (O)
	867-766-3541 (H)
	867-445-3389 (cell)
Director, Hydro Division- Colin Steed	867-669-3326 (O)
	867-920-4574 (H)
	867-446-4712 (cell)
Manager, System Control	867-669-3347 (O)

	(H)
	867-445-6515 (cell)
Director shall report to:	
President & CEO	867-874-5245 (O)
	(H)
	780-719-0612 (cell)
Manager, Corp. Health, Safety & Envi. – Ed Smith	867-874-5327 (O)
	867-874-2491 (H)
	867-875-7737 (cell)
Local Agencies (Yellowknife):	
Fire or Emergency	867-873-2222
Ambulance	867-873-2222
Hospital	867-669-4111
RCMP	867-669-1111
City of Yellowknife	867-920-5600

Appendix A Safety Inspection Form

Inspection Details	
Location:	Plant:
Inspected by:	Date:

#	Inspection Item	Y	N	NA	Notes
1.0	**Housekeeping**				
1.1	Are all buildings clean & organized inside?				
1.2	Are all walkways and doorways clear and free of debris?				
1.3	Is the yard clean & organized with no vegetation control required?				
1.4	Is the transformer storage platform solid and well-organized?				
1.5	Is the pole storage rack solid and well-organized?				
1.6	Are garbage cans fire resistant with self-closing lids? Emptied at the end of each day?				
1.7	Are all spills and leaks cleaned up?				
1.8	Are floors clean and tidy and free of slippery substances (e.g., water, oil, grease)?				
1.9	Are floors level and well maintained with no projecting surfaces and no tripping hazards?				
1.10	Are windows clean, both inside and outside, and kept obstruction free?				
2.0	**Storage**				
2.1	Are tools and materials properly stored in racks, shelves, and bins wherever possible?				
2.2	Are commonly used and heavy items stored between mid-thigh and shoulder height?				
2.3	Are floors around racks, shelves, pallets, etc. clear?				
2.4	Are racks, shelves, pallets, etc. kept in good condition?				
2.5	Are storage areas safe from falling objects?				

#	Inspection Item	Y	N	NA	Notes
2.6	Are storage racks, shelves, etc. free of sharp edges?				
2.7	Is there a safe means of accessing high shelves?				
3.0	**Tools & Equipment**				
3.1	Are tools & equipment maintained in good condition, clean, suitable for intended use?				
3.2	Are all necessary machine guards in place?				
3.3	Are spill pads, drip trays, and crankcase vent containers emptied or replaced as required?				
3.4	Are batteries free of leaks with terminals clean and protective covers in place?				
3.5	Are line & electrical tools available, properly stored, certified, and in good condition?				
3.6	Is rigging & lifting equipment available, properly stored, certified, in good condition?				
3.7	Are compressed gas cylinders undamaged, stored upright, and secured?				
3.8	Are pipes leak-free, colour coded, and properly painted?				
4.0	**Personal Protective Equipment (PPE)**				
4.1	Is all PPE available onsite (hard hats, safety glasses, rubber gloves, earing protection)?				
4.2	Is all PPE properly stored?				
4.3	Is all PPE clean?				
4.4	Is all PPE in good condition?				
4.5	Is all PPE correctly used?				
5.0	**Emergency Equipment**				
5.1	Is the Emergency Response Plan available onsite and current?				
5.2	Is the Spill Response Plan available onsite and current?				
5.3	Is the Hazardous Waste Management Plan available onsite and current?				

#	Inspection Item	Y	N	NA	Notes
5.4	Are the NWT Safety Act & NWT Occupational Health & Safety Regulations available onsite?				
5.5	Are emergency phone numbers posted and up-to-date?				
5.6	Are emergency lights functional for a 30 second test?				
5.7	Are eyewash stations available and functional with the solution changed every 6 months?				
5.8	Are fire extinguishers available, charged, and inspected monthly?				
5.9	Are fire extinguishers secured on the wall and not free standing?				
5.10	Is access to fire extinguishers free and unobstructed?				
5.11	Are 1st aid kits available, inspected monthly fully stocked? Outdated items replaced?				
5.12	Are exits clearly marked with functional exit signs?				
5.13	Are exits functional and free from obstructions?				
6.0	**Chemicals**				
6.1	Are Safety Data Sheets (SDS) available and up-to-date within the last 3 years?				
6.2	Are all chemicals properly labelled and stored in proper containers (as per WHMIS)?				
6.3	Are all flammable products stored in proper containers and kept in a flammable cabinet?				
6.4	Are unused or unnecessary substances disposed of in a safe manner?				
6.5	Are all chemical containers and drums leak free?				
7.0	**Building**				
7.1	Are buildings in good condition on the inside with no repairs required?				
7.2	Are buildings in good condition on the outside with no repairs required?				
7.3	Are floors level and well maintained with no projecting surfaces and no tripping hazards?				

#	Inspection Item	Y	N	NA	Notes
7.4	Are windows clean, both inside and outside, and kept obstruction free?				
7.5	Is ventilation equipment clean, obstruction free, well maintained, and fully functional?				
7.6	Is the air temperature comfortable?				
7.7	Are all inside & outside lights functional?				
7.8	Do existing lights provide adequate lighting?				
7.9	Are all necessary warning signs in place with no new or additional signs required?				
7.10	Are all signs and notices in good condition?				
7.11	Are employee facilities (e.g., washrooms, lockers, crew trailers) clean, tidy, maintained, and adequate?				
8.0	**Security**				
8.1	Are all fences in good condition with barbwire intact?				
8.2	Are all gates and doors kept locked when unattended?				
8.3	Are all doors and locks in working order?				
9.0	**Electrical**				
9.1	Are ground connections present and in good working condition?				
9.2	Are electrical boxes & breakers properly covered?				
9.3	Are all electrical plugs and switches in good condition?				
9.4	Are all electrical cords in good condition?				
9.5	Are all power tools in good condition?				
9.6	Is all temporary wiring properly routed?				

#	Inspection Item	Y	N	NA	Notes
10.0	**Work Protection**				
10.1	Are sufficient Work Protection tags and forms available onsite?				
10.2	Is the Work Protection Log book available and up-to-date?				
10.3	Are all Single Line Diagrams posted and up-to-date?				
11.0	**Hazardous Waste Storage Area**				
11.1	Are all wastes properly separated to ensure no mixing of wastes?				
11.2	Are all waste storage containers in good condition with lids securely in place, no leaks?				
11.3	Are all waste containers labelled clearly and accurately?				
11.4	Are spill response materials available onsite (e.g., spill kits, sorbents, hand tools, PPE)?				
11.5	Are all sources of ignition kept away from the waste storage area?				
11.6	Is a fire extinguisher kept close to the waste storage area? Inspected monthly and charged?				
11.7	Does the storage area have proper drainage to prevent leaks or spills from leaving the site?				
11.8	Is the *Waste Accumulation Log* up-to-date?				
11.9	Is the *Waste Storage Inventory Log* up-to-date?				

Provide completed form to manager.

Corrective Actions (to be assigned by manager and followed up until completed)		
Manager:	Signature:	Date:

#	Corrective Action	CMMS #	Resp. Party	Due Date	Completed
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
12					
13					

Appendix B Incident Report Form

Sections A-E to be completed by worker.

Section A – Incident Details			
Date & time of incident:	Date: Time:	Date & time reported:	Date: Time:
Reported by:	Name: Position:	Reported to Manager:	Name: Position:
Incident location:			
Incident description (attach sketch if necessary):			

Section B – Type of Incident		
☐ Injury/Illness ☐ Rules/Procedures	☐ Property Damage ☐ Environmental	☐ Production Loss ☐ Near Miss

Section C – Injury			
Injured party:	Name: Position:	Phone: Email:	☐ NTPC employee ☐ Contractor ☐ Member of the public
Address:		First aid provided: ☐Y ☐N Medical treatment provided: ☐Y ☐N	
Description of injury:			

Section D – Property/Environmental Damage	
Description of damage:	

Section E – Incident Ranking (Reasonable Potential for Harm)		
☐ Low (potential First Aid Injury, minor property/environmental damage or production loss)	☐ Medium (potential Medical Treatment Injury, medium property/environmental damage or production loss)	☐ High (potential Serious Injury or Fatality, major property/environmental damage or production loss)

Send completed form to your manager and to the HSE Director by email or fax (1-888-458-4627).

Sections F- I to be completed by manager.

Section F – Incident Ranking (Reasonable Potential for Harm)		
☐ Low (potential First Aid Injury, minor property/environmental damage or production loss)	☐ Medium (potential Medical Treatment Injury, medium property/environmental damage or production loss)	☐ High (potential Serious Injury or Fatality, major property/environmental damage or production loss)

Section G – Immediate Actions Taken		
Hierarchy of Controls: 1) Elimination 2) Substitution 3) Engineering 4) Administration 5) PPE		
Action	**Responsible Party**	**Date Completed**

Section H – Further Corrective Actions				
	Action	**Responsible Party**	**Due Date**	*** Date Completed**
1				
2				
3				
4				
5				
6				

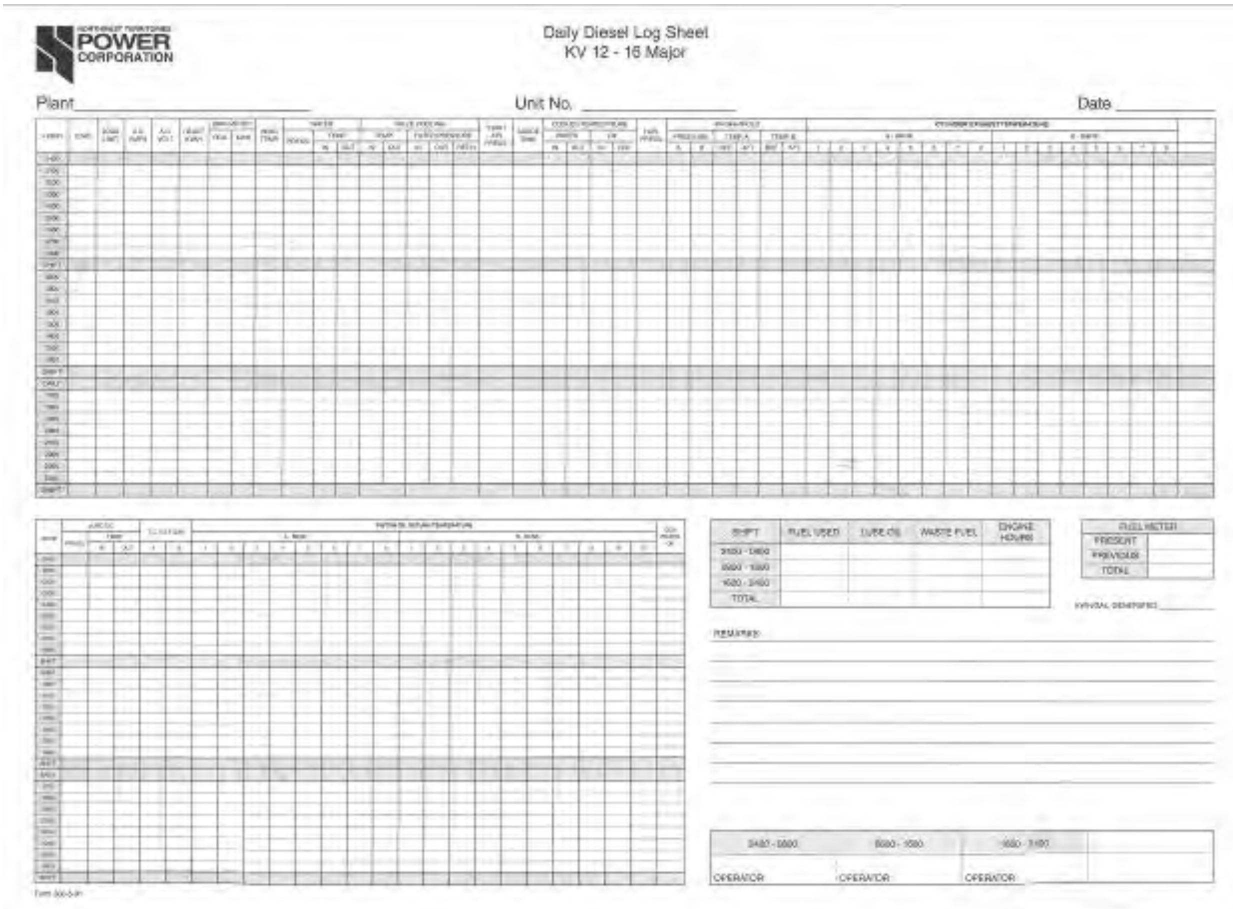
Section I – Management Review		
Name:	Position:	Review date:
Comments:		

Section J – Health & Safety Department Review		
Name:	Position:	Review date:
Comments:		

* Inform HSE Director of corrective action completion dates.

Appendix C Log Sheets

KV-16 Daily Log Sheet


NORTHWEST TERRITORIES POWER CORPORATION

Daily Diesel Log Sheet
KV 12 - 16 Major

Plant ________ Unit No. ________ Date ________

SHIFT	FUEL USED	LUBE OIL	WASTE FUEL	ENGINE HOURS
2400 - 0800				
0800 - 1600				
1600 - 2400				
TOTAL				

FUEL METER	
PRESENT	
PREVIOUS	
TOTAL	

REMARKS

2400 - 0800	0800 - 1600	1600 - 2400
OPERATOR	OPERATOR	OPERATOR

EMD Daily Log sheet

NORTHWEST TERRITORIES POWER CORPORATION

Daily Diesel Log Sheet
E.M.D Engine

Plant ____________ Unit No. ____________ Date ____________

HOUR	LOAD	LOAD LIMIT	A.C. AMPS	A.C. VOLTS	P.F.	KWH METER REG.	KWH METER KWH	FUEL PRESS	RAW WATER PRESS	RAW WATER TEMPERATURE IN	RAW WATER TEMPERATURE OUT	FUEL TANK LEVEL	COOL WATER PRESS	WATER TANK	COOLER TEMPERATURE WATER IN	COOLER TEMPERATURE WATER OUT	COOLER TEMPERATURE OIL IN	COOLER TEMPERATURE OIL OUT	OIL PRESS	CYLINDER EXHAUST TEMPERATURE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	AIR BOX OPEN CLOSE
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DAILY																																								
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2200																																								
2300																																								
2400																																								
SHIFT																																								

SHIFT	LUBE OIL
2400 - 0800	
0800 - 1600	
1600 - 2400	
TOTAL	

FUEL METER AT 1600 HOURS		
	1	2
Present		
Previous		
TOTAL		

ENGINE HOURS 1600	
Previous	
Operated	
TOTAL	

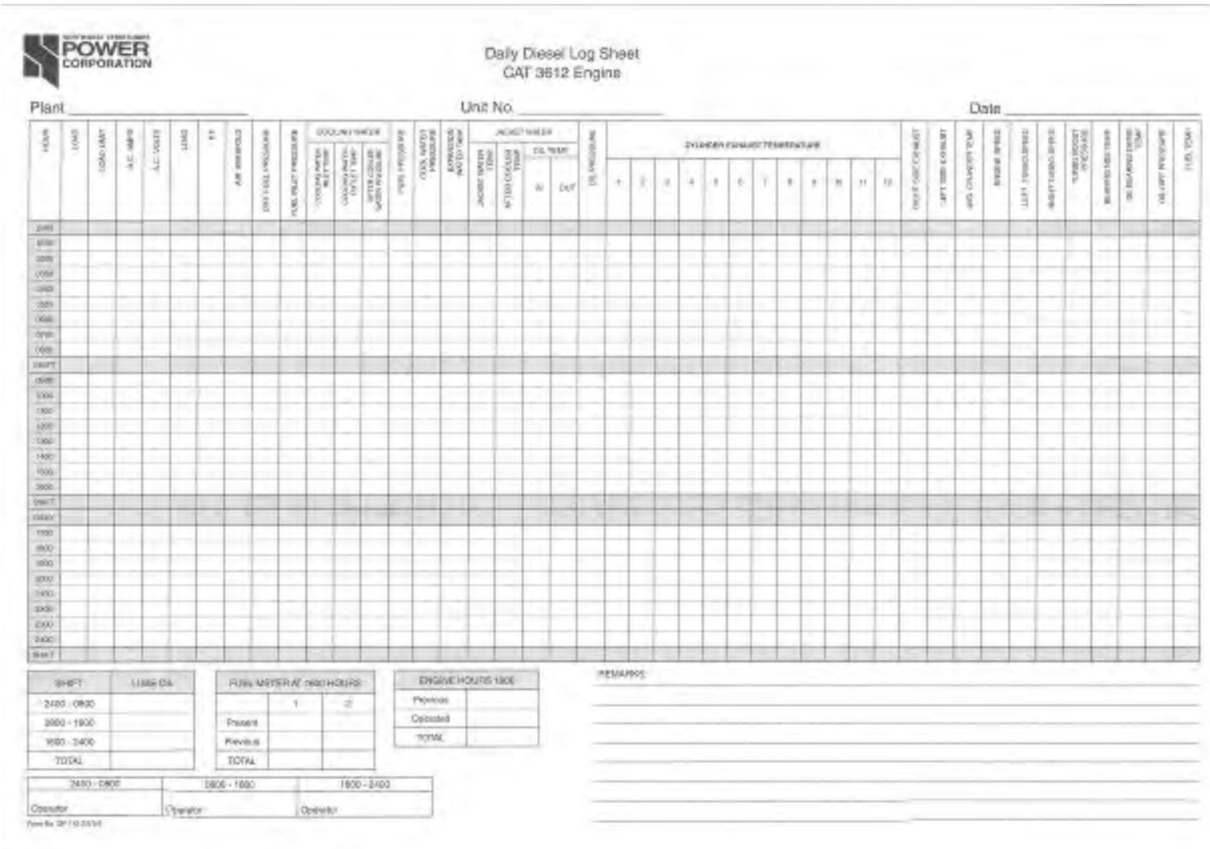
REMARKS:

2400 - 0800	0800 - 1600	1600 - 2400
Operator	Operator	Operator

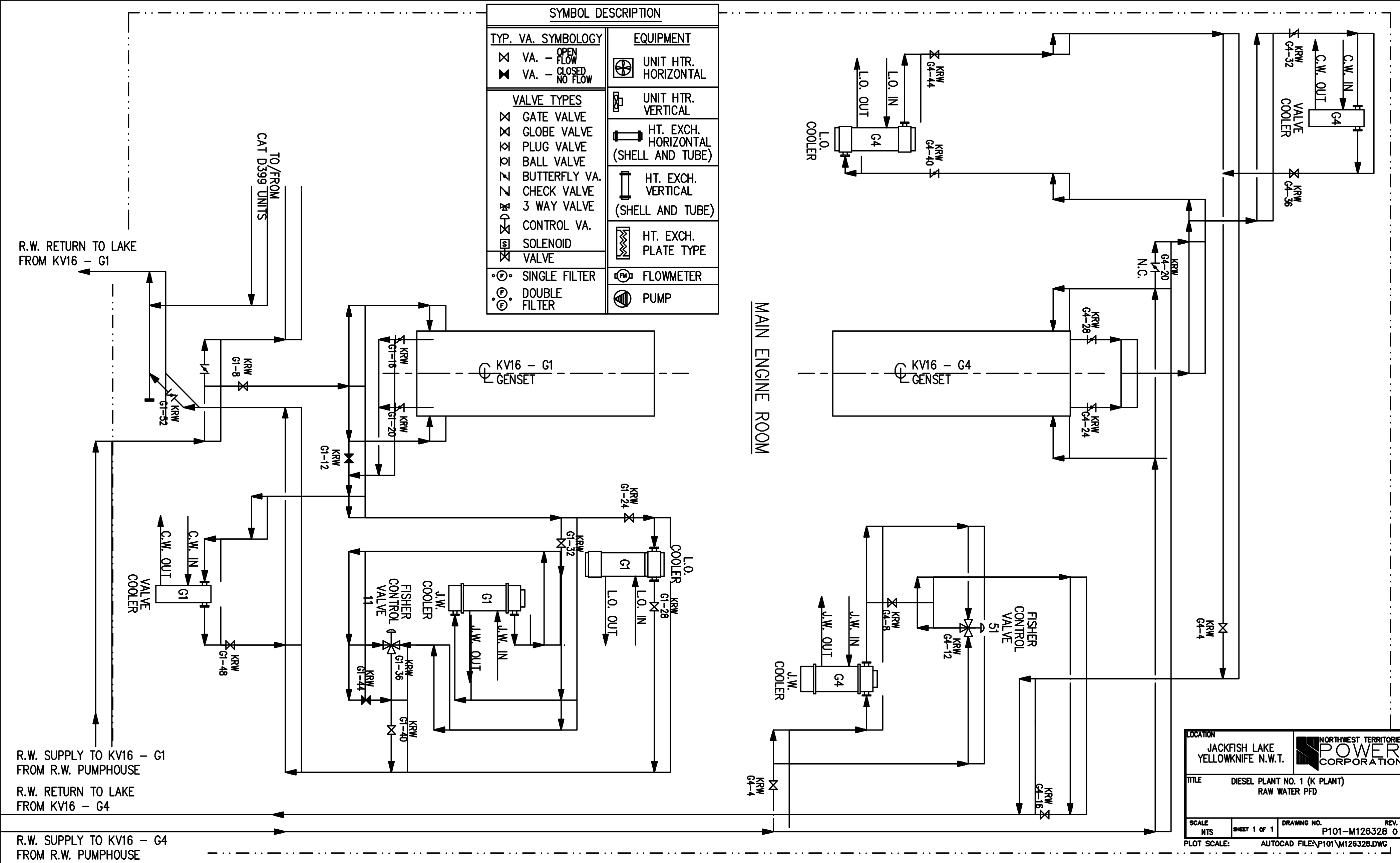
Form No. OP 40

NORTHWEST TERRITORIES POWER CORPORATION
Empowering Communities

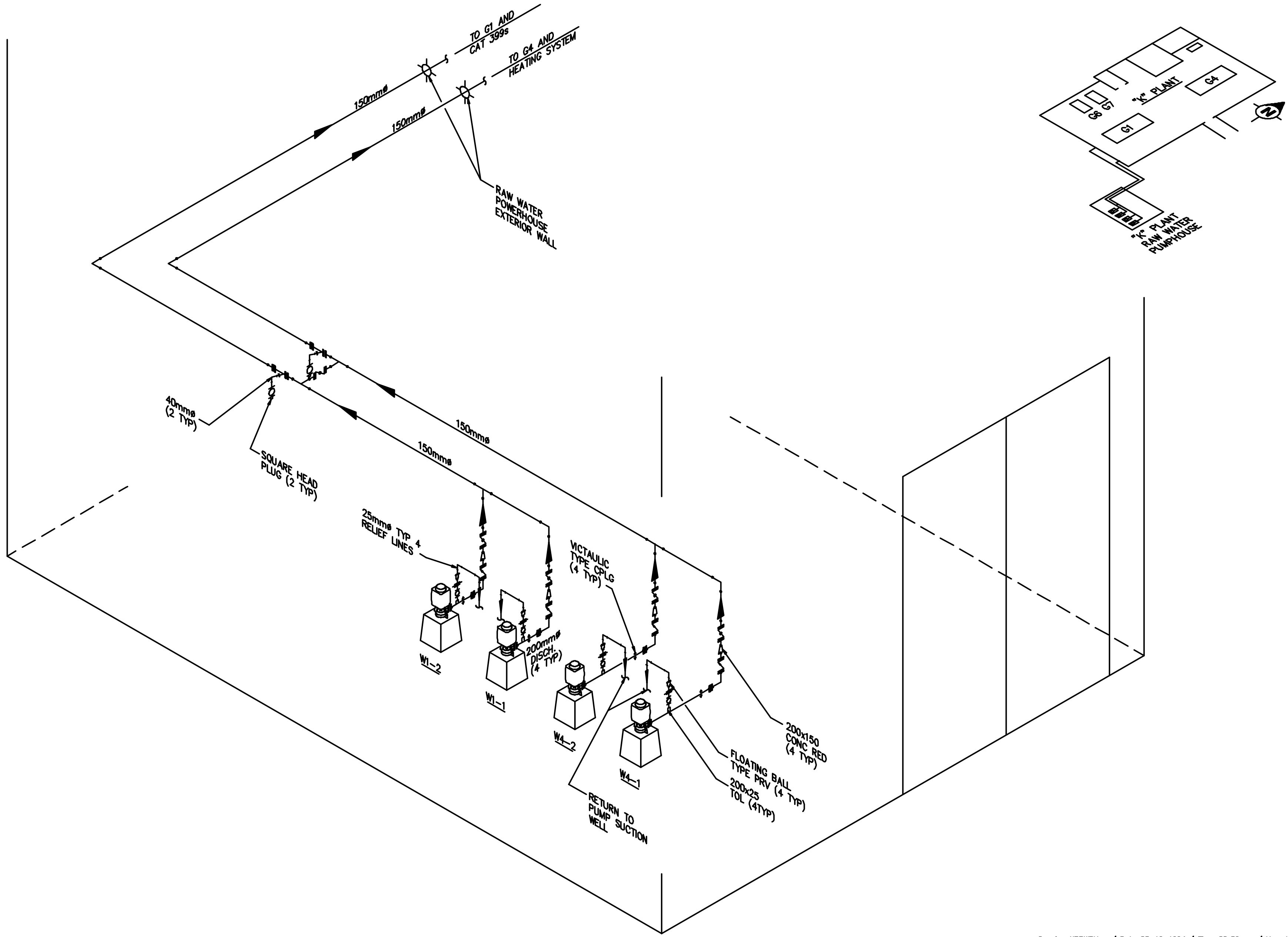
CAT Daily Log Sheet



Appendix D Cooling System Drawings



"K" PLANT – RAW WATER – FLOW SHEET



Drawing: KPRWPH / Date: 05-10-1994 / Time: 09:59 / User ID: RL

DRAWING NO.	TITLE	REVISION LETTER	REVISION	WORK ORDER	NAME	DATE	CHECKED BY	DESIGNED BY
		0	ORIGINAL	525/94	R.LAYCOCK	MAY.8/94		

REFERENCE DRAWINGS — DRAWN BY — APPROVED FOR CONSTRUCTION BY: CIVIL, MECH, ELEC, T & D, P & C — STATUS OF DRAWING — DATE

LOCATION: JACKFISH LAKE YELLOWKNIFE N.W.T.

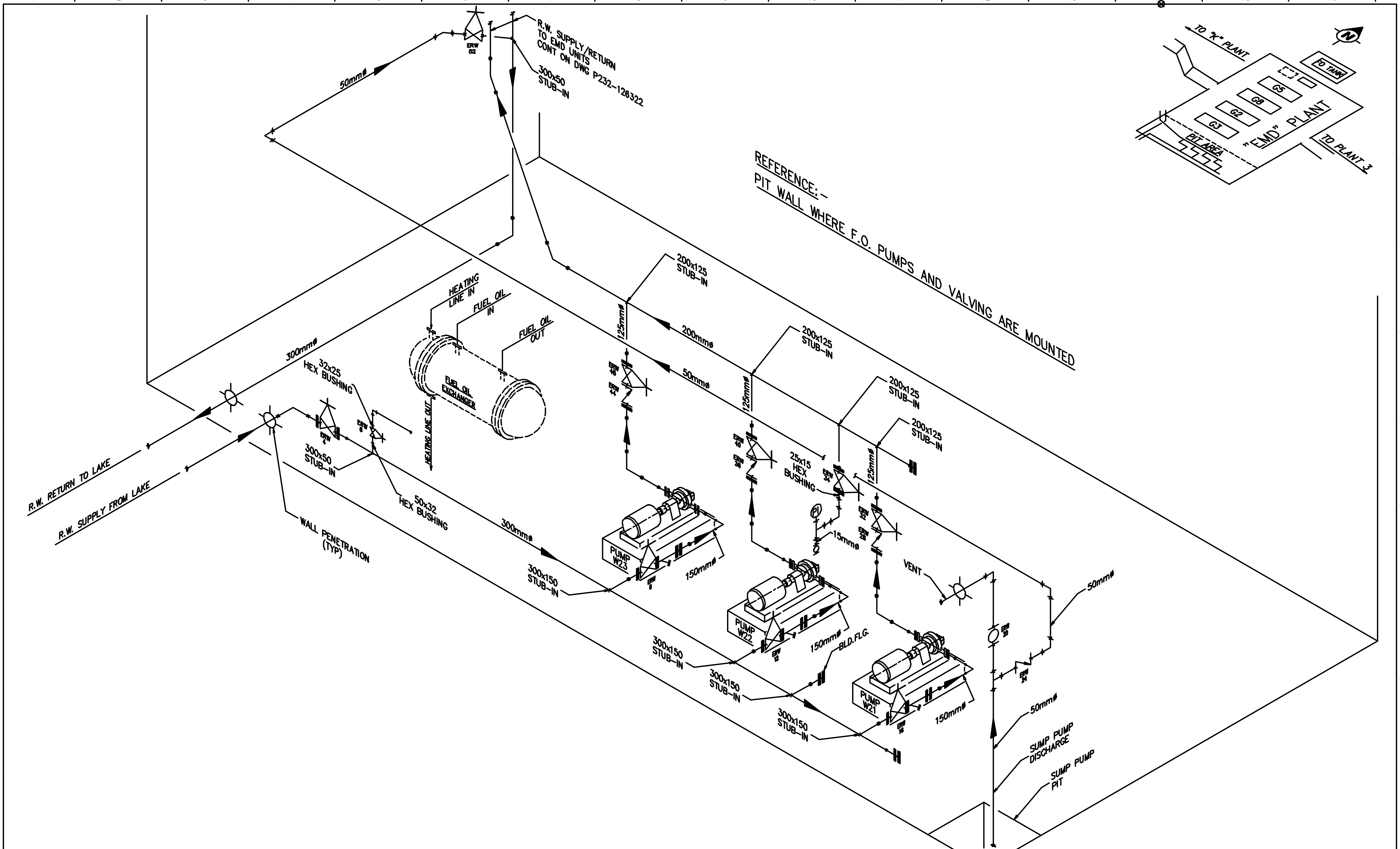
NORTHWEST TERRITORIES POWER CORPORATION

PLANT: 01

TITLE: "K" PLANT RAW WATER SYSTEM RAW WATER PUMP HOUSE SYSTEM ISOMETRIC

SCALE: NTS — SHEET 1 OF 1 — DRAWING NO. P101-M126325 — REV. 0

AUTOCAD FILE: \P101\M126325.DWG — PLOT SCALE: 1:1



THIS AREA IS LOCATED IN THE PIT AT THE "SOUTH" END OF THE BUILDING

DRAWING NO.	TITLE	REVISION LETTER	REVISION	WORK ORDER	DRAWN BY NAME	DRAWN BY DATE	CHECKED BY	DESIGNED BY	CIVIL	MECH	ELEC	T & D	P & C	STATUS OF DRAWING	DATE
		B	VALVE NUMBERS REVISED		R.L.	12/00								AS BUILT 2000	12/00
P232 – 126322	R.W. DISCH. TO EMD UNITS	A	AS BUILT AS PER FIELD INFO PROVIDED	901-6310	F.L.	04/97	S.E.S.								
		0	ORIGINAL	525-94	R.LAYCOCK	MAY.31/94									

REFERENCE DRAWINGS

LOCATION: JACKFISH LAKE YELLOWKNIFE N.W.T.

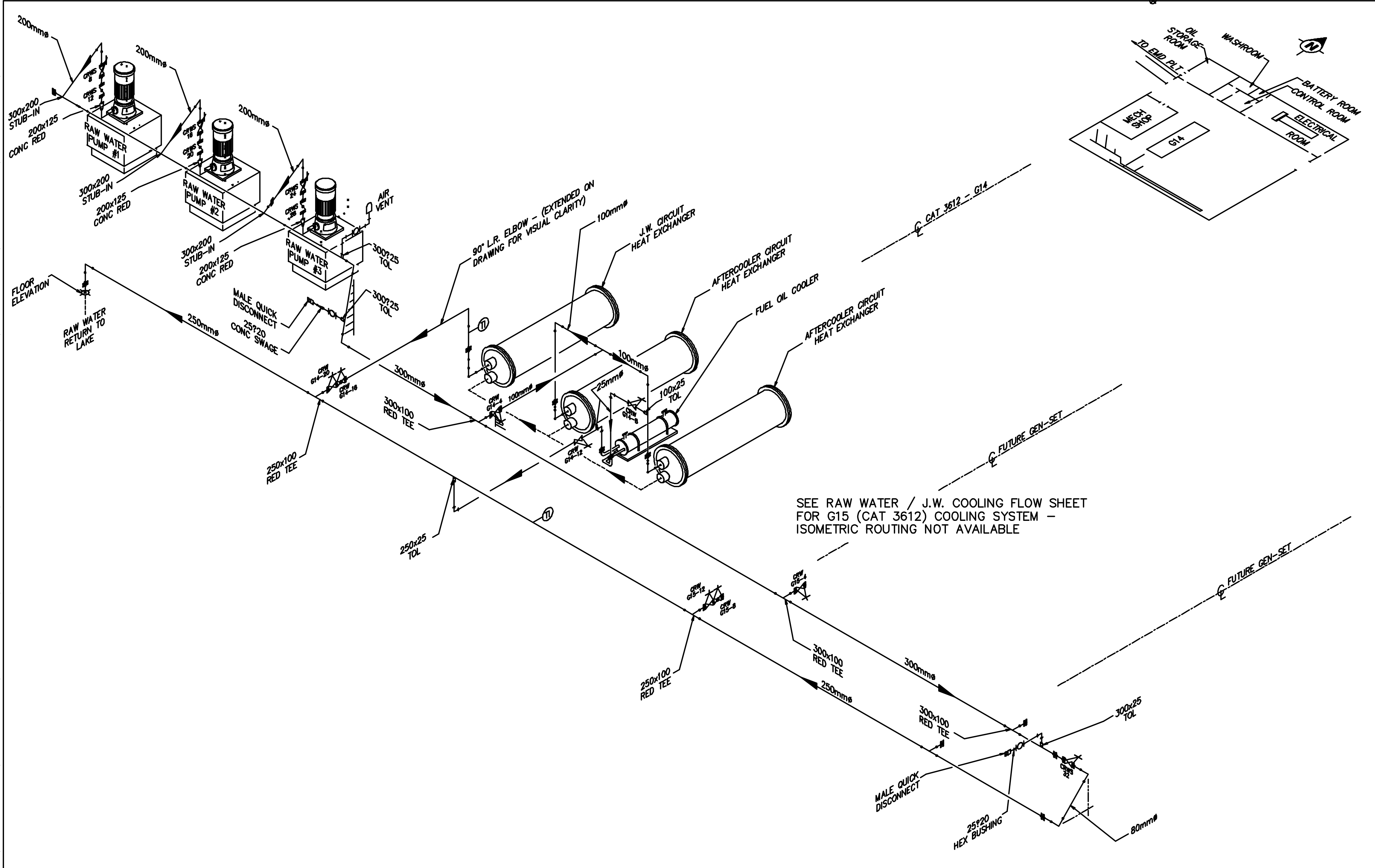
NORTHWEST TERRITORIES POWER CORPORATION

PLANT

TITLE: 1974 DIESEL PLANT (EMD) RAW WATER SYSTEM PUMP SUCTION AND DISCHARGE PIPE ROUTING SYSTEM ISOMETRIC

SCALE: NTS | SHEET 1 OF 1 | DRAWING NO. P232 – 126323 | REV. B

AUTOCAD FILE: P232/126323 PLOT SCALE: 1:1



DRAWING NO.	TITLE	REVISION LETTER	REVISION	WORK ORDER	NAME	DATE	CHECKED BY	DESIGNED BY	CIVIL	MECH	ELEC	T & D	P & C	STATUS OF DRAWING	DATE
		B	VALVE NUMBERS REVISED		R.L.	12/00								AS BUILT 2000	12/00
		A	AS BUILT AS PER FIELD INFO PROVIDED	901-6310	F.L.	04/97	S.E.S.								
		0	ORIGINAL	525-94	R.LAYCOCK	JUNE.20/94									
REFERENCE DRAWINGS					DRAWN BY				APPROVED FOR CONSTRUCTION BY						

LOCATION
JACKFISH LAKE
YELLOWKNIFE N.W.T.

NORTHWEST TERRITORIES POWER CORPORATION

PLANT

TITLE
DIESEL PLANT #3
RAW WATER SYSTEM
PUMPING AND DISTRIBUTION ROUTING
SYSTEM ISOMETRIC

SCALE	SHEET	DRAWING NO.	REV.
NTS	SHEET 1 OF 1	P231 - 126323	B

AUTOCAD FILE: P231/126323 PLOT SCALE: 1:1

NORTHWEST TERRITORIES
POWER
CORPORATION
Empowering Communities

PUBLIC SAFETY AND AWARENESS PLAN

JACKFISH LAKE
GENERATING FACILITY, NWT
PLANT #120
YELLOWKNIFE, NORTHWEST TERRITORIES

February 2019

DOCUMENT MAINTENANCE AND CONTROL

The Director, Health, Safety & Environment is responsible for the distribution, maintenance and updating of the Public Safety and Awareness Plan. This document will be reviewed annually and changes in phone numbers, names of individuals, etc. that do not affect the intent of the plan are to be made as required. Additional copies can be provided by the Director, Health, Safety & Environment.

DOCUMENT HISTORY				
Revision #	**Revised Section(s)**	**Description of Revision**	**Prepared by**	**Issue Date**
0	N/A	First Version	NTPC	Feb 2019

TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

This Public Safety and Awareness Plan has been created to present the methods the Northwest Territories Power Corporation (NTPC) will take to inform the public of potential hazards and restricted access in the vicinity of the Jackfish Lake Generating Facility to minimize the possibility of personal injury to members of the public.

This report summarizes the results of NTPC's signage, mitigation measures and communication for public safety management at the Jackfish Lake Generating Facility.

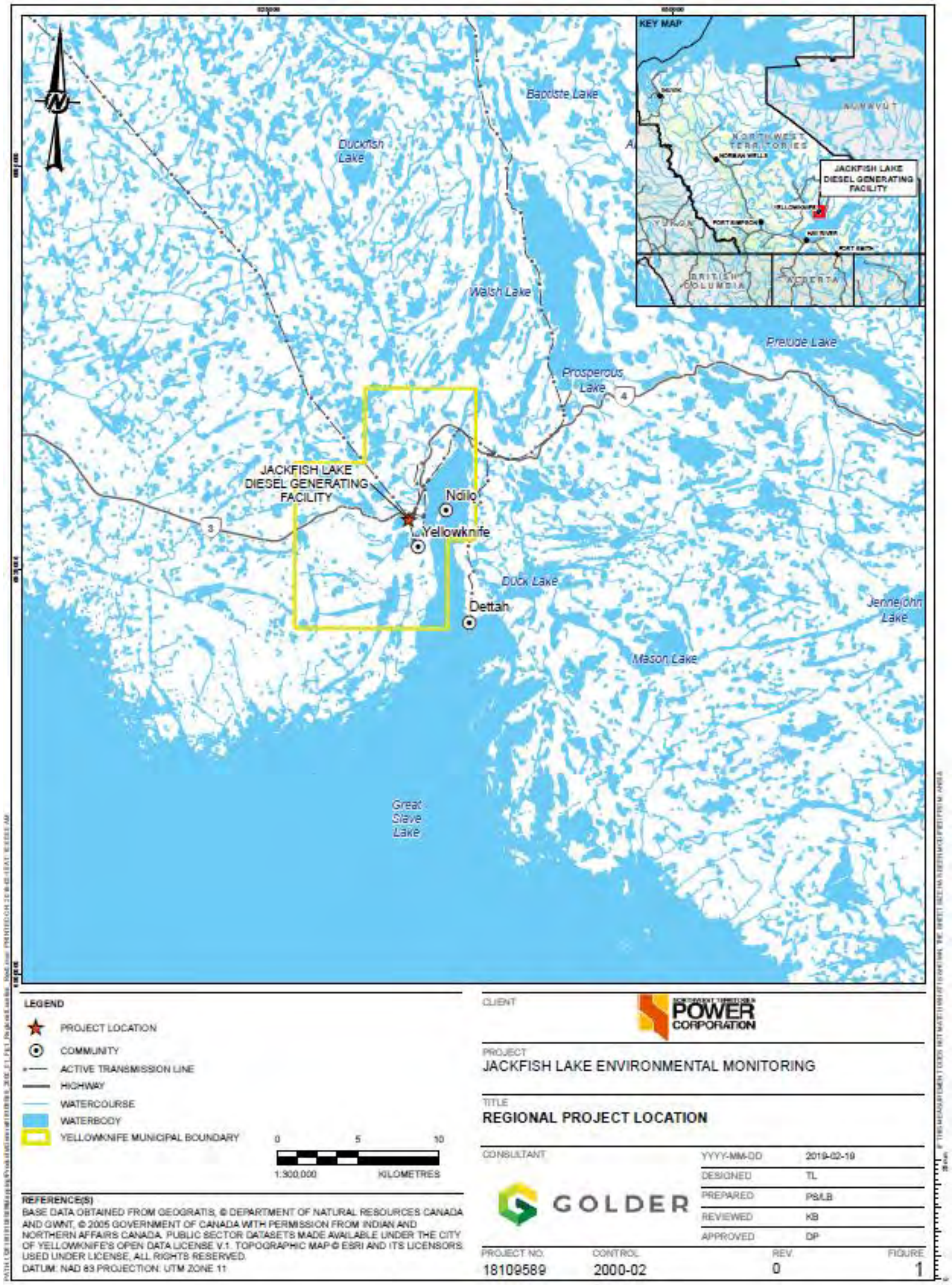
2.0 SITE

The Jackfish Lake Generating Facility is located on the northeast shore of Jackfish Lake (also known as Stock Lake) in Yellowknife, Northwest Territories.

While the North Slave communities of Yellokwnife, Ndilo and Dettah primarily use electricity generated at NTPC's Snare and Bluefish hydroelectric sites, the Jackfish Facility provides a critical source of backup power to the electrical system in events of peak power demand, during hydro maintenance shutdowns or in outage situations with the loss of the transmission line to the Snare Hydro. There are three distinct generation plants within the Jackfish Facility: the CAT plant (built in 1993), the EMD plant (built in 1974) and the K plant (built in 1969). Each plant has a cooling system for the generators that utilizes water from Jackfish Lake. The Facility is surrounded by chain-link fence and is presented in Figures 1, 2 and 3.

The arrangement of buildings from east to west along the south side of the property is as follows: the administration building, the Cat Plant, the EMD Plant, the K-Plant (the three plants are joined by covered walkways), the warehouse, and the line shop. There is a water pump house located south of the K-Plant, a fuel pump house north of the K-Plant, and a storage shed northeast of the line shop. On the north side of the property from east to west is the substation, three modular generating units (G20, G22 and G23), a 90,000 L horizontal fuel tank, the Ruston Plant (used for material storage), a drum storage berm, the tank farm, and the line yard. Pole storage is located outside the fence north of the Ruston Plant.

Figure 1: Regional Location of Jackfish Lake Generating Facility



NORTHWEST TERRITORIES POWER CORPORATION
Empowering Communities

Figure 2: Location of Jackfish Lake Generating Facility

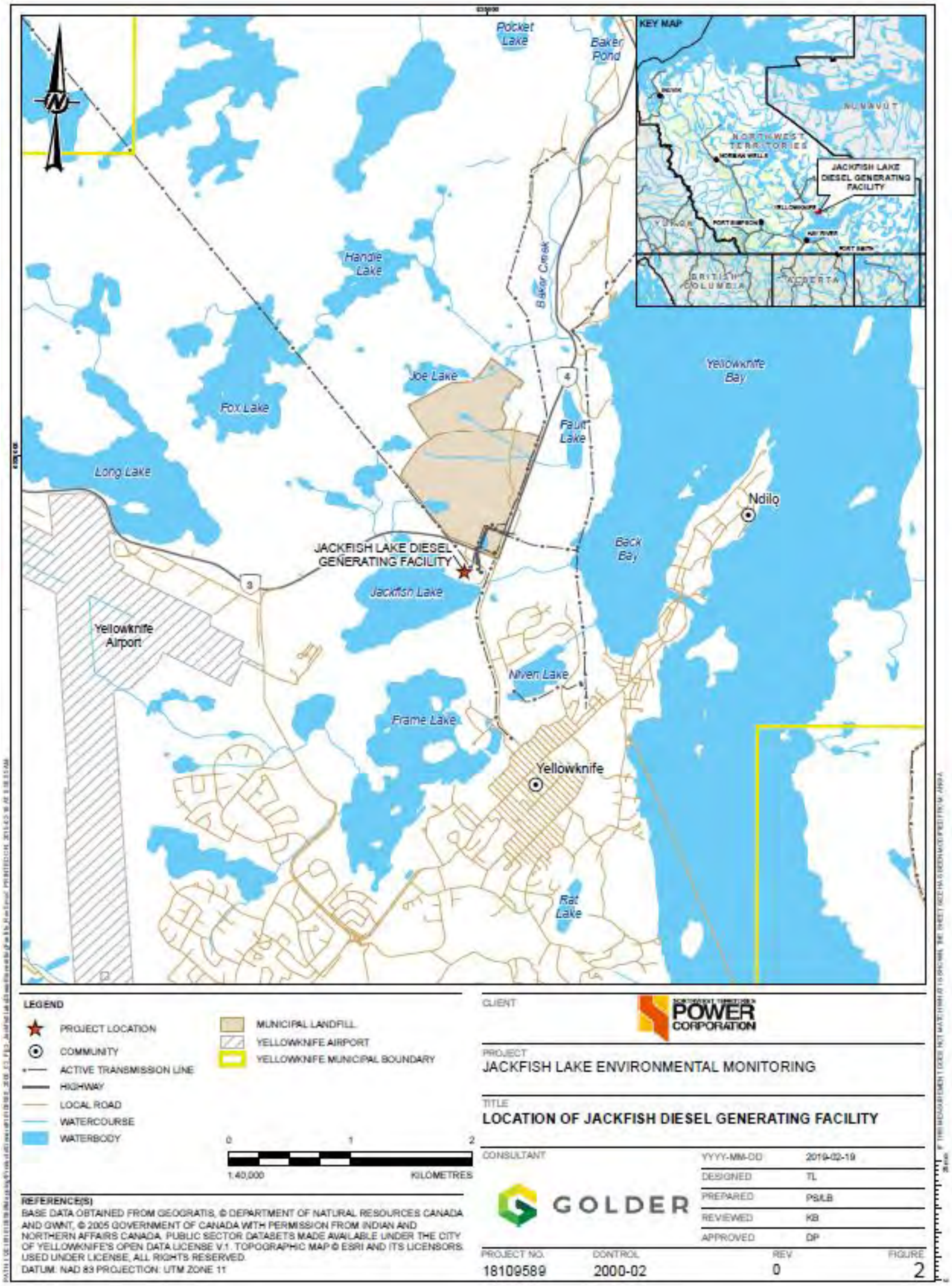


Figure 3: Jackfish Lake Generating Facility

3.0 PUBLIC SAFETY AND AWARENESS CONSIDERATIONS

3.1 FACILITY INTERACTIONS

The Jackfish Lake Generating Facility is located on the north end of Yellowknife on the northeast shore of Jackfish Lake (also known as Stock Lake). It is located near the intersection of Highway 3 and 48 Street/Highway 4 within the municipal limits of the City of Yellowknife. The location of the Jackfish facility is presented in Figures 1, 2 and 3

The Facility is accessed by a laneway turnoff from Highway 3 roughly 200m west of the Highway 3 and 48 Street/Highway 4 intersection. This laneway leads down to the parking lot and front of the administration building, which are the only parts of the Facility that are not surrounded by chain-link fence. There is a small area at the front of the administration building that the public can access to pay power bills during normal business hours.

The rest of the Facility is surrounded by chain link fence. The main access for the Facility is a man gate and a controlled automatic vehicle gate in the southeast corner of the property which can only be accessed by employees and contractors. There is also secondary access through a double gate located on the north side of the property near the Ruston Plant and a man gate and a double gate on the west side of the property, all of which are kept closed and locked.

Although the Facility is within the municipal limits of the City of Yellowknife it is isolated due to geography – it is bordered by Jackfish Lake on the south and west, by a steep rock cliff face to the north and by a steep roadside embankment on the east. On top of this the Facility is surrounded by chain-link fence with barbed wire around the top. The only way to access the Facility easily is through the laneway that turns off of Highway 3, which has several signs directing visitors to the administration office (see Figure 4). The only reason the public have to access the site is for bill payment, and this is done solely via the laneway off of Highway 3. It should also be noted that the majority of customers pay bills remotely and do not enter the site.

Figure 4: Facility Access Point

3.2 POTENTIAL HAZARDS

Given the isolated nature of the Facility, hazards to the public are limited:

- High voltage risk in substation
  - Persons entering the substation are at risk of electrocution by high voltage equipment.

- Danger ice around outlets
  - The ice is not safe in the area immediately around the outlets due to warmer water temperatures preventing proper ice formation.
  - The major hazard to the public occurs on the lake itself during winter months.
  - Persons snowmobiling or walking on Jackfish Lake ice near the outlets for the three generator cooling systems are at risk of breaking through the ice.

4.0 PUBLIC SAFETY AND AWARENESS CONSIDERATIONS

The following hazard awareness and mitigation measures have been developed to mitigate the potential hazards outlined in Section 3.2.

4.1 HIGH VOLTAGE RISK IN SUBSTATION

The primary measure to protect the public from high voltage hazards in the substation is restricting access to the Facility. This is done by the chain link fence crowned with barbwire that surrounds the entire facility. The main access gate is controlled and is for workers only, while secondary gates are kept locked. The substation itself is separated from the rest of the Facility by a chain link fence crowned with barbwire (see Figure 5). Gates to the substation are kept locked at all times. Fences are six feet high with an additional 1.5 feet of barbed wire around the top to prevent anyone from climbing over.

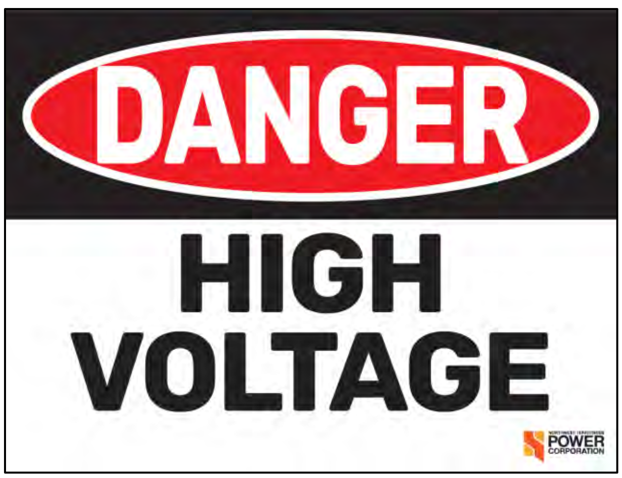
Figure 5: Jackfish Lake Generating Facility

The second mitigation measure to warn of the hazards within the substation is the signs that have been installed around the outside of the substation that warn of danger from high voltage (see Figure 6).

Figure 6: High Voltage Warning Signs

As part of the water licence renewal new, larger 18”x24” “DANGER – HIGH VOLTAGE” signs will be ordered and installed around the substation (see Figure 7).

Figure 7: New “Danger – High Voltage” Signs



4.2 DANGER ICE AROUND OUTLETS

The cooling systems for the three plants are always circulating water throughout the systems to avoid blockages and freezing. This results in a constant flow of water at the three outlets which prevents the formation of ice in the area immediately around the outlets (see Figure 8).

Figure 8: Danger Ice

The following mitigation measures are in place to warn the public of the danger ice hazard:

4.2.1 Barrier Around Danger Ice

NTPC has employed various barriers in the water and ice around the outlets for the cooling systems in Jackfish Lake. Since the facility has been in operation the following barriers have been employed:

- Dam safety buoys linked together to form full barrier
    - Was not an effective approach as buoys and connecting chain repeatedly broke due to ice shifting, high winds and weather and were not in proper place
    - Buoys also become covered in snow in winter and less visible
- Single warning buoys
    - Required less maintenance than full dam safety barrier but did not provide full barrier around danger ice.
- Danger signs frozen into the ice 10m apart around edge of danger ice
    - Method that was employed historically and revisited in 2018-2019.
    - Qualified contractor is hired to place 3' high "DANGER: UNSAFE ICE" signs around danger ice that are frozen into the ice. Refer to Figure 9.
    - New, larger 18"x24" signs will be employed in 2019-2020.
    - Preferred method that will be employed moving forward; clearly marks danger ice in a visible manner and stays in place.
    - Will be combined with additional signage outlined in Section 4.2.3.

Figure 9: Danger Signs Frozen into Ice

4.2.2 Public Notice

The following mitigation measures are in place to warn the public of the danger ice hazard around the outlets on Jackfish Lake:

- New release (see Figure 10) run on Yellowknife radio stations CJCD, CKLB, and Cabin Radio in early winter.
    - Ads will be run in November of each year
- Public notice run in The Yellowknifer newspaper and NTPC social media accounts including Facebook and Twitter (see Figure 11)
    - Ads will be run in November of each year

Figure 10: News Release for Yellowknife Radio Stations

NORTHWEST TERRITORIES POWER CORPORATION *Empowering Communities*

Recreation Enthusiasts Warned About Thin Ice and Open Water on Jackfish and Bluefish Lakes

HAY RIVER, Northwest Territories (December 13, 2018) -- NTPC is warning snowmobilers and others who use bodies of water such as Jackfish Lake for recreation and other activities that thin ice and open water pose a significant risk to their safety. People are advised to stay off Jackfish Lake near NTPC's power plant as well as off Bluefish Lake near the hydro dam.

"We have seen snowmobile tracks in areas close to our facilities that indicate people are placing themselves and their equipment at risk in areas where the ice is very thin," said Colin Steed, Assistant Director of Hydro Operations. *"Although we have posted warning signs in the area, they are either not being seen or are being overlooked by some snowmobilers. There is thin ice and open water near these facilities and should be avoided."*

In addition to signage, NTPC will continue to use its social media channels as well as print and radio advertisements to ensure that this message gets out. Safety is NTPC's top priority, both for its workers and for the general public.

NTPC is a wholly owned subsidiary of NT Hydro, which in turn is 100 percent owned by the Government of the Northwest Territories.

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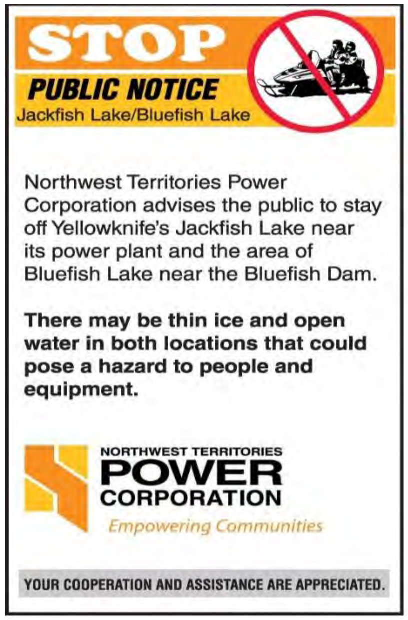
Media Contact:

Doug Prendergast
Communications Manager

(867) 874-5202
dprendergast@ntpc.com

Figure 11: Public Notice in Yellowknifer and NTPC Social Media



4.2.3 Signage

NTPC has or will have signage posted all around the Jackfish Facility. Existing signage includes:

- A large illuminated sign that states "DANGER- THIN ICE DO NOT PROCEED" that is placed on the ice on the west side of the facility. This large sign is clearly visible from Highway 3 and the west side of the lake.

Figure 12: Danger Ice Winter Warning Sign

New signage that will be installed to increase public awareness of the danger ice and mitigate risks to the public are:

- Warning signs at all pedestrian, boat, and all-terrain vehicle (ATV)/ snowmobile access points to Jackfish Lake including the boat launch, three ATV trails.
    - Signs will state "Danger Ice present at outlets of Jackfish Facility" with simple diagram

Figure 13: Snowmobile trails and boat launch

- Two new 4'x6' Danger sign will be installed at each end of the danger ice and attached to the fence of the Facility.
    - Signs will state "DANGER- Cooling System Outlets- KEEP OUT"

5.0 CONTACTS

Operations Manager Robert Sunderland	867-669 3338
Director, Hydro Region Colin Steed	867-669-3326
Manager, Communications Doug Prendergast	867-874-5202
Director, Health, Safety & Environment Eddie Smith	867-874-5327
Senior Environmental Licensing Specialist Matthew Miller	867-874-5417
Yellowknife System Control	867- 669-3370

DRAFT CONDITIONS ANNEXED TO AND FORMING PART OF WATER LICENCE NUMBER MV2019L1-00**

Part A: Scope and Definitions

1) **Scope**

   a) This Licence entitles the Northwest Territories Power Corporation to use water for cooling systems at the Jackfish Lake Generating Facility located in Yellowknife, Northwest Territories at Latitude 62° 28' 10" North and Longitude 114° 23' 00" West.

   b) This Licence is issued subject to the conditions contained herein with respect to the taking of water.

   c) Compliance with terms and conditions of this Licence does not absolve the Licensee from responsibility for compliance with the requirements of all applicable Federal, Territorial and Municipal legislation.

2) **Definitions**

Act means the *Waters Act*.

Aquatic Effects Monitoring Program means a monitoring program designed to determine the short- and long-term effects in the Receiving Environment resulting from the Jackfish Facility; to evaluate the accuracy of anticipated effects; to assess the effectiveness of planned impact mitigation measures; and to identify additional impact mitigation measures to reduce or eliminate environmental effects.

Analyst means an Analyst designated by the Minister under Section 65(1) of the Act.

Board means the Mackenzie Valley Land and Water Board established by Section 99(1) of the *Mackenzie Valley Resource Management Act*.

Construction means any activities undertaken to construct or build any components of, or associated with, the development of the Jackfish Facility.

Discharge means the direct or indirect release of any water.

Jackfish Facility means the Jackfish Lake Generating Station intakes, outlets, and pumps as described in Cooling System Detailed Blueprints submitted with the application.

Inspector means an Inspector designated by the Minister under Section 65(1) of the Act.

Licensee means the holder of this Licence.

Minister means a duly appointed member of the Executive Council who is responsible for the Act or the department responsible for administering that Act.

Modification means a change, other than an expansion, that does not alter the purpose or function of a structure.

Receiving Environment means, for the purpose of this Licence, the natural aquatic environment that receives any discharge from the Jackfish Facility.

Regulations means Regulations promulgated pursuant to Section 63 of the Act.

Spill Contingency Plan means a document, developed in accordance with Indian and Northern Affairs Canada's April 2007 Guidelines for Spill Contingency Planning, which describes the set of procedures to be implemented to minimize the effects of a spill.

Surveillance Network Program (SNP) means the monitoring requirements detailed in Annex A of this Licence.

Unauthorized Discharge means a release or Discharge of any water or Waste not authorized under this Licence.

Waste means Waste as defined by Section 1 of the Act.

Waste Management Plan means a document, developed in accordance with the Board's March 2011, or subsequent editions, *Guidelines for Developing a Waste Management Plan,* that describes the methods of Waste management from Waste generation to final disposal.

Waters means any waters defined by Section 1 of the Act.

Part B: GENERAL CONDITIONS

1) The Licensee shall ensure a copy of the Licence is maintained on site at all times.

2) All information submitted to the Board for this Licence must be submitted in a form acceptable to the Board.

3) The Licensee shall comply with the Surveillance Network Program annexed to this Licence, and any amendment to the said Surveillance Network Program as may be made from time to time, pursuant to the conditions of this Licence.

4) The attached Surveillance Network Program and compliance dates specified in the Licence may be amended at the discretion of the Board.

5) The Licensee shall post and maintain signs to identify the stations listed in the attached Surveillance Network Program. All postings shall be located and maintained to the satisfaction of an Inspector.

6) The Licensee shall file an Annual Report with the Board not later than March 31st of the year following the calendar year reported which shall be in accordance with Schedule 1.

7) The Licensee shall adhere to the approved **Engagement Plan** prepared in accordance with the Mackenzie Valley Land and Water Board's June 2013, or subsequent editions, *Engagement*

Guidelines for Applicants and Holders of Water Licences and Land Use Permits, and shall annually review the Plan and make any necessary revisions to reflect changes in operations, or as directed by the Board. Revisions to the plan shall be submitted to the Board for approval.

Part C: CONDITIONS APPLYING TO SECURITY REQUIREMENTS

1) The Licensee shall maintain the current security deposit of $50,000 pursuant to Section 35(1) of the Act. The Licensee shall also post any further amounts required by the Board during the term of this Licence.

2) The Licensee shall be liable for any and all costs related to the abandonment and restoration of the Jackfish Facility over and above the total amount of the security deposit posted under Part C, item 1.

PART D: CONDITIONS APPLYING TO OPERATION

1) The daily quantity of water used shall not exceed 50,000 cubic metres.

2) The Licensee shall install and maintain a guard on all water intakes to prevent entrainment of fish in accordance with the *Fisheries Act* and any other applicable legislation.

PART E: CONDITIONS APPLYING TO MODIFICATIONS

1) The Licensee may, without written consent from the Board, carry out Modifications to the Jackfish Facility provided that such Modifications are consistent with the terms of this Licence and the following requirements are met:

   a) the Licensee has notified the Board in writing of such proposed modifications at least sixty (60) days prior to beginning the modifications;

   b) such modifications do not place the Licensee in contravention of either the Licence or the Act;

   c) the Board has not, during the sixty (60) days following the notification of the proposed modifications, informed the Licensee that review of the proposal will require more than sixty (60) days; and

   d) the Board has not rejected the proposed modifications.

2) Modifications for which all the conditions referred to in Part E, Item 1, have not been met, can be carried out only with the written consent of the Board.

3) The Licensee shall provide to the Board as-built plans and drawings of the modifications referred to in Part E, Item 1 within ninety (90) days of their completion.

Part F: CONDITIONS APPLYING TO WATER AND WASTE MANAGEMENT

1) Within sixty (60) days following issuance of this Licence, the Licensee shall submit a **Waste Management Plan** to the Board for approval, in accordance with the Mackenzie Valley Land and Water Board's March 2011, or subsequent editions, *Guidelines for the Development of a Waste Management Plan*.

PART G: CONDITIONS APPLYING TO CONTINGENCY PLANNING

1) The Licensee shall, within ninety (90 days) of issuance of this Licence, submit to the Board for approval a **Spill Contingency Plan** in accordance with the Indian and Northern Affairs Canada's *Guidelines for Spill Contingency Planning, 2007* or subsequent versions, and shall be submitted to the Board for approval.

2) If, during the period of this Licence, an unauthorized discharge of Waste occurs, or if such a discharge is foreseeable, the Licensee shall:

   a) employ the Spill Contingency Plan;

   b) report the incident immediately via the 24 Hour Spill Reporting Line at (867) 920-8130 in accordance with the instructions contained in the Spill Report Form NWT 1752/0593 or subsequent editions;

   c) Report each spill and Unauthorized Discharge to the Board and an Inspector within 24 hours; and

   d) submit to an Inspector a detailed report on each occurrence Discharge, including descriptions of root causes, response actions and any changes to procedures to prevent similar occurrences in the future, not later than thirty (30) days after initially reporting the event.

3) The Licensee shall annually review the Spill Contingency Plan and modify it to reflect any changes in operation and technology. Any proposed modifications shall be submitted to the Board for approval.

4) All spills and unauthorized discharges of Waste shall be reclaimed to the satisfaction of the Inspector.

PART H: CONDITIONS APPLYING TO ABANDONMENT AND RESTORATION

1) The Licensee shall, within ninety (90 days) of issuance of this Licence, submit to the Board for approval a **Conceptual Abandonment and Restoration Plan**. All revisions to the Conceptual Abandonment and Restoration Plan shall be submitted to the Board for approval.

2) The Licensee shall submit to the Board for approval a **Final Abandonment and Restoration Plan** at

least eighteen (18) months prior to abandoning the Jackfish Facility.

3) The Licensee shall complete the restoration work within the time schedule specified in the Final Abandonment and Restoration Plan, or as subsequently approved by the Board.

PART I: CONDITIONS APPLYING TO AQUATIC EFFECTS MONITORING PROGRAM

1) Within ninety (90) days following issuance of this Licence, the Licensee shall submit an **Aquatic Effects Monitoring Program (AEMP) Design Plan** to the Board for approval. The Licensee shall submit a revised AEMP Design Plan to the Board for approval by December 1, 2023, and every three years thereafter or as directed by the Board.

2) The Licensee shall implement the AEMP Response Plan as and when approved by the Board.

3) The Licensee shall submit a revised AEMP Response Plan as directed by the Board.

SCHEDULE 1

Attached to Water Licence MV2019L1-00**

ANNUAL WATER LICENCE REPORT

The **Annual Water Licence Report** shall include, but not be limited to, the following:

1) **Measuring and Reporting on Water**

   a) A record of annual and monthly water use flows recorded at the Surveillance Network Program locations;

   b) A record of water temperatures recorded at the Surveillance Network Program locations; and

   c) Any other details on water use, construction or operating procedures requested by the Board on or before November 1st of the year being reported.

2) **Management Plans and Activities**

   a) A summary of engagement activities conducted in accordance with the approved **Engagement Plan**, undertaken during the previous calendar year, including a brief description of activities planned for the forthcoming year;

   b) A summary of **Modification** activities and major maintenance work carried out on the Jackfish Facility, as it relates to water use in accordance with Part E of this Licence, undertaken during the previous calendar year;

   c) A summary of activities conducted in accordance with the approved **Waste Management Plan**, undertaken during the previous calendar year, including a summary of updates or changes to the process or facilities required for the management of water and wastewater;

   d) A summary of activities conducted in accordance with the approved **Spill Contingency Plan**, undertaken during the previous calendar year, including:

      i) A list and description for all Unauthorized Discharges that occurred during the previous calendar year including the date, NWT spill number, volume, location, summary of the circumstances and follow-up actions taken;

      ii) status (i.e., open or closed), in accordance with the reporting requirements in Part G, item 2 of this Licence; and

      iii) An outline of any spill training and communications exercises carried out during the previous calendar year.

ANNEX A: SURVEILLANCE NETWORK PROGRAM

LICENSEE:	Northwest Territories Power Corporation
LICENCE NUMBER:	MV2019L1-00**
EFFECTIVE DATE OF LICENCE:	
EFFECTIVE DATE OF SURVEILLANCE NETWORK PROGRAM (SNP):	

Part A – Surveillance Network Program Description and Monitoring Requirements

1) The location of sampling sites and specific monitoring requirements are as follows:

   a) **<u>Surveillance Network Program (SNP) 00xx-1:</u>**

Description:	SNP 00xx-1a,b,c,d – Intakes to the K (2 intakes), EMD (1 intake), and CAT (1 intake) plants
Location:	SNP 00xx-1a - K plant intake 1 SNP 00xx-1b - K plant intake 2 SNP 00xx-1c - EMD plant intake SNP 00xx-1d - CAT plant intake
Sampling Frequency:	Continuous in-situ measurements during periods of discharge to Jackfish Lake
Sampling Parameters:	Water Temperature

b) **Surveillance Network Program (SNP) 00xx-2:**

Description:	SNP 00xx-2a,b,c - Discharges from the K, EMD and CAT plants, respectively
Location:	SNP 00xx-2a - K plant discharge SNP 00xx-2b - EMD plant discharge SNP 00xx-2c - CAT plant discharge
Sampling Frequency:	Continuous in-situ measurements during periods of discharge to Jackfish Lake
Sampling Parameters:	Water Temperature Flow

Part B – Volume, Flow and Temperature Measurement Requirements

1) All flow, volume and temperature measurements shall be measured and recorded continuously (i.e., using electronic data storage chips or equivalent) during periods of discharges and reported on a quarterly basis:

   a) The daily, monthly, and annual quantities of cooling water circulated from Surveillance Network Program Station Numbers 00xx-1a, 00xx-1b, 00xx-1c, and 00xx-1d shall be measured and recorded in cubic metres; and

   b) The water temperature at Surveillance Network Program Station Numbers 00xx-1a, 00xx-1b, 00xx-1c, 00xx-1d, 00xx-2a, 00xx-2b, and 00xx-2c shall be measured and recorded in degrees Celsius.

Part C – Reports

1) The Licensee shall, within sixty (60) days of the end of each quarter being reported, submit to the Board a quarterly report, in electronic and printed formats acceptable to the Board, including all the data and information required under the Surveillance Network Program, including the results of the approved QA/QC program and any interpretive comments and calculations.

REPORT

2018 Environmental Monitoring Report

Jackfish Lake Generating Facility

Submitted to:

Matthew Miller
Senior Environmental Licensing Specialist
Heath, Safety and Environment
Northwest Territories Power Corporation
4 Capital Drive, Hay River, NWT X0E 0R6

Submitted by:

Golder Associates Ltd.
Yellowknife, Northwest Territories

1894709-11010

25 February 2019

Distribution List

1 electronic copy - Golder Associates Ltd.

1 electronic copy - Northwest Territories Power Corporation

Executive Summary

The Northwest Territories Power Corporation (NTPC) owns and operates the Jackfish Lake Generating Facility (Jackfish Facility), located on the northeast shore of Jackfish Lake in Yellowknife, Northwest Territories (NWT). The Jackfish Facility provides electricity to the North Slave communities of Yellowknife, Behchokǫ̀, Dettah and Ndilǫ when the demand exceeds the capacity of the Snare and Bluefish Hydroelectric facilities, or during planned outages.

The use of water from Jackfish Lake by the facility engine cooling systems is regulated under a water license which expires later in 2019. NTPC will apply for a new water licence for the Jackfish cooling systems in early 2019. To support the expected license process, NTPC developed and implemented a one-year environmental monitoring program in 2018 to gather monitoring data for the water licence renewal. This monitoring program included water temperature at the intakes and discharges for the cooling systems of the Jackfish Facility, in-lake temperature data across the lake, lake bathymetry, water quality, plankton and benthos communities as well as fish. This report presents the results of the 2018 environmental program on Jackfish Lake.

Water Depth and Temperature

Jackfish Lake had an average depth of 5.0 m and a maximum depth of 7.8 m based on a limited number of measurements. Water surface elevation of Jackfish Lake varied by a total of 0.653 m over the monitoring period. Periods of rainfall correlated with increased water surface elevation in Jackfish Lake, and water surface elevation followed a similar trend as the cumulative rainfall.

For much of the monitoring period, the water level exceeded the upstream invert of the outflow culvert, but no outflow to Great Slave Lake via this culvert was observed. This suggests there is some topography upstream of the culvert that controls lake outflow.

In 2018, water temperature ranged from <1°C to 21.6°C at Jackfish Facility intakes, and from 0.9°C to 34.8°C at Jackfish Facility discharges. In-lake temperatures ranged from <1°C to approximately 23°C. Summer thermal stratification was observed in the deeper areas of the lake; shallow areas were more uniform in temperature with depth during the summer. Seasonal maximum lake temperature was observed between mid-July and mid-August. Temperatures in the immediate area surrounding the water discharges were generally warmer than in other parts of the lake, and were warmer throughout the water column during periods with or without power generation. Bottom temperatures at mid-lake remained cooler than other areas of the lake, even during periods of power generation. Temperature profiles were typical of a lake in this region, except for the area near the discharges which is warmer than the rest of the lake.

Water Quality

Jackfish Lake is a hard-water, alkaline lake, with moderate total dissolved solids (TDS) concentrations and low to moderate concentrations of total suspended solids. It is a eutrophic to hyper-eutrophic lake based on concentrations of total phosphorus (TP) and chlorophyll a, and shallow Secchi depth measurements in 2018. Likely sources of TP to Jackfish Lake are internal loading from lake sediments and loading from runoff. During stratified conditions in July and August, dissolved phosphorus concentrations were notably higher near the lake bottom compared to the lake surface at the mid-lake station. Increases in concentrations of all forms of

phosphorus occurred throughout the lake after fall turnover (in September) relative to stratified conditions, suggesting internal loading of phosphorus from lake sediments.

Vertical gradients in dissolved oxygen (DO) concentration were observed during all sampling events in Jackfish Lake except September. The lowest DO concentrations in Jackfish Lake occurred near the bottom of the lake. During summer (July and August), Jackfish lake was thermally stratified. This can limit re-oxygenation of bottom waters, which are also subject to oxygen demand from sediments due to biological activity. Accordingly, low DO concentrations were observed at the bottom at most stations in July and August in 2018. Total dissolved gases were below water quality guidelines.

Concentrations of most water quality parameters were water quality guidelines or within guideline ranges, with the exception of concentrations of DO at the lake bottom during summer, nitrite on one occasion, and three metals (total arsenic and copper; elevated zinc concentrations are considered anomalous). Arsenic concentrations have historically been above the water quality guidelines in Jackfish Lake and in the lakes around Yellowknife due to the historical contamination from mining in the area. These high total arsenic concentrations have the potential to affect aquatic life in Jackfish Lake but are not related to the discharge from the Jackfish Facility. High copper concentrations were observed near or within the discharge, indicating that the discharge could be influencing copper concentrations in the immediate vicinity of the discharge; however, historical concentrations of total copper have also been above the water quality guideline. Based on the three 2018 concentrations of total copper above the water quality guideline in Jackfish Lake, the risk to aquatic life in Jackfish Lake is considered low.

A qualitative comparison of water quality in Jackfish Lake in 2018 to water quality data collected in 1987, 2014, 2015, and 2017, showed no clear changes over time in water quality in Jackfish Lake.

Plankton and Algal Bloom Monitoring

The phytoplankton community in Jackfish Lake was dominated by cyanobacteria in 2018. Thermal effects on phytoplankton communities are similar to those observed when nutrients are in excess in a waterbody (Wetzel 2001), which is the case in Jackfish Lake. There was a lack of a clear spatial difference in temperature and phytoplankton abundance and biomass among stations, which suggests that the discharge from the Jackfish Facility was not the main factor affecting the phytoplankton community in the lake.

Chlorophyll *a* concentrations in Jackfish Lake correspond to the low to mid-range of bloom conditions and the phytoplankton community was dominated by a single species (*Planktothrix* sp.); therefore, the conditions in Jackfish Lake in 2018 are considered representative of bloom conditions. However, the cyanobacterial biomass did not reach a point where it results in a visual nuisance (i.e., discolouration of the waterbody beyond typical conditions or presence of scums).

Benthic Invertebrates

The community in Jackfish Lake was dominated by chironomids (midges) and similar in composition to those observed in lentic environments in the NWT. In 2018, the benthic invertebrate community included a number of common taxa that are tolerant of wide ranges in temperature and environmental disturbances in general, such as the chironomid genera *Tanypus, Procladius*, and *Chironomus*, aquatic mites, and oligochaete worms.

There was a visually consistent response of most benthic invertebrate endpoints (i.e., density and richness) to near-bottom DO concentrations measured during the July and August field surveys. As the life cycles of benthic invertebrates can extend over one or more years, the effects of the previous year’s or season’s oxygen depletion events would be reflected in the current community. Historical data also suggest that the low oxygen levels in the summer may be a regular occurrence in Jackfish Lake.

Fish

Three species of fish were documented in Jackfish Lake in 2018: Lake Whitefish, Northern Pike, and Trout-perch. The captured Lake Whitefish were mostly adults in good body condition, with full stomachs. Northern Pike adults were also captured but were slender; one juvenile or young-of-year Northern Pike was captured suggesting reproduction is occurring in the lake. Mercury tissue concentrations in Lake Whitefish and Northern Pike were below CFIA (2018) guidelines. Mean total dissolved gas concentrations were lower than threshold of 110%. Brief external assessments of fish did not document evidence of gas bubble trauma. Water temperature in the immediate vicinity of the discharge is high enough that it could cause effects to fish at various life stages. Based on one year of observation, thermal effects on the fish population are not likely because access to deeper, cooler water in the lake is available for fish.

Study Limitations

Golder Associates Ltd. (Golder) has prepared this document in a manner consistent with the level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this document. No warranty, express or implied, is made.

This document, including all text, data, tables, plans, figures, drawings and other documents contained herein, represents Golder's professional judgement based on the knowledge and information available at the time of completion. Golder is not responsible for any unauthorized use or modification of this document.

The data, interpretations, suggestions, recommendations and opinions expressed in this document pertain to the specific project, site conditions, development and purpose described to Golder by Northwest Territories Power Corporation (NTPC), and are not applicable to any other project or site location. In order to properly understand the data, interpretations, suggestions, recommendations and opinions expressed in this document, reference must be made to the entire document.

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TABLES

FIGURES

APPENDICES

ACRONYM LIST

Acronym	Definition
ALS	ALS Canada Ltd.
Biologica	Biologica Environmental Services Ltd.
$CaCO_3$	calcium carbonate
CCME	Canadian Council of Ministers of the Environment
CFIA	Canadian Food Inspection Agency
CPUE	catch-per-unit-effort
CTMax	critical thermal maxima
CWQG	Canadian Water Quality Guidelines
Golder	Golder Associates Ltd.
Jackfish Facility	Jackfish Lake Generating Facility
DL	detection limit
DO	dissolved oxygen
GPS	Global Positioning System
NTPC	The Northwest Territories Power Corporation
NWT	Northwest Territories
QA	quality assurance
QC	quality control
RPD	relative percent difference
SDI	Simpson's diversity index
SEI	Simpson's evenness index
Sub-Arctic	Sub-Arctic Geomatics Ltd.
TDS	total dissolved solids
TN	total nitrogen
TOC	total organic carbon
TP	total phosphorus
TSS	total suspended solids
UTM	Universal Transverse Mercator

SYBMOLS AND UNITS OF MEASURE

Unit	Definition
%	percent
ºC	degrees Celsius
$\underline{+}$	plus or equal to
<	less than
>	greater than
µg/L	micrograms per litre
µm	micrometre
µS/cm	microSiemens per centimetre
cells/L	cells per litre
g	gram
km	kilometre
km/h	kilometres per hour
km^2	square kilometre
kPa	kilopascal
m	metre
m^2	square metre
m^3	cubic metre
m^3/s	cubic metres per second
masl	metres above sea level
mg/kg	milligrams per kilogram
mg/L	milligrams per litre
mg-P/L	milligrams phosphorus per litre
mm	millimetre
ms	millisecond
org/m2	organisms per square metre
µL/L	microlitres per litre

1.0 INTRODUCTION

The Northwest Territories Power Corporation (NTPC) owns and operates the Jackfish Lake Generating Facility (Jackfish Facility), located on the northeast shore of Jackfish Lake in Yellowknife, Northwest Territories (NWT) (Figure 1-1). The Jackfish Facility provides electricity to the North Slave communities of Yellowknife, Behchokǫ̀, Dettah and Ndilǫ when the demand exceeds the capacity of the Snare and Bluefish Hydroelectric facilities, or during planned outages.

The use of water from Jackfish Lake by the facility engine cooling systems is regulated under Water Licence N1L1-1632 (MVLWB 1995). Water Licence N1L1-1632 was issued in 1995 and expires at the end of 2019. NTPC will apply for a new water licence for the Jackfish cooling systems in early 2019.

The current water licence does not require environmental monitoring of Jackfish Lake. The updated water licence is expected to have environmental monitoring requirements; therefore, to support the application, and to support subsequent monitoring under the new water licence, NTPC developed and implemented a one-year environmental monitoring program in 2018 to develop a dataset to be employed in the water licence renewal process.

This environmental monitoring report provides an overview of the 2018 environmental monitoring program in Jackfish Lake including details on sampling frequency and station locations (Section 2), and field methods and Quality Assurance (QA) and Quality Control (QC) practices by component in Sections 3 to 7. Specific details are provided in the *2018 Environmental Monitoring Field Work Plan* (Golder 2018). A discussion of the results in the context of federal guidelines and a comparison to historical data, if available, as well a description of seasonal and spatial trends is provided by component in Sections 3 to 7, and a summary and discussion of overall results and recommendations for future monitoring are provided in Sections 8 and 9.

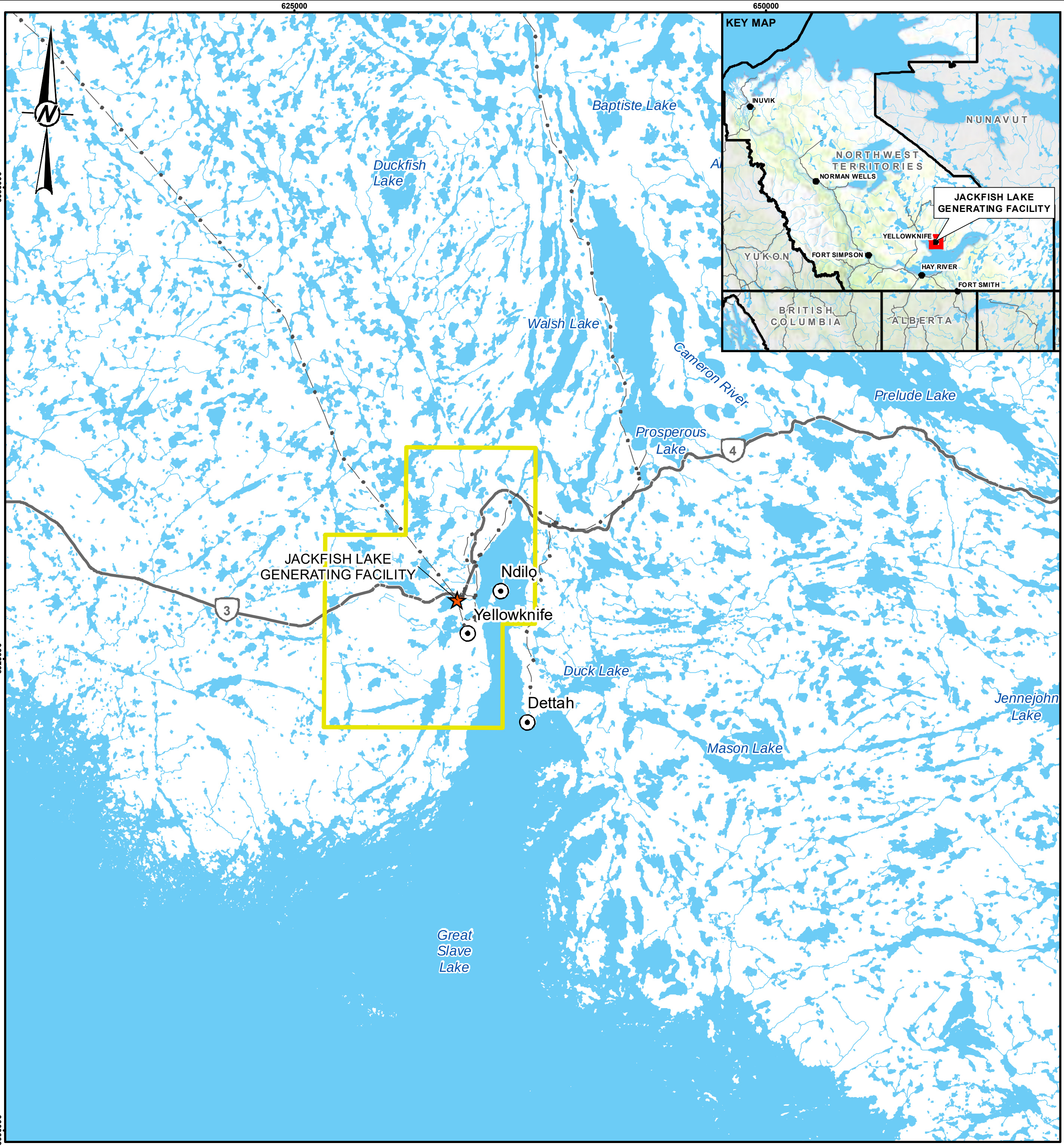
1.1 Location and Facility

Jackfish Lake is located on the northern end of Yellowknife, immediately southwest of the intersection of Highway 3 and the former access to the Ingraham Trail, and approximately 300 m south of the Yellowknife Solid Waste Facility (Figure 1-1). The lake outlet intermittently drains toward Yellowknife Bay of Great Slave Lake, approximately 750 m east of Jackfish Lake but has not done so in recent years due to low water levels. The topography throughout the area is similar and typical of the Precambrian Shield. Lakes and ponds are frequent in the area and vary in size and depth. Jackfish Lake, which was formerly known as Stock Lake, is located in an area of low rocky hills which are sparsely covered with black spruce, popular, and birch (Roberge and Gillman 1986). The lake has a surface area of approximately 0.6 km^2 (Baker 1987).

The Jackfish Facility is located on the northeast shore of Jackfish Lake and is a standby plant for the North Slave System. The diesel generating units at Jackfish are only utilized when there is an instantaneous loss of hydro supply (outage), a shortage of hydro generating capacity or there is a diminished supply of hydro due to low water inflows. Lake water is used to cool the generators in the system. The cooling systems consist of intake pipes that allow water from Jackfish Lake to flow through closed-loop cooling systems. The raw water is pumped through the system and returns to Jackfish Lake via a common gravity pipe.

The Jackfish Facility has three different diesel power plants; the CAT Plant, EMD Plant and the K-Plant (Figure 1-2). Each plant has an engine cooling system that circulates water to and from Jackfish Lake. K-Plant has two intakes, and EMD Plant and CAT Plant each have one intake; each plant has one discharge pipe. The Jackfish Facility also has a substation, an office facility, a warehouse, a line-shop and fuel storage on site.

The K-plant was built in 1969 and expanded in 1988 (NTPC 2019). It contains two generators, but only one is in service at this time. The EMD Plant was built in 1974 and expanded in 1988 and contains four EMD’s (Electro-Motive Division); two E-series generators and two F-series generators each. The CAT Plant was built in 1993 and contains two generators. The Jackfish Facility was developed so the total installed diesel generating capacity would be capable of providing power to the communities in the event of a failure of the L199 transmission line from the Snare Hydro System. Over time the diesel generating capacity of the Jackfish Station has sequentially increased until the construction of the 4300 kw Snare Cascades Hydro Plant in 1996. With all pumps running, the Jackfish Facility raw water pumps have the capacity to cycle through and discharge water at a rate of 0.58 m^3/s. Based on 2016 rates, the mean annual discharge from the Jackfish Facility to Jackfish Lake was 0.47 m^3/s of water (NTPC 2019).



LEGEND

- PROJECT LOCATION
- COMMUNITY
- ACTIVE TRANSMISSION LINE
- HIGHWAY
- WATERCOURSE
- WATERBODY
- YELLOWKNIFE MUNICIPAL BOUNDARY

0 5 10

1:300,000 KILOMETRES

REFERENCE(S)

BASE DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA AND GWNT, © 2005 GOVERNMENT OF CANADA WITH PERMISSION FROM INDIAN AND NORTHERN AFFAIRS CANADA. PUBLIC SECTOR DATASETS MADE AVAILABLE UNDER THE CITY OF YELLOWKNIFE'S OPEN DATA LICENSE V.1. TOPOGRAPHIC MAP © ESRI AND ITS LICENSORS. USED UNDER LICENSE, ALL RIGHTS RESERVED.
DATUM: NAD 83 PROJECTION: UTM ZONE 11

CLIENT
NORTHWEST TERRITORIES POWER CORPORATION

PROJECT
JACKFISH LAKE ENVIRONMENTAL MONITORING

TITLE
REGIONAL LOCATION OF JACKFISH LAKE

CONSULTANT
GOLDER

YYYY-MM-DD	2019-02-22
DESIGNED	TL
PREPARED	PS/LB
REVIEWED	KB
APPROVED	DP

PROJECT NO.	CONTROL	REV.	FIGURE
1894709	11000-11010	0	1-1

PATH: I:\2018\1894709\Mapping\MXD\General\1894709_11000_11010_Fig1_1_Regional_Location_Rev0.mxd PRINTED ON: 2019-02-22 AT: 12:54:54 PM

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25mm
0

REFERENCE(S)
AERIAL PHOTO PROVIDED BY CLIENT, 2018.

CLIENT
NORTHWEST TERRITORIES POWER CORPORATION

PROJECT
JACKFISH LAKE ENVIRONMENTAL MONITORING

TITLE
JACKFISH LAKE GENERATING STATION 2018

CONSULTANT
GOLDER

YYYY-MM-DD	2019-02-22
DESIGNED	TL
PREPARED	AA
REVIEWED	KB
APPROVED	DP

PROJECT NO.	CONTROL	REV.	FIGURE
1894709	11000-11010	0	1-2

PATH: I:\2018\1894709\Mapping\MXD\General\1894709_11000_11010_Fig1_2_GeneratingStation2018_Rev0.mxd PRINTED ON: 2019-02-22 AT: 1:02:55 PM

2.0 ENVIRONMENTAL MONITORING OVERVIEW

2.1 Objectives

The overall objectives of the 2018 Jackfish Lake environmental monitoring program were to collect one year of environmental monitoring data to develop an environmental dataset for the lake and begin to analyze the potential effects of the cooling system water discharges on Jackfish Lake. As noted above, the data gathered during the 2018 environmental monitoring program will be used to support of the new Water Licence application for the Jackfish Facility in 2019. The data will also be used to support future monitoring requirements expected under the new water licence.

2.2 Components

Five environmental components were studied in 2018:

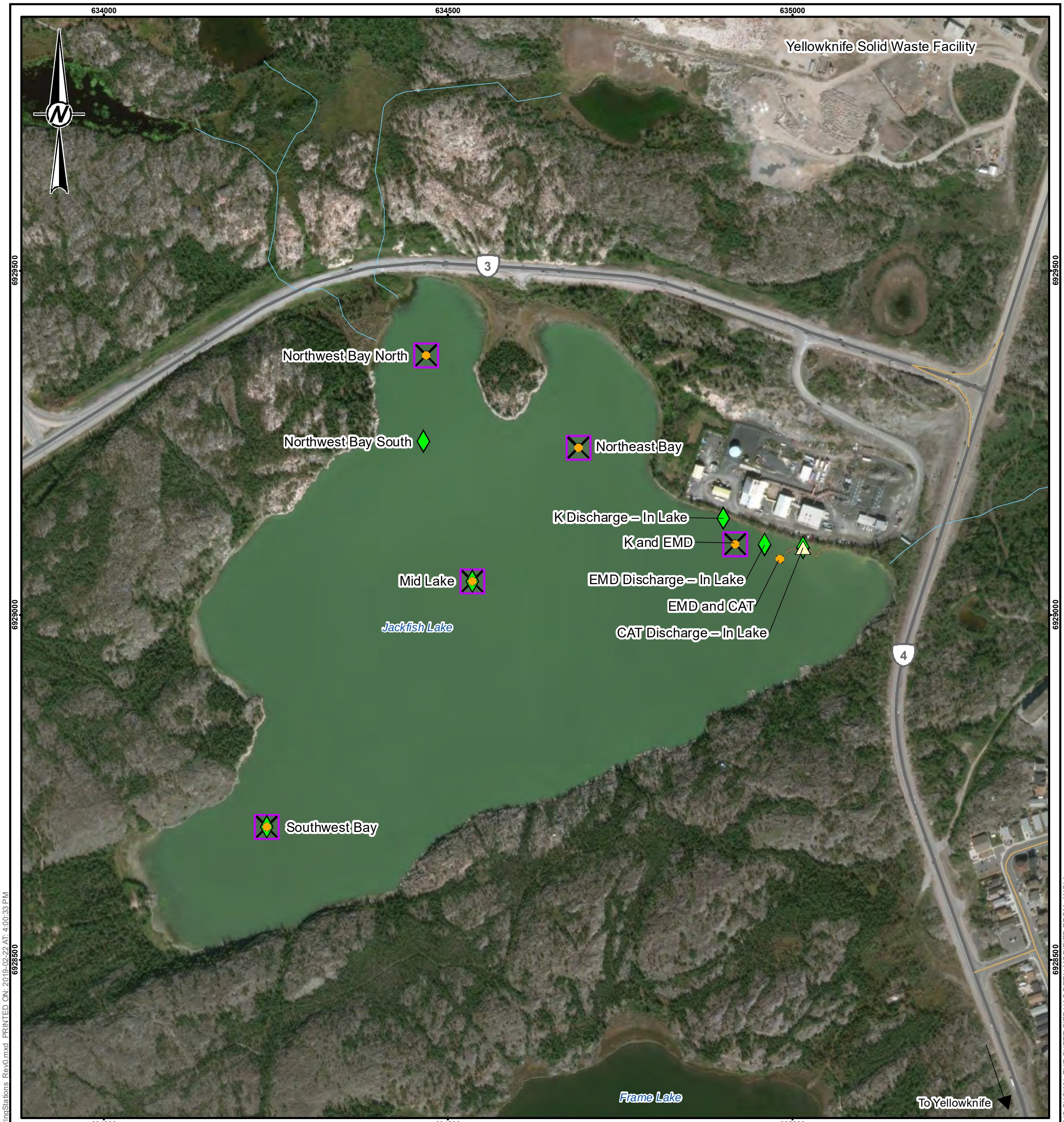
- Water Temperature and Water Level (Section 3)
- Water Quality (Section 4)
- Phytoplankton (Section 5)
- Benthic Invertebrate Community and Supporting Sediment Quality (Section 6)
- Fish Community and Fish Tissue Chemistry (Section 7).

2.3 Sampling Locations

Sampling locations were selected in the *2018 Environmental Monitoring Field Work Plan* based on the following criteria:

- Proximity to each intake to monitor the water surface elevation.
- Proximity to each discharge to monitor aquatic components in the immediate vicinity of the discharges.
- To monitor within approximately 500 m of the discharges for both the middle of the lake and the Northeast Bay.
- To monitor in the Northwest Bay in proximity to where external runoff (e.g., from Highway 3, potentially the Yellowknife Solid Waste Facility and cemetery) enters Jackfish Lake.
- To monitor in the Southwest Bay of Jackfish Lake at the farthest distance from the discharge from the Jackfish Facility.
- For fish, throughout the lake, along the shallow shorelines and deeper locations.

Specific field sampling locations were then based on depth requirements and logistics (e.g., boat access). The sampling stations for each monitoring component, except for fish, are shown in Figure 2-1 and are described in Table 2-1. Specific fish sampling areas are presented in Section 7.



LEGEND

SAMPLING STATION

- BENTHIC INVERTEBRATE COMMUNITY
- PHYTOPLANKTON COMMUNITY
- TEMPERATURE LOGGER
- WATER LEVEL
- WATER QUALITY

- HIGHWAY
- LOCAL ROAD
- WATERCOURSE

0 100 200

1:8,000 METRES

REFERENCE(S)

HYDROGRAPHY, POPULATED PLACE, AND ROAD DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED. IMAGERY COPYRIGHT © 20120115 ESRI AND ITS LICENSORS. SOURCE: YELLOWKNIFE. USED UNDER LICENSE, ALL RIGHTS RESERVED.
PROJECTION: UTM ZONE 11 DATUM: NAD 83

CLIENT

NORTHWEST TERRITORIES POWER CORPORATION

PROJECT

JACKFISH LAKE ENVIRONMENTAL MONITORING

TITLE

2018 JACKFISH LAKE ENVIRONMENTAL MONITORING STATIONS

CONSULTANT

GOLDER

YYYY-MM-DD	2019-02-22
DESIGNED	TL
PREPARED	AA
REVIEWED	KB
APPROVED	DP

PROJECT NO.	CONTROL	REV.	FIGURE
1894709	11000-11010	0	2-1

Table 2-1: 2018 Environmental Monitoring Stations, Jackfish Lake

Area	Station	UTM Coordinates (NAD 83, Zone 11)		Component				
		Easting	Northing	Water Temperature[a]	Water Level	Water Quality	Phytoplankton Community	Benthic Invertebrate Community
In Facility	K Intake – Facility	n/a	n/a	x[b]	-	x	-	-
	K Intake – Facility	n/a	n/a	x[b]	-	x	-	-
	EMD Intake – Facility	n/a	n/a	x[b]	-	x	-	-
	CAT Intake – Facility	n/a	n/a	x[b]	-	x	-	-
	K Discharge – Facility	n/a	n/a	-	-	x	-	-
	EMD Discharge - Facility	n/a	n/a	-	-	n/p	-	-
	CAT Discharge – Facility	n/a	n/a	-	-	x	-	-
In Lake	K Discharge – In Lake	634900	6929141	x[b]	-	-	-	-
	EMD Discharge – In Lake	634960	6929103	x[b]	-	-	-	-
	CAT Discharge – In Lake	635016	6929098	x[b]	x	-	-	-
	K and EMD[c]	634917	6929104	-	-	x	x	x
	EMD and CAT[d]	634982	6929082	-	-	x	-	-
	Mid-Lake	634535	6929050	x	-	x	x	x
	Northeast Bay	634690	6929244	-	-	x	x	x
	Northwest Bay South	634464	6929253	x	-	-	-	-
	Northwest Bay North	634468	6989378	-	-	x	x	x
	Southwest Bay	634237	6928693	x	-	x	x	x
	K Intake1 Thermistor	n/a	n/a	x	-	-	-	-
	K Intake2 Thermistor	n/a	n/a	x	-	-	-	-
	EMD Intake Thermistor	n/a	n/a	x	-	-	-	-
	CAT Intake Thermistor	n/a	n/a	x	-	-	-	-
	K Discharge Thermistor	n/a	n/a	x	-	-	-	-
	EMD Discharge Thermistor	n/a	n/a	x	-	-	-	-
	CAT Discharge Thermistor	n/a	n/a	x	-	-	-	-

(a) Continuous water temperature data collection with temperature data loggers and thermistors.

(b) Each intake and discharge was instrumented with thermistors In Lake (installed on intake and discharge screens) and not in Facility.

(c) Station located in between K and EMD discharges to overlap water, phytoplankton and benthic invertebrate community requirements.

(d) Station located in between EMD and CAT discharges for purposes of collecting water quality from both discharges.

UTM = Universal Transverse Mercator; n/a = not applicable; "-" = not collected because it was not required; n/p = collection was not possible because the tap was not functional.

2.4 Sampling Schedule

Monitoring dates for each component are provided in Table 2-2. Temperature and water level loggers were installed between 8 and 14 March 2018 and were left in place; data from March to December 2018 are included in this report. To capture seasonal variability in Jackfish Lake, five sampling events were conducted for water quality and phytoplankton in 2018: spring, summer, a peak warm-weather day, fall, and winter (i.e., under-ice).

Table 2-2: 2018 Environmental Monitoring Sampling Schedule, Jackfish Lake

Sampling Events	Dates (2018)	Component					
		Water Temperature	Water Level	Water Quality	Phytoplankton Community	Benthic Invertebrate Community	Fish
Equipment Installation	7 to 14 March	Temperature data logger and thermistors	Levelogger and Barologger	-	-	-	-
	9 April	Thermistor data logger	-	-	-	-	-
Spring	29 and 30 May	X	X	X	X	-	-
Summer	10 and 11 July	X	X	X	X	-	-
	24 to 26 July	-	-	-	-	-	X
Peak Warm Weather	1 and 2 August	X	X	X	X	-	-
Fall	25 to 26 September	X	X	X	X	X	-
Winter (under-ice)	11 to 13 December	X	X	X	-	-	-

Note: Water temperature and water level surveys included download of data, water level surveys with rod and level, and equipment relocation and maintenance, when required.

3.0 WATER TEMPERATURE AND WATER LEVEL

3.1 Introduction and Objectives

Instrumentation to record temperatures at the cooling water intakes and discharges, and throughout Jackfish Lake, was deployed from March to December 2018. Instrumentation to log water levels was also deployed from March to December 2018. The objectives of the data collection were:

- determine the range of temperatures observed at the intakes and discharges and in Jackfish Lake
- quantify the temperature distribution of Jackfish Lake to help support biological monitoring components of this project
- record one year of water level/elevation data for Jackfish Lake
- update the lake bathymetry.

3.2 Methods

3.2.1 Water Temperature

At each of the seven intake and discharge structures, RST Instruments 3K negative temperature coefficient thermistors[1] were installed on 14 March 2018, and connected to a single data logger (thermistor data logger), which was installed on 9 April 2018. To record lake water temperature data, twenty in-lake temperature data loggers (HOBO Pendant MX Water Temperature Data Loggers[2]) were installed at six locations in Jackfish Lake (Figure 2-1, Table 2-1) on 7, 8 and 13 March 2018.

A qualified dive team was contracted by NTPC to install the thermistors directly at the intake and discharge of each cooling system in the lake. A threaded rod was installed in holes drilled through the outlet of the discharge pipe and the thermistor bead was attached with galvanized steel wire and plastic cable ties, centered within the discharge flow. Thermistors were also attached directly to the intake structure screens with galvanized steel wire and plastic cable ties. Each plant has one discharge pipe. K-Plant has two separate but adjacent intake structures, and EMD Plant and CAT Plant each have one intake, for a total of seven thermistors. Cables were run from the thermistors to the single data logger installed on land for ease of access and downloading.

The in-lake temperature monitoring stations were set using an anchor, steel cable, and buoy to suspend the in-lake temperature data loggers in the water column. All stations are comprised of three in-lake temperature data loggers distributed along its depth, except for the Mid-Lake station, which has four, and the EMD Discharge in-lake station, which has a duplicate data logger at mid-depth for quality control of data. For the in-lake stations near the plant discharges (K Discharge, EMD Discharge, CAT Discharge), in-lake temperature data loggers were positioned between 0.2 and 0.4 m below the water surface, 1.0 m above the lake bottom, and at mid-depth, as open water conditions were expected year-round. For stations in Northwest Bay and Southwest Bay, in-lake temperature data loggers were positioned 1.0 m below the water surface, 1.0 m above the lake bottom, and at mid-depth, as ice was expected to form at these stations. For the Mid-Lake station, in-lake temperature data

[1] Sensor accuracy for a RST 3K negative temperature coefficient thermistor is ±0.1°C from 0° to 75°C

[2] Sensor accuracy for the Onset “HOBO MX2201” is ±0.5°C from -20° to 70°C

loggers were positioned a target of 1.0 m below the water surface, 1.0 m above the lake bottom, and at 1/3 and 2/3 of water depth. Lengths and data logger position for in-lake temperature monitoring stations are tabulated in Table 3-1. Extra length was included in the construction of the thermistors strings to allow for increase in lake level during freshet and to prevent wave action from lifting anchors from the lake bed.

Table 3-1: In-Lake Temperature Monitoring Station Lengths and Data Logger Positions, 2018

In-Lake Monitoring Station (Monitoring period)	Total String Length (m)	Data Logger Depth from Buoy (m)			
		Top	Middle	Middle2	Bottom
K Discharge - In Lake (13 Mar to 12 Dec)	2.50	0.20	0.90	-	1.50
EMD Discharge - In Lake (13 Mar to 12 Dec)	5.00	0.30	2.50[(a)]	-	4.00
CAT Discharge - In Lake (13 Mar to 12 Dec)	3.40	0.40	1.90	-	2.55
Mid-Lake (7 Mar to 11 Dec)	8.54	1.00	3.37	5.54	7.54
Northwest Bay South (7 Mar to 10 Jul)	6.80	1.00	4.10	-	5.80
Northwest Bay South[(b)] (10 Jul to 11 Dec)	8.50	1.00	4.25	-	7.50
Southwest Bay (8 Mar to 26 Jun)	3.97	1.00	2.02	-	2.97
Southwest Bay[(b)] (26 Jun to 13 Dec)	5.60	1.00	2.80	-	4.60

(a) A data logger was installed at the same depth in duplicate as a quality assurance/quality control measure.
(b) Deployment of a replacement station with a longer string.
"-" = logger was not installed at this position.

Immediately after ice-off (29 and 30 May 2018), the six in-lake temperature loggers were downloaded, at which time each string was repositioned to account for drifting of the stations due to wind/ice break-up. Data was also downloaded from the thermistor data logger. After ice-off, in-lake temperature data logger and thermistor logger downloads were paired with water quality field programs (Table 2-2) so data collection was done at the same time.

Prior to freeze up of Jackfish Lake, on 25 and 26 September 2018, each of the six in-lake temperature stations, the thermistor data logger were visited. Data were downloaded, and locations confirmed to verify that in-lake temperature stations will freeze in the current location. Stations were marked with a flagged buoy to facilitate their location in December 2018.

During the winter field program, on 11 to 13 December 2018, data from the in-lake temperature data loggers and the thermistor data logger were downloaded. It was observed that the three in-lake temperature monitoring stations near the Jackfish Facility (K Discharge – In Lake, EMD Discharge – In Lake, CAT Discharge – In Lake) were in open water during the winter program. Accordingly, these were accessed by personnel trained in ice rescue, wearing Ice Commander suits, and under supervision by an Ice Rescue Technician. The three temperature data logger strings away from the Jackfish Facility were accessed by drilling a hole using an auger adjacent to the flagged buoy and using a hook to pull the string above the ice.

Instrumentation (in-lake temperature data logger strings and thermistors) remains installed and recording in Jackfish Lake for future use by NTPC.

3.2.2 Water Level

To record lake water surface elevation, one Solinst Levelogger[3] and one Solinst Barologger[4] were deployed on the shoreline near the CAT Plant discharge on 13 March 2018, where open water conditions were expected to exist year-round. The water surface was surveyed by rod and level to a geodetically referenced benchmark, so that water surface and bathymetry data are referenced to a geodetic datum.

Publicly available meteorological data was collected from the Environment and Climate Change Canada Yellowknife A (Climate ID 2204101) (ECCC 2018) meteorological station, located 3.1 km west of the Jackfish Facility at an elevation of 205.70 m. Air temperature and daily rainfall data are used to infer increases in water level to hydrological events, such as freshet and surface runoff during precipitation events.

During the field program on 29 and 30 May 2018 (immediately after ice-off), Levelogger location and function was checked after break-up, and the Levelogger and Barologger data were downloaded. The water level survey was completed, and the upstream invert of the outflow culvert of Jackfish Lake was surveyed to a geodetic benchmark. Water level surveys and downloads of the Levelogger and Barologger were done at the same time as subsequent water quality field programs to allow for paired data (Table 2-2).

On 26 July 2018, Sub-Arctic Geomatics Ltd. (Sub-Arctic), surveyors engaged by NTPC, established two geodetic benchmarks on site. Temporary benchmarks established prior to this were surveyed to geodetic benchmarks to establish a geodetic water surface elevation record over the monitoring period. All benchmarks used in 2018 are summarized in Table 3-2.

[3] Sensor accuracy for the Solinst “Levelogger Edge”, type M5, model 3001, is ±0.05% of full scale. Full scale is 5.0 m.

[4] Sensor accuracy for the Solinst “Barologger Edge” is ±0.05 kPa (kilopascal).

Table 3-2: Jackfish Facility Benchmarks Surveyed in 2018

Benchmark	Location	Easting, 11V (m)	Northing, 11V (m)	Description	Elevation (m; geodetic)	Reference Benchmark
TBM1	West edge of CAT Plant exhaust stacks	635015	6929137	Paint mark on concrete slab (mark no longer exists)	175.482	BM2
TBM2	Yellow concrete bollard near Admin building; farthest one from building	635124	6929127	Highest point of bollard	176.389	BM2
BM1	West edge of CAT Plant exhaust stacks; established by Sub-Arctic	635015	6929137	Top of fastener in siding of plant, marked with embossed tag	175.733	-
BM2	West edge of CAT Plant exhaust stacks; established by Sub-Arctic	635015	6929137	Top of bolt, marked with embossed tag	175.527	-

Note: All coordinates provided in Table 3-2 were collected using a handheld GPS and are subject to a horizontal accuracy of plus or minus 3 m to 5 m.

Prior to freeze up of Jackfish Lake, on 25 and 26 September 2018 the Levelogger was repositioned to prevent freezing of the Levelogger in border ice. During the winter field program on 12 December 2018 the Levelogger and Barologger were removed for the end of the monitoring period and the data were downloaded.

3.2.3 Lake Bathymetry

Bathymetric survey data were measured on 26 June 2018, using a boat mounted Garmin GPSMap 521s. Due to time restrictions, there were a limited number of transects for the survey. Additional spot depth measurements measured on 10 July and 13 December 2018 using a depth sounder were recorded to fill gaps in the data coverage from 26 June 2018. Depths measured on 13 December 2018 were measured from bottom of ice to bottom of lake.

3.3 Data Analysis

3.3.1 Water Temperature

Data from in-lake temperature data loggers were compiled into a spreadsheet. Data points that are non-representative of lake temperature (before initial installation, and when stations are pulled from lake during read-out) were identified and removed from the compiled dataset. Data from the thermistor data logger were compiled in the same manner. From this compilation, lake temperature plots were generated and maximum and minimum temperature at each station position and thermistor were determined. Water temperatures over the monitoring period were plotted with the daily diesel energy generated by the Jackfish Facility as a whole as reported by NTPC (Miller 2018).

3.3.2 Water Level

The Levelogger pressure transducer measured total pressure (atmospheric and water pressure) and was compensated by the atmospheric pressure measured by the Barologger pressure transducer in order to return the hydrostatic pressure, which is covered to water depth. The record of continuous water depth measurements is converted to a record of continuous water surface elevation by applying offset and drift corrections to fit the time series to rod and level surveys which measured the water surface elevation at known times.

Air temperature and daily rainfall data measured at Environment and Climate Change Canada Yellowknife A (Climate ID 2204101) (ECCC 2018) were used to verify changes in water level during the correction process, especially during freshet and during rainfall events

3.3.3 Lake Bathymetry

Raw bathymetry data was composed of a series of depth measurements. Supplementary depth measurements were taken on 10 July and 13 December 2018 and were adjusted to the water surface elevation on 26 June 2018 of 174.274 m such that the dataset has a consistent datum. A publicly available lake outline published by Natural Resources Canada (2001) was used for the shoreline of Jackfish Lake. This lake outline was considered to have a depth of 0 m. ArcGIS 10.4.1 software was used to create a triangulated irregular network to interpolate a bathymetric surface, from which contours were generated.

3.4 Quality Assurance/Quality Control

The QA/QC measures were taken for the temperature, elevation, and bathymetry work. This included a duplicate in-lake data logger for temperature, frequent inspections of field equipment, hand-held measurements compared to in-lake logger measurements, and examination of data for suspect or invalid data (Appendix). Further, professional surveyors established two geodetic benchmarks on site which allowed comparisons to Levelogger and rod/level measurements. Alterations and re-locations of the in-lake instrumentation were needed on multiple occasions to accommodate local weather effects in 2018 including high wind, ice break-up and heavy rains creating high water levels. Some data exclusions and gaps were noted (Appendix B); in general, data was acceptable for use.

3.5 Results

3.5.1 Water Temperature

Water temperature is presented in Section 3.5.1.1 for the Jackfish Facility intake and discharge and Section 3.5.1.2 for in-lake. Compiled thermistor and in-lake temperature logger data are presented in Appendix A (Table A-1 and A-2).

3.5.1.1 Intake and Discharge Temperatures

The Jackfish Facility intakes ambient water; this ranged in temperature from <1°C to approximately 20°C (Table 3-3; Appendix A). The discharges released water that ranged from approximately 1°C in winter to summer peak of 34.8°C. Discharge temperature follows the pattern of intake temperature with intermittent peaks in temperature.

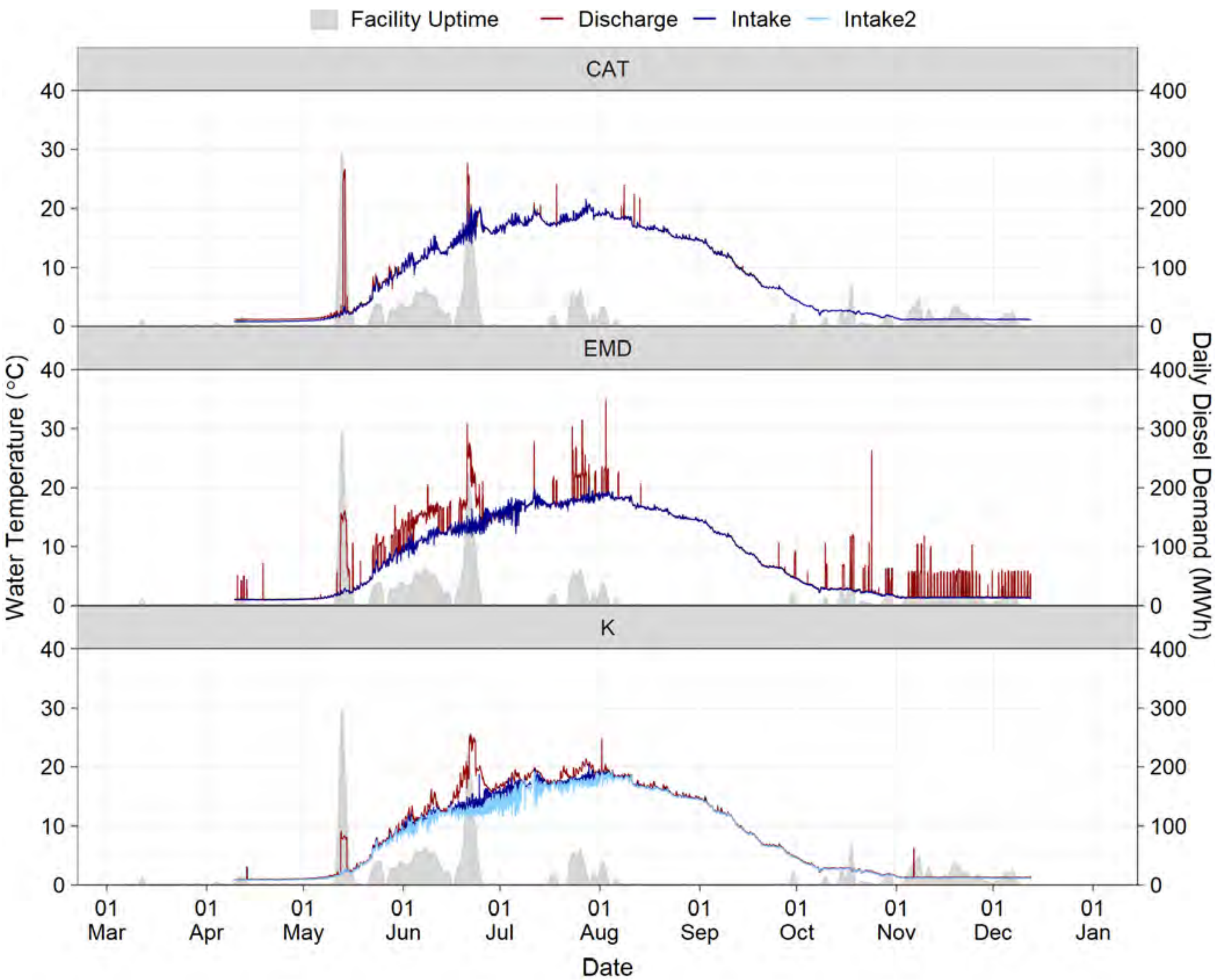
Table 3-3: Minimum and Maximum Temperatures at Jackfish Facility, 2018

Monitoring Area	Temperature Monitoring Station	Date and Time	Temperature (°C)
CAT Plant	Intake Thermistor	14 Apr 2018, 12:15	0.7[a]
		27 Jul 2018, 17:45	21.6
	Discharge Thermistor[b]	11 Apr 2018, 04:15	1.1[a]
		20 Jun 2018, 23:15	27.6
EMD Plant	Intake Thermistor	19 Apr 2018, 05:30	0.8[a]
		28 Jul 2018, 15:45	20.3
	Discharge Thermistor	19 Apr 2018, 07:15	1.0
		2 Aug 2018, 22:00	34.8
K-Plant	Intake Thermistor	19 Apr 2018, 04:15	0.8
		28 Jul 2018, 16:45	20.4
	Discharge Thermistor	11 Apr 2018, 05:15	0.9[a]
		22 Jun 2018, 00:30	25.5[a]

(a) The same temperature value was recorded for multiple timestamps; the earliest timestamp is tabulated.
(b) Temperature value originates from an incomplete dataset due to equipment failure (Figure 3-3).
"-" = position is not applicable.

Discharge temperature is in part related to level of diesel power generation of the Jackfish Facility (Figure 3-4). When the plants are inactive, intake and discharge temperatures were generally within 1°C. However, discharge from EMD Plant was typically 4°C to 5°C warmer than the water temperature measured at its intake during periods of power generation. Over periods of high rates or sustained periods of power generation, greater temperature differences were measured. On one day of high demand, 13 May 2018, temperature from the EMD Plant discharge was 13.2°C warmer than the intake water for EMD Plant, and on 20 June 2018, the discharge was at maximum 17.2°C warmer. The maximum temperature difference measured between a discharge and intake during the monitoring period was measured at EMD Plant on 24 October 2018 with a difference of 23.7°C but this event was very brief and lasted less than two hours. Similar responses of increased water temperature at the discharge compared to the intake during periods of power generation were observed at other plants (Figure 3-1).

Figure 3-1: Temperature Measured by Thermistors at Facility Intakes and Discharges in Jackfish Lake, 2018



3.5.1.2 *In-Lake Temperatures*

In-lake temperatures ranged from <1°C to approximately 23°C (Table 3-3; Appendix A). Seasonal and spatial patterns in temperature were observed (Figure 3-2).

- Summer temperature stratifications were observed in the deeper area of the lake; shallower areas were more uniform in temperature during the summer (Section 4.5.2.1).
- Seasonal maximum lake temperatures were typically observed between mid-July and mid-August.
- Temperatures in the immediate area surrounding the water discharges were generally warmer than the whole lake and were warmer throughout the water column including during periods without power generation.

- Bottom temperatures in Mid-Lake remained cooler than other areas of the lake, even during periods of power generation (Appendix A).
- In general, on the basis of one year of data, the temperature profile is typical of a lake in this region (e.g., Roberge and Gillman 1986; Puznicki 1996) with the exception of the area near the discharges which is warmer than the rest of the lake.
- Given the above 0˚C water temperatures around the discharge area in winter (and potentially the effect of discharge-related turbulence), this one area of the lake remains ice-free year-round.

Table 3-4: Minimum and Maximum Temperatures Measured by In-Lake Temperature Data Loggers in Jackfish Lake, 2018

Temperature Monitoring Station	Position	Date and Time	Temperature (°C)
CAT Discharge - In Lake	Top	5 Dec 2018 06:15	0.6
		20 Jun 2018 15:00	23.1
	Middle[b]	20 Apr 2018 22:30	0.7
		27 Jul 2018 19:00	21.5
	Bottom[b]	22 Apr 2018 06:00	0.7
		27 Jul 2018 19:00	21.4
EMD Discharge - In Lake	Top	4 Apr 2018 09:15	0.9[a]
		2 Aug 2018 22:00	22.9
	Middle	4 Apr 2018 09:30	0.8[a]
		27 Jul 2018 18:45	21.2
	Bottom	18 Apr 2018 23:00	0.7[a]
		12 Jul 2018 09:30	21.2
K Discharge - In Lake	Top[b]	5 Dec 2018 06:13	0.9
		21 Jul 2018 16:15	22.4
	Middle	30 Mar 2018 06:15	0.7 [a]
		20 Jun 2018 16:15	22.1
	Bottom	16 Apr 2018 14:45	0.8 [a]
		20 Jun 2018 16:00	22.0
Mid-Lake	Top[b]	8 Apr 2018 14:30	0.0[a]
		20 Jun 2018 18:15	22.0
	Middle[b]	7 Nov 2018 00:15	1.0[a]
		29 Jul 2018 00:30	20.1[a]
	Middle2[b]	4 Dec 2018 08:15	1.2[a]
		10 Aug 2018 15:15	18.3
	Bottom[b]	2 Nov 2018 00:00	1.6
		3 Sep 2018 09:30	13.7
Northwest Bay South	Top[b]	16 Apr 2018 18:30	0.0[a]
		20 Jun 2018 16:30	22.0
	Middle	12 Apr 2018 01:15	0.6[a]
		2 Aug 2018 18:30	19.9[a]
	Bottom[b]	31 Oct 2018 12:15	1.3[a]
		13 Aug 2018 14:30	16.9

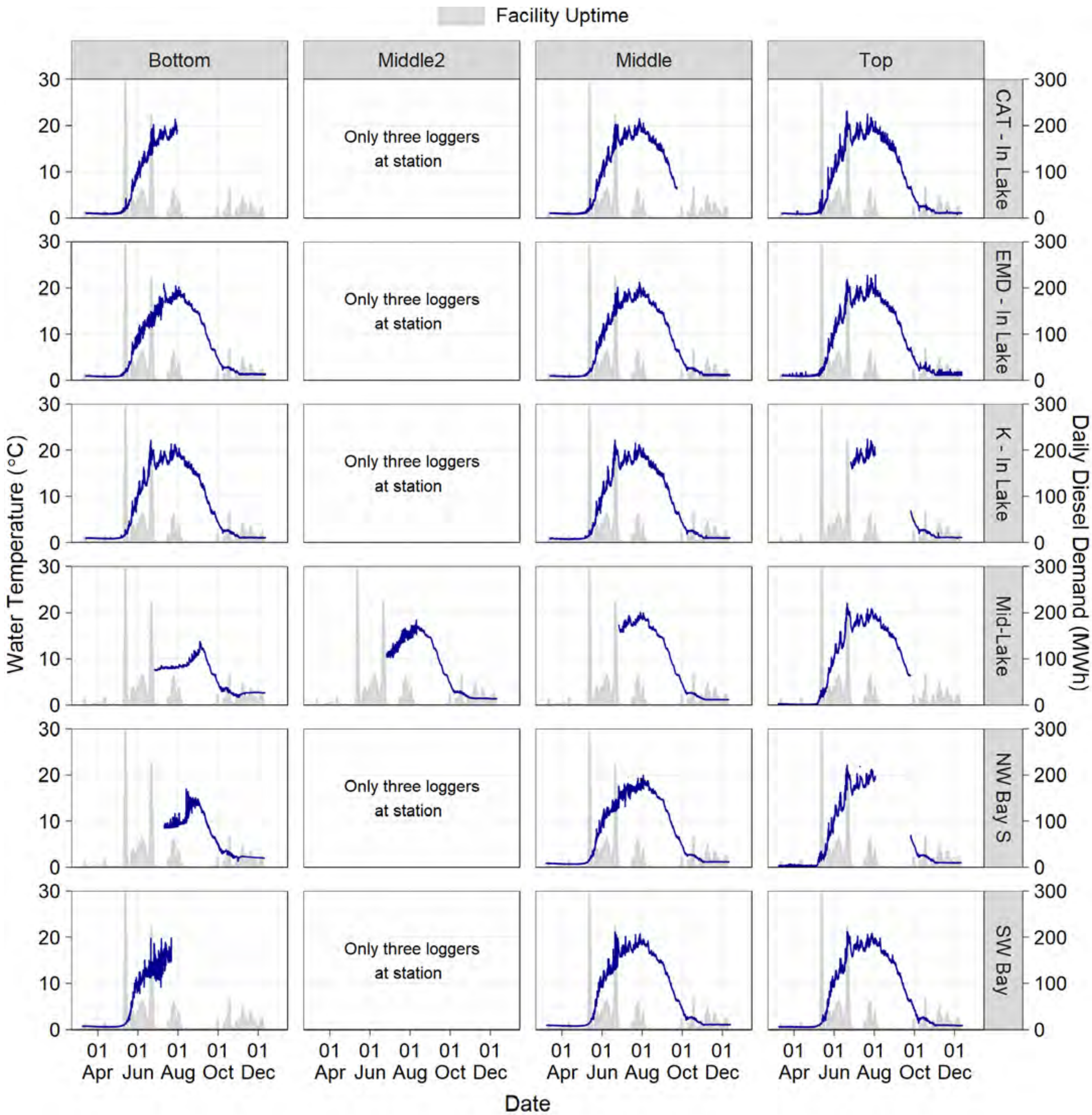
Table 3-4: Minimum and Maximum Temperatures Measured by In-Lake Temperature Data Loggers in Jackfish Lake, 2018

Temperature Monitoring Station	Position	Date and Time	Temperature (°C)
Southwest Bay	Top	15 Apr 2018 13:30	0.4
		20 Jun 2018 18:15	21.3
	Middle	14 Apr 2018 07:57	0.7[(a)]
		20 Jun 2018 18:12	21.2
	Bottom[(b)]	8 Apr 2018 05:45	0.5[(a)]
		21 Jul 2018 22:15	19.8

(a) The same temperature value was recorded for multiple timestamps; the earliest timestamp is tabulated.

(b) Temperature values originate from an incomplete dataset, due to equipment failure (Figure 3-3).

Figure 3-2: In-Lake Water Temperature in Jackfish Lake, 2018



3.5.2 Water Level

A water level survey was performed upon installation of the Levelogger and Barologger, during subsequent water quality field programs, and upon retrieval of the Levelogger and Barologger. The water surface elevations recorded in 2018 are summarized in Table 3-5.

Table 3-5: Manual Water Surface Elevation Measurements at Jackfish Lake, 2018

Date and Time	Water Surface Elevation (m; geodetic)	Method
13 March 2018 17:00	173.896	Rod and level by Golder
29 May 2018 16:00	174.094	Rod and level by Golder
30 May 2018 16:30	174.088	Rod and level by Golder
26 July 2018 10:03	174.521	Real time kinematic GPS by Sub-Arctic
02 August 2018 12:30	174.536	Rod and level by Golder
25 September 2018 12:30	174.477	Rod and level by Golder
12 December 2018 15:00	174.504	Rod and level by Golder

Continuous water surface elevations, derived from Levelogger data compensated by the atmospheric pressure measured by the Barologger, are presented in Figure 3-3. The water surface elevation record of Jackfish Lake is presented with the daily rainfall and mean daily temperature records. The record of barometric pressure with daily and cumulative rainfall is presented in Figure 3-4. Tabulated water surface elevation of Jackfish Lake, daily mean atmospheric pressure, daily total precipitation and daily mean air temperature are presented in Appendix A (Tables A-3 to A-6).

During rain events in June and July, displacement of the logger was observed, potentially due to mobilization of the slope on which the logger was deployed under the increased head. An incremental drift correction to the logger data presented in Figure 3-3 was applied to data between the level surveys on 30 May and 2 August 2018 for compensated logger data to agree with both level surveys. There is a high level of confidence in the 2 August 2018 survey (Appendix B).

The lowest observed water surface elevation of 173.901 metres above sea level (masl) was observed on 21 March 2018 and the highest observed water surface elevation of 174.554 masl was observed on 20 July 2018. The upstream invert of the outflow culvert to Great Slave Lake, which passes beneath the road embankment to the east of the Jackfish Facility, was measured to be 174.391 masl. Periods of rainfall correlated with increased water surface elevations in Jackfish Lake, and water surface elevations followed a similar trend as the cumulative rainfall (Figures 3-3 and 3-4).

The water surface elevation of Jackfish Lake exceeded the elevation of the invert of the outflow culvert on 30 June 2018 and remained higher for the remainder of the monitoring period. Lake outflow through the culvert was not observed on any field visits, and no ice was observed on the upstream side of the outflow culvert on 12 December 2018. This suggests there is topography between the culvert and Jackfish Lake that controls outflow into the culvert and into Great Slave Lake. A limited investigation into the topography was completed in 2018 and this verified that high points in the topography upstream of the channel were blocking outflow from the lake (Miller 2019).

Figure 3-3: Water Surface Elevation Measured at Jackfish Lake, and Air Temperature and Rainfall Observed at Yellowknife A Meteorological Station, 2018

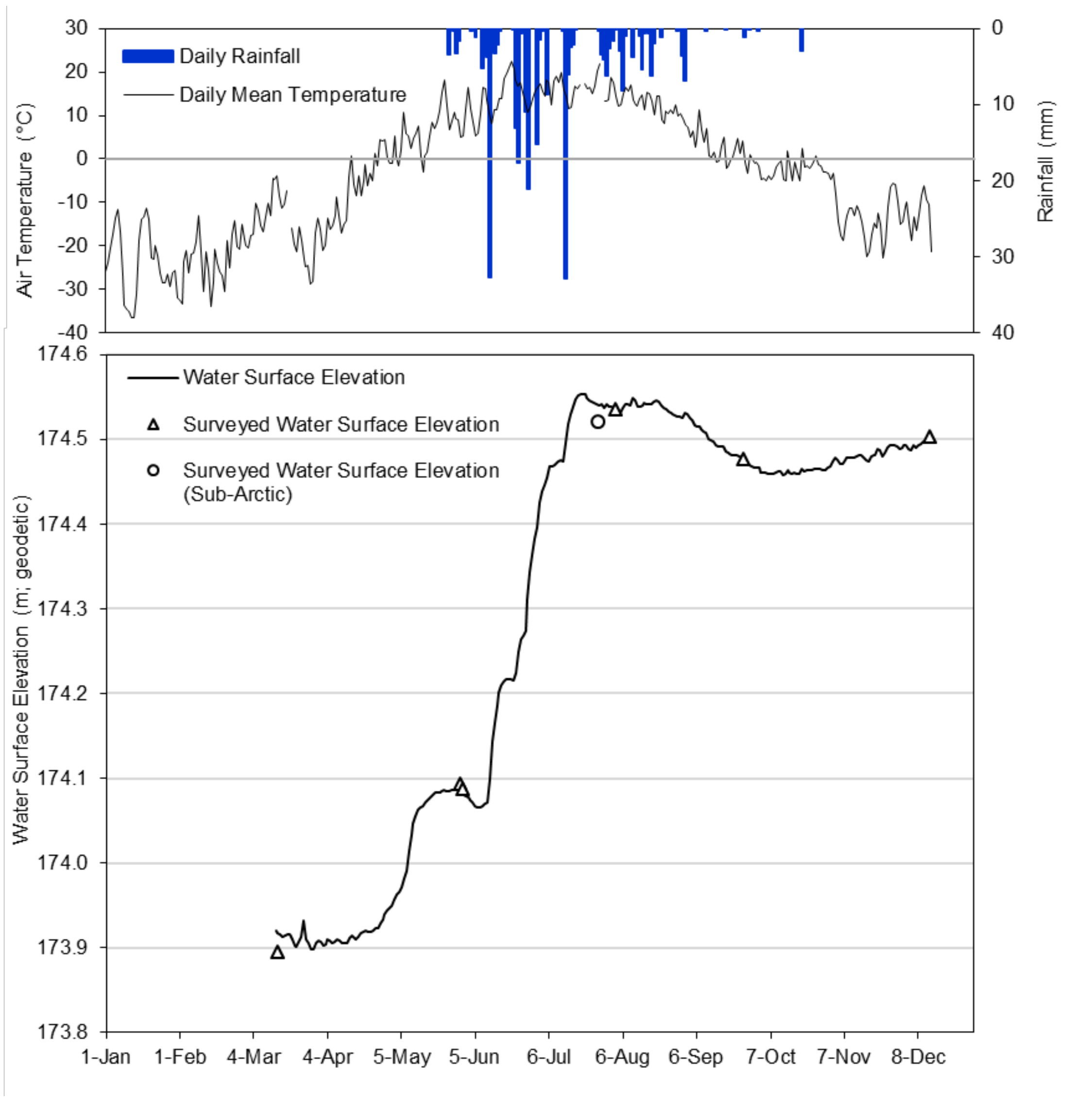
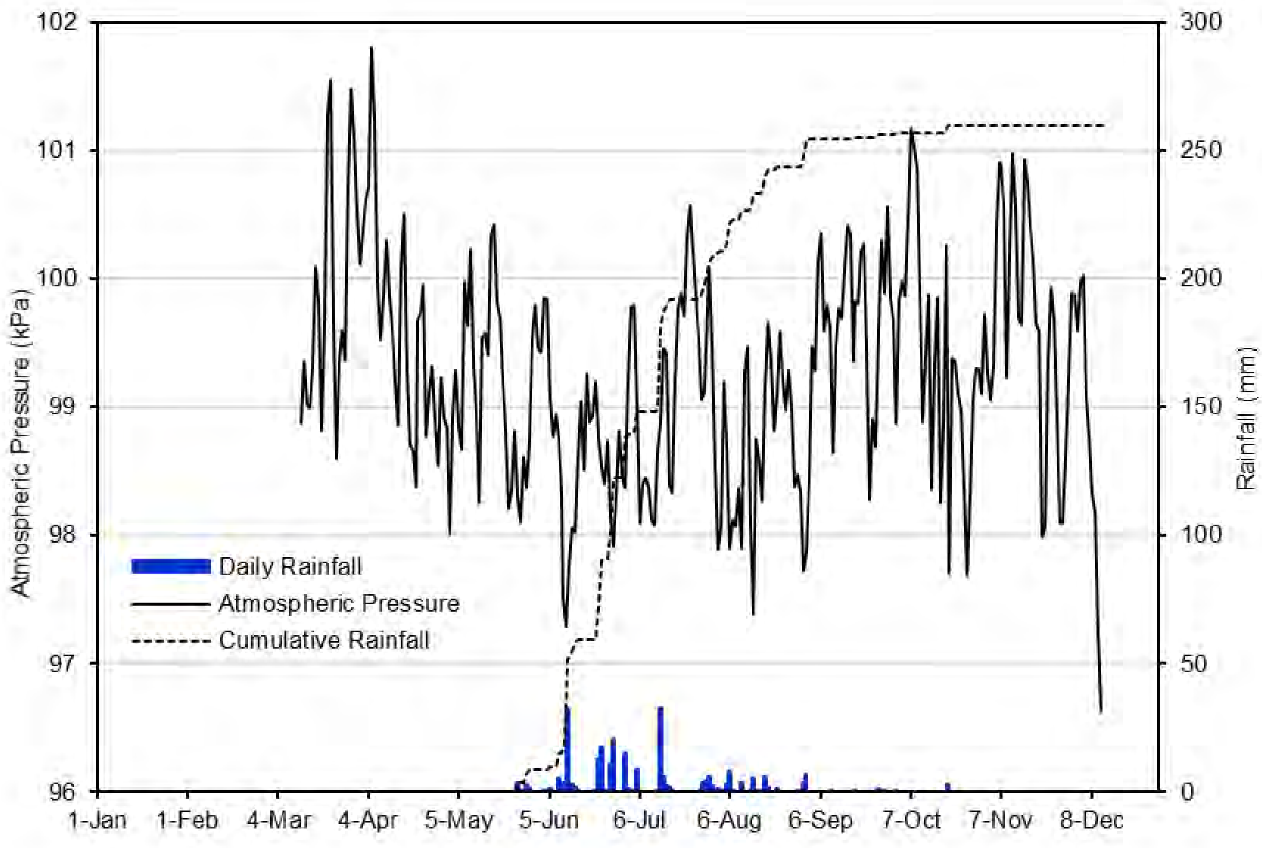


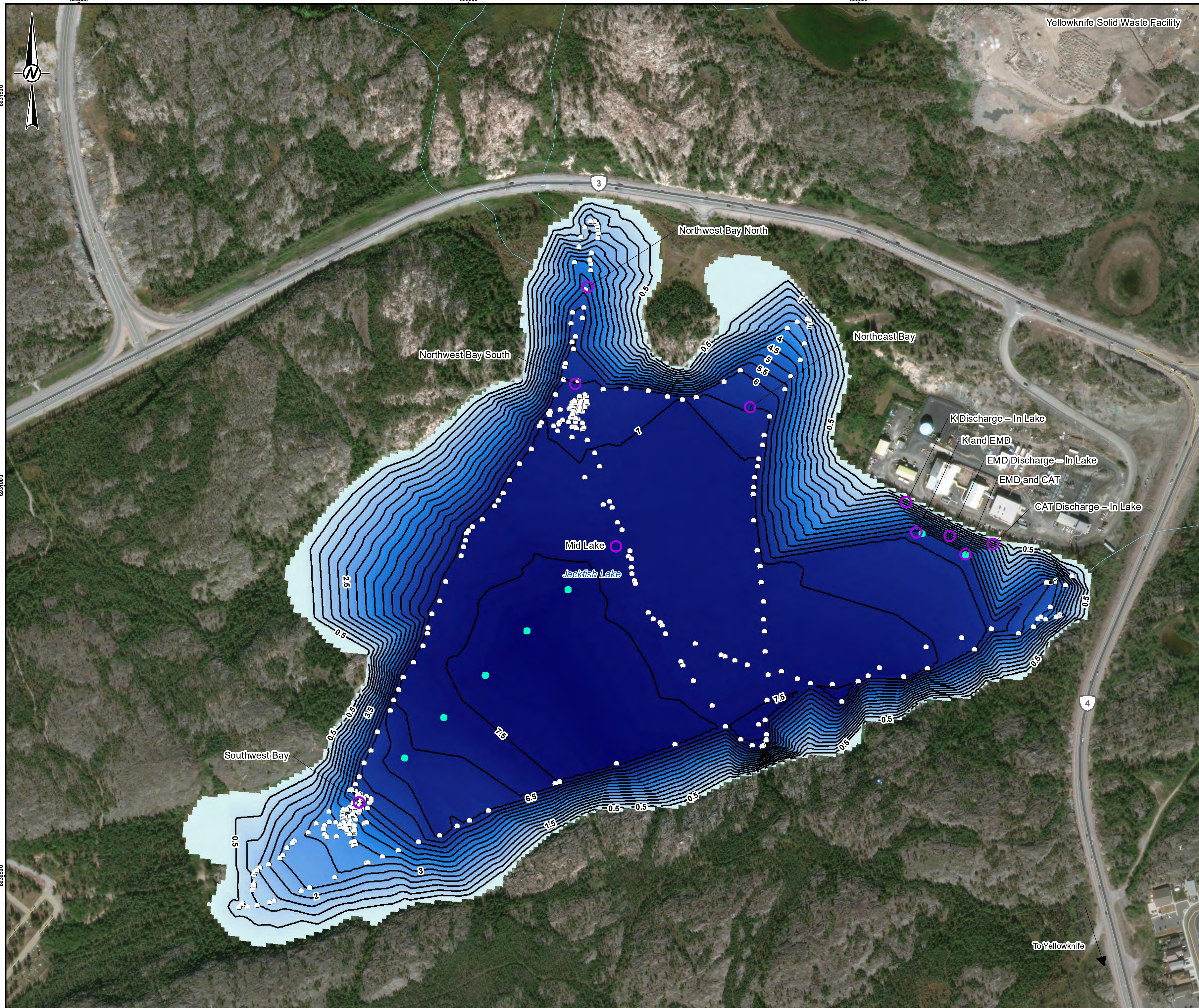
Figure 3-4: Barometric Pressure Measured at Jackfish Lake and Rainfall Observed at Yellowknife A Meteorological Station, 2018



3.5.3 Lake Bathymetry

In 2018, Jackfish Lake had an estimated mean depth of 5.1 m, a maximum depth of 7.8 m, a surface area of 516,575 m^2 and storage of 2,617,389 m^3. A preliminary bathymetric map presented in Figure 3-5, and elevation-area and elevation-storage relationships for Jackfish derived from the bathymetric surface are presented in Figure 3-6 (elevation-area) and Figure 3-7 (elevation-storage).

Because of a lack of data near the shoreline of Jackfish Lake, slopes in shallow areas of the lake are modeled to shallower than expected, which results in an underestimation of the lake surface area and volume as a function of stage.



LEGEND

- IN-LAKE STATION
- 0.5 m DEPTH CONTOUR
- LOCAL ROAD
- HIGHWAY
- WATERCOURSE

DEPTH MEASUREMENT TYPE

- DEPTH DATA COLLECTED BY SPOT MEASUREMENTS
- DEPTH DATA COLLECTED BY BOAT MOUNTED GPS

DEPTH (m)

0

7.832

0 100 200

1:5,000 METRES

NOTE(S)

DEPTH OF 0 m CORRESPONDS TO A WATER SURFACE ELEVATION OF 174.274 m.

REFERENCE(S)

HYDROGRAPHY, POPULATED PLACE, AND ROAD DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED. IMAGERY COPYRIGHT © 20120115 ESRI AND ITS LICENSORS. SOURCE: YELLOWKNIFE. PROJECTION: UTM ZONE 11 DATUM: NAD 83

CLIENT

NORTHWEST TERRITORIES POWER CORPORATION

PROJECT

JACKFISH LAKE ENVIRONMENTAL MONITORING

TITLE

PRELIMINARY BATHYMETRY OF JACKFISH LAKE

CONSULTANT

GOLDER

YYYY-MM-DD	2019-02-22
DESIGNED	EH
PREPARED	SK
REVIEWED	KB
APPROVED	DP

PROJECT NO.	CONTROL	REV.	FIGURE
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25mm

Figure 3-6: Elevation-area Curve of Jackfish Lake Derived from Bathymetry Data Collected in 2018

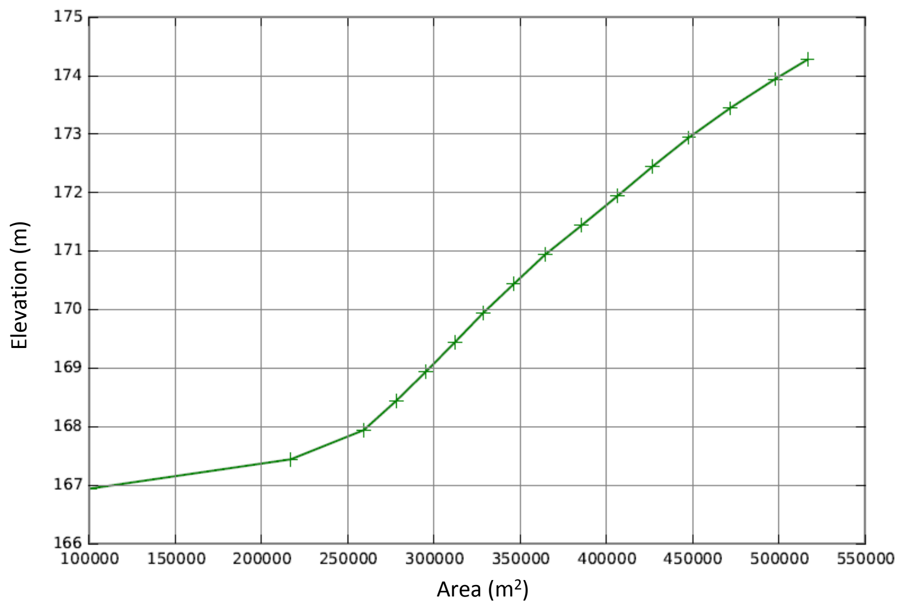
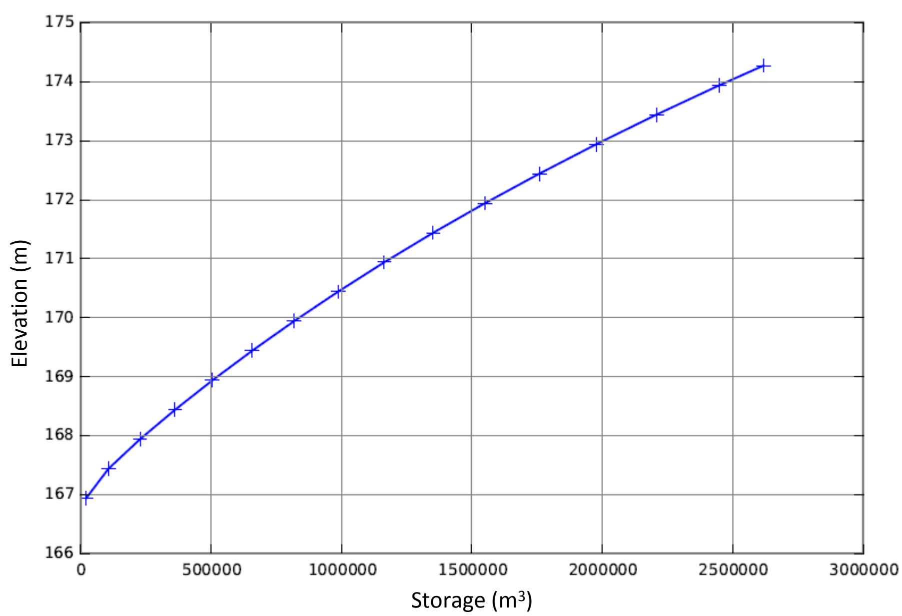


Figure 3-7: Elevation-storage Curve of Jackfish Lake Derived from Bathymetry Data Collected in 2018



3.6 Summary and Conclusions

The 2018 water temperature and water level programs in Jackfish Lake successfully met the objectives of the program, which were to determine the range of temperatures observed at the intakes and discharges, and in Jackfish Lake; quantify the temperature distribution of Jackfish Lake to help support biological monitoring components of this project; record one year of water level/elevation data for Jackfish Lake; and update the lake bathymetry. The results of the Jackfish Lake water temperature and water level programs can be summarized as follows:

- Temperatures ranged from <1°C to 21.6°C at Jackfish Facility intakes, 0.9°C to 34.8°C at Jackfish Facility discharges.
- Discharge temperature is in part related to plant facility activity and temperatures near the discharges are warmer than other areas of the lake.
- In-lake temperatures ranged from <1°C to approximately 23°C. Seasonal and spatial patterns in temperature were observed:
  - summer temperature stratification was observed in the deeper areas of the lake; shallower areas were more uniform in temperature during the summer
  - seasonal maximum lake temperature was observed between mid-July and mid-August
  - temperatures in the immediate area surrounding the water discharges were generally warmer than other parts of the lake, and were warmer throughout the water column during periods with and without power generation
  - bottom temperatures in Mid-Lake remained cooler than other areas of the lake even during periods of power generation
  - the temperature profile is typical of lakes in this region, except in the area near the discharges, which is warmer than the rest of the lake
- The water surface elevation of Jackfish Lake varied a total of 0.653 m over the monitoring period. Periods of rainfall correlated with increased water surface elevation in Jackfish Lake, and water surface elevation followed a similar trend as the cumulative rainfall.
- For much of the monitoring period, the water level exceeded the upstream invert of the outflow culvert, but no outflow to Great Slave Lake via this culvert was observed. This suggests there is some topography upstream of the culvert that controls lake outflow, which was verified through an initial investigation into this topography was completed in 2018 (Miller 2019).
- Jackfish Lake had an average depth of 5.0 m and a maximum depth of 7.8 m based on a limited number of measurements.

4.0 WATER QUALITY

4.1 Introduction and Objectives

Water quality monitoring was completed in Jackfish Lake and within the Jackfish Facility in 2018.The objectives of the Jackfish Lake water quality monitoring program were to:

- characterize water quality in Jackfish Lake
- assess the potential for water quality in Jackfish Lake to be influenced by the Jackfish Facility discharges
- provide water quality results to help support biological monitoring of the lake.

A detailed description of the field methods used to collect the water quality data in 2018 is provided in Section 4.2. Data analyses methods, which included comparisons to relevant water quality guidelines and assessment of spatial patterns and seasonal and historical trends, are described in Section 4.3. The methods and results of the QA/QC checks completed for the program are summarized in Section 4.4. Results are discussed in Section 4.5 and summarized in Section 4.6. Laboratory and field data tables from the 2018 program (Appendix C.1), spatial and seasonal plots of 2018 water quality data (Appendix C.2), comparisons of 2018 water quality to historical data (Appendix C.3), QA/QC methods and results (Appendix C.4), 2018 Certificates-of-Analysis (Appendix C.5), and a general description of water quality parameters (Appendix C.6) are provided in appendices to this report.

4.2 Sampling Methods

4.2.1 Field Sampling

Five water quality sampling events were completed in Jackfish Lake in 2018. Each sampling event required two to three days to complete. Sampling was completed immediately after ice break-up (late-May), early summer (July), fall (September) and winter (December), as well as one additional sampling event during a period of higher temperature (August) (Table 2-2). Water quality sampling was completed at the same time as the phytoplankton sampling during the May, July and August sampling events. Water quality monitoring was completed at six stations in Jackfish Lake (Figure 2-1, Table 2-1).

Facility water quality samples were collected during the early summer sampling event at five facility stations (at the three intakes to the Jackfish Facility and at two discharges from the facility) (Tables 2-1 and 2-2).

Prior to collecting lake water samples, field profile measurements were recorded at one-metre depth intervals using a handheld multi-parameter water quality meter (SmarTROLL, AquaTroll) and total dissolved gas meter (P4 – Total Dissolved Gas Pressure Meter) to record:

- water temperature (°C)
- pH
- dissolved oxygen (DO; as mg/L and% saturation)
- specific conductivity (microSiemens per centimetre [µS/cm])
- total dissolved gases (% saturation)
- Secchi depth (m).

Field turbidity (in nephelometric turbidity units [NTU]) was measured at water quality stations using a LaMotte turbidity meter; field turbidity measurements were calculated as the average of three readings taken from the depth and location where the water quality sample was collected. Total water depth and sample depth was also measured at each water quality station.

During each sampling event, a total of nine lake samples (six lake samples and three QA/QC samples) were collected using a Kemmerer at mid-depth for all parameters except nutrients, which were depth-integrated samples within the euphotic zone. Methods for depth-integrated nutrient sampling are provided in Section 5.2. At the deep Mid-Lake station (i.e., Mid-Bottom), samples were also collected at 1 m above the bottom of the lake. Lake samples were poured from the Kemmerer into sample bottles provided by the laboratory. When more than one volume of the Kemmerer was required to fill the bottle suite (e.g., when additional parameters were required), the bottles were filled by splitting the sample from each Kemmerer volume equally between the bottles. The same methods were used when taking duplicate samples. Water from the Kemmerer was also used to measure turbidity in the field. For the Jackfish Facility intake and discharge samples, sample bottles were filled directly at the inlet and discharges using taps installed by NTPC.

Dissolved nutrients were filtered and preserved according to laboratory instructions. Prior to transport to the analytical laboratory, samples were stored in coolers and kept cool with ice packs. Analysis request and chain-of-custody forms were used to request analysis and track samples, respectively.

4.2.2 Laboratory Analysis

Water quality samples were sent to ALS Canada Ltd. (ALS) in Yellowknife, NWT. Specific ALS analytical methods, detection limits (DL), and QC checks are provided in Appendix C.4. Parameters analyzed by the laboratory in 2018 water samples were:

- Routine parameters: pH, specific conductivity, hardness, total alkalinity, total suspended solids, total dissolved solids (TDS), and turbidity.
- Major Ions: calcium, chloride, fluoride, magnesium, potassium, sodium, and sulphate.
- Nutrients: total ammonia (as nitrogen), total phosphorus, dissolved phosphorus, ortho-phosphate (as phosphorus), nitrate (as nitrogen), nitrite (as nitrogen), nitrate and nitrite (as nitrogen), total nitrogen, total Kjeldahl nitrogen, soluble reactive silica, and total organic carbon (TOC).
- Total metals: aluminum, antimony, arsenic, barium, beryllium, boron, bismuth, cadmium, cesium, chromium, cobalt, copper, iron, lead, lithium, manganese, mercury, molybdenum, nickel, rubidium, selenium, silver, strontium, thallium, tin, titanium, uranium, vanadium, and zinc.

During the July program, additional parameters were collected at two stations in Jackfish Lake to screen for the presence of petroleum hydrocarbons and other organics in the lake. The two stations were K and EMD, and the Mid-Lake station. These samples were sent to ALS for analysis of:

- benzene, toluene, ethylbenzene, and xylenes
- F1 (C6-C10)
- F2 (C10-C16)

- F3 (C16-C34)
- F4 (C34-C50).

Concentrations of petroleum hydrocarbons were below the DL for all the July samples and therefore no additional sampling for petroleum hydrocarbons was completed in Jackfish Lake.

4.2.3 Sampling Plan and Protocol Deviations

Every effort was made to collect samples from each station as planned. However, the EMD Discharge sample was not collected in 2018, as the tap where the sample was to be collected did not work (Table 2-1).

4.3 Data Analysis

4.3.1 Approach

The 2018 and historical water quality data were uploaded directly into Golder's Environmental Quality Information System database, which was used to manage the water quality data for this project and contains historical water quality data collected from the site (see below for more details). A general characterization of the 2018 water quality in Jackfish Lake and the discharges was provided. The 2018 water quality data from Jackfish Lake and the intake and discharges of the Jackfish Facility were tabulated and compared to Canadian Water Quality Guidelines (CWQGs) (CCME 1999). Concentrations or values of parameters in the lake were further assessed for spatial patterns and seasonal trends, and compared to available historical data.

4.3.2 General Water Quality Characterization and Comparisons to Water Quality Guidelines

Water chemistry in surface waters depends on the interaction of biological, physical and chemical processes. The 2018 water quality data from Jackfish Lake and the Jackfish Facility's intakes and discharges were used to generally characterize water quality in the lake and discharges by describing the parameters commonly used to evaluate water quality, as described in Appendix C.6.

The 2018 water quality data at lake and facility stations were compared to applicable CWQGs; the majority of CWQGs were long-term exposure guidelines (28 parameters) and 4 parameters also had short-term exposure guidelines (chloride, cadmium, uranium, and zinc) (Appendix C, Table C.1-1). Results of historical data CWQG comparisons from 1987, 2014, 2015, and 2017 were used to provide context to 2018 concentrations above CWQGs.

Parameter-dependent CWQGs (i.e., total ammonia, aluminum, cadmium, copper, lead, nickel, and zinc) were calculated for each sampling event and for each sampling station based on individual sample parameter values. In 2018, the CWQG for zinc was updated to be dependent on dissolved organic carbon and applicable to dissolved zinc concentrations; the updated CWQG includes both a short-term and long-term guideline. Guidance from Canadian Council of Ministers of the Environment (CCME;(1999) is to compare total zinc concentrations to the dissolved zinc CWQG when dissolved concentrations are not available. Dissolved organic carbon was not measured in 2018; therefore, the most conservative value for dissolved organic carbon in the guideline range (i.e., 0.3 mg/L) was used to calculate the CWQG for zinc.

4.3.3 2018 Discharge and Spatial Lake Patterns and Seasonal Trends

The 2018 data in Jackfish Lake were assessed for vertical patterns and spatial patterns within the lake that may have been related to the discharge and seasonal trends.

An assessment of vertical gradients in water quality at stations in Jackfish Lake in 2018 were completed for the four field parameters: DO, temperature, specific conductivity, and pH. Differences between mid-depth, or euphotic zone for nutrient parameters, and bottom concentrations were also evaluated at the Mid-Lake station where two depths were sampled (i.e., euphotic zone and bottom depth for nutrients and mid and bottom depths for all other parameters).

Horizontal patterns in water quality in Jackfish Lake potentially linked to discharges from the Jackfish Facility and seasonal trends were evaluated by plotting the 2018 data from the intake, discharge, and Jackfish Lake stations by sampling event and station. Intake and discharge data were plotted side by side to allow comparisons of the water as it enters and leaves each of the plants. Data from stations in Jackfish Lake were plotted from left to right in approximate order of increasing distance from the Jackfish Facility discharges to identify potential spatial trends related to the discharges from the Jackfish Facility. Applicable CWQGs were included on the plots for context; for parameter-dependent CWQGs, minimum CWQGs based on 2018 data, were shown. Values below the applicable DLs were presented as an open marker at the DL. Parameters with concentrations in a discharge that were notably higher (i.e., greater than 20%) than the corresponding intake were evaluated further for spatial patterns in Jackfish Lake that could indicate that discharges from the Jackfish Facility are influencing water quality in the lake. If a discharge-related spatial pattern was identified, the likelihood that the pattern was related to the discharge, the potential cause, and the environmental significance was further evaluated. Spatial patterns and seasonal trends were not assessed for parameters that were typically not detectable (i.e., 95% of the data were below the DL) unless a discharge concentration was notably higher than an intake concentration for that parameter or concentrations were only detectable in one season.

4.3.4 Comparisons to Historical Data

Historical water quality data were available from samples collected in Jackfish Lake in 1987, 2014, 2015, and 2017. Available water quality data from a fisheries feasibility program in Jackfish Lake program conducted in 1987, and from water quality programs carried out by the Government of the Northwest Territories in 2015 and 2017, and by Golder in 2015 and 2017 were compiled and compared to 2018 data. In February of 1987, five stations were sampled at a depth of 0 and 6 m in Jackfish Lake (Baker 1987). More recently, surface (unless otherwise noted) water quality samples in Jackfish Lake were collected at:

- one station in October 2014 (Palmer et. al 2015)
- two stations in May 2015 (Golder unpublished data)
- one station in May 2017 (Golder unpublished data) and five stations in August 2017, including one bottom sample (Staples 2018).

Ranges in 2018 water quality concentrations were compared to historical ranges to identify notable increases in concentrations. The 2018 and historical data were tabulated to identify 2018 concentrations that were notably different (i.e., maximums greater than 20%) than the historical data. When 2018 maximum concentrations were greater than historical concentrations, the causes and implications of these differences were discussed.

Differences in the number of samples collected, sampling seasons, depths, and DLs were taken into account in the comparison of water quality over time in Jackfish Lake.

4.4 Quality Assurance/Quality Control Summary

Quality assurance (QA) and quality control (QC) practices determine data integrity and are relevant to all aspects of the Jackfish Lake baseline water quality monitoring program, from sample collection to data analysis and reporting. Quality assurance encompasses management and technical practices designed to confirm that the data generated are of consistent high quality. Quality control is an aspect of QA that includes the procedures used to measure and evaluate data quality, and the corrective actions applied when data quality objectives are not met.

As part of the QA/QC for the field programs, a series of QC samples were collected during each sampling event. Four types of QC samples were collected or prepared as part of the Jackfish Lake water quality monitoring programs:

- Duplicate water samples to assess variability introduced during sample collection, sample handling, and laboratory analytical procedures.
- Equipment blank samples to assess potential contamination due to sample equipment.
- Field blank to assess potential contamination during sample collection.
- Travel blanks to determine if contamination may have occurred during transportation, storage, or analysis.

A duplicate sample was collected and an equipment blank and either a travel or field blank was prepared during each sampling event. The QC samples were submitted “blind” to ALS and were analyzed for the same set of parameters as the collected water samples, with the exception of the organics, which had no relating QC samples.

A multi-step validation process was used to assess the quality of the analytical results provided by the laboratory and the field data collected at Jackfish Lake (Appendix C.4). Historical laboratory data validation was not completed because they were assumed to have been previously validated; therefore, the QA/QC assessment was limited to the data collected by Golder in 2018. Details on QA/QC practices applied during this study, evaluations of QC data and a description of the implications of QC results to the interpretation of study results are provided in Appendix C.4.

4.5 Results and Discussion

This section of the report presents an evaluation of water quality data collected from Jackfish Lake in 2018; detailed laboratory and field results from the 2018 program are provided in Appendix C.1 (Table C.1[1 and 2]).

4.5.1 2018 General Water Quality Characterization and Comparisons to Water Quality Guidelines

4.5.1.1 Routine Parameters

Jackfish Lake is relatively shallow, with a mean depth of approximately 5 m, and was generally well-mixed during early and late open-water conditions in 2018; thermal stratification was evident during the sampling events in warmer months (July and August) when water temperatures were lower at the bottom of the lake, particularly at deeper locations in the lake, compared to the surface (Section 3). The waters were generally turbid, as indicated by a consistent Secchi depth of 0.5 m throughout the 2018 sampling events. The 2018 field pH values measured in Jackfish Lake (7.0 to 9.0) and in discharges to Jackfish Lake (8.9) indicated that the lake water ranged from neutral to alkaline between May and December and discharge waters were alkaline in July and within the CWQG (Table C.1-1; Appendix C.6).

The DO concentration in lake water is a function of the balance of the processes that introduce oxygen into (e.g., wind mixing and photosynthesis by algae) and remove oxygen from the water column (e.g., respiration by algae and aquatic organisms, microbial decomposition, and chemical oxidation). Based on the 2018 measurements of DO concentrations, Jackfish Lake is well-oxygenated with the exception of bottom concentrations during July and August; during these months, low DO concentrations (2 to 4 mg/L) were observed at the bottom of shallower locations (5 m) and anoxic conditions (0 mg/L) were observed at deeper locations (6 m). Lower DO concentrations measured near the bottom of Jackfish Lake may be due to natural processes in or near the sediment boundary that consume oxygen (e.g., microbial decomposition of organic matter in the sediments) and the thermal stratification of the lake during warmer months, which limits mixing of surface waters with bottom waters. The CWQG for DO for cold water biota early life stages is 9.5 mg/L, and for all other life stages is 6.5 mg/L. Concentrations of DO were typically above the minimum CWQG of 6.5 mg/L, with the exception of 1 to 2 m from the bottom at most stations in Jackfish Lake in July and August (Table C.1-1; Figure C.2-64b and c). Plots of DO profiles from the summer of 1980 indicate that DO concentrations near the bottom of Jackfish Lake have been below the CWQG of 6.5 mg/L historically (Baker 1987). Concentrations of DO in the discharges were above the minimum CWQG in July.

The total dissolved gases in Jackfish Lake ranged from 93% to 108%; monthly average total dissolved gases ranged from 98% to 103% (Table C.1.2). The CCME sets guidance for supersaturation at a maximum of 103% to 110% depending on water depth and pressure (CCME 1999). Given the available deep water as refuge, there is low potential for effects to aquatic life.

Total suspended solids concentrations in Jackfish Lake in 2018 (3.3 to 19.0 mg/L) and in the discharges (7.3 to 15.1 mg/L) are considered low to moderate, and not harmful to aquatic life (Table C.1-1; Appendix C.6). Total alkalinity in Jackfish Lake (101 to 116 mg/L) and in the discharges (106 to 107 mg/L) have a large acid neutralizing capacity, indicating an overall low acid sensitivity (Table C.1-1; Appendix C.6).

4.5.1.2 Major Ions

Major ions in surface water may be expressed in terms of hardness, TDS (measured directly or calculated), and specific conductivity (Appendix C.6). As hardness increases in surface water, the toxicity of many metals decreases. Based on the 2018 hardness measured in Jackfish Lake (133 to 168 mg/L, as calcium carbonate [$CaCO_3$]) and in the discharges (152 to 154 mg/L, as $CaCO_3$), waters in Jackfish Lake and the discharges are characterized as hard (Table C.1-1; Appendix C.6). The ranges in concentrations of measured and calculated TDS (226 to 271 mg/L and 249 to 250 mg/L, respectively) and values of specific conductivity (405 to 562 and 407 to 408 µS/cm, respectively) indicate a moderate level of total ion concentrations in the surface waters Jackfish Lake in 2018 (Table C.1-1; Appendix C.6). Concentrations of TDS (both measured and calculated) and specific conductivity in the discharges were similar to those in Jackfish Lake (Table C.1-1). Two major ions measured in Jackfish Lake and discharges, chloride and fluoride, have CWQGs; concentrations of chloride and fluoride in Jackfish Lake and in the discharges were below their respective CWQGs in 2018 (Table C.1-1).

4.5.1.3 Organic Carbon

Total organic carbon comprises particulate and dissolved organic carbon. Natural waters have concentrations that vary between 1 to 30 mg/L. Most TOC is derived from humic substances and partly degraded plant and animal materials (Appendix C.6). Higher concentrations of dissolved organic carbon have been shown to have a protective effect against metal toxicity in aquatic organisms and has been incorporated into the calculation of some guidelines (e.g., CWQG for zinc) (CCME 1999; Appendix C.6). Concentrations of TOC are characterized as moderate in Jackfish Lake (10.4 to 13.8 mg/L) and in discharges (12.0 to 12.9 mg/L) (Table C.1-1).

4.5.1.4 Nutrients

The main nutrients of concern in most freshwaters are phosphorus and nitrogen, as both are required for plant growth in small amounts. Phosphorus is often the limiting nutrient, which means that small additions of phosphorus can result in increased productivity (Appendix C.6). Increased nutrient concentrations may result in excessive algal growth in water or on rock substrates, which can decrease oxygen concentration in water at night and under ice when photosynthesis and wind driven mixing, respectively, are not present. Phosphorus is often measured as three forms: dissolved phosphorus, total phosphorus (TP) and orthophosphate.

The CCME (2004) recommends basing trophic status classification of lakes and streams on TP concentration (Appendix C.6). Based on this classification and the monthly mean concentrations of TP measured in 2018, the trophic status of Jackfish Lake varied between eutrophic (nutrient rich, highly productive) and hyper-eutrophic (nutrient rich, very highly productive), with mean TP concentrations ranging from 0.065 (August) to 0.111 milligrams phosphorus per litre [mg-P/L] (September) (Appendix C.6). Concentrations of TP in the discharges in July were within the eutrophic range (0.059 to 0.091 mg-P/L) (Table C.1-1). Elevated concentrations of TP could be related to internal loading of TP from lake sediments or loading from runoff.

Nitrogen can be present in both dissolved and particulate forms in surface waters. Dissolved inorganic forms include nitrate, nitrite and ammonia and particulate forms include both organic and inorganic nitrogen. Three CWQGs exist for the dissolved inorganic forms of nitrogen (total ammonia, nitrate, and nitrite); the CWQG for ammonia is temperature and pH dependent (CCME 1999). In 2018, concentrations of total ammonia, nitrate and nitrite were below CWQGs in Jackfish Lake and discharges to Jackfish Lake, with the exception of one nitrite concentration at the Mid-Bottom station in August. The higher nitrite concentration at Mid-Bottom in August (0.0620 milligrams nitrogen per litre, Table C.1-1) was likely related to the higher total nitrogen concentrations and lower DO concentrations measured at this location; low DO concentration can result in anaerobic processes such as denitrification, which reduce more oxygenated forms of nitrogen such as nitrate to less oxygenated forms of nitrogen, such as nitrite or ammonia. Historically, nitrite concentrations have been below the CWQG in Jackfish Lake (Appendix C.3).

4.5.1.5 Metals and Hydrocarbons

Metals naturally occur in surface waters in small quantities. Aquatic organisms can be adversely affected by high metal concentrations; however, the level at which metals are toxic to aquatic organisms varies and several environmental factors (e.g., organic matter, hardness, pH) can modify the toxicity of metals (Appendix C.6).

Total metal concentrations in 2018 were below CWQGs in Jackfish Lake and the discharges except arsenic, copper and zinc. Total arsenic concentrations were consistently above CWQG at all intake, discharge, and lake stations, during all sampling events in 2018 (Table C.1-1), as well as in all historical samples collected from Jackfish Lake (Appendix C.3). Concentrations of total arsenic are routinely above the CWQG in lakes in and around Yellowknife due to the historical contamination from former gold mines in the area (Palmer et. al 2015). Total copper concentrations were above guidelines in one discharge sample (K Discharge at 0.0089 mg/L on 11 July) and four lake samples: EMD and CAT (0.0033 mg/L on 29 May), twice at K and EMD (0.0105 mg/L on 29 May and 0.0033 mg/L on 10 July) and Mid-Lake Bottom (0.0036 mg/L on 1 August) (Table C.1-1). Two of these concentrations (i.e., 0.0033 mg/L) were marginally above the CWQG (by less than 1%) and the duplicate of a third concentration (0.0105 mg/L) was below the CWQG. Total copper concentrations above the CWQG have also been observed historically in Jackfish Lake (Appendix C.3). One total zinc concentration was above the long-term CWQG at Southwest Bay in May (Table C.1-1); historical concentrations of total zinc in Jackfish Bay have historically been similar to or higher than those measured in 2018 (Appendix C.3).

Elevated levels of organic compounds may be harmful to aquatic organisms; however, toxicity varies widely by chemical (Appendix C.6). Lake samples tested for hydrocarbons were below DLs and CWQGs (Table C.1-1).

4.5.2 2018 Spatial Patterns

The assessment of spatial patterns in water quality at the Jackfish Lake stations focussed on field parameters, routine parameters, major ions, nutrients, and metals that were typically above the DL. Spatial patterns for metals typically below DLs (i.e., beryllium, bismuth, cadmium, cesium, cobalt, mercury, selenium, silver, and thallium) and hydrocarbons, which were consistently below DLs, were not assessed.

4.5.2.1 Vertical Patterns

Vertical gradients in Jackfish Lake were observed for all field parameters in multiple 2018 field programs with the exception of specific conductivity; vertical gradients in specific conductivity were not observed in Jackfish Lake in 2018 (Table C.1-2; Figure C.2-61a to e [May, July, August, September, December]).

Vertical gradients in pH were observed during the July and August sampling events; pH decreased with depth by approximately 0.5 to 1.0 between 4 m and the bottom during the July program and by approximately 0.5 to 1.5 between 4 m and the bottom during the August program (Table C.1-2; Figure C.2-62c). No vertical gradients in pH values were observed during the May, September or December sampling events (Table C.1-2; Figure C.2-62a, d and e).

Seasonal and spatial patterns in water temperatures at the bottom, middle and top of the water column are discussed in Section 3.5.1 based on temperature logger data; a discussion of the detailed profile measurements (at 1-m depth intervals) of temperature collected during the five sampling events is provided here.

Vertical gradients in temperatures were observed in Jackfish Lake during all the 2018 field programs but most noticeably in July and August when the lake was thermally stratified and the thermocline was observed in the bottom 1 to 2 m of the lake. In May, temperatures at most stations in Jackfish Lake gradually decreased with depth by approximately 0.5°C to 1.0°C (Table C.1-2; Figure C.2-63a [May]). At K and EMD, a sharp decrease in temperature of 0.9°C was observed between 0.3 and 1 m, after which the temperature gradually decreased with depth (by 1°C from 1 m to the bottom) similar to other locations in Jackfish Lake in May. Thermal stratification in the lake was evident during the July sampling event; temperatures decreased by approximately 0.5°C to 1.0°C between the surface and 2 m, remained similar between depths of 2 to 4 m and then decreased again by approximately 1°C to 6°C between 4 m and the bottom of the lake (Table C.1-2; Figure C.2-63b [July]). In August, when additional mixing has occurred to reduce thermal stratification, temperatures remained similar between the surface and 4 to 5 m of Jackfish Lake, and then gradually decreased by approximately 3°C to 4°C from 5 m to the bottom of the lake at deeper locations (i.e., Mid-Lake, Northeast Bay, EMD and CAT and K and EMD) (Table C.1-2; Figure C.2-63c [August]). By September, thermal stratification was no longer observed; temperatures at all stations showed a slight increase of approximately 1°C between 0.3 and 1 m, and then remained relatively uniform throughout the water column (Table C.1-2; Figure C.2-63d [September]). In December, temperatures in Jackfish Lake increased slightly (by less than 1°C) from below the ice (0.2 to 0.4 m) and 2 m, and then gradually decreased slightly (by less than 1°C) from 2 m to the bottom (Table C.1-2; Figures C.2-63e [December]). Additional details regarding temperature patterns in 2018 in Jackfish Lake are provided in Section 3.

Vertical gradients in DO concentrations, where DO concentrations decreased with increasing depth, were observed during all sampling events except in September. In May, DO concentrations decreased by approximately 2 to 4 mg/L between 2 m and the bottom at the Northeast Bay, Northwest Bay North and Mid-Lake stations; vertical gradients were not observed at the two stations closest to the discharge (K and EMD station and EMD and CAT station) or at the shallower location farthest from the discharge, Southwest Bay, in May (Table C.1-2; Figure C.2-64a [May]). During the July and August field programs, strong vertical gradients in DO concentrations were observed; concentrations typically decreased sharply by approximate 6 to 10 mg/L within the thermocline and were near 0 mg/L in the hypolimnion (Table C.1-2; Figure C.2-64b and c [July and August]). During the September program, the water column was well-mixed and vertical gradients in DO were not evident at any stations in Jackfish Lake (Table C.1-2; Figure C.2-64d [September]). The lowest DO concentrations in Jackfish Lake typically occurred near the bottom of the lake, where oxygen consumption can increase due to biological activity in the sediment. During open-water conditions, the density difference between the cooler, denser layer of the water at the bottom of the lake (i.e., the hypolimnion) and the warmer layer above inhibited mixing of the water column, thereby reducing the potential for aeration in the deeper portion of the water.

During early ice-covered conditions in December, slight vertical gradients in DO concentrations were evident at all stations in Jackfish Lake with a decrease in concentrations of approximately less than 1 mg/L from the surface to the bottom (Table C.1-2; Figure C.2-64e [December]). Saturation concentrations of DO decrease as water temperatures increase with depth. The increases in temperature with depth and a lack of re-aeration potential due to ice-cover and oxygen consumption through natural biological and chemical processes in the water column can cause naturally low bottom DO concentrations in lakes during winter conditions (Catalan et al. 2002).

Differences in water chemistry were also observed between the mid-depth (euphotic zone for nutrients) and bottom samples collected at the Mid-Lake station (Mid-Bottom). Concentrations of nutrients were occasionally higher at the bottom of Mid-Lake compared to the euphotic zone: total ammonia in July (Table C.1-1; Figure C.2-27), nitrite, nitrate, and dissolved phosphorus in August (Table C.1-1; Figures C.2-24, C.2-25, C.2-31), total nitrogen in July and August (Table C.1-1; Figure C.2-29) and total phosphorus in July and September (Table C.1-1; Figure C.2-30). Some metal concentrations were also higher at the bottom of Mid-Lake relative to mid-depth at Mid-Lake: barium, iron and manganese in July (Table C.1-1; Figures C.2-36, C.2-45, and C.2-48) and copper in August (Table C.1-1; Figure C.2-44). Higher concentrations of nutrients at bottom-depth may be due to increased biological activity or lower bottom DO concentrations observed at this location, or both. Higher concentrations of some metals at the bottom of Mid-Lake may also be related to the lower DO concentrations, which can increase the potential for some metals to be released from the sediment to the water column through geochemical reactions.

4.5.2.2 Horizontal Patterns

Water quality concentrations at mid-depth, or within the euphotic zone for nutrients, across Jackfish Lake were typically similar during each field program. Consistent gradients in water quality concentrations that would indicate whole-lake water quality changes in Jackfish Lake from the Jackfish Facility discharges were not observed. Higher concentrations of some parameters were observed in the discharges relative to the intake concentrations. During the field program when intake and discharge samples were collected, the field crew observed black flecks in the discharge from the K-Plant, which may explain the higher concentrations of some parameters (e.g., TSS) in this discharge. Concentrations of TSS, sodium, TP, and total aluminum, chromium, copper, iron, lead, manganese, nickel, selenium, and titanium at K Discharge were higher than K Intake concentrations and field turbidity values at CAT Discharge were higher than CAT Intake values (Table C.1-1). Concentrations of these parameters were below CWQGs in the discharge, with the exception of copper, and did not demonstrate a spatial pattern of higher concentrations at stations closer to the discharges compared to farther from the discharges, with the possible exception of lead and copper.

Total lead concentrations in May and September at the K and EMD location near the discharges were the highest in Jackfish Lake for those months (Table C.1-1). However, higher concentrations of total lead at the K and EMD location were not observed in other months or in the duplicate sample collected in May, which was below the DL (Appendix C.4); total lead concentrations at the EMD and CAT location near the discharges were consistently below the DL in 2018. Total lead concentrations in Jackfish Lake were below the DL in July and maximum total lead concentrations occurred at stations farther from the discharges; Northeast Bay in August and Southwest Bay in December. Additionally, the overall 2018 range in total lead concentrations at K and EMD were within the range of total lead concentrations at Southwest Bay, the station farthest from the discharges.

Based on the data collected in 2018, the likelihood of the discharges from the K-Plant influencing concentrations of total lead in Jackfish Lake near the discharge is low. Nothing is added to the water that is pumped from Jackfish Lake and flows through the pipes in the cooling system; evaporation is expected to be negligible because it is a closed system. Therefore, the most likely potential source of lead in the discharge are the pipes that contain the cooling water; these pipes are older and could be corroding and contributing small amounts of material, including metals, to the cooling water. If the discharge is influencing total lead concentrations, the environmental significance to aquatic organisms is expected to be negligible because the elevated concentrations near the discharge were well below the CWQG and did not extend beyond the immediate vicinity of the discharges.

Total copper concentrations in May and July at both the K and EMD, and EMD and CAT locations near the discharges were the highest in Jackfish Lake for those months and slightly above the CWQG (Table C.1-1). Total copper concentrations at these two locations were below the CWQG and similar or lower than concentrations at stations farther from the discharges in August, September, and December. Total copper concentrations were similar with distance from the discharge at the three lake stations beyond K and EMD and EMD and CAT. Based on the data collected in 2018, the K Discharge may be influencing concentrations of total copper in Jackfish Lake near the discharge. If the discharge is influencing total copper concentrations in Jackfish Lake, the environmental significance to aquatic organisms is expected to be low because two of the three elevated concentrations near the discharge were marginally above (i.e., by less than 1%) the CWQG, which is considered a conservative benchmark for Jackfish Lake because it does not consider site-specific species or conditions beyond hardness values. The third elevated concentration (0.0105 mg/L), which is well above the hardness-dependent CWQG for the sample (0.0033 mg/L), was notably different than its duplicate sample (0.0030 mg/L) and below the CWQG.

Similar to lead, the most likely potential source of copper in the discharge are the pipes that contain the cooling water.

Concentrations of some parameters were higher in the intakes relative to lake and discharge concentrations. Orthophosphate concentrations at K Intake and EMD Intake were higher than the concentrations in the discharges or lake stations and the total iron concentration at CAT Intake was higher than the CAT Discharge and mid-depth lake stations (Table C.1-1). No spatial gradients in these parameters were identified within Jackfish Lake, indicating that the difference may be due to natural variability in water quality concentrations.

4.5.3 2018 Seasonal Trends

Seasonal trends over the 2018 monitoring period (May to December) were observed in multiple field and routine parameters (pH, DO, specific conductivity, TDS, and total alkalinity), three major ions, TOC, most nutrient parameters and one metal (manganese).

Values of mid-depth field pH in Jackfish Lake varied slightly over 2018 (by 1 pH value) but were consistently highest in July and August and lowest in May and December. In 2018, field pH values ranged from 7.9 (i.e., December at Southwest Bay) to 8.9 (i.e., in July at all stations except Northwest Bay North and in August at Southwest Bay, K and EMD, and EMD and CAT; Table C.1-1; Figures C.2-4 and C.2-5). Mid-depth concentrations of DO at Jackfish Lake stations were consistently lowest in July and August and highest in May and September (Table C.1-1; Figure C.2-9). In 2018, DO concentrations ranged from 8.9 mg/L (i.e., August at Northwest Bay North) to 12.8 (i.e., May at Southwest Bay). Early (May) and late (September) open-water conditions cause the water column to be cooler and well-mixed, respectively, which both increase the DO concentrations in the water column. Water temperatures in Jackfish Lake decreased further in December and increased the saturation concentration of DO but the ice-cover likely contributed to lower mixing and interaction with the ambient air, which would result in naturally lower DO concentrations (Table C.1-1; Figures C.2-8 and C.2-9).

Specific conductivity (both field and laboratory, calculated TDS concentrations, and total alkalinity typically decreased between May and July and then increased over the open-water season (Table C.1-1; Figures C.2-2, C.2-3 and C.2-14). The lower calculated TDS, specific conductivity and total alkalinity between May and July may be attributed to the spring melt, which increases the water volume and dilution, while evaporation and lower water volumes later in the season may have caused the increased concentrations in these parameters. Three of the major ions (chloride, calcium, and sodium) also followed an increasing concentration trend over the open-water season, which could be related to evaporation and/or lower water volumes over this period (Table C.1-1; Figure C.2-16, C.2-17, and C.2-21). No consistent seasonal trend was observed for measured TDS, TSS, hardness or turbidity in 2018 (Table C.1-1; Figures C.2-1 to C.2-3 and C.2-11 to C.2-13). The lack of clear seasonal trend in measured TDS may be related to the higher variability in measured TDS compared to calculated TDS concentrations.

Total organic carbon concentrations typically increased from May to August, decreased in September and increased again in December (Table C.1-1; Figure C.2-15); the increase in TOC concentrations from May to August may be related to the increase in biological activity over the open-water season. Concentrations of dissolved nitrogen parameters (nitrate, nitrite, nitrate + nitrite, and ammonia) and ortho-phosphate were highest during the May program and then decreased in July, typically below the DL for dissolved nitrogen parameters, which is likely related to biological uptake of nutrients (Table C.1-1; Figures C.2-24 to C.2-27). Concentrations of total phosphorus and soluble reactive silica were lowest in the July and August programs, likely due to the uptake of these nutrients during periods of higher growth during warmer months (Table C.1-1; Figure C.2-30).

A consistent seasonal trend in metals in Jackfish Lake over the 2018 sampling period was limited to total manganese concentrations; however, some metals were consistently higher or lower during one or more of the field programs. Total manganese concentrations were highest in May, decreased to the lowest concentrations in July, and then continued to increase from July to December (Table C.1-1; Figure C.2-48). Concentrations of total arsenic, boron, lithium, molybdenum and strontium were typically lowest in May and concentrations of total barium, boron, lithium, manganese and strontium were typically highest in December (Table C.1-1; Figures C.2-36, C.2-39, C.2-47, C.2-48, and C.2-55). Vanadium concentrations in Jackfish Lake were above DL in July at all stations including the in-facility stations, and below DL during all other sampling events (Table C.1-1; Figure C.2-59). Total copper concentrations in Jackfish Lake were typically lowest in September and December in 2018 (Table C.1-1; Figure C.2-44). The cause of the seasonal trend in manganese and differences in other metals is unclear, but could be related to the seasonal trends in pH and DO concentrations, which have the potential to influence geochemical reactions of metals in the sediment and water column.

4.5.4 Comparisons to Historical Data

Maximum 2018 concentrations or values of most parameters were either within the historical ranges or not notably higher than historical ranges. Maximum field specific conductivity and concentrations of sodium, total ammonia, nitrate, nitrite, dissolved phosphorus, and total chromium and lead in 2018 were notably higher than historical maximums. The 2018 maximum laboratory specific conductivity was not notably greater than historical maximum, indicating that the higher field measurements may be related to variability in field and laboratory measurements, and not indicative of an increase in conductivity. Maximum concentrations of TDS, which are typically correlated to conductivity, were also not notably higher in 2018 compared to historical maximums. Sodium concentrations in 2018 were notably higher (by 23%) than historical concentrations; the difference may be related to natural variation or indicative of a small increase. Because the number of samples collected in 2018 in Jackfish Lake (35) was greater than the number of samples collected in other years (6 or less), the potential to capture a larger natural range in water quality is greater.

The 2018 maximum concentrations of total ammonia, nitrate and nitrite and dissolved phosphorus were measured at the bottom depth at Mid-Lake in July or August, or both; all total ammonia, nitrate, and dissolved phosphorus concentrations in 2018 were within the historical range (Appendix C.3). The historical dataset contains limited bottom samples in open-water (one sample in August 2017) so it unclear if the elevated July/August concentration in 2018 are higher than historical concentrations or reflect higher concentrations due to sample depth and time of year. The 2018 nitrite concentrations were below the DL, except for one elevated concentration in August (at the bottom of Mid-Lake) and concentrations in May, which were also notably above the historical range in nitrite (Table C.1-1; Appendix C.3). Because the May samples were collected within the euphotic zone (and also at the bottom at Mid-Lake), it is unclear whether the 2018 nitrite concentrations are higher than historical concentrations or are higher due to differences in the sampling depth.

Maximum concentrations of total chromium and lead in 2018 were notably higher than the maximum detectable concentrations of these two metals in the historical dataset (Appendix C.3). Most of the 2018 total chromium concentrations in Jackfish Lake were below the maximum historical detectable concentration (65%); total chromium concentrations are only available from nine samples collected in 2015 and 2017 (nine samples) and therefore, are unlikely to represent the natural range in total chromium concentrations in the lake. Similarly, most of the 2018 total lead concentrations in Jackfish lake were below the maximum historical detectable concentrations (70%). Total lead concentrations are available from 1987, 2015 and 2017 (19 samples); however, half of these samples (from 1987) were reported as below a DL that is above all measured concentrations in 2018. Therefore, similar to chromium, the likelihood that the concentrations of lead measured in 2015 and 2017 represent the range of natural variability in Jackfish Lake is low.

Overall, no clear changes in water quality concentrations have occurred over time, however additional data collected at consistent times of year, depths, and locations, and analyzed at consistent DLs are needed to better evaluate temporal trends over time in Jackfish Lake.

4.6 Summary and Conclusions

The 2018 water quality monitoring program in Jackfish Lake successfully met the objectives of the program which were to collect environmental monitoring data to develop a dataset for water quality, to provide a preliminary assessment of whether water quality in Jackfish Lake is influenced by discharges from the Jackfish Facility, and to provide supporting information to the biological components.

The results of the Jackfish Lake water quality monitoring program can be summarized as follows:

- Jackfish Lake is an alkaline lake, with hard and generally turbid water, moderate TDS concentrations, low to moderate concentrations of TSS and low sensitivity to acidification. Total phosphorus concentrations in the lake indicated that the lake was eutrophic to hyper-eutrophic, which could be related to internal loading from lake sediments or loading from runoff.
- Concentrations and values of water quality parameters were below, or above for DO concentrations and pH, CWQGs with the exception of concentrations of DO, nitrite and three metals (total arsenic, copper and zinc).
  - Concentrations of DO were typically above the minimum CWQG with the exception of 1 to 2 m from the bottom at most stations in July and August, when the dissolved oxygen concentrations dropped to near 0.0 mg/L. Historical DO concentrations have been below the CWQG of 6.5 mg/L near the bottom of Jackfish Lake during the open-water period.
  - A single nitrite concentration was above the CWQG at the Mid-Bottom station in 2018. The higher concentration may be related to the low DO concentrations, which can result in anaerobic processes such as denitrification, which reduce more oxygenated forms of nitrogen such as nitrate to less oxygenated forms of nitrogen, such as nitrite or ammonia. Historically, nitrite concentrations have been below the CWQG in Jackfish Lake. No spatial pattern in nitrite concentrations were observed and nitrite concentrations were typically below the DL in Jackfish Lake, therefore the single nitrite concentration above the CWQG was unlikely related to the Jackfish Facility discharges or of concern to aquatic life.
  - All total arsenic concentrations measured in Jackfish Lake and discharges to Jackfish Lake in 2018 were above the CWQG. Arsenic concentrations have historically been above the CWQG in Jackfish Lake and in the lakes around Yellowknife due to the historical contamination from former gold mines in the area. The total arsenic concentrations are not related to the discharges from the Jackfish Facility.
  - A single total zinc concentration was above the long-term CWQG at a location farthest from the Jackfish Facility discharges (Southwest Bay); this result was likely an anomaly because all but three measured zinc concentrations in Jackfish Lake in 2018 were below the DL (0.003 mg/L). The 2018 total zinc

concentrations were within the range of historical total zinc concentrations. No spatial pattern in total zinc concentrations were observed and total zinc concentrations were typically below the DL in Jackfish Lake, therefore the single total zinc concentration above the long-term CWQG was unlikely related to the Jackfish Facility discharges or of concern to aquatic life.

- Five measured concentrations of total copper in 2018 were above the CWQG; four of these concentrations were either in a discharge sample (one) or at a location in Jackfish Lake close to the discharge (three), indicating that the discharge may be influencing copper concentrations in the immediate vicinity of the discharge. Based on the three 2018 concentrations of total copper above the CWQG in Jackfish Lake, the risk to aquatic life in Jackfish Lake is considered low. Two of the concentrations were marginally above the CWQG (by less than 1%), which is a conservative guideline because it does not account for site-specific species or conditions other than hardness, and a duplicate sample corresponding to the third concentration was below the CWQG. Historical concentrations of total copper have also exceeded the CWQG.

- Vertical patterns were observed in pH, temperature and DO concentrations in multiple months, but not in September.
  - Vertical gradients of decreasing pH with depth were observed during the July and August sampling events; no vertical gradients in pH values were observed during the May, September or December sampling events.
  - Vertical gradients in temperatures were observed in Jackfish Lake during all the 2018 field programs. In May, temperatures at most stations in Jackfish Lake gradually decreased with depth. In July, temperatures decreased between the surface and 2 m, remained similar between depths of 2 to 4 m and then decreased again by approximately between 4 m and the bottom of the lake. In August, when additional mixing has occurred, temperatures remained similar between the surface and 4 to 5 m of Jackfish Lake, and then gradually decreased by approximate from 5 m to the bottom of the lake at deeper locations. In September, temperatures at all stations showed a slight increase between 0.3 and 1 m, and then remained relatively uniform throughout the water column. In December, temperatures in Jackfish Lake increased slightly from below the ice (0.2 to 0.4 m) and 2 m, and then gradually decreased from 2 m to the bottom.
  - Vertical gradients in DO concentrations were observed during all sampling events except in September. In May, DO concentrations decreased with depth at three of the deeper stations farther from the discharge. During the July and August field programs, strong gradients were observed; concentrations typically decreased by approximately 6 to 10 mg/L within 2 to 4 m of the bottom. The lowest DO concentrations in Jackfish Lake typically occurred near the bottom of the lake, where oxygen consumption can increase due to biological activity in the sediment. During open-water conditions, the density difference between the cooler, denser layer of the water at the bottom of deeper stations and the warmer layer above may have inhibited mixing of the water column, thereby reducing the potential for aeration in the deeper portion of the water. In December, a slight vertical gradient was evident at all stations in Jackfish Lake. The lack of re-aeration potential due to ice-cover can cause naturally lower DO concentrations in lakes during winter conditions.

- Water quality at mid-depth, or within the euphotic zone for nutrients, across Jackfish Lake were typically similar during each field program. Consistent gradients in water quality concentrations that would indicate whole-lake water quality changes in Jackfish Lake from the Jackfish Facility discharges were not observed. Elevated concentrations of copper in the discharge from the K-Plant and at locations near the discharges indicate that the discharges from the Jackfish Facility may be influencing copper concentrations in Jackfish Lake in the immediate vicinity of the discharges.
- Seasonal trends in water quality concentrations or values in 2018 were observed for pH, DO, specific conductivity, calculated TDS, total alkalinity, three major ions (chloride, calcium and sodium), most nutrients and one metal (manganese). The seasonal trends in water quality were attributed to seasonal changes in temperatures, natural variation in lake volume due to spring melt, precipitation and evaporation, and biological uptake of nutrients.
- Based on a qualitative comparison of water quality in Jackfish Lake in 2018 to limited water quality data collected in 1987, 2014, 2015, and 2017, no clear changes in water quality in Jackfish Lake were observed relative to previous water quality surveys.

5.0 PHYTOPLANKTON

5.1 Introduction

Phytoplankton are microscopic plants, ranging in size between 2 and 20 micrometres (µm) (Wehr and Sheath 2015). Phytoplankton are free-floating photosynthesizing algae and cyanobacteria, which can fix large amounts of carbon; they form the base of the food web for aquatic animals (Wetzel 2001). Many factors can influence phytoplankton community abundance, biomass, and composition, including:

- light
- temperature
- nutrients
- toxic substances
- grazing by zooplankton

For the purposes of this study, phytoplankton were divided into eight major taxonomic groups:

- Cyanobacteria
- Chrysophyceae (chrysophytes)
- Bacillariophyceae (diatoms)
- Chlorophyceae (chlorophytes)
- Cryptophyceae (cryptophytes)
- Dinophyceae (dinoflagellates)
- Euglenophyceae (euglenoids)
- Xanthophyceae (xanthophytes)

These groups have different physiological requirements and their abundances vary in response to physical and chemical parameters such as light, temperature, nutrients, and other chemical substances. Despite differences among groups in their response to these factors, many of these phytoplankton groups coexist in a waterbody but at different proportions (Wetzel 2001).

Phytoplankton pigments, such as chlorophylls *a, b,* and *c* can be used to understand algal viability and the health of the phytoplankton community. Viability within the algal community is important because it can be a major driver of primary production (Franklin et al. 2012). Chlorophyll *a* is the primary photosynthetic pigment contained in phytoplankton, and is widely used as a surrogate measure of phytoplankton biomass. Chlorophyll *c* is a secondary pigment found in chrysophytes, cryptophytes, and diatoms. Chlorophyll concentrations are affected by changes in environmental conditions, such as light, nutrient availability, and temperature, as well as by phytoplankton community composition (Healey 1975). Therefore, while not always a good surrogate for phytoplankton biomass, chlorophyll *a* concentrations are often used in conjunction with nutrients (TP and total nitrogen [TN]) and water transparency (Secchi depth) to determine the trophic status (i.e., level of productivity) of a waterbody.

The Jackfish Facility uses water from Jackfish Lake for its cooling system. The discharges have caused an increase in the water temperature in Jackfish Lake (Baker 1987), which may impact the phytoplankton community. Temperature strongly influences cellular composition, uptake of nutrients, carbon dioxide fixation, photosynthesis, and growth rates of phytoplankton (Wetzel 2001). Growth rate will increase with increased temperature for many phytoplankton taxa up to their temperature optimum, but will then decrease rapidly with further increases. There is great diversity in tolerances and optimum temperatures among and within phytoplankton groups. For many diatom taxa, the optimum temperature is approximately 5°C and for other diatom taxa it is 15°C, while for many chlorophytes and cyanobacteria, higher water temperatures (25°C to 30°C) are needed for photosynthesis (Wetzel 2001).

5.1.1 Objectives

The objectives of the Jackfish Lake phytoplankton monitoring program were as follows:

- develop a preliminary phytoplankton dataset for comparisons with future monitoring data
- begin to assess whether the phytoplankton community in Jackfish Lake is affected by temperature increases caused by the Facilities' cooling water discharge
- monitor Jackfish Lake for phytoplankton (i.e., algal) blooms during the open-water period, to identify taxa responsible for blooms, and assess the potential cause of the blooms, if observed.

5.2 Methods

5.2.1 Field Sampling

Phytoplankton sampling was conducted monthly throughout the open-water period (i.e., May to September) in 2018 to fully characterize the phytoplankton community. Phytoplankton sampling was completed in conjunction with the water quality component, at five of the six water quality stations in Jackfish Lake (Tables 2-1 and 2-2, Figure 2-1).

Supporting information (i.e., water depth, Secchi depth, conductivity, pH and DO) was collected at each station as part of the water quality program. The Secchi depth measurement was used to estimate the depth of the euphotic zone, which is defined as the region within the water column where photosynthesis typically occurs and can be estimated as two times the Secchi depth.

A Kemmerer water sampler was used to collect depth-integrated phytoplankton samples within the euphotic zone. Discrete water samples were collected every metre within the euphotic zone (i.e., at the surface, 1 m, 2 m, 3 m, etc.). These discrete water samples were combined in a large, clean, bucket to form a depth-integrated composite sample, the water was then mixed and subsamples for phytoplankton, chlorophyll *a* and *c*, and nutrients (i.e., total ammonia, nitrate, nitrite, nitrate and nitrite, TN, total Kjeldahl nitrogen, TP, dissolved phosphorus, ortho-phosphate, soluble reactive silica, and total organic carbon) were collected from this composite water sample.

At each station, a single phytoplankton sample was collected. Water from the depth-integrated composite sample was transferred into a 500 mL amber Nalgene bottle and preserved with 5 mL of acidic Lugol's solution. Duplicate phytoplankton samples were collected at one station during every sampling event for quality QA/QC purposes. At the end of the field program, the phytoplankton samples were sent to Biologica Environmental Services Ltd. (Biologica) in Victoria, British Columbia, for taxonomic identification and enumeration.

At each station, a single composite chlorophyll *a*/*c* sample was collected. Water from the depth-integrated composite sample was transferred into a 1-L amber Nalgene bottle. The chlorophyll *a/c* sample was kept on ice and transferred to the Golder office for sample processing. For each chlorophyll sample, 500 to 1,000 mL of water, depending on the sample, was filtered through a 47 mm diameter Whatman GF/C glass fibre filter; the volume filtered for each sample was recorded and used by the laboratory to estimate chlorophyll *a/c* concentrations. This process was repeated for each composite sample, resulting in two subsamples per station. The filters were frozen and shipped to the Biogeochemical Analytical Service Laboratory (BASL) at the University of Alberta in Edmonton, Alberta for analysis.

5.2.2 Laboratory Analysis

5.2.2.1 Chlorophyll a and c

Chlorophyll *a* and *c* samples submitted to BASL were analyzed fluorometrically with a DL of 0.04 µg/L and 0.01 µg/L, respectively.

5.2.2.2 Phytoplankton Community

The phytoplankton community samples submitted to Biologica followed Biologica’s specific analytical methods, which are summarized below and Biologica’s quality control checks, which are provided in Appendix D. The phytoplankton samples were thoroughly mixed by gently shaking the containers, and 1 to 3 mL sub-samples were transferred into settling chambers, and allowed to settle for 24 hours in an Utermöhl settling chamber. Sub-samples were then systematically scanned using a Zeiss Axio Vert.A1 inverted phase contrast microscope at 400x magnification. All algal cells were counted in a series of randomly located fields of view until a minimum of 300 algal units were enumerated. Algal units represented a single cell, colony, coenobia or filaments. Enumerating units, rather than cells, allows for a more equal representation of algal taxonomic groups regardless of whether they exist as single cells, or in other forms. The mean number of cells per unit (equal to one for single cells or greater than one for all other algal forms) were estimated for all taxa and used to calculate total abundance. Only “viable” cells (those that appeared to be alive at the time of collection) were identified and enumerated. All chrysophyte loricas were also identified and counted (Grace Analytical Lab 1994). Cell abundances (cells per litre [cells/L]) were determined using a calculation that involved the subsample volume, number of fields of view assessed, number of units counted and number of cells per unit.

Biovolume calculations were performed for the six dominant algal taxa by measuring at least 10 cells of each taxon and applying standard geometric formulas best fitted to the shape of the cell (Hillebrand et al. 1999). Biovolume estimates were expressed as µL/L and converted to biomass (in µg/L) assuming a specific gravity of one.

Algae were identified to genus, where possible, following the most up-to-date taxonomic references (Cox 1996; Hillebrand et al. 1999; Komárek and Anagnostidis 2000 a,b,c; John et al. 2002; Taylor et al. 2007; Coesel and Meesters 2007; Wehr et al. 2015; Guiry and Guiry 2017) and collaboration with international and local algal taxonomic experts. Species-level identifications were only given to identifiable taxa for which there are reliable taxonomic references available that encompass the species-level morphological diversity in North America. This approach ensures long-term consistency of datasets and is in accordance with the trend in algal taxonomic practice to be more conservative with delineation of species. Species-level identifications for some taxa are problematic due to widespread phenotypic plasticity that can artificially inflate species richness (Wehr et al. 2015). When applicable, terms “cf.” (confertim, possibly for species) and “sp.1” (a single undetermined species) were employed to distinguish between different species in the same genus.

5.2.3 Data Analysis

The 2018 chlorophyll *a*/*c* and phytoplankton data were compared graphically among-stations and by season to explore seasonal and spatial trends in Jackfish Lake. The following summary variables were calculated for each of the phytoplankton samples:

- chlorophyll *a* and *c* concentrations (as µg/L)
- total abundance (abundance as cells/L)
- total biomass (biomass as µg/L)
- total taxonomic richness (richness as total number of taxa at a station), calculated at the genus level
- relative abundance (as percentages of major taxonomic groups)
- relative biomass (as percentages of major taxonomic groups).

Abundance and biomass data were divided into major taxonomic groups including Cyanobacteria, Chlorophyceae (chlorophytes), Chrysophyceae (chrysophytes), Cryptophyceae (cryptophytes), Dinophyceae (dinoflagellates), Bacillariophyceae (diatoms), and Euglenophyceae (euglenoids). Relative abundance and biomass quantify the relative proportion of each major taxon within the phytoplankton community.

Taxonomic richness was calculated at the genus level for phytoplankton. Richness is the total number of taxa (in this case, genera) at a station. Richness provides an indication of diversity; higher richness values typically indicate more healthy and balanced communities. Taxa with unconfirmed genus identifications were excluded from taxonomic richness calculations.

5.3 Quality Assurance/Quality Control

5.3.1 Overview of Procedures

Quality assurance and quality control procedures were applied during all aspects of the phytoplankton component to verify that the data collected are of known and acceptable quality. Two chlorophyll *a* and *c* subsamples were collected at each station (Appendix D, Table D-1). Duplicate phytoplankton samples were collected at one station during each sampling event (i.e., four QC samples in total), representing greater than 10% of the total number of samples collected during this study. Duplicate samples were collected to capture variation in the plankton community at a station resulting from natural variability and field sampling techniques.

Duplicate phytoplankton samples were collected during each sampling event at the following stations:

- May: K and EDM
- July: Southwest Bay
- August: Northwest Bay
- September: Mid-Lake.

The inherent variability associated with the phytoplankton samples makes the establishment of a QC threshold value difficult. For the purposes of the phytoplankton QC program, samples were flagged if there was a greater than 50% difference, calculated as the relative percent difference (RPD), in total abundance between the original and duplicate samples. The RPD was calculated using the following formula:

RPD = (|difference in abundance between duplicate samples| / mean abundance) x 100

In addition, the Bray-Curtis dissimilarity index, which is a measure of ecological distance between two communities, was used to assess the overall similarity between duplicate samples. The value of the Bray-Curtis index ranges from zero (identical communities) to one (very dissimilar communities) and is calculated using the following formula:

$$b = \frac{\sum_{k=1}^{n} \left| x_{ik} - x_{jk} \right|}{\sum_{k=1}^{n} \left(x_{ik} + x_{jk} \right)}$$

Where *b* is the Bray-Curtis dissimilarity index, *n* is the number of species in the sample, X_{ik} and X_{jk} are abundance of species *(i)* in the original *(j)* and the duplicate *(k)* samples, respectively.

Index values greater than 0.5 were flagged and follow-up discussions with the taxonomist were initiated. Due to the typically high variability in species present between duplicate phytoplankton samples, the Bray-Curtis comparisons were performed on data at the major ecological group level (i.e., diatoms, chlorophytes, chrysophytes, cyanobacteria, cryptophytes, euglenophytes and dinoflagellates). Duplicate data were not automatically rejected because of an exceedance of the acceptance criterion; rather, they were evaluated on a case-by-case basis because some level of within-station variability is expected, which will be reflected as variation between duplicate samples.

Two samples, representing 10% of the total number of phytoplankton samples were split and analyzed separately by the taxonomist to verify reproducibility of the processing and analytical methods. The replicate samples were chosen at random and were processed at different times by different taxonomist to reduce counting and identification bias.

The following phytoplankton samples were split for QC purposes:

- July: Mid-Lake
- September: Southwest Bay

Taxonomic consistency was evaluated based on the percent agreement (PA) between QC samples. Percent agreement was calculated using the following formula:

PA = [100 – (difference in abundance between samples)/total abundance in original sample)] x100

The percent agreement was calculated on total phytoplankton abundance from the two independent phytoplankton counts.

5.3.2 Summary of Data Validation Results

For the chlorophyll *a* split samples, the RPD values ranged from 1% to 44%, with the exception of one pair of samples which was considered notably different from one another (i.e., RPD value was greater than 50%), having an RPD value of 87% (Appendix D, Table 5D-1. For chlorophyll *c*, the RPD values ranged from 2% to 35%, with the exception of two pairs of split samples which were considered notably different from one another, having RPD values of 57% and 68% (Appendix D, Table D-2). The level of reproducibility of the chlorophyll *a* and *c* samples is considered acceptable.

The QC results for the phytoplankton data are reported in Appendix D, Tables D-5 and D-6. The QC results indicate that the overall occurrence of dominant taxa was consistent between the original and QC samples (i.e., in the field duplicates).

Each of the phytoplankton field QC duplicate samples had exceedances above the 50% criterion for RPD, based on differing abundances of major taxonomic groups between the field duplicates (Appendix D, Table D-5). However, in all cases, the total phytoplankton abundances did not differ by more than 20% between the original and field duplicate samples, and all phytoplankton duplicate samples were within the acceptable range as assessed by the Bray-Curtis distance index.

The phytoplankton laboratory QC (split) samples had good agreement between the original sample and the split sample (Appendix D, Table D-6). For the Mid-Lake sample, there was 85% agreement between the taxonomist split samples and for the Southwest Bay sample, there was 98% agreement.

Overall, dominant taxa were similar between the original and duplicate phytoplankton samples; most RPD values for the chlorophyll and phytoplankton samples were less than the 50% criterion; and the Bray-Curtis index values were below the 0.5 criterion for all samples. Therefore, QC results indicate that the 2018 chlorophyll and phytoplankton data are of acceptable quality and no data were invalidated.

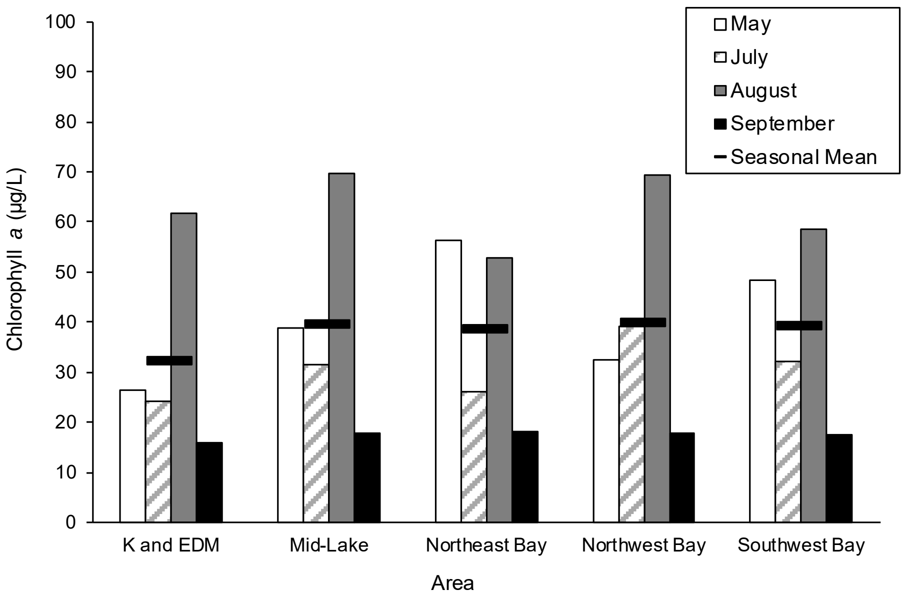
5.4 Results and Discussion

5.4.1 Chlorophyll Concentrations

Mean open-water chlorophyll *a* concentrations were similar among stations and ranged between 32 and 40 µg/L in Jackfish Lake in 2018 (Figure 5-1). These chlorophyll *a* concentrations are within the eutrophic range (i.e., mean chlorophyll *a* greater than 14.3 µg/L; Section 5.4.3, Table 5-2; Vollenweider and Kerekes 1982).

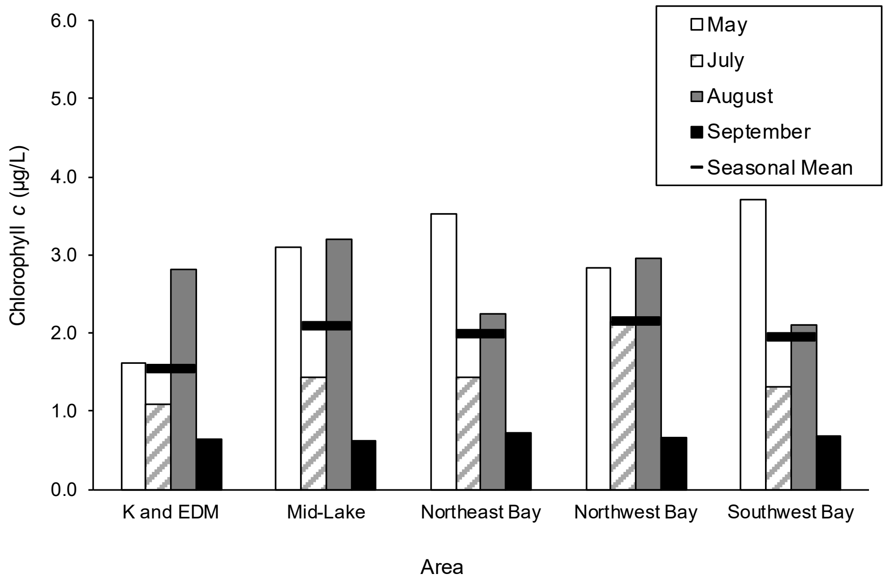
Chlorophyll *a* concentrations varied during the open-water season in Jackfish Lake in 2018 (Figure 5-1). Concentrations were lowest in September at all stations, ranging from 16 to 18 µg/L (mean = 17 µg/L). Higher concentrations were observed in July (24 to 39 µg/L; mean = 31 µg/L), followed by May (26 to 56 µg/L; mean = 41 µg/L) and August (53 to 70 µg/L; mean = 62 µg/L). Chlorophyll *a* concentrations peaked in August at most stations in Jackfish Lake, with the exception of the Northeast Bay station, where concentrations were similar between May and August. The 2018 chlorophyll *a* concentrations indicate that peak primary productivity occurred in August in Jackfish Lake.

Figure 5-1: Chlorophyll *a* Concentrations in Jackfish Lake, 2018



Mean open-water chlorophyll *c* concentrations were similar among stations and ranged between 0.6 and 3.7 µg/L in Jackfish Lake in 2018 (Figure 5-2), indicating low biomass of chrysophytes, diatoms and/or cryptophytes. Chlorophyll *c* concentrations varied seasonally in Jackfish Lake in 2018 (Figure 5-2). Concentrations were lowest in September at all stations, ranging from 0.6 to 0.7 µg/L (mean = 0.7 µg/L). Higher concentrations were observed in July (1.1 to 2.1 µg/L; mean = 1.5 µg/L), followed by May (1.6 to 3.7 µg/L; mean = 3.0 µg/L) and August (2.1 to 3.2 µg/L; mean = 2.7 µg/L), which were similar. Chlorophyll *c* concentrations peaked in May or August at most stations in Jackfish Lake. The August peak is associated with the overall peak in primary productivity that occurred in August, as seen in the chlorophyll *a* concentrations, while the May peak is likely the result of increased diatom biomass in the spring.

Figure 5-2: Chlorophyll *c* Concentrations in Jackfish Lake, 2018

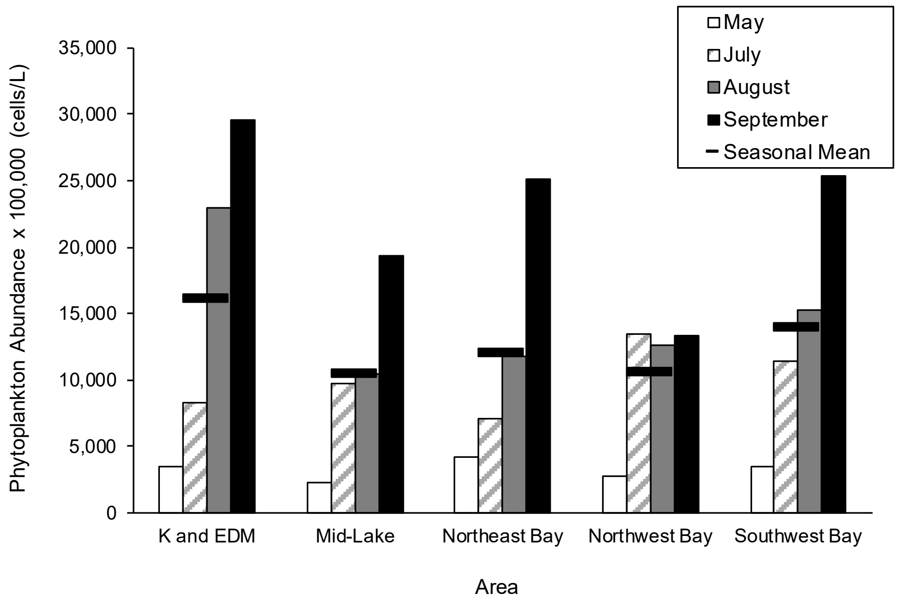


5.4.2 Phytoplankton Community

5.4.2.1 Total Abundance

Mean open-water phytoplankton abundance in Jackfish Lake in 2018 was highest at the K and EDM station (1,611 x10^6 cells/L), the station closest to the Jackfish Facility discharges, followed by the Southwest Bay station (1,390 x10^6 cells/L) (Figure 5-3). The remainder of the stations in Jackfish Lake had similar phytoplankton abundances, ranging from 1,043 x10^6 cells/L to 1,206 x10^6 cells/L. Seasonally, total phytoplankton abundance was highest in September, and lowest in May (Figure 5-3). The seasonal trend in phytoplankton abundance was similar across stations, except for Northwest Bay, where total phytoplankton abundance was similar in July, August and September.

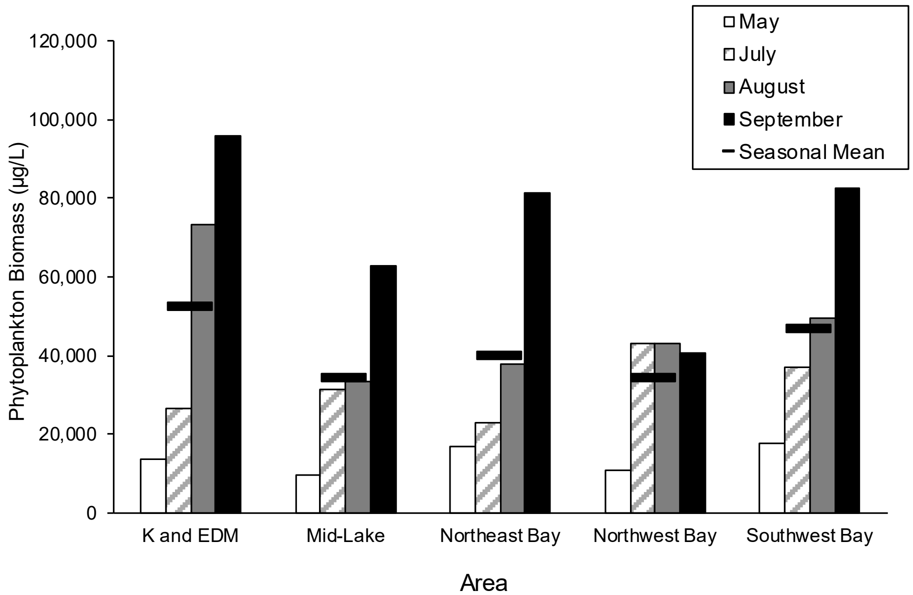
Figure 5-3: Total Phytoplankton Abundance in Jackfish Lake, 2018



5.4.2.2 Total Biomass

Spatial patterns and seasonal trends in total phytoplankton biomass closely followed those observed for total phytoplankton abundance in Jackfish Lake in 2018 (Figure 5-4). Mean open-water phytoplankton biomass was highest at the K and EDM station (52,399 µgL), the station closest to the Jackfish Facility, followed by the Southwest Bay station (46,614 µgL) (Figure 5-4). The remainder of the stations had similar phytoplankton biomass, ranging from 34,322 µgL to 39,826 µgL. Phytoplankton biomass was lowest in May, and typically increased throughout the year until reaching a peak in September. This seasonal trend was similar at all stations, except for Northwest Bay, where phytoplankton biomass was similar in July, August and September. The seasonal trends and spatial patterns in phytoplankton biomass in Jackfish Lake were generally not consistent with the trends and patterns observed in chlorophyll *a* concentrations (Figure 5-1), indicating that chlorophyll *a* may not be an accurate surrogate measure of phytoplankton biomass in Jackfish Lake.

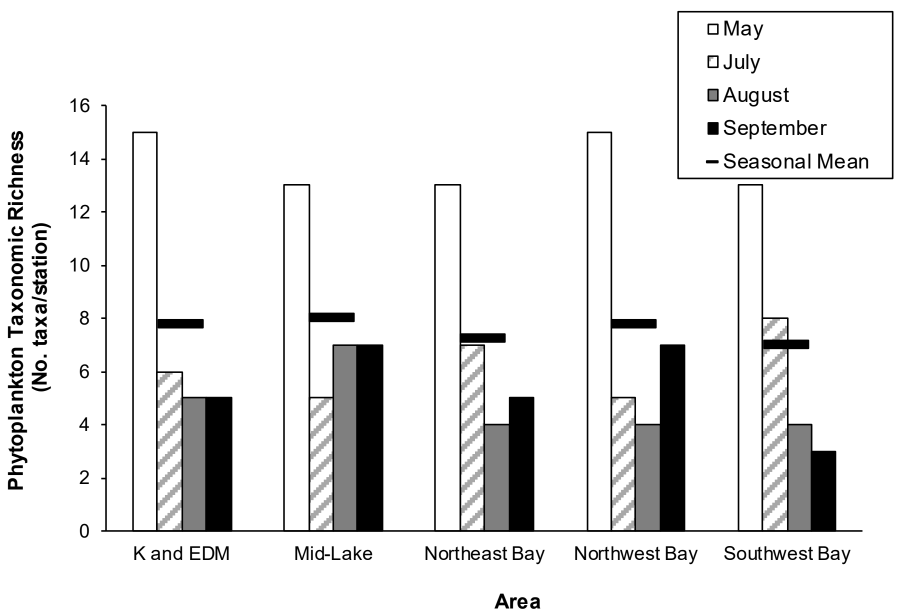
Figure 5-4: Total Phytoplankton Biomass in Jackfish Lake, 2018



5.4.2.3 Total Richness

Mean total phytoplankton richness was low, and similar among stations in Jackfish Lake in 2018, ranging from 7 to 8 taxa (Figure 5-5). Richness was highest in May, ranging from 13 to 15 taxa per station, and lowest in August and September, when it ranged from 3 to 7 taxa per station.

Figure 5-5: Total Phytoplankton Taxonomic Richness in Jackfish Lake, 2018



No. of taxa/station = number of taxa per station.

5.4.2.4 Community Composition

There was little seasonal or spatial variation in phytoplankton community composition based on relative abundance in Jackfish Lake in 2018 (Table 5-1). All stations were dominated by cyanobacteria from May to September (98% to 100%) in Jackfish Lake. Low abundances of diatoms (1%) and chlorophytes (1%) were observed at each station in May, and low abundances of chlorophytes (2%) were observed in August at Northwest Bay. The other major groups of phytoplankton (i.e., chrysophytes, cryptophytes, dinoflagellates, euglenophytes and other flagellate and non-flagellate algae) accounted for less than 1% of the total abundance at each station. Within the cyanobacteria, the dominant taxon was *Planktothrix* sp., which accounted for 95% to 100% of the cyanobacteria abundance across stations and seasons (Appendix D, Table D-3).

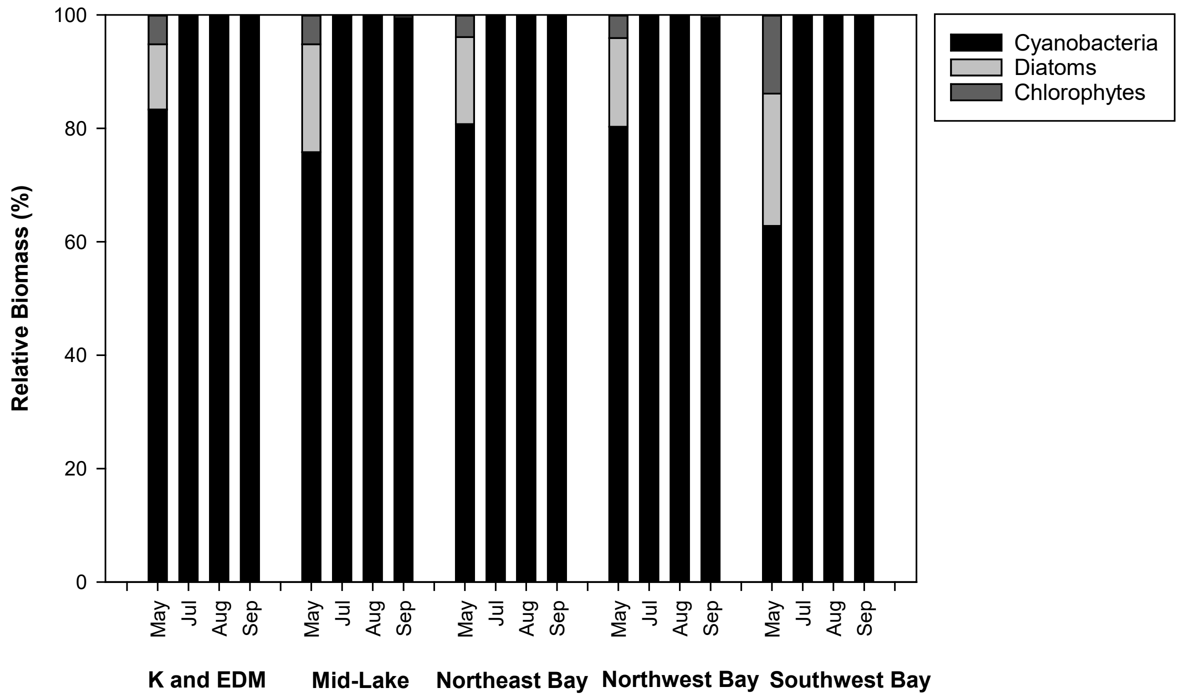
Table 5-1: Relative Abundances of Phytoplankton in Jackfish Lake, 2018

Station	Month	Cyanobacteria (%)	Diatoms (%)	Chlorophytes (%)	Others[(a)] (%)
K and EDM	May	99	0.3	0.3	0.1
	July	100	0.0	0.0	0.0
	August	100	0.0	0.0	0.0
	September	100	0.0	0.2	0.0
Mid-Lake	May	99	0.5	0.3	0.4
	July	100	0.0	0.0	0.0
	August	100	0.0	0.0	0.0
	September	99	0.0	0.4	0.1
Northeast Bay	May	99	0.4	0.2	0.2
	July	100	0.0	0.0	0.1
	August	100	0.0	0.0	0.0
	September	100	0.0	0.2	0.0
Northwest Bay	May	99	0.4	0.3	0.2
	July	100	0.0	0.0	0.0
	August	98	0.0	1.5	0.1
	September	100	0.0	0.0	0.1
Southwest Bay	May	98	0.7	1.0	0.4
	July	100	0.0	0.0	0.0
	August	100	0.0	0.0	0.0
	September	100	0.0	0.0	0.0

(a) The “others” group includes chrysophytes, cryptophytes, dinoflagellates, euglenophytes and other flagellated and non-flagellated algae.

Similar to relative abundance, relative biomass was dominated by cyanobacteria, which accounted for 99% to 100% of the community from July to September (Figure 5-6). In May, cyanobacteria were still the dominant group accounting for 63% to 83% of the community composition; however, diatoms and chlorophytes were also present representing 11% to 23%, and 4% to 14% of the community composition, respectively (Figure 5-6). In May, diatom and chlorophyte relative biomass were highest at the Southwest Bay station, while the remainder of the stations had similar proportions of diatoms and chlorophytes.

Figure 5-6: Relative Phytoplankton Biomass in Jackfish Lake, 2018



5.4.3 Trophic Status Classification

The essential nutrients necessary for phytoplankton growth are nitrogen and phosphorus, typically quantified as TN and TP for evaluating trophic status. The primary nutrient that often limits phytoplankton growth in lakes is phosphorus (Schindler 1974); therefore, phosphorus is often used to establish overall trophic status. Nitrogen is not often the limiting nutrient in surface waters, although in certain waterbodies, it may be limiting and should be considered when estimating trophic status (Wetzel 2001). Chlorophyll *a* is the primary photosynthetic pigment contained in phytoplankton. Secchi depth can be used as a coarse surrogate for phytoplankton growth, because in many waterbodies, Secchi depth is inversely related to phytoplankton biomass (Dodds and Whiles 2010); therefore, it is also considered in certain cases when establishing trophic status. A robust estimate of trophic status can be obtained by considering all of these variables together.

The three main classes of trophic status are as follows:

- oligotrophic (nutrient-poor, unproductive systems)
- mesotrophic (moderately productive systems)
- eutrophic (nutrient-rich, highly productive systems)

Vollenweider and Kerekes (1982) developed a classification scheme for lakes using TP, TN, chlorophyll *a*, and Secchi depth (Table 5-2). This general classification system is internationally accepted based on analyses of over 200 waterbodies during the International Program on Eutrophication conducted by the Organization for Economic Cooperation and Development. While this general classification system is relatively simple, complications can arise due to overlap in the ranges of trophic categories, as well as differences in categorization between constituents.

Table 5-2: General Trophic Status Classification for Lakes

Trophic Status	Total Phosphorus (mg/L)		Total Nitrogen (mg/L)		Chlorophyll *a* (µg/L)		Secchi Depth (m)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Oligotrophic	0.008	0.003 to 0.018	0.661	0.307 to 1.630	1.7	0.3 to 4.5	9.9	5.4 to 28.3
Mesotrophic	0.0267	0.011 to 0.096	0.753	0.361 to 1.367	4.7	3.0 to 11.0	4.2	1.5 to 8.1
Eutrophic	0.0844	0.016 to 0.386	1.875	0.393 to 6.100	14.3	3.0 to 78.0	2.45	0.8 to 7.0

Source: Vollenweider and Kerekes (1982).

The trophic status in Jackfish Lake was evaluated by examining nutrient concentrations (i.e., TP and TN), chlorophyll *a*, and Secchi depth using the Vollenweider and Kerekes (1982) trophic classification scheme for lakes (Table 5-2). Mean annual depth-integrated TP and TN concentrations ranged from 0.07 to 0.08 mg P/L for TP and from 1.24 to 1.30 mg N/L for TN among stations in Jackfish Lake in 2018 and chlorophyll *a* concentrations ranged from 29 to 40 µg/L (Table 5-3). Secchi depths in Jackfish Lake were shallow and the mean annual Secchi depth for all stations was less than 1 m in 2018. Based on the trophic classification system of Vollenweider and Kerekes (1982) Jackfish Lake can be classified as eutrophic.

Table 5-3: Total Concentrations of Phosphorus, Nitrogen and Chlorophyll *a* and Secchi Depth in Jackfish Lake, 2018

Station	Total Phosphorus (mg/L)		Total Nitrogen (mg/L)		Chlorophyll *a* (µg/L)		Secchi Depth (m)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
K and EDM	0.08	0.06 to 0.12	1.30	1.05 to 1.50	32.0	15.8 to 61.7	0.68	0.5 to 1.11
Mid	0.08	0.06 to 0.11	1.24	1.11 to 1.44	39.5	17.9 to 69.8		
Northeast Bay	0.08	0.06 to 0.12	1.28	1.15 to 1.45	38.4	18.0 to 56.4		
Northwest Bay	0.08	0.06 to 0.10	1.29	1.10 to 1.54	39.7	17.8 to 69.3		
Southwest Bay	0.07	0.04 to 0.10	1.25	1.09 to 1.46	29.2	17.4 to 58.4		
Trophic Status Classification	eutrophic		mesotrophic to eutrophic		eutrophic		eutrophic	

Note: The range represents the open-water range in values from May to September.

5.4.4 Cyanobacteria in Jackfish Lake

Cyanobacteria were the dominant algal group in Jackfish Lake in 2018 (Section 5.4.2). Within the cyanobacteria group, eight genera were present in Jackfish Lake, including *Aphanizomenon* sp., *Dolichospermum* sp., *Planktothrix* sp., *Phormidium* sp., *Limnothrix* sp., *Pseudanabaena* sp., *Cyanodictyon* sp., and *Synechococcus* sp. The dominant taxon (in terms of both abundance and biomass) was *Planktothrix* sp., which was present at all stations and during all sampling events, accounting for 93% to 100% of total phytoplankton abundance and 63% to 100% of total phytoplankton biomass (Appendix D, Tables D-3 and D-4).

Planktothrix sp. is a filamentous freshwater alga that does not produce heterocysts, which means it is not capable of nitrogen-fixation and requires both nitrogen and phosphorus for growth, unlike nitrogen-fixing taxa, which can survive in low nitrogen environments and only require sustained inputs of phosphorus (Wehr and Sheath 2015). *Planktothrix* sp. also does not produce akinetes, which are used during the dormancy stage of many cyanobacteria taxa to resist adverse environmental conditions such as desiccation, extreme temperatures, and phosphate-deprivation (Wehr and Sheath 2015). Instead, *Planktothrix* sp. is able to dominate communities as a result of its ability to use gas vacuoles to maintain its position in the water column (Meriluoto et al. 2017). The simple cellular structure (prokaryotic, solitary trichome) of *Planktothrix* sp. results in relatively low energy input, which both decreases the light demand it requires and leaves more energy to acquire limiting nutrients and facilitate phosphorus acquisition (Meriluoto et al. 2017).

The specific *Planktothrix* sp. species identified in Jackfish Lake, *Planktothrix agardhii*, is typical of shallow, turbid lakes with high mixing rates (Meriluoto et al. 2017). *Planktothrix* sp. can tolerate both continuous mixing of the water column and calm conditions, because of its ability to regulate buoyancy (Meriluoto et al. 2017). In Jackfish Lake, thermal stratification was observed during the summer (Section 4), which isolated the surface waters from nutrients trapped in the deeper water and sediment, which limited the internal nutrient supply to phytoplankton. However, buoyancy regulation allows *Planktothrix* sp. to adjust their position in the water column for light accessibility and allows them to outcompete other groups of algae for nutrients and light (Meriluoto et al. 2017), which may have resulted in the high cyanobacteria abundance and biomass in Jackfish Lake throughout the summer.

In addition, during thermal stratification in eutrophic lakes, with low oxygen concentrations in the sediments, there can be a release of phosphorus from the sediment into the hypolimnion (i.e., deeper water), which can lead to high phosphorus concentrations in the hypolimnion. In September, surface water temperatures cooled and thermal stratification was no longer observed in Jackfish Lake as a result of water column mixing and typical autumn turn-over (Wetzel 2001). Mixing of the water column can release phosphorus from the hypolimnion to the entire water column, which can provide a new influx of the limiting nutrient to the surface water layer. In Jackfish Lake, this process may have resulted in an increase of the already high cyanobacteria abundance and biomass in September (Figures 5-3 and 5-4).

Planktothrix sp. can produce hepatotoxins (liver toxins, i.e., microcystin) and anatoxins (a neurotoxin), which are both harmful to fish, livestock and humans (Meriluoto et al. 2017). Despite the ability to produce toxins, cyanobacteria taxa capable of doing so may or may not produce toxins, depending on the conditions within the waterbody. It is not known at this time what specific conditions will cause a toxin-producing cyanobacteria to produce a toxin (Meriluoto et al. 2017). Collection of water samples for toxin analysis are the only way to determine if toxins are being produced in a lake. Since water samples from Jackfish Lake were not analyzed for toxins in 2018, it is not known whether toxins were produced in Jackfish Lake.

Planktothrix agardhii tends to form persistent and perennial monocultures (Meriluoto et al. 2017). The large number of filaments that form in these monocultures and the filamentous-nature of *Planktothrix* sp. can interfere with zooplankton filtration rates, thereby reducing zooplankton grazing to negligible levels (Meriluoto et al. 2017), which in turn allows the taxon to continue to proliferate.

In temperate regions, cyanobacterial blooms generally occur in the summer when water temperatures are above 20°C and thermal stratification of the water column is established (for lakes greater than 3 m deep) (Meriluoto et al. 2017). In Jackfish Lake, surface water temperatures during the summer (July and August) were at or near 20°C and thermal stratification of the water column was evident (Section 4). These conditions, in combination with sufficient nutrients (i.e., as indicated by TP and TN concentrations in Table 5-3), and the potentially negligible zooplankton grazing rates are optimal bloom conditions.

During a bloom, as more algae grow and biomass increases, others die and sink to the bottom sediment as dead organic matter (Wetzel 2001). This dead organic matter becomes food for bacteria that decompose it. With more food available, the bacteria increase in number and use up the DO in the water. A decrease in the DO content can be harmful for many fish and aquatic insects. In extreme cases it can result in localized die-offs of fish populations known as fish kills.

A bloom can be defined as an increase in cyanobacterial biomass in a lake (often measured as chlorophyll a concentrations) over a relatively short period of time (between a few days and 1 or 2 weeks) and is characterized by the dominance (greater than 80%) of only one or a few species within the phytoplankton community (Meriluoto et al 2017). In mesotrophic or less-eutrophic lakes, chlorophyll a concentrations from 30 to 50 µg/L correspond to blooms; whereas in eutrophic and hypereutrophic lakes, chlorophyll a concentrations from 300 to 400 µg/L can be found during blooms (Meriluoto et al. 2017). Chlorophyll a concentrations in Jackfish Lake correspond to the low to mid-range of these bloom conditions (30 to 40 µg/L) and dominance in the lake was characterized by a single species; therefore, the conditions in Jackfish Lake in 2018 are considered representative of bloom conditions. However, the cyanobacterial biomass did not reach a point where it is a visual nuisance (i.e., no discolouration of the waterbody beyond typical conditions or presence of scums), which is the criterion established at the beginning of the monitoring program for initiating an algal response program (Section 5.4.6).

5.4.5 Thermal Effects on the Phytoplankton Community

Phytoplankton growth and diversity may be controlled by seasonal temperature changes and increasing water temperatures. Temperature strongly influences cellular composition, uptake of nutrients, carbon dioxide fixation, photosynthesis, and growth rates of phytoplankton (Wetzel 2001). Growth rate will increase with increased temperature for many phytoplankton taxa up to their temperature optimum, but will then decrease rapidly with further increases. There is great diversity in thermal tolerances and optimum temperatures among and within phytoplankton groups; and the variability in these factors among the broad physiological diversity of phytoplankton are not well understood (Schabhuttl et al. 2013). In general, higher temperatures result in higher proportions of cyanobacteria in phytoplankton communities (Se7); however, an increase in nutrients will also have a similar effect. For many diatom taxa, the optimum temperature is approximately 5°C and for other diatom taxa it is 15°C, while for many chlorophytes and cyanobacteria, higher water temperatures (25°C to 30°C) are needed for photosynthesis (Wetzel 2001). In a controlled laboratory experiment, Schabhuttl et al. (2013) showed that higher temperatures resulted in higher proportions of cyanobacteria and a decrease in phytoplankton diversity, which is similar to observations in Jackfish Lake.

In temperate regions, cyanobacterial blooms generally occur in the summer when water temperatures are above 20°C (Meriluoto et al. 2017), which was observed in Jackfish Lake in 2018. *Planktothrix* sp., the dominant taxon observed in Jackfish Lake, thrive across an extensive temperature range and do not require the warm water temperatures to survive (Meriluoto et al. 2017).

Surface water temperatures in Jackfish Lake were similar among the stations sampled in the summer; slightly warmer water was observed at the station closest to the Jackfish Facility discharges (K and EMD); however, the difference in water temperature was within a degree of the other stations (Section 4). Similarly, phytoplankton abundance and biomass were only slightly higher at the K and EMD station during the summer and fall. During the spring and fall, surface water temperatures were warmer at the K and EMD station; however, phytoplankton abundance and biomass and chlorophyll *a* concentrations did not substantially differ among stations.

The lack of spatial differences in temperature and phytoplankton abundance and biomass suggest that the cooling water discharges (i.e., temperature) from the Jackfish Facility are not the main factor affecting the phytoplankton community in Jackfish Lake. In addition, the described thermal effects on phytoplankton communities are the same as those observed when nutrients are in excess in a waterbody (Wetzel 2001), which is the case in Jackfish Lake. Based on consideration of available information for Jackfish Lake, it is unlikely that the phytoplankton community in 2018 was reflecting a thermal effect caused by the Jackfish Facility. Rather, it appears likely that the high concentrations of nutrients were a major factor influencing the phytoplankton community composition and biomass in Jackfish Lake in 2018, in combination with physical characteristics of the lake (e.g., small size, limited flow-through, summer stratification).

5.4.6 Algal Bloom Monitoring and Response

As noted, an algal bloom is a rapid increase or accumulation in algal biomass in a waterbody. Typically only one or a few species are involved (Wetzel 2001). For the purposes of the Jackfish Lake algal bloom monitoring program, a bloom was identified if there was a discoloration of the water resulting from the high abundance of pigmented cells, or a visible scum along the shorelines (i.e., a visible nuisance bloom). Colours that are observed during a bloom are often green, bright blue-green, yellowish-brown, brown, or red. Some algal blooms are composed of algae known to naturally produce toxins; those blooms can be harmful for wildlife, livestock and humans and are called harmful algal blooms. Specific water sampling is required to determine if toxins are being produced. Toxin sampling did not occur in Jackfish Lake in 2018, because a visible nuisance bloom was not observed.

Jackfish Lake has a history of algal blooms, which occurred in 2013, 2014, 2015, and 2016. In 2014, the NWT Department of Environment and Natural Resources identified the algae responsible for the blooms in Jackfish Lake as cyanobacteria (CBC 2015). Given this, algal bloom monitoring was included as part of the 2018 phytoplankton monitoring program. Golder monitored Jackfish Lake by completing monthly monitoring programs, periodic visual drive-by inspections and by staying in regular contact with NTPC staff, who were onsite daily and could observe nuisance bloom events. If a visual algal bloom was reported, Golder was prepared with an algal bloom response plan which would have included phytoplankton and water quality sampling. Results of algal bloom monitoring in 2018 indicated that no nuisance blooms were observed or reported in Jackfish Lake throughout the open-water period.

5.5 Summary and Conclusions

The 2018 phytoplankton monitoring program in Jackfish Lake successfully met the objectives of the program which were to collect environmental monitoring data to develop a preliminary phytoplankton dataset, to begin to assess whether the phytoplankton community in Jackfish Lake is affected by the Jackfish Facility discharges, and to monitor Jackfish Lake for visual phytoplankton blooms and assess the potential cause, if necessary.

The Jackfish Lake phytoplankton community results can be summarized as follows:

- Based on concentrations of TP, TN and chlorophyll *a*, as well as Secchi depth, Jackfish Lake can be classified as a eutrophic lake.
- Chlorophyll *a* concentrations indicate that peak primary productivity occurred in August in Jackfish Lake, while phytoplankton abundance and biomass data suggest peak productivity occurred in September.
- Chlorophyll *a* concentrations were generally similar among stations, while for phytoplankton abundance and biomass, slightly higher abundance and biomass were observed at the K and EDM station, the station closest to the Jackfish Facility, the remainder of the stations were generally similar.
- The seasonal trends and spatial patterns in phytoplankton biomass in Jackfish Lake were generally not consistent with the trends and patterns observed in chlorophyll *a* concentrations, indicating that chlorophyll *a* may not be an accurate surrogate measure of phytoplankton biomass in Jackfish Lake.
- Chlorophyll *c* concentrations were low and did not provide further insight into the phytoplankton community compared to that provided by the phytoplankton community data.
- Total phytoplankton richness was low and similar among stations in Jackfish Lake in 2018.
- There was little seasonal or spatial variation in phytoplankton community composition based on relative abundance or biomass in Jackfish Lake in 2018. The community was dominated almost exclusively by cyanobacteria, notably *Planktothrix* sp.
- *Planktothrix* sp. is a toxin producing taxa; however, since water samples from Jackfish Lake were not analyzed for toxins in 2018, it is not known whether toxins were produced in Jackfish Lake.
- Chlorophyll *a* concentrations in Jackfish Lake correspond to the low to mid-range of the bloom conditions and dominance in the lake was characterized by a single species; therefore, the conditions in Jackfish Lake in 2018 are considered representative of bloom conditions. However, the cyanobacterial biomass did not reach a point where it is a visual nuisance (i.e., discolouration of the waterbody beyond typical conditions or presence of scums), which was the criterion established at the beginning of the monitoring program for initiating an algal response program.

There was a lack of a clear spatial difference in temperature and phytoplankton abundance and biomass among stations in Jackfish Lake in 2018 which suggests that the cooling water discharges (i.e., temperature) from the Jackfish Facility are not the main factor affecting the phytoplankton community in Jackfish Lake. In addition, the described thermal effects on phytoplankton communities are the same as those observed when nutrients are in excess in a waterbody (Wetzel 2001), which is the case in Jackfish Lake. Based on consideration of available information for Jackfish Lake, it is unlikely that the phytoplankton community in 2018 was reflecting a thermal effect caused by the Jackfish Facility. Rather, it appears likely that the high concentrations of nutrients was a major factor influencing the phytoplankton community composition and biomass in Jackfish Lake in 2018, in combination with physical characteristics of the lake (e.g., small size, limited flow-through, summer stratification). There is some uncertainty in this conclusion given this is based on one year of data collected in a high-water year with heavy rains and wind, and because no analogue reference lake data are available. An understanding of the nutrient dynamics to determine the potential for internal phosphorus loading from bottom sediments (i.e., sampling nutrients above and below the thermocline) within Jackfish Lake would also aid in assessing what is contributing to bloom conditions in Jackfish Lake.

Many physicochemical and biological factors and processes are known to have an impact on the population dynamics of phytoplankton, particularly on cyanobacteria, and on both their vertical and horizontal distribution in waterbodies. The multiple interactions among these factors makes the prediction of the medium and long-term (several weeks or months) development of cyanobacterial blooms difficult to predict, which highlights the need for continued monitoring both visually for nuisance blooms and systematically (i.e., monthly during the open-water period) for phytoplankton biomass, abundance and community composition, and supporting information.

6.0 BENTHIC INVERTEBRATE COMMUNITY AND SUPPORTING SEDIMENT QUALITY

6.1 Introduction

Freshwater benthic invertebrates include mostly insect larvae, crustaceans, worms, leeches, snails, and clams living on the bottoms of lakes and streams. Benthic invertebrates live on the surface of the sediments or burrow into sediments, although some species are closely associated with aquatic plants (Rosenberg and Resh 1993). Benthic invertebrate communities often consist of thousands of organisms per square metre and are an integral part of aquatic ecosystems, as a primary food source for fish and as secondary producers (Minshall et al. 2014). Benthic invertebrate communities in northern lakes are typically dominated by insect larvae (primarily midges [family Chironomidae]), along with molluscs (such as the fingernail clam family Pisidiidae), aquatic worms (Oligochaeta), and amphipods (a shrimp-like, freshwater crustacean), and occasionally other taxa (De Beers 2016; De Beers 2018; Dominion 2018).

Benthic invertebrates are frequently sampled to monitor the environmental quality of lakes and rivers, because they are sensitive to a large variety of disturbances, present in nearly all waterbodies, and have relatively long lifecycles and small home ranges (Rosenberg and Resh 1993). The presence and abundances of specific invertebrates in the benthic community present at a location serve as indicators of aquatic ecosystem health, and can be used to evaluate anthropogenic effects on the ecosystem (Minshall et al. 2014). Benthic invertebrate communities often display a wide range of tolerance to contaminants, exposure conditions, and habitat types (Hauer and Lamberti 2007).

Temperature can strongly influence reproduction and growth rates of benthic invertebrates (Wetzel 2001) as well timing of emergence (Hauer and Lamberti 2007), and can impose constraints on metabolic rates and primary production rates (Thorp and Covich 2001). Changes in thermal conditions has the potential to alter species composition, and negatively affect the abundance and richness of the taxa present (Thorp and Covich 2001). Benthic Invertebrates show a range in tolerances and optimal thermal ranges, where the upper limit for most species is between 30ºC to 40ºC, with the exception of the most sensitive taxa (Thorp and Covich 2001). Additionally, thermal effects on the benthic invertebrate community have resulted in increases in macrophyte-associated taxa (such as gastropods and ostracods), increase or decrease of EPT (Ephemeroptera, Plecoptera, Trichoptera) taxa, depression of sensitive taxa, decreased diversity of Chironomidae species, favouring taxa with larger body sizes and/or increased presence of thermally tolerant taxa, such as *Procladius*, *Tanypus*, and *Chironomus*, Physidae, Hydracarina, and Oligochaeta, particularly Tubificinae (Environment Canada 2014).

6.1.1 Objectives

The main objectives of the benthic invertebrate sampling program were:

- characterize the benthic community in Jackfish Lake
- begin to assess whether the Jackfish Facility is impacting benthic invertebrates in Jackfish Lake

This report section provides a summary of the benthic invertebrate community data collected during the fall of 2018 in Jackfish Lake.

6.2 Methods

6.2.1 Field Sampling

The benthic invertebrate community of Jackfish Lake was sampled on 25 September 2018 (Figure 2-1, Table 2-2). Samples were collected in the fall, which is the period of highest community diversity and stability (MOECC 2007). Samples were collected from five stations in Jackfish Lake (Figure 2-1, Table 2-1), at locations that aligned with other components (i.e., water quality and phytoplankton), and were adjusted to access suitable water depths within 5 m from the water quality stations (Figure 2-1). Prior to the field program, bathymetric data were reviewed to aid in the standardization of sample depth across stations to the extent possible. All sampling stations were located in depositional areas with fine-grained bottom sediments.

Benthic invertebrate samples were collected by a two-person field crew, where depths were sufficiently similar (i.e., approximately 5 m to <8 m) to allow comparison of lake areas. Samples were collected using a standard Ekman grab (15 x 15 x cm). At each station, three samples were collected and sieved separately in the field using a 500 µm mesh Nitex mesh bag, transferred to a labelled 1-L plastic container, and preserved with 10% buffered formalin (for a total of 15 samples). Samples were then shipped to a qualified taxonomist (Jack Zloty, PhD., Summerland, British Columbia) for taxonomic identification and enumeration.

Bottom sediment quality samples were collected concurrently with the benthic invertebrate samples to capture key habitat variables. At each of the five benthic invertebrate sampling locations, one composite sediment sample, consisting of three grabs (i.e., five samples in total), was collected and analyzed for particle size and TOC to provide supporting information for the benthic invertebrate community analysis. Sediment samples were collected from the top 10 to 15 cm of sediment using the Ekman grab, transferred to an appropriate container and kept in coolers before being shipped for analysis. One duplicate sediment sample also consisting of three grabs was collected as part of the QA/QC program for the study.

A number of in situ water quality measurements and habitat characteristics were recorded at each sampling location to support the benthic invertebrate community program:

- water temperature (°C)
- water depth (m)
- DO concentration (as mg/L and% saturation)
- pH
- conductivity and specific conductivity (as µS/cm)
- Secchi depth (m) and water colour (visual observation)
- substrate observations (i.e., particle size, odour, sheen)

6.2.2 Laboratory Analysis

Benthic invertebrate samples were shipped to a qualified taxonomist (J. Zloty, PhD) for enumeration and taxonomic identification. Each sample was processed separately and was divided into coarse fractions. No subsampling was necessary, due to low abundances of invertebrates in the samples.

Invertebrates were identified to the lowest practical taxonomic level using current literature and nomenclature:

- phylum – Nematoda
- class – Ostracoda
- family – Copepoda
- subfamily – Oligochaeta
- genus – Cladocera, Diptera, Ephemeroptera, Bivalvia, Hydracarina, and Trichoptera
- species – Gastropoda

Organisms that could not be identified to the desired taxonomic level (e.g., small or damaged specimens) were reported as a separate category at the lowest level of taxonomic resolution possible. This was typically family level, which is the level recommended in the technical guidance document for metals mining Environmental Effects Monitoring (Environment Canada 2012). The most common taxa were distinguishable based on gross morphology and required only a few slide mounts (five to ten) for verification. Organisms that required detailed microscopic examination for identification (i.e., Chironomidae and Oligochaeta) were mounted on microscope slides using an appropriate medium. A reference collection was prepared, consisting of representative specimens from each taxon. The reference collection was archived by the taxonomist for possible comparison with benthic invertebrate community data from future studies and for quality control of future taxonomic identifications. Raw invertebrate abundance data were received from the taxonomist in electronic format. Sediment quality samples were submitted to ALS Yellowknife for laboratory analysis of particle size distribution and TOC.

6.2.3 Data Analysis

Prior to data analysis, field, laboratory, and taxonomic datasets were screened, based on the sampling criteria provided to the field crews for collection with respect to sampler fullness and presence of sufficient proportions of fine sediments.

Sediment quality data received from the laboratory was summarized in a tabular format and visually compared for habitat differences among the sampling stations. Results are reported in Section 6.4.1.

Raw benthic invertebrate abundance data were received from taxonomist as the number of organisms per sample. The data were reviewed for unusual abundance values. Although variation in benthic invertebrate abundances among stations was observed, none of the data were obviously inaccurate; therefore, the full dataset was used in the analysis. Data for meiofauna (i.e., Nematoda) were removed from the dataset before analysis, as they are not reliably enumerated using 500 µm mesh (Environment Canada 2012). In addition, non-benthic organisms (i.e., Copepoda, Cladocera and Chaoboridae) were also removed from the dataset because they are not bottom-dwelling taxa.

Abundances per sample were converted to densities (number of organisms per square metre [no./m^2]) based on the bottom area of the sampling device (i.e., Ekman grab 0.0232 m^2).

The following variables were included in the data analysis:

- total invertebrate density

- taxonomic richness (i.e., total number of taxa per station at the lowest level of identification)
- dominance (relative abundance, as a percentage, of the dominant taxon at a station)
- Simpson's diversity index (SDI) (measures the proportional distribution of organisms in the community, which takes into account the abundance patterns and taxonomic richness of the community)
- Simpson's evenness index (SEI) (measures the distribution of total abundance among the taxa present in a sample)
- densities of dominant taxa (selected according to percentage of total invertebrates across all stations in 2018):
  - Chironomidae (87.1%)
  - Hydracarina (5.7%)

Additional aspects of benthic community structure examined visually included presence-absence by each invertebrate taxon and community composition by major taxonomic group.

For interpretation purposes, ranges in benthic invertebrate densities and richness values were operationally defined as low/moderate/high based on experience with northern lakes, as documented by benthic invertebrate components of ongoing Aquatic Effects Monitoring Programs (AEMP) (i.e., Diavik AEMP [Golder 2017], De Beers Gahcho Kué AEMP [De Beers 2018]). Observed density and richness values were categorized as follows:

- low: density less than 5,000 org/m² and richness less than 10 taxa/station
- moderate: density ranging from 5,000 to 50,000 org/m², and richness ranging from 10 to 40 taxa/station
- high: density greater than 50,000 org/m² and richness greater than 40 taxa/station.

When compared to other (e.g., temperate and tropical) lake environments, the ranges of densities described above are relatively low, considering some lake environments have densities greater than 100,000 individuals per square metre (Hynes 1970; Resh and Rosenberg 1984; Rosenberg and Resh 1993).

6.3 Quality Assurance/Quality Control

Quality assurance procedures for the benthic invertebrate survey included use of specific work instructions to field crews, sample collection by experienced field personnel using standard operating procedures, and calibration of field equipment at appropriate intervals. Detailed field notes were recorded in pencil in waterproof field notebooks, and on pre-printed waterproof field data sheets. Field data were checked at the end of each day to verify that the necessary data have been recorded, and entries are in the appropriate ranges for the data being recorded. Following field data entry, the data underwent a 100% transcription check by a second person not involved in the initial data entry process.

One QC duplicate sediment quality sample consisting of a composite of three grabs was collected and submitted for laboratory analysis of particle size and TOC. Due to inherent variability associated with the sediment samples, samples were flagged if there was a greater than 20% difference, calculated as the RPD, in particle size or TOC between the original and duplicate samples. The RPD was calculated using the following formula:

RPD = (|difference in between duplicate values| / mean of duplicate values) x 100

Raw taxonomy data were reviewed for unusual abundance values, to be potentially verified with the taxonomist. Ten percent of the benthic invertebrate samples were re-sorted by the taxonomist to evaluate invertebrate removal efficiency, with a data quality objective of 90% removal.

Summary tables and calculations were checked to identify anomalous values and transcription errors. All results were reviewed by a senior scientist.

6.3.1 Data Validation Results

One duplicate sediment quality sample was collected in Southwest Bay (JFL-SQ-05). Resulting RPDs for TOC and particle size were less than the QC criterion of 20% for duplicate samples (Appendix E, Table E-1). Therefore, the level of reproducibility of the field sediment quality samples is considered acceptable. Laboratory duplicate testing was completed on the sediment sample collected in Mid-Lake (JFL-SQ-02) for particle size. The RPD values ranged from 1% to 6%, which met the QC criterion and indicate acceptable reproducibility. The QC results for the re-sorted benthic invertebrate samples met the QC criterion of >90% removal (Appendix E, Table E-2).

6.4 Results and Discussion

6.4.1 Habitat Variation

Habitat data for the five BIC stations sampled are summarized in Table 6-1. Sediment composition was variable among stations in Jackfish Lake (Figure 6-1), but can generally be characterized as fine sediments at all station, with low to moderate TOC content. The sediment near the K- and EMD Plants was equal parts sand (47%) and silt (48%), whereas Southwest Bay was primarily silt (58%) with some sand (29%) and clay (13%). Mid-Lake, Northeast Bay, and Northwest Bay were dominated by silt (68% to 88%) and had very little sand (0% to 8%), but had variable levels of clay (8% to 32%). The percentage of fine sediments ranged from 52.9% to 99.8% with the lowest percentage at K and EMD station. There was some variability in TOC among stations (Figure 6-2), with the highest value in Northeast Bay (8.8%) and the lowest at Mid-Lake (4.4%). The variation in TOC did not appear to reflect sediment particle size distribution. At all stations except Northeast Bay, the sediments had a flocculant appearance, indicating a layer of organic material on the surface. During sample collection, the field crew also noted a sulphur-like smell from the sediment at three stations (Table 6-1), which suggests that the sediment at those locations was anoxic.

DO, pH, and conductivity were consistent throughout Jackfish Lake. Although spot measurements of DO at the time of sampling in late September suggested that the lake was sufficiently oxygenated, analysis of measurements collected throughout the year indicate that near-bottom DO concentration was low throughout the summer (Table 6-2 and Section 4.3.1). The higher DO concentrations measured in September during benthic invertebrate sampling reflect break-down of thermal stratification and complete vertical mixing of the water column during fall turnover, which resulted in re-oxygenation of the bottom waters in Jackfish Lake.

DO concentration near the lake bottom was below the CCME CWQG for the Protection of Aquatic Life (CWQG) for coldwater biota of all life stages (i.e., >6.5 mg/L; CCME 1999) at all stations during July and August, and was particularly low at K and EMD, Mid-Lake, and Northeast Bay (i.e., <2 mg/L). A desktop review of a historical data from Jackfish Lake confirmed that anoxic conditions were observed since 1987 (Baker 1987). Anoxic summer conditions likely act as a key driver of low benthic invertebrate abundance and richness discussed below (Section 6.4.2).

Table 6-1: Summary of Supporting Habitat Variables Measured during the Benthic Invertebrate Community Survey, Jackfish Lake, Fall 2018

Station	UTM Coordinates (NAD 83 Zone 17T)		Depth (m)	Sediment Composition (%)				TOC (%)	Water Tempera-ture (˚C)	Dissolved Oxygen (mg/L)	pH	Specific Conductivity (µS/cm)	Sediment Description
	Easting	Northing		Sand	Silt	Clay	Fines						
K and EMD	634919	6929106	4.5	47.1	47.5	5.4	52.9	6.1	6.2	12.0	8.5	563.5	Fine wooden debris, floc on top layer, sulphuric odour
Mid-Lake	634532	6929067	7.9	4.1	87.9	8.0	95.9	4.4	6.2	12.0	8.5	563.5	Floc on top layer, sulphuric odour
Northeast Bay	634699	6929243	7.0	7.7	70.6	21.7	92.3	8.8	6.2	11.7	7.8	557.7	Clumps of clay on top layer, sulphuric odour
Northwest Bay	634465	6929382	5.7	<1.0	67.7	32.1	99.8	7.7	6.2	11.6	8.3	563.7	Floc on top layer
Southwest Bay	634236	6928695	5.3	29.2	58.1	12.7	70.8	6.1	6.1	11.9	8.5	562.9	Floc on top layer

UTM = Universal Transverse Mercator; TOC = total organic carbon; µS/cm = microSiemens per centimetre.

Table 6-2: Summary of Open Water Dissolved Oxygen Concentration at the Lake Bottom for Benthic Invertebrate Sampling Areas in Jackfish Lake, May to September 2018

Station	Month	Dissolved Oxygen	
		(mg/L)	% Saturation
K and EMD	May	11.6	103
	July	**1.4**	29
	August	**0.2**	2
	September	12.0	98
Mid-Lake	May	8.1	69
	July	**0.1**	<1
	August	**0.2**	1
	September	12.0	99
Northeast Bay	May	10.3	94
	July	**<0.1**	<1
	August	**<0.1**	<1
	September	11.7	86
Northwest Bay	May	9.0	83
	July	**3.9**	27
	August	**3.7**	35
	September	11.6	96
Southwest Bay	May	12.5	112
	July	**3.1**	33
	August	**2.7**	14
	September	12.1	99

Bolded values indicate that dissolved oxygen concentration was below the minimum Canadian Council Ministers of the Environment (CCME) Canadian Water Quality Guideline for the Protection of Aquatic Life (CWQG), for all life stages (i.e., >6.5 mg/L, CCME 1999).

Figure 6-1: Sediment Composition of Jackfish Lake Sample Stations, Fall 2018

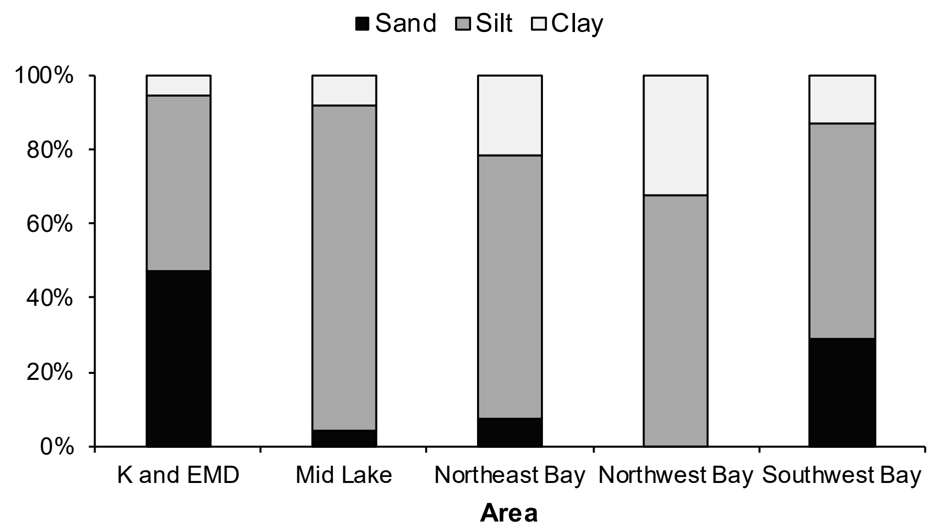
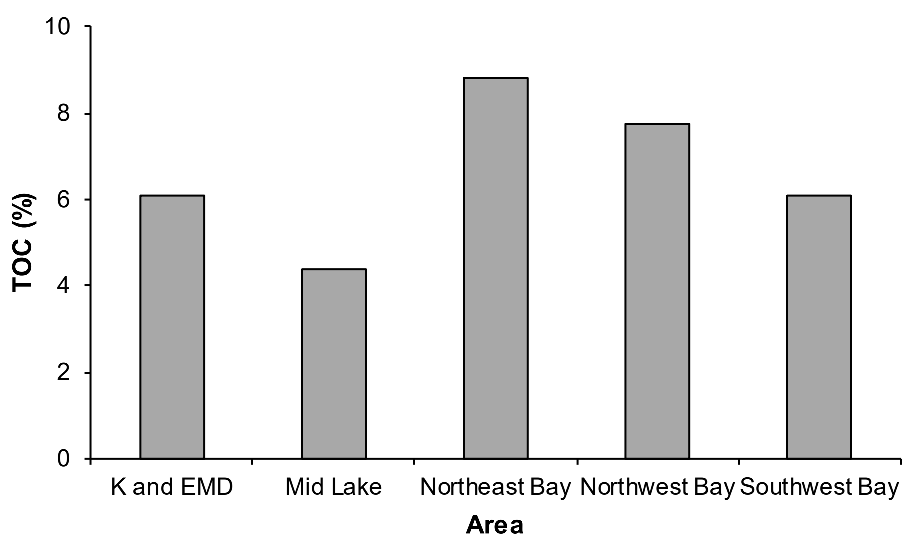


Figure 6-2: Total Organic Carbon Content of Sediments Collected from Jackfish Lake, Fall 2018

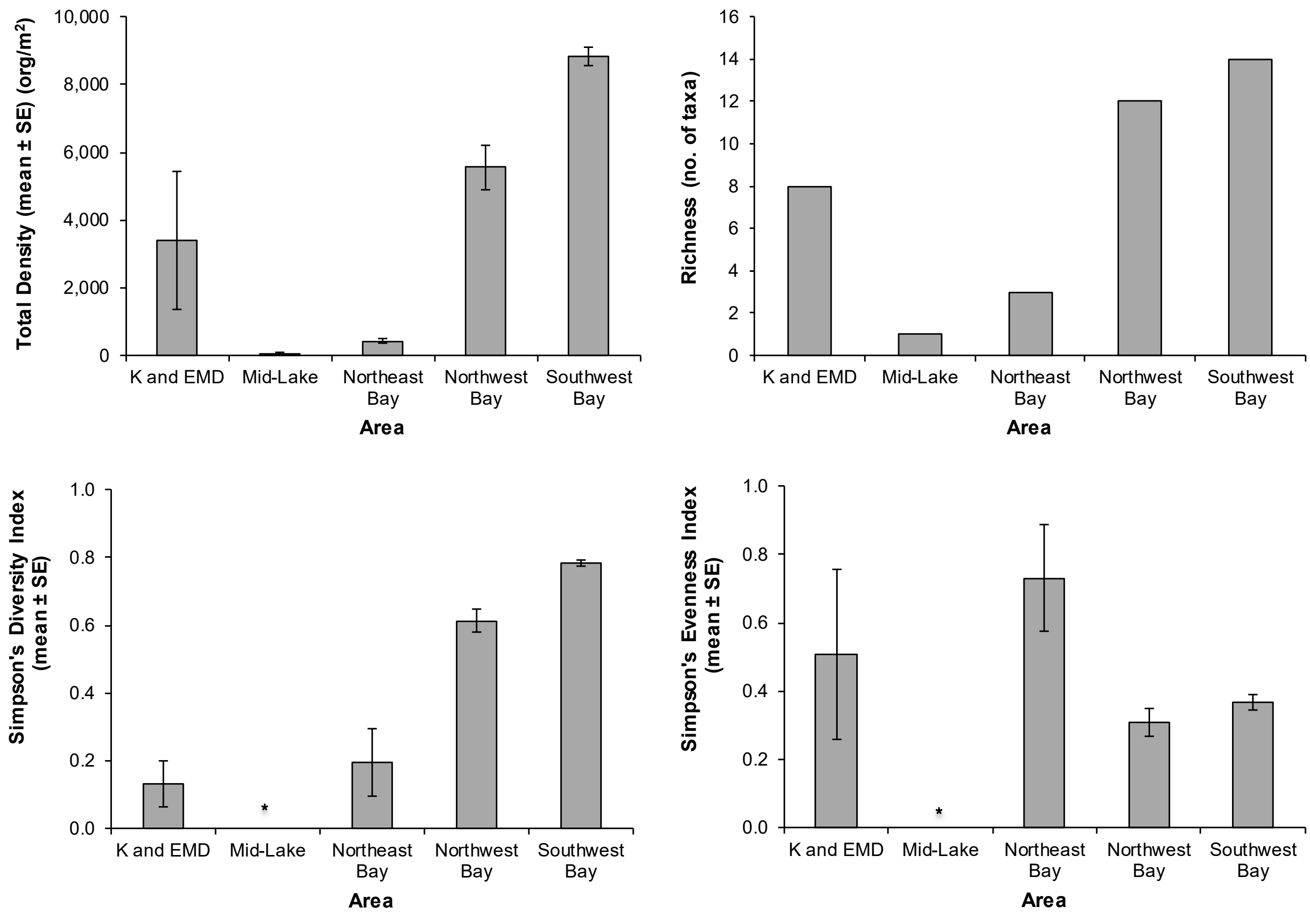


6.4.2 Benthic Invertebrate Community Indices

Benthic community indices are summarized in Appendix E, Table E-3. The benthic community in Jackfish Lake had generally low diversity and richness, with less than 10,000 organisms/m^2 and fewer than 14 taxa per station. Differences were observed between the areas of Jackfish Lake, ranging from almost absent communities to low-moderate density and richness. Total density was lowest at Mid-Lake (43 ± 43 org/m^2) and highest in Southwest Bay (8,835 ± 274 org/m^2) (Figure 6-3). Total density was particularly variable at K and EMD station, where it ranged from 1,034 to 7,456 org/m^2 between discrete samples. Richness and SDI followed a similar trend to density, where the highest values were in Southwest Bay and Northwest Bay stations, and the lowest values in K and EMD and Northeast Bay stations (Figure 6-3). This indicates that the communities in Southwest Bay and Northwest Bay were represented by a greater number of taxa and were not as extensively dominated by a single taxon. Evenness (SEI) had the opposite trend, being higher at Northeast Bay and K and EMD, and lowest in Southwest Bay and Northwest Bay.

Visual interpretation of the data suggested a relationship between BIC metrics and low DO concentration during the summer. The greatest densities, richness, and diversity in Jackfish Lake were found in Southwest Bay and Northwest Bay, which had the highest levels of DO during the summer. This suggests that low oxygen levels are a key driving factor of the differences in the benthic community among stations, and the overall state of the Jackfish Lake benthic invertebrate community.

Figure 6-3: Benthic Invertebrate Community Indices, NTPC Jackfish Lake, Fall 2018



org/m² = organisms per square metre; SE = standard error; no. of taxa = number of taxa.
*SDI and SEI were not calculated for Mid-Lake, as there was only one taxa present.

6.4.3 Community Composition

The benthic invertebrate community was dominated by Chironomidae in all areas of Jackfish Lake, which accounted for 80% to 100% of the community (Figure 6-4). The most prevalent chironomid was the genus *Chironomus*, which was the dominant taxon in all areas except Southwest Bay, where the chironomid community was somewhat evenly divided among the genera *Chironomus*, *Tanypus*, and *Procladius*. After Chironomidae, the next most prominent taxon was the aquatic mites, Hydracarina, which accounted for <10% of the community in Northeast Bay, Northwest Bay, and Southwest Bay. The K and EMD and Northwest Bay stations each had one unique taxon relative to the rest of the lake (i.e., the mayfly genus *Callibaetis* and oligochaete subfamily Naidinae, respectively), whereas Southwest Bay had four taxa that were not found at any other stations (i.e., the snail *Valvata sincera*, pea clam *Pisidium*, as well as the mayfly genus *Caenis* and chironomid *Cladopelma*). All taxa found at Mid-Lake and Northeast Bay were present in at least two other areas of the Lake (Table 6-3). In relation to field water quality measurements, the two stations with near-bottom DO concentrations above 2.5 mg/L in July and August (i.e., Northwest Bay and Southwest Bay; Table 6-2) had notably more diverse communities compared to the other three stations, where DO concentrations were less than 1 mg/L during the summer months.

Samples taken from Mid-Lake and Northeast Bay also had a relatively high proportion of non-benthic taxa that were removed during the screening process, specifically the phantom midge *Chaoborus*, a semi-benthic invertebrate that accounted for 80% to 100% of organisms in Mid-Lake samples, and 40% to 65% of organisms in Northeast Bay. At the Mid-Lake station two of the three sampling stations had no remaining organisms post-screening (i.e., stations were completely populated by *Chaoborus*).

Figure 6-4: Benthic Invertebrate Community Composition, NTPC Jackfish Lake, Fall 2018

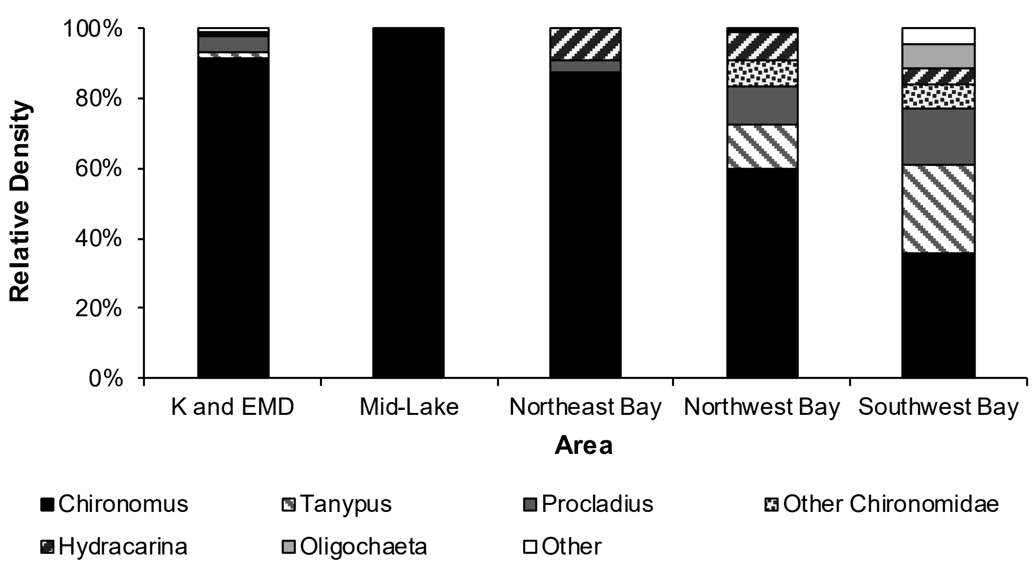


Table 6-3: Presence-Absence of Benthic Invertebrate Taxa in Jackfish Lake, Fall 2018

Major Taxonomic Group	Family	Subfamily / Tribe	Genus / Species	K and EMD	Mid-Lake	NE Bay	NW Bay	SW Bay
Oligochaeta	Naididae	Naidinae	-	-	-	-	X	-
		Tubificinae	-	X	-	-	X	X
Hydracarina	Pionidae	-	*Piona* sp.	-	-	X	X	X
	Unionicolidae	-	*Neumania* sp.	X	-	-	X	X
Ostracoda	-	-	-	-	-	-	X	X
Gastropoda	Valvatidae	-	*Valvata sincera*	-	-	-	-	X
Bivalvia	Pisidiidae	-	*Pisidium* sp.	-	-	-	-	X
Ephemeroptera	Baetidae	-	*Callibaetis* sp.	X	-	-	-	-
	Caenidae	-	*Caenis* sp.	-	-	-	-	X
Trichoptera	Phryganeidae	-	*Phryganea* sp.	X	-	-	X	-
Diptera	Chironomidae	Tanypodinae	*Procladius* sp.	X	-	X	X	X
			Tanypus sp.	X	-	-	X	X
		Chironomini	*Chironomus* sp.	X	X	X	X	X
			Cryptochironomus sp.	-	-	-	X	X
			Cladopelma sp.	-	-	-	-	X
			Polypedilum sp.	X	-	-	X	X
		Tanytarsini	*Tanytarsus* sp.	-	-	-	X	X
Total Taxa				**8**	**1**	**3**	**12**	**14**

X = taxon is present at a station; - = taxon is absent.

6.4.4 Thermal Tolerance

Overall, Northwest Bay and Southwest Bay were the warmest measured stations in Jackfish Lake (based on profile data), with water temperatures reaching 15ºC to 17ºC during the summer (Table 6-4), whereas Northeast Bay remained the coldest during the summer (water temperatures only reached 12ºC). Temperature loggers showed maximum water temperature recorded at K and EDM station reached 22ºC in June and Southwest Bay water temperatures reached 19.8ºC in July. All stations had similar water temperatures in the spring and fall.

Upper limits of water temperature for the taxa found in Jackfish Lake are listed in Table 6-5. Thermal tolerance values for all taxa collected from Jackfish Lake were above 20ºC, and many taxa are tolerant to temperatures above 30ºC. Comparisons of the thermal tolerance ranges of benthic invertebrates with the lake bottom temperatures in Jackfish Lake sampled during the 2018 field survey (Table 6-5), indicate that the in situ measurements and the majority of the temperature logger measurements were below the lowest thermal tolerance limit (20ºC) of the taxa present in Jackfish Lake. No apparent visual patterns in the distribution of organisms between sampling stations and their temperature ranges were observed. Peak water temperatures measured at the lake bottom during the 2018 field survey reached a maximum of 22.0ºC at the K and EMD station.

Table 6-4: Summary of Maximum Water Temperatures on the Lake Bottom in Jackfish Lake, May to September 2018

Station	Month	In Situ Maximum Bottom Temperature (ºC)	Temperature Logger Maximum Bottom Temperature (ºC)
K and EMD	May	9.1	10.9
	June	-	22.0
	July	13.5	21.4
	August	15.0	20.4
	September	6.2	-
Mid-Lake	May	7.8	-
	June	-	13.8
	July	11.5	13.7
	August	14.2	12.0
	September	6.2	13.7
Northeast Bay	May	8.9	-
	July	11.4	-
	August	12.3	-
	September	6.2	-
Northwest Bay	May	8.1	-
	July	16.3	11.6
	August	17.7	16.9
	September	6.2	14.2
Southwest Bay	May	9.6	11.3
	June	-	19.7
	July	15.6	19.8
	August	17.5	-
	September	6.1	-

- = not available

Table 6-5: Thermal Tolerances for Benthic Invertebrate Taxa Residing in Jackfish Lake, 2018

Major Taxonomic Group	Family	Subfamily / Tribe	Genus / Species	Upper Thermal Tolerance Limit (°C)
Oligochaeta	Naididae	Naidinae	-	25 - 35
		Tubificinae	-	35
Hydracarina	Pionidae	-	*Piona* sp.	31
	Unionicolidae	-	*Neumania* sp.	31
Ostracoda	-	-	-	20 - 42
Gastropoda	Valvatidae	-	*Valvata sincera*	33 - 40
Bivalvia	Pisidiidae	-	*Pisidium* sp.	32 - 34
Ephemeroptera	Baetidae	-	*Callibaetis* sp.	21 - 41
	Caenidae	-	*Caenis* sp.	27
Trichoptera	Phryganeidae	-	*Phryganea* sp.	23
Diptera	Chironomidae	Tanypodinae	*Procladius* sp.	30
			Tanypus sp.	
		Chironomini	*Chironomus* sp.	30
			Cryptochironomus sp.	
			Cladopelma sp.	
			Polypedilum sp.	
		Tanytarsini	*Tanytarsus* sp.	27 - 33

Source: Environment Canada (2014) and Külköylüoğlu (2013).
Note: Tolerances were estimated based on genus or family level depending on availability of data. Upper limits are shown for taxa where a range was not available. Ranges presented are based on higher taxonomic resolution.

6.5 Summary and Conclusions

The results of the benthic invertebrate community survey completed in September 2018 in Jackfish Lake are presented in this report section. The main objective of the benthic sampling program was to collect benthic invertebrate samples and characterize the community in Jackfish Lake, and to assess whether the cooling water discharge from the Jackfish Facility is impacting the benthic invertebrate community. As part of the benthic survey, sediment physical characteristics and in situ water quality data were evaluated to provide additional supporting data for interpretation of the benthic invertebrate survey results.

The findings of the 2018 benthic invertebrate survey are summarized below:

- Benthic invertebrate communities in sub-Arctic lakes are typically dominated by a limited number of taxa, most commonly the family Chironomidae. The community in Jackfish Lake was chironomid-dominated and similar in composition to those observed in lentic environments in the NWT (De Beers 2018; Dominion 2018). The benthic invertebrate community in Jackfish Lake includes a number of common taxa that are tolerant of increases in temperature and environmental disturbances in general, such as the chironomid genera *Tanypus, Procladius*, and *Chironomus*, aquatic mites, and oligochaete worms.
- The benthic invertebrate community in Jackfish Lake exhibited low densities and richness (i.e., less than 10,000 org/m^2 and less than 14 taxa, respectively), consistent with the results commonly observed in other sub-Arctic lakes.
- The dominant benthic invertebrate taxon in Jackfish Lake was *Chironomus* sp. and the dominant non-benthic taxon was *Chaoborus* sp. Both genera are adapted to anoxic conditions (Thorp and Covich 2001) and have high thermal tolerance limits of >30ºC (Environment Canada 2014).

- There was a visually consistent response of most benthic invertebrate endpoints with near-bottom DO concentrations measured during the July and August field surveys. As the life cycles of benthic invertebrates can extend over one or more years (Merritt et al. 2008), the effects of the previous year’s or season’s oxygen depletion events would be reflected in the current community. Historical data also suggest that the low oxygen levels in the summer may be a regular occurrence in Jackfish Lake (Baker 1987).
- The benthic invertebrate community does not appear to be visually aligned with variation in sediment composition or differences in TOC among stations. There does appear to be some association between invertebrate endpoints and depth; however, since station depth and DO depletion in the summer followed similar trends, community characteristics were more likely reflective of variation in summer DO concentrations.
- The benthic invertebrate survey proved successful in characterizing the existing community in Jackfish Lake. Data obtained during the survey did not suggest that the Jackfish Facility discharge is impacting benthic invertebrates in Jackfish Lake, because water temperature remained within the majority of tolerance ranges of the invertebrates present, and no spatial trends were apparent in relation to the discharge location. However, interpretation of results in relation to effects from the Jackfish Facility is subject to uncertainty due to lack of a reference lake dataset, because the potential for a whole-lake effect cannot be ruled out based on the study results.

7.0 FISH COMMUNITY AND FISH TISSUE CHEMISTRY

7.1 Objective

Historically, Jackfish Lake was locally used for sport fishing. Recently the use of the lake for sport fishing has declined due to the presence of cyanobacteria and local arsenic contamination (CBC 2016). The objectives of the fish component are:

- document Jackfish Lake's current fisheries
- provide information to evaluate effects of the Jackfish Facility discharges on fish including discharge temperatures (e.g., thermal effects) and released total dissolved gases (e.g., gas bubble trauma).
- collect and analyze fish tissue chemistry samples
- collect and archive fish ageing structures.

7.2 Methods

7.2.1 Field Sampling

Jackfish Lake was sampled for fish between 24 and 26 July 2018 (Table 7-7-1). The field program was conducted by a three-person field crew, consisting of two fisheries biologists and one NTPC staff. Five general areas of Jackfish Lake were sampled for fish: Northwest Bay North, Northeast Bay, West Bay, Southwest Bay, and East Bay. Sampling was limited to the perimeter of the lake with some efforts extending into deeper areas. Lake areas were sampled at a range of depths from 0.2 m to 6.0 m.

The selection of sampling sites was based on:

- Gear type accessibility (i.e., shoreline habitat features for minnow traps, less than 0.7 m in depth and accessible shoreline for seine netting, safe footing and good water visibility for backpack electrofishing).
- Proximity to concurrent fish efforts (i.e., multiple gear type efforts were conducted at the same time within the same area of the lake to maximize fishing time).
- Health and safety concerns (i.e., shoreline not suitable for wading, limited boat access).

Due to time constraints the central areas of the lake (i.e., Mid-Lake) with water depths up to 7.8 m (Figure 7-7-1) were not sampled. In addition, shorelines of Jackfish Lake were flooded at the time of the survey due to heavy local rain which created challenging sampling conditions for seine netting and backpack electrofishing, and poor water clarity also reduced backpack electrofishing efficiency. Sites were accessed by boat or by foot.

The work was conducted under FWI-ACC-2018-17 Animal Use Permit issued by the Freshwater Institute Animal Care Committee, S-18/19-3011-YK License to Fish for Scientific Purposes issued by Fisheries and Oceans Canada, and Scientific Research Licence No. 16320 issued by Aurora Research Institute.

7.2.1.1 Supporting Environmental Data

Supporting environmental variables provide information that allows for the classification of aquatic habitats. Field parameters (i.e., water temperature [˚C], dissolved oxygen [%, mg/L], specific conductivity [µS], pH, and Secchi depth [m]) were collected once or twice daily at mid-depth using a handheld multi-parameter water quality meter (SmarTROLL). Dissolved oxygen and pH data collected in the field were compared to water quality guidelines (CCME 1999).

In addition, the following supporting environmental variables were documented for each sampling effort, and at each location where field parameters were collected:

- Weather conditions (air temperature, wind direction, percent cloud cover and precipitation).
- Habitat information (e.g., minimum and maximum water depth, substrate type [when water clarity permitted a visual assessment], aquatic vegetation, photographs of the area).

Seasonal water temperature was continuously collected throughout 2018, starting in March (Section 3). Total dissolved gases, in%, were collected at the same time as water quality (Section 4) and compared to the lethal thresholds outlined in NAS-NAE (1972) to provide information to evaluate effects of the cooling system on the fish in Jackfish Lake.

7.2.1.2 Fish collection

The study targeted both small and large-bodied fish. Each deployment of fishing gear was assigned a unique effort number and each fish sampled was assigned a fish identification number. Fish were captured by backpack electrofishing, seine netting, gill netting, minnow trapping, and angling (Table 7-1), following Golder standard procedures. Backpack electrofishing, seine netting and minnow trapping occurred exclusively along the shorelines; gill nets and angling efforts occurred along the perimeter of the lake with some efforts extending into deeper areas of the lake.

Backpack Electrofishing

Backpack electrofishing was performed using a Smith Root, Inc. (Vancouver WA, USA) Type LR-24 unit and the waveform, duty cycle and output voltage were adjusted daily to water conditions before each effort. Voltage ranged from 110 to 115 volts (V), frequency and duty cycle remained constant at 30 hertz (Hz) and 12% with a 4 ms pulse width. The following information was recorded:

- sampling date
- start and end times
- effort number
- start and end UTM coordinates
- fishing effort, as electrofishing duration in seconds
- electrofisher settings (voltage [V], frequency [Hz], duty cycle [%], and pulse width [ms])
- number and species of fish captured and observed.

Seine Netting

Seine netting was performed using a small mesh seine. The net was 25 m in length, 2 m in width, 5 mm mesh, and attached to poles. Seine netting was limited because the lake shorelines were flooded, creating challenging sampling conditions. The following information was recorded for each seine net effort:

- sampling date
- start and end times
- effort number
- area sampled (m^2)
- start and end UTM coordinates
- number and species of fish captured and observed.

Gill Netting

Gill netting was performed using four types of monofilament gill nets:

- a 100 m long and 1.8 m wide medium-mesh net with a mesh size of 56 mm
- a multi-panel nets 25 m long and 1.8 m wide with mesh sizes of 11.4 mm, 17.7 mm, 24.2 mm and 37.3 mm
- a medium multi-panel net 50 m long and 1.8 m wide with mesh sizes of 11.4 mm, 17.7 mm, 24.2 mm and 37.3 mm
- a 50 m long and 1.65 m wide medium multi-panel net with mesh sizes of 105 mm, 62 mm, 135 mm, 39 mm, 92 mm, 52 mm, 119 mm, and 76 mm

Gill nets were set as floating nets at the surface that, based on the depth of the sample site, extended throughout the water column in shallow sections and fished the upper water column in deeper sections (Photograph 1). All gill nets were deployed for a short duration during daylight hours to minimize fish mortality. Gill net efforts were decreased from two-hour to one-hour sets to limit fish stress. The following information was recorded for each gill net effort:

- sampling date
- start and end times
- effort number
- water depth of each gill net set (e.g., minimum and maximum, in m)
- dimension of the gill net used (e.g., net type, small or medium mesh)
- dimensions and mesh size of the gill net used
- start and end UTM coordinates
- number and species of fish captured

Minnow Trapping

Both Gee-type and Frabill-type minnow traps were used and baited using cisco and/or wet and dry cat food. The traps were placed along near-shore locations in a variety of habitat. Each effort consisted of a set of either 4 or 8 traps placed over a section of shoreline. Minnow traps were set overnight and checked throughout the day. The following information was recorded for each minnow trap effort:

- sampling date
- start and end times
- effort number
- UTM coordinates
- number of traps deployed
- number and species of fish captured

Angling

Fish were angled by one or two anglers using a rod and lures (barbless treble-hook Red Devil spoons and barbless double treble-hooked Rapala Jointed fishing lure). Anglers either casted from the shore or from a slow-moving boat over a section of the lake. The following information was recorded for each angling effort:

- sampling date
- start and end times
- effort number
- angling gear (i.e., rod type, number of rods, tackle, hooks)
- number of fishers
- start and end UTM coordinates (i.e., a single UTM coordinate for shoreline casting, a start/end UTM coordinates when casting from a boat)

Table 7-1: Fishing Effort, 2018 Jackfish Lake Environmental Monitoring, July 2018

Gear Type	Total Fishing Effort
Backpack Electrofishing	2,229 seconds
Seine Net	0.16 hours
Gill Net Effort	13.75 hours
Minnow Traps	463.2 hours
Angling	2.60 hours

Photograph 1: Gill Net deployment in Jackfish Lake Southwest Bay, 24 July 2018

LEGEND

- LAKE AREA
- HIGHWAY
- LOCAL ROAD
- WATERCOURSE

SAMPLING EFFORT LOCATION

- ANGLING
- SEINE NET
- WATER QUALITY STATION

SAMPLING EFFORT TRACK

- ANGLING
- ELECTROFISHING
- SMALL MESH GILLNET
- MEDIUM MESH GILLNET
- MINNOW TRAP

0 100 200

1:5,000 METRES

REFERENCE(S)

HYDROGRAPHY, POPULATED PLACE, AND ROAD DATA OBTAINED FROM GEOGRATIS, © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED. IMAGERY COPYRIGHT © 20120115 ESRI AND ITS LICENSORS. SOURCE: YELLOWKNIFE.
PROJECTION: UTM ZONE 11 DATUM: NAD 83

CLIENT

NORTHWEST TERRITORIES POWER CORPORATION

PROJECT

JACKFISH LAKE ENVIRONMENTAL MONITORING

TITLE

BASELINE FISHERIES SAMPLING LOCATIONS OF JACKFISH LAKE

CONSULTANT

GOLDER

YYYY-MM-DD	2019-02-22
DESIGNED	MR
PREPARED	HR/PS
REVIEWED	KB
APPROVED	DP

PROJECT NO.	CONTROL	REV.	FIGURE
1894709	11000-11010	0	7-1

7.2.1.3 Fish Processing

For each fish captured, the following information was recorded:

- species
- fish number
- fork length (±1 mm)
- total length (±1 mm)
- total body weight (g)
- sex (if evident, otherwise recorded as unknown)
- life stage (if evident, otherwise recorded as unknown)
- photograph of the fish.

Live captured fish were held in a tote box filled with fresh lake water and were released into Jackfish Lake after measurements. When survival was in doubt, fish were sacrificed according to approved permit methods. Dead fish were retained for further analyses.

An external assessment was completed as time permitted on mortalities and sacrificed fish following Golder standard procedures. An external assessment was not completed on live fish to minimize additional stress caused from fish handling. The following information was collected:

- external observations (examination on each fish of the eyes, gills, thymus, skin, body form, fins, and opercula)
- presence of abnormal features (e.g., wounds, tumours, parasites, fin fraying, gill parasites, lesions, signs of gas bubble trauma [i.e., bubbles in the eyes or fins])
- photographs of any fish with abnormal external features.

At the end of each field day, mortalities/sacrificed fish were brought to the lab for further processing. Internal condition was observed and recorded the same day of capture immediately following the opening of the body cavity; on occasion time did not permit the full internal assessment. The following information was collected:

- internal pathology (i.e., liver, spleen and kidney colour, fat content)
- sex
- state of reproductive development
- stomach contents (% fullness)
- internal parasites recorded
- liver weight (±0.1 g)

- gonad weight (±0.1 g)
- ageing structures (e.g., sagittal otoliths, scales, pelvic fin rays, and/or cleithra).

Muscle tissue was removed from ten large-bodied fish using a clean stainless-steel filleting knife and weighed, placed in individually-labelled plastic bags. To avoid cross contamination between samples, the cutting board was covered with new plastic wrap and the filleting knife was rinsed in 5% nitric acid between fish.

Tissue samples were collected from a total of seven Lake Whitefish (*Coregonus clupeaformis*) and three Northern Pike (*Esox lucius)*. No additional samples were collected due to time constraints and to stay within permitted fish mortality limits. Tissue samples were sent to ALS in Burnaby, British Columbia, for analysis of total moisture and total metals. Ageing structures (i.e., scales, pelvic fin rays, and sagittal otoliths from Lake Whitefish; scales, pelvic fin rays, and cleithra from Northern Pike) were collected on the fish sampled for tissue chemistry analyses. The ageing structures were archived for potential future analysis.

7.2.2 Field Plan Deviations

The Jackfish Lake 2018 Environmental Monitoring Field Work Plan (Golder 2018) stated that sampling would be conducted throughout the lake. However, due to time constraints, the Mid Lake with water depths up to 7.8 m were not sampled.

The Field Work Plan also outlined that ten large-bodied fish of the same species and size class would be processed for tissue analyses and internal assessment. However, tissue analyses were conducted on two different species: seven Lake Whitefish and three Northern Pike. Fish were not kept in the fridge or frozen for processing at a later date as this would cause degradation in tissue. After the first day of sampling, Lake Whitefish were no longer targeted for the remaining program to avoid further mortalities and to stay within the mortality limits outlined in the Department of Fisheries and Oceans Licence to Fish for Scientific Purposes S-18/19-3011YK. One Northern Pike was sacrificed on 26 July 2018 to supplement the results for prior Northern Pike incidental mortalities and for internal assessment. Three of the four Trout-perch (*Percopsis omiscomaycus*) incidental mortalities were retained for species identification and archived .

7.3 Quality Assurance/Quality Control

The field and laboratory QA/QC procedures were implemented at each stage of the fish survey to confirm that field sampling, data entry, data analysis, and report preparation produced technically sound and scientifically defensible results.

7.3.1 Field QA/QC Procedures

As part of practices for field operations for this program, the following QA/QC procedures were undertaken:

- Detailed specific work instructions outlining each field task were provided to the field personnel prior to the field programs.
- A pre-field meeting with the field crew and team lead was conducted to review the specific work instructions so that procedures were understood.
- Samples were collected by experienced personnel and were collected, labelled, preserved and shipped according to laboratory instructions and Golder internal technical procedures.

- Field equipment (i.e., electronic scales, water quality meter) was regularly calibrated according to manufacturer's recommendations.
- Detailed field notes were recorded in pencil in waterproof field notebooks, on waterproof pre-printed field data sheets, or directly entered electronically into an excel spreadsheet during lab fish processing.
- Field data (i.e., datasheets, notebook, and electronic spreadsheets) were checked at the end of the day for completeness and accuracy.
- Photographs of fish were viewed by a separate fish biologist to confirm the species.
- Samples were documented and tracked using chain-of-custody forms, and receipt of samples by the analytical laboratory was confirmed. Field crews were responsible for managing sample shipping to the analytical laboratory. Prior to sample shipping, field crews confirmed the following:
  - required samples were collected and accounted for
  - chain-of-custody and analytical request forms were completed and correct
  - proper labelling and documentation procedures were followed.

7.3.2 Field and Laboratory Data

Data collected in the field were entered into a spreadsheet and tabulated for data analyses and interpretation. Various data cross-check and screening procedures (e.g., examination of scatterplots and data ranges) were preformed to examine the data for any potential data entry errors or outliers. At least 10% of the data entered electronically were verified by a second person to identify transcription errors.

Upon receipt of tissue chemistry data from ALS, standard checks were performed to screen for potential data quality issues:

- confirm that the requested variables were analyzed
- comparison of method DL to laboratory quotation
- review of units
- review of internal laboratory QA/QC results.

ALS results were plotted using scatter plots to visually examine the data for any potential data entry errors or unusual observations. Values that deviated significantly from the trend often indicate a data entry or other error may have occurred and were requested for re-analyses.

7.3.3 Quality Assurance/Quality Control Results

A total of four unusual results were identified during fish tissue chemistry QC checks and re-analyzed by ALS. Three of the unusual values were confirmed after re-analysis and the original result was kept (Table 7-2). The re-analysis result of one unusual value was kept because it was closer to the expected value.

Table 7-2: Tissue Chemistry Result Outliers, Jackfish Lake, 2018

Fish Identification Number	Parameter	Original Value (mg/kg wwt)	New Value (mg/kg wwt)	Reason for Re-Analyses and Decision on Data
JL-18-GN-LKWH-K-002	Titanium	0.085	-	Significantly higher than the mean and the detection limit. Values confirmed by re-analysis.
	Uranium	0.00327	-	
JL-18-GN-LKWH-K-006	Chromium	0.213	-	Significantly higher than the mean. Value confirmed by re-analysis.
JL-18-AL-NRPK-K-001	Aluminum	2.54	<0.4	Significantly higher than the mean result values and the detection limit. Re-analysis value was kept.

wwt = wet weight

7.4 Data Analysis

7.4.1 Catch-Per-Unit-Effort

Catch-per-unit-effort (CPUE) provides an estimate of abundance by standardizing catch data according to fishing effort. CPUE was calculated by for each species captured and was summarized by sampling method. The CPUE for each sampling method was calculated as:

- electrofishing: number of fish captured per 100 seconds effort (#fish/100 s)
- seine netting: number of fish captured per 100 m^2 per hour (#fish/100 m^2)
- gill netting: number of fish captured per 100 m^2 per hour (#fish/100 m^2)
- minnow trapping: number of fish captured per hour (#fish/h)
- angling: number of fish captured per angler per hour (#fish/angler/h)

7.4.2 Length-Frequency and Length-Weight Analyses

Length-frequency analyses provide an important description of population structure and are used to provide information for the interpretation of age and growth, especially for young fish. The length-frequency distribution of a population is shown graphically, and fish are grouped in size-range bins which vary for each fish species.

Length-weight relationships can be used in order to assess the state of well-being of a fish population. As a fish population size increases and/or food resources decline, individual fish become thinner and the ratio of weigh to length decreases. The logged relationship between fish length and body weight is linear, and can be represented by the following function:

$$log\ W = \log a + b \log L$$

Where W = weight, L = length, and ‘a’ and ‘b’ are constants which are characteristic of the population being examined. The constant ‘b’ reflects the rotundness of the fish or the rate at which weight increases for a given increase in length.

7.4.3 Condition Factor

Condition factor is used to describe the plumpness and, by inference, the well-being of individual fish. The condition factor (K) is calculated as follows:

$$K = \frac{[weight\ (g) \times 10^5]}{fork\ length^3\ (mm)}$$

Condition factor is believed to reflect the nutritional state or well-being on an individual fish. The K value will be 1.0 for fish whose weight is equal to the cube of its length. Fish which have a K value >1.0 are more plump and are thought to have a higher degree of well-being or better nutritional state-of-health, whereas fish with a value <1.0 are considered to be less robust.

7.4.4 Fish Tissue Chemistry

Metals concentrations in the tissue were compared to available national guidelines for human consumption. The Canadian Food Inspection Agency (CFIA) and Health Canada guidelines state fish collected for commercial use may contain a maximum of 0.5 mg/kg ww mercury to be approved for human consumption (CFIA 2018). While fish from Jackfish Lake are not sold commercially, this guideline was considered relevant for the purpose of consistent comparisons between years during future monitoring work. No historical fish tissue chemistry data from Jackfish Lake were available for comparison.

7.4.5 Thermal Effects on Fish

To begin to understand the thermal effect of the Jackfish Facility discharges on fish, water temperatures measured in 2018 were compared to the documented lethal temperature thresholds for the species found in Jackfish Lake (Environment Canada 2014; Hasnain et al. 2012).

7.5 Results

7.5.1 Supporting Environmental Variables

Field Parameters

Field parameters were collected on five occasions: twice at the Southwest Bay and Northeast Bay, and once at the West Bay (Table 7-3). Secchi disk depth was of 0.7 m in average. The mean water temperature for the days of fish sampling was 20°C. The mean DO level was 10.9 mg/L, which is above the minimum cold-water biota value for early life stages (6.5 mg/L; CCME 1999). Mean water conductivity was 485 µS/cm, and within the typical range of 50 to 1,500 µS/cm of most surface waters, but about 100 µS/cm higher than maximum measurements collected historically in the region (Puznicki 1996), and than historical maximums in Jackfish Lake (Section 4). Mean pH was slightly basic at 8.8 and within CCME guidelines for aquatic life (CCME 1999). As noted in Section 4, the total dissolved gas measurement was below the CCME guideline.

Table 7-3: Jackfish Lake Field Parameters, July 2018

WQ Site	WQ 1	WQ 2	WQ 3	WQ 4	WQ 5	Average
Sampling Area	**Southwest Bay**	**Southwest Bay**	**Northeast Bay**	**Northeast Bay**	**West Bay**	-
Sample Date	24 July	25 July	25 July	26 July	26 July	-
Sample Time	15:20	15:50	14:00	10:45	14:45	-
Easting UTM Coordinates (Zone 11 V)	634239	634423	634641	634759	635067	-
Northing UTM Coordinates	6928678	6928603	6929360	6929370	6929043	-
Weather						
Air Temp (˚C)	19	20	18	20	23	19
Cloud Cover (%)	0	0	0	0	2	0.4
Wind Direction	W	N	N	N	S	-
Wind Speed (km/h)	10	15	15	15	5	12
Water Quality						
Sample Depth (m)	0.46	n/c	3.2	n/c	n/c	1.8
Secchi Depth (m)	0.65	0.70	0.70	0.70	0.70	0.69
Water Temp (˚C)	18.5	20.4	18.4	18.4	19.5	20.0
DO (mg/L)	10.8	11.5	9.57	11.3	11.1	10.9
DO (%)	117.0	129.4	103.0	122.0	123.1	118.9
Specific Conductivity (µS/cm)	536	467	470	478	472	485
pH	8.9	8.9	8.7	9.0	8.8	8.8

Note:
There was no observed precipitation throughout the fish field program.
n/c = data not collected because of an oversight.

Weather Conditions

The weather during the sampling program was sunny with no cloud cover, no precipitation, and a wind speed at or below 17 km/h (Table 7-3; Appendix F, Table F-1). Mean air temperature was 20°C.

Habitat

Habitat data are provided in Appendix F, Table F-1. At the time of the survey the lake was flooded beyond the shorelines and no beach areas existed such that shoreline habitat information could not be recorded (Photograph 2). Sampling depths ranged from 0 to 6 m. Dominant substrates were sand, silt and clay, with gravel, boulder and bedrock being sub-dominant. Emergent vegetation (e.g., sedges, cattails, lily pads) was present within each general sampling area. Northwest Bay North and Northeast Bay both had shorelines with abundant grasses, whereas West Bay had mostly rocky shoreline and Southwest Bay had significant rocky shoreline (Photograph 3). East Bay was flooded with substantial presence of woody debris and grasses (Photograph 2). A beaver lodge was observed in the Northeast Bay.

Photograph 2: Flooded shoreline of the East Bay of Jackfish Lake, July 2018

Photograph 3: Emergent grass habitat with presence of lily pads alongside rocky shoreline habitat of the Southwest Bay of Jackfish Lake, July 2018

7.5.2 Catch-Per-Unit-Effort

A total of 29 fish were captured and 9 fish were observed in Jackfish Lake during the 2018 fish survey. Captured or observed fish species were Northern Pike, Lake Whitefish, and Trout-perch (Table 7-4, Appendix F, Tables F-2 to F-7); both Northern Pike and Lake Whitefish were captured in surveys in the 1980s (Roberge and Gillman 1986). Fish were caught in either Northeast Bay, Northwest Bay, or Southwest Bay. No fish were caught in West Bay or East Bay. Most fish were collected with gill nets, including Lake Whitefish and Trout-perch. Northern Pike were captured by all fishing methods except seine netting, with most Northern Pike being captured with gill netting and angling. Of the 29 fish captured, 12 were live-released (8 Northern Pike and 4 Lake Whitefish) and the remaining 17 were either mortalities or sacrificed (3 Northern Pike, 10 Lake Whitefish, 4 Trout-perch).

Fish species captured during the fish study are native to the NWT and have a wide distribution range across the mainland of the territory (Richardson et al. 2001). Northern Pike and Lake Whitefish, which are valued as sport/food species by recreational anglers and local community members, are listed as “secure” according to the Northwest Territory General Status Ranking Program (WGGS 2016).

Lake Whitefish was the most abundant species caught with 14 captures with Northern Pike the second most abundant, with 11 captures (Table 7-4). Trout-perch were the least abundant species, with four captures. Relative abundance (standardized as CPUE) was highest for Lake Whitefish when gill netting, but highest for Northern Pike based on the other fishing methods (Table 7-5). Seine net CPUE was not presented in Table 4 because no fish were captured using seine nets. Detailed CPUE results are presented in Appendix F, Tables F-2 to F-6. Although considerable effort was made towards capturing both small and large-body fish (Table 7-1), electrofishing, seine netting, and minnow trapping yielded no small-body fish captures (Table 7-4).

7.5.3 Fish Population Data

Measurements and life stage estimates from fish captured in Jackfish Lake are provided in Table 7-7. Individual length and weight measurements along with additional observation notes are provided in Appendix F, Table F-7. Complete internal assessments were conducted on one lethally-sampled Northern Pike (out of a total lethal catch of three) and seven lethally-sampled Lake Whitefish (out of a total lethal catch of ten). Sex and life-stage were recorded for all lethally-sampled fish. Most fish captured were adult and there was an equal distribution of males to females. Examinations yielded no body deformities, no obvious signs of gas bubble trauma, and no parasites such as tapeworms. All Lake Whitefish had substantial mesenteric fat and an average of 93% stomach fullness (Photograph 4). Most adult Northern Pike caught or observed appeared slender (Photograph 5).

Photograph 4: A rotund adult Lake Whitefish caught in Jackfish Lake with a Gill Net, July 2018

Photograph 5: A slender-shaped adult Northern Pike caught in Jackfish Lake with a Gill Net, July 2018

Table 7-4: Number of Fish Captured by Gear Type, Jackfish Lake, July 2018

Species	Electrofishing	Gill Net	Minnow Traps	Angling	Total Number	Abundance (% total catch)
Northern Pike	1	5	1	4	11[(a)]	38
Lake Whitefish	0	14	0	0	14	48
Trout-perch	0	4	0	0	4	14
Total	1	23	1	4	29	100

(a) An additional nine fish were observed.

Table 7-5: Fish CPUE Summary of Jackfish Lake, July 2018

Species	Electrofishing	Gill Netting	Minnow Trapping	Angling
	# Fish/100 s	# Fish/100 m²/h	# Fish/h	# Fish/angler/h
Northern Pike	0.04	0.05	0.45	1.27
Lake Whitefish	0	0.13	0	0
Trout-perch	0	0.04	0	0
All species	0.04	0.21	<0.01	1.27

CPUE = catch-per-unit-effort.

Table 7-6: Fish Length and Weight Summary, July 2018

Species	Sample Size	Fork Length (mm)			Total Length (mm)			Weight (g)			Life Stages Captured
		Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	
Northern Pike	11	89	637	493	95	684	539	8	1,090	719	Adult/Juvenile
Lake Whitefish	14	316	515	450	336	571	489	510	2,328	1,663	Adult/Juvenile
Trout-perch	4	48	82	63	54	90	68	1.2	5.5	3	Adult/Unknown

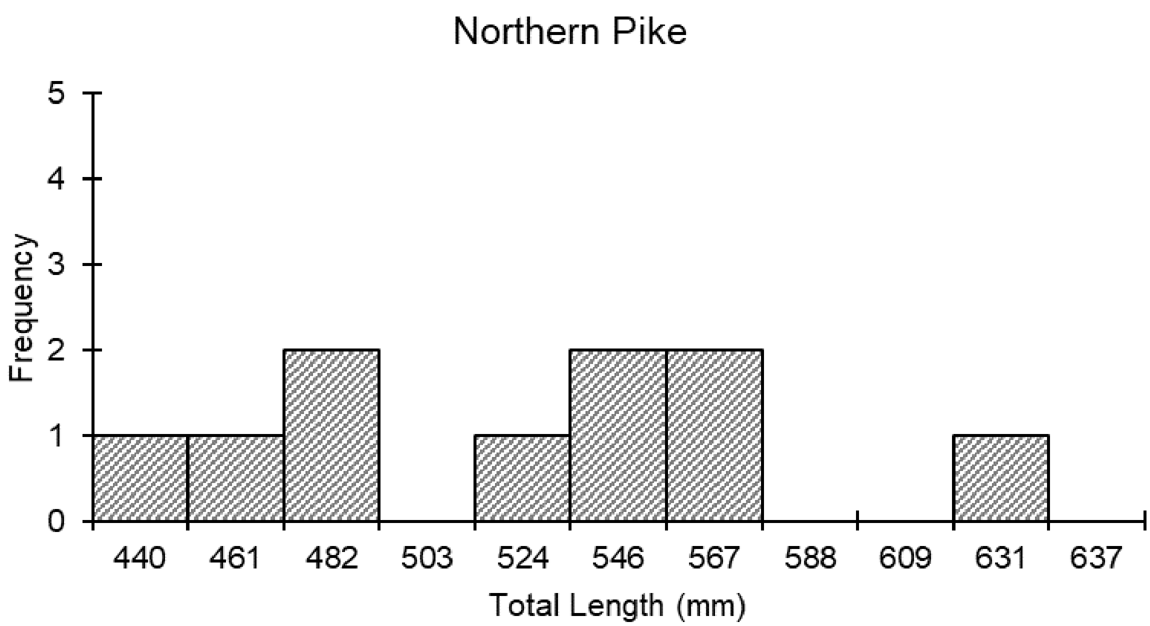
Notes: Min = minimum, Max = maximum, Avg = average.

7.5.3.1 Length-Frequency and Length-Weight Analyses

Length-Frequency Distribution

The length-frequency distribution sampled fish was calculated. Northern Pike show three adult size classes amongst the sampled fish (Figure 7-2) with an additional juvenile outlier not shown on the plot (Photograph 5). While one sample is limiting, the presence of the juvenile of a standard body conditions suggests successful reproduction by Northern Pike in the Jackfish Lake in 2018. Captured Lake Whitefish were of two potential size classes (Figure 7-3). Three sizes classes of Trout-perch were captured (Figure 7-4; Photograph 6).

Figure 7-2: Length-Frequency Distribution of Northern Pike Caught in Jackfish Lake, July 2018



Note: Histogram excludes one juvenile Northern Pike

Figure 7-3: Length-Frequency Distribution of Lake Whitefish Caught in Jackfish Lake, July 2018

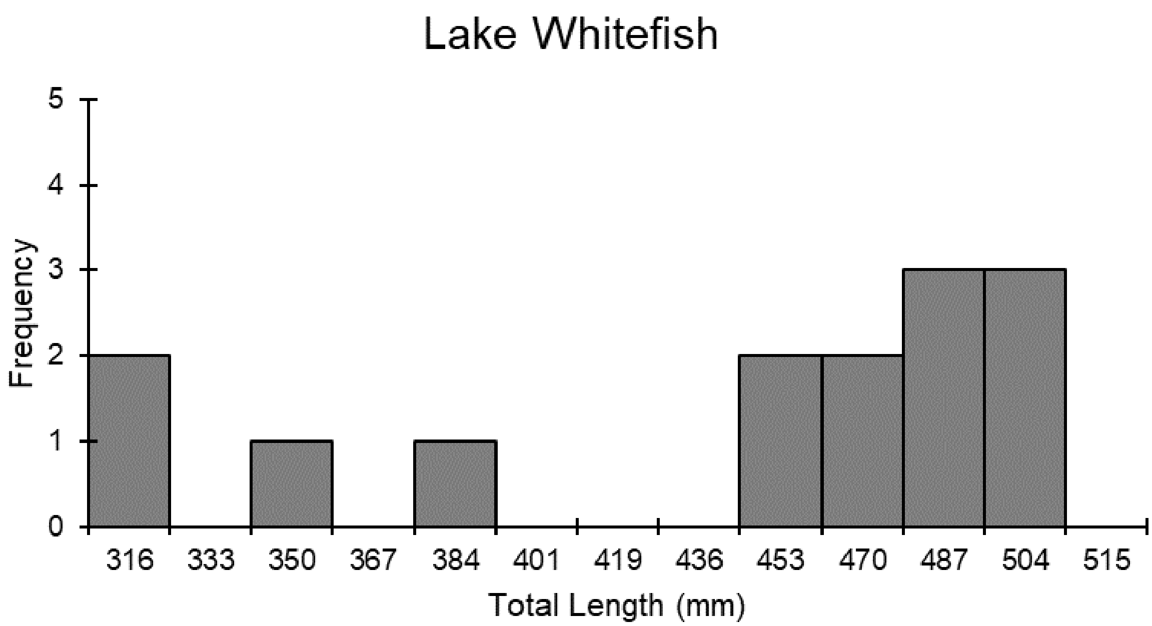
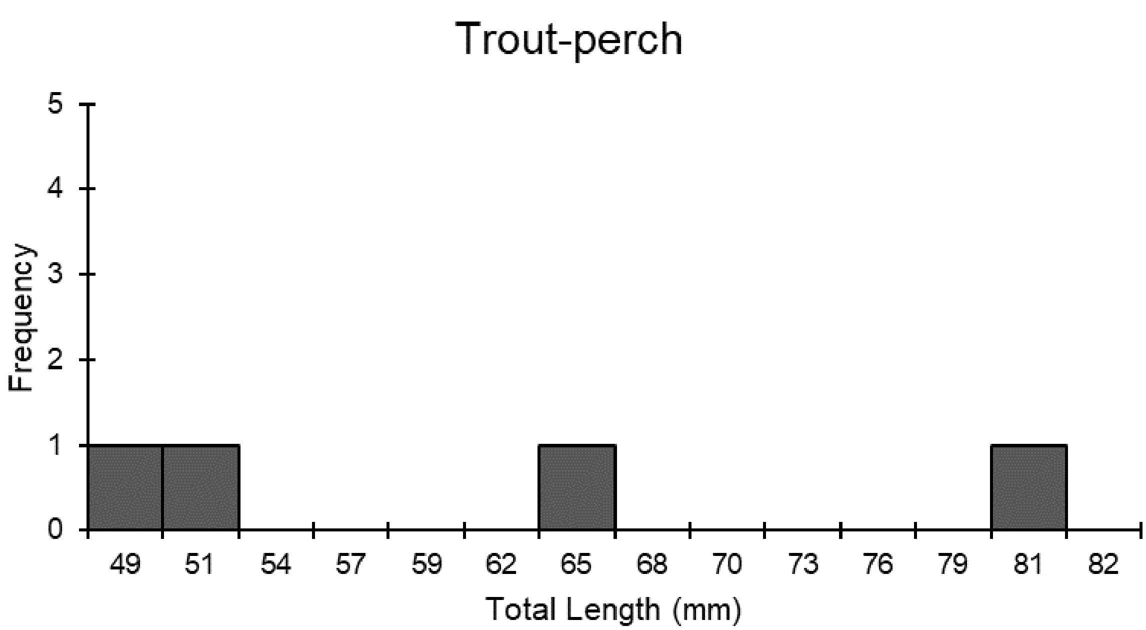


Figure 7-4: Length-Frequency Distribution of Trout-perch Caught in Jackfish Lake, July 2018



Photograph 6: Three Size Classes of Trout-perch Caught in Jackfish Lake by Gill Net, July 2018

Length-Weight Relationship

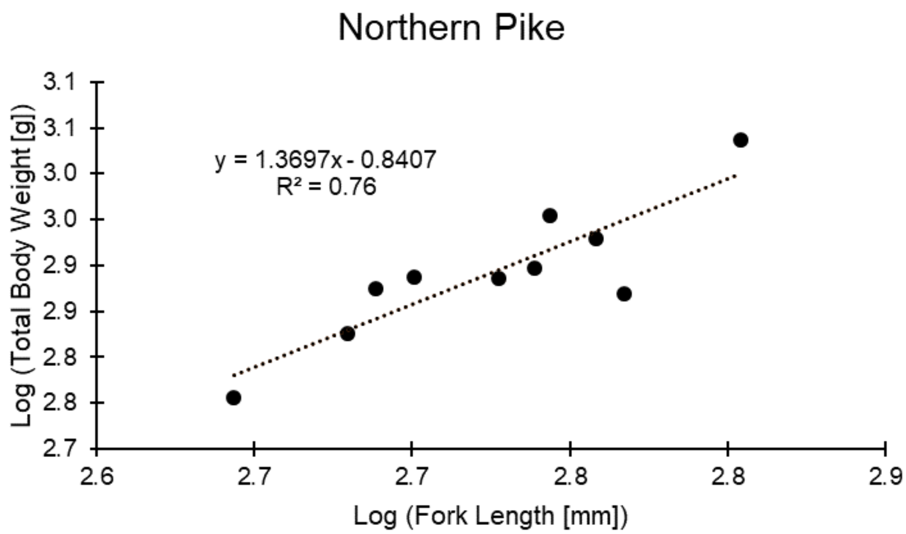
Regression models were plotted to show the relationship between fork length and total body weight of the fish species populations collected. The data was log transformed prior to plotting. Northern Pike was plotted excluding an outlier (Photograph 7). The fish populations of Jackfish Lake can be described by the formulas in Table 7-7, calculated from the relationships (Figures 7-5 to Figure 7-7). Regression models were limited by the small sample sizes and should be interpreted with caution.

Table 7-7: Summary of the Length-Weight Relationships for the Fish Populations of Jackfish Lake, July 2018

Fish Species	Relationship	R^2
Northern Pike	y = 1.3697x - 0.8407	0.76
Lake Whitefish	y = 3.1379x - 5.1375	0.98
Trout-perch	y = 2.9054x - 4.7975	0.98

The R^2 values represent the goodness of the fit of the data within the relationships.

Figure 7-5: Log Transformed Length-weight Relationship of 13 Northern Pike from Jackfish Lake, July 2018



Note: Figure excludes one juvenile Northern Pike

Figure 7-6: Log Transformed Length-weight Relationship of 11 Lake Whitefish from Jackfish Lake, July 2018

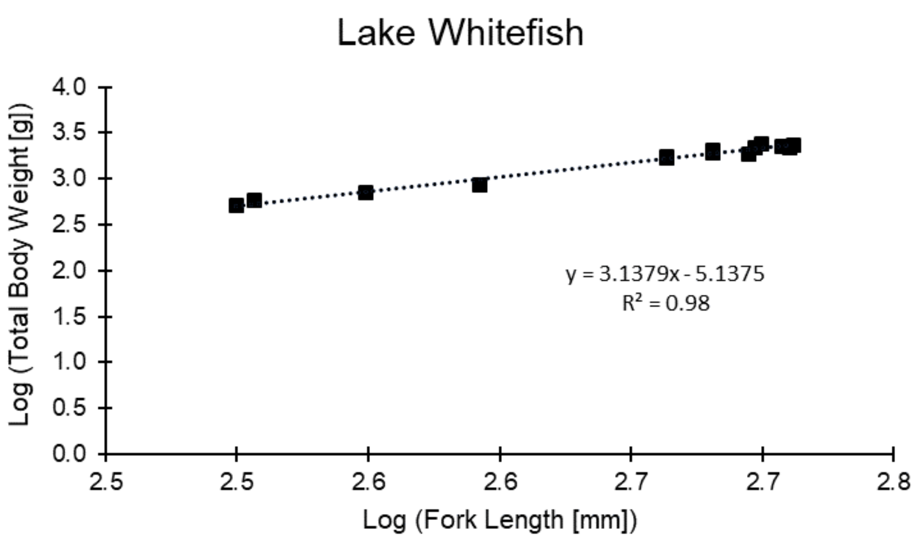
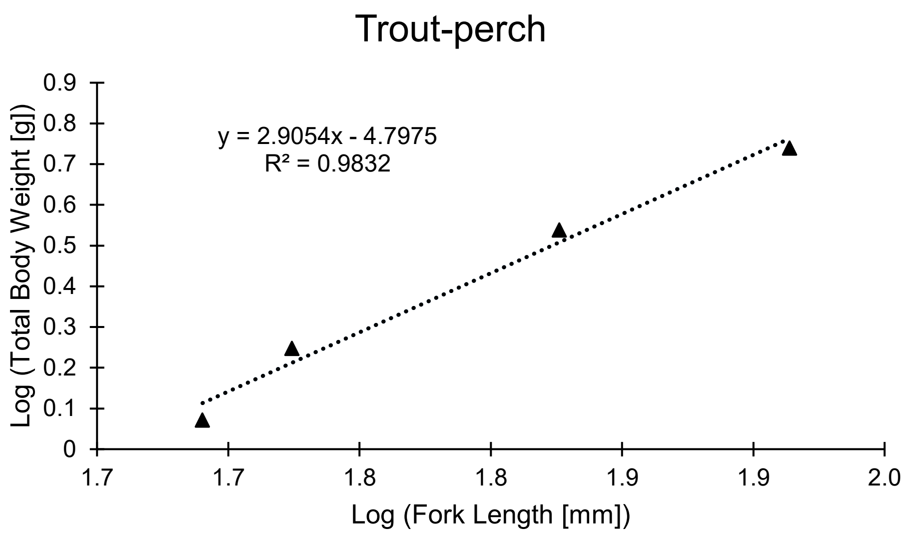


Figure 7-7: Log Transformed Length-weight Relationship of four Trout-perch from Jackfish Lake, July 2018



Photograph 7: Juvenile Northern Pike Outlier Caught in Jackfish Lake with a Minnow Trap, July 2018

7.5.3.2 Condition Factor

Fish were evaluated on the Condition Factor (K), where the K value will be 1.0 for fish whose weight is equal to the cube of its length. Lake Whitefish found in Jackfish Lake are rotund (Appendix F-7) with an average Condition Factor for the 14 sampled Lake Whitefish of 1.7, with a range from 1.4 to 1.9. Based on four samples, Trout-perch appeared to be of normal condition, with an average *K* value of 1.08. The condition of Northern Pike was more variable. Based from 11 samples, Northern Pike had an average *K* value of 0.72 that ranged from 0.37 to 1.13. It should be noted that the median *K* value for Northern Pike was 0.53, and that the fish with the 1.13 *K* value was a juvenile (Photograph 5).

7.5.4 Fish Tissue Chemistry

Tissue samples were analyzed for three Northern Pike and seven Lake Whitefish (Appendix F, Table F-8). Mercury concentrations for all fish were below the CFIA (2018) guideline of 0.5 mg/kg ww. Most of parameters' concentrations were higher in Northern Pike than in Lake Whitefish.

7.5.5 Thermal Effects on Fish

Water temperature ranges differed whether measured immediately at the Jackfish Facility discharges, near the discharges, or further away from the discharges (Section 3). The thermal effect on fish depends on temperature ranges:

- At the discharges: maximum temperatures ranging from 27.6ºC to 34.8ºC were documented. These maximums exceeded the documented lethal temperature thresholds for Northern Pike and Lake Whitefish and the critical thermal maxima (CTMax) of Trout-perch (Environment Canada 2014, Hasnain et al. 2012, Table 7-8).
- Near the discharges: water temperatures decreased in the area around the discharges, to a maximum of 23.1°C. These maximums do not exceed the documented lethal temperature thresholds for Northern Pike and Lake Whitefish but exceeded the CTMax of Trout-perch (Environment Canada 2014; Hasnain et al. 2012, Table 7-8).
- Further from the discharges: temperatures reached a maximum of 22.0°C. These temperatures did not exceed the documented lethal temperature thresholds for Northern Pike or Lake Whitefish, or the CTMax of Trout-perch.

In summary, water temperature within the discharge pipe may be lethal to fish but did not exceed the lethal thresholds around the discharges. Fish have access to cooler, deeper waters.

Table 7-8: Temperature Thresholds of the Fish Species Found in Jackfish Lake, July 2018

Fish Species	Life Stage	Upper LT50 [(a)] (˚C)	UILT [(b)] (˚C)	CTMax [(c)] (˚C)
Northern Pike	Larvae	24.8	31.0	-
	Juvenile	33.0		
Lake Whitefish	Young-of-year	26.65	23.9	-
Trout-perch	-	-	-	22.9

(a) Lethal temperature for 50% of the population (Environment Canada 2014)
(b) Upper incipient lethal temperature, no stage specified (Hasnain et al. 2012)
(c) Critical thermal maxima, no stage specified (Hasnain et al. 2012)
LT50 = lethal temperature for 50% of the population; UILT = Upper incipient lethal temperature; CTMax = Critical thermal maxima.

7.6 Summary and Conclusions

The findings of the 2018 fish community and fish tissue chemistry survey are summarized below:

- The fish survey documented three species of fish in Jackfish Lake: Northern Pike, Lake Whitefish, Trout-perch. The captured Lake Whitefish were mostly adults in good body conditions with full stomachs. Northern Pike adults were also captured but were slender; one juvenile or young-of-year Northern Pike was captured suggesting reproduction is occurring in the lake.
- Water levels were high during the study due to heavy local rains which created poor water clarity; these conditions reduced the efficacy of the fish sampling and habitat observations. Under these conditions, gill netting was the most effective tool for capturing a broad range of fish species.
- Northwest Bay North and Northeast Bay both had shorelines with abundant grasses, whereas West Bay had mostly rocky shoreline and Southwest Bay had significantly rocky shoreline. East Bay was flooded with substantial presence of woody debris and grasses.
- Mean total dissolved gas concentrations were lower than threshold of 110%. Brief external assessments of fish did not document evidence of gas bubble trauma.
- Mercury tissue concentrations in Lake Whitefish and Northern Pike were below CFIA (2018) guidelines.
- Water temperature in the immediate vicinity of the discharge is high enough that it could cause effects to fish at various life stages.

8.0 SUMMARY

Aquatic environmental components were monitored in Jackfish Lake in 2018. This included water temperature of intake and discharge of the Jackfish Facility, in-lake temperature, lake bathymetry, water quality, plankton and benthos communities as well as fish.

Water Depth and Temperature

The water surface elevation of Jackfish Lake was measured to have varied a total of 0.653 m over the monitoring period. Periods of rainfall correlated with increased water surface elevations in Jackfish Lake, and water surface elevation followed a similar trend as the cumulative rainfall.

For much of the monitoring period, the water level exceeded the upstream invert of the outflow culvert, but no outflow to Great Slave Lake via this culvert was observed. This suggests there is some topography upstream of the culvert that controls lake outflow.

Jackfish Lake had an average depth of 5.0 m and a maximum depth of 7.8 m based on a limited number of measurements.

In 2018, water temperature ranged from <1°C to 21.6°C at Jackfish Facility intakes, and 0.9°C to 34.8°C at Jackfish Facility discharges. Discharge temperature is in part related to facility activity and temperatures near the discharges are warmer than other areas of the lake.

In-lake temperatures ranged from <1°C to approximately 23°C. Summer temperature stratification was observed in the deeper areas of the lake; shallower areas were more uniform in temperature during the summer. Seasonal maximum lake temperature was observed between mid-July and mid-August. Temperatures in the immediate area surrounding the water discharges were generally warmer than other lake areas, and were warmer throughout the water column during periods with and without power generation. Bottom temperatures in Mid-Lake remained cooler than other areas of the lake, even during periods of power generation. The temperature profile is typical of lakes in this region, except in the area near the discharges which is warmer than the rest of the lake.

Water Quality

Jackfish Lake is a hard-water, alkaline lake, with moderate TDS concentrations and low to moderate concentrations of TSS. It is a eutrophic to hyper-eutrophic lake based on concentrations of TP, chlorophyll *a*, and Secchi depth measurements in 2018. Mean TP concentration in Jackfish Lake ranged from 0.065 (August) to 0.111 mg-P/L (September). Likely potential sources of total phosphorus to Jackfish Lake are internal loading from lake sediments and loading from runoff. During stratified conditions in July and August, dissolved phosphorus concentrations were notably higher near the lake bottom compared to the lake surface at the mid-lake station. Increases in concentrations of all forms of phosphorus occurred throughout the lake after fall turnover (in September) relative to stratified conditions, suggesting internal loading of phosphorus from lake sediments.

Vertical gradients in DO concentration were observed during all sampling events in Jackfish Lake except September. The lowest DO concentrations in Jackfish Lake occurred near the bottom of the lake. During summer (July and August), Jackfish lake was thermally stratified. This can limit re-oxygenation of bottom waters, which are also subject to oxygen demand from sediments due to biological activity. Accordingly, low DO concentrations were observed at the bottom at most stations in July and August in 2018. In December, a slight vertical DO gradient in temperature was evident at all stations in Jackfish Lake. Total dissolved gases were below water quality guidelines.

Concentrations of most water quality parameters were below CWQGs or within guideline ranges, with the exception of concentrations of DO at the lake bottom during summer, nitrite on one occasion, and three metals (total arsenic and copper; elevated zinc concentrations are considered anomalous). Arsenic concentrations have historically been above the CWQG in Jackfish Lake and in the lakes around Yellowknife due to the historical contamination from mining in the area. These high total arsenic concentrations have the potential to affect aquatic life in Jackfish Lake but are not related to the discharges from the Jackfish Facility. The high copper concentrations were observed near or within the discharge, indicating that the discharge may be influencing copper concentrations in the immediate vicinity of the discharge. However, there was only three 2018 concentrations of total copper above the CWQG in Jackfish Lake in the immediate area around the outlets and the risk to aquatic life in Jackfish Lake from the copper concentrations observed in Jackfish Lake in 2018 is considered low. Historical concentrations of total copper have also been above the CWQG. A qualitative comparison of water quality in Jackfish Lake in 2018 to water quality data collected in 1987, 2014, 2015, and 2017 showed no clear changes over time in water quality in Jackfish Lake.

Plankton and Algal Bloom Monitoring

The phytoplankton community in Jackfish Lake was dominated by cyanobacteria in 2018. There was a lack of a clear spatial difference in temperature and phytoplankton abundance and biomass among stations, which suggests that the discharge from the Jackfish Facility is not the main factor affecting the phytoplankton community in the lake. Thermal effects on phytoplankton communities are similar to those observed when nutrients are in excess in a waterbody (Wetzel 2001), which is the case in Jackfish Lake.

During natural thermal stratification in eutrophic lakes, with low DO concentrations in the sediments, phosphorus may be released from the sediments into lake water, which can lead to high phosphorus concentrations in the hypolimnion. Mixing of the water column, usually during spring or fall turn-over, can release phosphorus from the hypolimnion to the entire water column, which can provide a new influx of the limiting nutrient to the surface water layer. Thermal discharges can extend this thermal stratification period, allowing a prolonged release of phosphorus into the hypolimnion, which can result in a large influx of nutrients into the water column in the spring and fall. The influx of phosphorus in the euphotic zone of the lake can enhance algal growth, which can lead to nuisance blooms. Water quality results suggested that phosphorus was released from sediments to lake water during stratified conditions in Jackfish Lake in 2018.

Chlorophyll *a* concentrations in Jackfish Lake correspond to the low to mid-range of the bloom conditions and dominance in the lake was characterized by a single species; therefore, the conditions in Jackfish Lake in 2018 are considered representative of bloom conditions. However, the cyanobacterial biomass did not reach a point where it is a visual nuisance (i.e., discolouration of the waterbody beyond typical conditions or presence of scums).

Benthic Invertebrates

The community in Jackfish Lake was dominated by chironomids (midges) and similar in composition to those observed in lentic environments in the NWT. In 2018, the benthic invertebrate community included a number of common taxa that are tolerant of increases in temperature and environmental disturbances in general, such as the chironomid genera *Tanypus, Procladius*, and *Chironomus*, aquatic mites, and oligochaete worms.

There was a visually consistent response of most benthic invertebrate endpoints (i.e., density and richness) to near-bottom DO concentrations measured during the July and August field surveys. As the life cycles of benthic invertebrates can extend over one or more years, the effects of the previous year's or season's oxygen depletion events would be reflected in the current community. Historical data also suggest that the low oxygen levels in the summer may be a regular occurrence in Jackfish Lake.

Fish

Three species of fish were documented in Jackfish Lake in 2018: Lake Whitefish, Northern Pike, and Trout-perch. The captured Lake Whitefish were mostly adults in good body conditions with full stomachs. Northern Pike adults were also captured but were slender; one juvenile or young-of-year Northern Pike was captured suggesting reproduction is occurring in the lake. Mercury tissue concentrations in Lake Whitefish and Northern Pike were below CFIA (2018) guidelines. Mean total dissolved gas concentrations were lower than threshold of 110%. Brief external assessments of fish did not document evidence of gas bubble trauma. Water temperature in the immediate vicinity of the discharge is high enough that it could cause effects to fish at various life stages. Based on one year of observation, thermal effects on the fish population are not likely because access to deeper, cooler water in the lake is available for fish.

Table 8-1: 2018 Jackfish Lake Environmental Monitoring Summary

Component	Objective	Summary
Water Temperature	determine the range of temperatures observed at the intakes and discharges and in Jackfish Lake	■ water temperature at the intakes ranges from <1°C to 21.6°C ■ water temperatures at the discharges ranged from <1°C to 34.8°C ■ water temperatures at the discharge were typically warmer than at the intakes, to a maximum difference of 23.7°C ■ discharge temperatures increased with plant facility activity
	quantify the temperature distribution of Jackfish Lake to help support biological monitoring components of this project	■ water temperature ranged from <1°C to 23.1°C in Jackfish Lake at the Southwest Bay station, away from the Jackfish Facility ■ temperatures near the discharges are warmer than other areas of the lake ■ temperature continues to be monitored for 2019
Water Level	record one year of water level data for Jackfish Lake	■ 0.653 m variation ■ periods of rainfall correlated with increased water surface elevations in Jackfish Lake, and water surface elevation followed a similar trend as the cumulative rainfall ■ exceeded the upstream invert of the outflow culvert, but no outflow to Great Slave Lake via this culvert was observed ■ bathymetry average depth of 5.1 m and a maximum depth of 7.8 m
Water Quality	characterize water quality in Jackfish Lake	■ alkaline lake, hard water, moderate TDS, low to moderate TSS, low sensitivity to acidification ■ total phosphorus concentrations indicated that the lake was eutrophic to hypereutrophic ■ water quality parameters were within CWQGs except DO, nitrite, and total arsenic, copper and zinc ■ vertical patterns were observed in pH, temperature and DO concentrations in multiple months, but not in September ■ seasonal trends were observed for pH, DO, specific conductivity, calculated TDS, total alkalinity, chloride, calcium, sodium, most nutrients and manganese ■ seasonal trends attributed to seasonal changes in temperatures, natural variation in lake volume due to spring melt, precipitation and evaporation, and biological uptake of nutrients ■ no clear changes in water quality in Jackfish Lake have occurred relative to historical data

Table 8-1: 2018 Jackfish Lake Environmental Monitoring Summary

Component	Objective	Summary
	assess the potential for water quality in Jackfish Lake to be influenced by the Jackfish Facility discharges	■ water quality at mid-depth, or within the euphotic zone for nutrients, across Jackfish Lake were typically similar during each field program ■ no whole-lake water quality changes from the Jackfish Facility discharges were observed ■ discharges from the Jackfish Facility may be influencing copper concentrations in Jackfish Lake in the immediate vicinity of the discharges
Phytoplankton Community	characterize phytoplankton community in Jackfish Lake	■ eutrophic lake ■ cyanobacteria, notably *Planktothrix* sp were dominant
	begin to assess whether the phytoplankton community is affected by Jackfish Facility discharges	■ no clear spatial difference in phytoplankton abundance and biomass ■ discharges likely not the main factor affecting the phytoplankton community, rather effects on phytoplankton communities may be due to nutrient excess and physical characteristics of the lake
	monitor Jackfish Lake for phytoplankton blooms	■ no visual observations triggered an algal response program. ■ concentrations of chlorophyll *a* in Jackfish Lake were representative of bloom conditions
Benthic Community	characterize the benthic community in Jackfish Lake	■ chironomid-dominated ■ low densities and richness ■ consistent with regional data ■ low benthic invertebrate densities may be associated with low summer bottom DO
	begin to assess whether the benthic invertebrate community is affected by Jackfish Facility discharges	■ no spatial trends were apparent in relation to the discharge location
Fish Community and Fish Tissue Chemistry	document Jackfish Lake's current fisheries	■ Northern Pike, Lake Whitefish, Trout-perch were documented ■ Lake Whitefish in good condition, Northern Pike were slender ■ mercury tissue concentrations in Lake Whitefish and Northern Pike were below CFIA (2018) guidelines
	provide information to evaluate effects of the cooling system on the fish in Jackfish Lake	■ water temperature water temperature within the discharge pipe may be lethal to fish but did not exceed the lethal thresholds around the discharges. ■ fish have access to cooler, deeper waters mean total dissolved gas concentrations were lower than threshold of 110% ■ no evidence of gas bubble trauma

Notes: CWQG = Canadian Water Quality Guideline; CFIA = Canadian Food Inspection Agency; DO = dissolved oxygen; TDS = total dissolved solids; TSS = total suspended solids

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APPENDIX A

Water Temperature, Water Level and Meteorological Data and Figures

Legend:

- HOBO Pendant MX installed, data available
- Onset Tidbit v2 installed, data available
- Logger installed, but data not available
- Downloaded

Station	Position	March 7, 8 - In-Lake Logger Deployment	April 9 - Thermistor Logger Installed	May 29, 30 - May Field		June 26 - Logger Troubleshoot	July 10, 11 - July Field		August 1, 2 - August Field		September 20 - CAT Thermistor Damaged	September 26, 27 - September Field		December 11 - 13 - December Field	
CAT	Top	20287696			20287696			20287696		20287696			20287696		20287696
	Mid	20317261			20317261			20317261		20317261			20317261		20317261
	Bottom	20317263			20317263			20317263		20317263			20317263		20317263
EMD	Top	20317274			20317274			20317274		20317274			20317274		20317274
	Mid QC	20317273			20317273			20317273		20317273			20317273		20317273
	Mid	20287695			20287695			20287695		20287695			20287695		20287695
	Bottom	20317275			20317275			10343208		10343208			10343208		20427410
K	Top	20287692				10367979		10367979		10367979			10367979		20317272
	Mid	20317268			20317268			20317268		20317268			20317268		20317268
	Bottom	20317271			20317271			20317271		20317271			20317271		20317271
NW Bay South	Top	20317260			20317260			10343202		10343202			10343202		20317260
	Mid	20317272			20317272			10343194		10343194			10343194		20427409
	Bottom	20317270						10343195		10343195			10343195		20427414
Southwest	Top	20317264			20317264			20317264		20317264			20317264		none installed
	Mid	20317262			20317262			20317262		20317262			20317262		20317262
	Bottom	20317266			20317266			20317266		20317266			20317266		20317264
Mid Lake	Top	20317259			20317259			20317259		20317259			20317259		20317259
	Mid 1	20309920				2421371		2421371		2421371			2421371		20427411
	Mid 2	20317265				10105803		10105803		10105803			10105803		20427412
	Bottom	20317269				10367973		10367973		10367973			10367973		20427413
Thermistor	K Intake 1	Logger not Installed	TS4667		TS4667			TS4667		TS4667			TS4667		TS4667
	K Intake 2		TS4668		TS4668			TS4668		TS4668			TS4668		TS4668
	EMD Intake		TS4665		TS4665			TS4665		TS4665			TS4665		TS4665
	CAT Intake		TS4670		TS4670			TS4670		TS4670			TS4670		TS4670
	K Discharge		TS4669		TS4669			TS4669		TS4669			TS4669		TS4669
	EMD Discharge		TS4666		TS4666			TS4666		TS4666			TS4666		TS4666
	CAT Discharge		TS4671		TS4671			TS4671		TS4671			TS4671		TS4671

Figure A 1: In-Lake Temperature Data Logger and Thermistor Information, Installation and Download Dates and Data Availability, 2018

Table A-1: Raw Data from Thermistors, Jackfish Lake 2018

Table A-2_Jackfish 2018 Compiled thermistor data.xlsx is available upon request.

Table A-2: Raw Data From the In-Lake Temperature Loggers, Jackfish Lake 2018

Table A-1_Jackfish 2018 Compiled logger data.xlsx is available upon request.

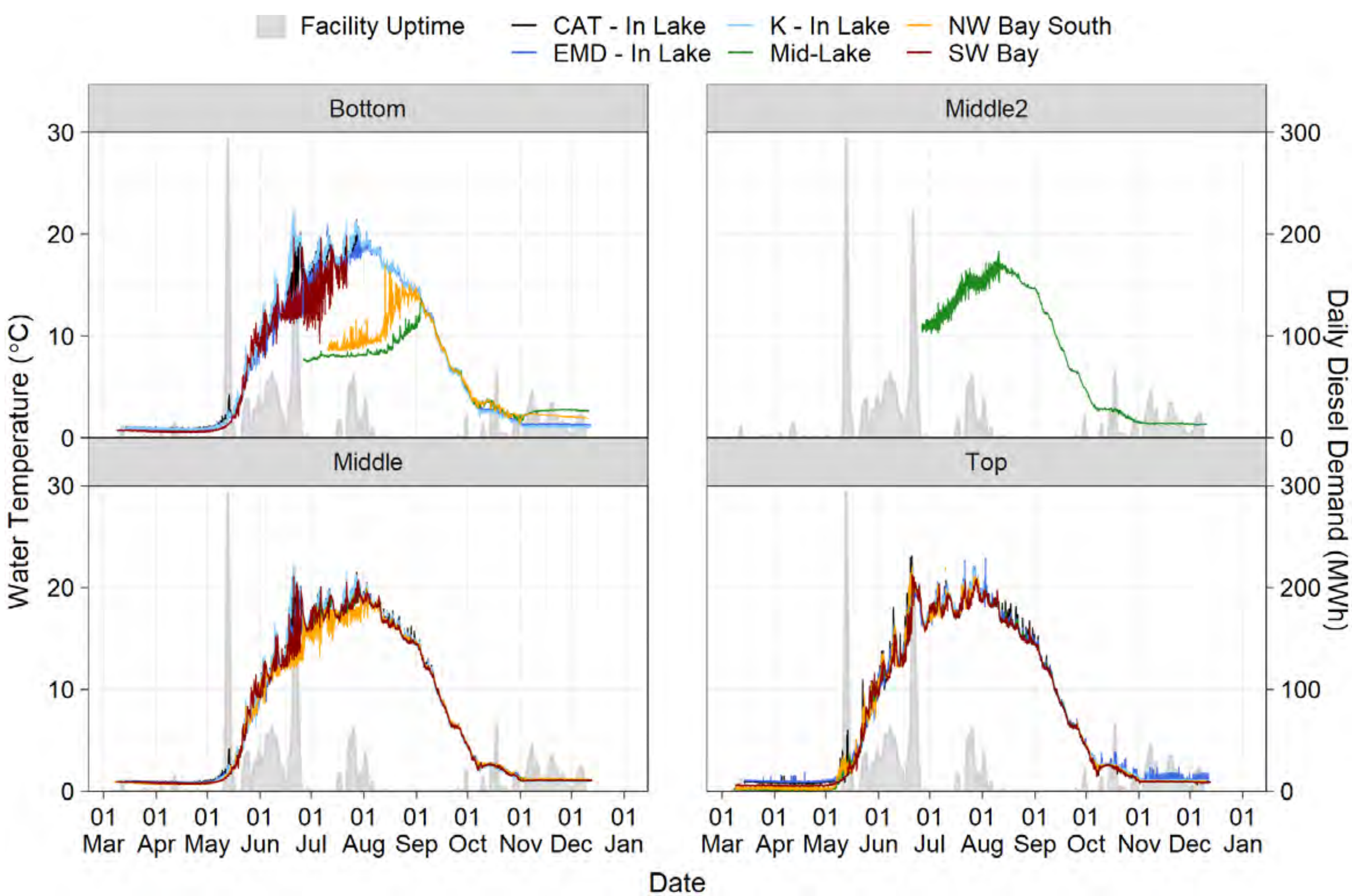


Figure A-2: Temperature Measured by In-Lake Temperature Monitoring Stations in Jackfish Lake by Station, 2018

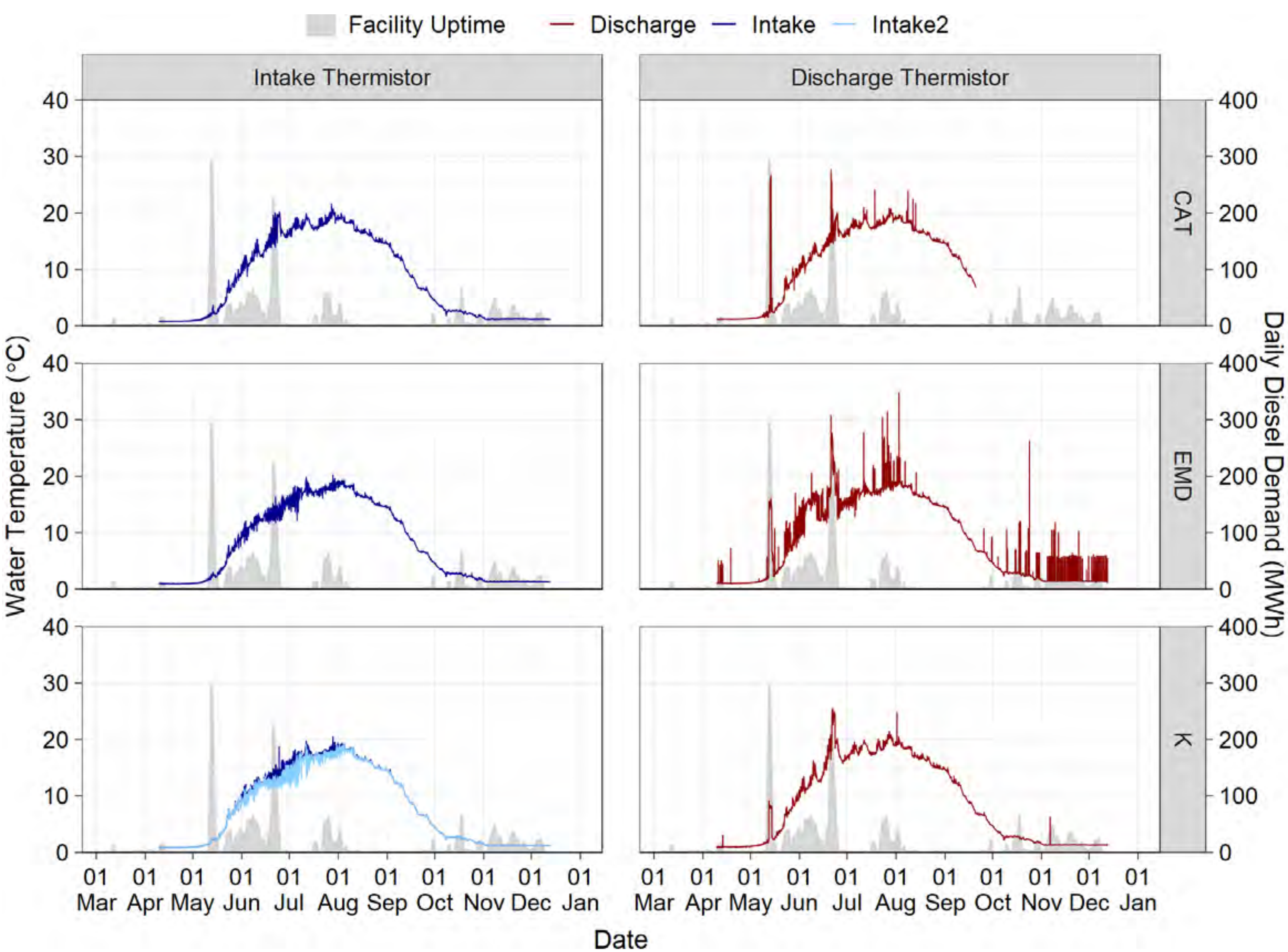


Figure A-3: Temperature Measured by Thermistors at Facility Intakes and Discharges in Jackfish Lake, 2018

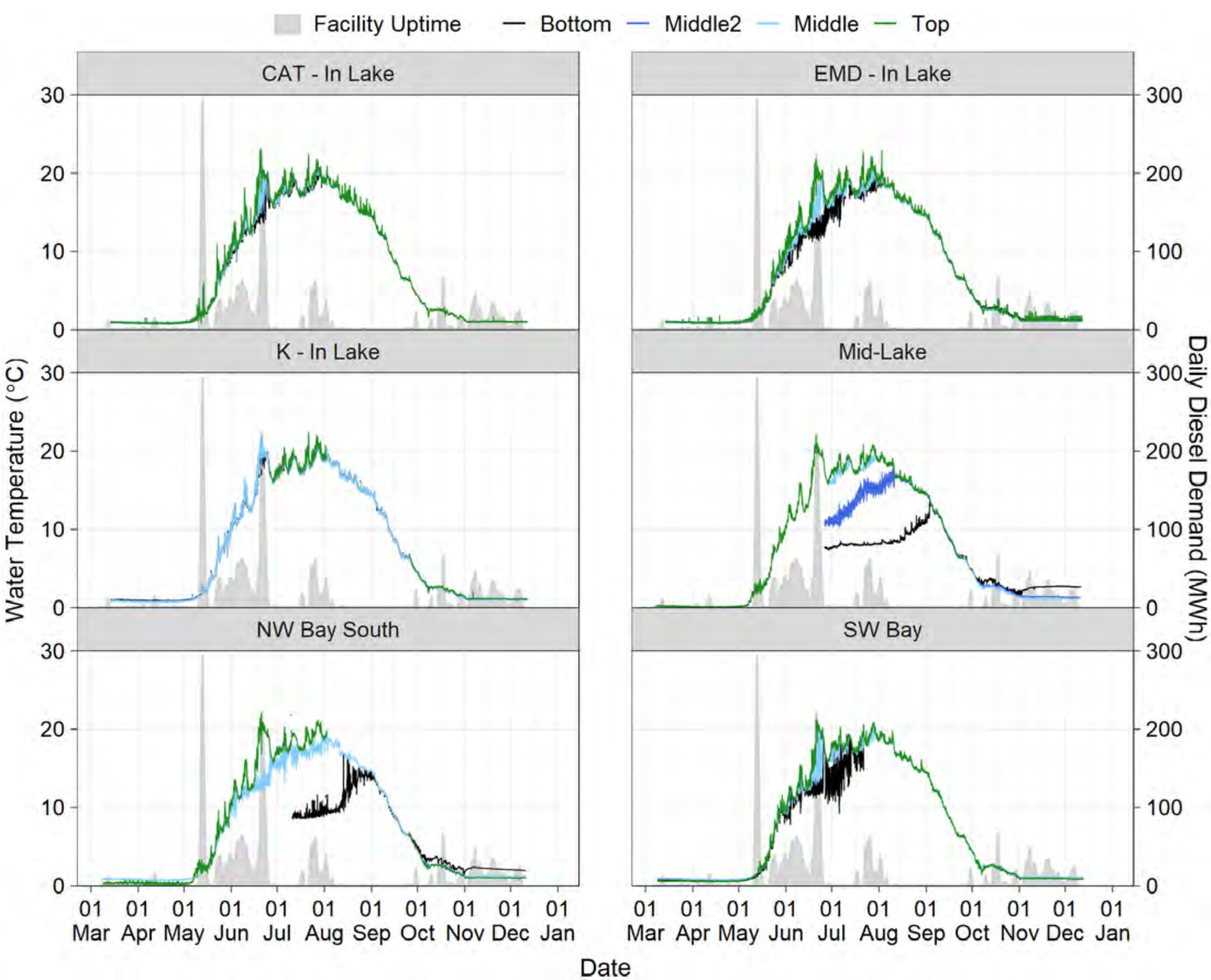


Figure A-4: Temperature Measured by In-Lake Temperature Monitoring Stations in Jackfish Lake by Position, 2018

Table A-3: Daily Mean Water Surface Elevation at Jackfish Lake, 2018

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	ND	ND	ND	173.907	173.949	174.079	174.396	174.538	174.531	174.466	174.468	174.490
2	ND	ND	ND	173.903	173.957	174.077	174.426	174.536	174.530	174.466	174.473	174.492
3	ND	ND	ND	173.904	173.962	174.074	174.439	174.536	174.525	174.461	174.478	174.493
4	ND	ND	ND	173.909	173.966	174.071	174.446	174.531	174.522	174.461	174.475	174.488
5	ND	ND	ND	173.908	173.972	174.067	174.454	174.531	174.517	174.460	174.471	174.487
6	ND	ND	ND	173.906	173.982	174.066	174.469	174.537	174.515	174.459	174.471	174.493
7	ND	ND	ND	173.907	173.991	174.065	174.469	174.542	174.515	174.458	174.475	174.490
8	ND	ND	ND	173.910	174.014	174.067	174.470	174.541	174.512	174.460	174.478	174.492
9	ND	ND	ND	173.909	174.034	174.070	174.472	174.540	174.509	174.461	174.479	174.494
10	ND	ND	ND	173.905	174.046	174.072	174.474	174.549	174.507	174.462	174.478	174.497
11	ND	ND	ND	173.906	174.056	174.100	174.476	174.545	174.501	174.462	174.478	174.496
12	ND	ND	ND	173.905	174.063	174.143	174.474	174.539	174.499	174.458	174.479	174.499
13	ND	ND	173.920	173.912	174.066	174.166	174.495	174.538	174.497	174.459	174.482	ND
14	ND	ND	173.918	173.914	174.067	174.186	174.518	174.540	174.493	174.463	174.482	ND
15	ND	ND	173.916	173.912	174.072	174.200	174.529	174.543	174.492	174.461	174.479	ND
16	ND	ND	173.913	173.909	174.074	174.209	174.539	174.542	174.491	174.459	**174.475**	ND
17	ND	ND	173.914	173.912	174.077	174.214	174.547	174.542	174.492	174.461	174.474	ND
18	ND	ND	173.915	173.918	174.080	174.217	174.551	174.541	174.486	174.459	174.479	ND
19	ND	ND	173.916	173.919	174.083	174.217	174.553	174.544	174.484	174.459	174.481	ND
20	ND	ND	173.910	173.920	174.083	174.217	174.553	174.546	174.482	174.464	174.482	ND
21	ND	ND	173.902	173.918	174.084	174.216	174.554	174.545	174.481	174.462	174.488	ND
22	ND	ND	173.901	173.919	174.085	174.225	174.549	174.540	174.482	174.464	174.487	ND
23	ND	ND	173.907	173.920	174.085	174.249	174.546	174.537	174.481	174.463	174.480	ND
24	ND	ND	173.913	173.923	174.084	174.265	174.544	174.535	174.479	174.464	174.484	ND
25	ND	ND	**173.932**	173.923	174.085	174.268	174.542	174.533	174.478	174.465	174.490	ND
26	ND	ND	**173.910**	173.929	174.087	174.274	174.541	174.532	174.473	174.465	174.493	ND
27	ND	ND	**173.906**	173.934	174.086	174.310	174.540	174.530	174.469	174.464	174.493	ND
28	ND	ND	**173.899**	173.939	174.087	174.343	174.541	174.529	174.469	174.464	174.493	ND
29	ND	-	**173.899**	173.944	174.092	174.364	174.537	174.527	174.468	174.463	174.492	ND
30	ND	-	173.906	173.947	174.087	174.382	174.541	174.526	174.467	174.463	174.489	ND
31	ND	-	173.909	-	174.080	-	174.539	174.526	-	174.466	-	ND
Maximum	ND	ND	173.932	173.947	174.092	174.382	174.554	174.549	174.531	174.466	174.493	174.499
Mean	ND	ND	173.911	173.916	174.050	174.182	174.507	174.537	174.495	174.462	174.481	174.493
Minimum	ND	ND	173.899	173.903	173.949	174.065	174.396	174.526	174.467	174.458	174.468	174.487

Note: Elevations in table are in metres (geodetic); bolded values are days where erroneous Barologger readings were removed and interpolation between Barologger readings was used to fill gaps

- = day not present in month; ND = no data

Table A-4: Daily Mean Barometric Pressure at Jackfish Lake, 2018

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	ND	ND	ND	100.111	98.844	99.466	98.376	98.544	97.871	99.678	99.722	99.888
2	ND	ND	ND	100.376	98.015	99.427	99.215	97.886	98.453	98.879	99.265	99.881
3	ND	ND	ND	100.624	98.926	99.847	99.786	98.066	99.469	99.831	99.062	99.604
4	ND	ND	ND	100.709	99.286	99.842	99.789	99.197	99.294	99.982	99.331	99.977
5	ND	ND	ND	101.804	98.851	99.071	99.011	98.703	100.139	99.858	100.402	100.023
6	ND	ND	ND	101.227	98.667	98.773	98.092	97.903	100.358	100.460	100.914	99.079
7	ND	ND	ND	99.965	99.974	98.941	98.409	98.113	99.597	101.176	100.889	98.772
8	ND	ND	ND	99.531	99.637	98.749	98.456	98.067	99.799	101.040	100.572	98.324
9	ND	ND	ND	99.878	100.233	98.314	98.383	98.373	99.608	100.866	99.234	98.187
10	ND	ND	ND	100.295	99.351	97.512	98.116	97.900	98.644	99.906	100.192	97.246
11	ND	ND	ND	99.866	98.941	97.291	98.083	99.274	99.470	98.887	100.973	96.636
12	ND	ND	98.878	99.594	98.251	97.770	98.643	99.473	99.775	99.392	100.549	95.730
13	ND	ND	99.363	99.200	99.543	98.055	98.885	98.088	99.687	99.879	99.690	ND
14	ND	ND	99.021	98.861	99.575	98.029	99.466	97.383	100.065	98.354	99.647	ND
15	ND	ND	98.987	100.083	99.403	98.614	99.415	98.747	100.416	99.335	100.928	ND
16	ND	ND	99.319	100.508	100.330	99.048	98.398	98.584	100.350	99.855	**100.752**	ND
17	ND	ND	100.096	99.282	100.422	98.503	98.333	98.267	99.357	98.254	100.407	ND
18	ND	ND	99.818	98.707	99.822	99.263	99.204	99.160	99.833	98.872	100.134	ND
19	ND	ND	98.820	98.670	99.692	98.883	99.769	99.659	99.801	100.263	99.640	ND
20	ND	ND	99.671	98.377	99.206	98.928	99.887	99.363	100.225	97.700	99.594	ND
21	ND	ND	101.275	99.683	98.824	99.197	99.714	98.823	100.276	99.377	97.987	ND
22	ND	ND	101.555	99.739	98.214	98.760	100.321	99.100	99.433	99.357	98.057	ND
23	ND	ND	99.660	99.955	98.343	98.527	100.576	99.592	98.275	99.104	99.364	ND
24	ND	ND	98.601	98.768	98.821	98.402	100.210	99.217	98.908	98.979	99.931	ND
25	ND	ND	**99.361**	99.108	98.299	98.742	99.848	98.977	98.688	98.368	99.679	ND
26	ND	ND	**99.601**	99.325	98.104	98.154	99.515	99.284	99.610	97.696	98.919	ND
27	ND	ND	**99.370**	98.899	98.614	97.912	99.060	98.991	100.302	98.313	98.095	ND
28	ND	ND	**100.741**	98.547	98.375	98.309	99.134	98.380	99.892	99.061	98.095	ND
29	ND	-	**101.484**	99.236	98.744	98.815	99.780	98.476	100.562	99.302	98.616	ND
30	ND	-	101.094	98.908	99.527	98.461	100.096	98.339	99.852	99.305	99.222	ND
31	ND	-	100.524	-	99.797	-	99.483	97.728	-	99.104	-	ND
Maximum	ND	ND	101.555	101.804	100.422	99.847	100.576	99.659	100.562	101.176	100.973	100.023
Mean	ND	ND	99.862	99.661	99.117	98.653	99.208	98.634	99.600	99.369	99.662	98.612
Minimum	ND	ND	98.601	98.377	98.015	97.291	98.083	97.383	97.871	97.696	97.987	95.730

Note: Values in table are in kilopascals (kPa); bolded values are days where erroneous Barologger readings were removed and interpolation between Barologger readings was used to fill gaps

- = day not present in month; ND = no data

Table A-5: Daily Rainfall at Yellowknife-A Meteorological Station (Climate ID 2204101), 2018

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	0	0	0	0	0	15.2	0	6.8	0	0	0
2	0	0	0	0	0	0	1.4	1.6	0	0.4	0	0
3	0	0	0	0	0	0.3	0.4	0.2	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	1.1	8.7	2.9	0	0	0	0
6	0	0	0	0	0	0	ND	8.2	0	0	0	0
7	0	0	0	0	0	0	0	1	0	0	0	0
8	0	0	0	0	0	5.3	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	3.8	0	3.8	0.4	0	0	0
11	0	0	0	0	0	32.6	0	0	0	0	0	0
12	0	0	0	0	0	1.8	0.4	0	0	0	0	0
13	0	0	0	0	0	3.2	32.8	1	0	0	0	0
14	0	0	0	0	0	2.2	6	5.4	0	0	0	ND
15	0	0	0	0	0	0.4	2.4	0.6	0	0	0	ND
16	0	0	0	0	0	0	2.1	0	0	0	0	ND
17	0	0	0	0	0	0	0.2	0.6	0	0	0	ND
18	ND	0	0	0	0	0	0	6.2	0.2	0	0	ND
19	0	0	0	0	0	0	0	2	0	0	0	ND
20	0	0	0	0	0	0	0	0	0	3	0	ND
21	0	0	0	0	0	0.2	0	0	0	0	0	ND
22	0	0	0	0	0	13	0	1.2	0	0	0	ND
23	ND	0	0	0	0	17.6	0	0	0	0	0	ND
24	0	0	0	0	0	0.6	0	0	0	0	0	ND
25	0	0	0	0	3.4	0	0	0	0	0	0	ND
26	0	0	0	0	0	11	0	0	1.2	0	0	ND
27	0	0	0	0	0.4	21	0.4	0	0	0	0	ND
28	0	0	0	0	3.2	0	3.4	0	0.2	0	0	ND
29	0	-	0	0	1.6	0	4	0.4	0	0	0	ND
30	0	-	0	0	0	0	6.2	0	0	0	0	ND
31	0	-	0	-	0	-	2.6	3.6	-	0	-	ND
Total	0	0	0	0	8.6	114.1	86.2	38.7	8.8	3.4	0	0

Note: Values in table are in millimetres (mm)

Source: Environment and Climate Change Canada Yellowknife A (Climate ID 2204101) (EC 2018)

- = day not present in month; ND = no data

Table A-6: Daily Mean Air Temperature at Yellowknife-A Meteorological Station (Climate ID 2204101), 2018

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	-26.0	-32.3	-20.0	-16.2	-1.0	11.4	16.3	18.8	7.9	-0.8	-4.8	-14.5
2	-23.8	-33.4	-20.5	-20.9	5.2	16.3	17.3	17.5	7.2	-1.7	-3.4	-10.9
3	-20.3	-23.6	-17.6	-20.0	0.8	11.6	15.6	14.3	5.0	-4.7	-8.1	-10.0
4	-17.4	-20.9	-17.4	-13.6	-1.5	8.5	14.3	12.2	6.3	-4.5	-14.3	-14.8
5	-13.7	-26.2	-10.1	-16.1	2.1	5.2	18.1	12.3	2.8	-5.0	-17.6	-18.8
6	-11.7	-21.9	-12.0	-15.4	10.6	5.9	17.7	15.0	4.5	-3.8	-18.7	-13.2
7	-16.8	-21.6	-15.4	-12.9	5.8	10.5	12.5	16.4	11.3	-4.7	-14.5	-16.3
8	-26.7	-19.1	-16.7	-8.6	5.3	16.4	17.8	15.7	6.7	-4.0	-13.1	-12.7
9	-33.7	-13.1	-13.2	-13.1	2.5	16.1	19.1	17.1	3.9	-1.9	-11.3	-8.3
10	-34.3	-21.2	-10.1	-17.1	4.8	13.7	17.5	13.6	6.9	-1.0	-11.4	-6.1
11	-35.1	-30.3	-13.1	-15.1	5.9	10.5	20.0	12.3	0.6	-0.3	-12.9	-9.2
12	-36.4	-21.2	-4.5	-14.1	7.7	8.2	16.0	12.2	0.3	-4.6	-10.7	-10.3
13	-36.5	-25.7	-4.6	-4.2	0.8	11.4	14.4	13.8	1.6	-4.9	-12.1	-21.4
14	-31.1	-34.0	-3.9	0.7	-3.0	11.3	11.5	14.6	-0.6	1.9	-14.3	ND
15	-18.8	-28.2	-8.3	-5.9	0.8	14.0	12.0	11.4	-0.3	-1.4	-18.0	ND
16	-13.9	-20.7	-11.4	-8.3	1.5	14.0	15.3	15.4	2.9	-5.0	-22.4	ND
17	-13.4	-24.0	-10.3	-4.0	5.4	18.4	16.7	15.0	5.0	-0.8	-21.2	ND
18	-11.3	-26.0	-7.2	-8.3	8.5	19.7	16.1	13.3	-2.2	-3.0	-17.4	ND
19	-14.0	-26.7	ND	-5.1	7.0	21.1	16.9	10.2	-2.0	-5.1	-14.7	ND
20	-22.7	-30.5	-15.8	-1.3	8.4	22.3	ND	14.4	-0.3	2.5	-15.9	ND
21	-23.0	-18.6	-19.7	-6.1	11.1	20.8	17.2	14.3	0.3	-2.0	-12.4	ND
22	-19.8	-24.9	-21.4	-3.3	15.3	18.2	16.2	9.1	2.3	-1.6	-14.9	ND
23	-22.2	-17.4	-15.5	-5.0	18.2	16.8	16.3	8.1	4.8	-2.1	-22.8	ND
24	-26.2	-14.1	-18.6	1.2	12.1	17.6	14.9	10.9	1.4	-1.4	-19.4	ND
25	-28.3	-20.1	-23.1	-1.5	6.8	15.4	16.7	10.5	4.0	-0.2	-11.1	ND
26	-28.3	-20.8	-24.8	4.3	8.6	13.0	20.1	11.2	-0.8	0.7	-6.3	ND
27	-26.5	-15.0	-24.3	4.2	10.7	10.6	21.9	10.3	-3.2	-1.2	-5.7	ND
28	-29.4	-18.5	-28.6	4.3	9.2	12.0	ND	12.4	1.0	-1.5	-6.0	ND
29	-26.2	-	-28.1	0.2	9.0	13.8	13.4	9.9	-0.2	-3.1	-9.8	ND
30	-25.7	-	-17.1	-0.9	4.9	15.6	13.2	10.3	-1.1	-3.1	-15.1	ND
31	-31.9	-	-13.7	-	5.3	-	13.7	9.3	-	-3.4	-	ND
Maximum	-11.3	-13.1	-3.9	4.3	18.2	22.3	21.9	18.8	11.3	2.5	-3.4	-6.1
Mean	-24.0	-23.2	-15.6	-7.4	6.1	14.0	16.2	13.0	2.5	-2.3	-13.3	-12.8
Minimum	-36.5	-34.0	-28.6	-20.9	-3.0	5.2	11.5	8.1	-3.2	-5.1	-22.8	-21.4

Note: Values in table are in degrees Celsius (°C)

Source: Environment and Climate Change Canada Yellowknife A (Climate ID 2204101) (EC 2018)

- = day not present in month; ND = no data

APPENDIX B

Water Temperature and Level Quality Assurance/Quality Control

B.1 Deviations Due to Weather and Equipment

QA/QC checks were done on field equipment during each program. Minor deviations from the field plan were required to accommodate local weather effects on in-lake instruments including high wind, ice break-up and heavy rains in 2018:

- On 11 July 2018, high winds blew the EMD plant in-lake temperature data logger station onto shore (approximately 20 m); it was repositioned on 12 July 2018. The temperature data logged over this period were erroneous and were removed from the dataset.
- Longer strings for in-lake temperature monitoring stations at Southwest Bay and Northwest Bay South were constructed for deployment on 26 June 2018 in response to rising lake levels due to extensive local rainfall. Temperature data loggers (HOBO Pendant) were transferred to the new string. The Northwest Bay South station buoy was submerted and could not be located on 26 June 2018; it was replaced on 10 July 2018 with a longer string with a set of Onset Tidbit v2 loggers.
- During the monitoring period, displacement of the in-lake monitoring stations was observed. After spring ice breakup all stations were observed to have from drifted approximately 100 m from their planned locations and needed to be repositioned. A high wind event on 10 August 2018 caused stations near the Jackfish facility to move, ranging from approximately 20 m to 125 m. Stations further from the Jackfish facility were measured to be 4 m to 6 m from planned locations, which was considered to be ‘in-position’ due to the horizontal accuracy of handheld GPS of plus or minus 3 m to 5 m. After spring breakup, each in-lake monitoring stations were repositioned to their planned locations on 30 May 2018 and after the high wind event on 10 August 2018, in-lake monitoring stations were repositioned to their planned locations on 4 September 2018. No data from these periods were removed, as erroneous data were not visually identifiable (see temperature results in the next section). However, in-lake stations near the plants may not have been in-line with discharge pipes after the event and before they were positioned so there is some uncertainty in the results for those dates.

Additional challenges occurred due to equipment malfunction:

- The Barologger was found to have recorded erroneous data over periods not exceeding 16 hours from 25 to 29 March 2018, and 16 November 2018. These data were omitted. Interpolated values between bracketing good data were used to fill gaps in data and were used to compensate Levelogger data on these days.
- In May 2018 five temperature data loggers (HOBO Pendant) were found to have failed; four were replaced with alternate temperature data loggers (Onset Tidbit v2[1]) on 26 June 2018.The fifth temperature logger could not be replaced on 26 June 2018 as the buoy was submerged and inaccessible due to the high water level, and was replaced with the alternate temperature data logger (Onset Tidbit v2) on 10 July 2018. On 10 July 2018, an additional failed temperature logger was identified and replaced with an alternate Onset Tidbit v2. HOBO Pendant data loggers failed due to a failed seal. These were substituted with Onset Tidbit v2 data loggers for the remainder of the monitoring period.

[1] Sensor accuracy for the Onset “TidbiT v2” is ±0.21°C from 0° to 50°C

- Some data were lost from memory corruption of data logger for both HOBO Pendant and Onset Tidbit v2 data loggers. The CAT plant discharge thermistor was damaged, and no data after 20 September 2018 is available. This is presumed to be due to accidental damage from NTPC operational work in-lake when working on the boom floats. Temperature data availability and notes on data gaps are presented in Appendix A (Figure A-1).
- On the December 2018 field program, all Onset Tidbit v2 data loggers were replaced with new HOBO Pendant data loggers. At that time, the Southwest Bay bottom position HOBO Pendant data logger was found to have failed. The HOBO Pendant data logger at the top position was redeployed in the bottom position to mitigate further data loss at depth, but resulted in no data logger installed in the Southwest Bay top position.

B.2 Water Temperature Data

A duplicate HOBO Pendant temperature data logger was installed at mid-depth at the EMD discharge in-lake station to verify repeatability of logged values (Figure B-1). During times of EMD plant inactivity, logged temperatures were found to be within 1.0°C, which is two times the accuracy of loggers. Differences of logged temperatures were found to exceed 1.0°C, up to 2.3°C during EMD plant activity. This was possibly due to turbulence caused by discharged water and mixing with the lake.

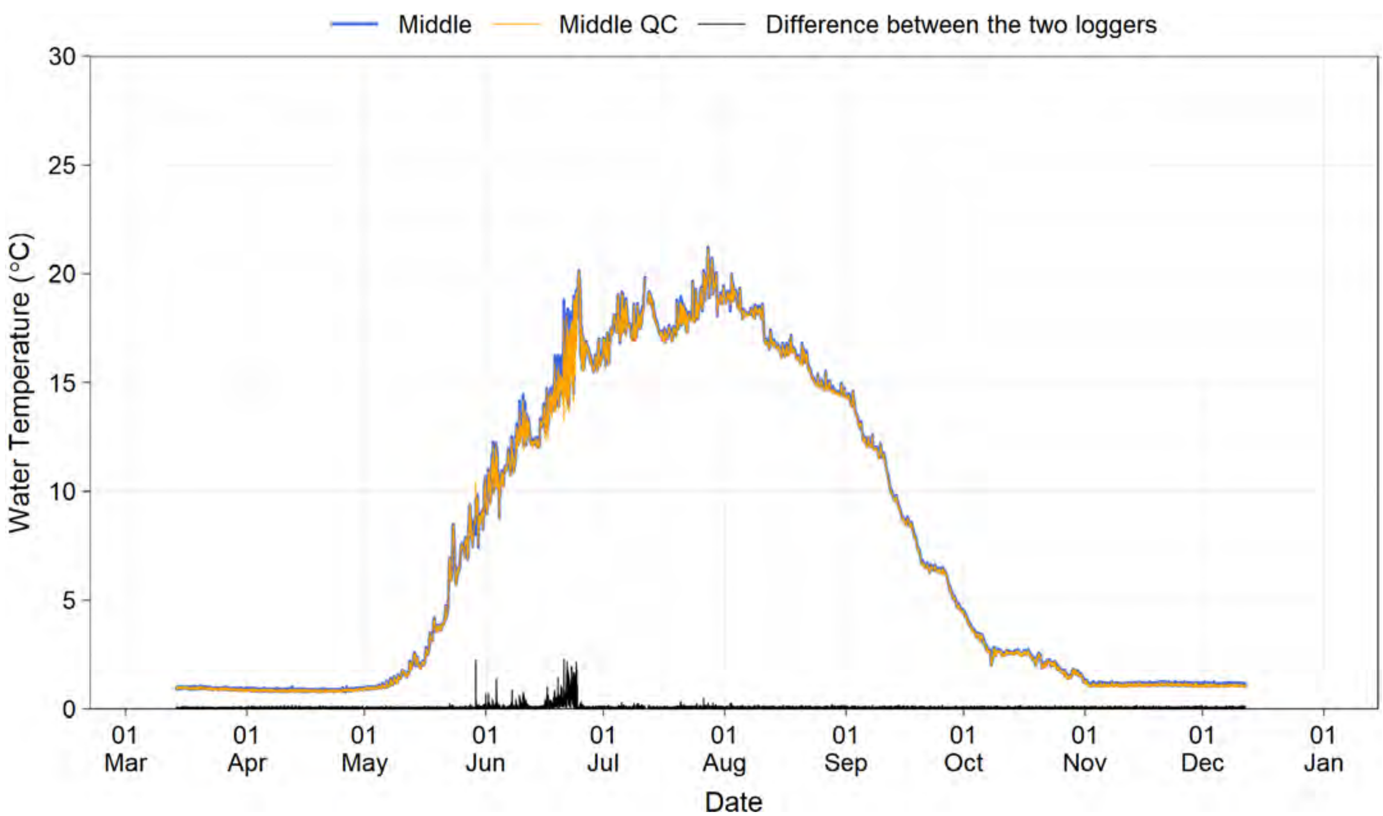


Figure B-1: Temperature Recorded by Duplicate Logger at EMD Discharge In-Lake Station as Quality Control, 2018

As part of the water quality field program, temperature data were collected using a handheld multi-parameter water quality meter (In-Situ SmarTROLL[2]; Section 4.2.1). Water temperature measured by the water quality meter was compared to temperatures measured by the in-lake temperature data loggers at Mid-Lake and Southwest Bay (Figure B-2), where water quality and in-lake temperature stations were at the same location. Temperatures measured by the in-lake temperature data loggers were within the data logger's accuracy range (±0.5°C) of the temperature measured by the water quality meter. Because no measurements with the water quality meter were taken adjacent to facility intakes or discharges, this quality control measure could not be used for thermistors.

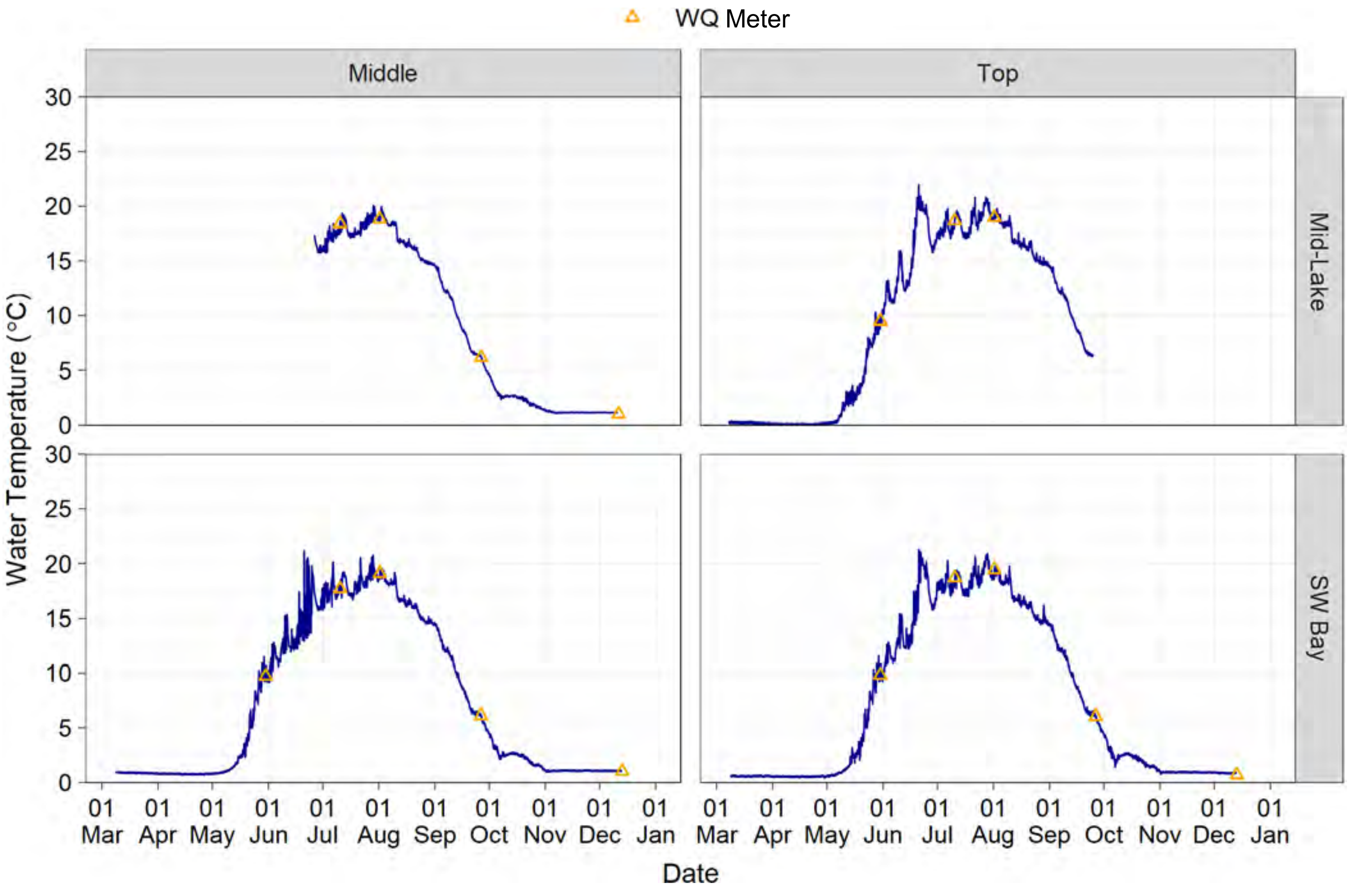


Figure B-2: Temperature Recorded by Water Quality Meter Compared to In-Lake Temperature Data Logger as Quality Control, 2018

B.3 Water Level Data

Water surface elevation measurements were taken using a rod and level during each of the water quality field programs and the data were used to correct and validate Levelogger data. Measurements of water surface elevation were taken during each site visit with two independent setups of a survey optical level until two or more results were within 5 mm, to show repeatability of survey and to reduce rod reading errors.

An independent water surface elevation survey was completed by Sub-Arctic using real-time kinematic (RTK) GPS on 26 July 2018. This survey was 1.5 cm less than the water surface elevation measurements taken using an optical level and rod survey on 2 August 2018, within the accuracy range of a typical RTK GPS survey. This increases confidence in the level survey methodology, particularly the 2 August measurement, which was used to correct the water surface elevation record as discussed in Section 3.5.2.

[2] Temperature sensor accuracy for In-Situ SmarTROLL is ±0.1 °C from -5° to 50°C

APPENDIX C

Water Quality Data, Figures, Quality Assurance/Quality Control, and Parameter Descriptions

Table C.1-1: Comparison of Intake, Discharge and Jackfish Lake Water Quality to Canadian Water Quality Guidelines, 2018

Parameter	Unit	Short-term Canadian Water Quality Guideline[a]	Long-term Canadian Water Quality Guideline[a]	CAT DISCHARGE	CAT INTAKE	EMD AND CAT					EMD INTAKE
			Sample Control Number	2018-0714	2018-0711	2018-0504	2018-0702	2018-0809	2018-0902	2018-1206	2018-0710
				11-Jul-18	11-Jul-18	29-May-18	10-Jul-18	1-Aug-18	26-Sep-18	12-Dec-18	11-Jul-18
Routine Parameters											
pH (field)	-	-	6.5 - 9.0	8.9	8.9	8.2	8.9	8.9	8.5	8.2	8.9
pH (laboratory)	-	-	6.5 - 9.0	8.6	8.5	8.3	8.6	8.8	8.4	8.2	8.5
Temperature (field)	°C	-	-	19.4	19.4	9.5	18.1	19.2	6.2	1.1	19.1
Dissolved oxygen (field)	mg/L	-	6.5 - 9.5[b]	10.03	9.51	12.04	10.12	10.33	12.04	10.31	9.71
Dissolved oxygen (field)	%	-	-	113	107	109	110	115	99	77	108
Specific conductivity (field)	µS/cm	-	-	407	405	473	407	465	563	448	407
Specific conductivity (laboratory)	µS/cm	-	-	414	426	440	414	432	454	465	427
Total alkalinity, as $CaCO_3$	mg/L	-	-	107	107	111	106	111	115	117	102
Hardness, as $CaCO_3$	mg/L	-	-	154	154	148	151	154	155	167	155
Total suspended solids	mg/L	-	-	7.3	9.1	7.0	9.1	13.9	12.6	15.4	9.5
Total dissolved solids	mg/L	-	-	273	272	282	272	266	266	301	294
Total dissolved solids (calculated)	mg/L			250	250	249	249	254	260	271	248
Turbidity (field)[d]	NTU	-	-	9.1	7.3	3.2	7.7	10.9	15.9	11.4	11.4
Turbidity (laboratory)	NTU	-	-	9.7	10.5	7.8	10.7	13.9	16.2	15.2	11.3
Major Ions											
Calcium	mg/L	-	-	40.8	40.7	39.9	40.0	40.6	41.8	44.3	40.8
Chloride	mg/L	640	120	54.6	54.5	52.9	55.6	56.2	56.7	59.1	54.9
Fluoride	mg/L	-	0.12	0.090	0.090	0.096	0.100	0.086	0.095	0.093	0.097
Magnesium	mg/L	-	-	12.8	12.7	11.7	12.5	12.9	12.4	13.7	12.8
Potassium	mg/L	-	-	4.4	4.4	3.7	4.2	4.1	4.3	4.5	4.5
Sodium	mg/L	-	-	31.6	31.6	26.4	30.7	30.8	31.1	32.2	31.6
Sulphate	mg/L	-	-	29.2	28.9	29.7	29.7	29.8	29.1	29.7	29.2
Nutrients											
Total ammonia	mg-N/L	-	0.062[e]	<0.0050	0.0082	0.0928	<0.0050	0.0051	0.0071	0.0164	0.0087
Total nitrogen	mg-N/L	-	-	1.00	1.06	1.25	1.25	1.24	1.49	1.97	1.07
Nitrate	mg-N/L	124	2.93	<0.0050	<0.0050	0.0449	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Nitrite	mg-N/L	-	0.06	<0.0010	<0.0010	0.0044	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Nitrate + nitrite	mg-N/L	-	-	<0.0051	<0.0051	0.0493	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051
Total Kjeldahl nitrogen	mg-N/L	-	-	1.03	1.02	1.19	1.17	1.25	1.48	1.51	1.00
Total phosphorus	mg-P/L	-	-	0.0591	0.0611	0.0826	0.0569	0.0620	0.1050	0.0940	0.0542
Dissolved phosphorus	mg-P/L	-	-	0.0125	0.0157	0.0154	0.0157	0.0139	0.0152	0.0123	0.0139
Orthophosphate	mg-P/L	-	-	0.0046	0.0050	0.0055	0.0045	0.0037	0.0047	0.0046	0.0227
Soluble reactive silica	mg/L	-	-	9.66	9.81	13.9	9.81	10.2	12.2	13.3	9.87
Organic Carbon											
Total organic carbon	mg/L	-	-	12.0	12.4	11.1	12.2	12.1	11.4	13.5	11.9
Total Metals[f]											
Aluminum	mg/L	-	0.10[g]	0.0059	0.0130	0.0082	0.0059	0.0062	0.0067	<0.0030	0.0069
Antimony	mg/L	-	-	0.00164	0.00160	0.00138	0.00159	0.00157	0.00142	0.00142	0.00162
Arsenic	mg/L	-	0.0050	0.0861	0.0851	0.0686	0.0833	0.0899	0.0835	0.0861	0.0836
Barium	mg/L	-	-	0.0348	0.0355	0.0345	0.0341	0.0313	0.0313	0.0363	0.0341
Beryllium	mg/L	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Bismuth	mg/L	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Boron	mg/L	29	1.5	0.028	0.028	0.022	0.028	0.029	0.028	0.029	0.028
Cadmium	mg/L	-	0.00020 - 0.00024[h]	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Cesium	mg/L	-	-	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Chromium	mg/L	-	0.001	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00011	<0.00010	<0.00010
Cobalt	mg/L	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Copper	mg/L	-	0.0030 - 0.0037[h]	0.0028	0.0031	0.0033	0.0027	0.0023	0.0014	0.0019	0.0027
Iron	mg/L	-	0.300	0.013	0.051	0.019	<0.010	0.014	0.012	0.010	0.017
Lead	mg/L	-	0.0046 - 0.0062[h]	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Lithium	mg/L	-	-	0.0063	0.0062	0.0058	0.0062	0.0062	0.0062	0.0062	0.0061
Manganese	mg/L	-	-	0.0197	0.0191	0.0953	0.0152	0.0227	0.0285	0.0817	0.0254
Mercury	mg/L	-	0.000026	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Molybdenum	mg/L	-	0.073	0.000261	0.000275	0.000212	0.000267	0.000278	0.000247	0.000232	0.000273
Nickel	mg/L	-	0.119 - 0.142[h]	0.00060	0.00073	0.00059	0.00055	0.00065	0.00053	0.00062	0.00064
Rubidium	mg/L	-	-	0.00289	0.00292	0.00256	0.00280	0.00262	0.00259	0.00276	0.00270
Selenium	mg/L	-	0.001	0.000054	0.000052	<0.000050	0.000058	<0.000050	0.000060	<0.000050	<0.000050
Silver	mg/L	-	0.00025	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Strontium	mg/L	-	-	0.0944	0.0926	0.0841	0.0931	0.0887	0.0947	0.0946	0.0932
Thallium	mg/L	-	0.0008	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Titanium	mg/L	-	-	<0.00030	<0.00030	<0.00030	0.00033	<0.00030	<0.00030	<0.00030	<0.00030
Uranium	mg/L	0.033	0.015	0.000653	0.000644	0.000583	0.000584	0.000656	0.000561	0.000596	0.000652
Vanadium	mg/L	-	-	0.00066	0.00068	<0.00050	0.00063	<0.00050	<0.00050	<0.00050	0.00061
Zinc	mg/L	0.074 to 0.090[i]	0.009 to 0.026[j]	<0.0030	<0.0030	0.0078	<0.0030	<0.0030	<0.0030	<0.0030	0.0038
Hydrocarbons											
Benzene	mg/L	-	0.370	-	-	-	-	-	-	-	-
Ethylbenzene	mg/L	-	0.090	-	-	-	-	-	-	-	-
Toluene	mg/L	-	0.002	-	-	-	-	-	-	-	-
Xylenes	mg/L	-	-	-	-	-	-	-	-	-	-
F1 (C6-C10)-BTEX	mg/L	-	-	-	-	-	-	-	-	-	-
F2 (C10-C16)	mg/L	-	-	-	-	-	-	-	-	-	-
F3 (C16-C34)	mg/L	-	-	-	-	-	-	-	-	-	-
F1 (C6-C10)	mg/L	-	-	-	-	-	-	-	-	-	-
General Organics											
Extractable Petroleum Hydrocarbons (C10-C19)	mg/L	-	-	-	-	-	-	-	-	-	-
Extractable Petroleum Hydrocarbons (C19-C32)	mg/L	-	-	-	-	-	-	-	-	-	-
Total Extractable Petroleum Hydrocarbons (C10-C30)	mg/L	-	-	-	-	-	-	-	-	-	-

Parameter	K AND EMD					K DISCHARGE	K INTAKE	MID-LAKE					MID-LAKE-BOTTOM
Sample Control Number	2018-0502	2018-0701	2018-0810	2018-0901	2018-1208	2018-0712	2018-0708	2018-0508	2018-0703	2018-0804	2018-0903	2018-1204	2018-0509
	29-May-18	10-Jul-18	1-Aug-18	26-Sep-18	12-Dec-18	11-Jul-18	11-Jul-18	30-May-18	10-Jul-18	1-Aug-18	26-Sep-18	11-Dec-18	30-May-18
Routine Parameters													
pH (field)	8.2	8.9	8.9	8.5	8.2	8.9	8.9	8.2	8.9	8.8	8.5	8.2	8.0
pH (laboratory)	8.3	8.7	8.7	8.4	8.2	8.6	8.5	8.3	8.6	8.7	8.4	8.2	8.3
Temperature (field)	9.5	17.8	19.2	6.2	1.1	20.1	19.5	9.3	18.4	18.7	6.2	1.0	8.5
Dissolved oxygen (field) (mg/L)	11.88	9.50	10.27	12.02	10.27	9.93	10.12	11.82	10.21	9.75	12.05	10.69	9.44
Dissolved oxygen (field) (%)	107	103	114	99	77	113	114	105	112	107	99	79	82
Specific conductivity (field)	473	409	466	564	448	408	407	474	408	466	564	185[c]	470
Specific conductivity (laboratory)	442	418	430	449	462	419	417	434	417	429	457	476	438
Total alkalinity, as $CaCO_3$	107	101	112	114	118	106	89.8	111	103	112	114	119	112
Hardness, as $CaCO_3$	149	148	154	157	166	152	133	152	151	155	155	167	153
Total suspended solids	6.8	9.7	13.7	13.8	13.6	15.1	9.9	5.7	9.9	13.1	12.0	19.0	5.3
Total dissolved solids	291	269	272	250	301	269	240	288	276	278	274	300	281
Total dissolved solids (calculated)	247	243	255	262	270	249	226	252	246	256	260	271	253
Turbidity (field)[d]	4.9	8.1	12.67	13.1	12.7	6.9	7.1	5.5	7.6	12.7	11.7	9.2	4.7
Turbidity (laboratory)	6.1	11.3	14.2	15.2	15.0	12.4	10.9	7.3	12.8	13.9	16.2	18.4	7.3
Major Ions													
Calcium	40.2	39.3	40.6	42.3	45.6	40.3	35.4	40.8	40.1	40.6	41.8	44.5	41.2
Chloride	52.8	54.7	56.3	56.8	58.8	55.0	54.7	52.9	54.7	56.1	56.8	60.2	52.8
Fluoride	0.097	0.098	0.086	0.096	0.092	0.090	0.092	0.096	0.090	0.086	0.095	0.094	0.095
Magnesium	11.9	12.2	12.9	12.5	12.6	12.6	10.7	12.1	12.4	13.0	12.3	13.6	12.2
Potassium	3.9	4.1	4.1	4.5	4.3	4.4	3.8	3.9	4.2	4.2	4.3	4.4	4.0
Sodium	26.8	29.7	30.8	31.9	32.0	31.1	25.7	27.5	30.5	31.4	30.8	29.5	27.8
Sulphate	29.6	29.1	29.9	29.1	29.6	29.4	29.2	29.7	29.3	29.7	29.2	30.3	29.7
Nutrients													
Total ammonia	0.1010	0.0093	0.0055	0.0098	0.0171	<0.0050	0.0083	0.0946	<0.0050	0.0057	0.0194	0.0105	0.1310
Total nitrogen	1.32	1.05	1.30	1.50	1.87	1.26	1.06	1.12	1.11	1.28	1.44	1.66	1.16
Nitrate	0.0461	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0438	<0.0050	<0.0050	<0.0050	<0.0050	0.0443
Nitrite	0.0046	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.005	<0.0010	<0.0010	<0.0010	<0.0010	0.0034
Nitrate + nitrite	0.0507	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051	0.0486	<0.0051	<0.0051	<0.0051	<0.0051	0.0476
Total Kjeldahl nitrogen	1.17	1.10	1.22	1.51	1.55	1.22	1.03	1.21	1.07	1.25	1.49	1.80	1.22
Total phosphorus	0.0818	0.0617	0.0657	0.1160	0.1040	0.0912	0.0615	0.0802	0.0637	0.0712	0.1060	0.1150	0.0829
Dissolved phosphorus	0.0161	0.0147	0.0147	0.0159	0.0121	0.0158	0.0144	0.0154	0.0138	0.0141	0.0143	0.0123	0.0147
Orthophosphate	0.0056	0.0045	0.0034	0.0051	0.0045	0.0047	0.0106	0.0060	0.0041	0.0040	0.0050	0.0049	0.0061
Soluble reactive silica	13.7	10.2	10.4	12.7	13.1	9.82	10.2	14.1	10.1	10.7	12.7	13.3	13.7
Organic Carbon													
Total organic carbon	12.8	11.9	12.6	13.0	12.7	12.9	12.1	10.6	11.8	12.5	11.2	13.3	10.8
Total Metals[f]													
Aluminum	0.0097	0.0065	0.0062	0.0086	<0.0030	0.0313	0.0086	0.0114	0.0059	0.0053	0.0089	<0.0030	0.0078
Antimony	0.00143	0.00161	0.00153	0.00143	0.00139	0.00166	0.00160	0.00142	0.00157	0.00151	0.00139	0.00142	0.00140
Arsenic	0.0678	0.0841	0.0903	0.0846	0.0856	0.0860	0.0822	0.0688	0.0821	0.0889	0.0854	0.0856	0.0693
Barium	0.0335	0.0343	0.0310	0.0328	0.0356	0.0360	0.0332	0.0344	0.0334	0.0310	0.0326	0.0356	0.0351
Beryllium	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Bismuth	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Boron	0.023	0.028	0.028	0.029	0.029	0.028	0.027	0.022	0.028	0.029	0.029	0.030	0.022
Cadmium	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Cesium	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Chromium	<0.00010	<0.00010	<0.00010	0.00018	0.00095	0.00013	<0.00010	<0.00010	<0.00010	<0.00010	0.00040	0.00027	<0.00010
Cobalt	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Copper	0.0105	0.0033	0.0023	0.0015	0.0019	0.0089	0.0029	0.0029	0.0025	0.0022	0.0015	0.0019	0.0024
Iron	0.020	0.011	0.013	0.015	0.014	0.166	0.015	0.020	<0.010	0.010	0.013	0.010	0.017
Lead	0.000141	<0.000050	<0.000050	0.000068	0.000112	0.000191	0.000090	0.000069	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Lithium	0.0057	0.0063	0.0061	0.0062	0.0063	0.0062	0.0061	0.0059	0.0061	0.0060	0.0061	0.0063	0.0059
Manganese	0.0910	0.0161	0.0219	0.0292	0.0758	0.1700	0.0173	0.0967	0.0157	0.0236	0.0289	0.0612	0.1040
Mercury	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.000025	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Molybdenum	0.000242	0.000263	0.000280	0.000268	0.000228	0.000283	0.000280	0.000228	0.000251	0.000268	0.000233	0.000251	0.000199
Nickel	0.00065	0.00059	0.00068	0.00055	0.00071	0.00077	0.00063	0.00056	<0.0005	0.00063	0.00053	0.00064	0.00058
Rubidium	0.00260	0.00274	0.00259	0.00258	0.00286	0.00293	0.00275	0.00244	0.00275	0.00264	0.00272	0.00296	0.00254
Selenium	<0.000050	<0.000050	<0.000050	<0.000050	0.000051	0.000065	0.000052	<0.000050	<0.000050	<0.000050	<0.000050	0.000068	<0.000050
Silver	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Strontium	0.0895	0.0942	0.0899	0.0989	0.0948	0.0931	0.0913	0.0866	0.0912	0.0881	0.0945	0.0973	0.0874
Thallium	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Titanium	0.00039	<0.00030	<0.00030	0.00034	<0.00030	0.00103	<0.00030	0.00032	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
Uranium	0.000618	0.000632	0.000641	0.000585	0.000564	0.000666	0.000637	0.000606	0.000532	0.000661	0.000548	0.000594	0.000594
Vanadium	<0.00050	0.00063	<0.00050	<0.00050	<0.00050	0.00074	0.00063	<0.00050	0.00068	<0.00050	<0.00050	<0.00050	<0.00050
Zinc	0.0033	<0.0030	<0.0030	<0.0030	<0.0030	0.0034	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
Hydrocarbons													
Benzene	-	<0.00050	-	-	-	-	-	-	<0.00050	-	-	-	-
Ethylbenzene	-	<0.00050	-	-	-	-	-	-	<0.00050	-	-	-	-
Toluene	-	<0.00045	-	-	-	-	-	-	<0.00045	-	-	-	-
Xylenes	-	<0.00075	-	-	-	-	-	-	<0.00075	-	-	-	-
F1 (C6-C10)-BTEX	-	<0.10	-	-	-	-	-	-	<0.10	-	-	-	-
F2 (C10-C16)	-	<0.30	-	-	-	-	-	-	<0.30	-	-	-	-
F3 (C16-C34)	-	<0.30	-	-	-	-	-	-	<0.30	-	-	-	-
F1 (C6-C10)	-	<0.10	-	-	-	-	-	-	<0.10	-	-	-	-
General Organics													
Extractable Petroleum Hydrocarbons (C10-C19)	-	<0.050	-	-	-	-	-	-	<0.050	-	-	-	-
Extractable Petroleum Hydrocarbons (C19-C32)	-	<0.050	-	-	-	-	-	-	<0.050	-	-	-	-
Total Extractable Petroleum Hydrocarbons (C10-C30)	-	<0.10	-	-	-	-	-	-	<0.10	-	-	-	-

Parameter	MID-LAKE-BOTTOM				NORTHEAST BAY					NORTHWEST BAY NORTH					SOUTHWEST BAY				
Sample Control Number	2018-0704	2018-0805	2018-0904	2018-1205	2018-0510	2018-0705	2018-0808	2018-0905	2018-1202	2018-0505	2018-0706	2018-0802	2018-0906	2018-1201	2018-0507	2018-0707	2018-0806	2018-0907	2018-1209
	10-Jul-18	1-Aug-18	26-Sep-18	11-Dec-18	30-May-18	10-Jul-18	1-Aug-18	26-Sep-18	11-Dec-18	30-May-18	10-Jul-18	1-Aug-18	26-Sep-18	11-Dec-18	30-May-18	10-Jul-18	1-Aug-18	26-Sep-18	13-Dec-18
Routine Parameters																			
pH (field)	7.2	7.0	8.5	8.1	8.2	8.9	8.8	8.4	8.1	8.2	8.8	8.7	8.3	8.1	8.2	8.9	8.9	8.5	7.9
pH (laboratory)	8.1	8.5	8.4	8.1	8.3	8.6	8.7	8.4	8.3	8.4	8.6	8.7	8.4	8.3	8.3	8.5	8.8	8.4	8.2
Temperature (field)	10.3	11.7	6.2	1.4	9.5	18.5	18.8	6.1	1.0	8.9	18.4	18.6	6.2	0.9	9.8	17.7	19.1	6.1	1.0
Dissolved oxygen (field) (mg/L)	0.03	0.04	12.02	10.03	12.04	10.25	9.04	11.77	10.44	11.76	9.94	8.95	11.65	10.71	12.77	9.81	10.33	12.09	10.69
Dissolved oxygen (field) (%)	0	0	99	75	107	113	99	97	77	103	109	97	96	79	114	106	115	99	78
Specific conductivity (field)	425	471	563	187[c]	475	409	465	564	186[c]	475	411	467	564	186[c]	473	409	465	563	421
Specific conductivity (laboratory)	431	429	454	460	440	422	437	451	469	440	422	430	453	463	444	423	432	454	463
Total alkalinity, as $CaCO_3$	109	111	115	118	110	102	111	116	114	110	105	112	115	112	113	107	113	116	116
Hardness, as $CaCO_3$	151	157	155	168	151	150	158	157	166	150	150	154	154	166	150	148	155	156	165
Total suspended solids	8.7	13.7	11.8	13.4	3.3	10.9	14.1	14.0	13.0	3.3	10.5	13.5	13.6	13.4	6.3	9.7	13.7	13.0	14.8
Total dissolved solids	276	283	267	297	275	274	274	265	312	276	264	282	270	299	271	276	277	254	298
Total dissolved solids (calculated)	249	266	260	268	249	245	256	260	265	249	246	255	259	267	251	246	256	261	267
Turbidity (field)[d]	4.4	10.9	12.6	10.7	6.1	8.3	11.1	18.9	10.5	4.1	11.1	10.5	12.4	13.7	5.1	7.2	11.7	14.2	16.6
Turbidity (laboratory)	9.4	17.0	14.7	13.8	6.4	10.8	15.1	16.1	14.5	6.5	11.9	13.4	13.7	15.8	6.9	11.4	14.5	15.8	15.7
Major Ions																			
Calcium	40.2	41.3	41.8	44.6	40.8	39.8	41.6	42.2	44.2	40.2	39.9	40.6	41.6	44.2	40.3	39.3	40.6	41.9	45.8
Chloride	54.2	55.5	56.8	58.7	52.7	54.7	56.2	56.8	59.0	53.1	54.9	56.3	56.7	59.0	52.9	54.6	56.2	56.7	58.6
Fluoride	0.096	0.086	0.096	0.091	0.095	0.090	0.086	0.095	0.093	0.095	0.098	0.087	0.094	0.091	0.094	0.098	0.086	0.095	0.090
Magnesium	12.4	13.0	12.4	13.9	12.0	12.4	13.1	12.5	13.4	11.9	12.2	12.9	12.2	13.6	12.0	12.2	13.0	12.4	12.4
Potassium	4.4	4.3	4.3	4.6	3.9	4.2	4.2	4.3	4.4	3.9	4.1	4.1	4.2	4.7	3.9	4.1	4.1	4.3	4.2
Sodium	29.8	30.4	31.2	30.0	27.3	30.6	31.5	31.2	29.6	27.0	30.2	30.9	31.1	33.3	27.5	29.8	31.3	31.3	30.9
Sulphate	28.3	29.6	29.1	29.4	29.5	29.0	29.7	29.1	29.6	29.7	29.2	29.8	29.1	29.5	29.8	29.2	29.8	29.1	29.6
Nutrients																			
Total ammonia	0.628	0.0064	0.0100	0.0127	0.1070	<0.0050	0.0062	0.0141	0.0118	0.1160	<0.0050	<0.0050	0.0138	0.0114	0.0338	<0.0050	0.0054	0.0094	0.0161
Total nitrogen	1.66	2.14	1.42	1.39	1.25	1.15	1.26	1.45	1.64	0.99	1.10	1.23	1.54	1.66	1.23	1.09	1.23	1.46	2.19
Nitrate	<0.0050	2.78	<0.0050	<0.0050	0.0438	<0.0050	<0.0050	<0.0050	<0.0050	0.0466	<0.0050	<0.0050	<0.0050	<0.0050	0.0410	<0.0050	<0.0050	<0.0050	<0.0050
Nitrite	<0.0010	0.062	<0.0010	<0.0010	0.004	<0.0010	<0.0010	<0.0010	<0.0010	0.003	<0.0010	<0.0010	<0.0010	<0.0010	0.004	<0.0010	<0.0010	<0.0010	<0.0010
Nitrate + nitrite	<0.0051	2.84	<0.0051	<0.0051	0.0474	<0.0051	<0.0051	<0.0051	<0.0051	0.0496	<0.0051	<0.0051	<0.0051	<0.0051	0.0450	<0.0051	<0.0051	<0.0051	<0.0051
Total Kjeldahl nitrogen	1.54	1.55	1.42	1.42	1.23	1.09	1.30	1.47	1.78	1.16	1.11	1.18	1.52	1.72	1.20	1.02	1.25	1.45	2.06
Total phosphorus	0.1410	0.0711	0.1380	0.0860	0.0852	0.0645	0.0737	0.1180	0.1200	0.0844	0.0627	0.0663	0.1010	0.0965	0.0915	0.0549	0.0440	0.0980	0.1560
Dissolved phosphorus	0.1060	0.1100	0.0168	0.0119	0.0153	0.0152	0.0109	0.0160	0.0126	0.0146	0.0132	0.0141	0.0153	0.0115	0.0155	0.0137	0.0125	0.0141	0.0154
Orthophosphate	0.0060	0.0035	0.0068	0.0046	0.0061	0.0046	0.0036	0.0046	0.0057	0.006	0.0047	0.0042	0.0046	0.0044	0.0053	0.0040	0.0036	0.0043	0.0044
Soluble reactive silica	10.9	10.4	12.1	12.6	13.4	10.0	10.6	11.5	12.9	13.3	9.41	10.2	12.1	12.5	13.2	9.58	10.2	12.6	12.8
Organic Carbon																			
Total organic carbon	11.2	12.9	11.2	12.6	10.4	12.1	12.4	12.0	13.3	10.6	12.3	12.2	11.2	13.3	10.5	11.9	12.4	11.9	13.8
Total Metals[f]																			
Aluminum	0.0092	0.0064	0.0051	0.0042	0.0079	0.0071	0.0092	0.0097	<0.0030	0.0088	0.0088	0.0067	0.0061	0.0036	0.0136	0.0064	0.0125	0.0067	0.0082
Antimony	0.00147	0.00150	0.00139	0.00144	0.00142	0.00161	0.00154	0.00136	0.00139	0.00143	0.00161	0.00149	0.00141	0.00147	0.00146	0.00158	0.00187	0.00137	0.00139
Arsenic	0.0878	0.0929	0.0820	0.0836	0.0679	0.0834	0.0942	0.0795	0.0850	0.0684	0.0831	0.0901	0.0858	0.0854	0.0701	0.0856	0.0978	0.0842	0.0839
Barium	0.0463	0.0313	0.0326	0.0350	0.0341	0.0338	0.0308	0.0300	0.0357	0.0349	0.0333	0.0307	0.0322	0.0333	0.0348	0.0342	0.0312	0.0319	0.0350
Beryllium	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Bismuth	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Boron	0.028	0.029	0.029	0.029	0.022	0.028	0.029	0.028	0.030	0.022	0.028	0.028	0.029	0.033	0.022	0.028	0.028	0.029	0.030
Cadmium	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Cesium	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Chromium	<0.00010	<0.00010	<0.00010	0.00011	0.00016	<0.00010	<0.00010	0.00013	0.00016	<0.00010	<0.00010	<0.00010	<0.00010	0.00019	0.00011	<0.00010	<0.00010	0.00021	0.00017
Cobalt	0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00010	<0.00010	<0.00010
Copper	0.0021	0.0036	0.0013	0.0018	0.0028	0.0025	0.0027	0.0013	0.0020	0.0023	0.0025	0.0022	0.0014	0.0019	0.0027	0.0026	0.0028	0.0014	0.0020
Iron	0.071	0.021	<0.010	0.016	0.017	<0.010	0.034	0.015	0.010	0.019	0.015	0.014	0.011	0.012	0.025	<0.010	0.053	0.012	<0.010
Lead	<0.000050	<0.000050	<0.000050	<0.000050	0.000053	<0.000050	0.000075	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.000057	0.000092	<0.000050	0.000114	<0.000050	0.000163
Lithium	0.0062	0.0060	0.0062	0.0063	0.0058	0.0061	0.0060	0.0060	0.0062	0.0060	0.0060	0.0059	0.0063	0.0064	0.0059	0.0060	0.0060	0.0062	0.0063
Manganese	0.8040	0.0535	0.0275	0.0708	0.0972	0.0160	0.0276	0.0275	0.0724	0.0986	0.0179	0.0278	0.0303	0.0583	0.0936	0.0189	0.0274	0.0267	0.0463
Mercury	<0.000025	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.000025	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Molybdenum	0.000201	0.000280	0.000238	0.000231	0.000205	0.000275	0.000283	0.000238	0.000249	0.000222	0.000282	0.000262	0.000229	0.000246	0.000212	0.000254	0.000277	0.000235	0.000235
Nickel	0.00055	0.00075	<0.0005	0.00056	0.00053	0.00069	0.00073	<0.0005	0.00064	0.00053	0.00061	0.00067	0.00053	0.00064	0.00056	0.00066	0.00076	<0.0005	0.00071
Rubidium	0.00292	0.00263	0.00257	0.00261	0.00255	0.00273	0.00266	0.00247	0.00291	0.00248	0.00266	0.00274	0.00258	0.00277	0.00260	0.00275	0.00257	0.00259	0.00289
Selenium	<0.000050	0.000051	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.000059	0.000053	0.000061	0.000050	0.000056	<0.000050	<0.000050	<0.000050	0.000056	<0.000050	0.000060	0.000064
Silver	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Strontium	0.0956	0.0896	0.0932	0.0974	0.0862	0.0935	0.0892	0.0940	0.0959	0.0869	0.0930	0.0875	0.0966	0.0948	0.0863	0.0927	0.0891	0.0942	0.0969
Thallium	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Titanium	0.00045	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	0.00030	<0.00030	0.00034	<0.00030	<0.00030	<0.00030	<0.00030	<0.0006	<0.00030	0.00049	<0.00030	<0.00030
Uranium	0.000538	0.000639	0.000524	0.000576	0.000593	0.000661	0.000661	0.000524	0.000578	0.000604	0.000612	0.000633	0.000556	0.000585	0.000600	0.000634	0.000645	0.000554	0.000580
Vanadium	0.00061	<0.00050	<0.00050	<0.00050	<0.00050	0.00061	<0.00050	<0.00050	<0.00050	<0.00050	0.00063	<0.00050	<0.00050	<0.00050	<0.00050	0.00064	<0.00050	<0.00050	<0.00050
Zinc	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	0.0157	<0.0030	<0.0030	<0.0030	<0.0030
Hydrocarbons																			
Benzene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ethylbenzene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Toluene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Xylenes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F1 (C6-C10)-BTEX	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F2 (C10-C16)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F3 (C16-C34)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F1 (C6-C10)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
General Organics																			
Extractable Petroleum Hydrocarbons (C10-C19)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Extractable Petroleum Hydrocarbons (C19-C32)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Extractable Petroleum Hydrocarbons (C10-C30)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(a) Source: Canadian Council of Ministers for the Environment (1999).
(b) Lowest acceptable dissolved oxygen concentrations for cold water biota are 9.5 mg/L for early life stages and 6.5 mg/L for other life stages.
(c) Data were invalidated due to notable differences between field and laboratory specific conductivity results and other field specific conductivity collected during the December field program (refer to Appendix C-4: QA/QC Procedures and Results for details)
(d) Field turbidity value is the average of three turbidity readings.
(e) The ammonia (as nitrogen) CWQG is dependent on temperature and pH. The guideline is calculated based on the individual field pH and temperature measurements for each sample. The most conservative guideline is shown, based on the maximum field pH of 8.9 and water temperature of 20.1°C measured at the intake, discharge and Jackfish Lake stations.
(f) The list of elements reported for metals analysis includes metalloids such as arsenic and non-metals such as selenium, which are collectively referred to as "metals" in this table.
(g) The CWQG for total aluminum is dependent on pH: 0.005 mg/L at pH less than 6.5 and 0.100 mg/L at pH equal to or greater than 6.5. The CWQG is based on the individual field pH value for each sample. The CWQG shown is based on the range of field pH values (7.0 to 8.9) measured at the intake, discharge and Jackfish Lake stations 2018.
(h) The CWQGs for total cadmium, copper, lead and nickel are dependent on hardness. The CWQG is calculated based on the individual hardness for each sample. The CWQG shown is based on the range of hardness (133 to 168 mg/L as $CaCO_3$) measured at the intake, discharge and Jackfish Lake stations in 2018.
(i) The CWQG for zinc for short-term exposure is dependent on hardness and DOC concentrations. The CWQG is for the dissolved fraction but was applied to the total fraction as a conservative estimate. The CWQG is calculated based on the individual hardness for each sample; concentrations of DOC were not measured as part of the 2018 baseline monitoring program, therefore, the minimum validated DOC range for the guideline equation (0.3 mg/L) was applied. The CWQG shown is based on the range of hardness (133 to 168 mg/L as CaCO3) measured at the intake, discharge and Jackfish Lake stations in 2018 and a DOC concentration of 0.3 mg/L.
(j) The CWQG for zinc for long-term exposure is dependent on hardness, pH and DOC concentrations. Guideline is for the dissolved fraction but was applied to the total fraction as a conservative estimate. The CWQG is calculated based on the individual hardness and pH for each sample. Concentrations of DOC were not measured as part of the 2018 baseline monitoring program, therefore, the minimum validated DOC range for the guideline equation (0.3 mg/L) was applied. The CWQG shown is based on the range of hardness (133 to 168 mg/L as CaCO3) and pH (7.0 to 8.9) at the intake, discharge and Jackfish Lake stations in 2018 and a DOC concentration of 0.3 mg/L.

Notes:
Shaded values indicate parameter concentration was above the applicable long-term CWQG; dissolved oxygen concentrations were shaded if concentrations were below the CWQG and pH values were shaded if they were below or above the CWQG range in pH values.
Water quality data and guidelines shown in this table were rounded to reflect laboratory or field instrument precision after comparisons to guidelines. Therefore, values slightly above guidelines may be displayed as being equal to the guidelines and not identified as exceedances. Measured concentrations equal to the guideline values were not identified as exceedances.
CWQG = Canadian Water Quality Guideline; NTU = nephelometric turbidity units; $CaCO_3$ = calcium carbonate; < = less than; µS/cm = microSiemens per centimetre; - = no applicable CWQG or parameter not monitored; BTEX = benzene, toluene, ethylbenzene and xylenes; mg-N/L = milligrams nitrogen per litre; mg-P/L = milligrams phosphorus per litre; DOC = dissolved organic carbon

Table C.1-2: Profiles of Field Water Quality Parameters in Jackfish Lake, 2018

Station	Date	Ice Thickness (m)	Secchi Depth (m)	Depth (m)	Temperature (°C)	Specific Conductivity (µS/cm)	Dissolved Oxygen (% Saturation)	Dissolved Oxygen (mg/L)	Total Dissolved Gases (% Saturation)	pH
EMD AND CAT	29-May-18	-	0.5	0.3	9.9	470	110	12.2	95	8.2
				1	9.7	472	110	12.2	97	8.2
				2	9.6	473	110	12.2[(a)]	98	8.2
				3	9.5	473	109	12.0	99	8.2
				4	9.5	474	107	11.9	100	8.2
				5	9.4	474	106	11.9	101	8.1
	10-Jul-18	-	0.5	0.3	20.3	412	118	10.3	102	8.9
				1	20.1	409	117	10.3	103	8.9
				2	18.5	407	112	10.2	104	8.9
				3	18.1	407	110	10.1	104	8.9
				4	17.8	407	103	9.6	104	8.9
				5	16.7	408	101	9.3	103	8.7
				6	12.9	399	5	0.5	98	7.7
	1-Aug-18	-	0.5	0.3	19.5	467	120	10.7	102	9.0
				1	19.4	465	118	10.6	103	9.0
				2	19.3	465	116	10.4	103	8.9
				3	19.2	465	115	10.3	103	8.9
				4	19.2	465	115	10.4	103	8.9
				5	19.1	466	115	10.3	103	8.9
				6	15.4	466	2	0.5	101	7.5
	26-Sep-18	-	0.5	0.3	6.0	567	99	12.2	98	8.5
				1	6.2	564	99	12.1	97	8.5
				2	6.2	563	99	12.1	96	8.5
				3	6.2	563	99	12.0	96	8.5
				4	6.2	563	99	12.0	96	8.5
				5	6.2	563	98	12.0	96	8.5
				6	6.2	563	98	12.0	96	8.5
	12-Dec-18	0.21	-	0.3	0.9	450	78	10.5	99	8.2
				1	1.0	448	77	10.4	101	8.3
				2	1.0	448	77	10.4	103	8.2
				3	1.1	448	77	10.3	105	8.2
				4	1.1	448	76	10.3	107	8.2
				5	1.1	448	76	10.2	107	8.2
				6	1.2	449	73	9.8	105	8.2
K AND EMD	29-May-18	-	0.5	0.3	10.7	457	106	11.5	95	8.1
				1	9.8	471	108	11.9	97	8.2
				2	9.6	473	107	11.9	98	8.2
				3	9.5	473	107	11.9	100	8.2
				4	9.4	473	105	11.7	102	8.1
				5	9.3	474	103	11.6	103	8.1
				6	9.1	474	103	11.6	106	8.1
	10-Jul-18	-	0.5	0.3	19.5	411	116	10.3	105	9.0
				1	19.5	410	116	10.3	105	9.0
				2	18.1	407	107	9.8	106	8.9
				3	17.8	409	103	9.5	105	8.9
				4	17.4	409	100	9.2	104	8.5
				5	16.0	407	47	4.6	103	8.3
				6	13.5	405	29	1.4	100	7.8
	1-Aug-18	-	0.5	0.3	19.4	466	116	10.4	101	8.9
				1	19.4	466	116	10.4	102	8.9
				2	19.3	466	115	10.3	102	8.9
				3	19.2	466	114	10.3	102	8.9
				4	19.1	466	113	10.2	102	8.9
				5	19.1	462	113	10.2	102	8.8
				6	15.0	470	2	0.2	97	7.2
	26-Sep-18	-	0.5	0.3	6.0	573	100	12.3	99	8.5
				1	6.1	564	99	12.1	97	8.5
				2	6.2	564	99	12.1	97	8.5
				3	6.2	564	99	12.0	97	8.5
				4	6.2	564	99	12.0	97	8.5
				5	6.2	564	98	12.0	97	8.5
				6	6.2	563	98	12.0	97	8.5
	12-Dec-18	0.20	-	0.3	0.8	449	77	10.4	96	8.3
				1	0.9	450	77	10.4	96	8.2
				2	1.0	449	77	10.3	96	8.2
				3	1.1	448	77	10.3	97	8.2
				4	1.1	448	77	10.3	96	8.2
				5	1.1	448	76	10.2	96	8.2
				6	1.1	448	76	10.2	96	8.2

Table C.1-2: Profiles of Field Water Quality Parameters in Jackfish Lake, 2018

Station	Date	Ice Thickness (m)	Secchi Depth (m)	Depth (m)	Temperature (°C)	Specific Conductivity (µS/cm)	Dissolved Oxygen (% Saturation)	Dissolved Oxygen (mg/L)	Total Dissolved Gases (% Saturation)	pH
MID-LAKE	30-May-18	-	0.5	0.3	9.6	475	106	11.9	96	8.2
				1	9.5	473	105	11.9	97	8.2
				2	9.4	473	106	11.9	98	8.2
				3	9.3	474	105	11.8	99	8.2
				4	9.3	475	104	11.7	100	8.2
				5	9.2	475	103	11.7	101	8.2
				6	8.5	470	82	9.4	103	8.0
				7	7.9	468	69	8.1	104	7.9
	10-Jul-18	-	0.5	0.3	18.6	410	113	10.2	103	8.9
				1	18.6	409	113	10.3	103	8.9
				2	18.6	409	113	10.3	103	8.9
				3	18.4	408	112	10.2	104	8.9
				4	17.6	406	98	9.1	104	8.8
				5	14.6	399	26	2.6	101	8.0
				6	11.5	413	0	0.1	96	7.5
	1-Aug-18	-	0.5	0.3	18.9	466	113	10.2	102	8.9
				1	19.0	466	113	10.2	102	8.9
				2	18.9	466	112	10.1	102	8.9
				3	18.8	466	110	10.0	103	8.9
				4	18.7	466	107	9.8	103	8.8
				5	18.4	468	57	6.2	101	8.2
				6	14.2	477	1	0.2	95	7.2
	26-Sep-18	-	0.5	0.3	5.9	567	100	12.2	99	8.5
				1	6.1	565	99	12.1	99	8.5
				2	6.2	564	99	12.1	100	8.5
				3	6.2	563	99	12.0	100	8.5
				4	6.2	564	99	12.1	101	8.5
				5	6.2	563	99	12.0	101	8.5
				6	6.2	563	99	12.0	101	8.5
				7	6.2	563	99	12.0	101	8.5
	11-Dec-18	0.27	-	0.3	0.4	187[(b)]	81	11.1	96	8.3
				1	0.6	185[(b)]	81	11.0	96	8.2
				2	0.9	186[(b)]	80	10.9	96	8.2
				3	1.0	186[(b)]	81	10.9	96	8.2
				4	1.0	185[(b)]	79	10.7	96	8.2
				5	1.1	185[(b)]	78	10.5	96	8.2
				6	1.2	186[(b)]	77	10.4	96	8.1
NORTHEAST BAY	30-May-18	-	0.5	0.3	9.8	477	108	12.1	96	8.1
				1	9.6	474	107	12.0	97	8.1
				2	9.5	474	107	12.0	99	8.2
				3	9.5	475	107	12.0	100	8.2
				4	9.4	473	107	12.0	101	8.2
				5	9.1	472	105	11.8	102	8.2
				6	8.9	471	94	10.3	102	8.0
	10-Jul-18	-	0.5	0.3	18.7	360	113	10.3	103	8.9
				1	18.6	360	113	10.3	104	8.9
				2	18.6	360	113	10.3	106	8.9
				3	18.5	358	113	10.3	107	8.9
				4	17.7	355	90	8.3	107	8.8
				5	14.6	325	15	1.4	96	7.8
				6	11.4	308	0	0.0	99	7.4
	1-Aug-18	-	0.5	0.3	19.2	465	114	10.2	101	8.9
				1	19.1	466	113	10.2	101	8.9
				2	19.0	466	111	10.0	102	8.9
				3	18.8	465	99	9.0	101	8.8
				4	18.5	469	76	7.0	101	8.5
				5	16.7	479	73	6.4	98	8.4
				6	15.4	463	9	1.4	96	7.6
				7	12.3	479	0	0.0	93	7.0
	26-Sep-18	-	0.5	0.3	5.8	567	97	11.9	97	8.4
				1	6.1	565	97	11.8	97	8.4
				2	6.1	564	97	11.8	97	8.4
				3	6.1	564	97	11.8	96	8.4
				4	6.1	564	97	11.8	96	8.4
				5	6.2	564	96	11.7	96	8.4
				6	6.2	564	97	11.7	96	8.4
				7	6.2	558	86	11.7	95	7.8
	11-Dec-18	0.27	-	0.3	0.2	191[(b)]	81	11.2	97	8.2
				1	0.7	188[(b)]	79	10.8	97	8.2
				2	0.9	186[(b)]	78	10.5	97	8.2
				3	1.0	186[(b)]	77	10.4	97	8.1
				4	1.0	185[(b)]	77	10.4	97	8.1
				5	1.1	185[(b)]	78	10.5	97	8.2
				6	1.2	185[(b)]	77	10.5	97	8.1

Table C.1-2: Profiles of Field Water Quality Parameters in Jackfish Lake, 2018

Station	Date	Ice Thickness (m)	Secchi Depth (m)	Depth (m)	Temperature (°C)	Specific Conductivity (µS/cm)	Dissolved Oxygen (% Saturation)	Dissolved Oxygen (mg/L)	Total Dissolved Gases (% Saturation)	pH
NORTHWEST BAY NORTH	30-May-18	-	0.5	0.3	9.0	476	103	11.7	97	8.2
				1	8.9	475	103	11.7	98	8.2
				2	8.9	475	103	11.8	99	8.2
				3	8.6	475	100	11.4	101	8.1
				4	8.5	474	91	10.4	102	8.1
				5	8.1	468	83	9.0	104	8.0
	10-Jul-18	-	0.5	0.3	18.5	411	111	10.1	101	8.9
				1	18.9	411	111	10.0	102	8.8
				2	18.4	411	109	9.9	105	8.8
				3	18.4	410	110	10.0	106	8.8
				4	18.3	410	110	10.7	106	8.8
				5	16.3	414	27	3.9	108	8.0
	1-Aug-18	-	0.5	0.3	18.9	466	113	10.2	102	8.9
				1	18.9	466	113	10.2	102	8.9
				2	18.9	466	112	10.1	103	8.9
				3	18.6	467	97	9.0	105	8.7
				4	18.3	470	75	7.0	105	8.5
				5	17.7	470	35	3.7	104	8.0
	26-Sep-18	-	0.5	0.3	6.0	565	97	11.8	99	8.3
				1	6.2	564	97	11.7	98	8.3
				2	6.2	564	96	11.7	99	8.3
				3	6.2	564	96	11.7	99	8.3
				4	6.2	564	96	11.7	100	8.3
				5	6.2	564	96	11.6	100	8.3
	11-Dec-18	0.35	-	0.3	-0.1	187[b]	81	11.4	97	7.9
				1	0.3	186[b]	80	11.1	98	8.1
				2	0.7	186[b]	79	10.8	99	8.2
				3	0.9	186[b]	79	10.7	101	8.1
				4	1.0	186[b]	79	10.7	101	8.1
				5	1.0	185[b]	78	10.6	102	8.1
SOUTHWEST BAY	30-May-18	-	0.5	0.30	9.9	471	113	12.6	98	7.9
				1	9.8	472	114	12.7	99	8.1
				2	9.8	473	114	12.8	100	8.2
				3	9.7	473	115	12.8	101	8.3
				4	9.6	473	112	12.5	103	8.3
	10-Jul-18	-	0.5	0.3	19.0	409	116	10.4	101	9.0
				1	18.7	406	114	10.3	102	9.0
				2	17.8	409	107	9.8	104	8.9
				3	17.7	409	106	9.8	105	8.9
				4	17.2	409	85	7.9	105	8.7
				5	15.6	411	33	3.1	104	8.1
	1-Aug-18	-	0.5	0.3	19.6	465	120	10.7	104	9.0
				1	19.5	463	119	10.6	104	8.9
				2	19.2	461	115	10.3	104	8.9
				3	19.1	465	115	10.3	104	8.9
				4	19.0	465	113	10.2	104	8.9
				5	17.5	461	14	2.7	103	8.0
	26-Sep-18	-	0.5	0.3	5.8	567	100	12.2	98	8.5
				1	6.0	564	100	12.2	97	8.5
				2	6.1	563	99	12.1	97	8.5
				3	6.1	563	99	12.1	97	8.5
				4	6.1	563	99	12.1	96	8.5
	13-Dec-18	0.33	-	0.3	0.4	430	79	11.0	101	7.9
				1	0.7	426	79	10.9	101	7.9
				2	1.0	422	78	10.7	102	7.9
				3	1.0	421	78	10.7	103	7.9
				4	1.1	420	79	10.7	104	7.9
				5	1.1	420	79	10.7	104	7.9

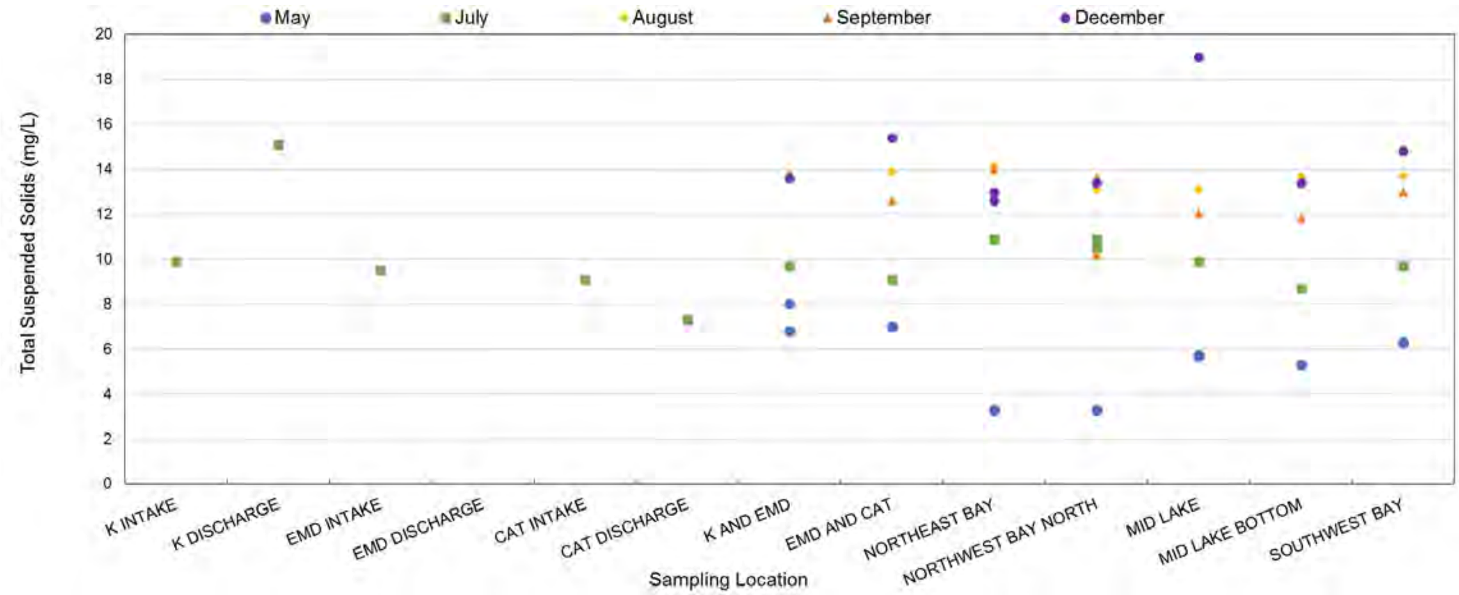
(a) Dissolved oxygen value was a transcriptional error in the field and was corrected from 12.98 to 12.23 based on the temperature and dissolved oxygen saturation results.

(b) Field specific conductivity measurements collected on 11 December were invalidated because they were notably lower than laboratory specific conductivity from samples collected at the same location and time, as well as field measurements of specific conductivity collected on 12 and 13 December (Appendix C.4).

Notes:

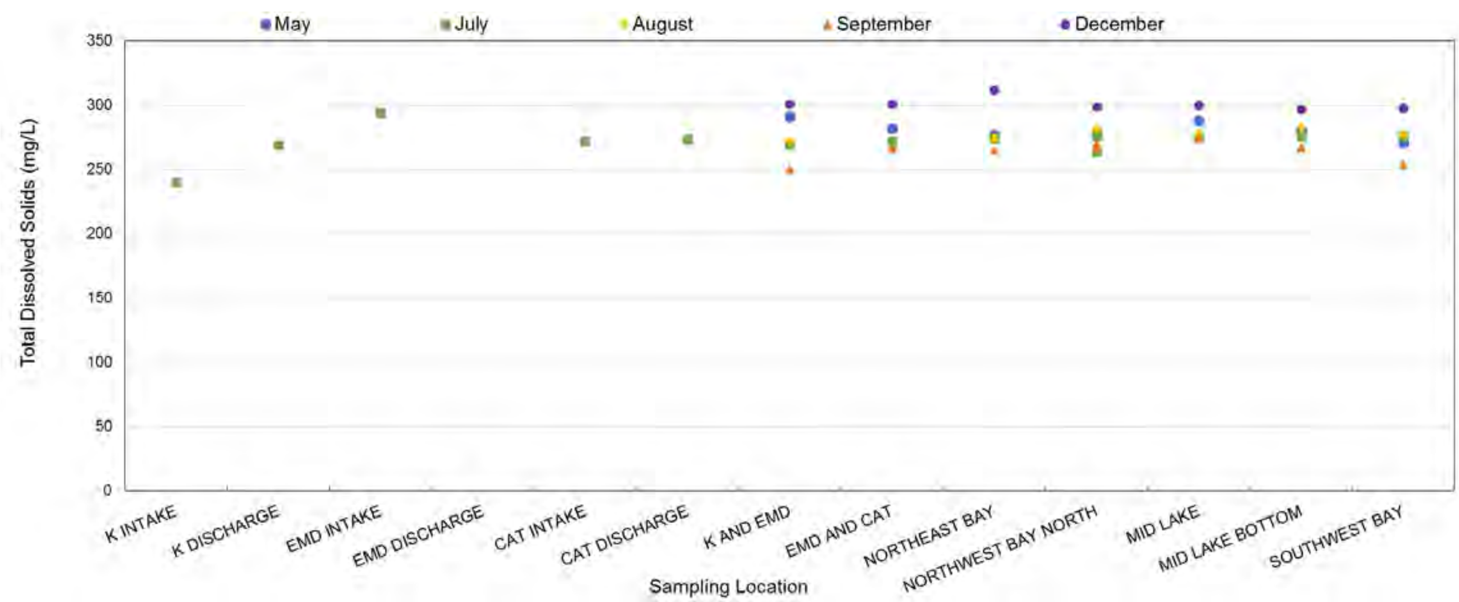
µS/cm = microSiemens per centimetre; - = not applicable/not collected.

Figure C.2-1: Total Suspended Solids Concentrations in Intakes, Discharges and Jackfish Lake, 2018



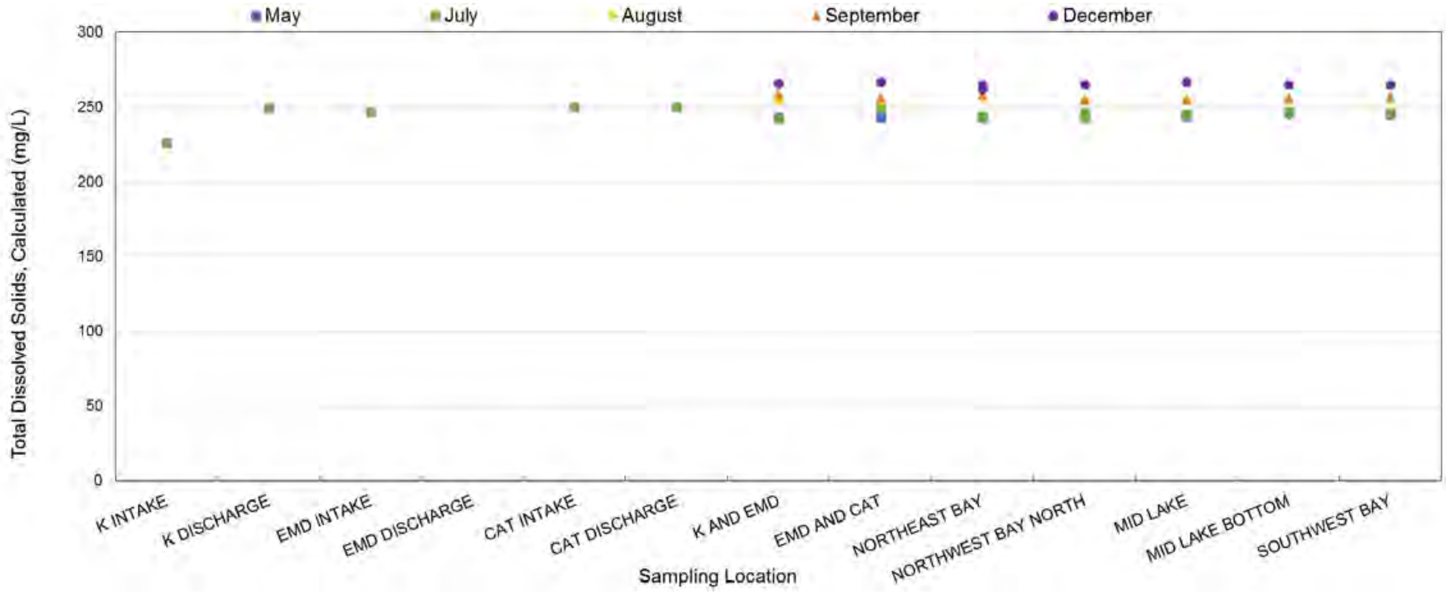
Note:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.

Figure C.2-2: Total Dissolved Solids Concentrations in Intakes, Discharges and Jackfish Lake, 2018



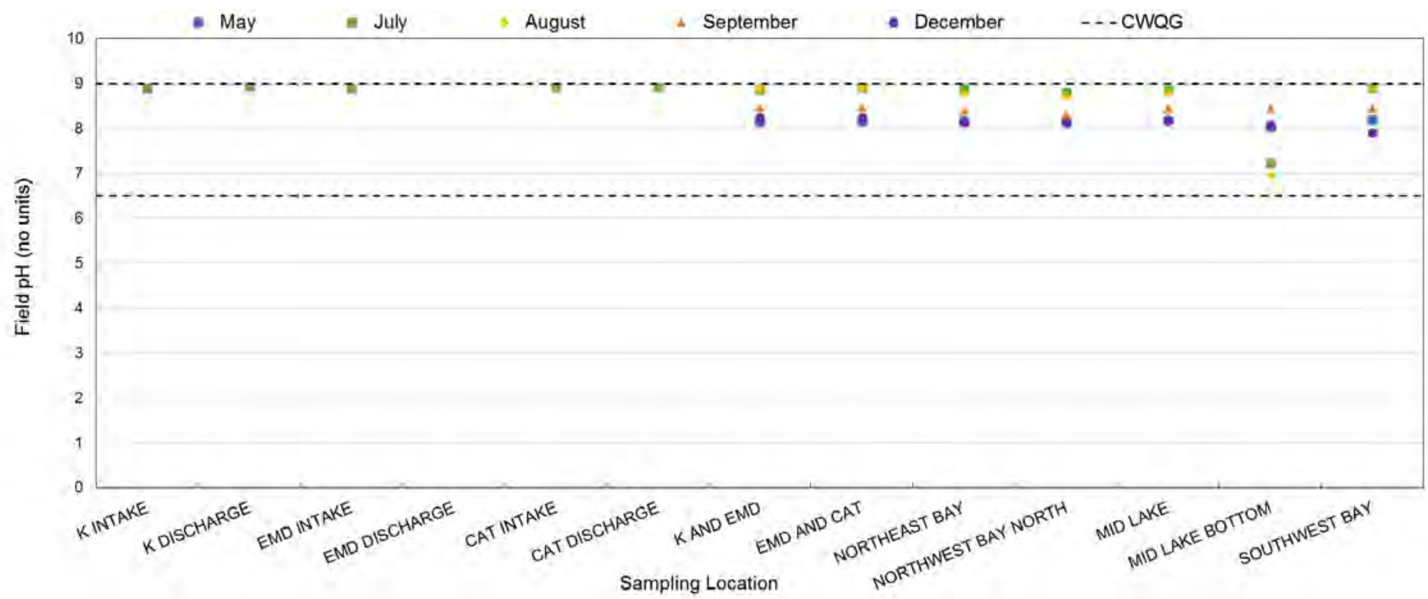
Note:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.

Figure C.2-3: Total Dissolved Solids (Calculated) Concentrations in Intakes, Discharges and Jackfish Lake, 2018



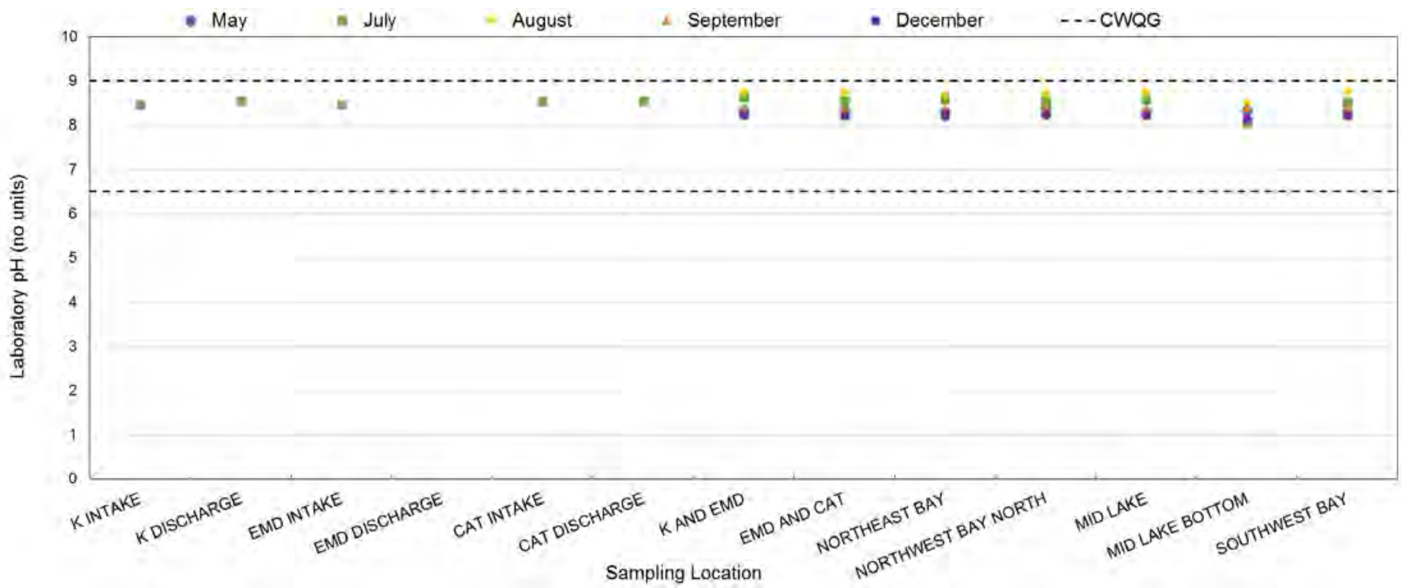
Note:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.

Figure C.2-4: Field pH in Intakes, Discharges and Jackfish Lake, 2018



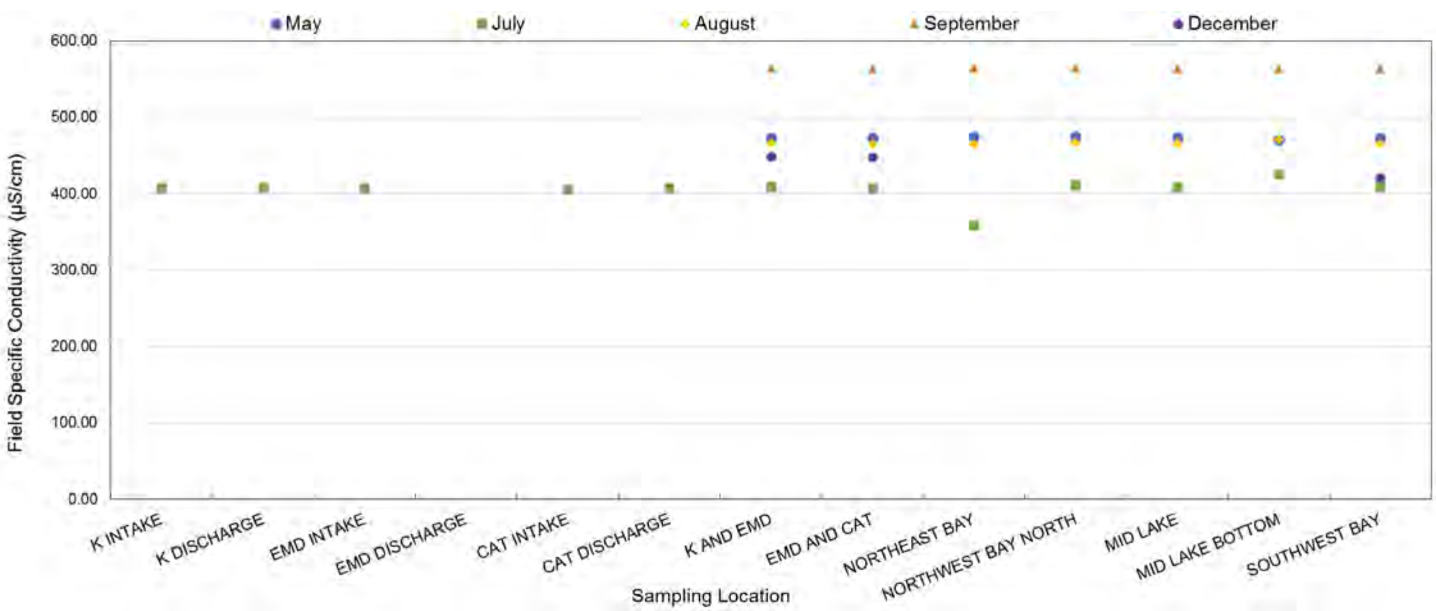
Notes:
All measurements were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM measurements; intake and discharge measurements were collected as spot measurements and MID LAKE BOTTOM measurements were collected at the bottom.
The CWQG range for pH is 6.5 and 9.0.
CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999);

Figure C.2-5: Laboratory pH in Intakes, Discharges and Jackfish Lake, 2018



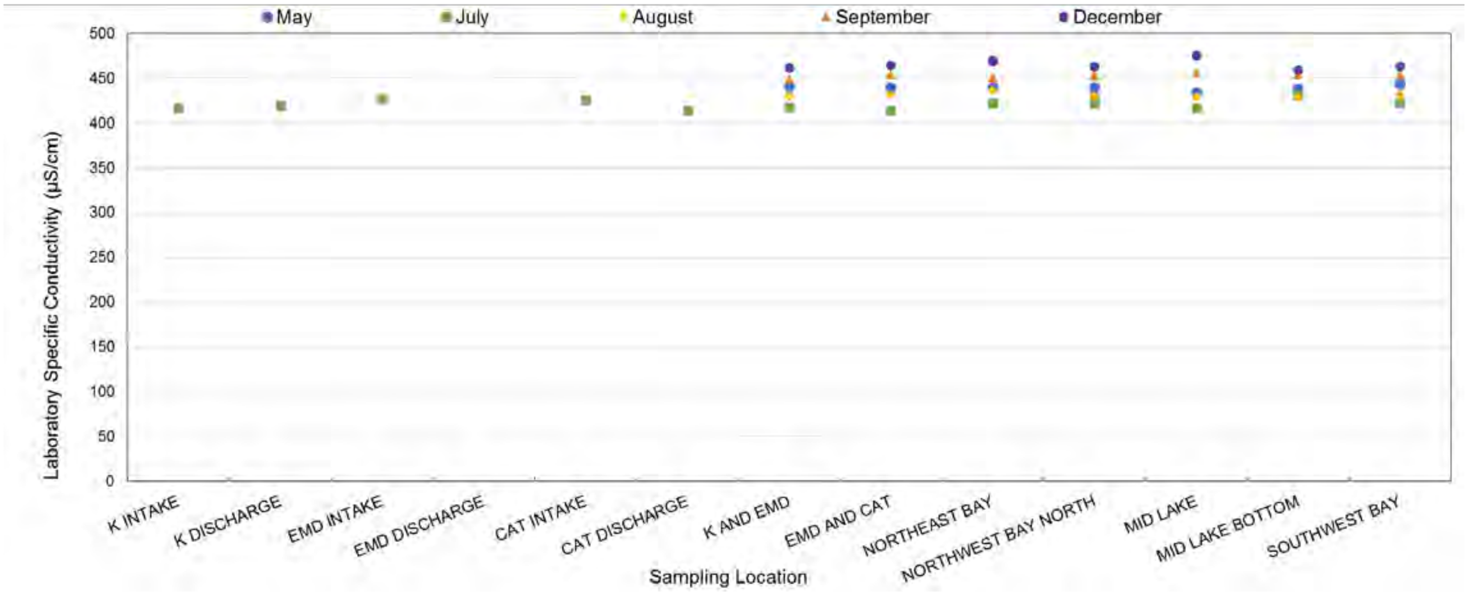
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
The CWQG range for pH is 6.5 and 9.0.
CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999).

Figure C.2-6: Field Specific Conductivity in Intakes, Discharges and Jackfish Lake, 2018



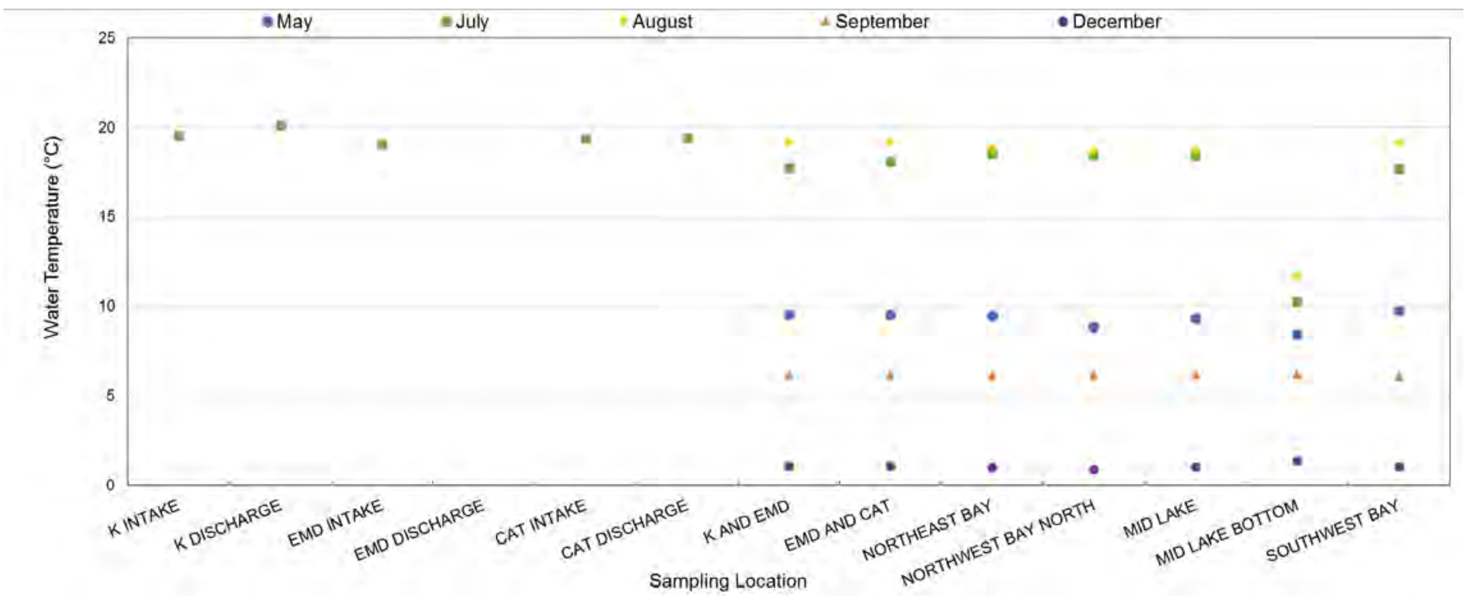
Notes:
All measurements were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM measurements; intake and discharge measurements were collected as spot measurements and MID LAKE BOTTOM measurements were collected at the bottom.
µS/cm = microSiemens per centimetre.

Figure C.2-7: Laboratory Specific Conductivity in Intakes, Discharges and Jackfish Lake, 2018



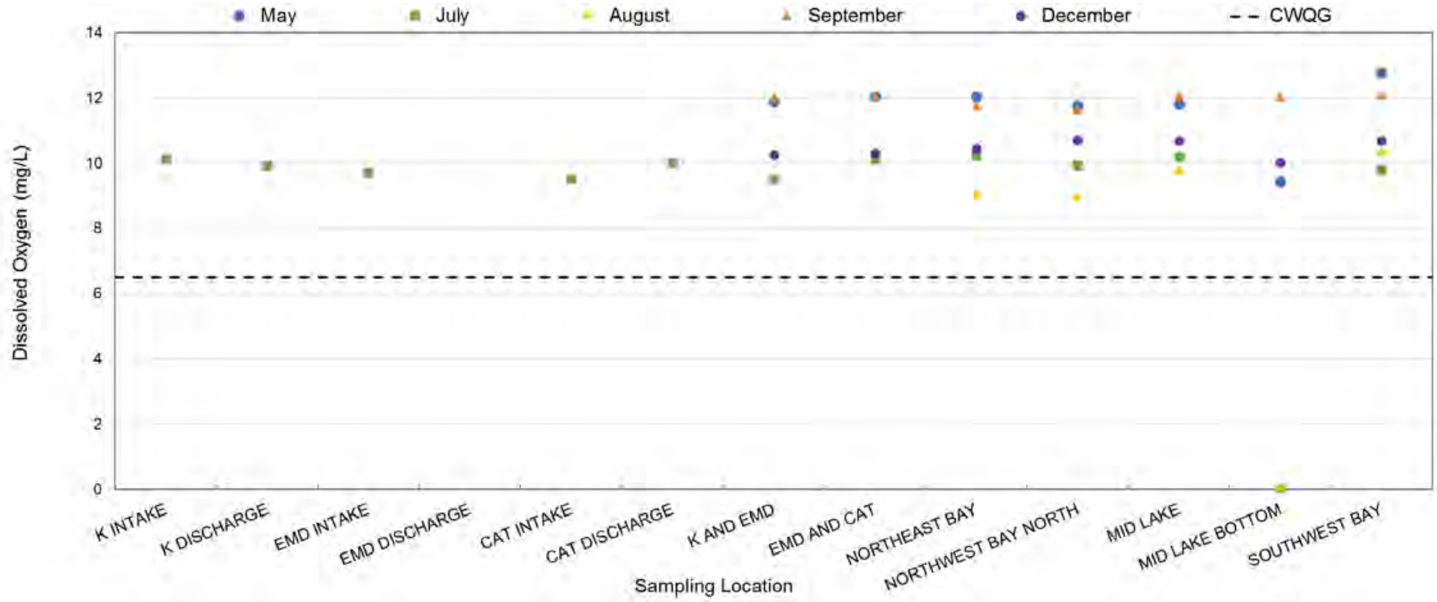
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
µS/cm = microSiemens per centimetre.

Figure C.2-8: Water Temperature in Intakes, Discharges and Jackfish Lake, 2018



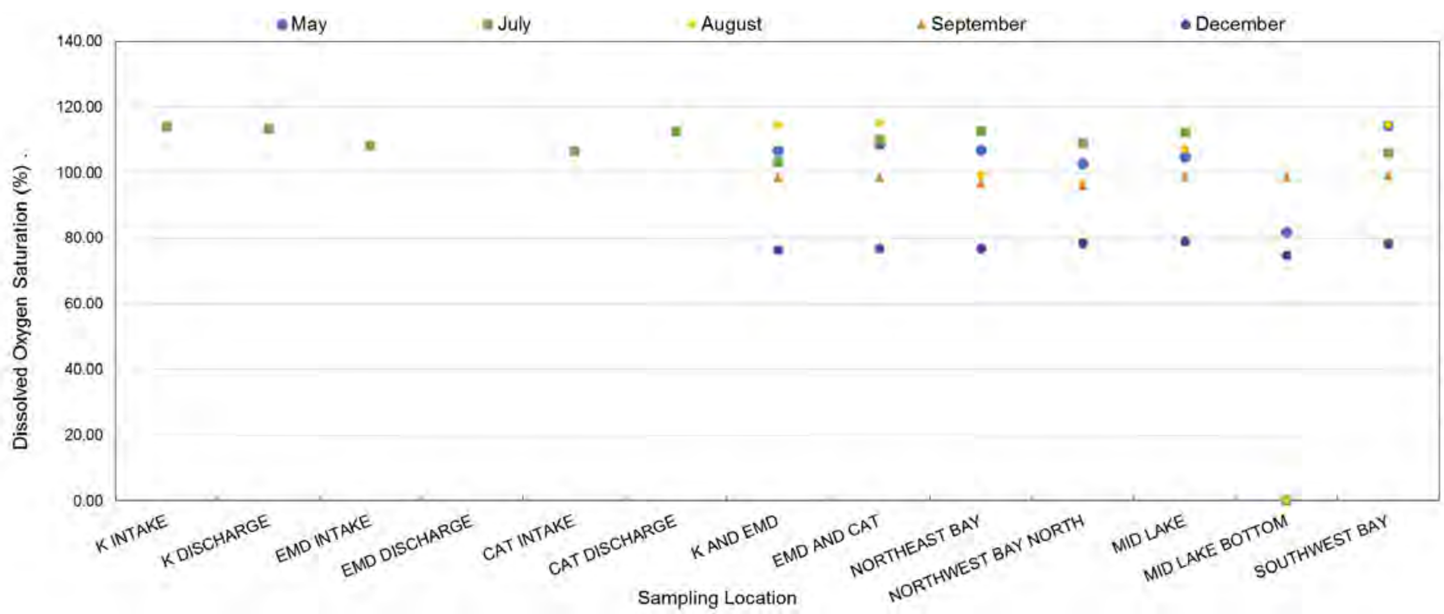
Note:
All measurements were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM measurements; intake and discharge measurements were collected as spot measurements and MID LAKE BOTTOM measurements were collected at the bottom.

Figure C.2-9: Dissolved Oxygen Concentrations in Intakes, Discharges and Jackfish Lake, 2018



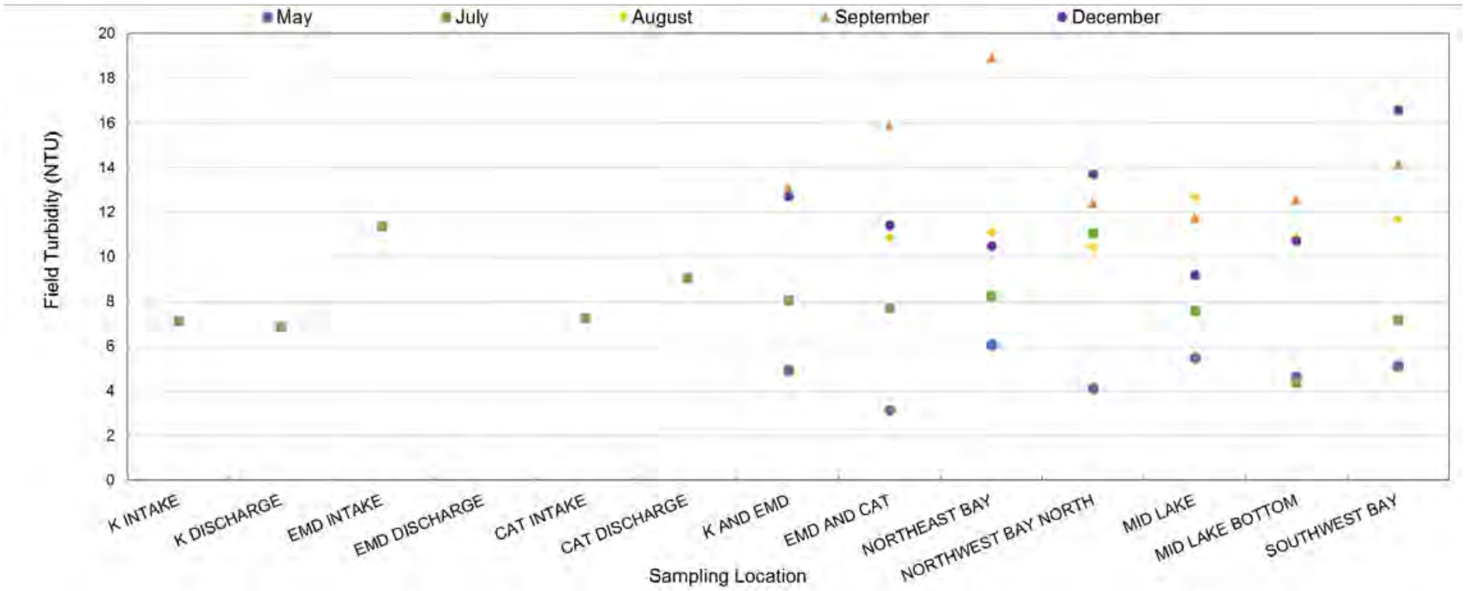
Notes:
All measurements were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM measurements; intake and discharge measurements were collected as spot measurements and MID LAKE BOTTOM measurements were collected at the bottom.
The lowest acceptable CWQG dissolved oxygen concentration for cold water biota is 9.5 mg/L for early life stages and 6.5 mg/L for other life stages.
CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999).

Figure C.2-10: Dissolved Oxygen Saturation in Intakes, Discharges and Jackfish Lake, 2018



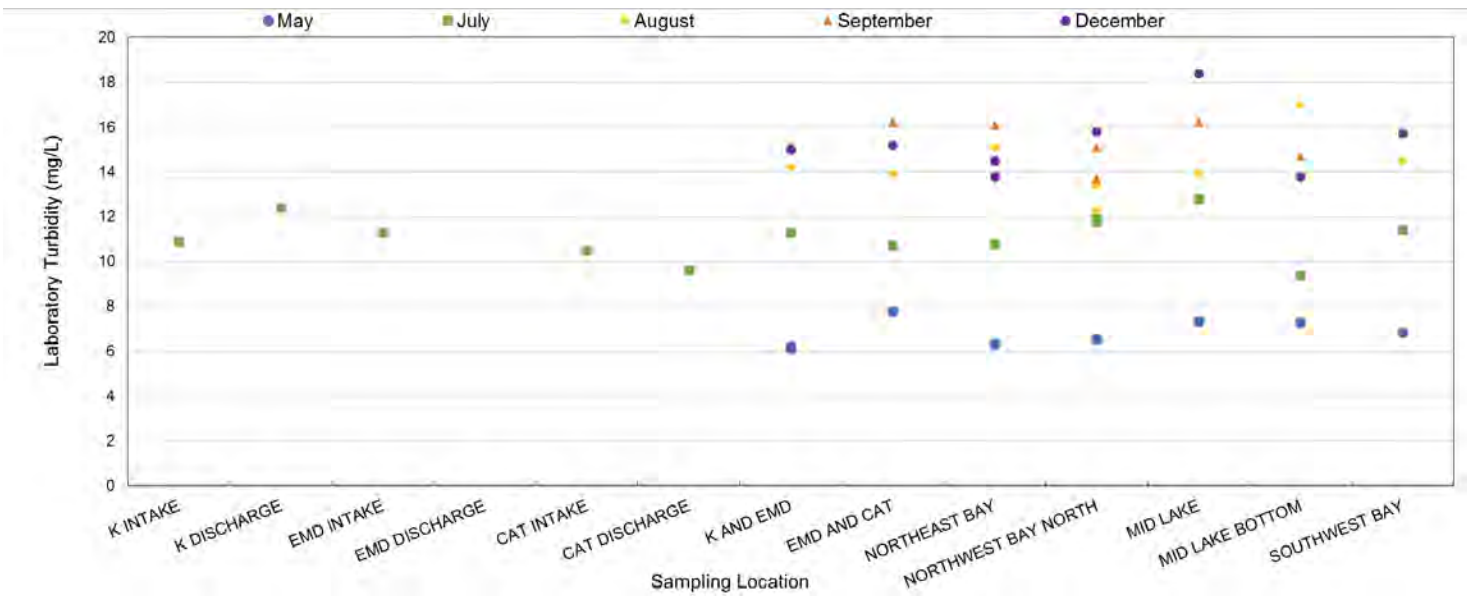
Note:
All measurements were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM measurements; intake and discharge measurements were collected as spot measurements and MID LAKE BOTTOM measurements were collected at the bottom.

Figure C.2-11: Field Turbidity in Intakes, Discharges and Jackfish Lake, 2018



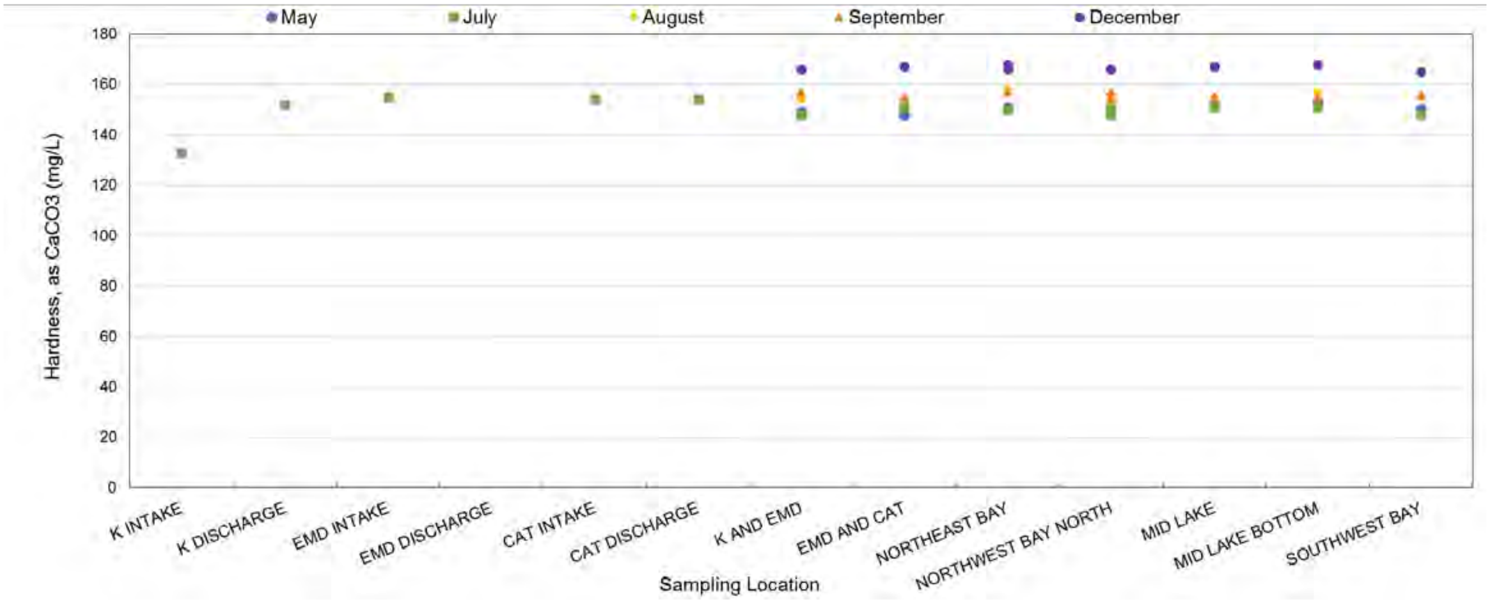
Notes:
All measurements were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM measurements; intake and discharge measurements were collected as spot measurements and MID LAKE BOTTOM measurements were collected at the bottom.
NTU = nephelometric turbidity units.

Figure C.2-12: Laboratory Turbidity in Intakes, Discharges and Jackfish Lake, 2018



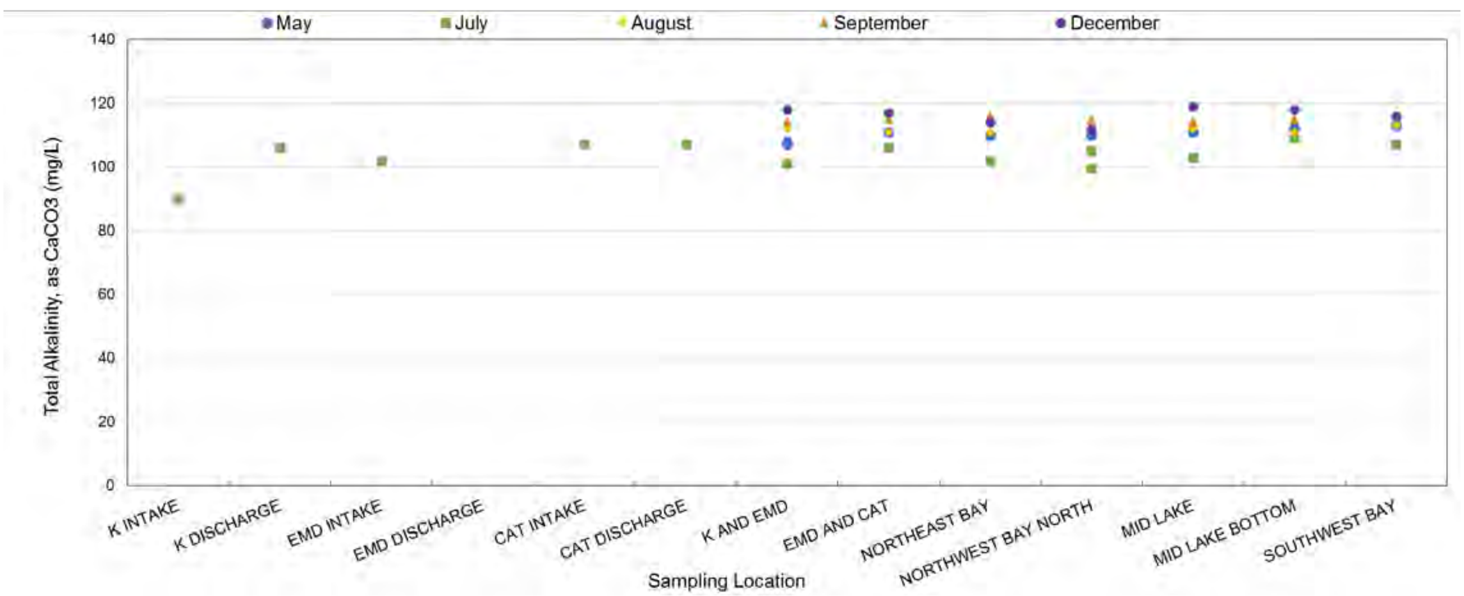
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
NTU = nephelometric turbidity units.

Figure C.2-13: Hardness (as $CaCO_3$) in Intakes, Discharges and Jackfish Lake, 2018



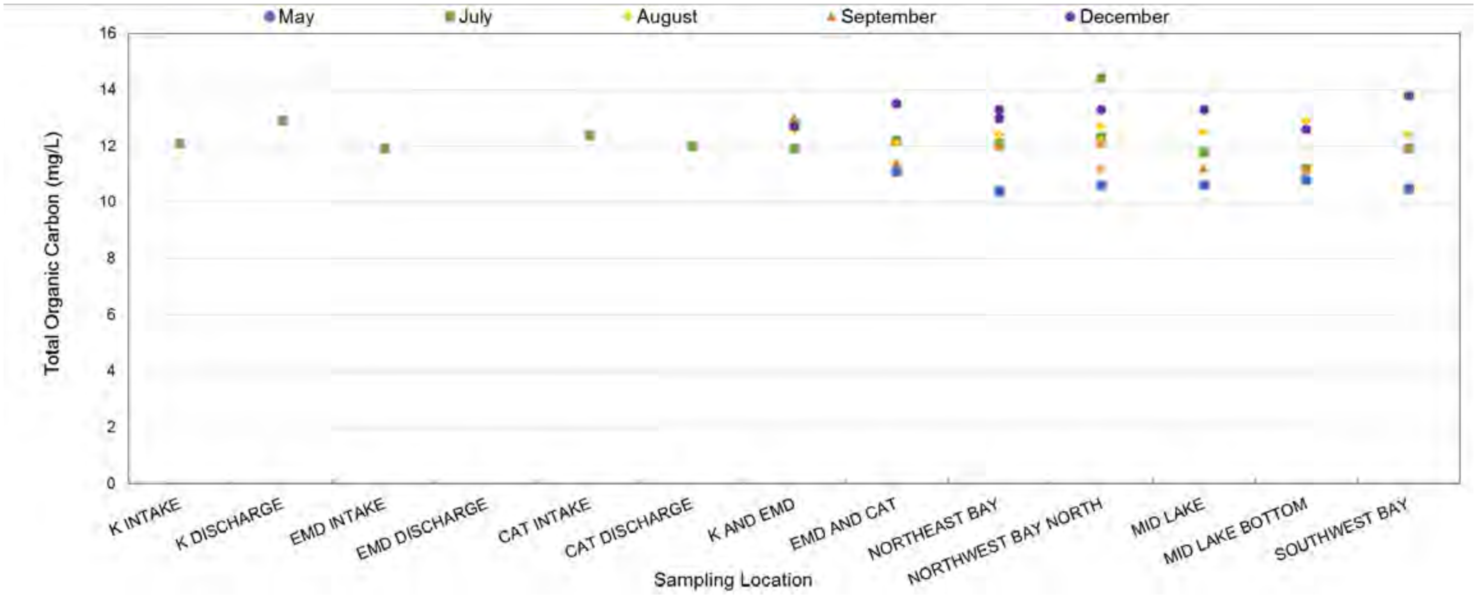
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
$CaCO_3$ = calcium carbonate.

Figure C.2-14: Total Alkalinity (as $CaCO_3$) in Intakes, Discharges and Jackfish Lake, 2018



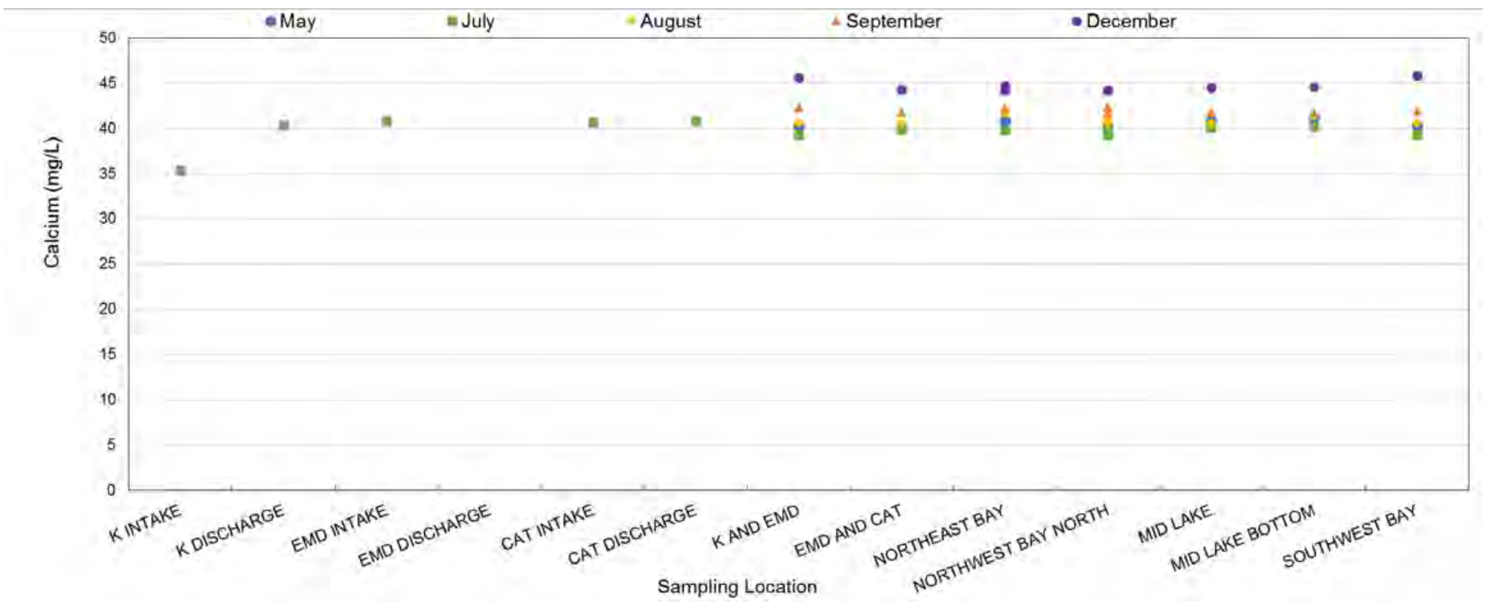
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
$CaCO_3$ = calcium carbonate.

Figure C.2-15: Total Organic Carbon Concentrations in Intakes, Discharges and Jackfish Lake, 2018



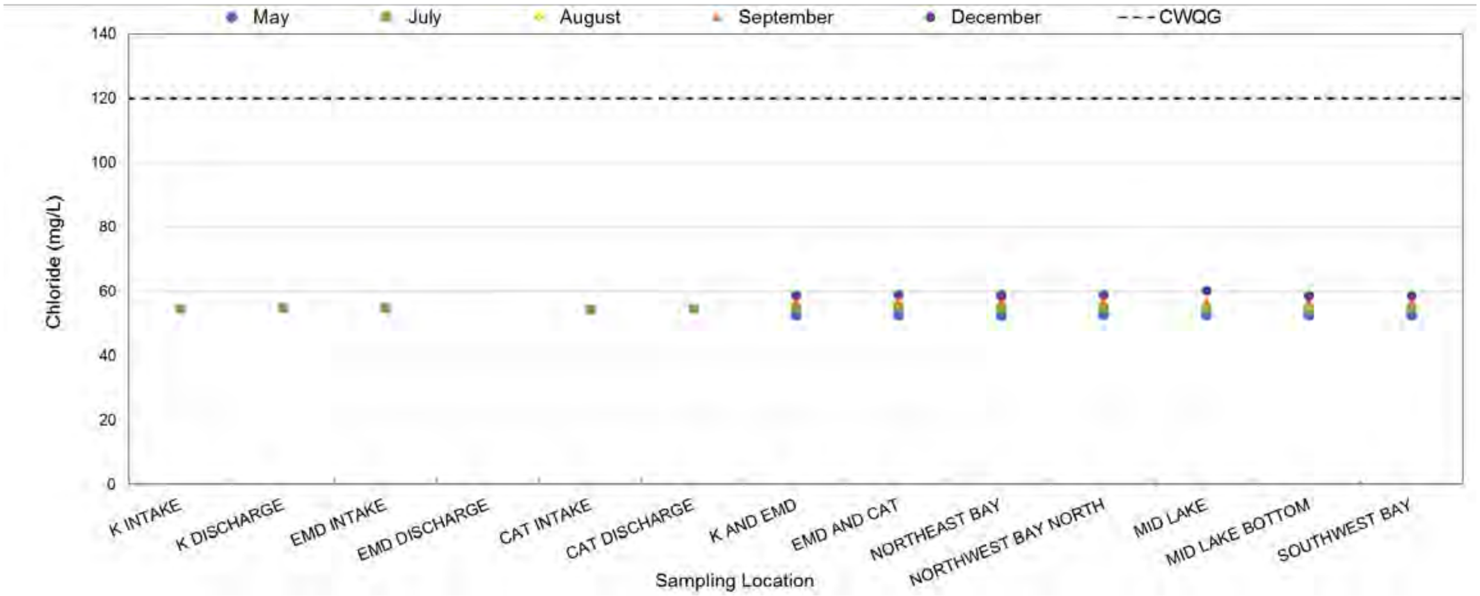
Note:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.

Figure C.2-16: Calcium Concentrations in Intakes, Discharges and Jackfish Lake, 2018



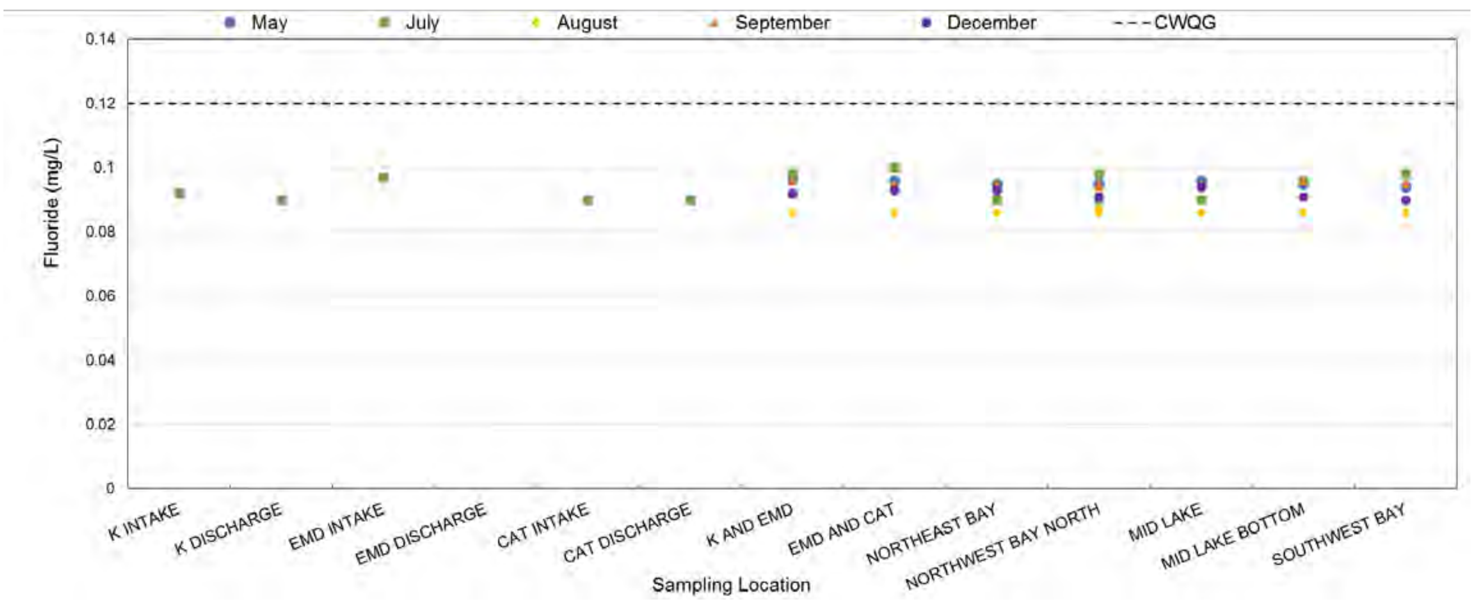
Note:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.

Figure C.2-17: Chloride Concentrations in Intakes, Discharges and Jackfish Lake, 2018



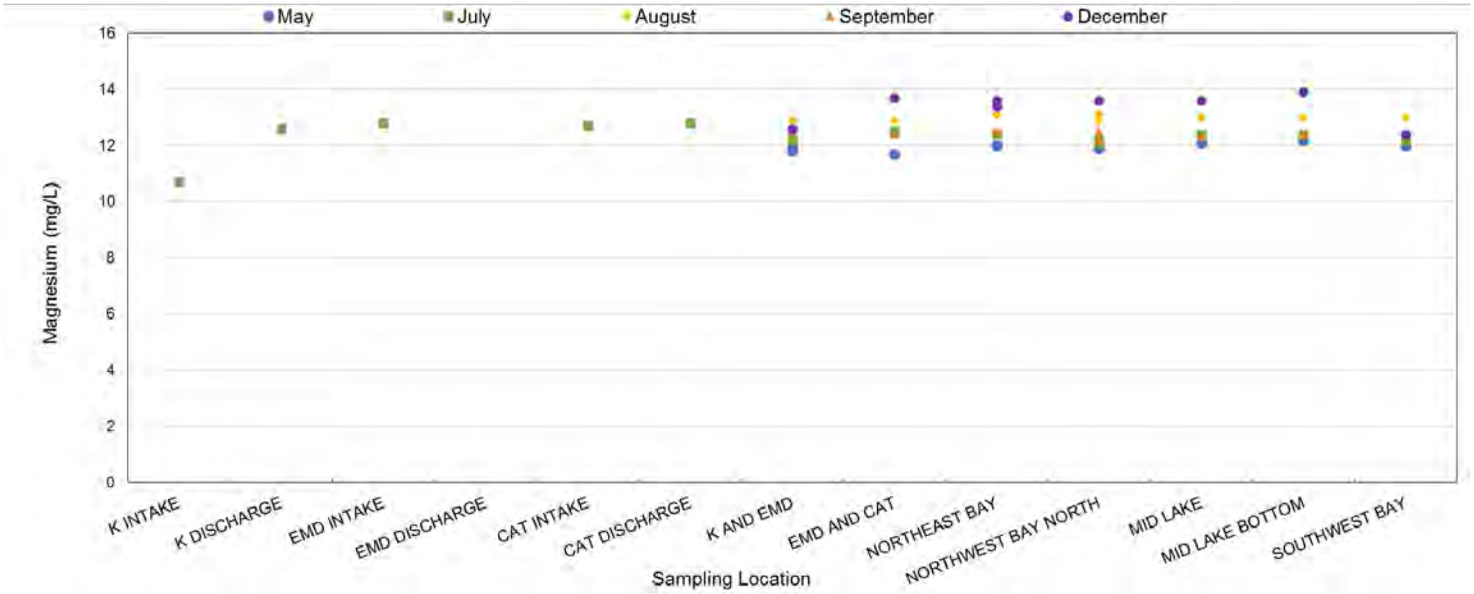
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
The long-term CWQG for chloride is 120 mg/L; the short-term CWQG for chloride (640 mg/L) is not presented on the figure.
CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999).

Figure C.2-18: Fluoride Concentrations in Intakes, Discharges and Jackfish Lake, 2018



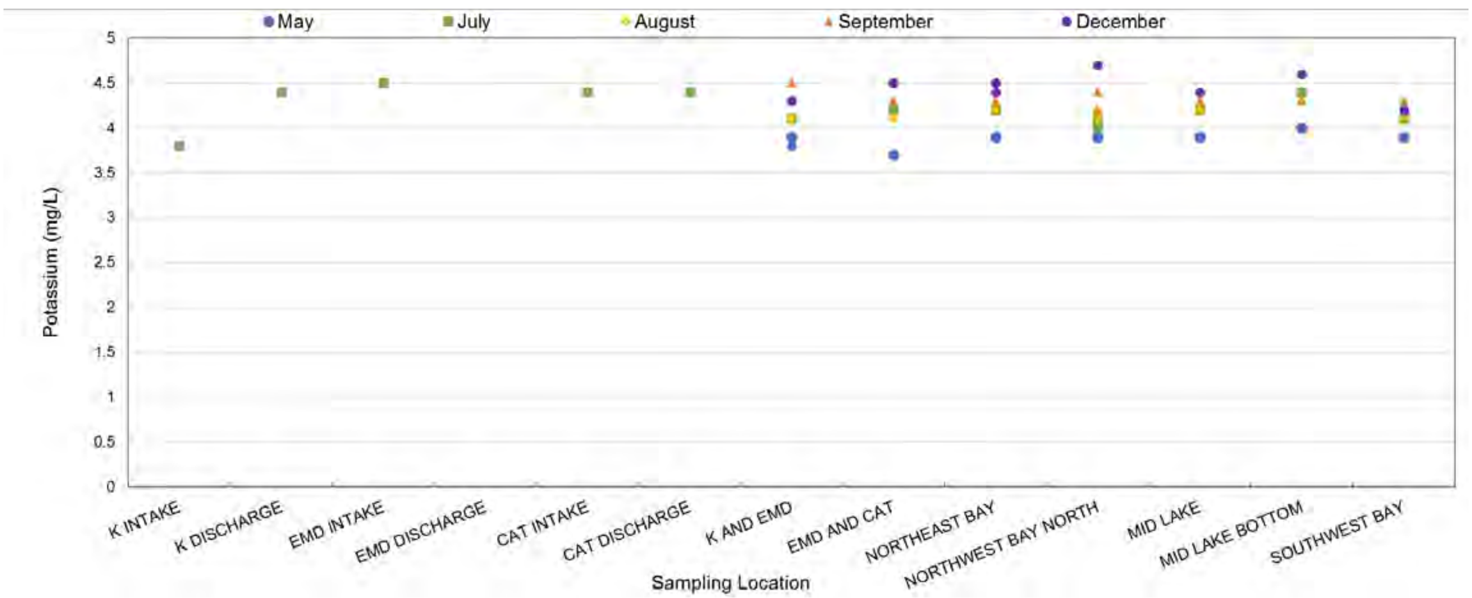
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
The CWQG for fluoride is 0.12 mg/L.
CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999).

Figure C.2-19: Magnesium Concentrations in Intakes, Discharges and Jackfish Lake, 2018



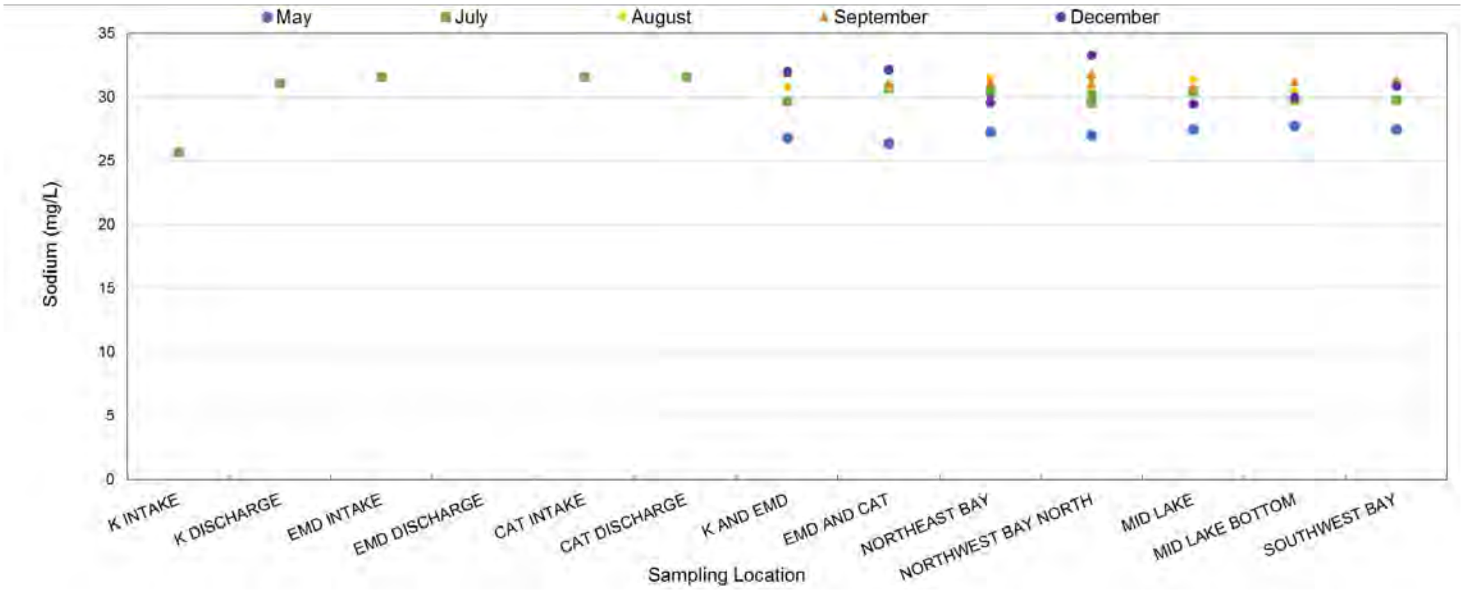
Note:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.

Figure C.2-20: Potassium Concentrations in Intakes, Discharges and Jackfish Lake, 2018



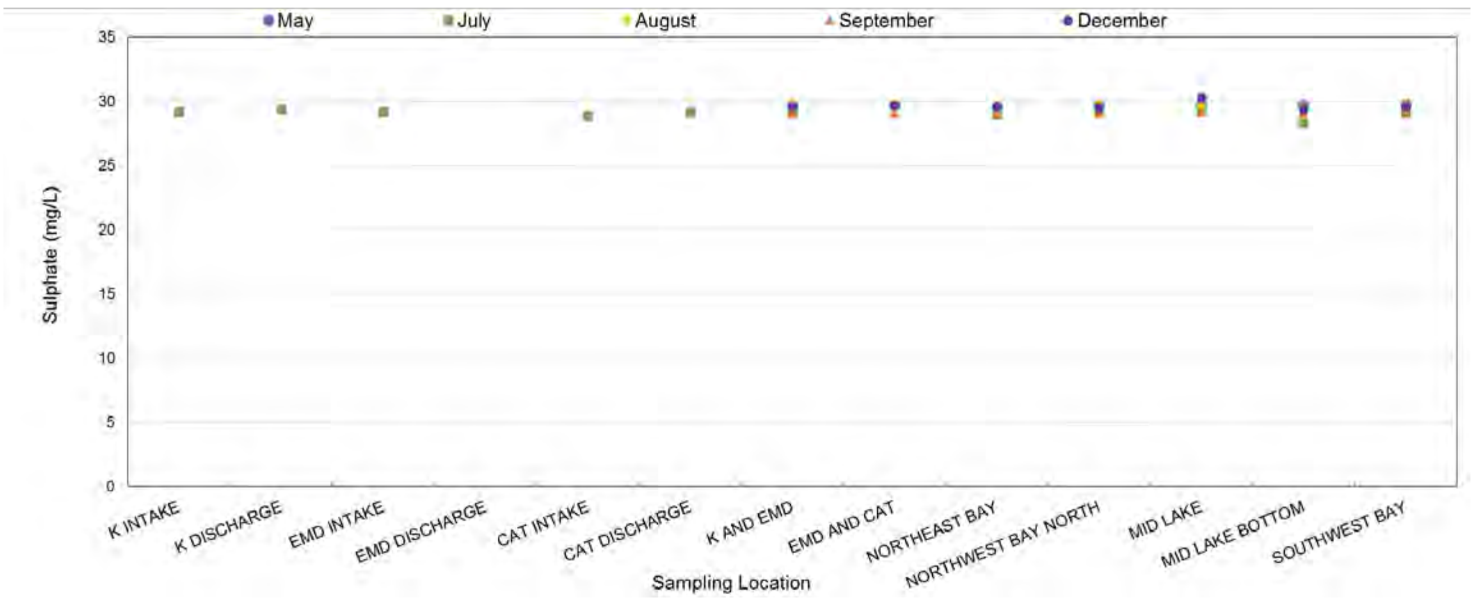
Note:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.

Figure C.2-21: Sodium Concentrations in Intakes, Discharges and Jackfish Lake, 2018



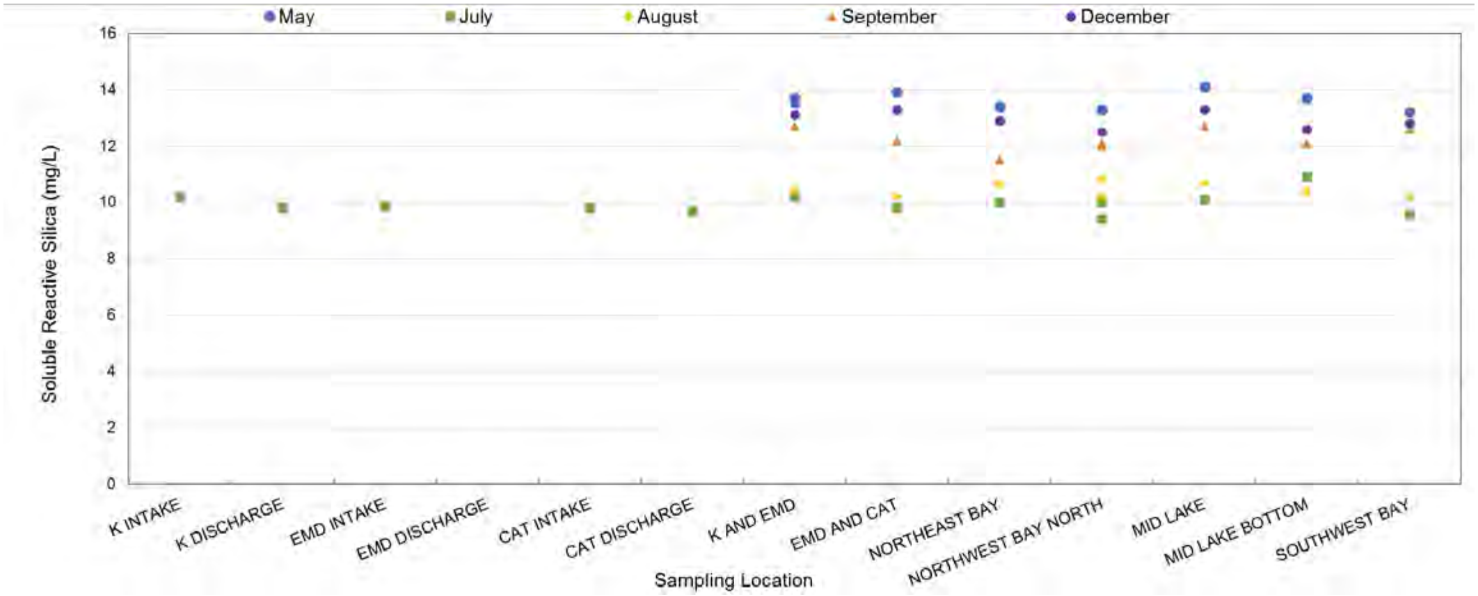
Note:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.

Figure C.2-22: Sulphate Concentrations in Intakes, Discharges and Jackfish Lake, 2018



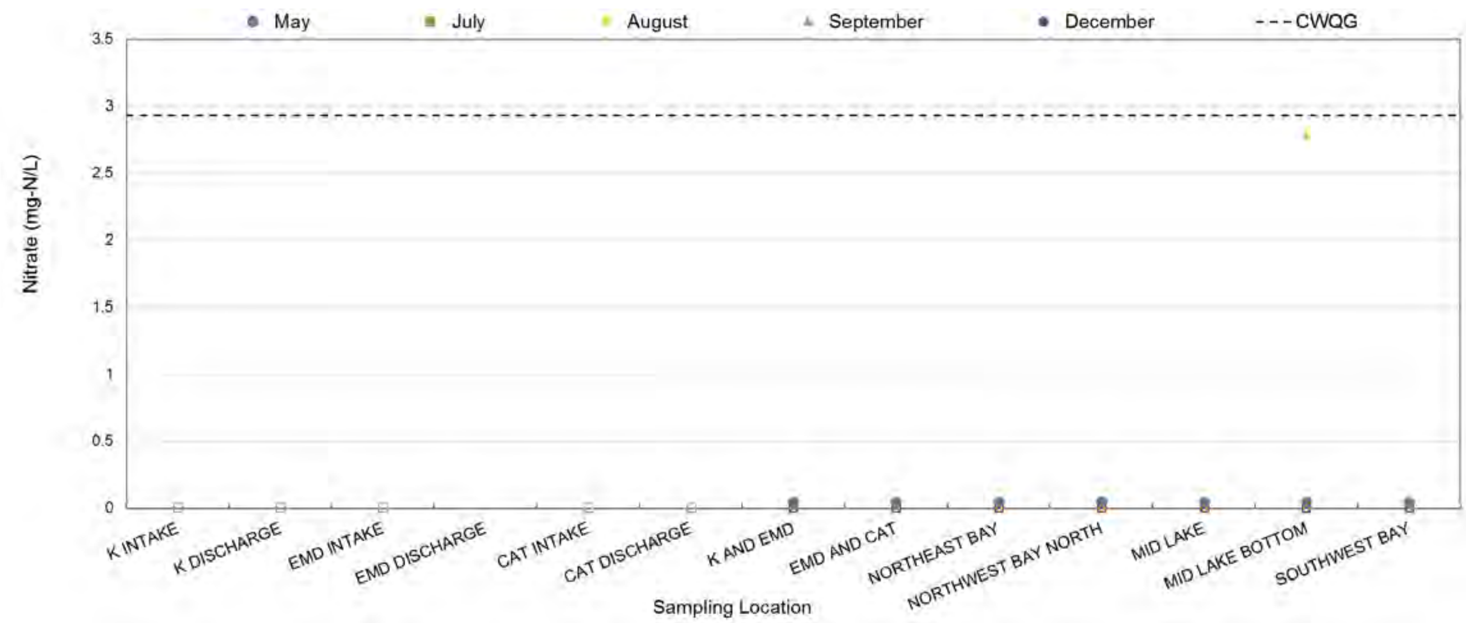
Note:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.

Figure C.2-23: Soluble Reactive Silica Concentrations in Intakes, Discharges and Jackfish Lake, 2018



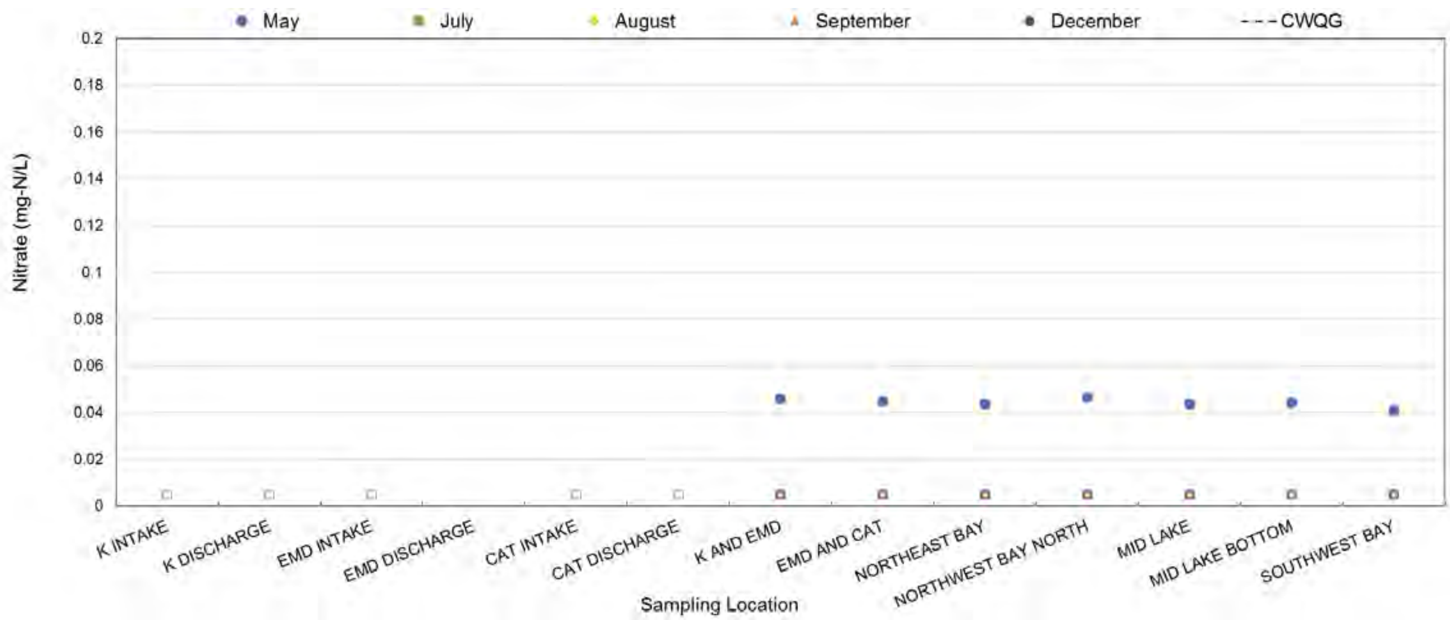
Note:
All samples were collected within the euphotic zone, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.

Figure C.2-24a: Nitrate Concentrations in Intakes, Discharges and Jackfish Lake, 2018 (Y-axis 3.5 mg/L)



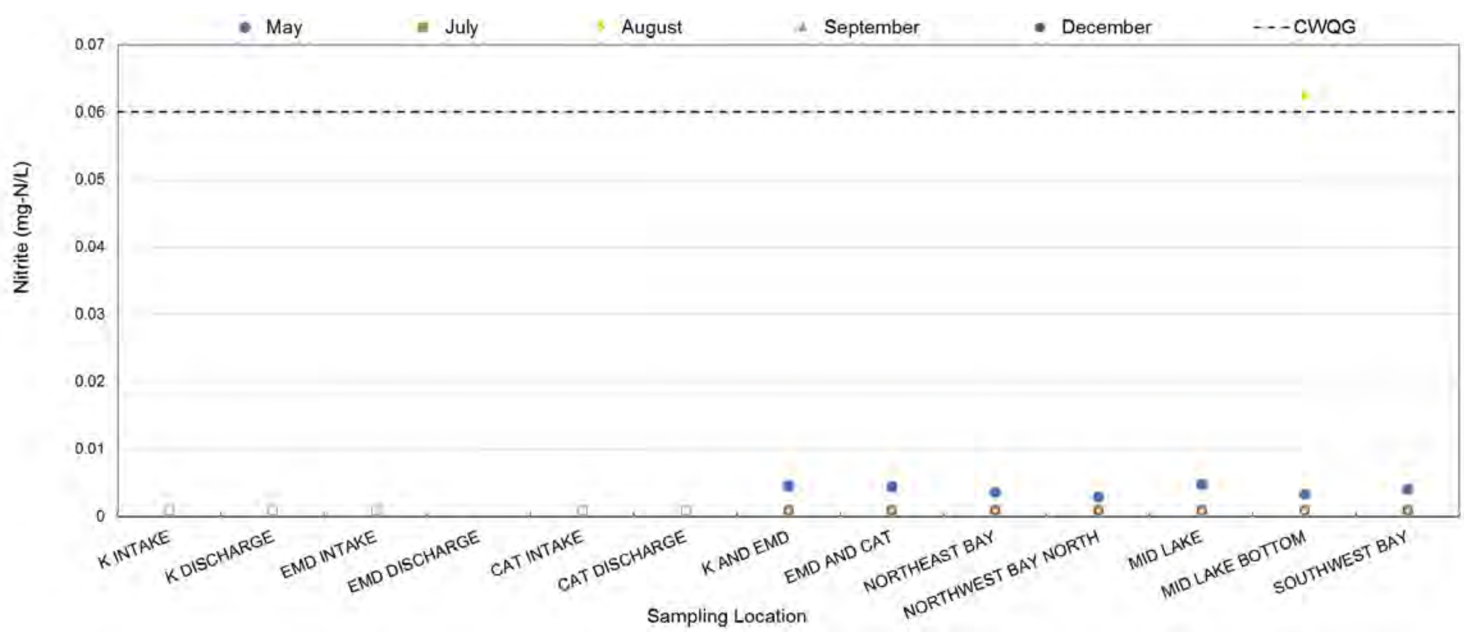
Notes:
All samples were collected within the euphotic zone, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
The long-term CWQG for nitrate is 2.93 mg/L; the short-term CWQG for nitrate (124 mg/L) is not presented on the figure.
CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999); DL = detection limit; mg-N/L = milligrams nitrogen per litre.

Figure C.2-24b Nitrate Concentrations in Intakes, Discharges and Jackfish Lake, 2018 (Y-axis 0.2 mg/L)



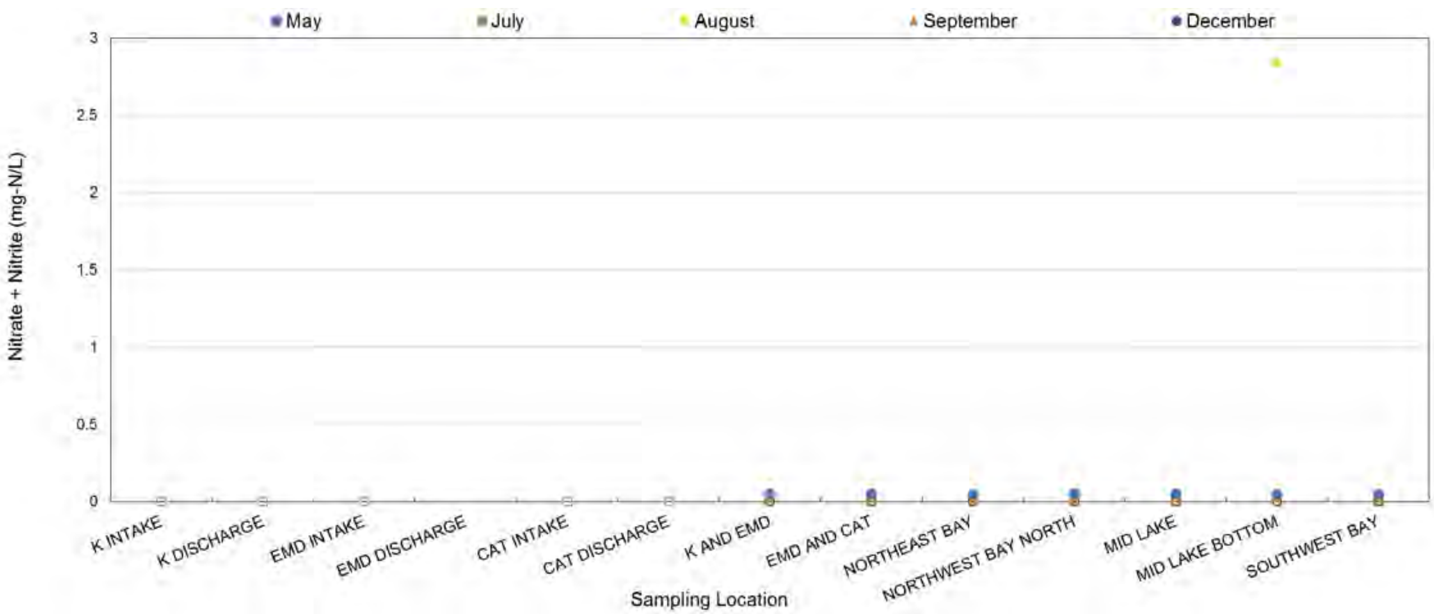
Notes:
All samples were collected within the euphotic zone, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
The long-term CWQG (2.93 mg/L) and short-term CWQG (124 mg/L) for nitrate are not presented on the figure.
CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999); DL = detection limit; mg-N/L = milligrams nitrogen per litre.

Figure C.2-25: Nitrite Concentrations in Intakes, Discharges and Jackfish Lake, 2018



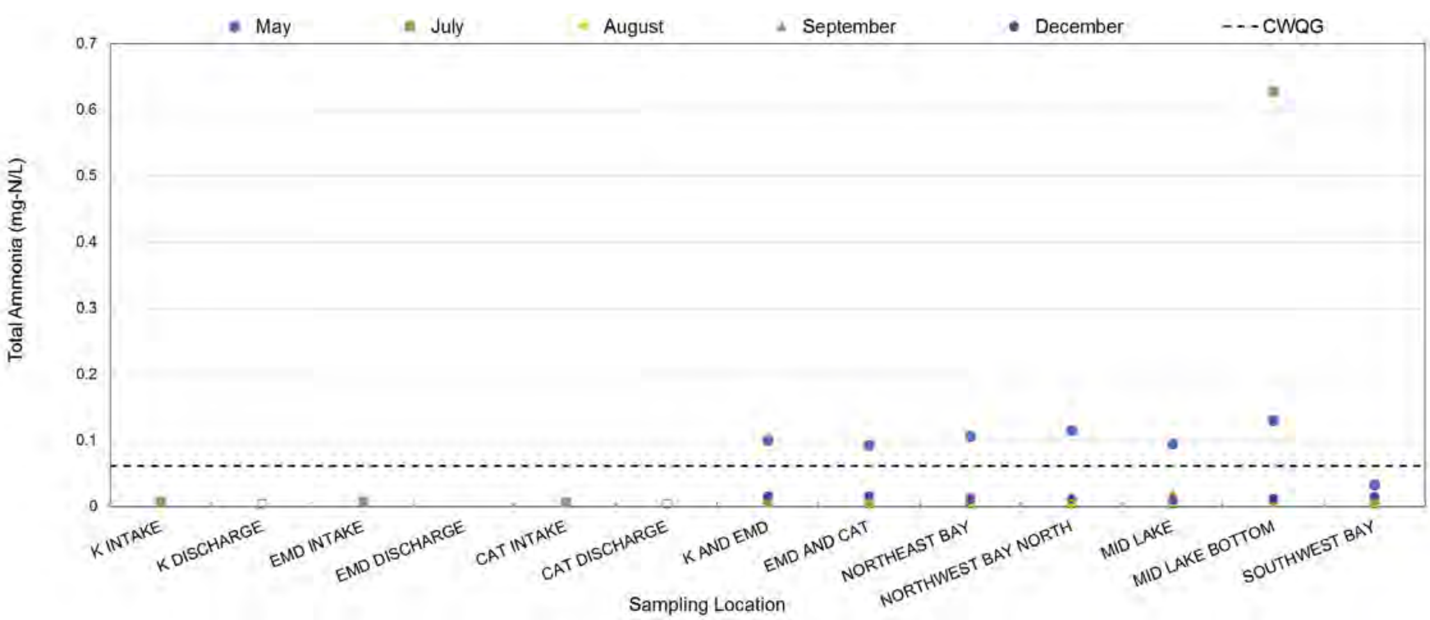
Notes:
All samples were collected within the euphotic zone, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
The CWQG for nitrite is 0.06 mg/L. CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999); DL = detection limit; mg-N/L = milligrams nitrogen per litre.

Figure C.2-26: Nitrate + Nitrite Concentrations in Intakes, Discharges and Jackfish Lake, 2018



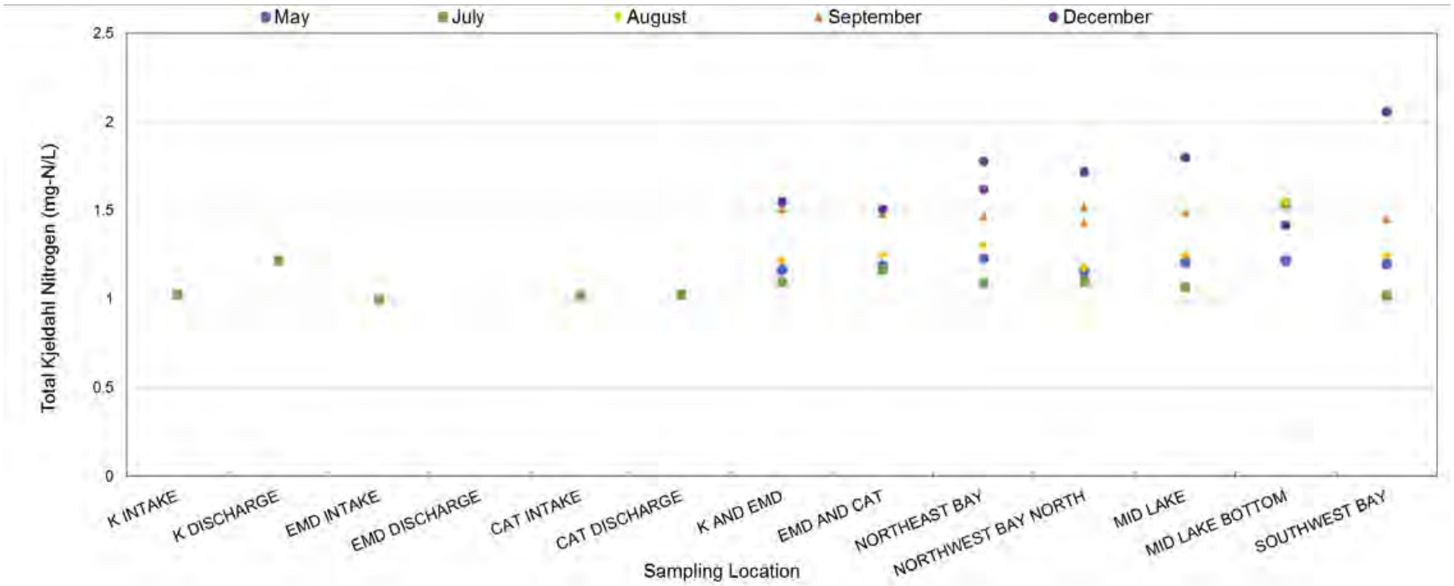
Notes:
All samples were collected within the euphotic zone, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
DL = detection limit; mg-N/L = milligrams nitrogen per litre.

Figure C.2-27: Total Ammonia Concentrations in Intakes, Discharges and Jackfish Lake, 2018



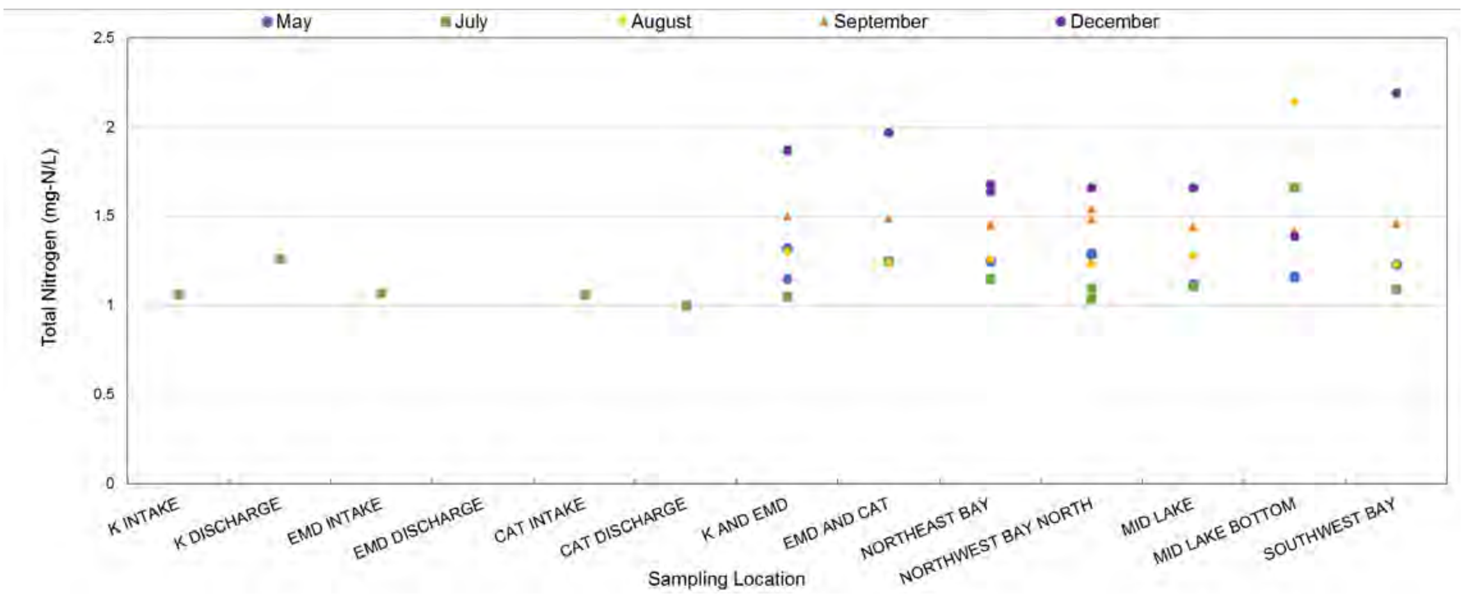
Notes:
All samples were collected within the euphotic zone, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
The CWQG for total ammonia is temperature and pH dependent. The minimum CWQG (0.062 mg/L), based on 2018 temperature and pH field values in Jackfish Lake and intake and discharge stations, is presented. Comparisons to the CWQG for individual samples from 2018 are provided in Table C.1a.
CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999); DL = detection limit; mg-N/L = milligrams nitrogen per litre.

Figure C.2-28: Total Kjeldahl Nitrogen Concentrations in Intakes, Discharges and Jackfish Lake, 2018



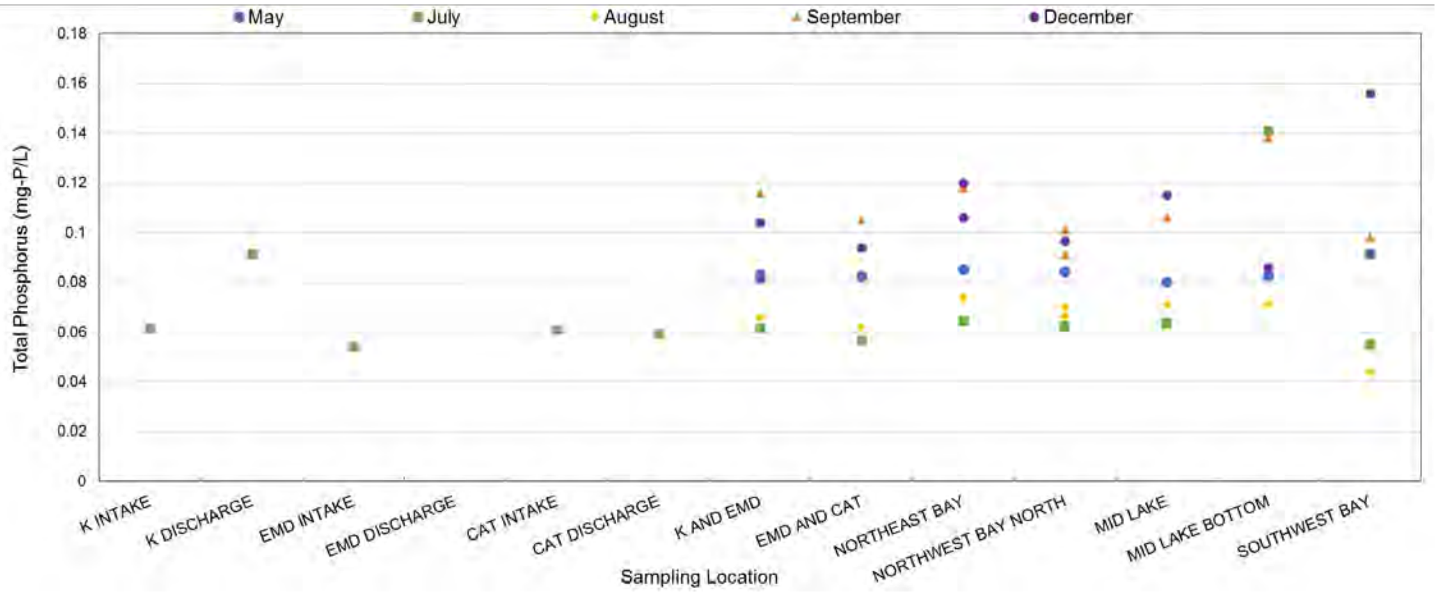
Notes:
All samples were collected within the euphotic zone, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
mg-N/L = milligrams nitrogen per litre.

Figure C.2-29: Total Nitrogen Concentrations in Intakes, Discharges and Jackfish Lake, 2018



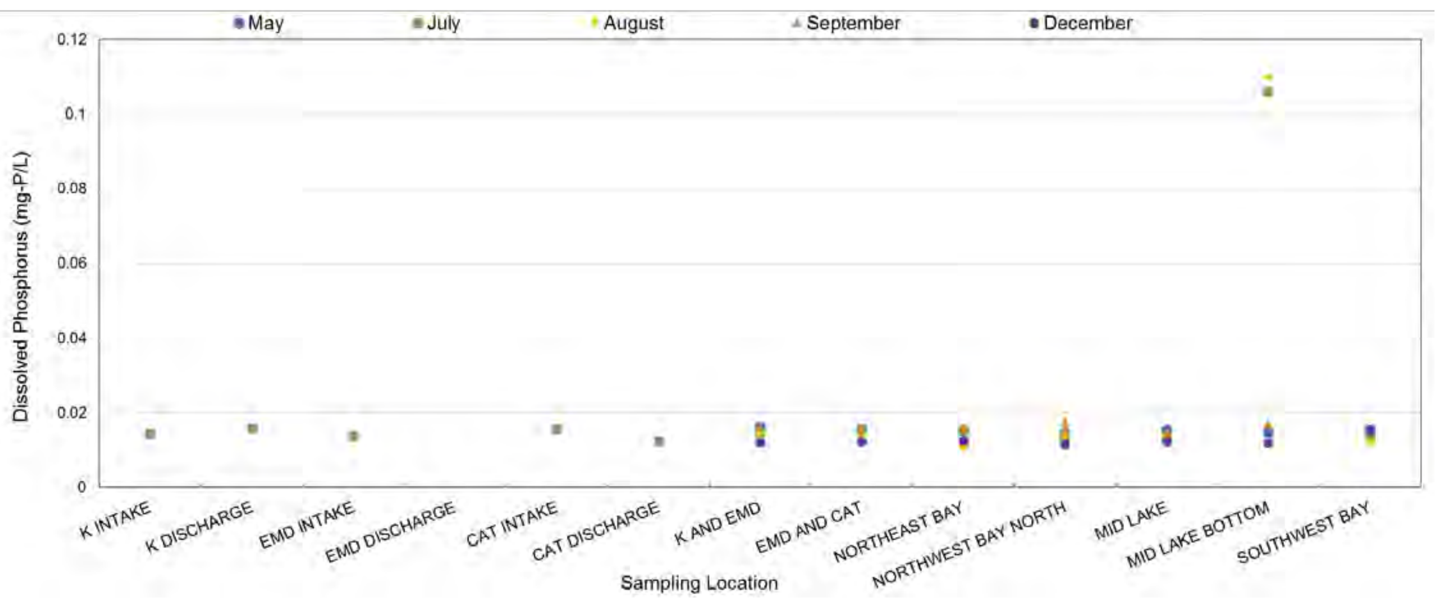
Notes:
All samples were collected within the euphotic zone, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
mg-N/L = milligrams nitrogen per litre.

Figure C.2-30: Total Phosphorus Concentrations in Intakes, Discharges and Jackfish Lake, 2018



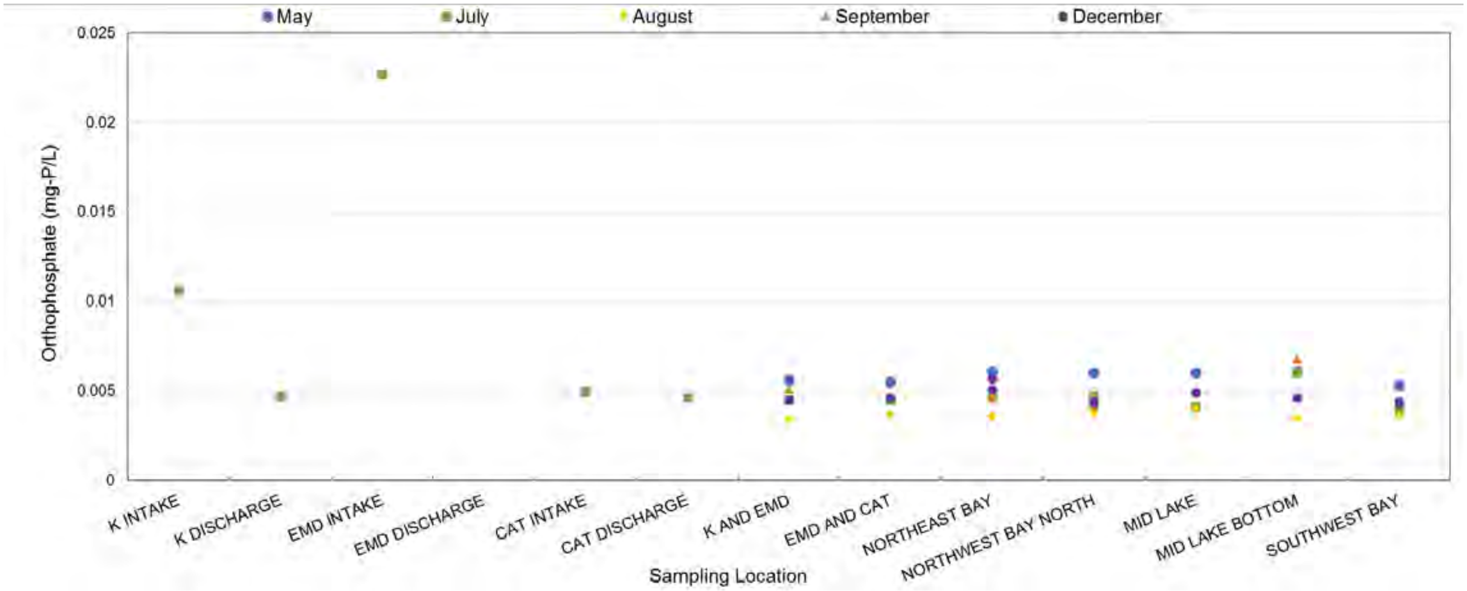
Notes:
All samples were collected within the euphotic zone, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
mg-P/L = milligrams phosphorus per litre.

Figure C.2-31: Dissolved Phosphorus Concentrations in Intakes, Discharges and Jackfish Lake, 2018



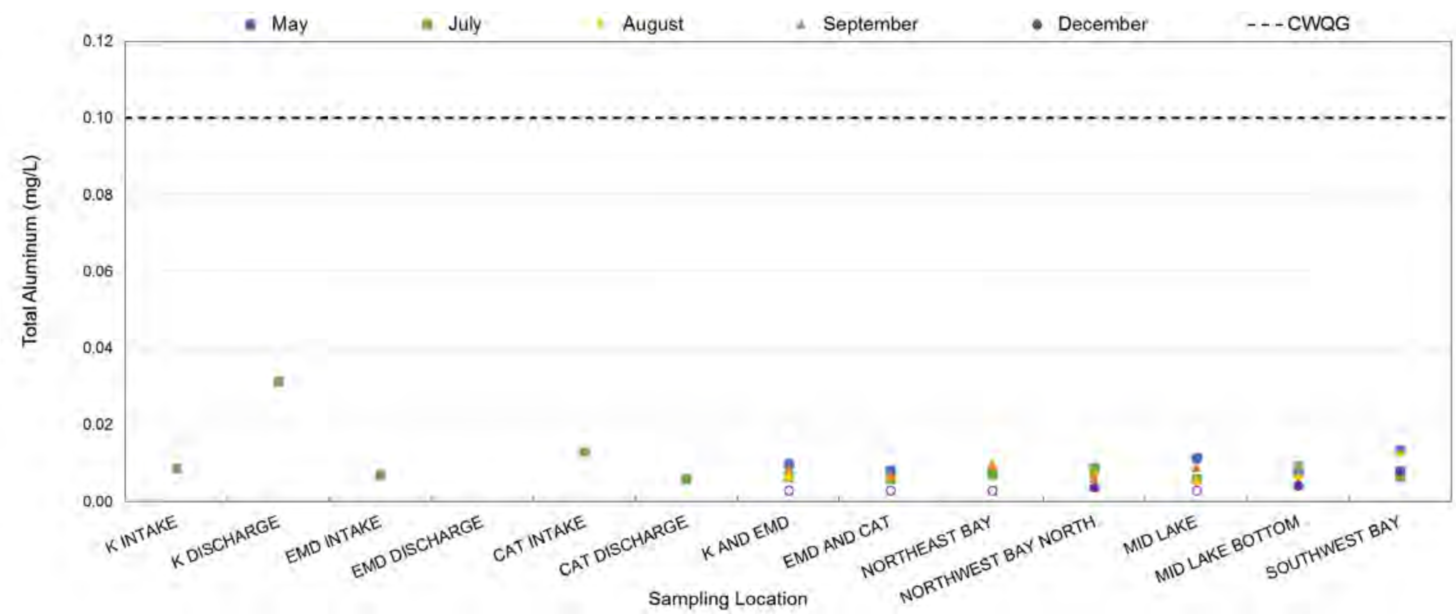
Notes:
All samples were collected within the euphotic zone, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
mg-P/L = milligrams phosphorus per litre.

Figure C.2-32: Orthophosphate Concentrations in Intakes, Discharges and Jackfish Lake, 2018



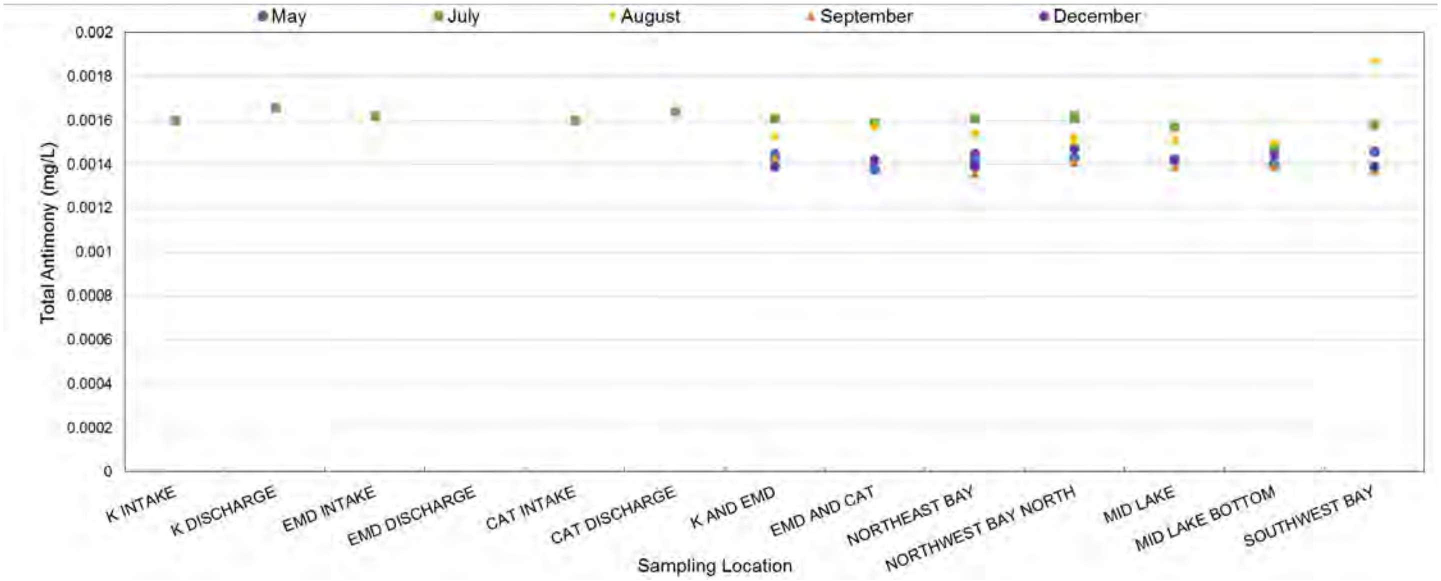
Notes:
All samples were collected within the euphotic zone, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
mg-P/L = milligrams phosphorus per litre.

Figure C.2-33: Total Aluminum Concentrations in Intakes, Discharges and Jackfish Lake, 2018



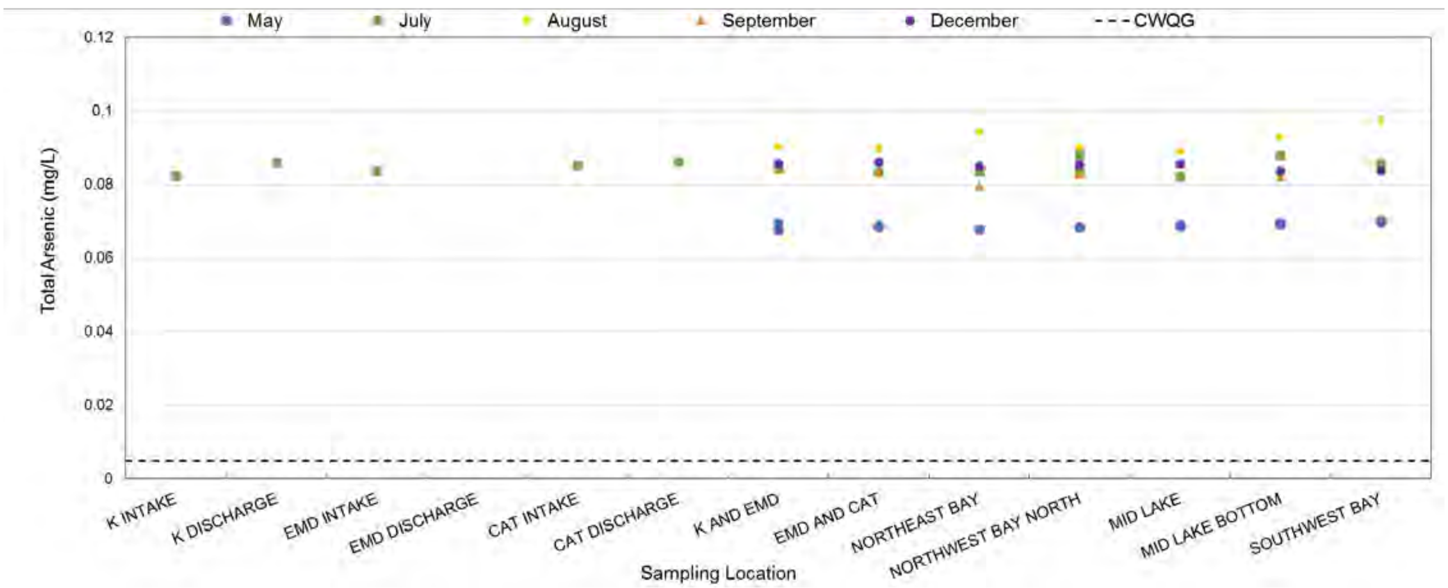
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
The CWQG for total aluminum is pH dependent. The applicable CWQG (0.100 mg/L), based on 2018 pH field values in Jackfish Lake and intake and discharge stations, is presented. Comparisons to the CWQG for individual samples from 2018 are provided in Appendix C.1a.
CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999); DL = detection limit.

Figure C.2-34: Total Antimony Concentrations in Intakes, Discharges and Jackfish Lake, 2018



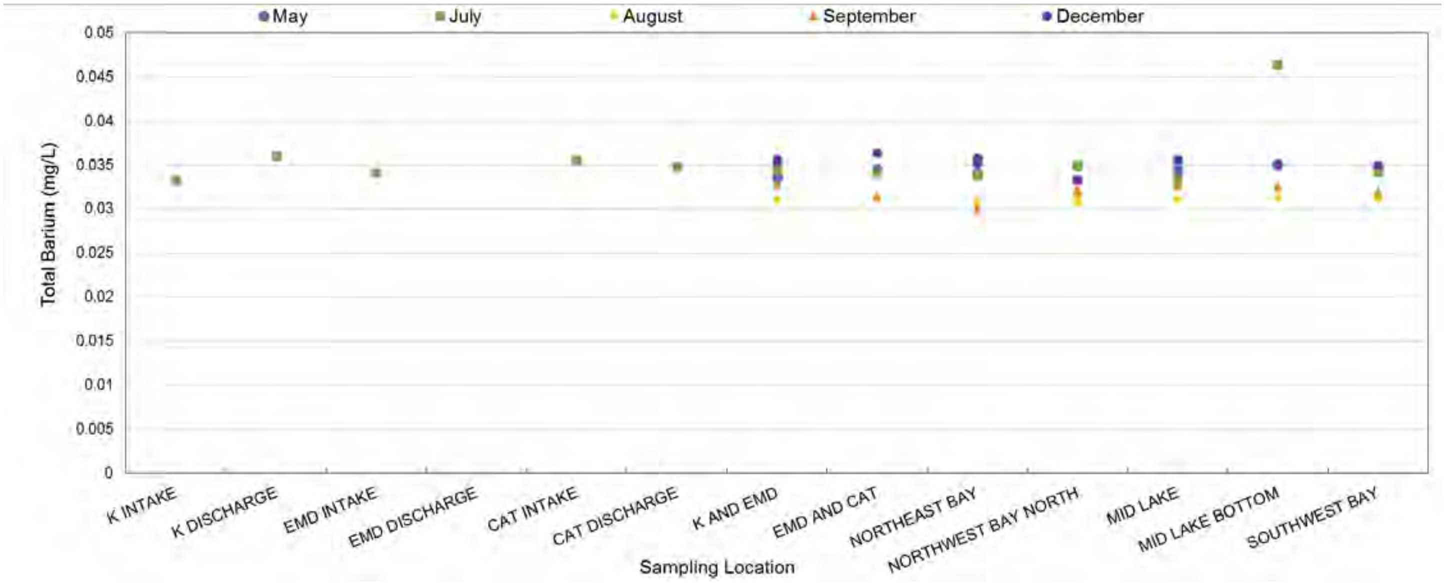
Note:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.

Figure C.2-35: Total Arsenic Concentrations in Intakes, Discharges and Jackfish Lake, 2018



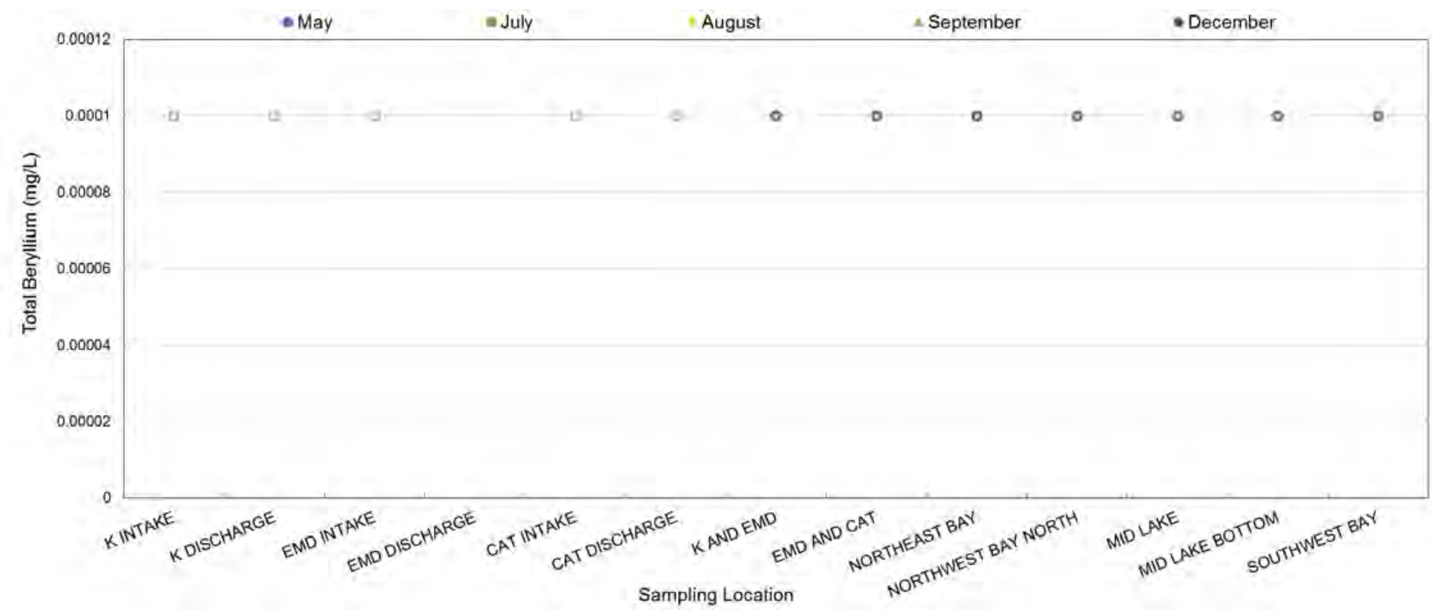
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
The CWQG for arsenic is 0.005 mg/L.
CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999).

Figure C.2-36: Total Barium Concentrations in Intakes, Discharges and Jackfish Lake, 2018



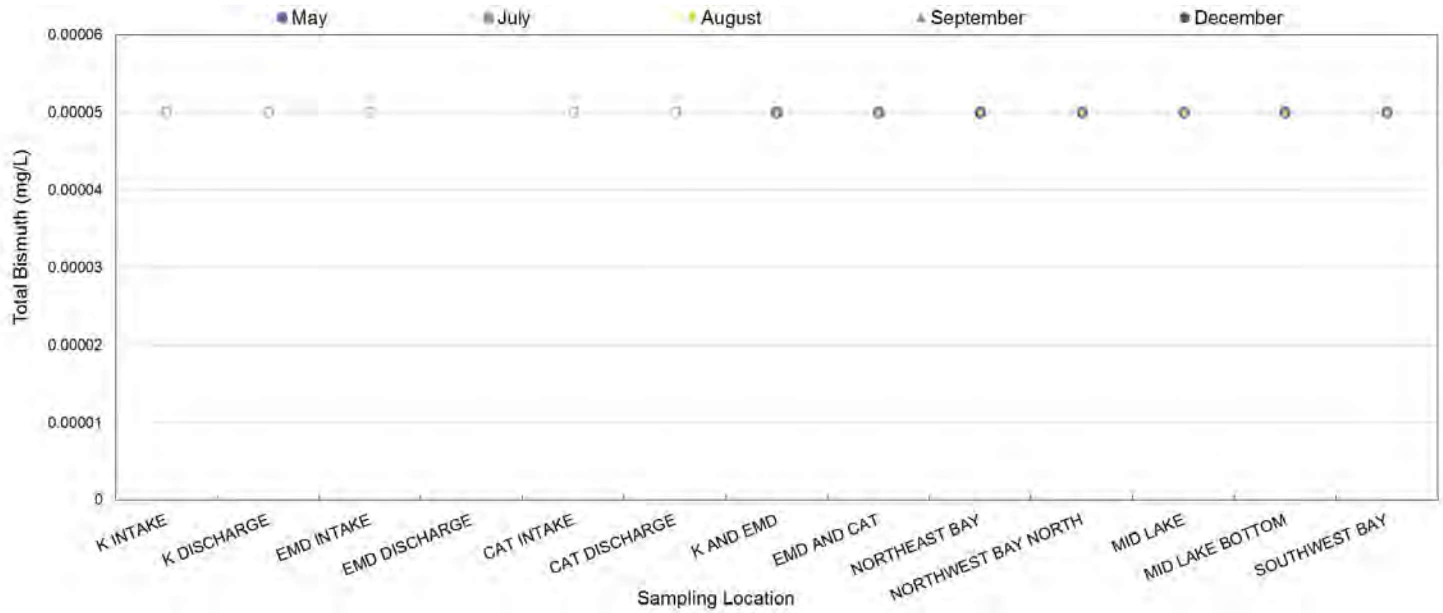
Note:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.

Figure C.2-37: Total Beryllium Concentrations in Intakes, Discharges and Jackfish Lake, 2018



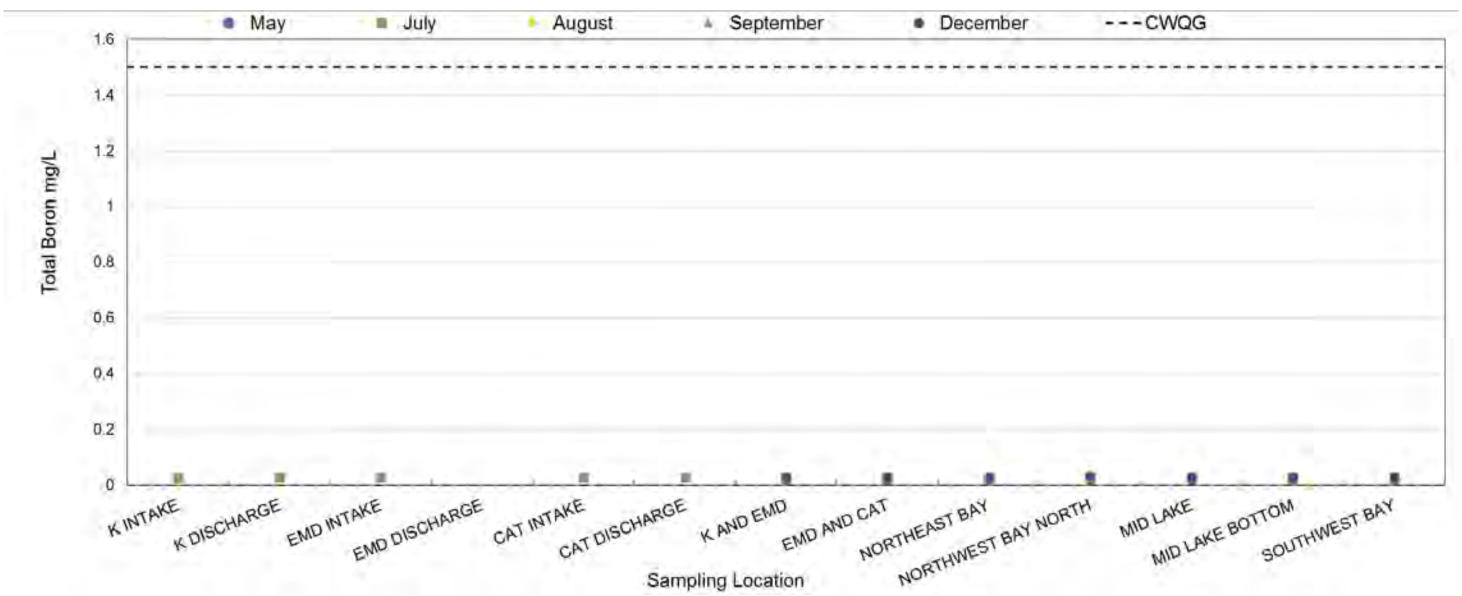
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
DL = detection limit.

Figure C.2-38: Total Bismuth Concentrations in Intakes, Discharges and Jackfish Lake, 2018



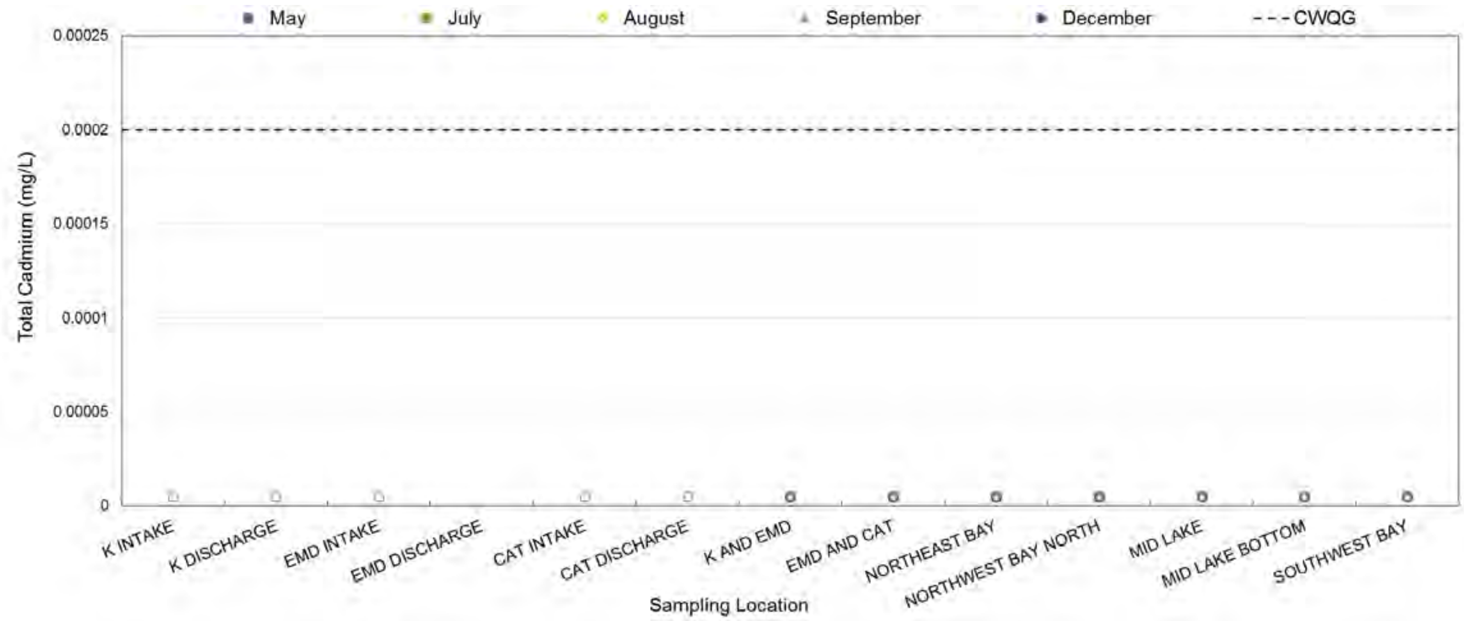
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
DL = detection limit.

Figure C.2-39: Total Boron Concentrations in Intakes, Discharges and Jackfish Lake, 2018



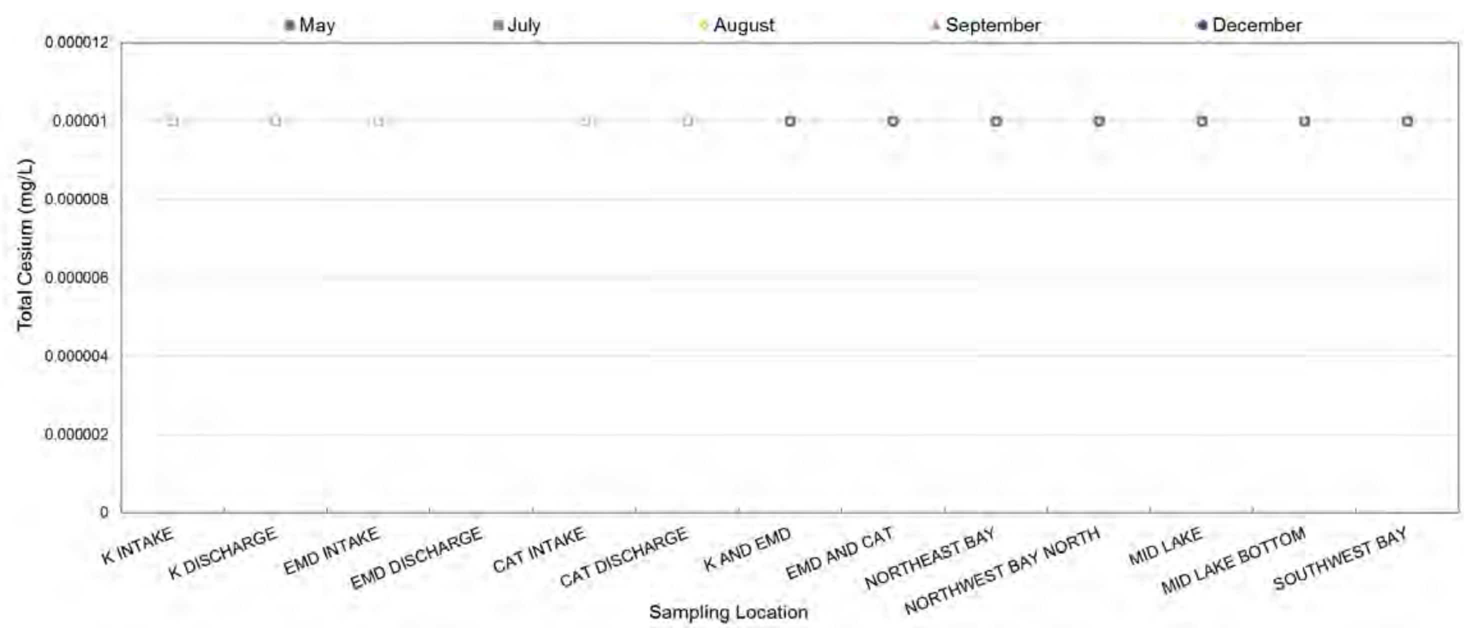
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
The long-term CWQG for total boron is 1.5 mg/L; the short-term CWQG for total boron of 29 mg/L is not presented on the figure.
CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999).

Figure C.2-40: Total Cadmium Concentrations in Intakes, Discharges and Jackfish Lake, 2018



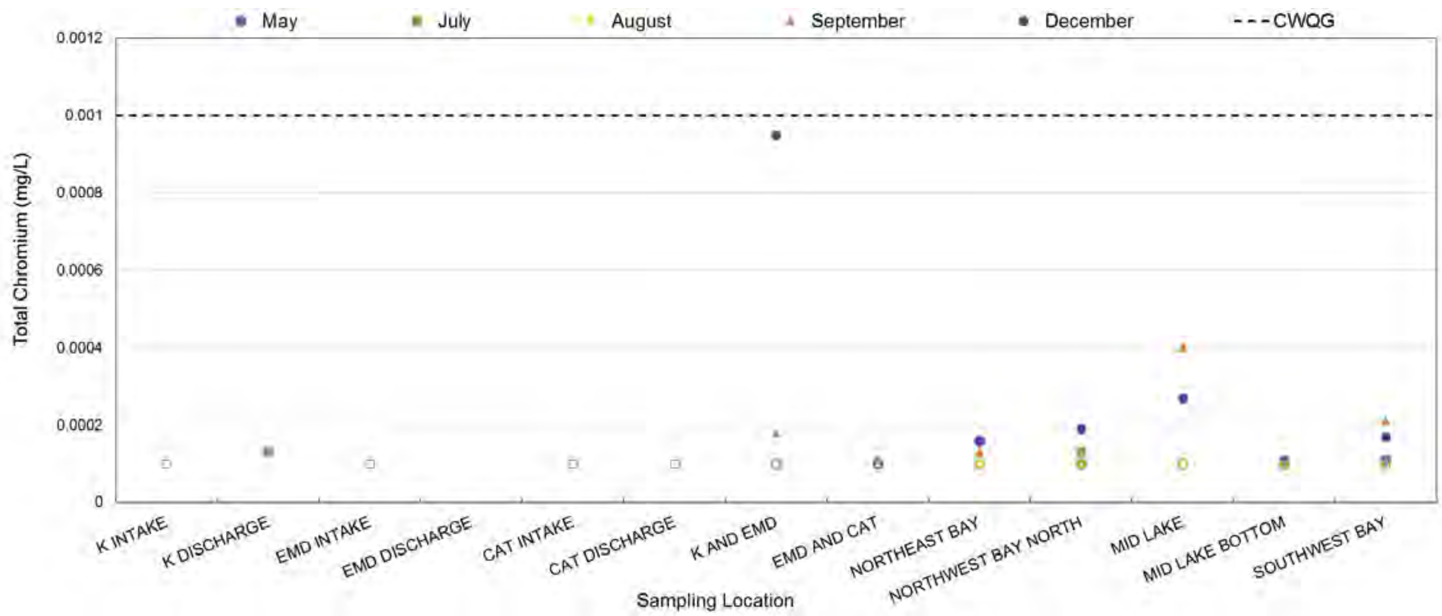
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
The CWQG for total cadmium is dependent on water hardness. The minimum CWQG (0.00020 mg/L), based on 2018 water hardness values in Jackfish Lake and intake and discharge stations, is presented. Comparisons to the CWQG for individual samples from 2018 are provided in Appendix C.1a.
CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999); DL = detection limit.

Figure C.2-41: Total Cesium Concentrations in Intakes, Discharges and Jackfish Lake, 2018



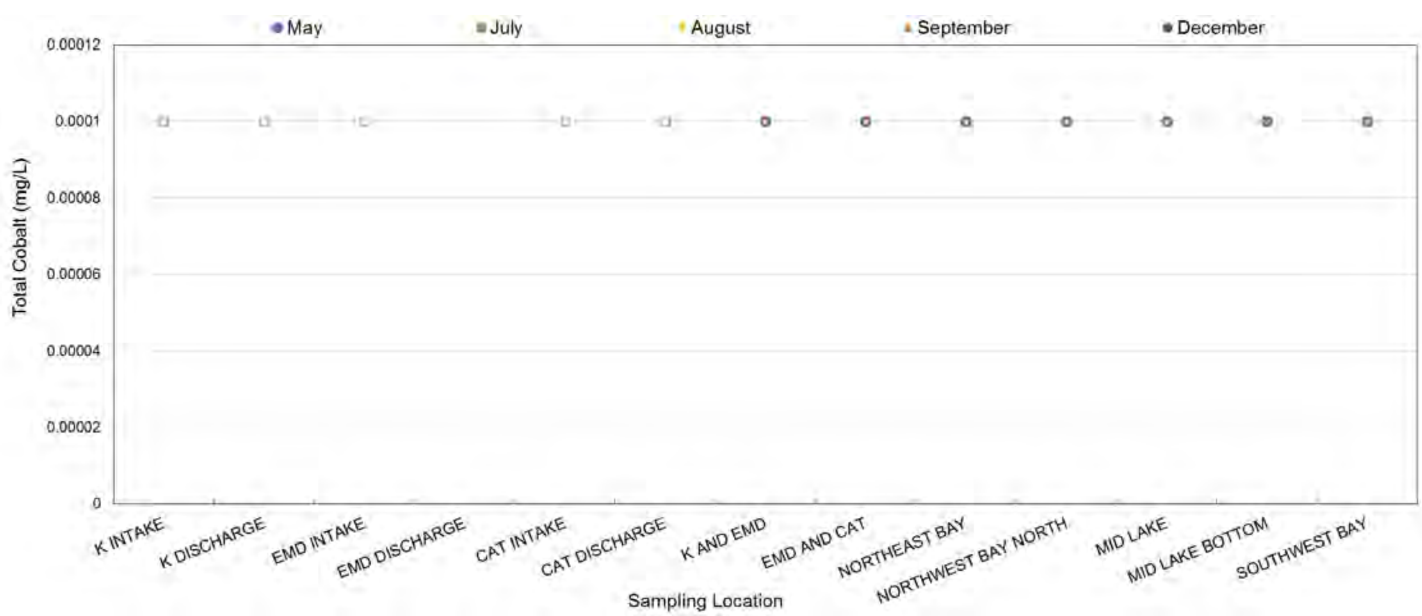
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
DL = detection limit.

Figure C.2-42: Total Chromium Concentrations in Intakes, Discharges and Jackfish Lake, 2018



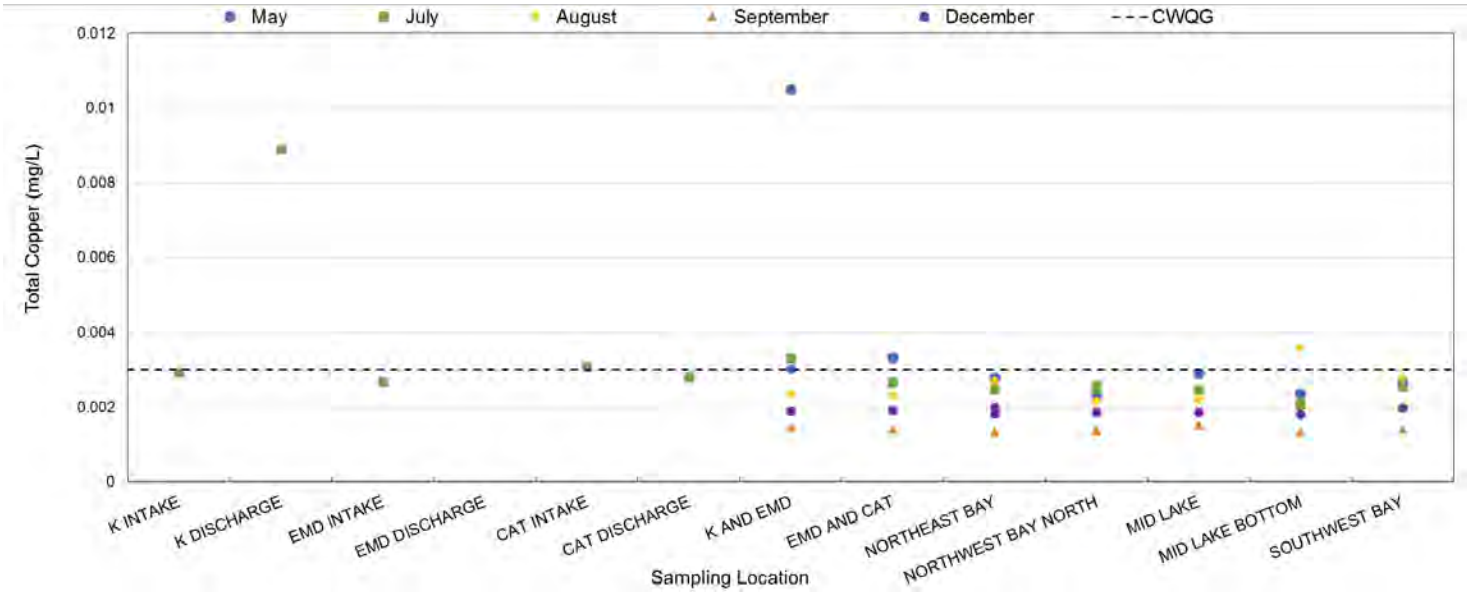
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
The CWQG for total chromium is 0.001 mg/L.
CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999); DL = detection limit.

Figure C.2-43: Total Cobalt Concentrations in Intakes, Discharges and Jackfish Lake, 2018



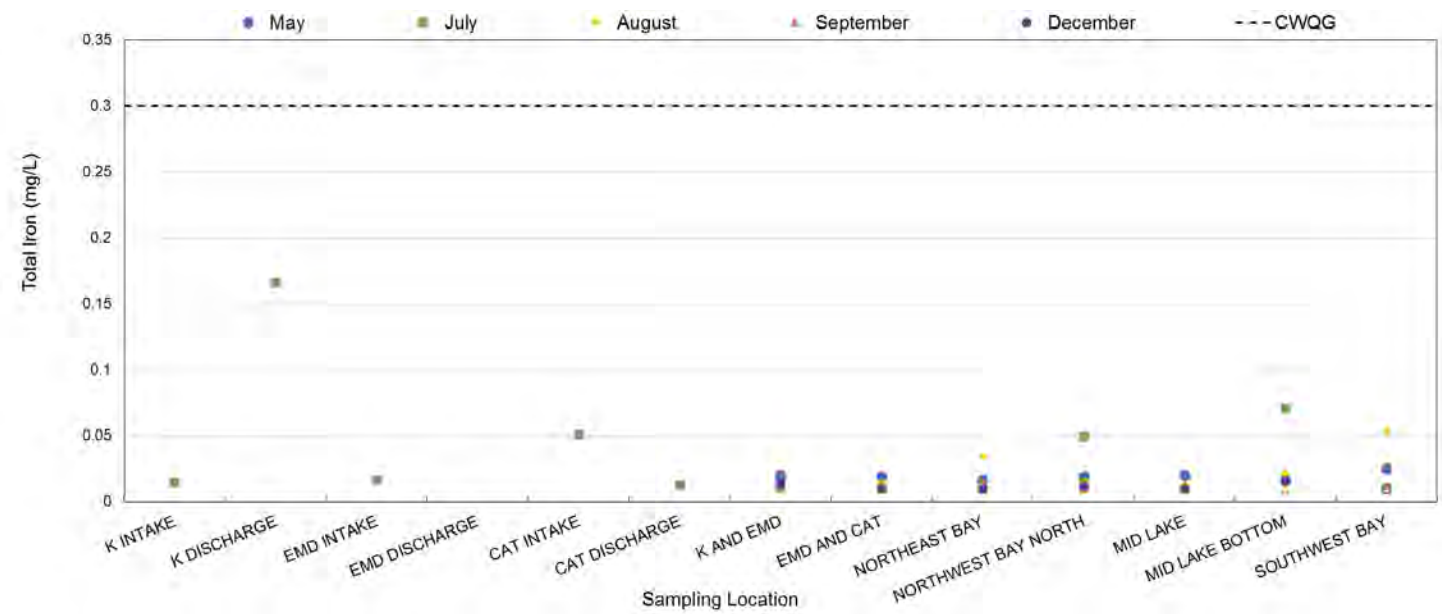
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
DL = detection limit.

Figure C.2-44: Total Copper Concentrations in Intakes, Discharges and Jackfish Lake, 2018



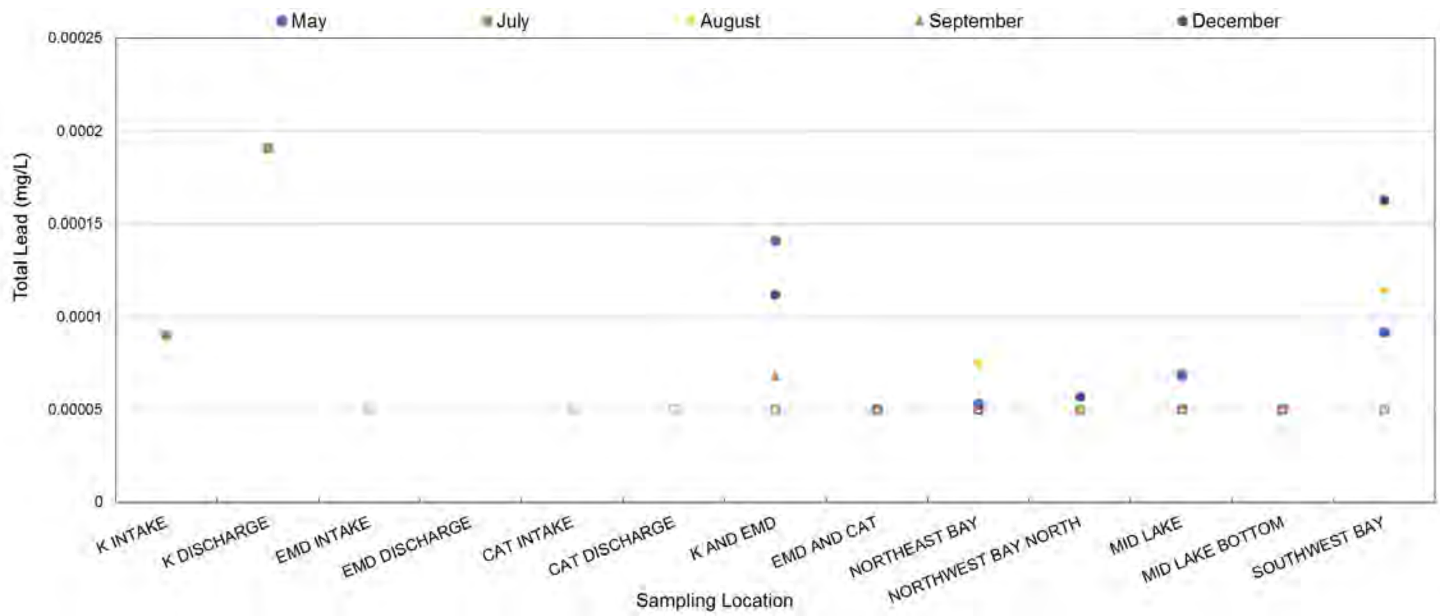
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
The CWQG for total copper is dependent on water hardness. The minimum CWQG (0.0030 mg/L), based on 2018 water hardness values in Jackfish Lake and intake and discharge stations, is presented. Comparisons to the CWQG for individual samples from 2018 are provided in Appendix C.1a.
CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999).

Figure C.2-45: Total Iron Concentrations in Intakes, Discharges and Jackfish Lake, 2018



Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
The CWQG for total iron is 0.300 mg/L.
CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999); DL = detection limit.

Figure C.2-46: Total Lead Concentrations in Intakes, Discharges and Jackfish Lake, 2018



Notes:

All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.

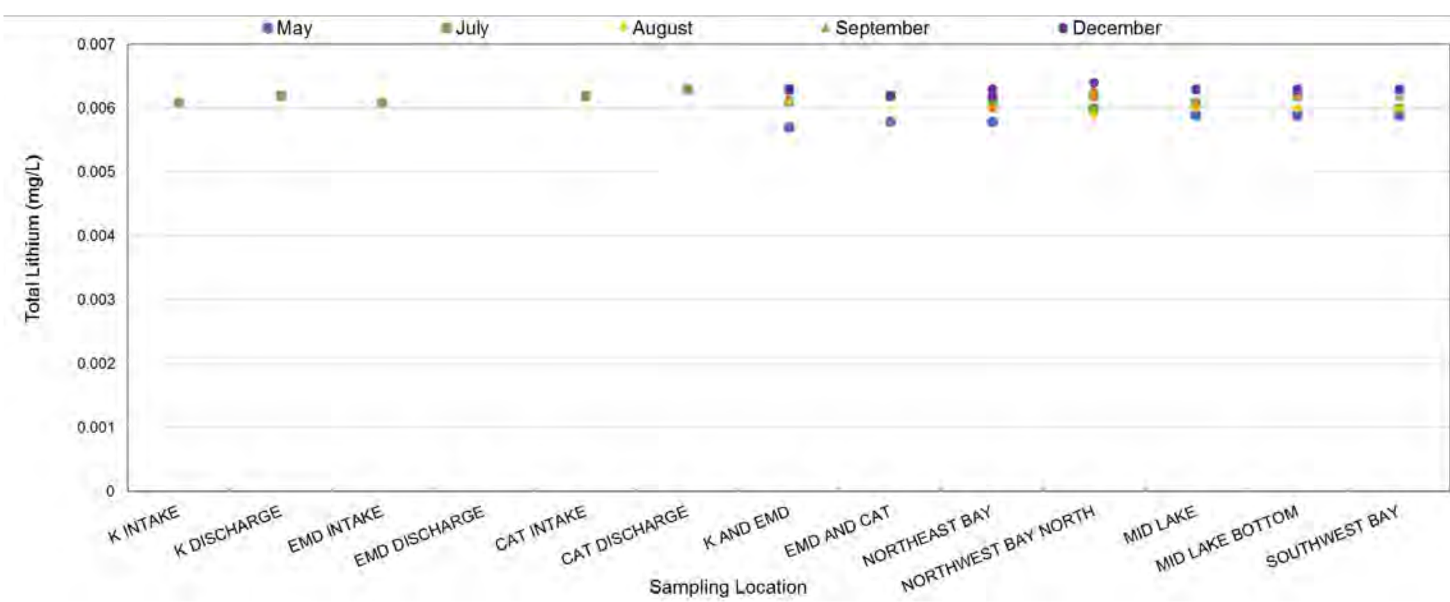
Concentrations below the DL are shown at the DL as open markers.

The CWQG for total lead is dependent on water hardness. The minimum CWQG (0.0046 mg/L), based on 2018 water hardness values in Jackfish Lake and intake and discharge stations, is not presented.

Comparisons to the CWQG for individual samples from 2018 are provided in Appendix C.1a.

CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999); DL = detection limit.

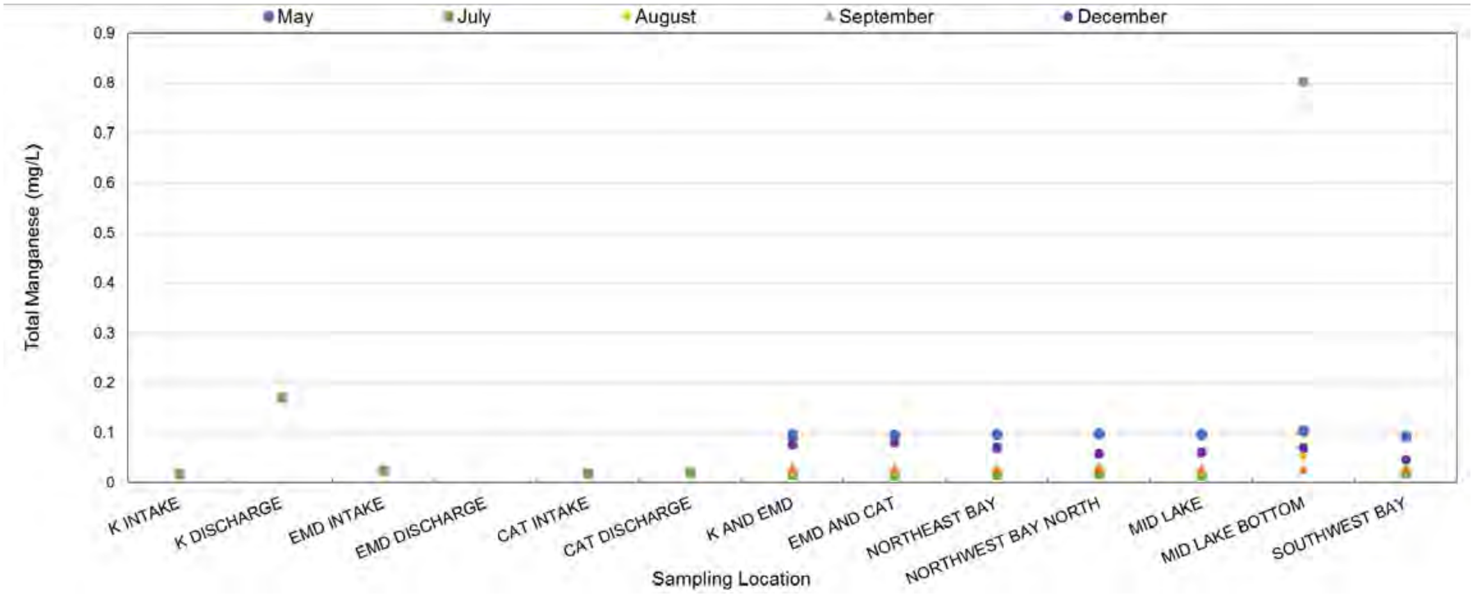
Figure C.2-47: Total Lithium Concentrations in Intakes, Discharges and Jackfish Lake, 2018



Note:

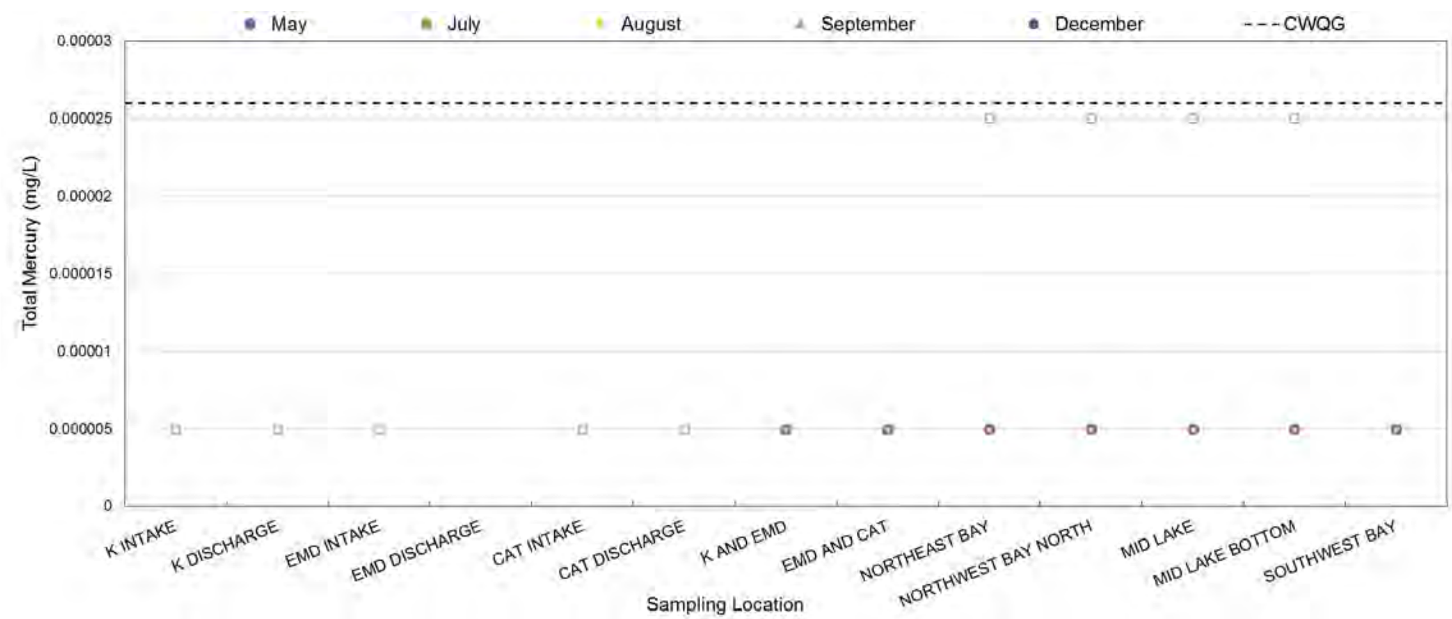
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.

Figure C.2-48: Total Manganese Concentrations in Intakes, Discharges and Jackfish Lake, 2018



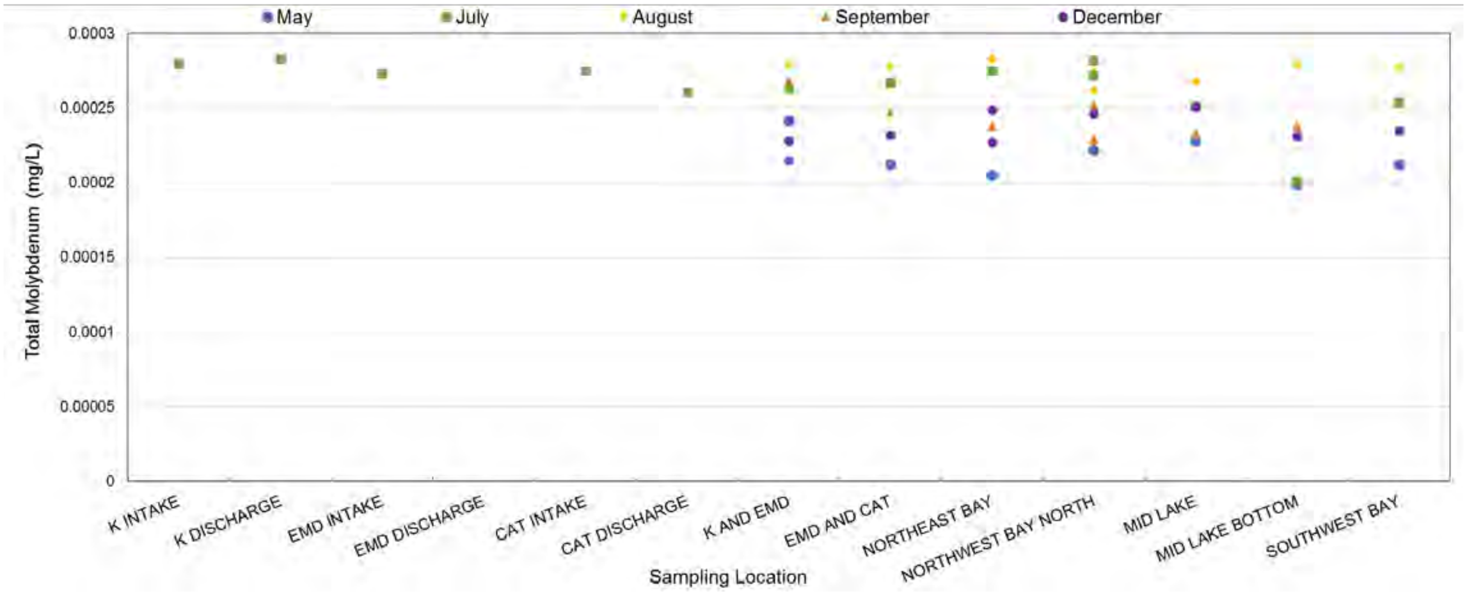
Note:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.

Figure C.2-49: Total Mercury Concentrations in Intakes, Discharges and Jackfish Lake, 2018



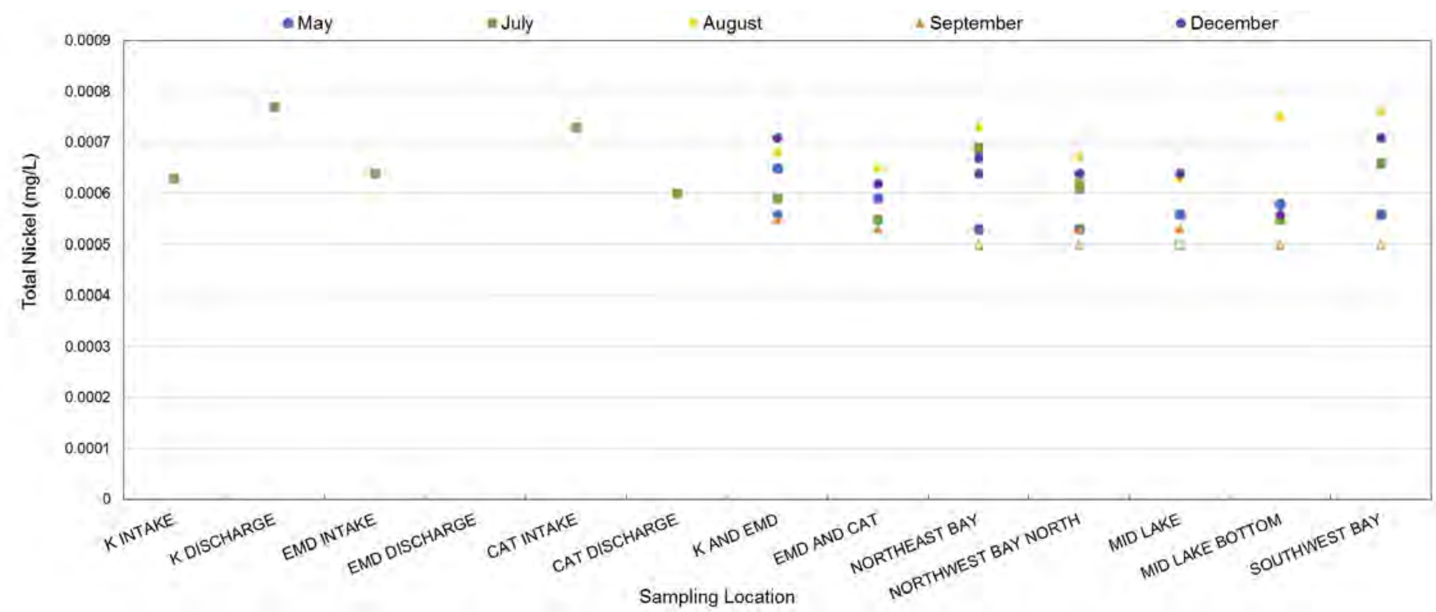
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
The CWQG for total mercury is 0.000026 mg/L.
CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999); DL = detection limit.

Figure C.2-50: Total Molybdenum Concentrations in Intakes, Discharges and Jackfish Lake, 2018



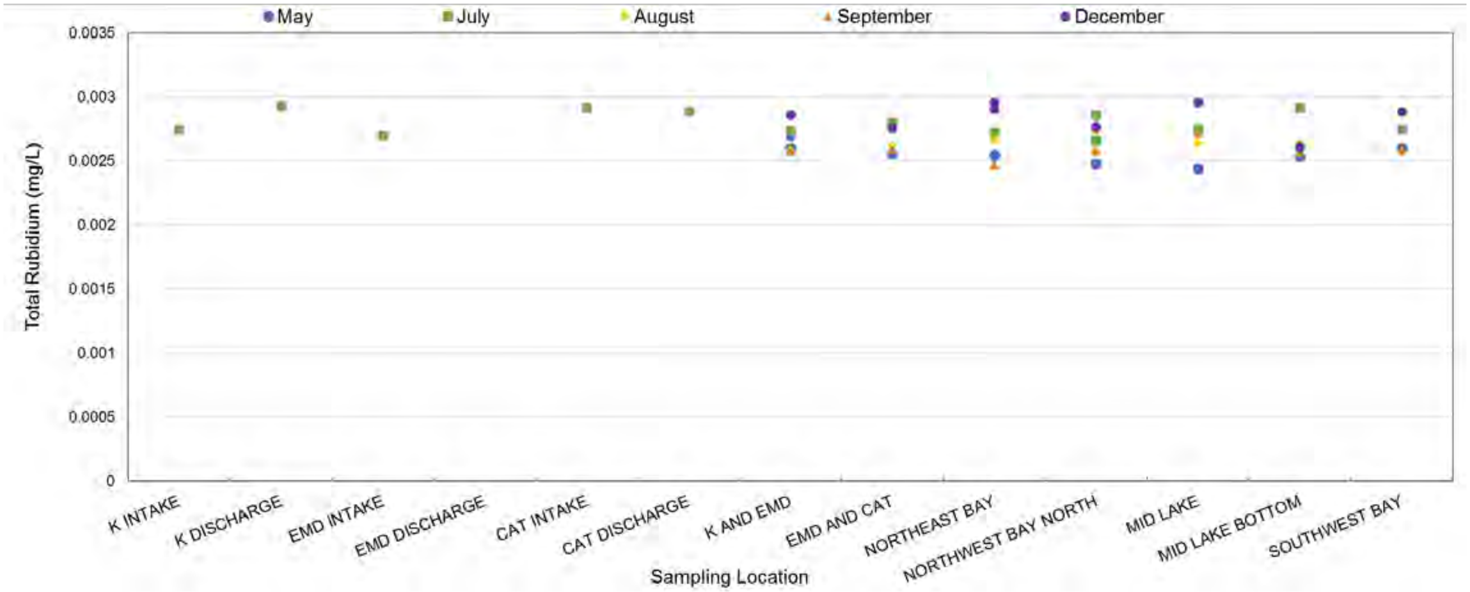
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
The CWQG for total molybdenum (0.073 mg/L) is not presented.
CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999).

Figure C.2-51: Total Nickel Concentrations in Intakes, Discharges and Jackfish Lake, 2018



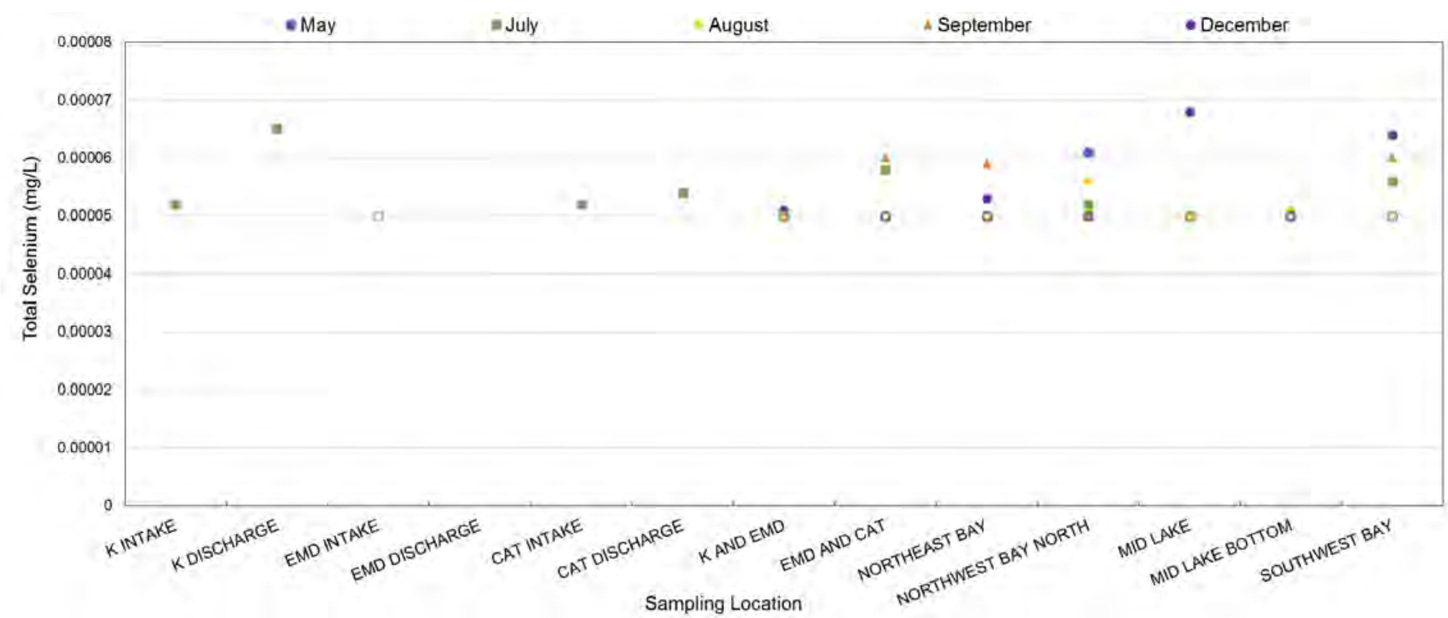
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
The CWQG for total nickel is dependent on water hardness. The minimum CWQG (0.119 mg/L), based on 2018 water hardness values in Jackfish Lake and intake and discharge stations, is not presented. Comparisons to the CWQG for individual samples from 2018 are provided in Appendix C.1a.
CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999); DL = detection limit.

Figure C.2-52: Total Rubidium Concentrations in Intakes, Discharges and Jackfish Lake, 2018



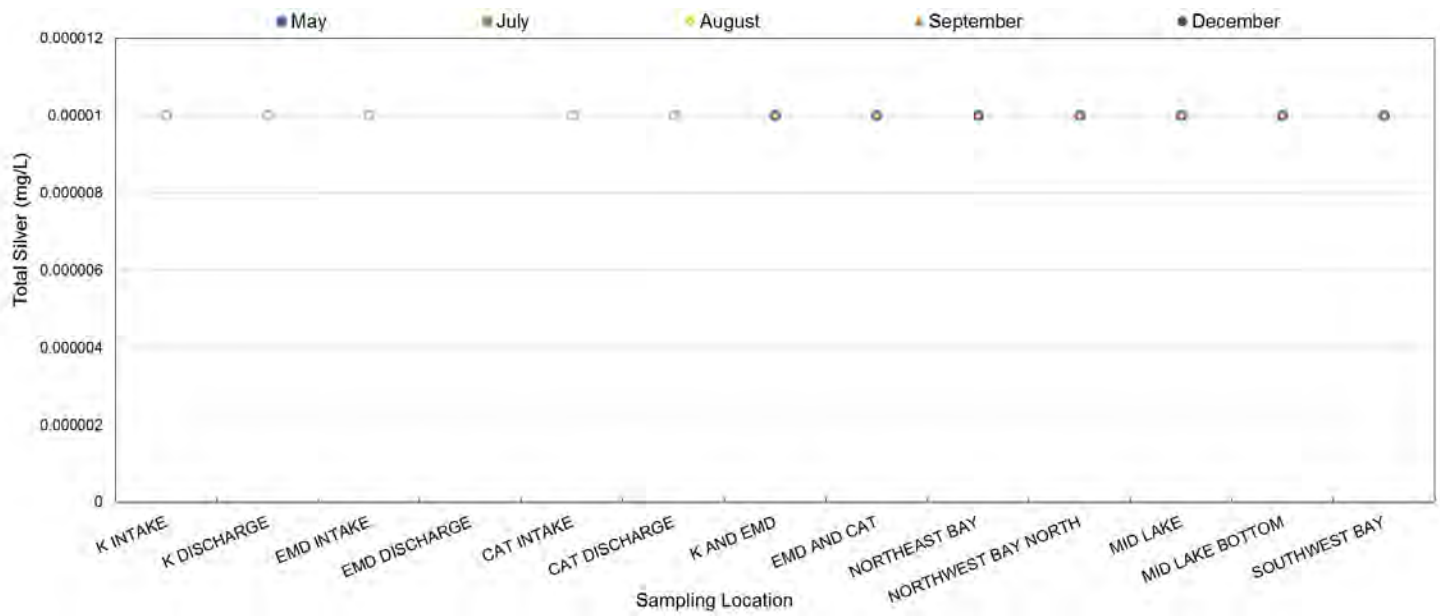
Note:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.

Figure C.2-53: Total Selenium Concentrations in Intakes, Discharges and Jackfish Lake, 2018



Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
The CWQG for total selenium (0.001 mg/L) is not presented.
CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999); DL = detection limit.

Figure C.2-54: Total Silver Concentrations in Intakes, Discharges and Jackfish Lake, 2018



Notes:

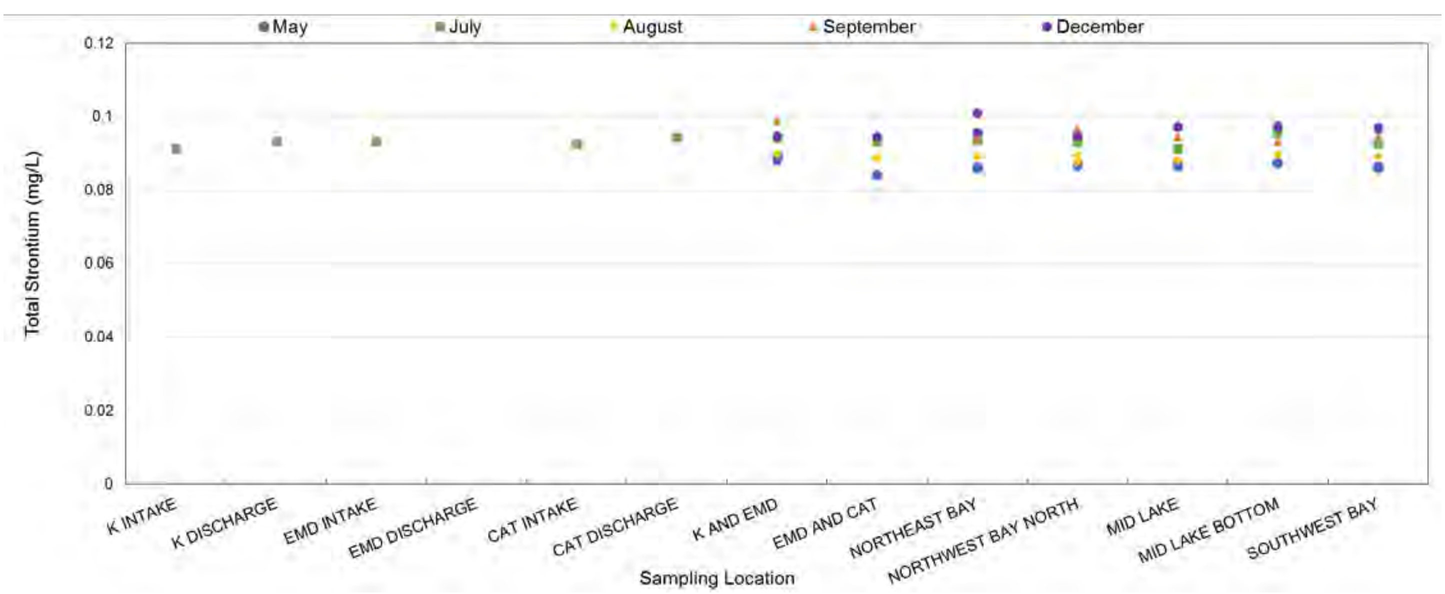
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.

Concentrations below the DL are shown at the DL as open markers.

The CWQG for total selenium (0.00025 mg/L) is not presented.

CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999); DL = detection limit.

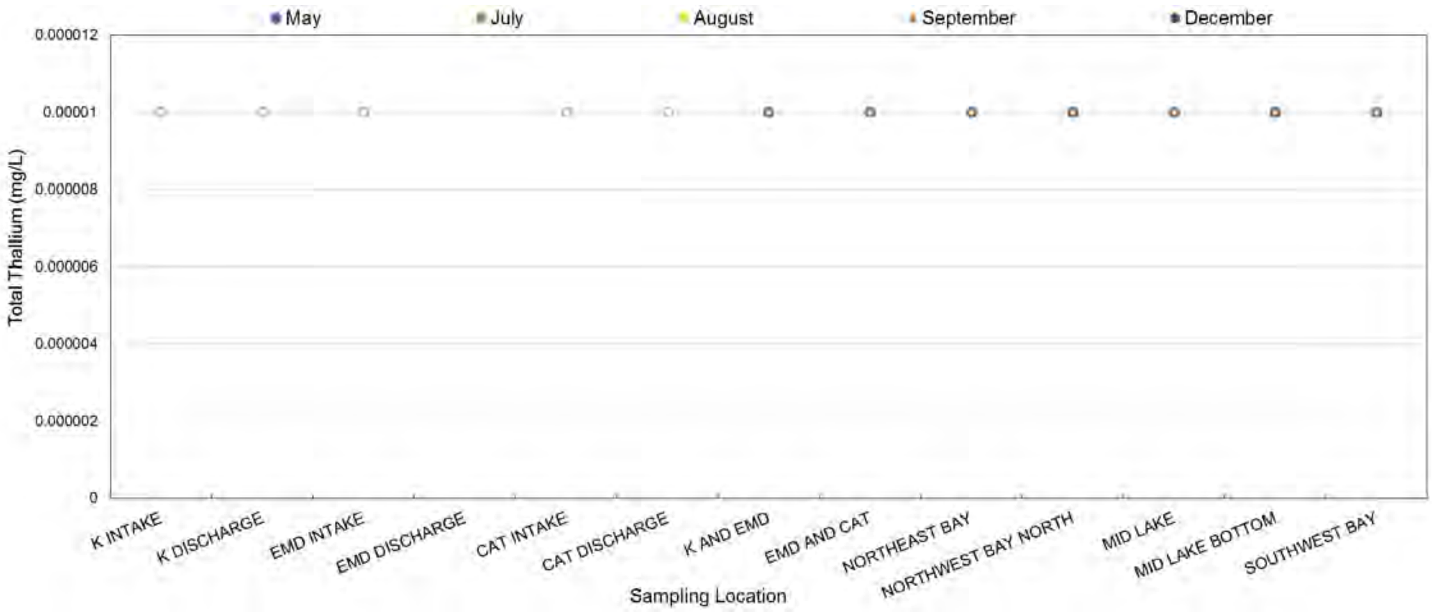
Figure C.2-55: Total Strontium Concentrations in Intakes, Discharges and Jackfish Lake, 2018



Note:

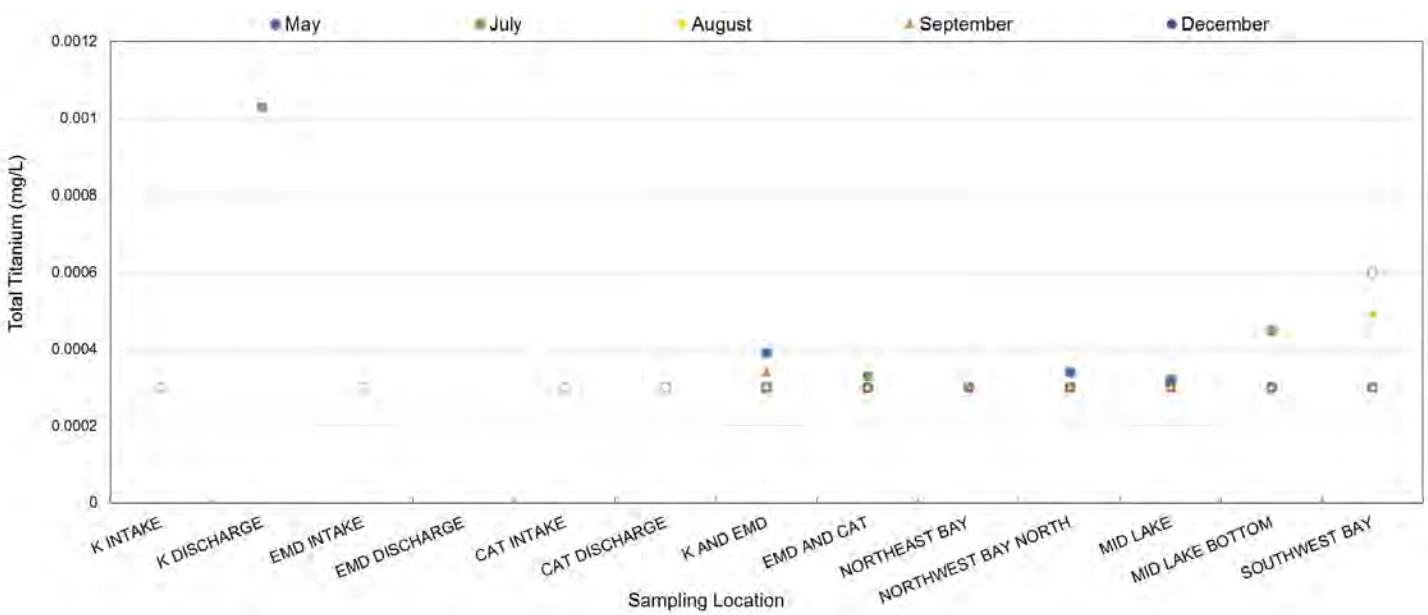
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.

Figure C.2-56: Total Thallium Concentrations in Intakes, Discharges and Jackfish Lake, 2018



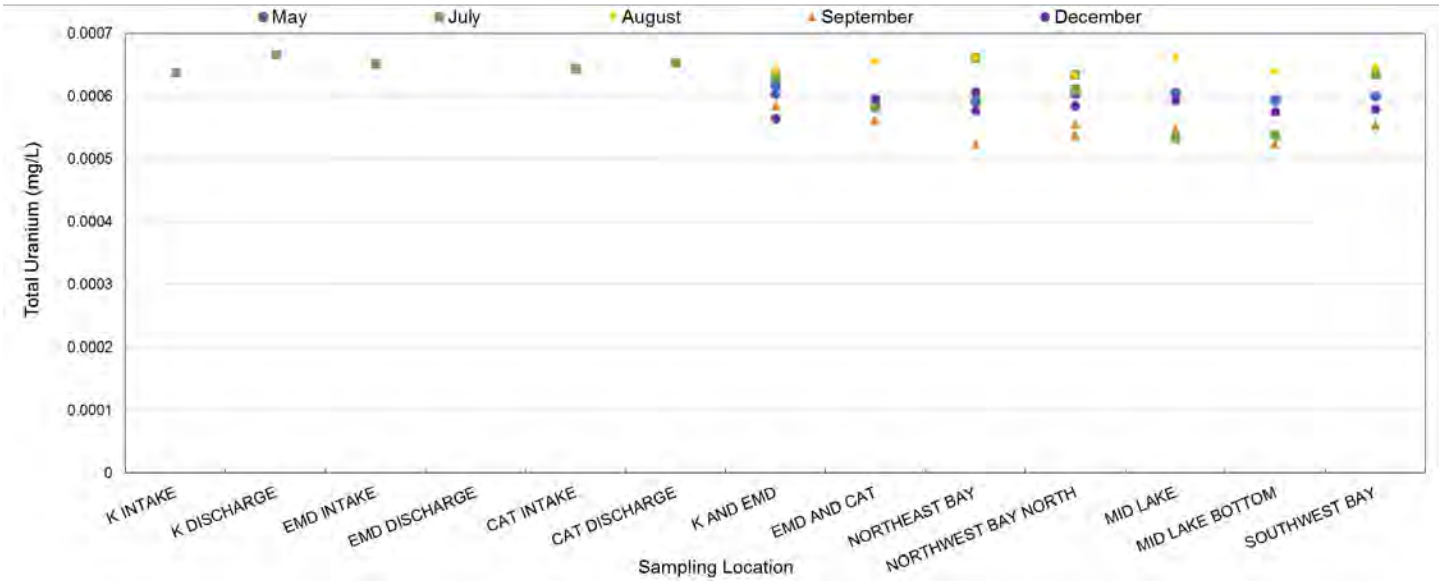
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
The CWQG for total thallium (0.0008 mg/L) is not presented.
CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999); DL = detection limit.

Figure C.2-57: Total Titanium Concentrations in Intakes, Discharges and Jackfish Lake, 2018



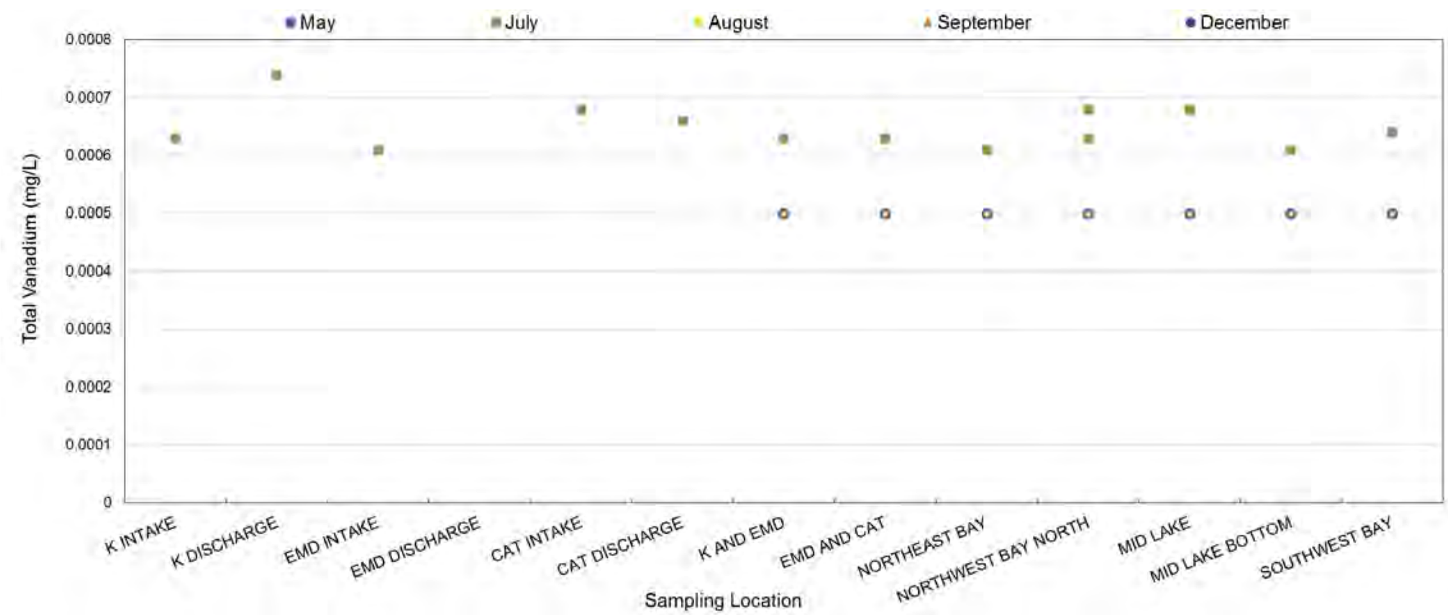
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
DL = detection limit.

Figure C.2-58: Total Uranium Concentrations in Intakes, Discharges and Jackfish Lake, 2018



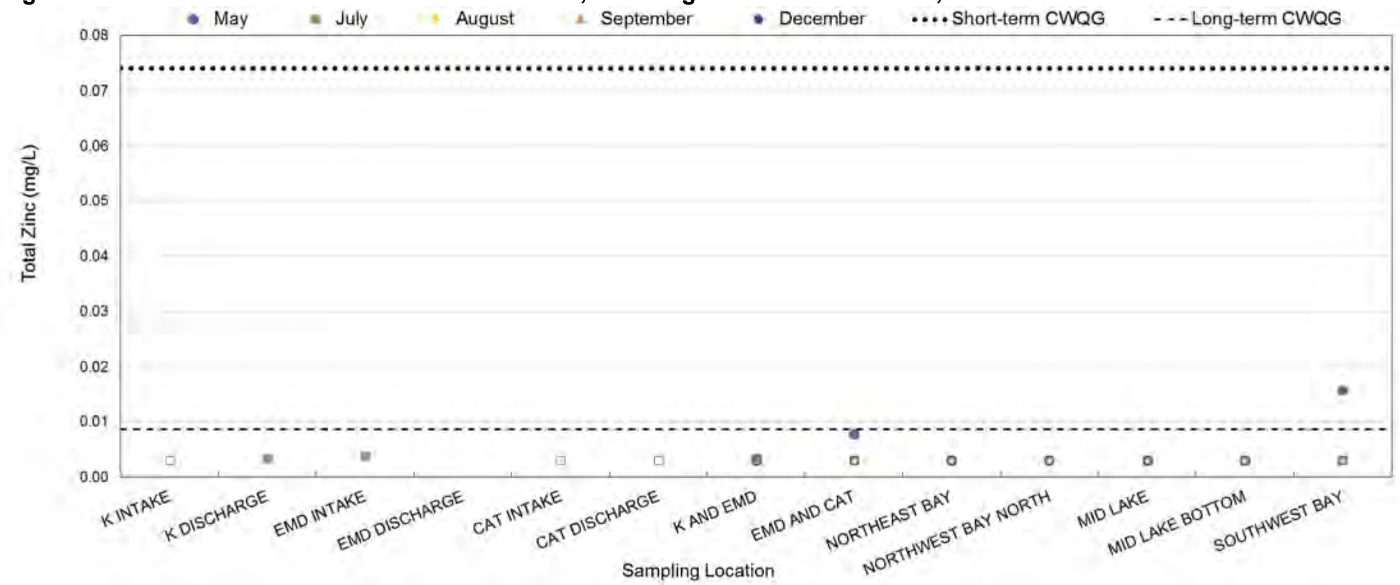
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
The long-term CWQG (0.015 mg/L) and short-term CWQG (0.030 mg/L) for total uranium are not presented on the figure.
CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999).

Figure C.2-59: Total Vanadium Concentrations in Intakes, Discharges and Jackfish Lake, 2018



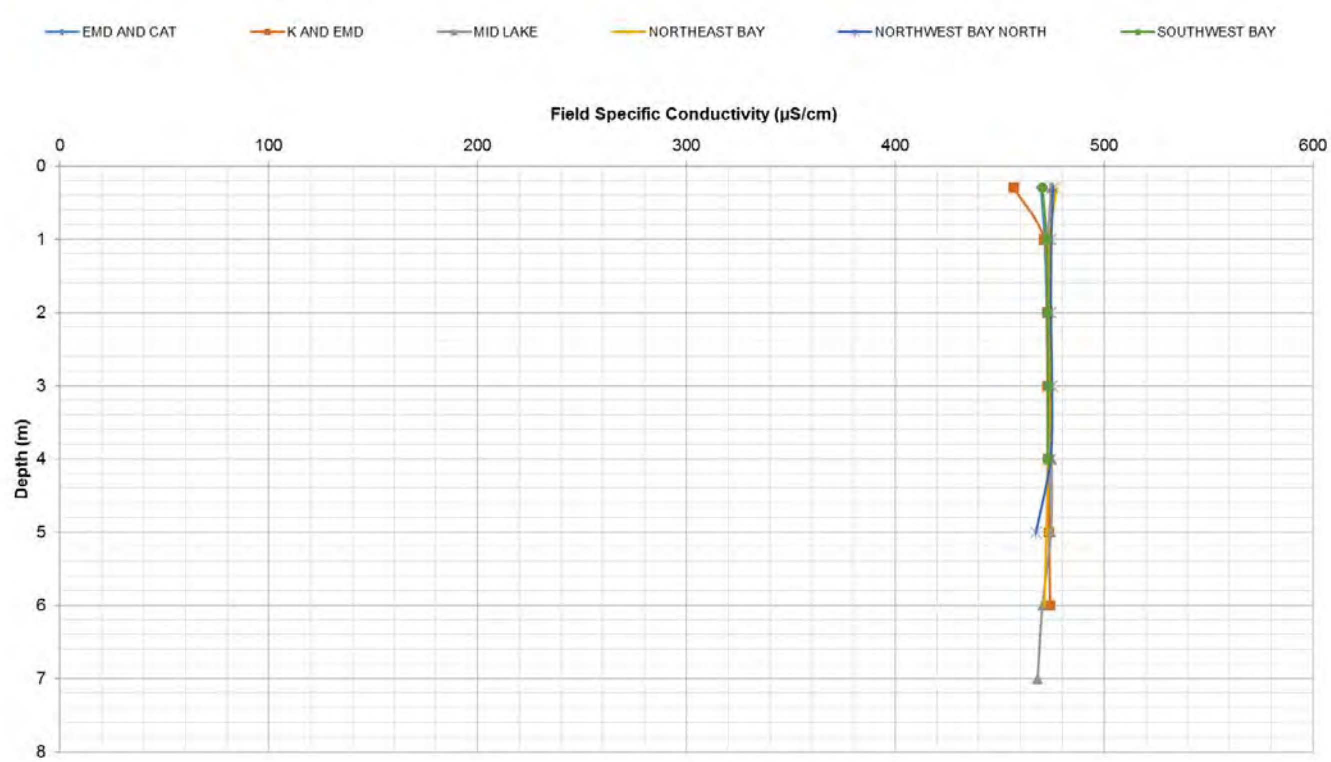
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
DL = detection limit.

Figure C.2-60: Total Zinc Concentrations in Intakes, Discharges and Jackfish Lake, 2018



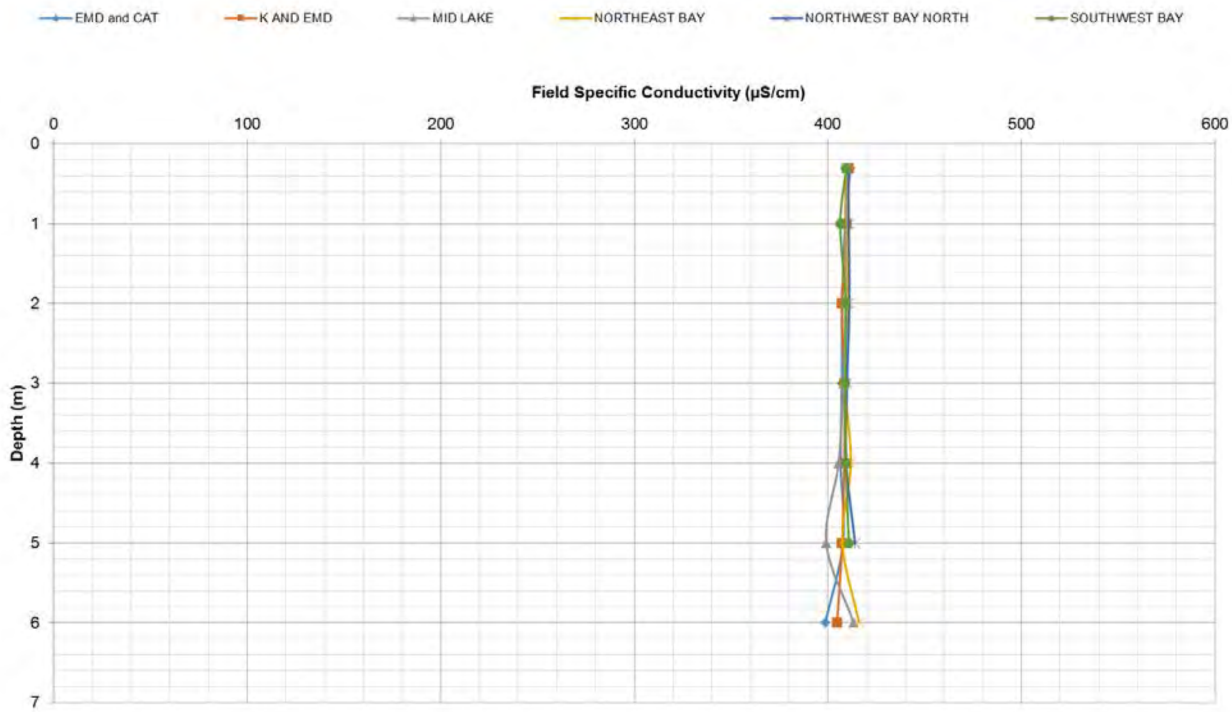
Notes:
All samples were collected at mid-depth, with the exception of the intake, discharge and MID LAKE BOTTOM samples; intake and discharge samples were collected as grab samples and MID LAKE BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
The long-term CWQG for zinc is dependent on pH, water hardness and DOC. The CWQG is for the dissolved fraction but was applied to the total fraction as a conservative estimate. The minimum CWQG (0.009 mg/L), based on 2018 the pH, water hardness and DOC values in Jackfish Lake and intake and discharge stations, is presented.
The short-term CWQG for zinc is dependent on pH, water hardness and DOC. The CWQG is for the dissolved fraction but was applied to the total fraction as a conservative estimate. The minimum CWQG (0.074 mg/L), based on 2018 the pH, water hardness and DOC values in Jackfish Lake and intake and discharge stations, is presented.
Comparisons to the long-term and short-term CWQG for individual samples from 2018 are provided in Appendix C.1a.
CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999); DOC = dissolved organic carbon; DL = detection limit.

Figure C.2-61a: Field Specific Conductivity Profiles in Jackfish Lake, May 2018



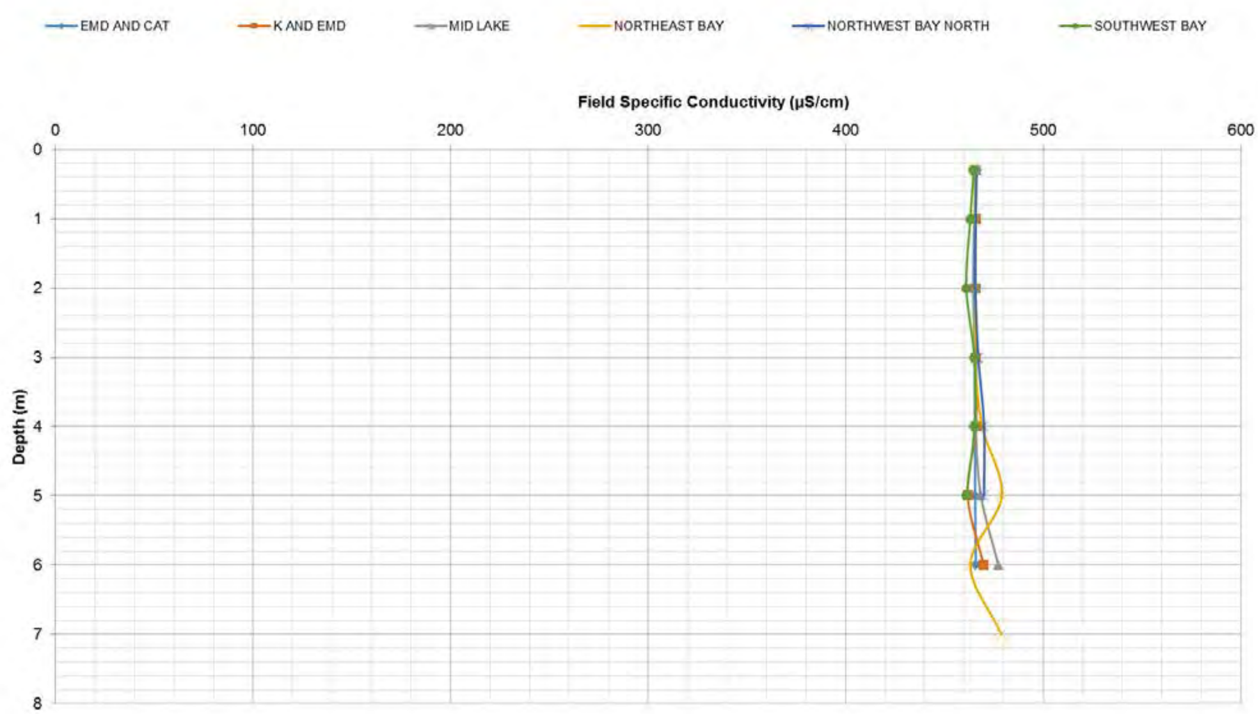
Note: µS/cm = microSiemens per centimetre.

Figure C.2-61b: Field Specific Conductivity Profiles in Jackfish Lake, July 2018



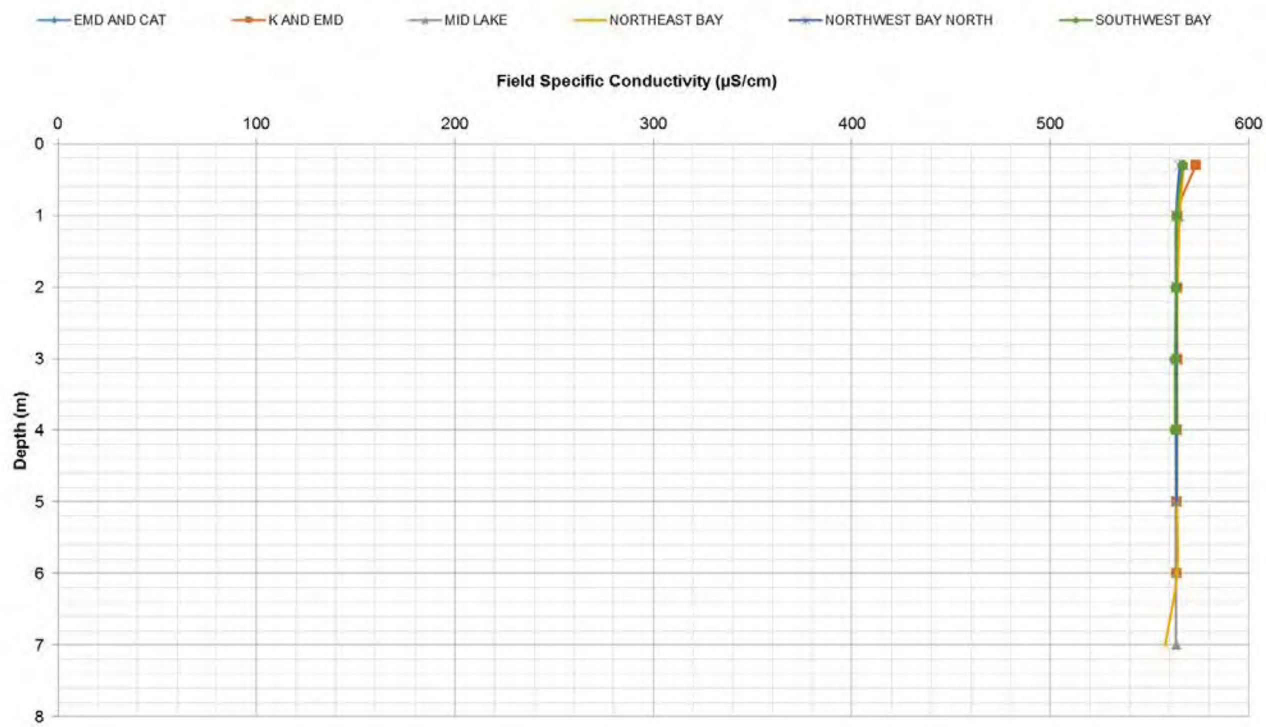
Note:
µS/cm = microSiemens per centimetre.

Figure C.2-61c: Field Specific Conductivity Profiles in Jackfish Lake, August 2018



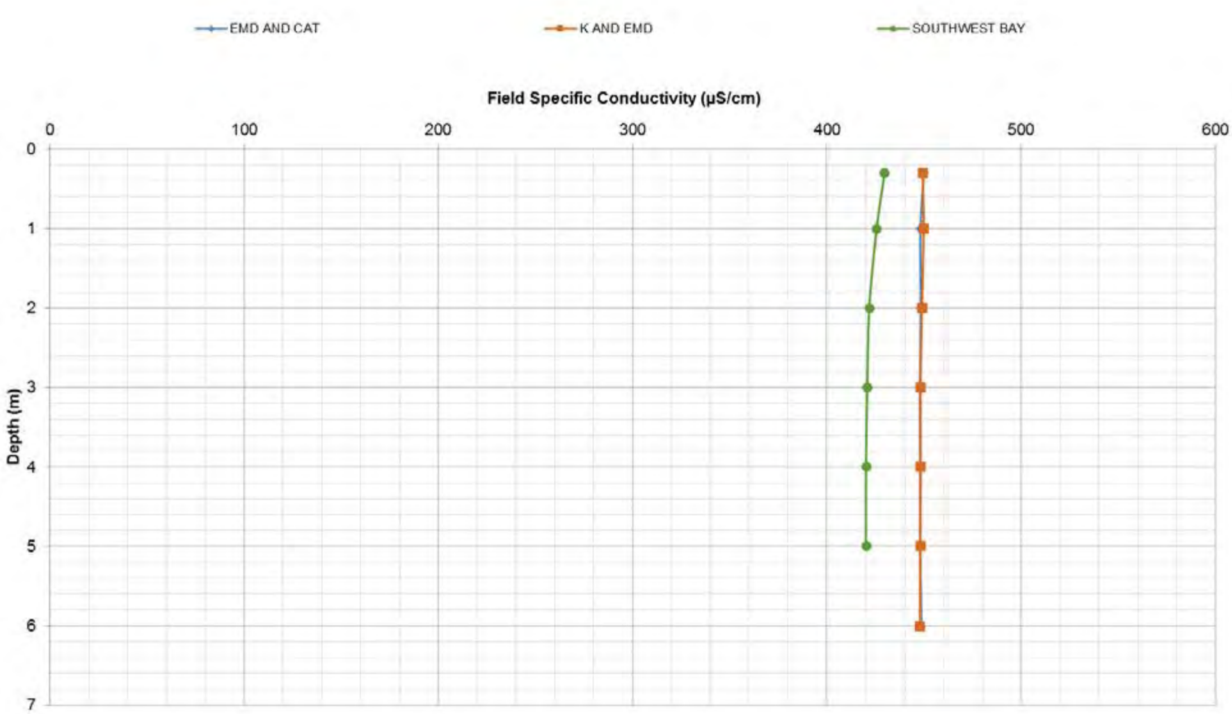
Note: µS/cm = microSiemens per centimetre.

Figure C.2-61d: Field Specific Conductivity Profiles in Jackfish Lake, September 2018



Note:µS/cm = microSiemens per centimetre.

Figure C.2-61e: Field Specific Conductivity Profiles in Jackfish Lake, December 2018



Notes: Field specific conductivity data were invalidated for Mid-Lake, Northwest Bay North, and Northeast Bay stations in December; details are provided Appendix C.4.
µS/cm = microSiemens per centimetre.

Figure C.2-62a: Field pH Profiles in Jackfish Lake, May 2018

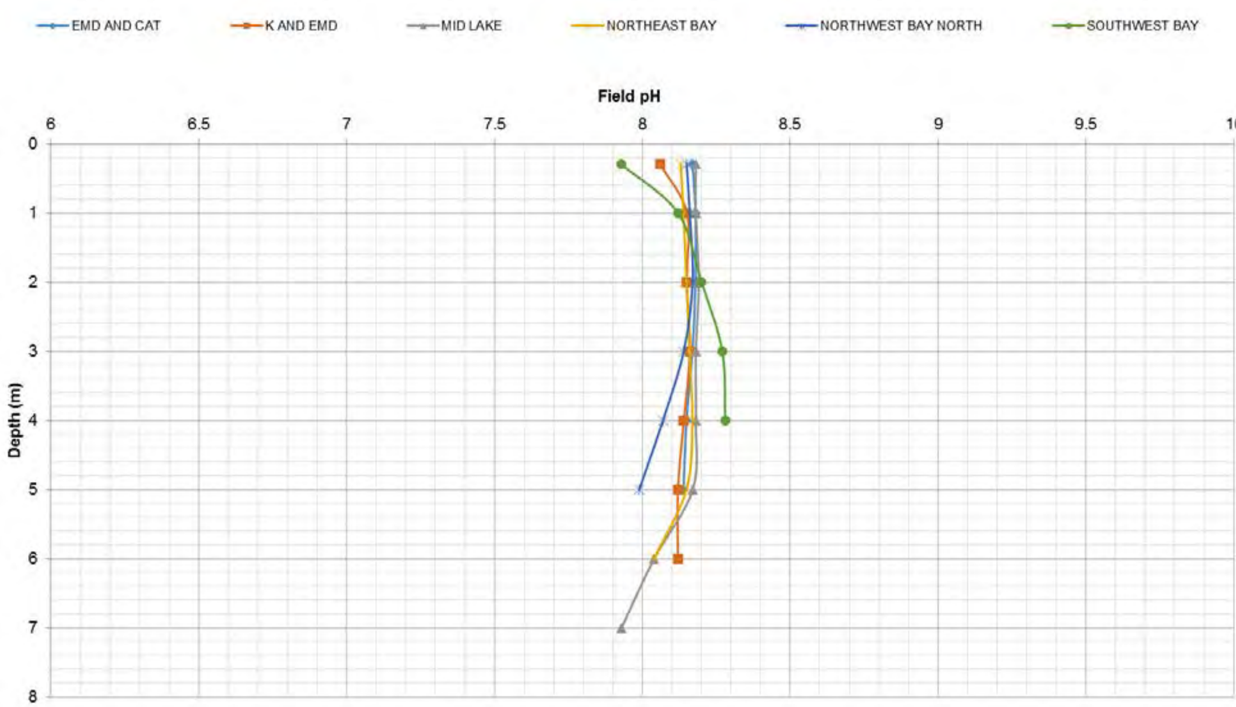


Figure C.2-62b: Field pH Profiles in Jackfish Lake, July 2018

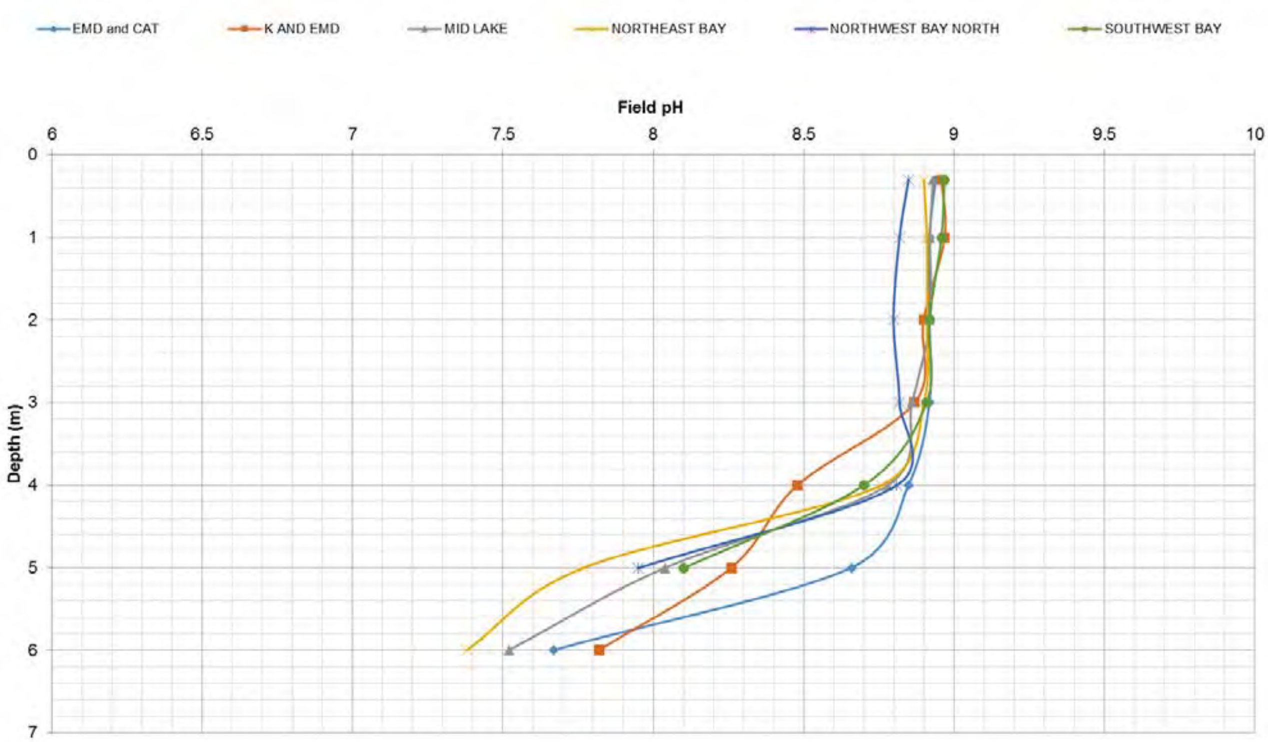


Figure C.2-62c: Field pH Profiles in Jackfish Lake, August 2018

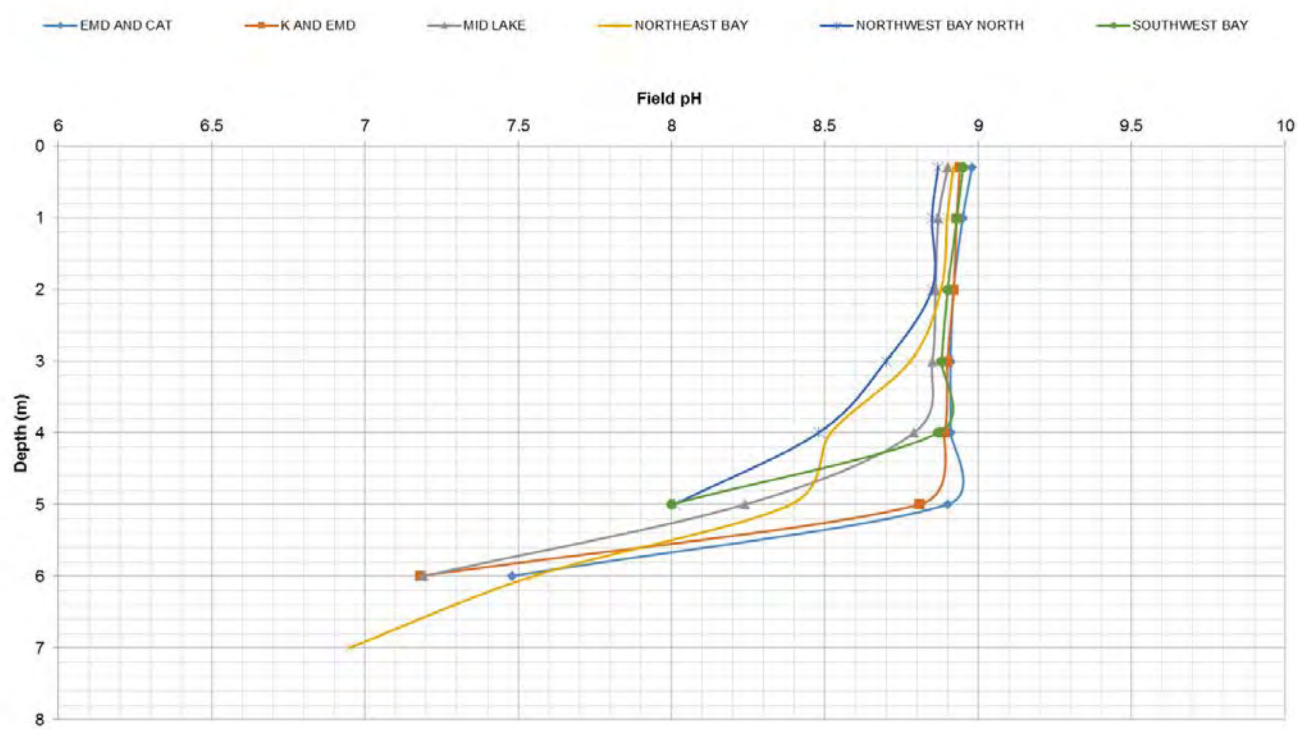


Figure C.2-62d: Field pH Profiles in Jackfish Lake, September 2018

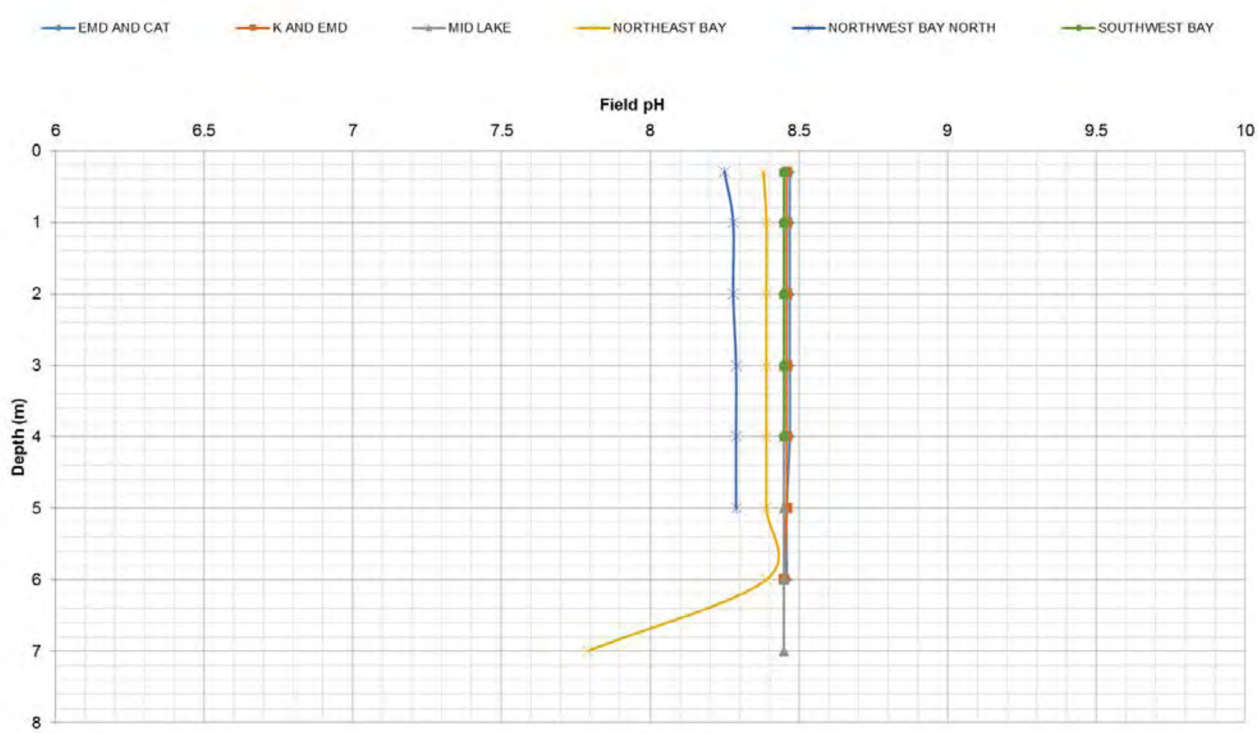


Figure C.2-62e: Field pH Profiles in Jackfish Lake, December 2018

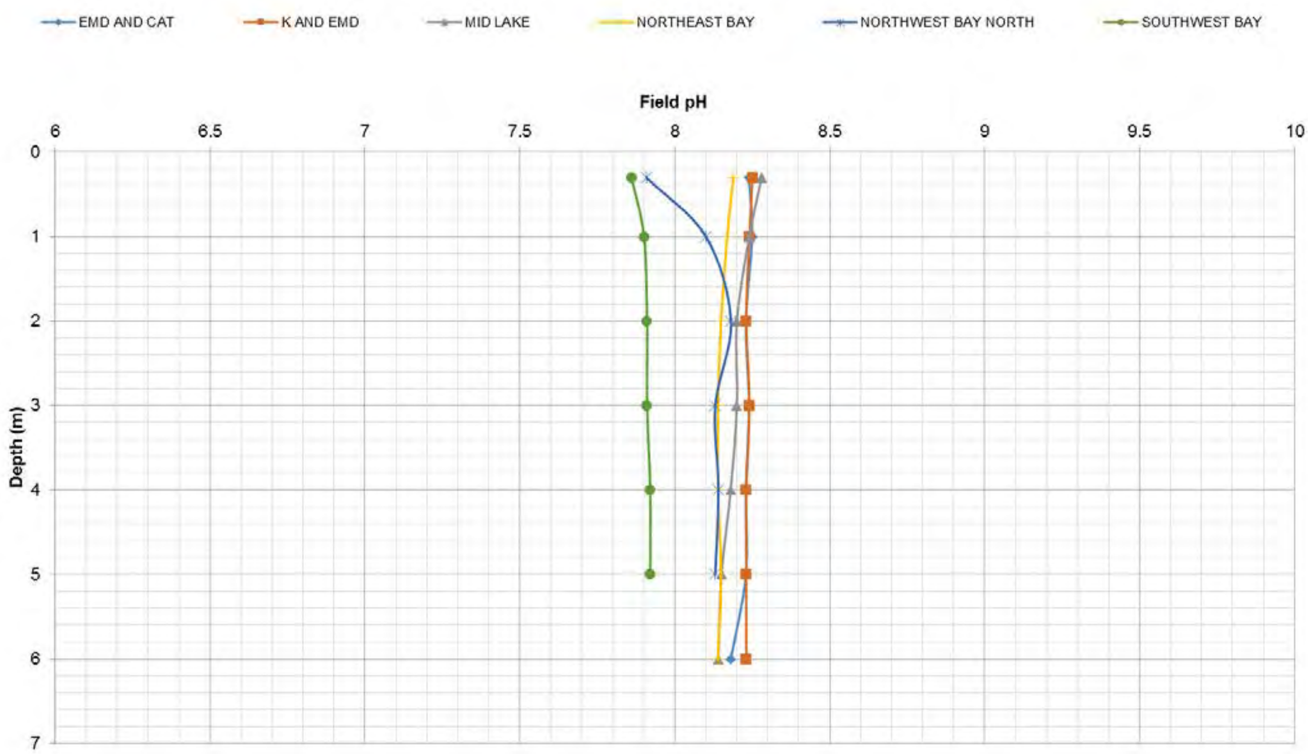


Figure C.2-63a: Temperature Profiles in Jackfish Lake, May 2018

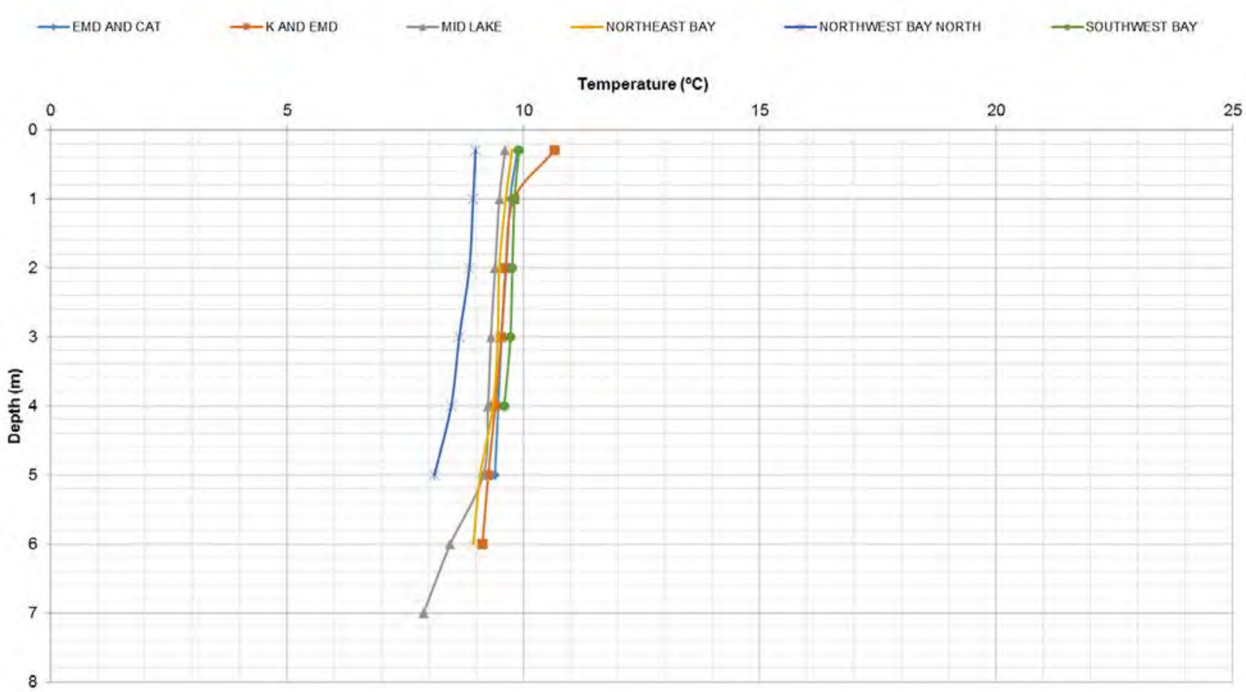


Figure C.2-63b: Temperature Profiles in Jackfish Lake, July 2018

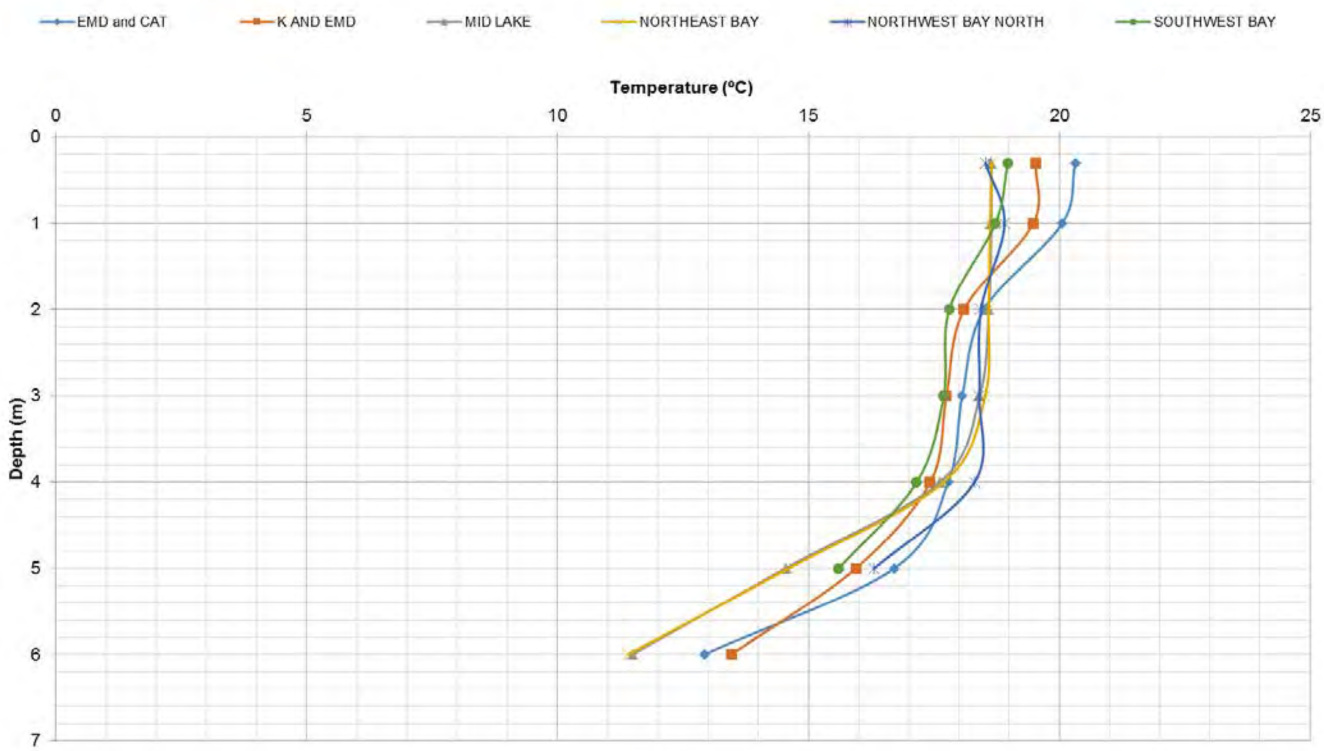


Figure C.2-63c: Temperature Profiles in Jackfish Lake, August 2018

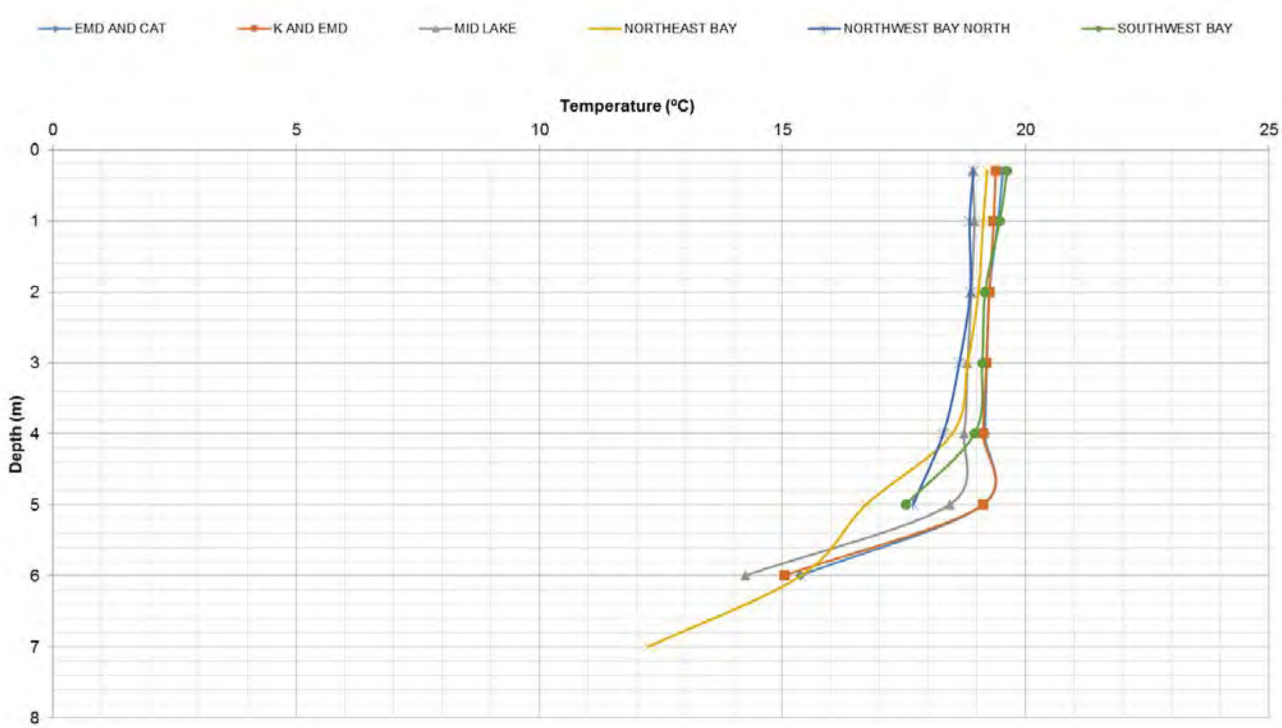


Figure C.2-63d: Temperature Profiles in Jackfish Lake, September 2018

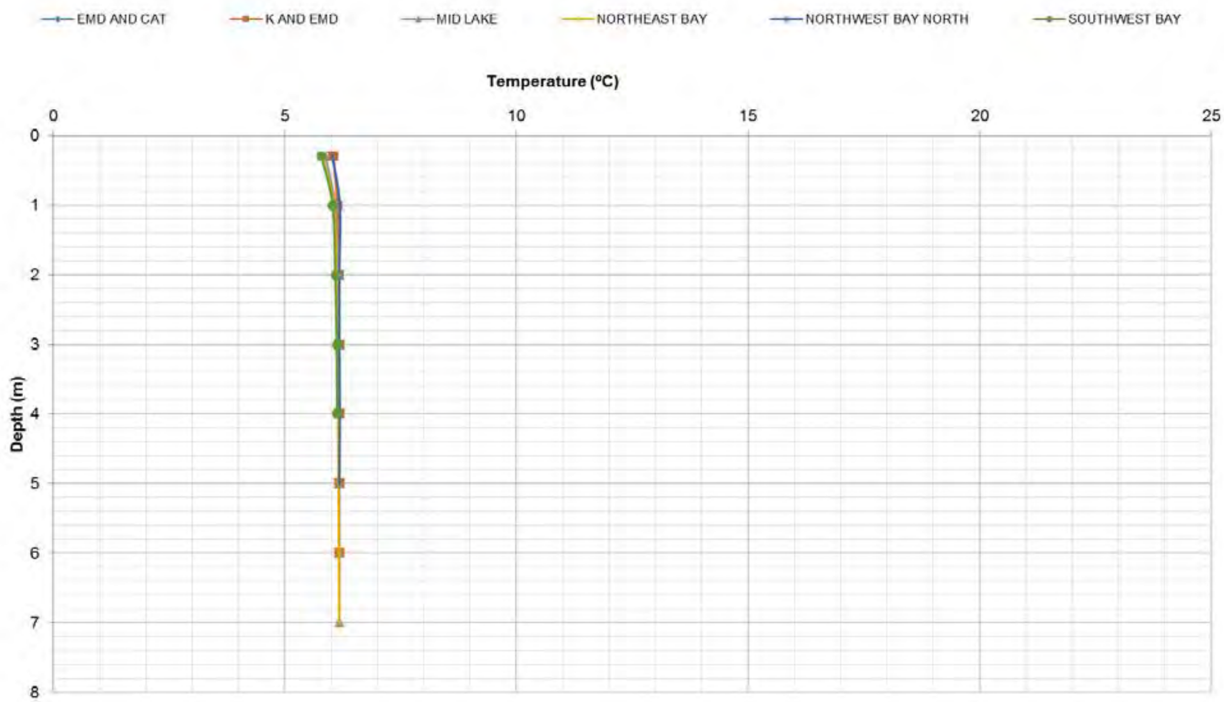


Figure C.2-63e: Temperature Profiles in Jackfish Lake, December 2018

Figure C.2-64a: Dissolved Oxygen Concentration Profiles in Jackfish Lake, May 2018

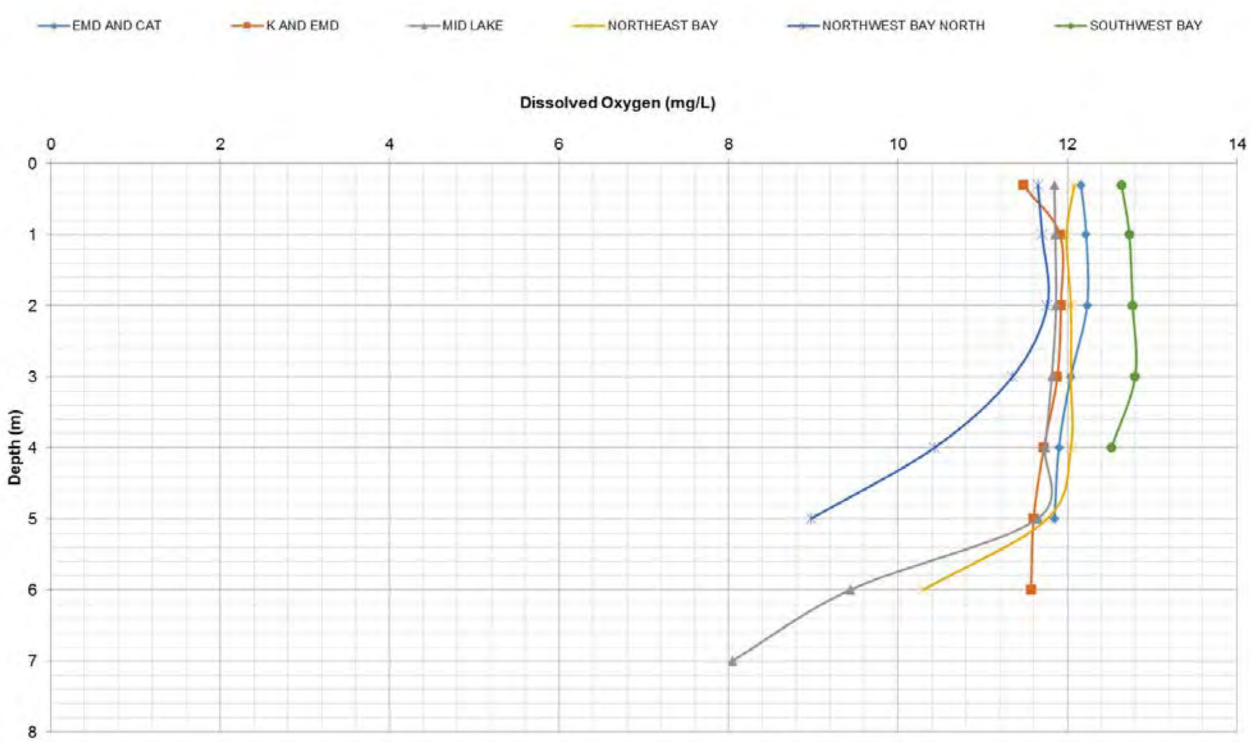


Figure C.2-64b: Dissolved Oxygen Concentration Profiles in Jackfish Lake, July 2018

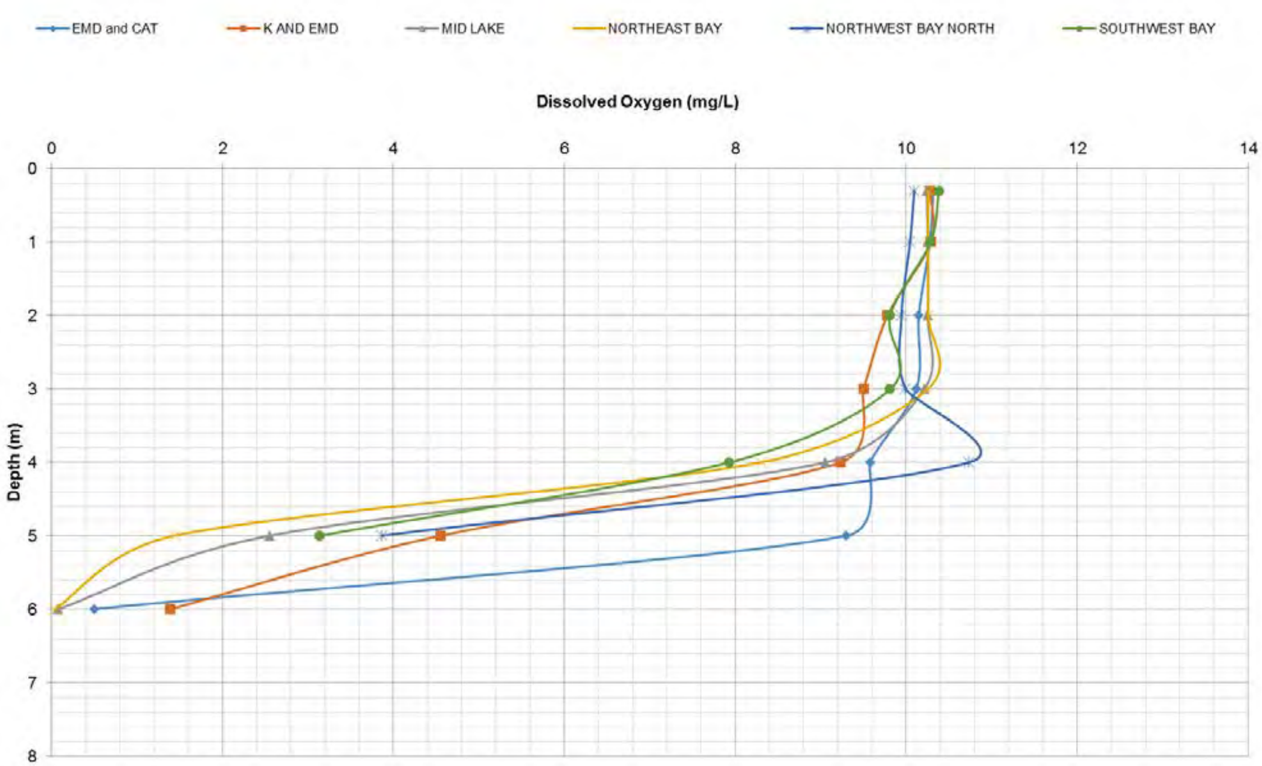


Figure C.2-64c: Dissolved Oxygen Concentration Profiles in Jackfish Lake, August 2018

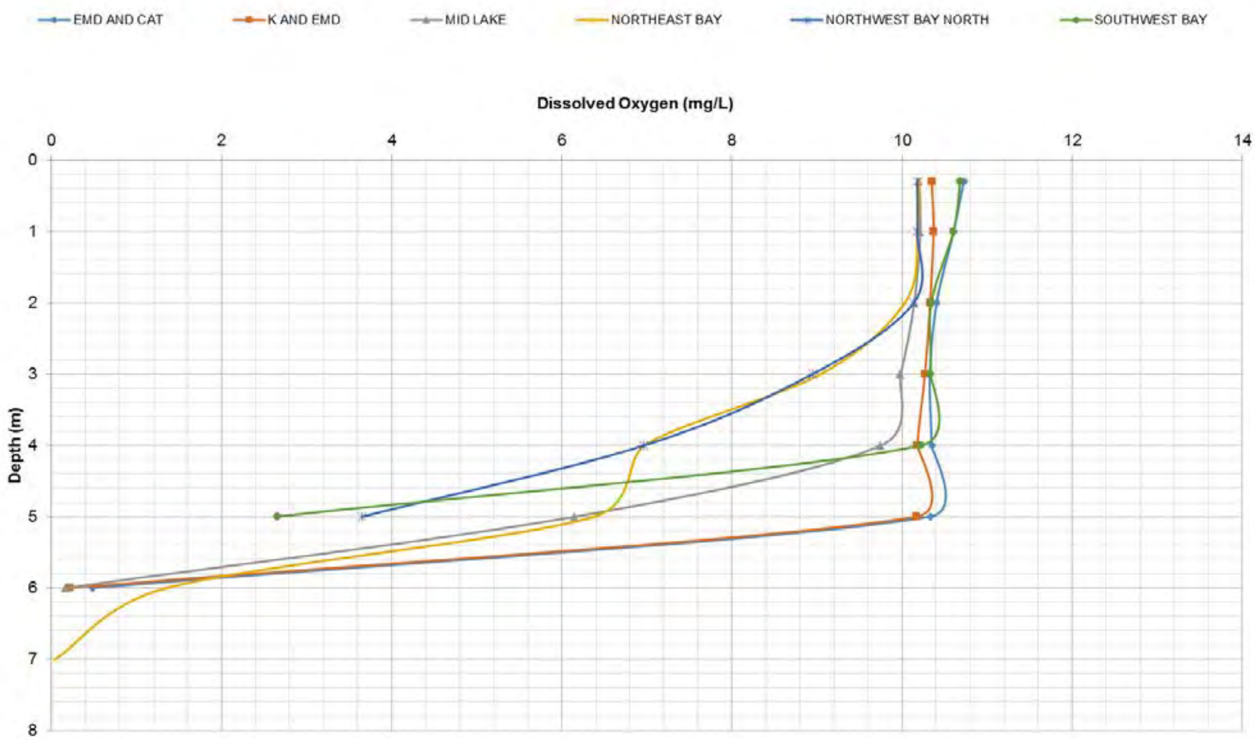


Figure C.2-64d: Dissolved Oxygen Concentration Profiles in Jackfish Lake, September 2018

Figure C.2-64e: Dissolved Oxygen Concentration Profiles in Jackfish Lake, December 2018

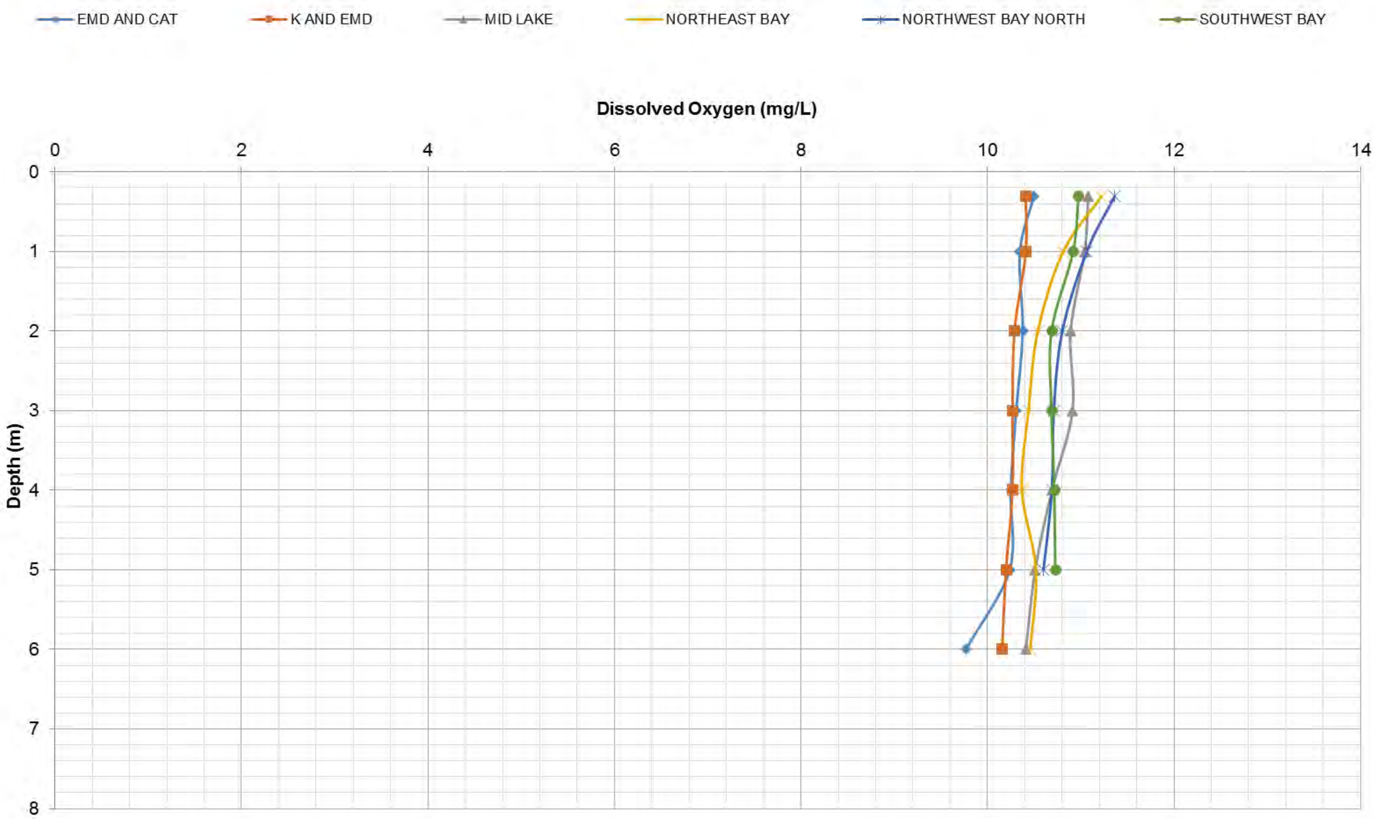


Table C.3: 2018 and Historical Ranges in Jackfish Lake Water Quality, 1987 to 2018.

	Year	1987			2014 to 2017				2018		
Parameter	Unit	Number of Samples	Minimum	Maximum	Number of Samples	Minimum	Maximum	Maximum Above Detection Limit	Number of Samples	Minimum	Maximum
Routine Parameters											
pH (field)	-	-	-	-	9	7.3	9.2	9.2	35	7.0	8.9
pH (laboratory)	-	-	-	-	9	7.1	9.1	9.1	35	8.1	8.8
Temperature (field)	°C	-	-	-	9	10.9	20.4	20.4	35	0.9	19.2
Dissolved oxygen (field)	mg/L	-	-	-	9	6.1	11.6	11.6	35	0.0	12.8
Dissolved oxygen (field)	%	-	-	-	9	67	129	129	35	0	115
Specific conductivity (field)	µS/cm	-	-	-	9	372	427	427	31	405	564
Specific conductivity (laboratory)	µS/cm	-	-	-	10	378	456	456	35	414	476
Total alkalinity, as $CaCO_3$	mg/L	10	80	108	10	97	132	132	35	101	116
Hardness, as $CaCO_3$	mg/L	-	-	-	11	130	151	151	35	148	168
Total suspended solids	mg/L	-	-	-	7	4.0	24.0	24.0	35	3.3	19.0
Total dissolved solids	mg/L	-	-	-	7	240	275	275	35	250	312
Total dissolved solids (calculated)	mg/L	-	-	-	11	159	246	246	35	243	271
Turbidity (field)	NTU	-	-	-	7	16.4	29.3	29.3	35	3.2	18.9
Turbidity (laboratory)	NTU	-	-	-	7	12.1	46.1	46.1	35	6.1	18.4
Major Ions											
Calcium	mg/L	10	27.9	30.2	11	34.0	39.9	39.9	35	39.3	45.8
Chloride	mg/L	-	-	-	11	40.8	51.3	51.3	35	52.7	60.2
Fluoride	mg/L	-	-	-	9	<0.1	3.3	3.3	35	0.086	0.100
Magnesium	mg/L	10	8.8	9.3	11	11.0	13.0	13.0	35	11.7	13.9
Potassium	mg/L	10	2.7	3.2	11	3.4	4.4	4.4	35	3.7	4.7
Sodium	mg/L	10	4.8	5.2	11	20.9	27.0	27.0	35	26.4	33.3
Sulphate	mg/L	-	-	-	11	7.0	33.0	33.0	35	28.3	30.3
Nutrients											
Total ammonia	mg-N/L	10	0.010	0.040	8	<0.005	0.420	0.420	35	<0.0050	0.6280
Total nitrogen	mg-N/L	-	-	-	8	0.81	2.17	2.17	35	0.99	2.19
Nitrate	mg-N/L	10	0.24	0.35	11	<0.005	0.09	0.09	35	<0.0050	2.78
Nitrite	mg-N/L	10	0.001	0.002	11	<0.001	0.0013	0.0013	35	<0.0010	0.062
Nitrate + nitrite	mg-N/L	-	-	-	10	<0.0051	0.0293	0.0293	35	<0.0051	2.84
Total Kjeldahl nitrogen	mg-N/L	-	-	-	1	1.90	1.90	1.90	35	1.02	2.06
Total phosphorus	mg-P/L	-	-	-	10	0.102	0.226	0.226	35	0.044	0.156
Dissolved phosphorus	mg-P/L	-	-	-	7	0.0054	0.0360	0.0360	35	0.0109	0.1100
Orthophosphate	mg-P/L	-	-	-	7	0.0037	0.0434	0.0434	35	0.0034	0.0068
Soluable reactive silica	mg/L	-	-	-	6	11.9	14.2	14.2	35	9.4	14.1
Organic Carbon											
Total organic carbon	mg/L	-	-	-	7	10.9	17.7	17.7	35	10.4	13.8
Total Metals[(a)]											
Aluminum	mg/L	-	-	-	9	0.0100	<3.0	0.0305	35	<0.0030	0.0136
Antimony	mg/L	-	-	-	9	0.0012	<0.60	0.00170	35	0.00136	0.00187
Arsenic	mg/L	10	0.094	0.100	9	0.0760	<0.20	0.101	35	0.0678	0.0978
Barium	mg/L	-	-	-	9	0.030	0.0558	0.0558	35	0.0300	0.0463
Beryllium	mg/L	-	-	-	9	<0.00001	<1.0	-	35	<0.00010	<0.00010
Bismuth	mg/L	-	-	-	8	<0.00020	<0.000020	-	35	<0.000050	<0.000050
Boron	mg/L	-	-	-	9	0.025	0.028	0.028	35	0.022	0.033
Cadmium	mg/L	-	-	-	9	<0.0000050	<0.020	-	35	<0.0000050	<0.0000050
Cesium	mg/L	-	-	-	6	<0.00010	<0.00010	-	35	<0.000010	<0.000010
Chromium	mg/L	-	-	-	9	<0.00010	<1.0	0.00020	35	<0.00010	0.00095
Cobalt	mg/L	-	-	-	9	0.000060	<0.3	0.00010	35	<0.00010	0.00010
Copper	mg/L	10	0.0012	0.0210	9	0.0013	<0.20	0.0037	35	0.0013	0.0100
Iron	mg/L	10	0.015	0.037	9	0.012	0.160	0.160	35	<0.010	0.071
Lead	mg/L	10	<0.0005	<0.0005	9	<0.00005	<0.2	0.00007	35	<0.000050	0.000163
Lithium	mg/L	-	-	-	9	0.0057	<0.02	0.0062	35	0.0057	0.0064
Manganese	mg/L	-	-	-	9	0.0231	1.18	1.18	35	0.0152	0.8040
Mercury	mg/L	-	-	-	7	<0.0000005	0.0000018	0.0000018	35	<0.000025	<0.0000050
Molybdenum	mg/L	-	-	-	8	0.0001	<0.2	0.0003	35	0.000199	0.000283
Nickel	mg/L	-	-	-	9	0.0003	<0.5	0.0007	35	<0.00050	0.00076
Rubidium	mg/L	-	-	-	5	0.0025	0.0027	0.0027	35	0.00244	0.00296
Selenium	mg/L	-	-	-	9	<0.00004	<0.2	0.00260	35	<0.000050	0.000068
Silver	mg/L	-	-	-	8	<0.000005	<0.1	-	35	<0.000010	<0.000010
Strontium	mg/L	-	-	-	8	0.0851	0.0928	0.0928	35	0.0841	0.0989
Thallium	mg/L	-	-	-	9	<0.000002	<0.2	-	35	<0.000010	<0.000010
Titanium	mg/L	-	-	-	9	0.00030	<1.0	0.00090	35	<0.00060	0.00049
Uranium	mg/L	-	-	-	9	0.00040	<0.1	0.000722	35	0.000524	0.000661
Vanadium	mg/L	-	-	-	9	0.0003	<1.0	0.00058	35	<0.00050	0.00068
Zinc	mg/L	10	0.0006	0.0340	9	<0.003	<3.0	0.0032	35	<0.0030	0.0078

(a) The list of elements reported for metals analysis includes metalloids such as arsenic and non-metals such as selenium, which are collectively referred to as “metals” in this table.

Notes:

Summary of historical and 2018 data are based on sample results and associated field measurements collected during each time period; data from field profiles were not included in the summaries.

NTU = nephelometric turbidity units; $CaCO_3$ = calcium carbonate; < = less than; µS/cm = microSiemens per centimetre; - = no data available; mg-N/L = milligrams nitrogen per litre; mg-P/L = milligrams phosphorus per litre.

Water Quality Data Quality Assurance/Quality Control

Table of Contents

1.0 INTRODUCTION

Quality assurance and quality control (QA/QC) practices determine data integrity and are relevant to the Jackfish Lake water quality monitoring program. Golder Associates Ltd. (Golder) applied these practices throughout the activities that Golder completed within the program, from sample collection to data analysis, and reporting. Quality assurance (QA) encompasses management and technical practices designed to confirm that the data generated are of consistent high quality. Quality control (QC) is an aspect of QA that includes the procedures used to measure and evaluate data quality, and the corrective actions applied when data quality objectives are not met.

This appendix describes QA/QC practices applied during this study, evaluates QC data, and describes the implications of QC results to the interpretation of study results.

2.0 QUALITY ASSURANCE

Quality assurance applicable to this study covers three areas: field work, laboratory analysis, and office operations.

2.1 Field Work

Golder field crews are trained to be proficient in standardized field sampling procedures, data recording, and equipment operations applicable to water quality sampling. Field work was completed according to approved specific work instructions and established Golder technical procedures. Specific work instructions are standardized forms that reference appropriate technical procedures and provide specific sampling instructions for the work to be undertaken. For example, specific work instructions provide field staff with descriptions of exact sampling locations, equipment needs and calibration requirements, sampling handling and storage requirements, sample labelling and shipping protocols, and internal and laboratory contacts. The specific work instructions also provide specific guidelines for field record keeping and sample tracking. Golder technical procedures are consistent with the information described in the relevant scientific literature (e.g., Environment Canada 1993; APHA 2012), and outline relevant information regarding protocols for field sample collection and in situ field measurements.

Other key QA processes applicable to field crews were:

- A pre-field meeting with the field crew and the project/task manager was held before the field work to discuss the purpose of the field program, specify the roles of crew members, address questions regarding the specific work instructions, and discuss equipment needs, field logistics, and contingency plans.
- During field work, field data were recorded on standardized field data sheets and in a bound waterproof field notebook, according to established field record-keeping procedures.
- Field crews checked in with task managers after each day to provide an update on work completed.
- All field data were checked at the end of the field program for completeness and accuracy.
- Calibrations were performed on the field water quality multi meters at the beginning of each day to maintain accuracy of the field data. End-of-day checks on the calibration of the multi meters were completed to evaluate the potential for drift in calibration during the field program. Records of calibration and end-of-day checks were reviewed further if unexpected field readings were measured.

- Samples were documented and tracked using sample control numbers (SCNs) and chain-of-custody forms; receipt of samples by the analytical laboratory was confirmed. Field crews were responsible for delivering the samples to the analytical laboratory. Prior to sample shipping, field crews confirmed the following:
  - All required samples were collected and accounted for prior to shipping.
  - Chain-of-custody and analytical request forms were completed and correct.
  - Proper bottle labelling and documentation procedures were followed.

2.2 Analytical Laboratory

A Canadian Association for Laboratory Accreditation Inc. (CALA) accredited analytical laboratory, ALS Canada Ltd. (ALS), was used for the analysis of water samples collected by Golder for this program. Under CALA's accreditation program, performance evaluation assessments are conducted for laboratory procedures, methods, and internal QC. As a result, there was high confidence that the analytical data reported by ALS were considered reliable.

One member of the Jackfish Lake water quality monitoring team from Golder was designated as the laboratory liaison to streamline communications with the laboratory.

2.3 Office Operations

Relevant elements of office-based QA were:

- using appropriately trained personnel for each data management, analysis, and reporting task
- using standardized data manipulation/summary tools, where applicable
- filing hard-copy and electronic data and project information according to standardized protocols
- using a data management system (i.e., EQuIS) to maintain an organized, consistent system to store, check and export field and laboratory data field
- reviewing work products (e.g., tables, figures, result descriptions) at appropriate milestones

3.0 QUALITY CONTROL PROCEDURES

3.1 Field Control Procedures

Four types of QC samples, which were analyzed for the same constituents analyzed during the field program, with the exception of hydrocarbons, were used in this program:

- **Travel blanks** consist of deionized water provided in sampling bottles by the analytical laboratory. Travel blanks accompany the samples through all steps of collection and transportation. These are shipped, handled, stored, and treated the same as the collected samples, but are not opened in the field. Travel blanks are used to detect potential sample contamination that may be due to ambient conditions, or that may have occurred during shipping and laboratory analysis.
- **Field blanks** consist of deionized water provided by the analytical laboratory that is transferred to sample bottles in the field. The field blanks are shipped, handled, stored, and treated the same, including sample

preservation and filtering, as the water samples collected during the field program. Field blanks are used to detect potential sample contamination during sample collection, handling, shipping, and laboratory analysis.

- **Equipment Blanks** consist of deionized water provided by the analytical laboratory that is transferred to the Kemmerer and then to the sample bottles at the Golder office's laboratory facility. The equipment blanks are shipped, handled, stored, and treated the same, including sample preservation and filtering, as the water samples collected during the field program. Equipment blanks are not brought in the field. Equipment blanks are used to detect potential sample contamination due to sampling equipment.
- **Duplicate samples** are additional samples collected at the same time and location as water samples collected during a field program, using the same sampling methods. They are used to check within-site variation, and the precision of field sampling methods and laboratory analysis.

The duplicate samples accounted for approximately 10% of the total number of water samples submitted for analysis and there was an equipment blank and either a travel blank or a field blank for each field program. All QC samples were submitted "blind" (i.e., with standard sample control numbers so as to not to identify them as QC samples) to the laboratory to test the validity of the analysis process.

3.2 2018 Field and Laboratory Data Quality Procedures

Field data, datasheets and the field notebook were reviewed for completeness and unexpected values. Upon receipt of water quality data from the laboratory, a series of seven standard checks were performed to screen for potential data quality issues (Sections 3.2.1 to 3.2.8):

- screening of individual laboratory and field results
- review of detection limits (DLs)
- review of units
- review of any holding times exceedances
- check for contamination in blank samples
- compare duplicates
- review of internal laboratory QA/QC results and qualifiers

3.2.1 Screening of Individual Laboratory and Field Results

Screening of individual laboratory and field results in 2018 involved:

- Project chain-of-custody forms were compared to sampling records to confirm sampling locations matched assigned SCNs and analytical request of all required parameters.
- Laboratory results were reviewed to confirm analysis of all required parameters.
- Field and laboratory data from the same sample were reviewed to check that field and laboratory data were similar for expected parameters. Flagged data were further reviewed, along with records of calibration and end-of-day calibration checks and concentrations of other relevant parameters within the sample, to assess the need to qualify or invalidate the laboratory or field result. Field and laboratory data were evaluated and flagged as follows:

  - Field versus laboratory pH: one unit difference between measurements.
  - Field versus laboratory specific conductivity (herein referred to as conductivity): relative percent difference [RPD] greater than 20%
  - Field versus laboratory turbidity: RPD greater than 20%
- Data logic checks were completed. The presence of zero values, which should not occur due to detection limits, was checked.

Laboratory results were requested to be re-analyzed if:

- Values were assessed as higher or lower than expected, based on comparisons to other lake data collected during the program or data collected during previous programs.
- Relative percent differences in parameter concentration in field and duplicate sample were well above 20% when concentrations were more than five times the DL, and the field or duplicate value were assessed as higher or lower than expected.
- Parameters were detected in concentrations above five times the DL in a blank.

If re-analysis confirmed the original analysis result (i.e., RPD less than 20%), the original result was retained. If the re-analysis was notably different than the original result (i.e., RPD greater than 20%), then a decision was made to keep the original or re-analyzed result based on discussions with the laboratory regarding any QC issues of the original and re-analyzed results, holding times exceedances, historical concentrations, concentrations of other parameters within the same sample, results of the QC samples or a combination of these factors. The rationale for requesting re-analyses or revising the original result to the re-analyzed result was documented.

3.2.2 Analytical Methods

Analytical methods were specified for each parameter or group of parameters for the Jackfish Water Quality program. Quoted methods received from the laboratory prior to 2018 sampling events were compared to the methods used by the laboratory for individual samples. If laboratory methods differed from standard methods, the laboratory was contacted to determine the reason for the deviation in method.

3.2.3 Detection Limits

Detection limits were specified for all chemical analyses for the Jackfish Lake Baseline program. Quoted standard DLs received from the laboratory prior to 2018 were compared to the DLs provided by the laboratory for individual samples.

If laboratory DLs were higher than the project standard DLs, the laboratory was notified and requested to provide an explanation for the change in DLs. If possible, a parameter was re-analyzed at the project standard DL. Changes in DLs by the laboratory during the program could cause limitations when comparing results with different DLs and results to water quality guidelines. An increase in DL above measured concentrations reduces the ability to detect spatial and temporal patterns; an increase in DL above a water quality guideline reduces the ability to detect guideline exceedances when concentrations are below DLs.

3.2.4 Units

The units reported by the laboratory were compared against the expected units, as coded into the database, for each parameter.

3.2.5 Holding Times

Holding times between sample collection and analysis for each parameter are specified by the laboratory, based on Table 1060: I – Summary of Special Sampling and Handling Requirements, *The Standard Methods for the Examination of Water and Wastewater* (APHA 2012). The laboratory reviews holding times for any exceedances and identifies any data that may be unreliable due to holding time exceedances. Holding time exceedances are considered when determining the validity of re-analyzed results from the laboratory.

times between sample collection and analysis for each parameter are specified by the laboratory, and are based on United Sates Environmental Protection Agency test methods. The laboratory reviews holding times for any exceedances and identifies any data that may be unreliable due to holding time exceedances.

3.2.6 Blank Samples

Water quality concentrations in travel or field blanks were considered notable if concentrations were greater than or equal to five times the corresponding DL. This threshold takes into account the potential for reduced precision when concentrations approach or are below DLs (AENV 2006; APHA 2012). This criterion was not applied to pH, however, because DLs are not applicable to the pH scale.

3.2.7 Duplicate Samples

Differences between concentrations measured in duplicate water samples were calculated as the RPD for each parameter. Before calculating the RPD, concentrations below the DL were replaced with the DL value in cases when only one of the concentrations for a given parameter was detectable. The RPD was calculated as per Equation 1:

$$RPD = (|difference\ in\ concentration\ between\ two\ of\ the\ duplicate\ samples|/mean\ concentration)\ x\ 100$$

[Equation 1]

The RPD value for a given parameter was notable if:

- it was greater than 20%
- concentrations in one or both samples were greater than five times the DL

The number of parameters with exceedances of the evaluation criteria was compared with the total number of parameters analyzed to evaluate analytical precision.

Within-site variability and field sampling precision of duplicate sample results were rated as:

- **Low and high**, respectively, if less than 10% of the parameters included in the duplicate sample analysis were notably different from one another
- **Moderate**, if 10% to 30% of the parameters included in the duplicate sample analysis were notably different from one another.

- **High and low**, respectively, if more than 30% of the parameters included in the duplicate sample analysis were notably different from one another.

3.2.8 Internal Laboratory Quality Control

The following internal QC information was submitted by the laboratory and reviewed by Golder for each sampling event:

- sample temperature and integrity of containers upon receipt
- data qualifiers
- percent recovery of spiked analytes
- comparison of internal duplicates to assess variability of analytical methods

Any issues that may have affected water quality results were discussed with the laboratory to assess the validity of impacted results.

3.3 Office Quality Control Procedures

Relevant elements of office-based QC were:

- saving unaltered field datasheets, field notebooks, and laboratory files (e.g., chain-of-custody forms, analysis request forms, certificates of analysis) in the Jackfish Lake water quality monitoring program directory to document the original and final sources of laboratory and field water quality data from each program.
- comparing sample field and laboratory data entered into the Jackfish Lake water quality monitoring program data management system against field datasheets and final laboratory reports to confirm data accuracy
- creating backup files before each major data processing step
- verifying the accuracy of calculations performed to generate summary statistics and complete guideline comparisons
- documenting the final results for the QA/QC assessment in the Jackfish Baseline Report

4.0 2018 FIELD AND LABORATORY DATA QUALITY RESULTS

4.1 Screening of Individual Laboratory and Field Results

4.1.1 Chain-of-custody Review

A review of the chain-of custody forms indicated that the planned and actual sampling locations matched for SCNs.

4.1.2 Parameters Requested for Analysis

A review of the analytical request forms indicated that the planned and actual sampling locations matched.

4.1.3 Field Data Review

One dissolved oxygen (mg/L) input was corrected; the concentration was corrected from 12.98 to 12.23 based on the temperature and dissolved oxygen saturation results and was assumed to be a transcriptional error (i.e., May at EMD and CAT at 2 m). and Based on the review of the field data, 1 field pH, 12 specific conductivity, and 25 turbidity results were further evaluated because the values were different than expected relative to laboratory values (Table C.4a). Both the field and laboratory values were retained, with the exception of four field specific conductivity values on 11 December, because no calibration issues were reported by the field crew or laboratory, with the exception of the calibration of field conductivity on 11 December. The cell constant for four of the specific conductivity values measured on 11 December was reported below the target value; although, the end-of-day-check indicated that the conductivity probe was accurately measuring the calibration solution, the field specific conductivity values on this date were invalidated because:

- The field specific conductivity values measured on 11 December were notably different (RPD greater than 20%) than those measured one day later at other locations in the lake
- The laboratory specific conductivity values from samples collected at different locations in Jackfish Lake on the 11 and 12 of December were notably different.
- The field specific conductivity values measured on 11 December were the lowest specific conductivity measured in Jackfish Lake in 2018.

4.1.4 Laboratory data review:

A total of 32 laboratory results, which represented less than 1% of the 2018 laboratory data, in 7 samples were further evaluated due to results that were either inconsistent with other sample results from 2018 or when data logic checks indicated a potential problem with the data (Table C.4a). In five cases of re-analysis, the re-analysis result was not notably different than the original result so the original result was retained. In 26 cases, the re-analysis result was retained because it was notably different than the original result and closer to the expected concentration and the laboratory provided rationale for the differences.

4.2 Analytical Methods

All parameters were analyzed by the laboratory using the standard analytic methods requested during the program.

4.3 Detection Limits

Most parameters were analyzed by the laboratory using DLs equal to the requested DL (Table C.4b). Eight parameters were analyzed at higher than requested DLs in 18% of the samples:

- total dissolved solids (20 mg/L compared to the requested 10 mg/L)
- nitrate + nitrite (0.0051 mg-N/L compared to the requested 0.003 mg-N/L)
- total ammonia (0.013 mg-N/L compared to the requested 0.005 mg-N/L)
- total Kjeldahl nitrogen (0.25 mg-N/L compared to the requested 0.05 mg-N/L)
- total nitrogen (0.006 mg-N/L and 0.3 mg-N/L compared to the requested 0.03 mg-N/L)
- total phosphorus (0.02 mg-P/L compared to the requested 0.002 mg-P/L)
- dissolved phosphorus (0.02 mg-P/L compared to the requested 0.002 mg-P/L)
- total titanium (0.0006 mg/L compared to the requested 0.0003 mg/L)

The laboratory used higher DLs in the analyses for these parameters because the samples had a turbidity reading of higher than 1 nephelometric unit (NTU); samples with elevated turbidity required additional sample preparation (i.e., sample digestion) resulting in an increase in the DL.

4.4 Units

The laboratory reported the expected units for each parameter in 2018.

4.5 Holding Times

Laboratory pH exceeded the recommended 15 minutes holding time for all samples (APHA 2012). Field pH was used to represent pH in the analyses of 2018 data, including in the calculation of Canadian Water Quality Guidelines that are pH-dependent.

Holding times were also occasionally missed for laboratory turbidity, nitrate, nitrite, dissolved orthophosphate, and total phosphorus in 2018. These parameters exceeded their holding time by a short time period and sample quality was not expected to be affected.

4.6 Blank Samples

Ten blank samples (five equipment blanks, two travel blanks and three field blanks) were collected and analyzed during the 2018 program (Table C.4c). The percentage of detectable concentrations in the blank samples was less than 2%. No reportable detections (i.e., greater than five times the DL) were found in the blank samples; therefore, no parameters were detected at a frequency or magnitude that were likely to influence the results of the water quality samples.

4.7 Duplicate Samples

One duplicate water quality sample was collected during each of the 2018 programs, totalling five duplicates (Table C.4d).

Less than 1% of the paired duplicate concentrations had an RPD of more than 20% when one or both parameter concentrations were above five times the DL (Table C.4e). The site variability and field precision for the 2018 dataset was rated as low and high, respectively.

4.8 Internal Laboratory Quality Control

No issues were identified in the review of internal quality control results.

5.0 SUMMARY OF DATA QUALITY

The results of the review of field data indicated that the majority of the field and laboratory data collected during was of high quality. Key findings from the 2018 QA/QC results are:

- In general, field measurements and results of laboratory samples collected during the 2018 sampling program have limited outliers in the data set based on all the data collected in 2018, with the exception of four specific conductivity values measured on December 11, which were invalidated likely due to equipment malfunction.
- No issues were identified in units reported by the laboratory.

- Total dissolved solids, nitrate + nitrite, total ammonia, total Kjeldahl nitrogen, total nitrogen, total phosphorus, dissolved phosphorus and total titanium were analyzed at higher than requested DLs for 18% of samples when the turbidity of the samples required additional manipulation of the sample.
- Evaluation of the water quality QC samples indicated that:
  - No notable contamination occurred in the blank samples.
  - The site variability and field precision for the 2018 dataset was rated as low and high, respectively.

The overall quality of the water quality data was determined to be high. Therefore, the results reported herein are determined to be reliable and meet the needs of the program.

6.0 REFERENCES

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TABLES

Table C.4a Summary of Rechecks for Field and Laboratory Results, Jackfish Lake, 2018

Sample Control Number	Station Name	Sample Date	Parameter(s)	Reason for Recheck	Field Result	Laboratory Result	Revised Result	Units	Decision
Field Results									
2018-0805	Mid-Lake-Bottom	01-Aug-18	Field and laboratory pH	Field pH was lower than expected based on the laboratory pH(a)	7.0	8.5	-	unitless	Calibration issues were not reported by either the field crew or laboratory; laboratory field pH was analyzed past holding time. Both field and laboratory values were retained but field pH values were used in the assessment.
2018-0901	K and EMD	26-Sep-18	Field and laboratory specific conductivity	Field specific conductivity was higher than expected based on the laboratory specific conductivity(b)	564	449	-	µS/cm	Calibration issues were not reported by either the field crew or laboratory; both field and laboratory values were retained.
208-0902	EMD and CAT				563	454			
2018-0903	Mid-Lake				564	457			
2018-0904	Mid-Lake-Bottom				563	454			
2018-0905	Northeast Bay				564	451			
2018-0906	Northwest Bay North				564	453			
2018-0907	Southwest Bay				563	454			
2018-0908	Duplicate at Northwest Bay North				564	452			
2018-1201	Northwest Bay North	11-Dec-18	Field and laboratory specific conductivity	Field specific conductivity was lower than expected based on the laboratory specific conductivity and previous values (b)	186	463	-	µS/cm	Data were invalidated due to calibration issues and additional discrepancies with the field specific conductivity collected on 11 December compared to 12 and 13 December.
2018-1202	Northeast Bay				186	469			
2018-1204	Mid-Lake				185	476			
2018-1205	Mid-Lake-Bottom				187	460			
2018-0502	K and EMD	29-May-18	Field and laboratory turbidity	Field turbidity was lower than expected based on laboratory turbidity(c)	4.9	6.1	-	NTU	Calibration issues were not reported by either the field crew or laboratory; both field and laboratory values were retained.
2018-0503	Duplicate at K and EMD	29-May-18			4.9	6.1			
2018-0504	EMD and CAT	29-May-18			3.2	7.8			
2018-0505	Northwest Bay North	30-May-18			4.1	6.5			
2018-0507	Southwest Bay	30-May-18			5.1	6.9			
2018-0508	Mid-Lake	30-May-18			5.5	7.3			
2018-0509	Mid-Lake-Bottom	30-May-18			4.7	7.3			
2018-0701	K and EMD	10-Jul-18			8.1	11.3			
2018-0702	EMD and CAT	10-Jul-18			7.7	10.7			
2018-0703	Mid-Lake	10-Jul-18			7.6	12.8			
2018-0704	Mid-Lake-Bottom	10-Jul-18			4.4	9.4			
2018-0705	Northeast Bay	10-Jul-18			8.3	10.8			
2018-0707	Southwest Bay	10-Jul-18			7.2	11.4			
2018-0708	K Intake Facility	11-Jul-18			7.1	10.9			
2018-0711	Cat Intake Facility	11-Jul-18			7.3	10.5			
2018-0712	K Discharge Facility	11-Jul-18			6.9	12.4			
2018-0802	Northwest Bay North	01-Aug-18			10.5	13.4			
2018-0805	Mid-Lake-Bottom	01-Aug-18			10.9	17.0			
2018-0806	Southwest Bay	01-Aug-18			11.7	14.5			
2018-0808	Northeast Bay	01-Aug-18			11.1	15.1			
2018-0809	EMD and CAT	01-Aug-18			10.9	13.9			
2018-0903	Mid-Lake	26-Sep-18			11.7	16.2			

Table C.4a Summary of Rechecks for Field and Laboratory Results, Jackfish Lake, 2018

Sample Control Number	Station Name	Sample Date	Parameter(s)	Reason for Recheck	Field Result	Laboratory Result	Revised Result	Units	Decision
Re-analyzed Laboratory Results									
2018-0505	Northwest Bay North	30-May-18	Total nitrogen	The sum of the corresponding total Kjeldahl nitrogen and nitrate+nitrite values are higher than 120%.	-	0.991	0.991	mg-N/L	Concentrations were confirmed by re-analysis; original result was retained
			Total Kjeldahl nitrogen		-	1.16	1.16		
2018-0708	K Intake Facility	10-Jul-18	Orthophosphate	Value exceeded the corresponding dissolved phosphorus value by 20% or more.	-	0.0446	0.0106	mg-P/L	Re-analysis result was retained because it was closer to the expected concentration.
2018-0710	EMD Intake Facility		Orthophosphate		-	0.0428	0.0227	mg-P/L	
2018-0711	CAT Intake Facility		Orthophosphate		-	0.0397	0.005	mg-P/L	
2018-0717	Travel Blank	11-Jul-18	Total aluminum	Value is greater than five time the detection limit in a blank sample.	-	176	<0.0030	µg/L	Re-analysis result was retained because it was closer to the expected concentration.
			Total arsenic		-	0.4	<0.00010		
			Total barium		-	3.14	<0.00010		
			Calcium		-	2170	<0.050		
			Total chromium		-	0.36	<0.00010		
			Total cobalt		-	0.21	<0.00010		
			Total copper		-	0.84	<0.00050		
			Total iron		-	422	<0.010		
			Total lead		-	0.058	0.000054		
			Total magnesium		-	286	<0.0050		
			Total magnanese		-	49.5	<0.00010		
			Total molybdenum		-	0.259	<0.000050		
			Total nickel		-	0.71	<0.00050		
			Total potassium		-	213	<0.050		
			Total rubidium		-	0.35	<0.00020		
			Total silicon		-	1610	<0.10		
			Total sodium		-	3670	<0.050		
			Total strontium		-	11.4	<0.00020		
			Total titanium		-	2.58	<0.00030		
			Total uranium		-	0.048	<0.000010		
			Total zicronium		-	1.6	<0.000060		
2018-0805	Mid-Lake-Bottom	01-Aug-18	Total nitrogen	The sum of the corresponding total Kjeldahl nitrogen and nitrate+nitrite values are higher than 120%.	-	2.14	2.41	mg-N/L	Concentrations were confirmed by re-analysis; original result was retained
			Total Kjeldahl nitrogen		-	1.55	1.50		
			Dissolved phosphorus	Dissolved phosphorus was greater than the total phosphorus by more than 20%.	-	0.11	0.10	mg-P/L	
			Total phosphorus		-	0.0711	0.0795		
	EMD and CAT	12-Dec-18	Total chromium	Total chromium value was greater than any other values from 2018.	-	0.00095	0.00101	mg/L	Concentration was confirmed by re-analysis; original result was retained
2018-1210	Equipment Blank	13-Dec-18	Orthophosphate	Orthophosphate was greater than five times the detection limit in a blank sample.	-	0.0137	0.00079	mg-P/L	Re-analysis result was retained because it was closer to the expected concentration.

Notes:

- = no data; µS/cm = microsiemens per centimetre; mg-N/L = milligrams nitrogen per litre; mg-P/L = milligrams phosphorus per litre; NTU = nephelometric turbidity units; RPD = relative percent difference

a) Result was reviewed further when the absolute difference between field and laboratory pH was greater than 1.

b) Result was further reviewed when the RPD between field was greater than 20%.

c) Result was further reviewed when the RPD between field and laboratory specific turbidity was greater than 20%.

Table C.4b: Summary of Detection Limits, Jackfish Lake, 2018

Parameter	Unit	Total Number of Samples	Standard Project Detection Limit			Alternate Detection Limit			Alternate Detection Limit		
			Value	Number of Samples	Frequency (%)	Value	Number of Samples	Frequency (%)	Value	Number of Samples	Frequency (%)
Routine Parameters											
Specific conductivity (laboratory)	µS/cm	55	2.0	55	100	-	-	-	-	-	-
Hardness	mg/L	55	0.50	55	100	-	-	-	-	-	-
Total alkalinity (as $CaCO_3$)	mg/L	55	1.0	55	100	-	-	-	-	-	-
Total dissolved solids, measured	mg/L	55	10	10	18	20	45	82	-	-	-
Total suspended solids	mg/L	55	3.0	55	100	-	-	-	-	-	-
Turbidity (laboratory)	NTU	55	0.10	55	100	-	-	-	-	-	-
Major Ions											
Bromide	mg/L	55	0.050	55	100	-	-	-	-	-	-
Calcium	mg/L	55	0.050	55	100	-	-	-	-	-	-
Chloride	mg/L	55	0.50	55	100	-	-	-	-	-	-
Fluoride	mg/L	55	0.020	55	100	-	-	-	-	-	-
Magnesium	mg/L	55	0.10	55	100	-	-	-	-	-	-
Potassium	mg/L	55	2.0	55	100	-	-	-	-	-	-
Sodium	mg/L	55	2.0	55	100	-	-	-	-	-	-
Sulphate	mg/L	55	0.30	55	100	-	-	-	-	-	-
Organic Carbon											
Total organic carbon	mg/L	55	0.50	55	100	-	-	-	-	-	-
Nutrients											
Nitrate	mg-N/L	55	0.005	55	100	-	-	-	-	-	-
Nitrite	mg-N/L	55	0.0010	55	100	-	-	-	-	-	-
Nitrate + nitrite	mg-N/L	55	0.0051	55	100	-	-	-	-	-	-
Total ammonia	mg-N/L	55	0.0050	54	98	-	-	-	-	-	-
Total Kjeldahl nitrogen	mg-N/L	55	0.050	53	96	0.250	2	4	-	-	-
Total nitrogen	mg-N/L	55	0.030	43	78	0.060	7	13	0.30	5	9
Total phosphorus	mg-P/L	55	0.0020	49	89	0.020	6	11	-	-	-
Dissolved phosphorus	mg-P/L	55	0.0020	53	96	0.020	2	4	-	-	-
Orthophosphate	mg-P/L	55	0.0010	55	100	-	-	-	-	-	-
Reactive silica	mg/L	51	0.50	51	100	-	-	-	-	-	-
Total Metals[(a)]											
Aluminum	mg/L	55	0.0030	55	100	-	-	-	-	-	-
Antimony	mg/L	55	0.00010	55	100	-	-	-	-	-	-
Arsenic	mg/L	55	0.00010	55	100	-	-	-	-	-	-
Barium	mg/L	55	0.00010	55	100	-	-	-	-	-	-
Beryllium	mg/L	55	0.00010	55	100	-	-	-	-	-	-
Bismuth	mg/L	55	0.000050	55	100	-	-	-	-	-	-
Cadmium	mg/L	55	0.0000050	55	100	-	-	-	-	-	-
Cesium	mg/L	55	0.000010	55	100	-	-	-	-	-	-
Chromium	mg/L	55	0.00010	55	100	-	-	-	-	-	-
Cobalt	mg/L	55	0.00010	55	100	-	-	-	-	-	-
Copper	mg/L	55	0.00050	55	100	-	-	-	-	-	-
Iron	mg/L	55	0.010	55	100	-	-	-	-	-	-
Lead	mg/L	55	0.000050	55	100	-	-	-	-	-	-
Lithium	mg/L	55	0.0010	55	100	-	-	-	-	-	-
Manganese	mg/L	55	0.00010	55	100	-	-	-	-	-	-
Mercury	mg/L	55	0.0000050	51	93	0.0000250	4	7	-	-	-
Molybdenum	mg/L	55	0.000050	55	100	-	-	-	-	-	-
Nickel	mg/L	55	0.00050	55	100	-	-	-	-	-	-
Rubidium	mg/L	55	0.00020	55	100	-	-	-	-	-	-
Selenium	mg/L	55	0.000050	55	100	-	-	-	-	-	-
Silver	mg/L	55	0.000010	55	100	-	-	-	-	-	-
Strontium	mg/L	55	0.00020	55	100	-	-	-	-	-	-
Thallium	mg/L	55	0.000010	55	100	-	-	-	-	-	-
Titanium	mg/L	55	0.00030	45	82	0.00060	1	2	-	-	-
Uranium	mg/L	55	0.000010	55	100	-	-	-	-	-	-
Vanadium	mg/L	55	0.00050	55	100	-	-	-	-	-	-
Zinc	mg/L	55	0.0030	55	100	-	-	-	-	-	-
Hydrocarbons											
Benzene	mg/L	3	<0.00050	3	100	-	-	-	-	-	-
Ethylbenzene	mg/L	3	<0.00050	3	100	-	-	-	-	-	-
Toluene	mg/L	3	<0.00045	3	100	-	-	-	-	-	-
Xylenes	mg/L	3	<0.00075	3	100	-	-	-	-	-	-
F1 (C6-C10)-BTEX	mg/L	3	<0.10	3	100	-	-	-	-	-	-
F2 (C10-C16)	mg/L	3	<0.30	3	100	-	-	-	-	-	-
F3 (C16-C34)	mg/L	3	<0.30	3	100	-	-	-	-	-	-
F1 (C6-C10)	mg/L	3	<0.10	3	100	-	-	-	-	-	-
EPH10-19	mg/L	3	<0.050	3	100	-	-	-	-	-	-
EPH19-32	mg/L	3	<0.050	3	100	-	-	-	-	-	-
TEH10-30	mg/L	3	<0.10	3	100	-	-	-	-	-	-

(a) The list of elements reported for metals analysis includes metalloids such as arsenic and non-metals such as selenium, which are collectively referred to as “metals” in this table.

Notes:

µS/cm = microSiemens per centimetre; $CaCO_3$ = calcium carbonate; NTU = nephelometric turbidity units; - = no alternate detection limit, BTEX = benzene, toluene, ethylbenzene and xylenes; EPH = extractable petroleum hydrocarbons; TEH = total extractable petroleum hydrocarbons; mg-N/L = milligrams nitrogen per litre; mg-P/L = milligrams phosphorus per litre

Table C.4c: Quality Control Blank Samples Results, Jackfish Lake, 29 May to 13 December 2018

Parameter	Unit	Field Blanks			Travel Blanks		Equipment Blanks				
		2018-0506	2018-0807	2018-1207	2018-0717	2018-0910	2018-0511	2018-0716	2018-0801	2018-0909	2018-1210
		30-May-18	1-Aug-18	12-Dec-18	11-Jul-18	26-Sep-18	31-May-18	11-Jul-18	1-Aug-18	25-Sep-18	13-Dec-18
Routine Parameters											
pH (laboratory)	unitless	5.4	5.5	5.5	5.5	5.6	5.3	5.5	5.5	5.6	5.5
Specific conductivity (laboratory)	μS/cm	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Hardness (as $CaCO_3$)	mg/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Total alkalinity (as $CaCO_3$)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total suspended solids	mg/L	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
Total dissolved solids	mg/L	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0
Total dissolved solids (calculated)	mg/L	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Turbidity (laboratory)	NTU	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Major Ions											
Bromide	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Calcium	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chloride	mg/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Fluoride	mg/L	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Magnesium	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Potassium	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Sodium	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Sulphate	mg/L	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Organic Carbon											
Total organic carbon	mg/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Nutrients											
Nitrate	mg-N/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Nitrite	mg-N/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Nitrate + nitrite	mg-N/L	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051
Total ammonia	mg-N/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0096
Total Kjeldahl nitrogen	mg-N/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Total nitrogen	mg-N/L	<0.030	<0.030	<0.030	<0.030	0.031	<0.030	<0.030	<0.030	0.051	<0.030
Total phosphorus	mg-P/L	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Dissolved phosphorus	mg-P/L	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
Orthophosphate	mg-P/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.00079
Reactive silica	mg/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Total Metals[(a)]											
Aluminum	mg/L	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
Antimony	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Arsenic	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00017	<0.00010	<0.00010	<0.00010	<0.00010
Barium	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Beryllium	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Bismuth	mg/L	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Cadmium	mg/L	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Cesium	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Chromium	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00011
Cobalt	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Copper	mg/L	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Iron	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Lead	mg/L	<0.000050	<0.000050	<0.000050	0.000054	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Lithium	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Manganese	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00011	<0.00010	<0.00010	<0.00010	0.00026
Mercury	mg/L	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Molybdenum	mg/L	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Nickel	mg/L	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Rubidium	mg/L	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Selenium	mg/L	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Silver	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Strontium	mg/L	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Thallium	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Titanium	mg/L	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
Uranium	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Vanadium	mg/L	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Zinc	mg/L	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
Hydrocarbons											
Benzene	mg/L	-	-	-	<0.00050	-	-	-	-	-	-
Ethylbenzene	mg/L	-	-	-	<0.00050	-	-	-	-	-	-
Toluene	mg/L	-	-	-	<0.000450	-	-	-	-	-	-
Xylenes	mg/L	-	-	-	<0.00075	-	-	-	-	-	-
F1 (C6-C10)-BTEX	mg/L	-	-	-	<0.10	-	-	-	-	-	-
F2 (C10-C16)	mg/L	-	-	-	<0.30	-	-	-	-	-	-
F3 (C16-C34)	mg/L	-	-	-	<0.30	-	-	-	-	-	-
F1 (C6-C10)	mg/L	-	-	-	<0.10	-	-	-	-	-	-
EPH10-19	mg/L	-	-	-	<0.050	-	-	-	-	-	-
EPH19-32	mg/L	-	-	-	<0.050	-	-	-	-	-	-
TEH10-30	mg/L	-	-	-	<0.10	-	-	-	-	-	-

(a) The list of elements reported for metals analysis includes metalloids such as arsenic and non-metals such as selenium, which are collectively referred to as “metals” in this table.

Notes:

No concentrations greater than five times the detection limit were measured in any of the field, equipment or travel blanks.

μS/cm = microSiemens per centimetre; $CaCO_3$ = calcium carbonate; NTU = nephelometric turbidity units; < = less than; - = parameter not required, BTEX = benzene, toluene, ethylbenzene and xylenes; EPH = extractable petroleum hydrocarbons; TEH = total extractable petroleum hydrocarbons; mg-N/L = milligrams nitrogen per litre; mg-P/L = milligrams phosphorus per litre

Table C.4d: Quality Control Duplicate Samples Results, Jackfish Lake, 2018

Parameters	Units	K and EMD		Northwest Bay North		Northwest Bay North		Northwest Bay North		Northeast Bay	
		2018-0502	2018-0503	2018-0706	2018-0715	2018-0802	2018-0803	2018-0906	2018-0908	2018-1202	2018-1203
		29-May-18		10-Jul-18		01-Aug-18		26-Sep-18		11-Dec-18	
Routine Parameters											
pH (laboratory)	-	8.3	8.4	8.6	8.5	8.7	8.7	8.4	8.4	8.3	8.2
Specific conductivity (laboratory)	µS/cm	442	440	422	427	430	430	453	452	469	470
Hardness (as $CaCO_3$)	mg/L	149	149	150	148	154	156	154	157	166	168
Total alkalinity (as $CaCO_3$)	mg/L	107	108	105	99.5	112	111	115	115	114	118
Total suspended solids	mg/L	6.8	8.0	10.5	10.9	13.5	13.1	13.6	10.2	13.0	12.6
Total dissolved solids	mg/L	291	270	264	277	282	281	270	266	312	277
Total dissolved solids (calculated)	mg/L	247	247	246	241	255	256	259	261	265	268
Turbidity (laboratory)	NTU	6.14	6.26	11.9	11.8	13.4	12.3	13.7	15.1	14.5	13.8
Major Ions											
Bromide	mg/L	0.052	<0.050	0.053	<0.050	0.050	0.053	<0.050	0.058	<0.050	<0.050
Calcium	mg/L	40.2	40.2	39.9	39.3	40.6	40.8	41.6	42.3	44.2	44.7
Chloride	mg/L	52.8	52.9	54.9	54.7	56.3	56.3	56.7	56.7	59.0	58.5
Fluoride	mg/L	0.097	0.096	0.098	0.090	0.087	0.086	0.094	0.095	0.093	0.090
Magnesium	mg/L	11.9	11.8	12.2	12.1	12.9	13.1	12.2	12.5	13.4	13.6
Potassium	mg/L	3.9	3.8	4.1	4.0	4.1	4.2	4.2	4.4	4.4	4.5
Sodium	mg/L	26.8	26.8	30.2	29.6	30.9	31.5	31.1	31.8	29.6	30.3
Sulphate	mg/L	29.6	29.7	29.2	29.2	29.8	29.8	29.1	29.1	29.6	29.6
Organic Carbon											
Total organic carbon	mg/L	12.8	12.8	12.3	14.4	12.2	12.7	11.2	12.1	13.3	13.0
Nutrients											
Nitrate	mg-N/L	0.046	0.046	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Nitrite	mg-N/L	0.0046	0.0044	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Nitrate + nitrite	mg-N/L	0.0507	0.0504	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051
Total ammonia	mg-N/L	0.1010	0.1030	<0.0050	<0.0050	<0.0050	0.0052	0.0138	0.0150	0.0118	0.0134
Total Kjeldahl nitrogen	mg-N/L	1.17	1.16	1.11	1.1	1.18	1.16	1.52	1.43	1.78	1.62
Total nitrogen	mg-N/L	1.32	1.15	1.10	1.04	1.23	1.24	1.54	1.48	1.64	1.68
Total phosphorus	mg-P/L	0.0818	0.0835	0.0627	0.0624	0.0663	0.0701	0.1010	0.0910	0.1200	0.1060
Dissolved phosphorus	mg-P/L	0.0161	0.0159	0.0132	0.0141	0.0141	0.0137	0.0153	0.0178	0.0126	0.0118
Orthophosphate	mg-P/L	0.0056	0.0057	0.0047	0.0043	0.0042	0.0038	0.0046	0.0042	0.0057	0.0051
Reactive silica	mg/L	13.7	13.5	9.41	10.0	10.2	10.8	12.1	12.0	12.9	12.9
Total Metals[(c)]											
Aluminum	mg/L	0.0097	0.0073	0.0088	0.0086	0.0067	0.0072	0.0061	0.0062	<0.0030	<0.0030
Antimony	mg/L	0.00143	0.00145	0.00161	0.00162	0.00149	0.00152	0.00141	0.00141	0.00139	0.00145
Arsenic	mg/L	0.0678	0.0695	0.0831	0.0880	0.0901	0.0891	0.0858	0.0827	0.0850	0.0849
Barium	mg/L	0.0335	0.0352	0.0333	0.0349	0.0307	0.0309	0.0322	0.0318	0.0357	0.0352
Beryllium	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Bismuth	mg/L	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Cadmium	mg/L	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Cesium	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Chromium	mg/L	<0.00010	<0.00010	<0.00010	0.00013	<0.00010	<0.00010	<0.00010	<0.00010	0.00016	0.00016
Cobalt	mg/L	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Copper	mg/L	0.01050	0.00303	0.00249	0.00259	0.00218	0.00220	0.00140	0.00137	0.00200	0.00183
Iron	mg/L	0.020	0.016	0.015	0.050	0.014	0.014	0.011	0.010	0.010	<0.010
Lead	mg/L	0.000141	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Lithium	mg/L	0.0057	0.0061	0.0060	0.0062	0.0059	0.0060	0.0063	0.0062	0.0062	0.0063
Manganese	mg/L	0.0910	0.0981	0.0179	0.0189	0.0278	0.0280	0.0303	0.0290	0.0724	0.0710
Mercury	mg/L	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Molybdenum	mg/L	0.000242	0.000215	0.000282	0.000272	0.000262	0.000274	0.000229	0.000252	0.000249	0.000227
Nickel	mg/L	0.00065	0.00056	0.00061	0.00062	0.00067	0.00067	0.00053	<0.0005	0.00064	0.00067
Rubidium	mg/L	0.0026	0.00269	0.00266	0.00286	0.00274	0.00258	0.00258	0.00258	0.00291	0.00296
Selenium	mg/L	<0.000050	<0.000050	0.00005	0.000052	0.000056	0.000051	<0.000050	<0.000050	0.000053	<0.000050
Silver	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Strontium	mg/L	0.0895	0.0881	0.0930	0.0942	0.0875	0.0893	0.0966	0.0963	0.0959	0.1010
Thallium	mg/L	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Titanium	mg/L	0.00039	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
Uranium	mg/L	0.000618	0.000603	0.000612	0.000634	0.000633	0.000634	0.000556	0.000537	0.000578	0.000607
Vanadium	mg/L	<0.00050	<0.00050	0.00063	0.00068	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Zinc	mg/L	0.0033	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030

(a) The list of elements reported for metals analysis includes metalloids such as arsenic and non-metals such as selenium, which are collectively referred to as "metals" in this table.

Notes:

Grey shading indicates a relative percent difference between field sample and duplicate sample are greater than 20% for parameter concentrations above five times the detection limit. Reanalyses confirmed the reported values and so they were retained.

The relative percent difference between field sample and duplicate samples was also calculated when one parameter concentration was equal to or less than five times the detection limit but no parameters that met this criteria had a relative percent difference greater than 20%.

Relative percent difference= [|duplicate concentration - field concentration|/|duplicate + field concentration|/2] X 100%

µS/cm = microSiemens per centimetre; $CaCO_3$ = calcium carbonate; NTU = nephelometric turbidity units; < = less than; - = parameter not required, BTEX = benzene, toluene, ethylbenzene and xylenes; EPH = extractable petroleum hydrocarbons; TEH = total extractable petroleum hydrocarbons; mg-N/L = milligrams nitrogen per litre; mg-P/L = milligrams phosphorus per litre

Table C.4e Summary of Relative Percent Differences Between Water Quality Duplicate Samples, Jackfish Lake, 2018

Duplicate Pairs Location	Date	Total Number of Parameters	Relative Percent Difference Above 20% (when one parameter was above five times the detection limit)		Relative Percent Difference Above 20% (when both parameters were above five times the detection limit)	
			Number of Parameters	Percent of Total Parameters (%)	Number of Parameters	Percent of Parameter (%)
Surface Water						
K and EMD	29-May-18	53	0	0	1	2
Northwest Bay North	10-Jul-18	53	0	0	0	0
Northwest Bay North	1-Aug-18	53	0	0	0	0
Northwest Bay North	26-Sep-18	53	0	0	0	0
Northeast Bay	11-Dec-18	53	0	0	0	0
	Total	**159**	**0**	**0**	**1**	**1**

Golder Associates Ltd.
ATTN: TAMARA DARWISH
9, 4905-48 ST
Yellowknife NT X1A 3S3

Date Received: 31-MAY-18
Report Date: 13-JUN-18 14:30 (MT)
Version: FINAL

Client Phone: 867-873-6319

Certificate of Analysis

Lab Work Order #: L2104031

Project P.O. #: NOT SUBMITTED
Job Reference: 1894709-5000-5020 JACKFISH BASELINE SAMPLING
C of C Numbers: XX-XXXX-XXXX
Legal Site Desc:

Rick Zolkiewski
General Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

		L2104031-1	L2104031-2	L2104031-3	L2104031-4	L2104031-5
	Sample ID	L2104031-1	L2104031-2	L2104031-3	L2104031-4	L2104031-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	29-MAY-18	29-MAY-18	29-MAY-18	30-MAY-18	30-MAY-18
	Sampled Time	16:17	16:17	17:34	10:00	11:00
	Client ID	2018-0502	2018-0503	2018-0504	2018-0505	2018-0506
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)	442	440	440	440	<2.0
	Hardness (as CaCO3) (mg/L)		149	148	150	<0.50
	Hardness (as CaCO3)	149				
	pH (pH)	8.33	8.35	8.34	8.41	5.39
	Total Suspended Solids (mg/L)	6.8	8.0	7.0	3.3	<3.0
	Total Dissolved Solids (mg/L)	291	270	282	276	<10
	Turbidity (NTU)	6.14	6.26	7.78	6.54	<0.10
Anions and Nutrients	Alkalinity, Bicarbonate (as CaCO3) (mg/L)	104	105	108	105	<1.0
	Alkalinity, Carbonate (as CaCO3) (mg/L)	3.0	3.2	3.0	5.4	<1.0
	Alkalinity, Hydroxide (as CaCO3) (mg/L)	<1.0	<1.0	<1.0	<1.0	<1.0
	Alkalinity, Phenolphthalein (as CaCO3) (mg/L)	<2.0	<2.0	<2.0	2.7	<2.0
	Alkalinity, Total (as CaCO3) (mg/L)	107	108	111	110	<1.0
	Ammonia, Total (as N) (mg/L)	0.101	0.103	0.0928	0.116	<0.0050
	Bromide (Br) (mg/L)	0.052	<0.050	<0.050	<0.050	<0.050
	Chloride (Cl) (mg/L)	52.8	52.9	52.9	53.1	<0.50
	Fluoride (F) (mg/L)	0.097	0.096	0.096	0.095	<0.020
	Nitrate and Nitrite (as N) (mg/L)	0.0507	0.0504	0.0493	0.0496	<0.0051
	Nitrate (as N) (mg/L)	0.0461	0.0460	0.0449	0.0466	<0.0050
	Nitrite (as N) (mg/L)	0.0046	0.0044	0.0044	0.0030	<0.0010
	Total Kjeldahl Nitrogen (mg/L)	1.17	1.16	1.19	1.16	<0.050
	Total Nitrogen (mg/L)	1.32	1.15	1.25	0.991	<0.030
	Orthophosphate-Dissolved (as P) (mg/L)	0.0056	0.0057	0.0055	0.0060	<0.0010
	Phosphorus (P)-Total Dissolved (mg/L)	0.0161	0.0159	0.0154	0.0146	<0.0020
	Phosphorus (P)-Total (mg/L)	0.0818	0.0835	0.0826	0.0844	<0.0020
	Silicate (as SiO2) (mg/L)	13.7	13.5	13.9	13.3	<0.50
	Sulfate (SO4) (mg/L)	29.6	29.7	29.7	29.7	<0.30
Organic / Inorganic Carbon	Total Organic Carbon (mg/L)	12.8	12.8	11.1	10.6	<0.50
Total Metals	Aluminum (Al)-Total (mg/L)	0.0097	0.0073	0.0082	0.0088	<0.0030
	Antimony (Sb)-Total (mg/L)	0.00143	0.00145	0.00138	0.00143	<0.00010
	Arsenic (As)-Total (mg/L)	0.0678	0.0695	0.0686	0.0684	<0.00010
	Barium (Ba)-Total (mg/L)	0.0335	0.0352	0.0345	0.0349	<0.00010
	Beryllium (Be)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Bismuth (Bi)-Total (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
	Boron (B)-Total (mg/L)	0.023	0.022	0.022	0.022	<0.010
	Cadmium (Cd)-Total (mg/L)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
	Calcium (Ca)-Total (mg/L)	38.1	33.9	32.9	33.7	<0.050

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2104031-6	L2104031-7	L2104031-8	L2104031-9	L2104031-10
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	30-MAY-18	30-MAY-18	30-MAY-18	30-MAY-18	31-MAY-18
	Sampled Time	11:40	13:00	13:00	14:30	12:51
	Client ID	2018-0507	2018-0508	2018-0509	2018-0510	2018-0511
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)	444	434	438	440	<2.0
	Hardness (as CaCO3) (mg/L)	150	152	153	151	<0.50
	Hardness (as CaCO3)					
	pH (pH)	8.30	8.31	8.33	8.30	5.31
	Total Suspended Solids (mg/L)	6.3	5.7	5.3	3.3	<3.0
	Total Dissolved Solids (mg/L)	271	288	281	275	<10
	Turbidity (NTU)	6.85	7.34	7.28	6.35	0.13
Anions and Nutrients	Alkalinity, Bicarbonate (as CaCO3) (mg/L)	113	109	110	108	<1.0
	Alkalinity, Carbonate (as CaCO3) (mg/L)	<1.0	2.4	2.6	2.0	<1.0
	Alkalinity, Hydroxide (as CaCO3) (mg/L)	<1.0	<1.0	<1.0	<1.0	<1.0
	Alkalinity, Phenolphthalein (as CaCO3) (mg/L)	<2.0	<2.0	<2.0	<2.0	<2.0
	Alkalinity, Total (as CaCO3) (mg/L)	113	111	112	110	<1.0
	Ammonia, Total (as N) (mg/L)	0.0338	0.0946	0.131	0.107	<0.0050
	Bromide (Br) (mg/L)	0.051	<0.050	<0.050	<0.050	<0.050
	Chloride (Cl) (mg/L)	52.9	52.9	52.8	52.7	<0.50
	Fluoride (F) (mg/L)	0.094	0.096	0.095	0.095	<0.020
	Nitrate and Nitrite (as N) (mg/L)	0.0450	0.0486	0.0476	0.0474	<0.0051
	Nitrate (as N) (mg/L)	0.0410	0.0438	0.0443	0.0438	<0.0050
	Nitrite (as N) (mg/L)	0.0040	0.0048	0.0034	0.0036	<0.0010
	Total Kjeldahl Nitrogen (mg/L)	1.20	1.21	1.22	1.23	<0.050
	Total Nitrogen (mg/L)	1.23	1.12	1.16	1.25	<0.030
	Orthophosphate-Dissolved (as P) (mg/L)	0.0053	0.0060	0.0061	0.0061	<0.0010
	Phosphorus (P)-Total Dissolved (mg/L)	0.0155	0.0154	0.0147	0.0153	<0.0020
	Phosphorus (P)-Total (mg/L)	0.0915	0.0802	0.0829	0.0852	<0.0020
	Silicate (as SiO2) (mg/L)	13.2	14.1	13.7	13.4	<0.50
	Sulfate (SO4) (mg/L)	29.8	29.7	29.7	29.5	<0.30
Organic / Inorganic Carbon	Total Organic Carbon (mg/L)	10.5	10.6	10.8	10.4	<0.50
Total Metals	Aluminum (Al)-Total (mg/L)	0.0136	0.0114	0.0078	0.0079	<0.0030
	Antimony (Sb)-Total (mg/L)	0.00146	0.00142	0.00140	0.00142	<0.00010
	Arsenic (As)-Total (mg/L)	0.0701	0.0688	0.0693	0.0679	RRV 0.00017
	Barium (Ba)-Total (mg/L)	0.0348	0.0344	0.0351	0.0341	<0.00010
	Beryllium (Be)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Bismuth (Bi)-Total (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
	Boron (B)-Total (mg/L)	0.022	0.022	0.022	0.022	<0.010
	Cadmium (Cd)-Total (mg/L)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
	Calcium (Ca)-Total (mg/L)	33.2	33.3	33.4	33.7	<0.050

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2104031-1	L2104031-2	L2104031-3	L2104031-4	L2104031-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	29-MAY-18	29-MAY-18	29-MAY-18	30-MAY-18	30-MAY-18
	Sampled Time	16:17	16:17	17:34	10:00	11:00
	Client ID	2018-0502	2018-0503	2018-0504	2018-0505	2018-0506
Grouping	**Analyte**					
WATER						
Total Metals	Cesium (Cs)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Chromium (Cr)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Cobalt (Co)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Copper (Cu)-Total (mg/L)	0.0105	0.00303	0.00333	0.00231	<0.00050
	Iron (Fe)-Total (mg/L)	0.020	0.016	0.019	0.019	<0.010
	Lead (Pb)-Total (mg/L)	0.000141	<0.000050	<0.000050	<0.000050	<0.000050
	Lithium (Li)-Total (mg/L)	0.0057	0.0061	0.0058	0.0060	<0.0010
	Magnesium (Mg)-Total (mg/L)	12.0	13.0	12.7	12.9	<0.0050
	Manganese (Mn)-Total (mg/L)	0.0910	0.0981	0.0953	0.0986	<0.00010
	Mercury (Hg)-Total (mg/L)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
	Molybdenum (Mo)-Total (mg/L)	0.000242	0.000215	0.000212	0.000222	<0.000050
	Nickel (Ni)-Total (mg/L)	0.00065	0.00056	0.00059	0.00053	<0.00050
	Phosphorus (P)-Total (mg/L)	0.088	0.113	0.096	0.101	<0.050
	Potassium (K)-Total (mg/L)	4.82	4.14	4.23	4.07	<0.050
	Rubidium (Rb)-Total (mg/L)	0.00260	0.00269	0.00256	0.00248	<0.00020
	Selenium (Se)-Total (mg/L)	<0.000050	<0.000050	<0.000050	0.000061	<0.000050
	Silicon (Si)-Total (mg/L)	6.58	6.06	6.16	6.21	<0.10
	Silver (Ag)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Sodium (Na)-Total (mg/L)	28.7	27.4	27.2	27.1	<0.050
	Strontium (Sr)-Total (mg/L)	0.0895	0.0881	0.0841	0.0869	<0.00020
	Sulfur (S)-Total (mg/L)	12.2	9.71	10.6	9.77	<0.50
	Tellurium (Te)-Total (mg/L)	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
	Thallium (Tl)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Thorium (Th)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Tin (Sn)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Titanium (Ti)-Total (mg/L)	0.00039	<0.00030	<0.00030	0.00034	<0.00030
	Tungsten (W)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Uranium (U)-Total (mg/L)	0.000618	0.000603	0.000583	0.000604	<0.000010
	Vanadium (V)-Total (mg/L)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
	Zinc (Zn)-Total (mg/L)	0.0033	<0.0030	0.0078	<0.0030	<0.0030
	Zirconium (Zr)-Total (mg/L)	0.000063	<0.000060	<0.000060	<0.000060	<0.000060
Dissolved Metals	Dissolved Metals Filtration Location	FIELD	FIELD	FIELD	FIELD	FIELD
	Calcium (Ca)-Dissolved (mg/L)	40.2	40.2	39.9	40.2	<0.050
	Magnesium (Mg)-Dissolved (mg/L)	11.9	11.8	11.7	11.9	<0.10
	Potassium (K)-Dissolved (mg/L)	3.9	3.8	3.7	3.9	<2.0
	Sodium (Na)-Dissolved (mg/L)	26.8	26.8	26.4	27.0	<2.0

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample ID		L2104031-6	L2104031-7	L2104031-8	L2104031-9	L2104031-10
Description		WATER	WATER	WATER	WATER	WATER
Sampled Date		30-MAY-18	30-MAY-18	30-MAY-18	30-MAY-18	31-MAY-18
Sampled Time		11:40	13:00	13:00	14:30	12:51
Client ID		2018-0507	2018-0508	2018-0509	2018-0510	2018-0511
Grouping	**Analyte**					
WATER						
Total Metals	Cesium (Cs)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Chromium (Cr)-Total (mg/L)	0.00011	<0.00010	<0.00010	0.00016	<0.00010
	Cobalt (Co)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Copper (Cu)-Total (mg/L)	0.00268	0.00290	0.00236	0.00278	<0.00050
	Iron (Fe)-Total (mg/L)	0.025	0.020	0.017	0.017	<0.010
	Lead (Pb)-Total (mg/L)	0.000092	0.000069	<0.000050	0.000053	<0.000050
	Lithium (Li)-Total (mg/L)	0.0059	0.0059	0.0059	0.0058	<0.0010
	Magnesium (Mg)-Total (mg/L)	12.7	12.4	12.7	12.2	<0.0050
	Manganese (Mn)-Total (mg/L)	0.0936	0.0967	0.104	0.0972	0.00011 RRV
	Mercury (Hg)-Total (mg/L)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
	Molybdenum (Mo)-Total (mg/L)	0.000212	0.000228	0.000199	0.000205	<0.000050
	Nickel (Ni)-Total (mg/L)	0.00056	0.00056	0.00058	0.00053	<0.00050
	Phosphorus (P)-Total (mg/L)	0.098	0.092	0.087	0.082	<0.050
	Potassium (K)-Total (mg/L)	4.08	3.98	3.99	3.88	<0.050
	Rubidium (Rb)-Total (mg/L)	0.00260	0.00244	0.00254	0.00255	<0.00020
	Selenium (Se)-Total (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
	Silicon (Si)-Total (mg/L)	5.95	6.10	6.16	6.12	<0.10
	Silver (Ag)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Sodium (Na)-Total (mg/L)	26.8	26.6	26.9	26.0	<0.050
	Strontium (Sr)-Total (mg/L)	0.0863	0.0866	0.0874	0.0862	<0.00020
	Sulfur (S)-Total (mg/L)	9.81	9.04	9.45	9.38	<0.50
	Tellurium (Te)-Total (mg/L)	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
	Thallium (Tl)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Thorium (Th)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Tin (Sn)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Titanium (Ti)-Total (mg/L)	<0.00060 DLM	0.00032	<0.00030	<0.00030	<0.00030
	Tungsten (W)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Uranium (U)-Total (mg/L)	0.000600	0.000606	0.000594	0.000593	<0.000010
	Vanadium (V)-Total (mg/L)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
	Zinc (Zn)-Total (mg/L)	0.0157	<0.0030	<0.0030	<0.0030	<0.0030
	Zirconium (Zr)-Total (mg/L)	<0.000060	0.000753	<0.000060	<0.000060	<0.000060
Dissolved Metals	Dissolved Metals Filtration Location	FIELD	FIELD	FIELD	FIELD	FIELD
	Calcium (Ca)-Dissolved (mg/L)	40.3	40.8	41.2	40.8	<0.050
	Magnesium (Mg)-Dissolved (mg/L)	12.0	12.1	12.2	12.0	<0.10
	Potassium (K)-Dissolved (mg/L)	3.9	3.9	4.0	3.9	<2.0
	Sodium (Na)-Dissolved (mg/L)	27.5	27.5	27.8	27.3	<2.0

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Method Blank	Total Nitrogen	B	L2104031-1, -10, -2, -3, -4, -5, -6, -7, -8, -9
Method Blank	Manganese (Mn)-Total	MB-LOR	L2104031-1
Method Blank	Sulfur (S)-Total	MB-LOR	L2104031-10
Matrix Spike	Arsenic (As)-Total	MS-B	L2104031-1
Matrix Spike	Barium (Ba)-Total	MS-B	L2104031-1
Matrix Spike	Calcium (Ca)-Total	MS-B	L2104031-1
Matrix Spike	Magnesium (Mg)-Total	MS-B	L2104031-1
Matrix Spike	Manganese (Mn)-Total	MS-B	L2104031-1
Matrix Spike	Potassium (K)-Total	MS-B	L2104031-1
Matrix Spike	Sodium (Na)-Total	MS-B	L2104031-1
Matrix Spike	Strontium (Sr)-Total	MS-B	L2104031-1
Matrix Spike	Phosphorus (P)-Total	MS-B	L2104031-1, -10, -2, -3, -4, -5, -6, -7, -8, -9

Qualifiers for Individual Parameters Listed:

Qualifier	Description
B	Method Blank exceeds ALS DQO. Associated sample results which are < Limit of Reporting or > 5 times blank level are considered reliable.
DLM	Detection Limit Adjusted due to sample matrix effects (e.g. chemical interference, colour, turbidity).
MB-LOR	Method Blank exceeds ALS DQO. Limits of Reporting have been adjusted for samples with positive hits below 5x blank level.
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.
RRV	Reported Result Verified By Repeat Analysis

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ALK-TITR-VA	Water	Alkalinity Species by Titration	APHA 2320 Alkalinity

This analysis is carried out using procedures adapted from APHA Method 2320 "Alkalinity". Total alkalinity is determined by potentiometric titration to a pH 4.5 endpoint. Bicarbonate, carbonate and hydroxide alkalinity are calculated from phenolphthalein alkalinity and total alkalinity values.

ANIONS-N+N-CALC-VA	Water	Nitrite & Nitrate in Water (Calculation)	EPA 300.0

Nitrate and Nitrite (as N) is a calculated parameter. Nitrate and Nitrite (as N) = Nitrite (as N) + Nitrate (as N).

BR-L-IC-N-VA	Water	Bromide in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

CARBONS-TOC-VA	Water	Total organic carbon by combustion	APHA 5310B TOTAL ORGANIC CARBON (TOC)

This analysis is carried out using procedures adapted from APHA Method 5310 "Total Organic Carbon (TOC)".

CL-IC-N-VA	Water	Chloride in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

EC-PCT-VA	Water	Conductivity (Automated)	APHA 2510 Auto. Conduc.

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

EC-SCREEN-VA	Water	Conductivity Screen (Internal Use Only)	APHA 2510

Qualitative analysis of conductivity where required during preparation of other tests - e.g. TDS, metals, etc.

F-IC-N-VA	Water	Fluoride in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

HARDNESS-CALC-VA	Water	Hardness	APHA 2340B

Hardness (also known as Total Hardness) is calculated from the sum of Calcium and Magnesium concentrations, expressed in CaCO3 equivalents. Dissolved Calcium and Magnesium concentrations are preferentially used for the hardness calculation.

HG-T-CVAA-VA	Water	Total Mercury in Water by CVAAS or CVAFS	EPA 1631E (mod)

Water samples undergo a cold-oxidation using bromine monochloride prior to reduction with stannous chloride, and analyzed by CVAAS or CVAFS.

MET-DIS-ICP-VA	Water	Dissolved Metals in Water by ICPOES	EPA SW-846 3005A/6010B

Reference Information

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedure involves filtration (EPA Method 3005A) and analysis by inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B).

MET-T-CCMS-VA	Water	Total Metals in Water by CRC ICPMS	EPA 200.2/6020A (mod)

Water samples are digested with nitric and hydrochloric acids, and analyzed by CRC ICPMS.

Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.

N-T-COL-VA	Water	Total Nitrogen in water by Colour	APHA4500-P(J)/NEMI9171/USGS03-4174

This analysis is carried out using procedures adapted from APHA Method 4500-P (J) "Persulphate Method for Simultaneous Determination of Total Nitrogen and Total Phosphorus" and National Environmental Methods Index - Nemi method 5735.

NH3-F-VA	Water	Ammonia in Water by Fluorescence	J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NO2-L-IC-N-VA	Water	Nitrite in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

NO3-L-IC-N-VA	Water	Nitrate in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

P-T-COL-VA	Water	Total P in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorus is determined colourimetrically after persulphate digestion of the sample.
Samples with very high dissolved solids (i.e. seawaters, brackish waters) may produce a negative bias by this method. Alternate methods are available for these types of samples.

Arsenic (5+), at elevated levels, is a positive interference on colourimetric phosphate analysis.

P-TD-COL-VA	Water	Total Dissolved P in Water by Colour	APHA 4500-P Phosphorous

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Dissolved Phosphorus is determined colourimetrically after persulphate digestion of a sample that has been lab or field filtered through a 0.45 micron membrane filter.
Samples with very high dissolved solids (i.e. seawaters, brackish waters) may produce a negative bias by this method. Alternate methods are available for these types of samples.

Arsenic (5+), at elevated levels, is a positive interference on colourimetric phosphate analysis.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PO4-DO-COL-VA	Water	Diss. Orthophosphate in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.
Samples with very high dissolved solids (i.e. seawaters, brackish waters) may produce a negative bias by this method. Alternate methods are available for these types of samples.

Arsenic (5+), at elevated levels, is a positive interference on colourimetric phosphate analysis.

SILICATE-COL-VA	Water	Silicate by Colourimetric analysis	APHA 4500-SiO2 E.

This analysis is carried out using procedures adapted from APHA Method 4500-SiO2 E. "Silica". Silicate (molybdate-reactive silica) is determined by the molybdosilicate-heteropoly blue colourimetric method.

SO4-IC-N-VA	Water	Sulfate in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

TDS-VA	Water	Total Dissolved Solids by Gravimetric	APHA 2540 C - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Dissolved Solids (TDS) are determined by filtering a sample through a glass fibre filter, TDS is determined by evaporating the filtrate to dryness at 180 degrees celsius.

TKN-F-VA	Water	TKN in Water by Fluorescence	APHA 4500-NORG D.

This analysis is carried out using procedures adapted from APHA Method 4500-Norg D. "Block Digestion and Flow Injection Analysis". Total Kjeldahl Nitrogen is determined using block digestion followed by Flow-injection analysis with fluorescence detection.

Reference Information

TSS-VA	Water	Total Suspended Solids by Gravimetric	APHA 2540 D - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Suspended Solids (TSS) are determined by filtering a sample through a glass fibre filter, TSS is determined by drying the filter at 104 degrees celsius.
Samples containing very high dissolved solid content (i.e. seawaters, brackish waters) may produce a positive bias by this method. Alternate analysis methods are available for these types of samples.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 Turbidity

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

XX-XXXX-XXXX

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Lab Copy

CoC#: XX-XXXX-XXXX

Jackfish Lake
Chain-of-Custody Record - Analytical Request Form

From:

Golder Associates - Jackfish
Address: 6925 Century Ave #100
Mississauga, ON, L5N 7K2
Telephone: (905) 561-4444
Contact: Tamara Darwish
TDarwish@golder.com

Send Samples For Analysis To:

ALS Group, Yellowknife
Address: 314 Old Airport Rd, Unit 116
Yellowknife, NT X1A 3T3
Phone: (867) 873-5593
Fax: (867) 920-4238
Contact: Rick Zolkiewski
Email: Rick.Zolkiewski@alsglobal.com

eMail Confirmation and Results To:

Please use full distribution list from quote
HMacpherson@golder.com
MMiller@ntpc.com
GAL_EQUIS@golder.com
AHumphries@golder.com
TDarwish@golder.com

Send Original Signed Lab Reports To:

Golder Associates Ltd.
Address: 9, 4905-48 Street
Yellowknife, NT, X1A 3S3
Telephone: (867) 873-6319
Fax: (867) 873-6379
Contact: Haley Macpherson
hmacpherson@golder.com

Send Invoice To:

Golder Associates Ltd.
Address: 6925 Century Ave #100
Mississauga, ON, L5N 7K2
Telephone: (905) 561-4444
Fax: (905) 567-6561
ATTN: Tamara Darwish
TDarwish@golder.com

FIELD SAMPLE INFORMATION

Fields Notes:

Filter and preserve dissolved parameters.

Please ensure that there is only one COC per report. Use email confirmation and results list on this COC.

Facilty Code:

Project # 1894709-5000-5020
Jackfish Baseline Sampling

Quote # Q66233

L2104031-COFC

REQUESTED LAB SUITES (see reverse side for details)

			Routine 1 (pH, conductivity, hardness, alkalinity, tss, tds (measured and calculated), anions, turbidity)	Routine 2 (orthophosphte, NO_2, NO_3)	Total metals	Dissolved metals (major cations Ca, Mg, K, and Na only)	Total mercury	[redacted]	Reactive Silica	Total Nutrients: TKN, NH3, TOC, TP, TN	Dissolved nutrients: TDP	[redacted]	[redacted]				
√ = Preserved :					√		√	[redacted]		√		[redacted]	[redacted]				
√ = Field Filtered :						√		[redacted]			√	[redacted]	[redacted]				
√ = 1-Day Rush :								[redacted]				[redacted]	[redacted]				

Sample Control Number	Lab Sample ID	Sample Date (dd-mmm-yy)	Sample Time (hh:mm)	Matrix	Laboratory Comments	Sampler Comments	G = Grab or C = Composite	Number of Containers	Routine 1	Routine 2	Total metals	Dissolved metals	Total mercury	[redacted]	Reactive Silica	Total Nutrients	Dissolved nutrients: TDP	[redacted]	[redacted]				
2018-0502		29-05-18	16:17	Water		Samples filtered + preserved!	G	14	√	√	√	√	√	[redacted]	√	√	√	[redacted]	[redacted]				
2018-0503		29-05-18	16:17	Water			G	14	√	√	√	√	√	[redacted]	√	√	√	[redacted]	[redacted]				
2018-0504		29-05-18	17:34	Water			G	14	√	√	√	√	√	[redacted]	√	√	√	[redacted]	[redacted]				
2018-0505		30-05-18	10:00	Water			G	14	√	√	√	√	√	[redacted]	√	√	√	[redacted]	[redacted]				
2018-0506		30-05-18	10:00	Water			G	14	√	√	√	√	√	[redacted]	√	√	√	[redacted]	[redacted]				
2018-0507		30-05-18	11:40	Water			G	14	√	√	√	√	√	[redacted]	√	√	√	[redacted]	[redacted]				
2018-0508		30-05-18	13:00	Water			G	14	√	√	√	√	√	[redacted]	√	√	√	[redacted]	[redacted]				
2018-0509		30-05-18	13:00	Water			G	14	√	√	√	√	√	[redacted]	√	√	√	[redacted]	[redacted]				

Relinquished by (Sampler Signature): Haley M	Date/Time: 31/05/18	Company: **Golder Associates**	Received by (Signature):	Company: ALS
Relinquished by (Signature):	Date/Time: 230	Company:	Received by (Signature):	Company:
Sampler (Printed Name): Haley Macpherson.	Sample Storage Temperature prior to Shipping (deg. C): 8.1	Sample Receipt Temperature (deg. C):	**SAMPLE CONDITION (lab use only)** Samples Received in Good Condition? Yes / No (If no, provide details.)	

[redacted]

[redacted]

Lab Copy

CoC#: XX-XXXX-XXXX

Jackfish Lake
Chain-of-Custody Record - Analytical Request Form

From:

From:	Send Samples For Analysis To:	eMail Confirmation and Results To:	Send Original Signed Lab Reports To:	Send Invoice To:
Golder Associates - Jackfish	ALS Group, Yellowknife	Please use full distribution list from quote	Golder Associates Ltd.	Golder Associates Ltd.
Address: 6925 Century Ave #100	Address: 314 Old Airport Rd, Unit 116	HMacpherson@golder.com	Address: 9, 4905-48 Street	Address: 6925 Century Ave #100
Mississauga, ON, L5N 7K2	Yellowknife, NT X1A 3T3	MMiller@ntpc.com	Yellowknife, NT, X1A 3S3	Mississauga, ON, L5N 7K2
Telephone: (905) 561-4444	Phone: (867) 873-5593	GAL_EQUIS@golder.com	Telephone: (867) 873-6319	Telephone: (905) 561-4444
	Fax: (867) 920-4238	AHumphries@golder.com	Fax: (867) 873-6379	Fax: (905) 567-6561
Contact: Tamara Darwish	Contact: Rick Zolkiewski	TDarwish@golder.com	Contact: Haley Macpherson	ATTN: Tamara Darwish
TDarwish@golder.com	Email: Rick.Zolkiewski@alsglobal.com		hmacpherson@golder.com	TDarwish@golder.com

FIELD SAMPLE INFORMATION

Fields Notes:

Filter and preserve dissolved parameters.

Please ensure that there is only one COC per report. Use email confirmation and results list on this COC.

Facilty Code:

Project # 1894709-5000-5020
Jackfish Baseline Sampling

Quote # Q66233

REQUESTED LAB SUITES (see reverse side for details)

Sample Control Number	Lab Sample ID	Sample Date (dd-mmm-yy)	Sample Time (hh:mm)	Matrix	Laboratory Comments	Sampler Comments	G = Grab or C = Composite	Number of Containers	Routine 1 (pH, conductivity, hardness, alkalinity, tss, tds (measured and calculated), anions, turbidity)	Routine 2 (orthophosphte, NO_2, NO_3)	Total metals	Dissolved metals (major cations Ca, Mg, K, and Na only)	Total mercury	[redacted]	Reactive Silica	Total Nutrients: TKN, NH3, TOC, TP, TN	Dissolved nutrients: TDP	[redacted]	[redacted]				
						√ = Preserved :					√		√	[redacted]		√		[redacted]	[redacted]				
						√ = Field Filtered :						√		[redacted]			√	[redacted]	[redacted]				
						√ = 1-Day Rush :								[redacted]				[redacted]	[redacted]				
2018-0510		30-05-18	14:30	Water		Samples filtered + preserved!	G	14	√	√	√	√	√	[redacted]	√	√	√	[redacted]	[redacted]				
2018-0511		31-05-18	12:51	Water			G	14	√	√	√	√	√	[redacted]	√	√	√	[redacted]	[redacted]				
2018-				Water			G	14	√	√	√	√	√	[redacted]	√	√	√	[redacted]	[redacted]				
2018-				Water			G	14	√	√	√	√	√	[redacted]	√	√	√	[redacted]	[redacted]				
2018-				Water			G	14	√	√	√	√	√	[redacted]	√	√	√	[redacted]	[redacted]				
2018-				Water			G	14	√	√	√	√	√	[redacted]	√	√	√	[redacted]	[redacted]				
2018-				Water			G	14	√	√	√	√	√	[redacted]	√	√	√	[redacted]	[redacted]				
2018-				Water			G	14	√	√	√	√	√	[redacted]	√	√	√	[redacted]	[redacted]				

Relinquished by (Sampler Signature):	Date/Time: 31/05/18.	Company: **Golder Associates**	Received by (Signature):	Company: ALS
Relinquished by (Signature):	Date/Time: 230	Company:	Received by (Signature):	Company:
Sampler (Printed Name): Haley Macpherson	Sample Storage Temperature prior to Shipping (deg. C): 8.1	Sample Receipt Temperature (deg. C):	**SAMPLE CONDITION (lab use only)** Samples Received in Good Condition? Yes / No (If no, provide details.)	

Golder Associates Ltd.
ATTN: Haley Macpherson
9, 4905-48 ST
Yellowknife NT X1A 3S3

Date Received: 11-JUL-18
Report Date: 22-AUG-18 18:23 (MT)
Version: FINAL REV. 2

Client Phone: 867-873-6319

Certificate of Analysis

Lab Work Order #: L2128122

Project P.O. #: NOT SUBMITTED
Job Reference: 1894709-6000-5050
C of C Numbers: 2017-0700 created
Legal Site Desc:

Comments: Please refer to the ALS Excel report for identification of parameters where the Limit of Reporting (LOR) has been raised. Where an LOR has been increased, and a specific qualifier is not listed in the report, the sample required dilution prior to analysis due to sample matrix effects (e.g. chemical interference, colour, turbidity, electrical conductivity) or due to the elevated concentration of one or more analytes in the sample. This will apply to results reported above the increased LOR.

This version of the report replaces all previous versions.

Rick Zolkiewski
General Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2128122-1	L2128122-2	L2128122-3	L2128122-4	L2128122-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	11-JUL-18	11-JUL-18	11-JUL-18	11-JUL-18	11-JUL-18
	Sampled Time	11:30	11:00	10:00	12:00	09:30
	Client ID	2018-07-08	2018-07-10	2018-07-11	2018-07-12	2018-07-14
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)	417	427	426	419	414
	Hardness (as CaCO3) (mg/L)	133	155	154	152	154
	pH (pH)	8.46	8.47	8.54	8.56	8.56
	Total Suspended Solids (mg/L)	9.9	9.5	9.1	15.1	7.3
	Total Dissolved Solids (mg/L)	240	294	272	269	273
	TDS (Calculated) (mg/L)	226	247	250	249	250
	Turbidity (NTU)	10.9	11.3	10.5	12.4	9.65
Anions and Nutrients	Alkalinity, Bicarbonate (as CaCO3) (mg/L)	85.6	97.7	100	99.7	100
	Alkalinity, Carbonate (as CaCO3) (mg/L)	4.2	4.6	7.0	6.6	7.2
	Alkalinity, Hydroxide (as CaCO3) (mg/L)	<1.0	<1.0	<1.0	<1.0	<1.0
	Alkalinity, Phenolphthalein (as CaCO3) (mg/L)	2.1	2.3	3.5	3.3	3.6
	Alkalinity, Total (as CaCO3) (mg/L)	89.8	102	107	106	107
	Ammonia, Total (as N) (mg/L)	0.0083	0.0087	0.0082	<0.0050	<0.0050
	Bromide (Br) (mg/L)	0.053	0.054	0.054	<0.050	0.051
	Chloride (Cl) (mg/L)	54.7	54.9	54.5	55.0	54.6
	Fluoride (F) (mg/L)	0.092	0.097	0.090	0.090	0.090
	Nitrate and Nitrite (as N) (mg/L)					
	Nitrate (as N) (mg/L)					
	Nitrite (as N) (mg/L)					
	Total Kjeldahl Nitrogen (mg/L)	1.03	1.00	1.02	1.22	1.03
	Total Nitrogen (mg/L)	1.06	1.07	1.06	1.26	1.00
	Orthophosphate-Dissolved (as P) (mg/L)					
	Phosphorus (P)-Total (mg/L)	0.0615	0.0542	0.0611	0.0912	0.0591
	Phosphorus (P)-Total Dissolved (mg/L)	0.0144	0.0139	0.0157	0.0158	0.0125
	Silicate (as SiO2) (mg/L)	10.2	9.87	9.81	9.82	9.66
	Sulfate (SO4) (mg/L)	29.2	29.2	28.9	29.4	29.2
	Anion Sum (meq/L)	3.95	4.21	4.29	4.29	4.30
	Cation Sum (meq/L)	3.87	4.58	4.56	4.51	4.57
	Cation - Anion Balance (%)	-1.1	4.2	3.1	2.4	3.1
Organic / Inorganic Carbon	Total Organic Carbon (mg/L)	12.1	11.9	12.4	12.9	12.0
Total Metals	Aluminum (Al)-Total (mg/L)	0.0086	0.0069	0.0130	0.0313	0.0059
	Antimony (Sb)-Total (mg/L)	0.00160	0.00162	0.00160	0.00166	0.00164
	Arsenic (As)-Total (mg/L)	0.0822	0.0836	0.0851	0.0860	0.0861
	Barium (Ba)-Total (mg/L)	0.0332	0.0341	0.0355	0.0360	0.0348
	Beryllium (Be)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Bismuth (Bi)-Total (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2128122-6	L2128122-7	L2128122-8	L2128122-9	L2128122-10
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	09-JUL-18	11-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18
	Sampled Time	15:00	09:30	16:30	18:00	13:00
	Client ID	2018-07-16	2018-07-17	2018-07-01	2018-07-02	2018-07-03
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)	<2.0	<2.0	418	414	417
	Hardness (as CaCO3) (mg/L)	<0.50	<0.50	148	151	151
	pH (pH)	5.48	5.48	8.65	8.56	8.58
	Total Suspended Solids (mg/L)	<3.0	<3.0	9.7	9.1	9.9
	Total Dissolved Solids (mg/L)	<10	<10	269	272	276
	TDS (Calculated) (mg/L)	<1.0	<1.0	242	249	245
	Turbidity (NTU)	<0.10	<0.10	11.3	10.7	12.8
Anions and Nutrients	Alkalinity, Bicarbonate (as CaCO3) (mg/L)	<1.0	<1.0	92.2	98.8	96.6
	Alkalinity, Carbonate (as CaCO3) (mg/L)	<1.0	<1.0	9.2	7.4	6.8
	Alkalinity, Hydroxide (as CaCO3) (mg/L)	<1.0	<1.0	<1.0	<1.0	<1.0
	Alkalinity, Phenolphthalein (as CaCO3) (mg/L)	<2.0	<2.0	4.6	3.7	3.4
	Alkalinity, Total (as CaCO3) (mg/L)	<1.0	<1.0	101	106	103
	Ammonia, Total (as N) (mg/L)	<0.0050	<0.0050	0.0093	<0.0050	<0.0050
	Bromide (Br) (mg/L)	<0.050	<0.050	<0.050	0.050	0.051
	Chloride (Cl) (mg/L)	<0.50	<0.50	54.7	55.6	54.7
	Fluoride (F) (mg/L)	<0.020	<0.020	0.098	0.100	0.090
	Nitrate and Nitrite (as N) (mg/L)					
	Nitrate (as N) (mg/L)					
	Nitrite (as N) (mg/L)					
	Total Kjeldahl Nitrogen (mg/L)	<0.050	<0.050	1.10	1.17	1.07
	Total Nitrogen (mg/L)	<0.030	<0.030	1.05	1.25	1.11
	Orthophosphate-Dissolved (as P) (mg/L)					
	Phosphorus (P)-Total (mg/L)	<0.0020	<0.0020	0.0617	0.0569	0.0637
	Phosphorus (P)-Total Dissolved (mg/L)	<0.0020	<0.0020	0.0147	0.0157	0.0138
	Silicate (as SiO2) (mg/L)	<0.50	<0.50	10.2	9.81	10.1
	Sulfate (SO4) (mg/L)	<0.30	<0.30	29.1	29.7	29.3
	Anion Sum (meq/L)	<0.10	<0.10	4.18	4.32	4.22
	Cation Sum (meq/L)	<0.10	<0.10	4.36	4.47	4.45
	Cation - Anion Balance (%)	0.0	0.0	2.1	1.7	2.7
Organic / Inorganic Carbon	Total Organic Carbon (mg/L)	<0.50	<0.50	11.9	12.2	11.8
Total Metals	Aluminum (Al)-Total (mg/L)	<0.0030	<0.0030	0.0065	0.0059	0.0059
	Antimony (Sb)-Total (mg/L)	<0.00010	<0.00010	0.00161	0.00159	0.00157
	Arsenic (As)-Total (mg/L)	<0.00010	<0.00010	0.0841	0.0833	0.0821
	Barium (Ba)-Total (mg/L)	<0.00010	<0.00010	0.0343	0.0341	0.0334
	Beryllium (Be)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Bismuth (Bi)-Total (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2128122-11	L2128122-12	L2128122-13	L2128122-14	L2128122-15
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	10-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18
	Sampled Time	13:00	11:40	10:30	10:30	15:30
	Client ID	2018-07-04	2018-07-05	2018-07-06	2018-07-15	2018-07-07
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)	431	422	422	427	423
	Hardness (as CaCO3) (mg/L)	151	150	150	148	148
	pH (pH)	8.05	8.58	8.55	8.53	8.53
	Total Suspended Solids (mg/L)	8.7	10.9	10.5	10.9	9.7
	Total Dissolved Solids (mg/L)	276	274	264	277	276
	TDS (Calculated) (mg/L)	247	244	246	243	246
	Turbidity (NTU)	9.38	10.8	11.9	11.8	11.4
Anions and Nutrients	Alkalinity, Bicarbonate (as CaCO3) (mg/L)	109	94.5	98.4	93.1	101
	Alkalinity, Carbonate (as CaCO3) (mg/L)	<1.0	7.6	6.2	6.4	6.0
	Alkalinity, Hydroxide (as CaCO3) (mg/L)	<1.0	<1.0	<1.0	<1.0	<1.0
	Alkalinity, Phenolphthalein (as CaCO3) (mg/L)	<2.0	3.8	3.1	3.2	3.0
	Alkalinity, Total (as CaCO3) (mg/L)	109	102	105	99.5	107
	Ammonia, Total (as N) (mg/L)	0.628	<0.0050	<0.0050	<0.0050	<0.0050
	Bromide (Br) (mg/L)	0.051	<0.050	0.053	<0.050	<0.050
	Chloride (Cl) (mg/L)	54.2	54.7	54.9	54.7	54.6
	Fluoride (F) (mg/L)	0.096	0.090	0.098	0.090	0.098
	Nitrate and Nitrite (as N) (mg/L)					
	Nitrate (as N) (mg/L)					
	Nitrite (as N) (mg/L)					
	Total Kjeldahl Nitrogen (mg/L)	1.54	1.09	1.11	1.10	1.02
	Total Nitrogen (mg/L)	1.66	1.15	1.10	1.04	1.09
	Orthophosphate-Dissolved (as P) (mg/L)					
	Phosphorus (P)-Total (mg/L)	0.141	0.0645	0.0627	0.0624	0.0549
	Phosphorus (P)-Total Dissolved (mg/L)	0.106	0.0152	0.0132	0.0141	0.0137
	Silicate (as SiO2) (mg/L)	10.9	10.0	9.41	10.0	9.58
	Sulfate (SO4) (mg/L)	28.3	29.0	29.2	29.2	29.2
	Anion Sum (meq/L)	4.29	4.19	4.25	4.15	4.30
	Cation Sum (meq/L)	4.51	4.44	4.41	4.35	4.36
	Cation - Anion Balance (%)	2.5	2.9	1.9	2.4	0.7
Organic / Inorganic Carbon	Total Organic Carbon (mg/L)	11.2	12.1	12.3	14.4	11.9
Total Metals	Aluminum (Al)-Total (mg/L)	0.0092	0.0071	0.0088	0.0086	0.0064
	Antimony (Sb)-Total (mg/L)	0.00147	0.00161	0.00161	0.00162	0.00158
	Arsenic (As)-Total (mg/L)	0.0878	0.0834	0.0831	0.0880	0.0856
	Barium (Ba)-Total (mg/L)	0.0463	0.0338	0.0333	0.0349	0.0342
	Beryllium (Be)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Bismuth (Bi)-Total (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2128122-16	L2128122-17	L2128122-18	L2128122-19	L2128122-20
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	10-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18
	Sampled Time	16:30	18:00	13:00	13:00	11:40
	Client ID	2018-07-01 ROUTINE 2 ONLY	2018-07-02 ROUTINE 2 ONLY	2018-07-03 ROUTINE 2 ONLY	2018-07-04 ROUTINE 2 ONLY	2018-07-05 ROUTINE 2 ONLY
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)					
	Hardness (as CaCO3) (mg/L)					
	pH (pH)					
	Total Suspended Solids (mg/L)					
	Total Dissolved Solids (mg/L)					
	TDS (Calculated) (mg/L)					
	Turbidity (NTU)					
Anions and Nutrients	Alkalinity, Bicarbonate (as CaCO3) (mg/L)					
	Alkalinity, Carbonate (as CaCO3) (mg/L)					
	Alkalinity, Hydroxide (as CaCO3) (mg/L)					
	Alkalinity, Phenolphthalein (as CaCO3) (mg/L)					
	Alkalinity, Total (as CaCO3) (mg/L)					
	Ammonia, Total (as N) (mg/L)					
	Bromide (Br) (mg/L)					
	Chloride (Cl) (mg/L)					
	Fluoride (F) (mg/L)					
	Nitrate and Nitrite (as N) (mg/L)	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051
	Nitrate (as N) (mg/L)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
	Nitrite (as N) (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Total Kjeldahl Nitrogen (mg/L)					
	Total Nitrogen (mg/L)					
	Orthophosphate-Dissolved (as P) (mg/L)	0.0045	0.0045	0.0041	0.0060	0.0046
	Phosphorus (P)-Total (mg/L)					
	Phosphorus (P)-Total Dissolved (mg/L)					
	Silicate (as SiO2) (mg/L)					
	Sulfate (SO4) (mg/L)					
	Anion Sum (meq/L)					
	Cation Sum (meq/L)					
	Cation - Anion Balance (%)					
Organic / Inorganic Carbon	Total Organic Carbon (mg/L)					
Total Metals	Aluminum (Al)-Total (mg/L)					
	Antimony (Sb)-Total (mg/L)					
	Arsenic (As)-Total (mg/L)					
	Barium (Ba)-Total (mg/L)					
	Beryllium (Be)-Total (mg/L)					
	Bismuth (Bi)-Total (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2128122-21	L2128122-22	L2128122-23	L2128122-24	L2128122-25
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	10-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18
	Sampled Time	10:30	10:30	15:30	11:30	11:00
	Client ID	2018-07-06 ROUTINE 2 ONLY	2018-07-15 ROUTINE 2 ONLY	2018-07-07 ROUTINE 2 ONLY	2018-07-08 ROUTINE 2 ONLY	2018-07-10 ROUTINE 2 ONLY
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)					
	Hardness (as CaCO3) (mg/L)					
	pH (pH)					
	Total Suspended Solids (mg/L)					
	Total Dissolved Solids (mg/L)					
	TDS (Calculated) (mg/L)					
	Turbidity (NTU)					
Anions and Nutrients	Alkalinity, Bicarbonate (as CaCO3) (mg/L)					
	Alkalinity, Carbonate (as CaCO3) (mg/L)					
	Alkalinity, Hydroxide (as CaCO3) (mg/L)					
	Alkalinity, Phenolphthalein (as CaCO3) (mg/L)					
	Alkalinity, Total (as CaCO3) (mg/L)					
	Ammonia, Total (as N) (mg/L)					
	Bromide (Br) (mg/L)					
	Chloride (Cl) (mg/L)					
	Fluoride (F) (mg/L)					
	Nitrate and Nitrite (as N) (mg/L)	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051
	Nitrate (as N) (mg/L)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
	Nitrite (as N) (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Total Kjeldahl Nitrogen (mg/L)					
	Total Nitrogen (mg/L)					
	Orthophosphate-Dissolved (as P) (mg/L)	0.0047	0.0043	0.0040	0.0106	0.0227
	Phosphorus (P)-Total (mg/L)					
	Phosphorus (P)-Total Dissolved (mg/L)					
	Silicate (as SiO2) (mg/L)					
	Sulfate (SO4) (mg/L)					
	Anion Sum (meq/L)					
	Cation Sum (meq/L)					
	Cation - Anion Balance (%)					
Organic / Inorganic Carbon	Total Organic Carbon (mg/L)					
Total Metals	Aluminum (Al)-Total (mg/L)					
	Antimony (Sb)-Total (mg/L)					
	Arsenic (As)-Total (mg/L)					
	Barium (Ba)-Total (mg/L)					
	Beryllium (Be)-Total (mg/L)					
	Bismuth (Bi)-Total (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2128122-26	L2128122-27	L2128122-28	L2128122-29	L2128122-30
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	10-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18
	Sampled Time	10:00	12:00	09:30	15:00	09:30
	Client ID	2018-07-11 ROUTINE 2 ONLY	2018-07-12 ROUTINE 2 ONLY	2018-07-14 ROUTINE 2 ONLY	2018-07-16 ROUTINE 2 ONLY	2018-07-17 ROUTINE 2 ONLY
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)					
	Hardness (as CaCO3) (mg/L)					
	pH (pH)					
	Total Suspended Solids (mg/L)					
	Total Dissolved Solids (mg/L)					
	TDS (Calculated) (mg/L)					
	Turbidity (NTU)					
Anions and Nutrients	Alkalinity, Bicarbonate (as CaCO3) (mg/L)					
	Alkalinity, Carbonate (as CaCO3) (mg/L)					
	Alkalinity, Hydroxide (as CaCO3) (mg/L)					
	Alkalinity, Phenolphthalein (as CaCO3) (mg/L)					
	Alkalinity, Total (as CaCO3) (mg/L)					
	Ammonia, Total (as N) (mg/L)					
	Bromide (Br) (mg/L)					
	Chloride (Cl) (mg/L)					
	Fluoride (F) (mg/L)					
	Nitrate and Nitrite (as N) (mg/L)	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051
	Nitrate (as N) (mg/L)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
	Nitrite (as N) (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Total Kjeldahl Nitrogen (mg/L)					
	Total Nitrogen (mg/L)					
	Orthophosphate-Dissolved (as P) (mg/L)	0.0050	0.0047	0.0046	<0.0010	<0.0010
	Phosphorus (P)-Total (mg/L)					
	Phosphorus (P)-Total Dissolved (mg/L)					
	Silicate (as SiO2) (mg/L)					
	Sulfate (SO4) (mg/L)					
	Anion Sum (meq/L)					
	Cation Sum (meq/L)					
	Cation - Anion Balance (%)					
Organic / Inorganic Carbon	Total Organic Carbon (mg/L)					
Total Metals	Aluminum (Al)-Total (mg/L)					
	Antimony (Sb)-Total (mg/L)					
	Arsenic (As)-Total (mg/L)					
	Barium (Ba)-Total (mg/L)					
	Beryllium (Be)-Total (mg/L)					
	Bismuth (Bi)-Total (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2128122-1	L2128122-2	L2128122-3	L2128122-4	L2128122-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	11-JUL-18	11-JUL-18	11-JUL-18	11-JUL-18	11-JUL-18
	Sampled Time	11:30	11:00	10:00	12:00	09:30
	Client ID	2018-07-08	2018-07-10	2018-07-11	2018-07-12	2018-07-14
Grouping	**Analyte**					
WATER						
Total Metals	Boron (B)-Total (mg/L)	0.027	0.028	0.028	0.028	0.028
	Cadmium (Cd)-Total (mg/L)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
	Calcium (Ca)-Total (mg/L)	41.5	42.0	41.5	42.0	42.5
	Cesium (Cs)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Chromium (Cr)-Total (mg/L)	<0.00010	<0.00010	<0.00010	0.00013	<0.00010
	Cobalt (Co)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Copper (Cu)-Total (mg/L)	0.00293	0.00268	0.00308	0.00890	0.00280
	Iron (Fe)-Total (mg/L)	0.015	0.017	0.051	0.166	0.013
	Lead (Pb)-Total (mg/L)	0.000090	<0.000050	<0.000050	0.000191	<0.000050
	Lithium (Li)-Total (mg/L)	0.0061	0.0061	0.0062	0.0062	0.0063
	Magnesium (Mg)-Total (mg/L)	13.8	14.0	14.2	13.8	14.4
	Manganese (Mn)-Total (mg/L)	0.0173	0.0254	0.0191	0.170	0.0197
	Mercury (Hg)-Total (mg/L)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
	Molybdenum (Mo)-Total (mg/L)	0.000280	0.000273	0.000275	0.000283	0.000261
	Nickel (Ni)-Total (mg/L)	0.00063	0.00064	0.00073	0.00077	0.00060
	Phosphorus (P)-Total (mg/L)	0.057	0.051	0.073	0.067	0.068
	Potassium (K)-Total (mg/L)	4.33	4.38	4.44	4.34	4.50
	Rubidium (Rb)-Total (mg/L)	0.00275	0.00270	0.00292	0.00293	0.00289
	Selenium (Se)-Total (mg/L)	0.000052	<0.000050	0.000052	0.000065	0.000054
	Silicon (Si)-Total (mg/L)	4.70	4.84	4.85	4.87	5.03
	Silver (Ag)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Sodium (Na)-Total (mg/L)	30.2	30.6	31.1	30.3	31.6
	Strontium (Sr)-Total (mg/L)	0.0913	0.0932	0.0926	0.0931	0.0944
	Sulfur (S)-Total (mg/L)	9.99	10.2	10.2	10.1	10.4
	Tellurium (Te)-Total (mg/L)	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
	Thallium (Tl)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Thorium (Th)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Tin (Sn)-Total (mg/L)	<0.00010	<0.00010	<0.00010	0.00011	<0.00010
	Titanium (Ti)-Total (mg/L)	<0.00030	<0.00030	<0.00030	0.00103	<0.00030
	Tungsten (W)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Uranium (U)-Total (mg/L)	0.000637	0.000652	0.000644	0.000666	0.000653
	Vanadium (V)-Total (mg/L)	0.00063	0.00061	0.00068	0.00074	0.00066
	Zinc (Zn)-Total (mg/L)	<0.0030	0.0038	<0.0030	0.0034	<0.0030
	Zirconium (Zr)-Total (mg/L)	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060
Dissolved Metals	Dissolved Metals Filtration Location	FIELD	FIELD	FIELD	FIELD	FIELD
	Calcium (Ca)-Dissolved (mg/L)	35.4	40.8	40.7	40.3	40.8
	Magnesium (Mg)-Dissolved (mg/L)	10.7	12.8	12.7	12.6	12.8

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2128122-6	L2128122-7	L2128122-8	L2128122-9	L2128122-10
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	09-JUL-18	11-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18
	Sampled Time	15:00	09:30	16:30	18:00	13:00
	Client ID	2018-07-16	2018-07-17	2018-07-01	2018-07-02	2018-07-03
Grouping	**Analyte**					
WATER						
Total Metals	Boron (B)-Total (mg/L)	<0.010	<0.010	0.028	0.028	0.028
	Cadmium (Cd)-Total (mg/L)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
	Calcium (Ca)-Total (mg/L)	<0.050	<0.050	42.4	42.1	41.6
	Cesium (Cs)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Chromium (Cr)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Cobalt (Co)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Copper (Cu)-Total (mg/L)	<0.00050	<0.00050	0.00331	0.00266	0.00247
	Iron (Fe)-Total (mg/L)	<0.010	<0.010	0.011	<0.010	<0.010
	Lead (Pb)-Total (mg/L)	<0.000050	0.000054 RRV	<0.000050	<0.000050	<0.000050
	Lithium (Li)-Total (mg/L)	<0.0010	<0.0010	0.0063	0.0062	0.0061
	Magnesium (Mg)-Total (mg/L)	<0.0050	<0.0050	14.2	14.0	13.8
	Manganese (Mn)-Total (mg/L)	<0.00010	<0.00010	0.0161	0.0152	0.0157
	Mercury (Hg)-Total (mg/L)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.000025 DLM
	Molybdenum (Mo)-Total (mg/L)	<0.000050	<0.000050	0.000263	0.000267	0.000251
	Nickel (Ni)-Total (mg/L)	<0.00050	<0.00050	0.00059	0.00055	<0.00050
	Phosphorus (P)-Total (mg/L)	<0.050	<0.050	0.059	<0.050	<0.050
	Potassium (K)-Total (mg/L)	<0.050	<0.050	4.40	4.38	4.32
	Rubidium (Rb)-Total (mg/L)	<0.00020	<0.00020	0.00274	0.00280	0.00275
	Selenium (Se)-Total (mg/L)	<0.000050	<0.000050	<0.000050	0.000058	<0.000050
	Silicon (Si)-Total (mg/L)	<0.10	<0.10	4.98	4.96	4.82
	Silver (Ag)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Sodium (Na)-Total (mg/L)	<0.050	<0.050	30.9	30.8	30.2
	Strontium (Sr)-Total (mg/L)	<0.00020	<0.00020	0.0942	0.0931	0.0912
	Sulfur (S)-Total (mg/L)	<0.50	<0.50	10.5	10.2	10.1
	Tellurium (Te)-Total (mg/L)	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
	Thallium (Tl)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Thorium (Th)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Tin (Sn)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Titanium (Ti)-Total (mg/L)	<0.00030	<0.00030	<0.00030	0.00033	<0.00030
	Tungsten (W)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Uranium (U)-Total (mg/L)	<0.000010	<0.000010	0.000632	0.000584	0.000532
	Vanadium (V)-Total (mg/L)	<0.00050	<0.00050	0.00063	0.00063	0.00068
	Zinc (Zn)-Total (mg/L)	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
	Zirconium (Zr)-Total (mg/L)	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060
Dissolved Metals	Dissolved Metals Filtration Location	FIELD	FIELD	FIELD	FIELD	FIELD
	Calcium (Ca)-Dissolved (mg/L)	<0.050	<0.050	39.3	40.0	40.1
	Magnesium (Mg)-Dissolved (mg/L)	<0.10	<0.10	12.2	12.5	12.4

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Grouping	Analyte					
	Sample ID	L2128122-11	L2128122-12	L2128122-13	L2128122-14	L2128122-15
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	10-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18
	Sampled Time	13:00	11:40	10:30	10:30	15:30
	Client ID	2018-07-04	2018-07-05	2018-07-06	2018-07-15	2018-07-07
WATER						
Total Metals	Boron (B)-Total (mg/L)	0.028	0.028	0.028	0.028	0.028
	Cadmium (Cd)-Total (mg/L)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
	Calcium (Ca)-Total (mg/L)	42.7	41.8	41.7	42.4	41.9
	Cesium (Cs)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Chromium (Cr)-Total (mg/L)	<0.00010	<0.00010	<0.00010	0.00013	<0.00010
	Cobalt (Co)-Total (mg/L)	0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Copper (Cu)-Total (mg/L)	0.00208	0.00248	0.00249	0.00259	0.00255
	Iron (Fe)-Total (mg/L)	0.071	<0.010	0.015	0.050	<0.010
	Lead (Pb)-Total (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
	Lithium (Li)-Total (mg/L)	0.0062	0.0061	0.0060	0.0062	0.0060
	Magnesium (Mg)-Total (mg/L)	14.2	14.1	13.7	14.4	14.1
	Manganese (Mn)-Total (mg/L)	0.804	0.0160	0.0179	0.0189	0.0189
	Mercury (Hg)-Total (mg/L)	DLM <0.000025	DLM <0.000025	<0.0000050	DLM <0.000025	<0.0000050
	Molybdenum (Mo)-Total (mg/L)	0.000201	0.000275	0.000282	0.000272	0.000254
	Nickel (Ni)-Total (mg/L)	0.00055	0.00069	0.00061	0.00062	0.00066
	Phosphorus (P)-Total (mg/L)	0.159	0.060	0.057	0.055	0.080
	Potassium (K)-Total (mg/L)	4.55	4.36	4.26	4.45	4.36
	Rubidium (Rb)-Total (mg/L)	0.00292	0.00273	0.00266	0.00286	0.00275
	Selenium (Se)-Total (mg/L)	<0.000050	<0.000050	0.000050	0.000052	0.000056
	Silicon (Si)-Total (mg/L)	6.20	4.89	4.86	4.94	4.96
	Silver (Ag)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Sodium (Na)-Total (mg/L)	30.2	30.7	30.2	31.5	30.7
	Strontium (Sr)-Total (mg/L)	0.0956	0.0935	0.0930	0.0942	0.0927
	Sulfur (S)-Total (mg/L)	9.80	10.2	9.96	10.0	10.0
	Tellurium (Te)-Total (mg/L)	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
	Thallium (Tl)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Thorium (Th)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Tin (Sn)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Titanium (Ti)-Total (mg/L)	0.00045	<0.00030	<0.00030	<0.00030	<0.00030
	Tungsten (W)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Uranium (U)-Total (mg/L)	0.000538	0.000661	0.000612	0.000634	0.000634
	Vanadium (V)-Total (mg/L)	0.00061	0.00061	0.00063	0.00068	0.00064
	Zinc (Zn)-Total (mg/L)	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
	Zirconium (Zr)-Total (mg/L)	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060
Dissolved Metals	Dissolved Metals Filtration Location	FIELD	FIELD	FIELD	FIELD	FIELD
	Calcium (Ca)-Dissolved (mg/L)	40.2	39.8	39.9	39.3	39.3
	Magnesium (Mg)-Dissolved (mg/L)	12.4	12.4	12.2	12.1	12.2

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2128122-16	L2128122-17	L2128122-18	L2128122-19	L2128122-20
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	10-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18
	Sampled Time	16:30	18:00	13:00	13:00	11:40
	Client ID	2018-07-01 ROUTINE 2 ONLY	2018-07-02 ROUTINE 2 ONLY	2018-07-03 ROUTINE 2 ONLY	2018-07-04 ROUTINE 2 ONLY	2018-07-05 ROUTINE 2 ONLY
Grouping	**Analyte**					
WATER						
Total Metals	Boron (B)-Total (mg/L)					
	Cadmium (Cd)-Total (mg/L)					
	Calcium (Ca)-Total (mg/L)					
	Cesium (Cs)-Total (mg/L)					
	Chromium (Cr)-Total (mg/L)					
	Cobalt (Co)-Total (mg/L)					
	Copper (Cu)-Total (mg/L)					
	Iron (Fe)-Total (mg/L)					
	Lead (Pb)-Total (mg/L)					
	Lithium (Li)-Total (mg/L)					
	Magnesium (Mg)-Total (mg/L)					
	Manganese (Mn)-Total (mg/L)					
	Mercury (Hg)-Total (mg/L)					
	Molybdenum (Mo)-Total (mg/L)					
	Nickel (Ni)-Total (mg/L)					
	Phosphorus (P)-Total (mg/L)					
	Potassium (K)-Total (mg/L)					
	Rubidium (Rb)-Total (mg/L)					
	Selenium (Se)-Total (mg/L)					
	Silicon (Si)-Total (mg/L)					
	Silver (Ag)-Total (mg/L)					
	Sodium (Na)-Total (mg/L)					
	Strontium (Sr)-Total (mg/L)					
	Sulfur (S)-Total (mg/L)					
	Tellurium (Te)-Total (mg/L)					
	Thallium (Tl)-Total (mg/L)					
	Thorium (Th)-Total (mg/L)					
	Tin (Sn)-Total (mg/L)					
	Titanium (Ti)-Total (mg/L)					
	Tungsten (W)-Total (mg/L)					
	Uranium (U)-Total (mg/L)					
	Vanadium (V)-Total (mg/L)					
	Zinc (Zn)-Total (mg/L)					
	Zirconium (Zr)-Total (mg/L)					
Dissolved Metals	Dissolved Metals Filtration Location					
	Calcium (Ca)-Dissolved (mg/L)					
	Magnesium (Mg)-Dissolved (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2128122-21	L2128122-22	L2128122-23	L2128122-24	L2128122-25
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	10-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18
	Sampled Time	10:30	10:30	15:30	11:30	11:00
	Client ID	2018-07-06 ROUTINE 2 ONLY	2018-07-15 ROUTINE 2 ONLY	2018-07-07 ROUTINE 2 ONLY	2018-07-08 ROUTINE 2 ONLY	2018-07-10 ROUTINE 2 ONLY
Grouping	**Analyte**					
WATER						
Total Metals	Boron (B)-Total (mg/L)					
	Cadmium (Cd)-Total (mg/L)					
	Calcium (Ca)-Total (mg/L)					
	Cesium (Cs)-Total (mg/L)					
	Chromium (Cr)-Total (mg/L)					
	Cobalt (Co)-Total (mg/L)					
	Copper (Cu)-Total (mg/L)					
	Iron (Fe)-Total (mg/L)					
	Lead (Pb)-Total (mg/L)					
	Lithium (Li)-Total (mg/L)					
	Magnesium (Mg)-Total (mg/L)					
	Manganese (Mn)-Total (mg/L)					
	Mercury (Hg)-Total (mg/L)					
	Molybdenum (Mo)-Total (mg/L)					
	Nickel (Ni)-Total (mg/L)					
	Phosphorus (P)-Total (mg/L)					
	Potassium (K)-Total (mg/L)					
	Rubidium (Rb)-Total (mg/L)					
	Selenium (Se)-Total (mg/L)					
	Silicon (Si)-Total (mg/L)					
	Silver (Ag)-Total (mg/L)					
	Sodium (Na)-Total (mg/L)					
	Strontium (Sr)-Total (mg/L)					
	Sulfur (S)-Total (mg/L)					
	Tellurium (Te)-Total (mg/L)					
	Thallium (Tl)-Total (mg/L)					
	Thorium (Th)-Total (mg/L)					
	Tin (Sn)-Total (mg/L)					
	Titanium (Ti)-Total (mg/L)					
	Tungsten (W)-Total (mg/L)					
	Uranium (U)-Total (mg/L)					
	Vanadium (V)-Total (mg/L)					
	Zinc (Zn)-Total (mg/L)					
	Zirconium (Zr)-Total (mg/L)					
Dissolved Metals	Dissolved Metals Filtration Location					
	Calcium (Ca)-Dissolved (mg/L)					
	Magnesium (Mg)-Dissolved (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2128122-26	L2128122-27	L2128122-28	L2128122-29	L2128122-30
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	10-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18
	Sampled Time	10:00	12:00	09:30	15:00	09:30
	Client ID	2018-07-11 ROUTINE 2 ONLY	2018-07-12 ROUTINE 2 ONLY	2018-07-14 ROUTINE 2 ONLY	2018-07-16 ROUTINE 2 ONLY	2018-07-17 ROUTINE 2 ONLY
Grouping	**Analyte**					
WATER						
Total Metals	Boron (B)-Total (mg/L)					
	Cadmium (Cd)-Total (mg/L)					
	Calcium (Ca)-Total (mg/L)					
	Cesium (Cs)-Total (mg/L)					
	Chromium (Cr)-Total (mg/L)					
	Cobalt (Co)-Total (mg/L)					
	Copper (Cu)-Total (mg/L)					
	Iron (Fe)-Total (mg/L)					
	Lead (Pb)-Total (mg/L)					
	Lithium (Li)-Total (mg/L)					
	Magnesium (Mg)-Total (mg/L)					
	Manganese (Mn)-Total (mg/L)					
	Mercury (Hg)-Total (mg/L)					
	Molybdenum (Mo)-Total (mg/L)					
	Nickel (Ni)-Total (mg/L)					
	Phosphorus (P)-Total (mg/L)					
	Potassium (K)-Total (mg/L)					
	Rubidium (Rb)-Total (mg/L)					
	Selenium (Se)-Total (mg/L)					
	Silicon (Si)-Total (mg/L)					
	Silver (Ag)-Total (mg/L)					
	Sodium (Na)-Total (mg/L)					
	Strontium (Sr)-Total (mg/L)					
	Sulfur (S)-Total (mg/L)					
	Tellurium (Te)-Total (mg/L)					
	Thallium (Tl)-Total (mg/L)					
	Thorium (Th)-Total (mg/L)					
	Tin (Sn)-Total (mg/L)					
	Titanium (Ti)-Total (mg/L)					
	Tungsten (W)-Total (mg/L)					
	Uranium (U)-Total (mg/L)					
	Vanadium (V)-Total (mg/L)					
	Zinc (Zn)-Total (mg/L)					
	Zirconium (Zr)-Total (mg/L)					
Dissolved Metals	Dissolved Metals Filtration Location					
	Calcium (Ca)-Dissolved (mg/L)					
	Magnesium (Mg)-Dissolved (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2128122-1	L2128122-2	L2128122-3	L2128122-4	L2128122-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	11-JUL-18	11-JUL-18	11-JUL-18	11-JUL-18	11-JUL-18
	Sampled Time	11:30	11:00	10:00	12:00	09:30
	Client ID	2018-07-08	2018-07-10	2018-07-11	2018-07-12	2018-07-14
Grouping	**Analyte**					
WATER						
Dissolved Metals	Potassium (K)-Dissolved (mg/L)	3.8	4.5	4.4	4.4	4.4
	Sodium (Na)-Dissolved (mg/L)	25.7	31.6	31.6	31.1	31.6
Volatile Organic Compounds	Benzene (mg/L)					
	Ethylbenzene (mg/L)					
	Methyl t-butyl ether (MTBE) (mg/L)					
	Styrene (mg/L)					
	Toluene (mg/L)					
	ortho-Xylene (mg/L)					
	meta- & para-Xylene (mg/L)					
	Xylenes (mg/L)					
	F1 (C6-C10) (mg/L)					
	Surrogate: 4-Bromofluorobenzene (SS) (%)					
	Surrogate: 1,4-Difluorobenzene (SS) (%)					
Hydrocarbons	EPH10-19 (mg/L)					
	EPH19-32 (mg/L)					
	F1-BTEX (mg/L)					
	TEH10-30 (mg/L)					
	F2 (C10-C16) (mg/L)					
	F3 (C16-C34) (mg/L)					
	F4 (C34-C50) (mg/L)					
	Surrogate: 2-Bromobenzotrifluoride (%)					
	Surrogate: 2-Bromobenzotrifluoride, F2-F4 (%)					
	Surrogate: 3,4-Dichlorotoluene (SS) (%)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Grouping	Analyte	L2128122-6	L2128122-7	L2128122-8	L2128122-9	L2128122-10
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	09-JUL-18	11-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18
	Sampled Time	15:00	09:30	16:30	18:00	13:00
	Client ID	2018-07-16	2018-07-17	2018-07-01	2018-07-02	2018-07-03
WATER						
Dissolved Metals	Potassium (K)-Dissolved (mg/L)	<2.0	<2.0	4.1	4.2	4.2
	Sodium (Na)-Dissolved (mg/L)	<2.0	<2.0	29.7	30.7	30.5
Volatile Organic Compounds	Benzene (mg/L)		<0.00050	<0.00050		<0.00050
	Ethylbenzene (mg/L)		<0.00050	<0.00050		<0.00050
	Methyl t-butyl ether (MTBE) (mg/L)		<0.00050	<0.00050		<0.00050
	Styrene (mg/L)		<0.00050	<0.00050		<0.00050
	Toluene (mg/L)		<0.00045	<0.00045		<0.00045
	ortho-Xylene (mg/L)		<0.00050	<0.00050		<0.00050
	meta- & para-Xylene (mg/L)		<0.00050	<0.00050		<0.00050
	Xylenes (mg/L)		<0.00075	<0.00075		<0.00075
	F1 (C6-C10) (mg/L)		<0.10	<0.10		<0.10
	Surrogate: 4-Bromofluorobenzene (SS) (%)		99.7	82.1		79.8
	Surrogate: 1,4-Difluorobenzene (SS) (%)		103.4	103.4		90.4
Hydrocarbons	EPH10-19 (mg/L)		<0.050	<0.050		<0.050
	EPH19-32 (mg/L)		<0.050	<0.050		<0.050
	F1-BTEX (mg/L)		<0.10	<0.10		<0.10
	TEH10-30 (mg/L)		<0.10	<0.10		<0.10
	F2 (C10-C16) (mg/L)		<0.30	<0.30		<0.30
	F3 (C16-C34) (mg/L)		<0.30	<0.30		<0.30
	F4 (C34-C50) (mg/L)		<0.30	<0.30		<0.30
	Surrogate: 2-Bromobenzotrifluoride (%)		95.4	114.9		100.8
	Surrogate: 2-Bromobenzotrifluoride, F2-F4 (%)		86.1	81.1		89.0
	Surrogate: 3,4-Dichlorotoluene (SS) (%)		76.2	73.7		84.4

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2128122-11	L2128122-12	L2128122-13	L2128122-14	L2128122-15
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	10-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18
	Sampled Time	13:00	11:40	10:30	10:30	15:30
	Client ID	2018-07-04	2018-07-05	2018-07-06	2018-07-15	2018-07-07
Grouping	**Analyte**					
WATER						
Dissolved Metals	Potassium (K)-Dissolved (mg/L)	4.4	4.2	4.1	4.0	4.1
	Sodium (Na)-Dissolved (mg/L)	29.8	30.6	30.2	29.6	29.8
Volatile Organic Compounds	Benzene (mg/L)					
	Ethylbenzene (mg/L)					
	Methyl t-butyl ether (MTBE) (mg/L)					
	Styrene (mg/L)					
	Toluene (mg/L)					
	ortho-Xylene (mg/L)					
	meta- & para-Xylene (mg/L)					
	Xylenes (mg/L)					
	F1 (C6-C10) (mg/L)					
	Surrogate: 4-Bromofluorobenzene (SS) (%)					
	Surrogate: 1,4-Difluorobenzene (SS) (%)					
Hydrocarbons	EPH10-19 (mg/L)					
	EPH19-32 (mg/L)					
	F1-BTEX (mg/L)					
	TEH10-30 (mg/L)					
	F2 (C10-C16) (mg/L)					
	F3 (C16-C34) (mg/L)					
	F4 (C34-C50) (mg/L)					
	Surrogate: 2-Bromobenzotrifluoride (%)					
	Surrogate: 2-Bromobenzotrifluoride, F2-F4 (%)					
	Surrogate: 3,4-Dichlorotoluene (SS) (%)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2128122-16	L2128122-17	L2128122-18	L2128122-19	L2128122-20
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	10-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18
	Sampled Time	16:30	18:00	13:00	13:00	11:40
	Client ID	2018-07-01 ROUTINE 2 ONLY	2018-07-02 ROUTINE 2 ONLY	2018-07-03 ROUTINE 2 ONLY	2018-07-04 ROUTINE 2 ONLY	2018-07-05 ROUTINE 2 ONLY
Grouping	**Analyte**					
WATER						
Dissolved Metals	Potassium (K)-Dissolved (mg/L)					
	Sodium (Na)-Dissolved (mg/L)					
Volatile Organic Compounds	Benzene (mg/L)					
	Ethylbenzene (mg/L)					
	Methyl t-butyl ether (MTBE) (mg/L)					
	Styrene (mg/L)					
	Toluene (mg/L)					
	ortho-Xylene (mg/L)					
	meta- & para-Xylene (mg/L)					
	Xylenes (mg/L)					
	F1 (C6-C10) (mg/L)					
	Surrogate: 4-Bromofluorobenzene (SS) (%)					
	Surrogate: 1,4-Difluorobenzene (SS) (%)					
Hydrocarbons	EPH10-19 (mg/L)					
	EPH19-32 (mg/L)					
	F1-BTEX (mg/L)					
	TEH10-30 (mg/L)					
	F2 (C10-C16) (mg/L)					
	F3 (C16-C34) (mg/L)					
	F4 (C34-C50) (mg/L)					
	Surrogate: 2-Bromobenzotrifluoride (%)					
	Surrogate: 2-Bromobenzotrifluoride, F2-F4 (%)					
	Surrogate: 3,4-Dichlorotoluene (SS) (%)					

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2128122-21	L2128122-22	L2128122-23	L2128122-24	L2128122-25
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	10-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18
	Sampled Time	10:30	10:30	15:30	11:30	11:00
	Client ID	2018-07-06 ROUTINE 2 ONLY	2018-07-15 ROUTINE 2 ONLY	2018-07-07 ROUTINE 2 ONLY	2018-07-08 ROUTINE 2 ONLY	2018-07-10 ROUTINE 2 ONLY
Grouping	**Analyte**					
WATER						
Dissolved Metals	Potassium (K)-Dissolved (mg/L)					
	Sodium (Na)-Dissolved (mg/L)					
Volatile Organic Compounds	Benzene (mg/L)					
	Ethylbenzene (mg/L)					
	Methyl t-butyl ether (MTBE) (mg/L)					
	Styrene (mg/L)					
	Toluene (mg/L)					
	ortho-Xylene (mg/L)					
	meta- & para-Xylene (mg/L)					
	Xylenes (mg/L)					
	F1 (C6-C10) (mg/L)					
	Surrogate: 4-Bromofluorobenzene (SS) (%)					
	Surrogate: 1,4-Difluorobenzene (SS) (%)					
Hydrocarbons	EPH10-19 (mg/L)					
	EPH19-32 (mg/L)					
	F1-BTEX (mg/L)					
	TEH10-30 (mg/L)					
	F2 (C10-C16) (mg/L)					
	F3 (C16-C34) (mg/L)					
	F4 (C34-C50) (mg/L)					
	Surrogate: 2-Bromobenzotrifluoride (%)					
	Surrogate: 2-Bromobenzotrifluoride, F2-F4 (%)					
	Surrogate: 3,4-Dichlorotoluene (SS) (%)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2128122-26	L2128122-27	L2128122-28	L2128122-29	L2128122-30
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	10-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18	10-JUL-18
	Sampled Time	10:00	12:00	09:30	15:00	09:30
	Client ID	2018-07-11 ROUTINE 2 ONLY	2018-07-12 ROUTINE 2 ONLY	2018-07-14 ROUTINE 2 ONLY	2018-07-16 ROUTINE 2 ONLY	2018-07-17 ROUTINE 2 ONLY
Grouping	**Analyte**					
WATER						
Dissolved Metals	Potassium (K)-Dissolved (mg/L)					
	Sodium (Na)-Dissolved (mg/L)					
Volatile Organic Compounds	Benzene (mg/L)					
	Ethylbenzene (mg/L)					
	Methyl t-butyl ether (MTBE) (mg/L)					
	Styrene (mg/L)					
	Toluene (mg/L)					
	ortho-Xylene (mg/L)					
	meta- & para-Xylene (mg/L)					
	Xylenes (mg/L)					
	F1 (C6-C10) (mg/L)					
	Surrogate: 4-Bromofluorobenzene (SS) (%)					
	Surrogate: 1,4-Difluorobenzene (SS) (%)					
Hydrocarbons	EPH10-19 (mg/L)					
	EPH19-32 (mg/L)					
	F1-BTEX (mg/L)					
	TEH10-30 (mg/L)					
	F2 (C10-C16) (mg/L)					
	F3 (C16-C34) (mg/L)					
	F4 (C34-C50) (mg/L)					
	Surrogate: 2-Bromobenzotrifluoride (%)					
	Surrogate: 2-Bromobenzotrifluoride, F2-F4 (%)					
	Surrogate: 3,4-Dichlorotoluene (SS) (%)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Matrix Spike	Total Organic Carbon	MS-B	L2128122-1, -2, -3, -4, -5, -6
Matrix Spike	Total Organic Carbon	MS-B	L2128122-1, -2, -3, -4, -5, -6
Matrix Spike	Total Organic Carbon	MS-B	L2128122-10, -11, -12, -13, -14, -15, -7, -8, -9
Matrix Spike	Arsenic (As)-Total	MS-B	L2128122-1, -10, -11, -12, -13, -14, -15, -2, -3, -4, -5, -6, -8, -9
Matrix Spike	Barium (Ba)-Total	MS-B	L2128122-1, -10, -11, -12, -13, -14, -15, -2, -3, -4, -5, -6, -8, -9
Matrix Spike	Calcium (Ca)-Total	MS-B	L2128122-1, -10, -11, -12, -13, -14, -15, -2, -3, -4, -5, -6, -8, -9
Matrix Spike	Calcium (Ca)-Total	MS-B	L2128122-7
Matrix Spike	Magnesium (Mg)-Total	MS-B	L2128122-1, -10, -11, -12, -13, -14, -15, -2, -3, -4, -5, -6, -8, -9
Matrix Spike	Potassium (K)-Total	MS-B	L2128122-1, -10, -11, -12, -13, -14, -15, -2, -3, -4, -5, -6, -8, -9
Matrix Spike	Sodium (Na)-Total	MS-B	L2128122-1, -10, -11, -12, -13, -14, -15, -2, -3, -4, -5, -6, -8, -9
Matrix Spike	Strontium (Sr)-Total	MS-B	L2128122-1, -10, -11, -12, -13, -14, -15, -2, -3, -4, -5, -6, -8, -9
Matrix Spike	Strontium (Sr)-Total	MS-B	L2128122-7
Matrix Spike	Total Nitrogen	MS-B	L2128122-1, -10, -11, -12, -13, -14, -15, -2, -3, -4, -5, -6, -7, -8, -9
Matrix Spike	Sulfate (SO4)	MS-B	L2128122-1, -10, -11, -12, -13, -14, -15, -2, -3, -4, -5, -6, -7, -8, -9

Qualifiers for Individual Parameters Listed:

Qualifier	Description
DLM	Detection Limit Adjusted due to sample matrix effects (e.g. chemical interference, colour, turbidity).
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.
RRV	Reported Result Verified By Repeat Analysis

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ALK-TITR-VA	Water	Alkalinity Species by Titration	APHA 2320 Alkalinity

This analysis is carried out using procedures adapted from APHA Method 2320 "Alkalinity". Total alkalinity is determined by potentiometric titration to a pH 4.5 endpoint. Bicarbonate, carbonate and hydroxide alkalinity are calculated from phenolphthalein alkalinity and total alkalinity values.

ANIONS-N+N-CALC-VA	Water	Nitrite & Nitrate in Water (Calculation)	EPA 300.0

Nitrate and Nitrite (as N) is a calculated parameter. Nitrate and Nitrite (as N) = Nitrite (as N) + Nitrate (as N).

BR-L-IC-N-VA	Water	Bromide in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

CARBONS-TOC-VA	Water	Total organic carbon by combustion	APHA 5310B TOTAL ORGANIC CARBON (TOC)

This analysis is carried out using procedures adapted from APHA Method 5310 "Total Organic Carbon (TOC)".

CL-IC-N-VA	Water	Chloride in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

EC-PCT-VA	Water	Conductivity (Automated)	APHA 2510 Auto. Conduc.

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

EC-SCREEN-VA	Water	Conductivity Screen (Internal Use Only)	APHA 2510

Qualitative analysis of conductivity where required during preparation of other tests - e.g. TDS, metals, etc.

EPH-L-ME-FID-VA	Water	EPH in Water (Low Level)	BC Lab Manual

EPH is extracted from water using a hexane micro-extraction technique, with analysis by GC-FID, as per the BC Lab Manual. EPH results include PAHs and are therefore not equivalent to LEPH or HEPH.

F-IC-N-VA	Water	Fluoride in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

Reference Information

F1-BTX-CALC-VA Water F1-Total BTX CCME CWS PHC TIER 1 (2001)

This analysis is based on the "Reference Method for the Canada-Wide Standard for Petroleum Hydrocarbons in Soil - Tier 1 Method, Canadian Council of Ministers of the Environment, December 2000." For F1 (C6-C10), the sample undergoes a purge and trap extraction prior to analysis by GC/FID. The F1-BTEX result is calculated as follows:

F1-BTEX: F1 (C6-C10) minus benzene, toluene, ethylbenzene and xylenes (BTEX).

F1-HSFID-VA Water CCME F1 By Headspace with GCFID EPA 5021A/CCME CWS PHC (Pub# 1310)

This analysis is based on the "Reference Method for the Canada-Wide Standard for Petroleum Hydrocarbons in Soil - Tier 1 Method, Canadian Council of Ministers of the Environment, December 2000." For F1 (C6-C10), the sample undergoes a headspace purge prior to analysis by GC/FID.

F1 (C6-C10): Sum of all hydrocarbons that elute between nC6 and nC10.

F2-F4-ME-FID-VA Water CCME F2-F4 Hydrocarbons in Water CCME CWS-PHC, Pub #1310, Dec 2001

F2-F4 is extracted from water using a hexane micro-extraction technique. Instrumental analysis is by GC-FID, as per the fiReference Method for the Canada-Wide Standard for Petroleum Hydrocarbons in Soil Œ Tier 1 Method, CCME, Dec 2001.fl

HARDNESS-CALC-VA Water Hardness APHA 2340B

Hardness (also known as Total Hardness) is calculated from the sum of Calcium and Magnesium concentrations, expressed in $CaCO_3$ equivalents. Dissolved Calcium and Magnesium concentrations are preferentially used for the hardness calculation.

HG-T-CVAA-VA Water Total Mercury in Water by CVAAS or CVAFS EPA 1631E (mod)

Water samples undergo a cold-oxidation using bromine monochloride prior to reduction with stannous chloride, and analyzed by CVAAS or CVAFS.

IONBALANCE-VA Water Ion Balance Calculation APHA 1030E

Cation Sum, Anion Sum, and Ion Balance (as % difference) are calculated based on guidance from APHA Standard Methods (1030E Checking Correctness of Analysis). Because all aqueous solutions are electrically neutral, the calculated ion balance (% difference of cations minus anions) should be near-zero.

Cation and Anion Sums are the total meq/L concentration of major cations and anions. Dissolved species are used where available. Minor ions are included where data is present. Ion Balance is calculated as:

Ion Balance (%) = [Cation Sum-Anion Sum] / [Cation Sum+Anion Sum]

MET-DIS-ICP-VA Water Dissolved Metals in Water by ICPOES EPA SW-846 3005A/6010B

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedure involves filtration (EPA Method 3005A) and analysis by inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B).

MET-T-CCMS-VA Water Total Metals in Water by CRC ICPMS EPA 200.2/6020A (mod)

Water samples are digested with nitric and hydrochloric acids, and analyzed by CRC ICPMS.

Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.

N-T-COL-VA Water Total Nitrogen in water by Colour APHA4500-P(J)/NEMI9171/USGS03-4174

This analysis is carried out using procedures adapted from APHA Method 4500-P (J) "Persulphate Method for Simultaneous Determination of Total Nitrogen and Total Phosphorus" and National Environmental Methods Index - Nemi method 5735.

NH3-F-VA Water Ammonia in Water by Fluorescence J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NO2-L-IC-N-VA Water Nitrite in Water by IC (Low Level) EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

NO3-L-IC-N-VA Water Nitrate in Water by IC (Low Level) EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

P-T-COL-VA Water Total P in Water by Colour APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorus is determined colourimetrically after persulphate digestion of the sample.
Samples with very high dissolved solids (i.e. seawaters, brackish waters) may produce a negative bias by this method. Alternate methods are available for these types of samples.

Arsenic (5+), at elevated levels, is a positive interference on colourimetric phosphate analysis.

P-TD-PRES-COL-VA Water Total Dissolved P in Water by Colour APHA 4500-P Phosphorous

Reference Information

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Dissolved Phosphorus is determined colourimetrically after persulphate digestion of a sample that has been lab or field filtered through a 0.45 micron membrane filter.
Samples with very high dissolved solids (i.e. seawaters, brackish waters) may produce a negative bias by this method. Alternate methods are available for these types of samples.

Arsenic (5+), at elevated levels, is a positive interference on colourimetric phosphate analysis.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PO4-DO-COL-VA	Water	Diss. Orthophosphate in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.
Samples with very high dissolved solids (i.e. seawaters, brackish waters) may produce a negative bias by this method. Alternate methods are available for these types of samples.

Arsenic (5+), at elevated levels, is a positive interference on colourimetric phosphate analysis.

SILICATE-COL-VA	Water	Silicate by Colourimetric analysis	APHA 4500-SiO2 E.

This analysis is carried out using procedures adapted from APHA Method 4500-SiO2 E. "Silica". Silicate (molybdate-reactive silica) is determined by the molybdosilicate-heteropoly blue colourimetric method.

SO4-IC-N-VA	Water	Sulfate in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

TDS-CALC-VA	Water	TDS (Calculated)	APHA 1030E (20TH EDITION)

This analysis is carried out using procedures adapted from APHA 1030E "Checking Correctness of Analyses".
The Total Dissolved Solids result is calculated from measured concentrations of anions and cations in the sample.

TDS-VA	Water	Total Dissolved Solids by Gravimetric	APHA 2540 C - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Dissolved Solids (TDS) are determined by filtering a sample through a glass fibre filter, TDS is determined by evaporating the filtrate to dryness at 180 degrees celsius.

TKN-F-VA	Water	TKN in Water by Fluorescence	APHA 4500-NORG D.

This analysis is carried out using procedures adapted from APHA Method 4500-Norg D. "Block Digestion and Flow Injection Analysis". Total Kjeldahl Nitrogen is determined using block digestion followed by Flow-injection analysis with fluorescence detection.

TSS-VA	Water	Total Suspended Solids by Gravimetric	APHA 2540 D - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Suspended Solids (TSS) are determined by filtering a sample through a glass fibre filter, TSS is determined by drying the filter at 104 degrees celsius.
Samples containing very high dissolved solid content (i.e. seawaters, brackish waters) may produce a positive bias by this method. Alternate analysis methods are available for these types of samples.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 Turbidity

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

VH-SURR-FID-VA	Water	VH Surrogates for Waters	BC Env. Lab Manual (VH in Solids)
VOC7-HSMS-VA	Water	BTEX/MTBE/Styrene by Headspace GCMS	EPA 5021A/8260C

The water sample, with added reagents, is heated in a sealed vial to equilibrium. The headspace from the vial is transfered into a gas chromatograph. Target compound concentrations are measured using mass spectrometry detection.

VOC7/VOC-SURR-MS-VA	Water	VOC7 and/or VOC Surrogates for Waters	EPA 5035A/5021A/8260C
XYLENES-CALC-VA	Water	Sum of Xylene Isomer Concentrations	CALCULATION

Calculation of Total Xylenes

Total Xylenes is the sum of the concentrations of the ortho, meta, and para Xylene isomers. Results below detection limit (DL) are treated as zero. The DL for Total Xylenes is set to a value no less than the square root of the sum of the squares of the DLs of the individual Xylenes.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

Reference Information

2017-0700 created

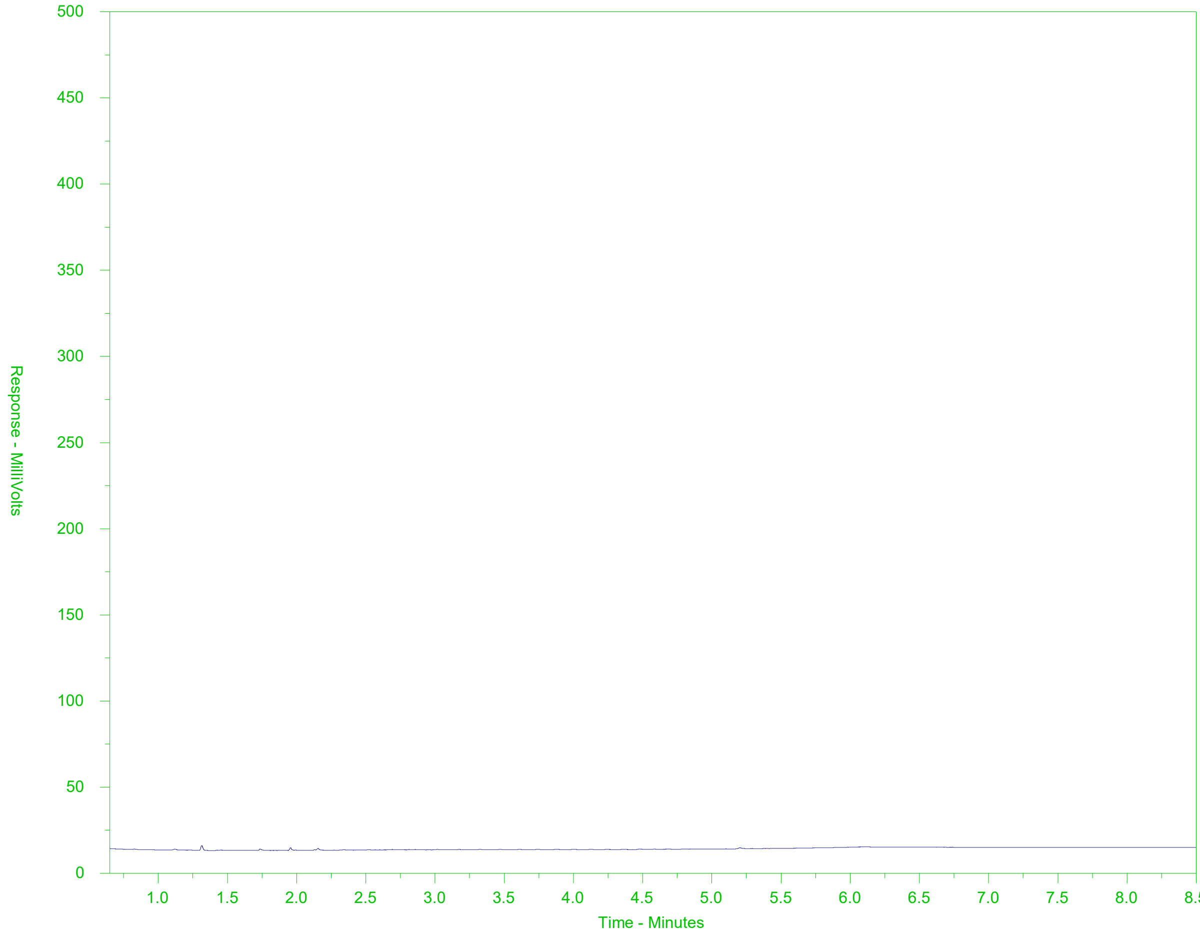
GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

CCME F2-F4 HYDROCARBON DISTRIBUTION REPORT

ALS Sample ID: L2128122-C-7
Client Sample ID: 2018-07-17



← F2 →	← F3 →	← F4 →	
nC10	nC16	nC34	nC50
174°C 346°F	287°C 549°F	481°C 898°F	575°C 1067°F
← Gasoline →	← Motor Oils/ Lube Oils/ Grease →		
← Diesel/ Jet Fuels →			

The CCME F2-F4 Hydrocarbon Distribution Report (HDR) is intended to assist you in characterizing hydrocarbon products that may be present in your sample.

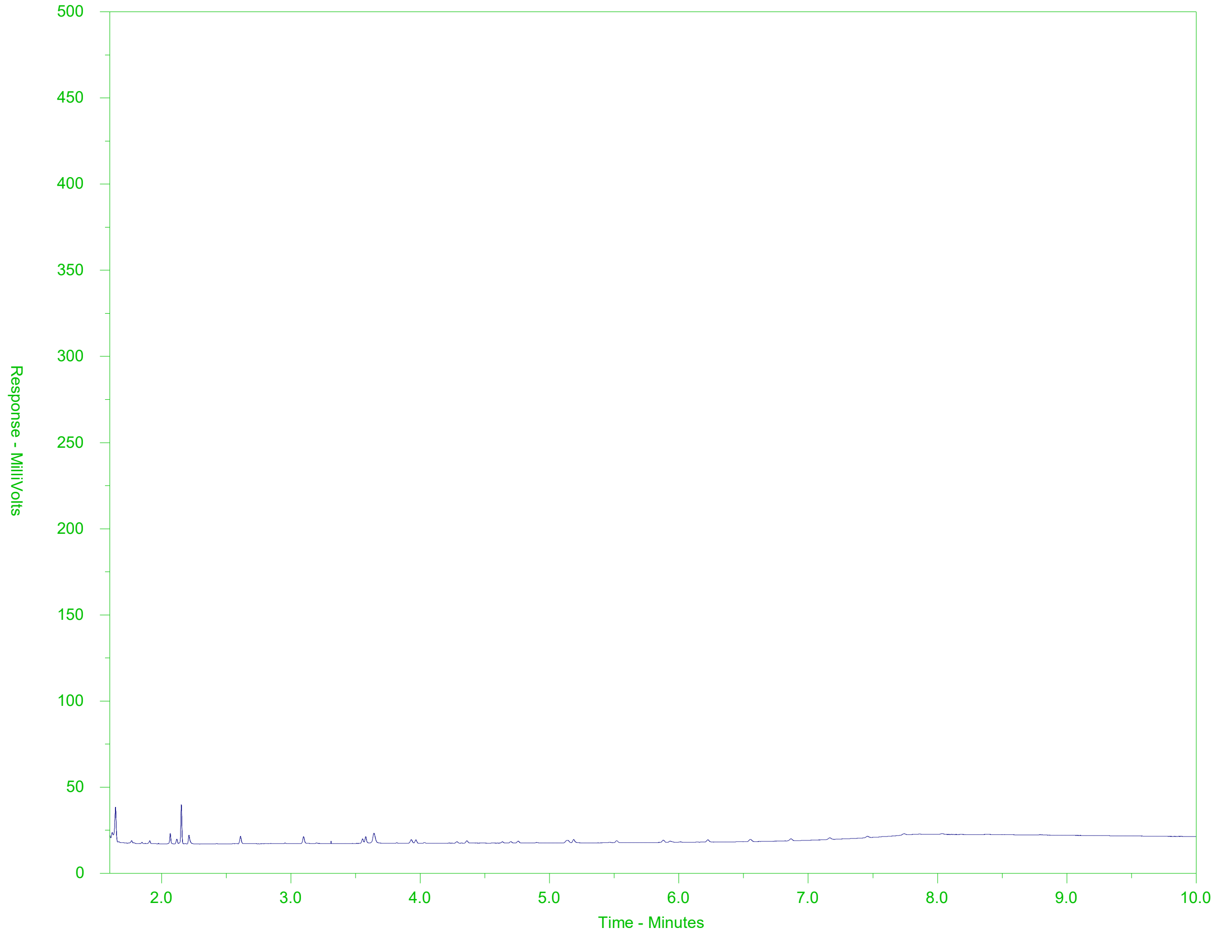
The scale at the bottom of the chromatogram indicates the approximate retention times of common petroleum products and four n-alkane hydrocarbon marker compounds. Retention times may vary between samples, but general patterns and distributions will remain similar.

Peak heights in this report are a function of the sample concentration, the sample amount extracted, the sample dilution factor, and the scale at left.

Note: This chromatogram was produced using GC conditions that are specific to ALS Canada CCME F2-F4 method. Refer to the ALS Canada CCME F2-F4 Hydrocarbon Library for a collection of chromatograms from common reference samples (fuels, oils, etc.). The HDR library can be found at www.alsglobal.com.

BC EPH HYDROCARBON DISTRIBUTION REPORT

ALS Sample ID: L2128122-L-7
Client Sample ID: 2018-07-17



EPH10-19		EPH19-32
nC10	nC19	nC32
174°C	330°C	467°C
346°F	626°F	873°F
Gasoline	Motor Oils/ Lube Oils/ Grease	
Diesel/ Jet Fuels		

The BC EPH Hydrocarbon Distribution Report (HDR) is intended to assist you in characterizing hydrocarbon products that may be present in your sample.

The scale at the bottom of the chromatogram indicates the approximate retention times of common petroleum products and three n-alkane hydrocarbon marker compounds. Retention times may vary between samples, but general patterns and distributions will remain similar.

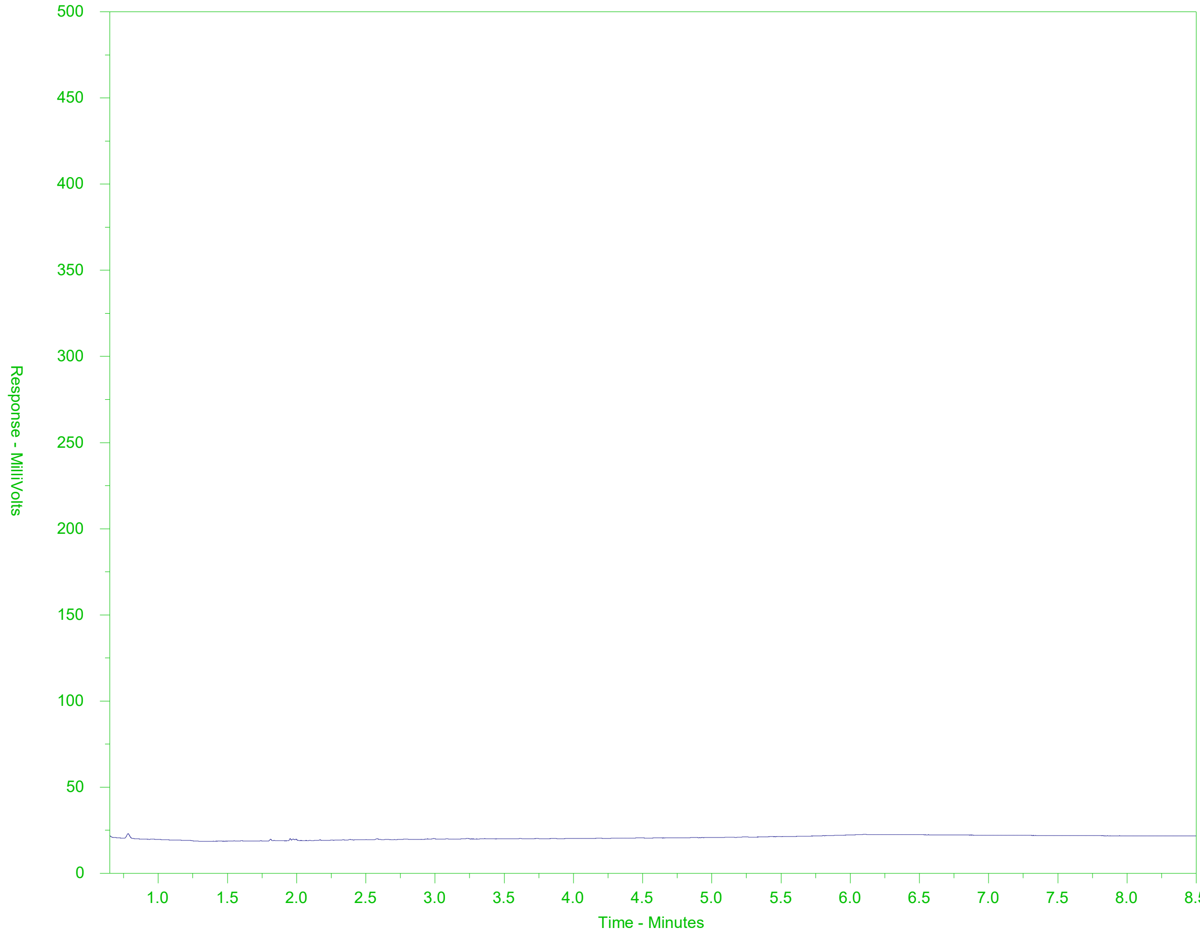
Peak heights in this report are a function of the sample concentration, the sample amount extracted, the sample dilution factor, and the scale at left.

A "-L-" in the sample ID denotes a low level sample. A "-S-" denotes a silica gel cleaned sample.

Note: This chromatogram was produced using GC conditions that are specific to the ALS Canada EPH method. Refer to the ALS Canada EPH Hydrocarbon Library for a collection of chromatograms from common reference samples (fuels, oils, etc.). The HDR library can be found at www.alsglobal.com.

CCME F2-F4 HYDROCARBON DISTRIBUTION REPORT

ALS Sample ID: L2128122-C-8
Client Sample ID: 2018-07-01



← F2 →	← F3 →	← F4 →	
nC10	nC16	nC34	nC50
174°C 346°F	287°C 549°F	481°C 898°F	575°C 1067°F
← Gasoline →	← Motor Oils/ Lube Oils/ Grease →		
← Diesel/ Jet Fuels →			

The CCME F2-F4 Hydrocarbon Distribution Report (HDR) is intended to assist you in characterizing hydrocarbon products that may be present in your sample.

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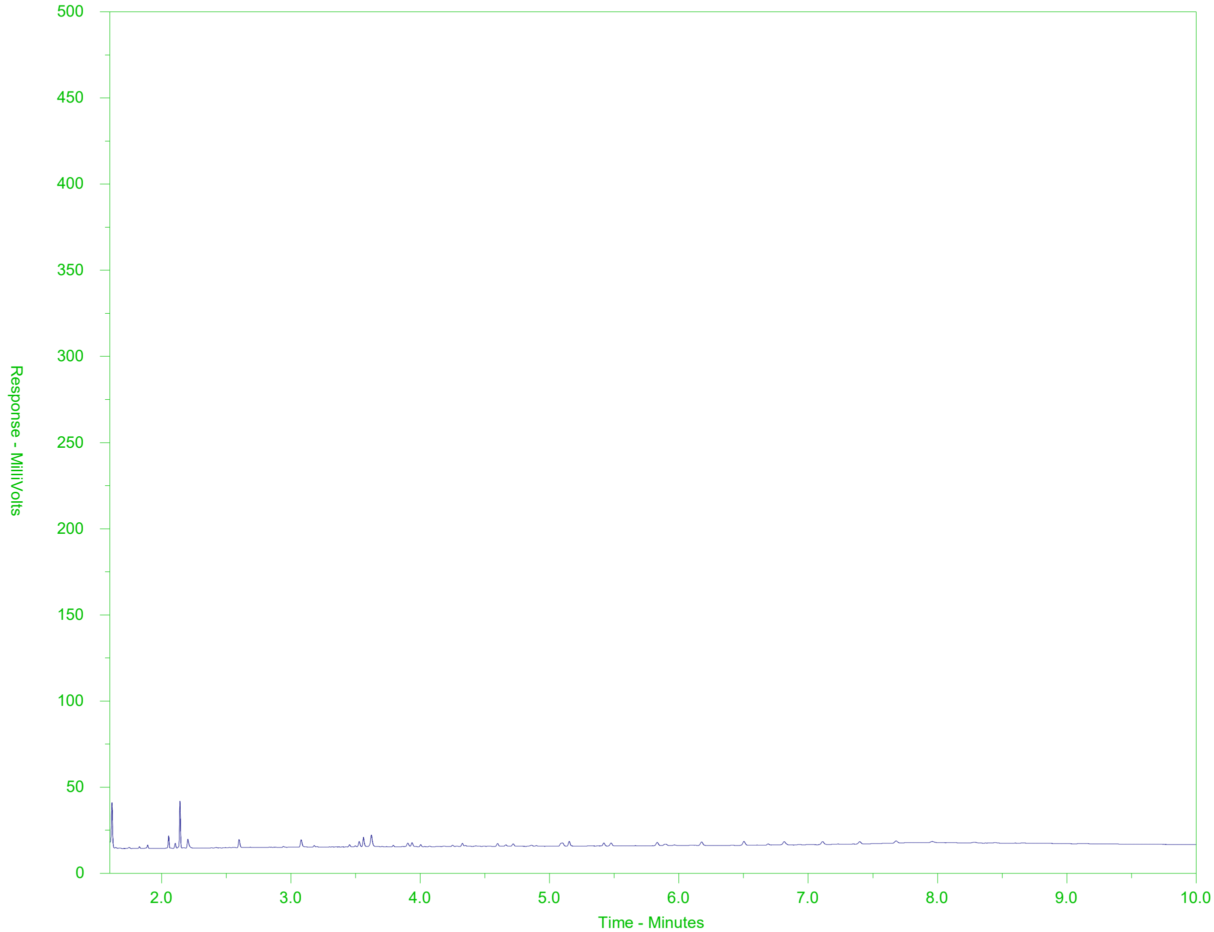
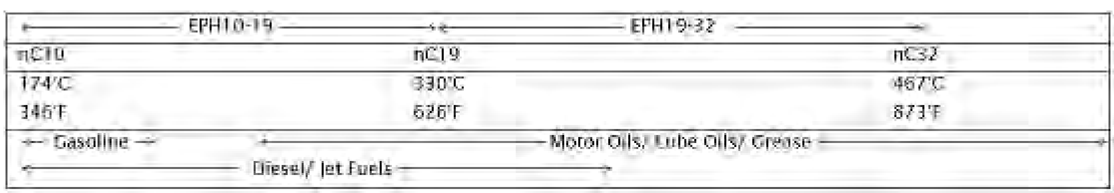
BC EPH HYDROCARBON DISTRIBUTION REPORT

ALS Sample ID: L2128122-L-8
Client Sample ID: 2018-07-01





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The scale at the bottom of the chromatogram indicates the approximate retention times of common petroleum products and three n-alkane hydrocarbon marker compounds. Retention times may vary between samples, but general patterns and distributions will remain similar.

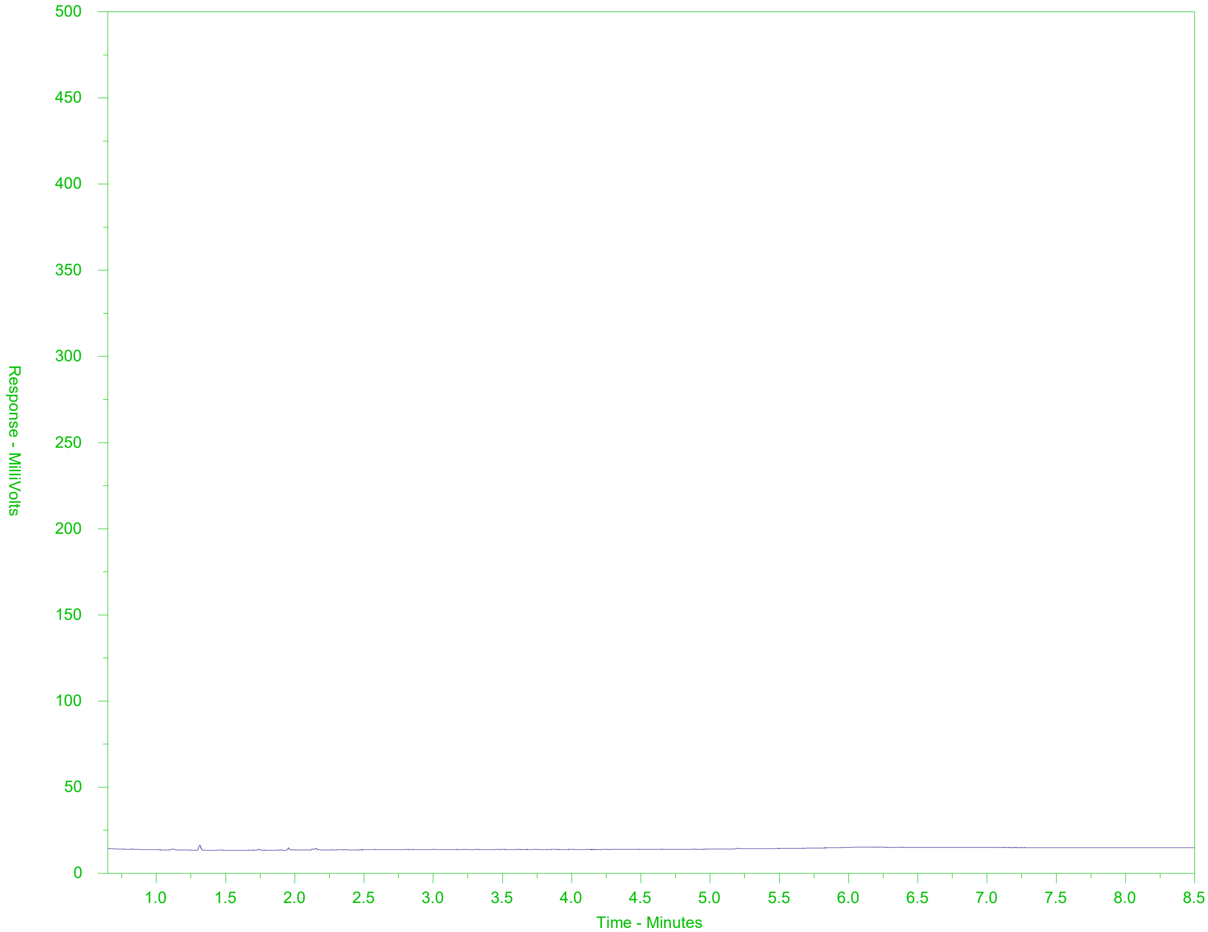
Peak heights in this report are a function of the sample concentration, the sample amount extracted, the sample dilution factor, and the scale at left.

A "-L-" in the sample ID denotes a low level sample. A "-S-" denotes a silica gel cleaned sample.

Note: This chromatogram was produced using GC conditions that are specific to the ALS Canada EPH method. Refer to the ALS Canada EPH Hydrocarbon Library for a collection of chromatograms from common reference samples (fuels, oils, etc.). The HDR library can be found at www.alsglobal.com.

CCME F2-F4 HYDROCARBON DISTRIBUTION REPORT

ALS Sample ID: L2128122-C-10
Client Sample ID: 2018-07-03



← F2 →	← F3 →	← F4 →	
nC10	nC16	nC34	nC50
174°C 346°F	287°C 549°F	481°C 898°F	575°C 1067°F

← Gasoline → ← Motor Oils/ Lube Oils/ Grease →

← Diesel/ Jet Fuels →

The CCME F2-F4 Hydrocarbon Distribution Report (HDR) is intended to assist you in characterizing hydrocarbon products that may be present in your sample.

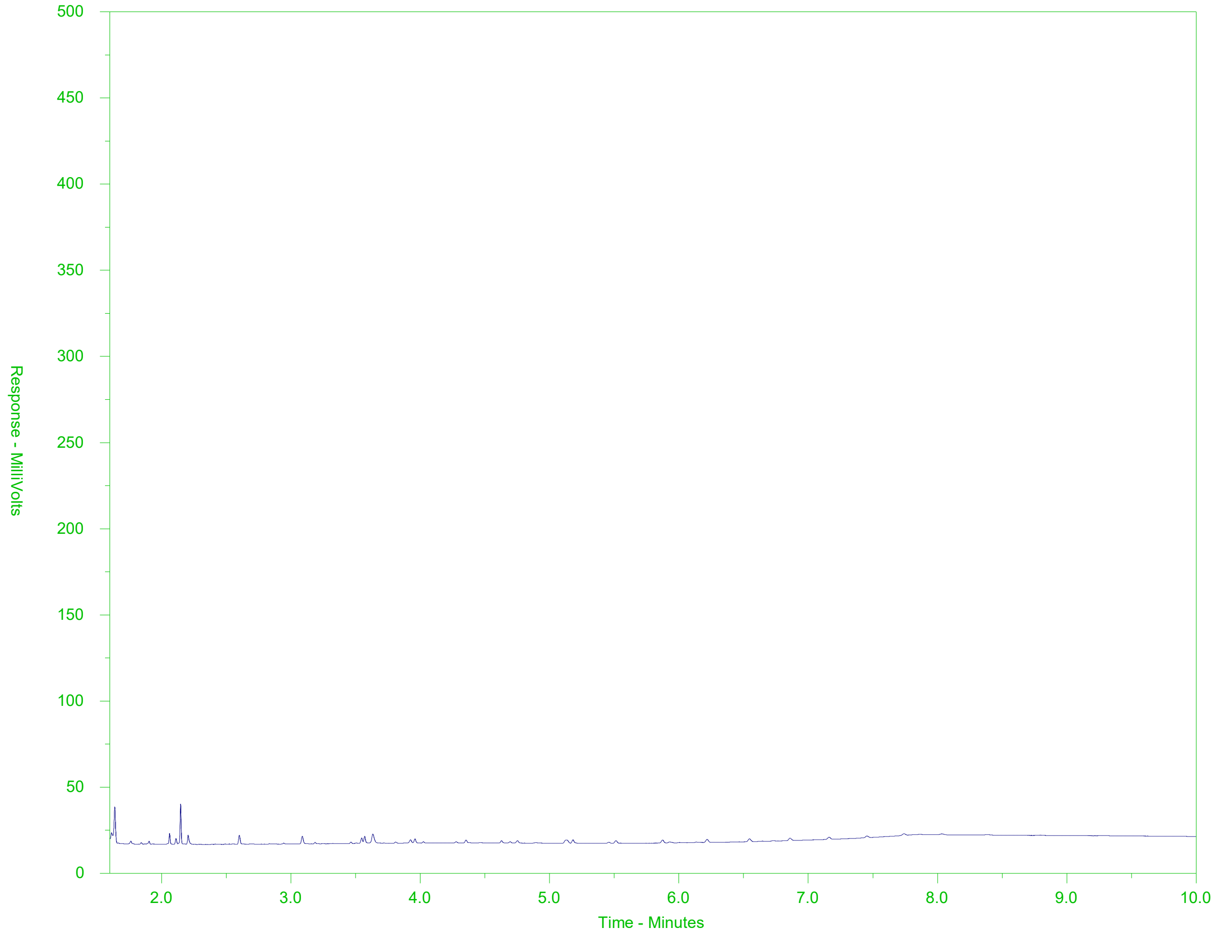
The scale at the bottom of the chromatogram indicates the approximate retention times of common petroleum products and four n-alkane hydrocarbon marker compounds. Retention times may vary between samples, but general patterns and distributions will remain similar.

Peak heights in this report are a function of the sample concentration, the sample amount extracted, the sample dilution factor, and the scale at left.

Note: This chromatogram was produced using GC conditions that are specific to ALS Canada CCME F2-F4 method. Refer to the ALS Canada CCME F2-F4 Hydrocarbon Library for a collection of chromatograms from common reference samples (fuels, oils, etc.). The HDR library can be found at www.alsglobal.com.

BC EPH HYDROCARBON DISTRIBUTION REPORT

ALS Sample ID: L2128122-L-10
Client Sample ID: 2018-07-03



EPH10-19		EPH19-32
nC10	nC19	nC32
174°C	330°C	467°C
346°F	626°F	873°F
Gasoline	Motor Oils/ Lube Oils/ Grease	
Diesel/ Jet Fuels		

The BC EPH Hydrocarbon Distribution Report (HDR) is intended to assist you in characterizing hydrocarbon products that may be present in your sample.

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Note: This chromatogram was produced using GC conditions that are specific to the ALS Canada EPH method. Refer to the ALS Canada EPH Hydrocarbon Library for a collection of chromatograms from common reference samples (fuels, oils, etc.). The HDR library can be found at www.alsglobal.com.

Lab Copy

Jackfish Lake
Chain-of-Custody Record - Analytical Request Form

CoC#: 2018-0700 Created

From:
Golder Associates - Jackfish
Address: 6925 Century Ave #100
Mississauga, ON, L5N 7K2
Telephone: (905) 561-4444
Contact: Tamara Darwish
TDarwish@golder.com

Send Samples For Analysis To:
ALS Group, Yellowknife
Address: 314 Old Airport Rd, Unit 116
Yellowknife, NT X1A 3T3
Phone: (867) 873-5593
Fax: (867) 920-4238
Contact: Rick Zolkiewski
Email: Rick.Zolkiewski@alsglobal.com

eMail Confirmation and Results To:
Please use full distribution list from quote
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MMiller@ntpc.com
GAL_EQUIS@golder.com
AHumphries@golder.com
TDarwish@golder.com
KMoreira@golder.com

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Telephone: (867) 873-6319
Fax: (867) 873-6379
Contact: Haley Macpherson
hmacpherson@golder.com

Send Invoice To:
Golder Associates Ltd.
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Mississauga, ON, L5N 7K2
Telephone: (905) 561-4444
Fax: (905) 567-6561
ATTN: Tamara Darwish
TDarwish@golder.com

FIELD SAMPLE INFORMATION

Fields Notes:
Filter and preserve dissolved parameters.
Please ensure that there is only one COC per report. Use email confirmation and results list on this COC.

Facilty Code:

Project # 1894709-6000-5050
Jackfish Baseline Sampling

Quote # Q66233

L2128122-COFC

REQUESTED LAB SUITES (see reverse side for details)

	Routine 1 (pH, conductivity, hardness, alkalinity, tss, tds (measured and calculated), anions, turbidity)	Routine 2 (orthophosphte, NO_2, NO_3) Silica	Total metals	Dissolved metals (major cations Ca, Mg, K, and Na only)	Total mercury	~~Oil and Grease~~ (EPH, CCME PHC)	Reactive Silica	Total Nutrients: TKN, NH3, TOC, TP, TN	Dissolved nutrients: TDP	F_2-F_4	BTEX & F_1				
√ = Preserved :			√		√	√		√							
√ = Field Filtered :				√					√						
√ = 1-Day Rush :															

Sample Control Number	Lab Sample ID	Sample Date (dd-mmm-yy)	Sample Time (hh:mm)	Matrix	Laboratory Comments	Sampler Comments	G = Grab or C = Composite	Number of Containers	Routine 1	Routine 2	Total metals	Dissolved metals	Total mercury	(EPH, CCME PHC)	Reactive Silica	Total Nutrients	Dissolved nutrients: TDP	F_2-F_4	BTEX & F_1				
2018-07-01		10-JUL-18	16:30	Water		FIELD FILTERED + PRESERVED	G	12	√	~~√~~	√	√	√	√		√	√	√	√				
2018-07-02		10-JUL-18	18:00	Water			G	6	√	~~√~~	√	√	√	~~√~~	√	√	√	~~√~~	~~√~~				
2018-07-03		10-JUL-18	13:00	Water			G	6	√	~~√~~	√	√	√	~~√~~	√	√	√	~~√~~	~~√~~				
2018-07-04		10-JUL-18	1300	Water			G	12	√	~~√~~	√	√	√	√	√	√	√	√	√				
2018-07-05		10-JUL-18	11:40	Water			G	6	√	~~√~~	√	√	√	~~√~~	√	√	√	~~√~~	~~√~~				
2018-07-06		10-JUL-18	10:30	Water			G	6	√	~~√~~	√	√	√	~~√~~	√	√	√	~~√~~	~~√~~				
2018-07-15		10-JUL-18	10:30	Water			G	6	√	~~√~~	√	√	√	~~√~~	√	√	√	~~√~~	~~√~~				
2018-07-07		10-JUL-18	15:30	Water			G	6	√	~~√~~	√	√	√	~~√~~	√	√	√	~~√~~	~~√~~				

Relinquished by (Sampler Signature): [signature]	Date/Time: 14:40 11-JUL-18	Company: **Golder Associates**	Received by (Signature): Tianli Liu	Company:
Relinquished by (Signature):	Date/Time: 14:44 11-Jul-18	Company:	Received by (Signature): [signature]	Company:
Sampler (Printed Name): Haley Macpherson	Sample Storage Temperature prior to Shipping (deg. C):	Sample Receipt Temperature (deg. C): 5.2	**SAMPLE CONDITION (lab use only)** Samples Received in Good Condition? Yes / No (If no, provide details.)	

Lab Copy

CoC#: 2018-0700 Created

Jackfish Lake
Chain-of-Custody Record - Analytical Request Form

From:

Golder Associates - Jackfish
Address: 6925 Century Ave #100
Mississauga, ON, L5N 7K2
Telephone: (905) 561-4444
Contact: Tamara Darwish
TDarwish@golder.com

Send Samples For Analysis To:
ALS Group, Yellowknife
Address: 314 Old Airport Rd, Unit 116
Yellowknife, NT X1A 3T3
Phone: (867) 873-5593
Fax: (867) 920-4238
Contact: Rick Zolkiewski
Email: Rick.Zolkiewski@alsglobal.com

eMail Confirmation and Results To:
Please use full distribution list from quote
HMacpherson@golder.com
MMiller@ntpc.com
GAL_EQUIS@golder.com
AHumphries@golder.com
TDarwish@golder.com
KMoreira@golder.com

Send Original Signed Lab Reports To:
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FIELD SAMPLE INFORMATION | ***REQUESTED LAB SUITES (see reverse side for details)***

Fields Notes:
Filter and preserve dissolved parameters.
Please ensure that there is only one COC per report. Use email confirmation and results list on this COC.

Facilty Code:

Project # **1894709-6000-5050**
Jackfish Baseline Sampling
Quote # **Q66233**

√ = Preserved :
√ = Field Filtered :
√ = 1-Day Rush :

Sample Control Number	Lab Sample ID	Sample Date (dd-mmm-yy)	Sample Time (hh:mm)	Matrix	Laboratory Comments	Sampler Comments	G = Grab or C = Composite	Number of Containers	Routine 1 (pH, conductivity, hardness, alkalinity, tss, tds (measured and calculated), anions, turbidity)	Routine 2 (orthophosphte, NO_2, NO_3) Silica.	Total metals	Dissolved metals (major cations Ca, Mg, K, and Na only)	Total mercury	~~Oil and Grease (EPH, CCME PHC)~~	~~Reactive Silica~~	Total Nutrients: TKN, NH3, TOC, TP, TN	Dissolved nutrients: TDP	~~F1-F4~~	~~BTEX & F1~~				
2018-07-08		11-JUL-18	11:30	Water		FIELD FILTERED & PRESERVED	G	6	√	~~√~~	√	√	√		~~√~~	√	√						
2018-07-10		11-JUL-18	11:00	Water			G	6	√	~~√~~	√	√	√		~~√~~	√	√						
2018-07-11		11-JUL-18	10:00	Water			G	6	√	~~√~~	√	√	√		~~√~~	√	√						
2018-07-12		11-JUL-18	12:00	Water			G	6	√	~~√~~	√	√	√		~~√~~	√	√						
2018-07-14		11-JUL-18	9:30.	Water			G	6	√	~~√~~	√	√	√		~~√~~	√	√						
2018-07-16		9-JUL-18	15:00	Water			G	6	√	~~√~~	√	√	√	~~√~~	~~√~~	√	√						
2018-07-17		11-JUL-18	9:30	Water			G	6	√	~~√~~	√	√	√	~~√~~	~~√~~	√	√						
2018-07-				Water			G	6	√	√	√	√	√	~~√~~	~~√~~	√	√						

Relinquished by (Sampler Signature): [signature]	Date/Time: 14:40 11JUL-18	Company: **Golder Associates**	Received by (Signature):	Company:
Relinquished by (Signature):	Date/Time:	Company:	Received by (Signature):	Company:
Sampler (Printed Name): Haley Macpherson.	Sample Storage Temperature prior to Shipping (deg. C):	Sample Receipt Temperature (deg. C):	**SAMPLE CONDITION (lab use only)** Samples Received in Good Condition? Yes / No (If no, provide details.)	

Lab Copy

CoC#: 2018-0700 Created

Jackfish Lake
Chain-of-Custody Record - Analytical Request Form

From:

Golder Associates - Jackfish	
Address: 6925 Century Ave #100 Mississauga, ON, L5N 7K2	
Telephone: (905) 561-4444	
Contact: Tamara Darwish TDarwish@golder.com	

Send Samples For Analysis To:

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Address: 314 Old Airport Rd, Unit 116 Yellowknife, NT X1A 3T3	
Phone: (867) 873-5593	
Fax: (867) 920-4238	
Contact: Rick Zolkiewski	
Email: Rick.Zolkiewski@alsglobal.com	

eMail Confirmation and Results To:

Please use full distribution list from quote
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FIELD SAMPLE INFORMATION

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Filter and preserve dissolved parameters.
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Facilty Code:

Project # 1894709-6000-5050
Jackfish Baseline Sampling
Quote # Q66233

REQUESTED LAB SUITES (see reverse side for details)

√ = Preserved :
√ = Field Filtered :
√ = 1-Day Rush :

Sample Control Number	Lab Sample ID	Sample Date (dd-mmm-yy)	Sample Time (hh:mm)	Matrix	Laboratory Comments	Sampler Comments	G = Grab or C = Composite	Number of Containers	Routine 1 (pH, conductivity, hardness, alkalinity, tds (measured and calculated), anions, turbidity)	Routine 2 (orthophosphte, NO_2, NO_3)	Total metals	Dissolved metals (major cations Ca, Mg, K, and Na only)	Total mercury	Oil and Grease (EPH, CCME PHC)	Reactive Silica	Total Nutrients: TKN, NH3, TOC, TP, TN	Dissolved nutrients: TDP	F_2-F_4	BTEX & F_1
2018-07-01	Routine 2 only	10-JUL-18	16:30	Water			G	14		√									
2018-07-02	Routine 2 only	10-JUL-18	18:00	Water			G	14		√									
2018-07-03	Routine 2 only	10-JUL-18	13:00	Water			G	14		√									
2018-07-04	Routine 2 only	10-JUL-18	13:00	Water			G	14		√									
2018-07-05	Routine 2 only	10-JUL-18	11:40	Water			G	14		√									
2018-07-06	Routine 2 only	10-JUL-18	10:30	Water			G	14		√									
2018-07-15	Routine 2 only	10-JUL-18	10:30	Water			G	14		√									
2018-07-07	Routine 2 only	10-JUL-18	15:30	Water			G	14		√									

Relinquished by (Sampler Signature): [signature]	Date/Time: 14:40 11-JUL-18	Company: **Golder Associates**	Received by (Signature):	Company:
Relinquished by (Signature):	Date/Time:	Company:	Received by (Signature):	Company:

SAMPLE CONDITION (lab use only)

Sampler (Printed Name): Haley Macpherson	Sample Storage Temperature prior to Shipping (deg. C):	Sample Receipt Temperature (deg. C):	Samples Received in Good Condition? Yes / No (If no, provide details.)

Lab Copy

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CoC#: 2018-0700 Created

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Project # 1894709-6000-5050
Jackfish Baseline Sampling

Quote # Q66233

REQUESTED LAB SUITES (see reverse side for details)

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Sample Control Number	Lab Sample ID	Sample Date (dd-mmm-yy)	Sample Time (hh:mm)	Matrix	Laboratory Comments	Sampler Comments	G = Grab or C = Composite	Number of Containers	[redacted]	Routine 2 (orthophosphite, NO_2, NO_3)	[redacted]					
2018-07-08		11-JUL-18	11:30	Water			G	1		√						
2018-07-10		11-JUL-18	11:00	Water			G	1		√						
2018-07-11		11-JUL-18	10:00	Water			G	1		√						
2018-07-12		11-JUL-18	12:00	Water			G	1		√						
2018-07-14		11-JUL-18	9:30	Water			G	1		√						
2018-07-16		9-JUL-18	15:00	Water			G	1		√						
2018-07-17		11-JUL-18	9:30	Water			G	1		√						

Relinquished by (Sampler Signature): HM	Date/Time: 11-Jul-18 14:40	Company: Golder Associates	Received by (Signature):	Company:
Relinquished by (Signature):	Date/Time:	Company:	Received by (Signature):	Company:
Sampler (Printed Name): Haley Macpherson	Sample Storage Temperature prior to Shipping (deg. C):	Sample Receipt Temperature (deg. C):	SAMPLE CONDITION (lab use only) Samples Received in Good Condition? Yes / No (If no, provide details.)	

Golder Associates Ltd.
ATTN: Haley Macpherson
6925 CENTURY AVE#100
MISSISSAUGA ON L5N 7K2

Date Received: 02-AUG-18
Report Date: 15-AUG-18 09:57 (MT)
Version: FINAL

Client Phone: 867-873-6319

Certificate of Analysis

Lab Work Order #: L2140607

Project P.O. #: NOT SUBMITTED
Job Reference: 1894709-7000-7050
C of C Numbers: 2018-08000
Legal Site Desc:

Rick Zolkiewski
General Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

Grouping	Analyte	L2140607-1	L2140607-2	L2140607-3	L2140607-4	L2140607-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	01-AUG-18	01-AUG-18	01-AUG-18	01-AUG-18	01-AUG-18
	Sampled Time	07:00	10:20	10:20	11:20	11:20
	Client ID	2018-08-01	2018-08-02	2018-08-03	2018-08-04	2018-08-05
WATER						
Physical Tests	Conductivity (uS/cm)	<2.0	430	430	429	429
	Hardness (as CaCO3) (mg/L)	<0.50	154	156	155	157
	pH (pH)	5.50	8.71	8.71	8.74	8.51
	Total Suspended Solids (mg/L)	<3.0	13.5	13.1	13.1	13.7
	Total Dissolved Solids (mg/L)	<10	282	281	278	283
	TDS (Calculated) (mg/L)	<1.0	254	255	255	254
	Turbidity (NTU)	<0.10	13.4	12.3	13.9	17.0
Anions and Nutrients	Alkalinity, Bicarbonate (as CaCO3) (mg/L)	<1.0	99.5	98.7	98.6	103
	Alkalinity, Carbonate (as CaCO3) (mg/L)	<1.0	12.8	12.6	13.4	7.4
	Alkalinity, Hydroxide (as CaCO3) (mg/L)	<1.0	<1.0	<1.0	<1.0	<1.0
	Alkalinity, Phenolphthalein (as CaCO3) (mg/L)	<2.0	6.4	6.3	6.7	3.7
	Alkalinity, Total (as CaCO3) (mg/L)	<1.0	112	111	112	111
	Ammonia, Total (as N) (mg/L)	<0.0050	<0.0050	0.0052	0.0057	0.0064
	Bromide (Br) (mg/L)	<0.050	0.050	0.053	0.054	0.054
	Chloride (Cl) (mg/L)	<0.50	56.3	56.3	56.1	55.5
	Fluoride (F) (mg/L)	<0.020	0.087	0.086	0.086	0.086
	Nitrate and Nitrite (as N) (mg/L)					
	Nitrate (as N) (mg/L)					
	Nitrite (as N) (mg/L)					
	Total Kjeldahl Nitrogen (mg/L)	<0.050	1.18	1.16	1.25	1.55
	Total Nitrogen (mg/L)	<0.030	1.23	1.24	1.28	2.14
	Orthophosphate-Dissolved (as P) (mg/L)					
	Phosphorus (P)-Total (mg/L)	<0.0020	0.0663	0.0701	0.0712	0.0711
	Phosphorus (P)-Total Dissolved (mg/L)	<0.0020	0.0141	0.0137	0.0141	0.110
	Silicate (as SiO2) (mg/L)					
	Sulfate (SO4) (mg/L)	<0.30	29.8	29.8	29.7	29.6
	Anion Sum (meq/L)	<0.10	4.46	4.44	4.44	4.40
	Cation Sum (meq/L)	<0.10	4.53	4.59	4.57	4.59
	Cation - Anion Balance (%)	0.0	0.8	1.7	1.4	2.1
Organic / Inorganic Carbon	Total Organic Carbon (mg/L)	<0.50	12.2	12.7	12.5	12.9
Total Metals	Aluminum (Al)-Total (mg/L)	<0.0030	0.0067	0.0072	0.0053	0.0064
	Antimony (Sb)-Total (mg/L)	<0.00010	0.00149	0.00152	0.00151	0.00150
	Arsenic (As)-Total (mg/L)	<0.00010	0.0901	0.0891	0.0889	0.0929
	Barium (Ba)-Total (mg/L)	<0.00010	0.0307	0.0309	0.0310	0.0313
	Beryllium (Be)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Bismuth (Bi)-Total (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2140607-6	L2140607-7	L2140607-8	L2140607-9	L2140607-10
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	01-AUG-18	01-AUG-18	01-AUG-18	01-AUG-18	01-AUG-18
	Sampled Time	13:35	13:35	14:15	15:15	16:15
	Client ID	2018-08-06	2018-08-07	2018-08-08	2018-08-09	2018-08-10
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)	432	<2.0	437	432	430
	Hardness (as CaCO3) (mg/L)	155	<0.50	158	154	154
	pH (pH)	8.76	5.46	8.68	8.75	8.74
	Total Suspended Solids (mg/L)	13.7	<3.0	14.1	13.9	13.7
	Total Dissolved Solids (mg/L)	277	<10	274	266	272
	TDS (Calculated) (mg/L)	255	<1.0	256	253	254
	Turbidity (NTU)	14.5	<0.10	15.1	13.9	14.2
Anions and Nutrients	Alkalinity, Bicarbonate (as CaCO3) (mg/L)	98.3	<1.0	99.4	97.4	98.4
	Alkalinity, Carbonate (as CaCO3) (mg/L)	14.4	<1.0	12.0	14.0	13.4
	Alkalinity, Hydroxide (as CaCO3) (mg/L)	<1.0	<1.0	<1.0	<1.0	<1.0
	Alkalinity, Phenolphthalein (as CaCO3) (mg/L)	7.2	<2.0	6.0	7.0	6.7
	Alkalinity, Total (as CaCO3) (mg/L)	113	<1.0	111	111	112
	Ammonia, Total (as N) (mg/L)	0.0054	<0.0050	0.0062	0.0051	0.0055
	Bromide (Br) (mg/L)	0.059	<0.050	<0.050	0.066	0.052
	Chloride (Cl) (mg/L)	56.2	<0.50	56.2	56.2	56.3
	Fluoride (F) (mg/L)	0.086	<0.020	0.086	0.086	0.086
	Nitrate and Nitrite (as N) (mg/L)					
	Nitrate (as N) (mg/L)					
	Nitrite (as N) (mg/L)					
	Total Kjeldahl Nitrogen (mg/L)	1.25	<0.050	1.30	1.25	1.22
	Total Nitrogen (mg/L)	1.23	<0.030	1.26	1.24	1.30
	Orthophosphate-Dissolved (as P) (mg/L)					
	Phosphorus (P)-Total (mg/L)	0.0440	<0.0020	0.0737	0.0620	0.0657
	Phosphorus (P)-Total Dissolved (mg/L)	0.0125	<0.0020	0.0109	0.0139	0.0147
	Silicate (as SiO2) (mg/L)					
	Sulfate (SO4) (mg/L)	29.8	<0.30	29.7	29.8	29.9
	Anion Sum (meq/L)	4.46	<0.10	4.44	4.44	4.45
	Cation Sum (meq/L)	4.56	<0.10	4.63	4.53	4.53
	Cation - Anion Balance (%)	1.1	0.0	2.2	1.0	0.9
Organic / Inorganic Carbon	Total Organic Carbon (mg/L)	12.4	<0.50	12.4	12.1	12.6
Total Metals	Aluminum (Al)-Total (mg/L)	0.0125	<0.0030	0.0092	0.0062	0.0062
	Antimony (Sb)-Total (mg/L)	0.00187	<0.00010	0.00154	0.00157	0.00153
	Arsenic (As)-Total (mg/L)	0.0978	<0.00010	0.0942	0.0899	0.0903
	Barium (Ba)-Total (mg/L)	0.0312	<0.00010	0.0308	0.0313	0.0310
	Beryllium (Be)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Bismuth (Bi)-Total (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2140607-11	L2140607-12	L2140607-13	L2140607-14	L2140607-15
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	01-AUG-18	01-AUG-18	01-AUG-18	01-AUG-18	01-AUG-18
	Sampled Time	07:00	10:20	10:20	11:20	11:20
	Client ID	2018-08-01	2018-08-02	2018-08-03	2018-08-04	2018-08-05
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)					
	Hardness (as CaCO3) (mg/L)					
	pH (pH)					
	Total Suspended Solids (mg/L)					
	Total Dissolved Solids (mg/L)					
	TDS (Calculated) (mg/L)					
	Turbidity (NTU)					
Anions and Nutrients	Alkalinity, Bicarbonate (as CaCO3) (mg/L)					
	Alkalinity, Carbonate (as CaCO3) (mg/L)					
	Alkalinity, Hydroxide (as CaCO3) (mg/L)					
	Alkalinity, Phenolphthalein (as CaCO3) (mg/L)					
	Alkalinity, Total (as CaCO3) (mg/L)					
	Ammonia, Total (as N) (mg/L)					
	Bromide (Br) (mg/L)					
	Chloride (Cl) (mg/L)					
	Fluoride (F) (mg/L)					
	Nitrate and Nitrite (as N) (mg/L)	<0.0051	<0.0051	<0.0051	<0.0051	2.84
	Nitrate (as N) (mg/L)	<0.0050	<0.0050	<0.0050	<0.0050	2.78
	Nitrite (as N) (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	0.0624
	Total Kjeldahl Nitrogen (mg/L)					
	Total Nitrogen (mg/L)					
	Orthophosphate-Dissolved (as P) (mg/L)	<0.0010	0.0042	0.0038	0.0040	0.0035
	Phosphorus (P)-Total (mg/L)					
	Phosphorus (P)-Total Dissolved (mg/L)					
	Silicate (as SiO2) (mg/L)	<0.50	10.2	10.8	10.7	10.4
	Sulfate (SO4) (mg/L)					
	Anion Sum (meq/L)					
	Cation Sum (meq/L)					
	Cation - Anion Balance (%)					
Organic / Inorganic Carbon	Total Organic Carbon (mg/L)					
Total Metals	Aluminum (Al)-Total (mg/L)					
	Antimony (Sb)-Total (mg/L)					
	Arsenic (As)-Total (mg/L)					
	Barium (Ba)-Total (mg/L)					
	Beryllium (Be)-Total (mg/L)					
	Bismuth (Bi)-Total (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

		L2140607-16	L2140607-17	L2140607-18	L2140607-19	L2140607-20
	Sample ID	L2140607-16	L2140607-17	L2140607-18	L2140607-19	L2140607-20
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	01-AUG-18	01-AUG-18	01-AUG-18	01-AUG-18	01-AUG-18
	Sampled Time	13:35	13:35	14:15	15:15	16:15
	Client ID	2018-08-06	2018-08-07	2018-08-08	2018-08-09	2018-08-10
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)					
	Hardness (as CaCO3) (mg/L)					
	pH (pH)					
	Total Suspended Solids (mg/L)					
	Total Dissolved Solids (mg/L)					
	TDS (Calculated) (mg/L)					
	Turbidity (NTU)					
Anions and Nutrients	Alkalinity, Bicarbonate (as CaCO3) (mg/L)					
	Alkalinity, Carbonate (as CaCO3) (mg/L)					
	Alkalinity, Hydroxide (as CaCO3) (mg/L)					
	Alkalinity, Phenolphthalein (as CaCO3) (mg/L)					
	Alkalinity, Total (as CaCO3) (mg/L)					
	Ammonia, Total (as N) (mg/L)					
	Bromide (Br) (mg/L)					
	Chloride (Cl) (mg/L)					
	Fluoride (F) (mg/L)					
	Nitrate and Nitrite (as N) (mg/L)	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051
	Nitrate (as N) (mg/L)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
	Nitrite (as N) (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Total Kjeldahl Nitrogen (mg/L)					
	Total Nitrogen (mg/L)					
	Orthophosphate-Dissolved (as P) (mg/L)	0.0036	<0.0010	0.0036	0.0037	0.0034
	Phosphorus (P)-Total (mg/L)					
	Phosphorus (P)-Total Dissolved (mg/L)					
	Silicate (as SiO2) (mg/L)	10.2	<0.50	10.6	10.2	10.4
	Sulfate (SO4) (mg/L)					
	Anion Sum (meq/L)					
	Cation Sum (meq/L)					
	Cation - Anion Balance (%)					
Organic / Inorganic Carbon	Total Organic Carbon (mg/L)					
Total Metals	Aluminum (Al)-Total (mg/L)					
	Antimony (Sb)-Total (mg/L)					
	Arsenic (As)-Total (mg/L)					
	Barium (Ba)-Total (mg/L)					
	Beryllium (Be)-Total (mg/L)					
	Bismuth (Bi)-Total (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Grouping	Analyte	L2140607-1	L2140607-2	L2140607-3	L2140607-4	L2140607-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	01-AUG-18	01-AUG-18	01-AUG-18	01-AUG-18	01-AUG-18
	Sampled Time	07:00	10:20	10:20	11:20	11:20
	Client ID	2018-08-01	2018-08-02	2018-08-03	2018-08-04	2018-08-05
WATER						
Total Metals	Boron (B)-Total (mg/L)	<0.010	0.028	0.028	0.029	0.029
	Cadmium (Cd)-Total (mg/L)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
	Calcium (Ca)-Total (mg/L)	<0.050	36.7	37.3	37.5	38.0
	Cesium (Cs)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Chromium (Cr)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Cobalt (Co)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Copper (Cu)-Total (mg/L)	<0.00050	0.00218	0.00220	0.00220	0.00358
	Iron (Fe)-Total (mg/L)	<0.010	0.014	0.014	0.010	0.021
	Lead (Pb)-Total (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
	Lithium (Li)-Total (mg/L)	<0.0010	0.0059	0.0060	0.0060	0.0060
	Magnesium (Mg)-Total (mg/L)	<0.0050	12.7	12.5	12.8	12.6
	Manganese (Mn)-Total (mg/L)	<0.00010	0.0278	0.0280	0.0236	0.0535
	Mercury (Hg)-Total (mg/L)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
	Molybdenum (Mo)-Total (mg/L)	<0.000050	0.000262	0.000274	0.000268	0.000280
	Nickel (Ni)-Total (mg/L)	<0.00050	0.00067	0.00067	0.00063	0.00075
	Phosphorus (P)-Total (mg/L)	<0.050	0.078	0.063	0.078	0.070
	Potassium (K)-Total (mg/L)	<0.050	4.22	4.15	4.25	4.23
	Rubidium (Rb)-Total (mg/L)	<0.00020	0.00274	0.00258	0.00264	0.00263
	Selenium (Se)-Total (mg/L)	<0.000050	0.000056	0.000051	<0.000050	0.000051
	Silicon (Si)-Total (mg/L)	<0.10	5.10	5.09	5.22	5.16
	Silver (Ag)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Sodium (Na)-Total (mg/L)	<0.050	29.7	29.4	30.1	29.5
	Strontium (Sr)-Total (mg/L)	<0.00020	0.0875	0.0893	0.0881	0.0896
	Sulfur (S)-Total (mg/L)	<0.50	10.5	10.4	10.2	10.3
	Tellurium (Te)-Total (mg/L)	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
	Thallium (Tl)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Thorium (Th)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Tin (Sn)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Titanium (Ti)-Total (mg/L)	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
	Tungsten (W)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Uranium (U)-Total (mg/L)	<0.000010	0.000633	0.000634	0.000661	0.000639
	Vanadium (V)-Total (mg/L)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
	Zinc (Zn)-Total (mg/L)	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
	Zirconium (Zr)-Total (mg/L)	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060
Dissolved Metals	Dissolved Metals Filtration Location	FIELD	FIELD	FIELD	FIELD	FIELD
	Calcium (Ca)-Dissolved (mg/L)	<0.050	40.6	40.8	40.6	41.3
	Magnesium (Mg)-Dissolved (mg/L)	<0.10	12.9	13.1	13.0	13.0

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2140607-6	L2140607-7	L2140607-8	L2140607-9	L2140607-10
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	01-AUG-18	01-AUG-18	01-AUG-18	01-AUG-18	01-AUG-18
	Sampled Time	13:35	13:35	14:15	15:15	16:15
	Client ID	2018-08-06	2018-08-07	2018-08-08	2018-08-09	2018-08-10
Grouping	**Analyte**					
WATER						
Total Metals	Boron (B)-Total (mg/L)	0.028	<0.010	0.029	0.029	0.028
	Cadmium (Cd)-Total (mg/L)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
	Calcium (Ca)-Total (mg/L)	37.2	<0.050	37.9	37.9	37.2
	Cesium (Cs)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Chromium (Cr)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Cobalt (Co)-Total (mg/L)	0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Copper (Cu)-Total (mg/L)	0.00278	<0.00050	0.00271	0.00231	0.00233
	Iron (Fe)-Total (mg/L)	0.053	<0.010	0.034	0.014	0.013
	Lead (Pb)-Total (mg/L)	0.000114	<0.000050	0.000075	<0.000050	<0.000050
	Lithium (Li)-Total (mg/L)	0.0060	<0.0010	0.0060	0.0062	0.0061
	Magnesium (Mg)-Total (mg/L)	12.5	<0.0050	12.6	12.7	12.7
	Manganese (Mn)-Total (mg/L)	0.0274	<0.00010	0.0276	0.0227	0.0219
	Mercury (Hg)-Total (mg/L)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
	Molybdenum (Mo)-Total (mg/L)	0.000277	<0.000050	0.000283	0.000278	0.000280
	Nickel (Ni)-Total (mg/L)	0.00076	<0.00050	0.00073	0.00065	0.00068
	Phosphorus (P)-Total (mg/L)	0.058	<0.050	0.078	0.065	0.060
	Potassium (K)-Total (mg/L)	4.22	<0.050	4.17	4.22	4.18
	Rubidium (Rb)-Total (mg/L)	0.00257	<0.00020	0.00266	0.00262	0.00259
	Selenium (Se)-Total (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
	Silicon (Si)-Total (mg/L)	5.15	<0.10	5.28	5.18	5.20
	Silver (Ag)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Sodium (Na)-Total (mg/L)	29.5	<0.050	29.9	29.9	29.9
	Strontium (Sr)-Total (mg/L)	0.0891	<0.00020	0.0892	0.0887	0.0899
	Sulfur (S)-Total (mg/L)	10.8	<0.50	10.9	10.5	10.8
	Tellurium (Te)-Total (mg/L)	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
	Thallium (Tl)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Thorium (Th)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Tin (Sn)-Total (mg/L)	0.00014	<0.00010	<0.00010	<0.00010	<0.00010
	Titanium (Ti)-Total (mg/L)	0.00049	<0.00030	<0.00030	<0.00030	<0.00030
	Tungsten (W)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Uranium (U)-Total (mg/L)	0.000645	<0.000010	0.000661	0.000656	0.000641
	Vanadium (V)-Total (mg/L)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
	Zinc (Zn)-Total (mg/L)	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
	Zirconium (Zr)-Total (mg/L)	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060
Dissolved Metals	Dissolved Metals Filtration Location	FIELD	FIELD	FIELD	FIELD	FIELD
	Calcium (Ca)-Dissolved (mg/L)	40.6	<0.050	41.6	40.6	40.6
	Magnesium (Mg)-Dissolved (mg/L)	13.0	<0.10	13.1	12.9	12.9

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID Description Sampled Date Sampled Time Client ID	L2140607-11 WATER 01-AUG-18 07:00 2018-08-01	L2140607-12 WATER 01-AUG-18 10:20 2018-08-02	L2140607-13 WATER 01-AUG-18 10:20 2018-08-03	L2140607-14 WATER 01-AUG-18 11:20 2018-08-04	L2140607-15 WATER 01-AUG-18 11:20 2018-08-05
Grouping	**Analyte**					
WATER						
Total Metals	Boron (B)-Total (mg/L)					
	Cadmium (Cd)-Total (mg/L)					
	Calcium (Ca)-Total (mg/L)					
	Cesium (Cs)-Total (mg/L)					
	Chromium (Cr)-Total (mg/L)					
	Cobalt (Co)-Total (mg/L)					
	Copper (Cu)-Total (mg/L)					
	Iron (Fe)-Total (mg/L)					
	Lead (Pb)-Total (mg/L)					
	Lithium (Li)-Total (mg/L)					
	Magnesium (Mg)-Total (mg/L)					
	Manganese (Mn)-Total (mg/L)					
	Mercury (Hg)-Total (mg/L)					
	Molybdenum (Mo)-Total (mg/L)					
	Nickel (Ni)-Total (mg/L)					
	Phosphorus (P)-Total (mg/L)					
	Potassium (K)-Total (mg/L)					
	Rubidium (Rb)-Total (mg/L)					
	Selenium (Se)-Total (mg/L)					
	Silicon (Si)-Total (mg/L)					
	Silver (Ag)-Total (mg/L)					
	Sodium (Na)-Total (mg/L)					
	Strontium (Sr)-Total (mg/L)					
	Sulfur (S)-Total (mg/L)					
	Tellurium (Te)-Total (mg/L)					
	Thallium (Tl)-Total (mg/L)					
	Thorium (Th)-Total (mg/L)					
	Tin (Sn)-Total (mg/L)					
	Titanium (Ti)-Total (mg/L)					
	Tungsten (W)-Total (mg/L)					
	Uranium (U)-Total (mg/L)					
	Vanadium (V)-Total (mg/L)					
	Zinc (Zn)-Total (mg/L)					
	Zirconium (Zr)-Total (mg/L)					
Dissolved Metals	Dissolved Metals Filtration Location					
	Calcium (Ca)-Dissolved (mg/L)					
	Magnesium (Mg)-Dissolved (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2140607-16	L2140607-17	L2140607-18	L2140607-19	L2140607-20
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	01-AUG-18	01-AUG-18	01-AUG-18	01-AUG-18	01-AUG-18
	Sampled Time	13:35	13:35	14:15	15:15	16:15
	Client ID	2018-08-06	2018-08-07	2018-08-08	2018-08-09	2018-08-10
Grouping	**Analyte**					
WATER						
Total Metals	Boron (B)-Total (mg/L)					
	Cadmium (Cd)-Total (mg/L)					
	Calcium (Ca)-Total (mg/L)					
	Cesium (Cs)-Total (mg/L)					
	Chromium (Cr)-Total (mg/L)					
	Cobalt (Co)-Total (mg/L)					
	Copper (Cu)-Total (mg/L)					
	Iron (Fe)-Total (mg/L)					
	Lead (Pb)-Total (mg/L)					
	Lithium (Li)-Total (mg/L)					
	Magnesium (Mg)-Total (mg/L)					
	Manganese (Mn)-Total (mg/L)					
	Mercury (Hg)-Total (mg/L)					
	Molybdenum (Mo)-Total (mg/L)					
	Nickel (Ni)-Total (mg/L)					
	Phosphorus (P)-Total (mg/L)					
	Potassium (K)-Total (mg/L)					
	Rubidium (Rb)-Total (mg/L)					
	Selenium (Se)-Total (mg/L)					
	Silicon (Si)-Total (mg/L)					
	Silver (Ag)-Total (mg/L)					
	Sodium (Na)-Total (mg/L)					
	Strontium (Sr)-Total (mg/L)					
	Sulfur (S)-Total (mg/L)					
	Tellurium (Te)-Total (mg/L)					
	Thallium (Tl)-Total (mg/L)					
	Thorium (Th)-Total (mg/L)					
	Tin (Sn)-Total (mg/L)					
	Titanium (Ti)-Total (mg/L)					
	Tungsten (W)-Total (mg/L)					
	Uranium (U)-Total (mg/L)					
	Vanadium (V)-Total (mg/L)					
	Zinc (Zn)-Total (mg/L)					
	Zirconium (Zr)-Total (mg/L)					
Dissolved Metals	Dissolved Metals Filtration Location					
	Calcium (Ca)-Dissolved (mg/L)					
	Magnesium (Mg)-Dissolved (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2140607-1	L2140607-2	L2140607-3	L2140607-4	L2140607-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	01-AUG-18	01-AUG-18	01-AUG-18	01-AUG-18	01-AUG-18
	Sampled Time	07:00	10:20	10:20	11:20	11:20
	Client ID	2018-08-01	2018-08-02	2018-08-03	2018-08-04	2018-08-05
Grouping	**Analyte**					
WATER						
Dissolved Metals	Potassium (K)-Dissolved (mg/L)	<2.0	4.1	4.2	4.2	4.3
	Sodium (Na)-Dissolved (mg/L)	<2.0	30.9	31.5	31.4	30.4

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2140607-6	L2140607-7	L2140607-8	L2140607-9	L2140607-10
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	01-AUG-18	01-AUG-18	01-AUG-18	01-AUG-18	01-AUG-18
	Sampled Time	13:35	13:35	14:15	15:15	16:15
	Client ID	2018-08-06	2018-08-07	2018-08-08	2018-08-09	2018-08-10
Grouping	**Analyte**					
WATER						
Dissolved Metals	Potassium (K)-Dissolved (mg/L)	4.1	<2.0	4.2	4.1	4.1
	Sodium (Na)-Dissolved (mg/L)	31.3	<2.0	31.5	30.8	30.8

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2140607-11	L2140607-12	L2140607-13	L2140607-14	L2140607-15
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	01-AUG-18	01-AUG-18	01-AUG-18	01-AUG-18	01-AUG-18
	Sampled Time	07:00	10:20	10:20	11:20	11:20
	Client ID	2018-08-01	2018-08-02	2018-08-03	2018-08-04	2018-08-05
Grouping	**Analyte**					
WATER						
Dissolved Metals	Potassium (K)-Dissolved (mg/L)					
	Sodium (Na)-Dissolved (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2140607-16	L2140607-17	L2140607-18	L2140607-19	L2140607-20
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	01-AUG-18	01-AUG-18	01-AUG-18	01-AUG-18	01-AUG-18
	Sampled Time	13:35	13:35	14:15	15:15	16:15
	Client ID	2018-08-06	2018-08-07	2018-08-08	2018-08-09	2018-08-10
Grouping	**Analyte**					
WATER						
Dissolved Metals	Potassium (K)-Dissolved (mg/L)					
	Sodium (Na)-Dissolved (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Matrix Spike	Total Organic Carbon	MS-B	L2140607-1, -10, -2, -3, -4, -5, -6, -7, -8, -9
Matrix Spike	Total Nitrogen	MS-B	L2140607-1, -10, -2, -3, -4, -5, -6, -7, -8, -9
Matrix Spike	Phosphorus (P)-Total	MS-B	L2140607-1, -10, -2, -3, -4, -5, -6, -7, -8, -9
Matrix Spike	Silicate (as SiO2)	MS-B	L2140607-11, -12, -13, -14, -15, -16, -17, -18, -19, -20

Qualifiers for Individual Parameters Listed:

Qualifier	Description
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ALK-TITR-VA	Water	Alkalinity Species by Titration	APHA 2320 Alkalinity

This analysis is carried out using procedures adapted from APHA Method 2320 "Alkalinity". Total alkalinity is determined by potentiometric titration to a pH 4.5 endpoint. Bicarbonate, carbonate and hydroxide alkalinity are calculated from phenolphthalein alkalinity and total alkalinity values.

ANIONS-N+N-CALC-VA	Water	Nitrite & Nitrate in Water (Calculation)	EPA 300.0

Nitrate and Nitrite (as N) is a calculated parameter. Nitrate and Nitrite (as N) = Nitrite (as N) + Nitrate (as N).

BR-L-IC-N-VA	Water	Bromide in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

CARBONS-TOC-VA	Water	Total organic carbon by combustion	APHA 5310B TOTAL ORGANIC CARBON (TOC)

This analysis is carried out using procedures adapted from APHA Method 5310 "Total Organic Carbon (TOC)".

CL-IC-N-VA	Water	Chloride in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

EC-PCT-VA	Water	Conductivity (Automated)	APHA 2510 Auto. Conduc.

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

EC-SCREEN-VA	Water	Conductivity Screen (Internal Use Only)	APHA 2510

Qualitative analysis of conductivity where required during preparation of other tests - e.g. TDS, metals, etc.

F-IC-N-VA	Water	Fluoride in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

HARDNESS-CALC-VA	Water	Hardness	APHA 2340B

Hardness (also known as Total Hardness) is calculated from the sum of Calcium and Magnesium concentrations, expressed in CaCO3 equivalents. Dissolved Calcium and Magnesium concentrations are preferentially used for the hardness calculation.

HG-T-CVAA-VA	Water	Total Mercury in Water by CVAAS or CVAFS	EPA 1631E (mod)

Water samples undergo a cold-oxidation using bromine monochloride prior to reduction with stannous chloride, and analyzed by CVAAS or CVAFS.

IONBALANCE-VA	Water	Ion Balance Calculation	APHA 1030E

Cation Sum, Anion Sum, and Ion Balance (as % difference) are calculated based on guidance from APHA Standard Methods (1030E Checking Correctness of Analysis). Because all aqueous solutions are electrically neutral, the calculated ion balance (% difference of cations minus anions) should be near-zero.

Cation and Anion Sums are the total meq/L concentration of major cations and anions. Dissolved species are used where available. Minor ions are included where data is present. Ion Balance is calculated as:

Ion Balance (%) = [Cation Sum-Anion Sum] / [Cation Sum+Anion Sum]

MET-DIS-ICP-VA	Water	Dissolved Metals in Water by ICPOES	EPA SW-846 3005A/6010B

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedure involves filtration (EPA Method 3005A) and analysis by inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B).

MET-T-CCMS-VA	Water	Total Metals in Water by CRC ICPMS	EPA 200.2/6020A (mod)

Water samples are digested with nitric and hydrochloric acids, and analyzed by CRC ICPMS.

Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.

Reference Information

N-T-COL-VA	Water	Total Nitrogen in water by Colour	APHA4500-P(J)/NEMI9171/USGS03-4174

This analysis is carried out using procedures adapted from APHA Method 4500-P (J) "Persulphate Method for Simultaneous Determination of Total Nitrogen and Total Phosphorus" and National Environmental Methods Index - Nemi method 5735.

NH3-F-VA	Water	Ammonia in Water by Fluorescence	J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NO2-L-IC-N-VA	Water	Nitrite in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

NO3-L-IC-N-VA	Water	Nitrate in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

P-T-PRES-COL-VA	Water	Total P in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorus is determined colourimetrically after persulphate digestion of the sample.
Samples with very high dissolved solids (i.e. seawaters, brackish waters) may produce a negative bias by this method. Alternate methods are available for these types of samples.

Arsenic (5+), at elevated levels, is a positive interference on colourimetric phosphate analysis.

P-TD-PRES-COL-VA	Water	Total Dissolved P in Water by Colour	APHA 4500-P Phosphorous

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Dissolved Phosphorus is determined colourimetrically after persulphate digestion of a sample that has been lab or field filtered through a 0.45 micron membrane filter.
Samples with very high dissolved solids (i.e. seawaters, brackish waters) may produce a negative bias by this method. Alternate methods are available for these types of samples.

Arsenic (5+), at elevated levels, is a positive interference on colourimetric phosphate analysis.

PH-PCT-VA	Water	pH by Meter (Automated)	APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PO4-DO-COL-VA	Water	Diss. Orthophosphate in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.
Samples with very high dissolved solids (i.e. seawaters, brackish waters) may produce a negative bias by this method. Alternate methods are available for these types of samples.

Arsenic (5+), at elevated levels, is a positive interference on colourimetric phosphate analysis.

SILICATE-COL-VA	Water	Silicate by Colourimetric analysis	APHA 4500-SiO2 E.

This analysis is carried out using procedures adapted from APHA Method 4500-SiO2 E. "Silica". Silicate (molybdate-reactive silica) is determined by the molybdosilicate-heteropoly blue colourimetric method.

SO4-IC-N-VA	Water	Sulfate in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

TDS-CALC-VA	Water	TDS (Calculated)	APHA 1030E (20TH EDITION)

This analysis is carried out using procedures adapted from APHA 1030E "Checking Correctness of Analyses".
The Total Dissolved Solids result is calculated from measured concentrations of anions and cations in the sample.

TDS-VA	Water	Total Dissolved Solids by Gravimetric	APHA 2540 C - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Dissolved Solids (TDS) are determined by filtering a sample through a glass fibre filter, TDS is determined by evaporating the filtrate to dryness at 180 degrees celsius.

TKN-F-VA	Water	TKN in Water by Fluorescence	APHA 4500-NORG D.

This analysis is carried out using procedures adapted from APHA Method 4500-Norg D. "Block Digestion and Flow Injection Analysis". Total Kjeldahl Nitrogen is determined using block digestion followed by Flow-injection analysis with fluorescence detection.

TSS-VA	Water	Total Suspended Solids by Gravimetric	APHA 2540 D - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Suspended Solids (TSS) are determined by filtering a sample through a glass fibre filter, TSS is determined by drying the filter at 104 degrees celsius.
Samples containing very high dissolved solid content (i.e. seawaters, brackish waters) may produce a positive bias by this method. Alternate analysis methods are available for these types of samples.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 Turbidity

Reference Information

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

2018-08000

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Lab Copy

Jackfish Lake
Chain-of-Custody Record - Analytical Request Form

CoC#: 2018-08000 Created: 31-7-18

From:

Golder Associates - Jackfish Address: 6925 Century Ave #100 Mississauga, ON, L5N 7K2 Telephone: (905) 561-4444 Contact: Tamara Darwish TDarwish@golder.com	Send Samples For Analysis To: **ALS Group, Yellowknife** Address: 314 Old Airport Rd, Unit 116 Yellowknife, NT X1A 3T3 Phone: (867) 873-5593 Fax: (867) 920-4238 Contact: Rick Zolkiewski Email: Rick.Zolkiewski@alsglobal.com	eMail Confirmation and Results To: Please use full distribution list from quote HMacpherson@golder.com MMiller@ntpc.com GAL_EQUIS@golder.com AHumphries@golder.com TDarwish@golder.com	Send Original Signed Lab Reports To: **Golder Associates Ltd.** Address: 9, 4905-48 Street Yellowknife, NT, X1A 3S3 Telephone: (867) 873-6319 Fax: (867) 873-6379 Contact: Haley Macpherson hmacpherson@golder.com	Send Invoice To: **Golder Associates Ltd.** Address: 6925 Century Ave #100 Mississauga, ON, L5N 7K2 Telephone: (905) 561-4444 Fax: (905) 567-6561 ATTN: Tamara Darwish TDarwish@golder.com

FIELD SAMPLE INFORMATION

Fields Notes:
Filter and preserve dissolved parameters.
Please ensure that there is only one COC per report. Use email confirmation and results list on this COC.

Facilty Code: 183527250

Project # 1894709-7000-7050
Jackfish Baseline Sampling

Quote # Q66233

L2140607-COFC

REQUESTED LAB SUITES (see reverse side for details)

	Sample Control Number	Lab Sample ID	Sample Date (dd-mmm-yy)	Sample Time (hh:mm)	Matrix	Laboratory Comments	Sampler Comments	G = Grab or C = Composite	Number of Containers	Routine 1 (pH, conductivity, hardness, alkalinity, tss, tds (measured and calculated), anions, turbidity)	Routine 2 (orthophosphte, NO_2, NO_3, silica)	Total metals	Dissolved metals (major cations Ca, Mg, K, and Na only)	Total mercury	EPH, CCME PHC	BTEX & F1	Total Nutrients: TKN, NH3, TOC, TP, TN	Dissolved nutrients: TDP	F_2-F_4					
							√ = Preserved :					√	√	√			√	√						
							√ = Field Filtered :						√					√						
							√ = 1-Day Rush :																	
9	2018-0809		01-08-18	15:15	Water		Dissolved Filtered	G	12	√	[redacted]	√	√	√	√	√	√	√	√					
10	2018-0810		01-08-18	16:15	Water		+ Preserved.	G	12	√	[redacted]	√	√	√	√	√	√	√	√					
11	2018-0801		01-08-18	7:00	Water			G	1	[redacted]	√	[redacted]												
12	2018-0802		01-08-18	10:20	Water		Routine	G	1		√													
13	2018-0803		01-08-18	10:20	Water		2	G	1		√													
14	2018-0804		01-08-18	11:20	Water		Only!	G	1		√													
15	2018-0805		01-08-18	11:20	Water			G	1		√													
16	2018-0806		01-08-18	13:25	Water			G	1		√													

Relinquished by (Sampler Signature):	Date/Time: Aug 2nd/18	Company: **Golder Associates**	Received by (Signature): Tianli Liu	Company:
Relinquished by (Signature):	Date/Time: Aug 2nd/18	Company:	Received by (Signature):	Company:
Sampler (Printed Name): Haley Macpherson -	Sample Storage Temperature prior to Shipping (deg. C):	Sample Receipt Temperature (deg. C): 15.5	**SAMPLE CONDITION (lab use only)** Samples Received in Good Condition? Yes / No (If no, provide details.)	

13:55

Lab Copy

Jackfish Lake
Chain-of-Custody Record - Analytical Request Form

CoC#: 2018-08000 Created: 31-7-18

From:	Send Samples For Analysis To:	eMail Confirmation and Results To:	Send Original Signed Lab Reports To:	Send Invoice To:
Golder Associates - Jackfish	**ALS Group, Yellowknife**	Please use full distribution list from quote	**Golder Associates Ltd.**	**Golder Associates Ltd.**
Address: 6925 Century Ave #100 Mississauga, ON, L5N 7K2	Address: 314 Old Airport Rd, Unit 116 Yellowknife, NT X1A 3T3	HMacpherson@golder.com	Address: 9, 4905-48 Street Yellowknife, NT, X1A 3S3	Address: 6925 Century Ave #100 Mississauga, ON, L5N 7K2
Telephone: (905) 561-4444	Phone: (867) 873-5593	MMiller@ntpc.com	Telephone: (867) 873-6319	Telephone: (905) 561-4444
	Fax: (867) 920-4238	GAL_EQUIS@golder.com	Fax: (867) 873-6379	Fax: (905) 567-6561
Contact: Tamara Darwish	Contact: Rick Zolkiewski	AHumphries@golder.com	Contact: Haley Macpherson	ATTN: Tamara Darwish
TDarwish@golder.com	Email: Rick.Zolkiewski@alsglobal.com	TDarwish@golder.com	hmacpherson@golder.com	TDarwish@golder.com

FIELD SAMPLE INFORMATION

Fields Notes:

Filter and preserve dissolved parameters.

Please ensure that there is only one COC per report. Use email confirmation and results list on this COC.

Facilty Code: 183527250

Project # 1894709-7000-7050 Jackfish Baseline Sampling

Quote # Q66233

REQUESTED LAB SUITES (see reverse side for details)

√ = Preserved :
√ = Field Filtered :
√ = 1-Day Rush :

	Sample Control Number	Lab Sample ID	Sample Date (dd-mmm-yy)	Sample Time (hh:mm)	Matrix	Laboratory Comments	Sampler Comments	G = Grab or C = Composite	Number of Containers	Routine 1 (pH, conductivity, hardness, alkalinity, tss, tds (measured and calculated), anions, turbidity)	Routine 2 (orthophosphte, NO_2, NO_3, silica)	Total metals	Dissolved metals (major cations Ca, Mg, K, and Na only)	Total mercury	EPH, CCME PHC	BTEX & F1	Total Nutrients: TKN, NH3, TOC, TP, TN	Dissolved nutrients: TDP	F_2-F_4					
17	2018-0807		01-08-18	13:25	Water		Routine 2 only!	G	1		√													
18	2018-0808		01-08-18	14:15	Water			G	1		√													
19	2018-0809		01-08-18	15:15	Water			G	1		√													
20	2018-0810		01-08-18	16:15	Water			G	1		√													
	~~2018-08-~~				~~Water~~			~~G~~	~~1~~															
	~~2018-~~				~~Water~~			~~G~~	~~1~~															
	~~2018-~~				~~Water~~			~~G~~	~~1~~															
	~~2018-08-~~				~~Water~~				~~1~~															

Relinquished by (Sampler Signature): [signature]	Date/Time: Aug 2nd/18	Company: **Golder Associates**	Received by (Signature): Tianli Liu — Company:
Relinquished by (Signature):	Date/Time: Aug 2nd/18	Company:	Received by (Signature): [signature] — Company:
Sampler (Printed Name): Haley Macpherson.	Sample Storage Temperature prior to Shipping (deg. C):	Sample Receipt Temperature (deg. C): 11.5	**SAMPLE CONDITION (lab use only)** Samples Received in Good Condition? Yes / No (If no, provide details.)

13:55

Lab Copy

Jackfish Lake
Chain-of-Custody Record - Analytical Request Form

CoC#: 2018-08000 Created: 31-7-18

From:

Golder Associates - Jackfish
Address: 6925 Century Ave #100 Mississauga, ON. L5N 7K2
Telephone: (905) 561-4444
Contact: Tamara Darwish TDarwish@golder.com

Send Samples For Analysis To:

ALS Group, Yellowknife
Address: 314 Old Airport Rd, Unit 116 Yellowknife, NT X1A 3T3
Phone: (867) 873-5593
Fax: (867) 920-4238
Contact: Rick Zolkiewski Email: Rick.Zolkiewski@alsglobal.com

eMail Confirmation and Results To:

Please use full distribution list from quote
HMacpherson@golder.com
MMiller@ntpc.com
GAL_EQUIS@golder.com
AHumphries@golder.com
TDarwish@golder.com

Send Original Signed Lab Reports To:

Golder Associates Ltd.
Address: 9, 4905-48 Street Yellowknife, NT, X1A 3S3
Telephone: (867) 873-6319
Fax: (867) 873-6379
Contact: Haley Macpherson hmacpherson@golder.com

Send Invoice To:

Golder Associates Ltd.
~~Address: 6925 Century Ave #100~~
Mississauga, ON. L5N 7K2
Telephone: (905) 561-4444
Fax: (905) 567-6561
ATTN: Tamara Darwish
TDarwish@golder.com

FIELD SAMPLE INFORMATION

Fields Notes:

Filter and preserve dissolved parameters.

Please ensure that there is only one COC per report. Use email confirmation and results list on this COC.

Facilty Code: **183527250**

Project # **1894709-7000-7050**
Jackfish Baseline Sampling

Quote # **Q66233**

REQUESTED LAB SUITES (see reverse side for details)

√ = Preserved :
√ = Field Filtered :
√ = 1-Day Rush :

Sample Control Number	Lab Sample ID	Sample Date (dd-mmm-yy)	Sample Time (hh:mm)	Matrix	Laboratory Comments	Sampler Comments	G = Grab or C = Composite	Number of Containers	Routine 1 (pH, conductivity, hardness, alkalinity, tss, tds (measured and calculated), anions, turbidity)	[redacted]	Total metals	Dissolved metals (major cations Ca, Mg, K, and Na only)	Total mercury	EPH, CCME PHC	BTEX & F1	Total Nutrients: TKN, NH3, TOC, TP, TN	Dissolved nutrients: TDP	F_2-F_4
1 2018-08-01		01-08-18	7:00	Water			G	12	√	[redacted]	√	√	√	√	√	√	√	√
2 2018-08-02		01-08-18	10:20	Water		Dissolved	G	12	√	[redacted]	√	√	√	√	√	√	√	√
3 2018-08-03		01-08-18	10:20	Water		filtered &	G	12	√	[redacted]	√	√	√	√	√	√	√	√
4 2018-08-04		01-08-18	11:20	Water		Preserved.	G	12	√	[redacted]	√	√	√	√	√	√	√	√
5 2018-08-05		01-08-18	11:20	Water			G	12	√	[redacted]	√	√	√	√	√	√	√	√
6 2018-08-06		01-08-18	13:25	Water			G	12	√	[redacted]	√	√	√	√	√	√	√	√
7 2018-08-07		01-08-18	13:25	Water			G	12	√	[redacted]	√	√	√	√	√	√	√	√
8 2018-08-08		01-08-18	14:15	Water			G	12	√	[redacted]	√	√	√	√	√	√	√	√

Relinquished by (Sampler Signature):	Date/Time: Aug 2nd/18	Company: **Golder Associates**	Received by (Signature): Tianli Liu	Company:
Relinquished by (Signature):	Date/Time: Aug 2nd/18	Company:	Received by (Signature):	Company:
Sampler (Printed Name): Haley Macpherson.	Sample Storage Temperature prior to Shipping (deg. C):	Sample Receipt Temperature (deg. C): 15.5	**SAMPLE CONDITION (lab use only)** Samples Received in Good Condition? Yes / No (If no, provide details.)	

13.5J

Recheck Analysis Report

Recheck #: **RC44493**
Dept #: **85110**
Dept: **Water Q. Analysis, Vancouver**

Due Date: **14-Sep-2018**
Issued By: **Rick Zolkiewski**
Date Initiated: **07-Sep-2018**
Original Results reported to Client: **Yes**

Recheck Comments:

TKN data confirmed by reanalysis (MS recovery 104.8%).TN confirmed by reanalysis, PO4 confirmed by re-analyse.

Reason for Recheck

Dissolved parameter significantly higher than total parameter

Sample # / Analyte	Account Name / Original Result	Units	LOR	Product / Recheck Result	RPD	Matrix / Recheck Result 2	Original Measure Date / RPD 2	UCL	Original Workgroup / Recheck Measure date	Original Analyst / Recheck Workgroup
L2140607-5	**Golder Associates Ltd.~Yellowknife**			**N-T-COL-VA**		**Water**	**14-Aug-2018**		**WG2849508**	**CWT**
Total Nitrogen	2.14	mg/L	0.30	2.48211	14.8	2.413574	12	20	09-Sep-2018	WG2872649
L2140607-5	**Golder Associates Ltd.~Yellowknife**			**P-T-PRES-COL-VA**		**Water**	**06-Aug-2018**		**WG2842050**	**NS4**
Phosphorus (P)-Total	0.0711	mg/L	0.0020	0.0795	11.2	0.0801	11.9	20	08-Sep-2018	WG2871439
L2140607-5	**Golder Associates Ltd.~Yellowknife**			**P-TD-PRES-COL-VA**		**Water**	**06-Aug-2018**		**WG2842073**	**NS4**
Phosphorus (P)-Total Dissolved	0.110	mg/L	0.02	0.0975	12	0.100	9.5	20	08-Sep-2018	WG2871440
L2140607-5	**Golder Associates Ltd.~Yellowknife**			**TKN-F-VA**		**Water**	**08-Aug-2018**		**WG2844335**	**FA**
Total Kjeldahl Nitrogen	1.55	mg/L	0.05	1.5	3.3			20	10-Sep-2018	WG2872804

Sample Comments:

L2140607-5 HG146(T), M362, N135, NP209, W698 ((BB))

Analyst Comments:

Golder Associates Ltd.
ATTN: Tamara Darwish
9 - 4905 48 Street
Yellowknife NT X1A 3S3

Date Received: 27-SEP-18
Report Date: 22-OCT-18 11:40 (MT)
Version: FINAL REV. 3

Client Phone: 867-873-6319

Certificate of Analysis

Lab Work Order #: L2171875

Project P.O. #:	NOT SUBMITTED
Job Reference:	1894709-8000-8050 JACKFISH BASELINE SAMPLING
C of C Numbers:	2018-09000
Legal Site Desc:	

Comments: ADDITIONAL 22-OCT-18 11:21

Please refer to the ALS Excel report for identification of parameters where the Limit of Reporting (LOR) has been raised. Where an LOR has been increased, and a specific qualifier is not listed in the report, the sample required dilution prior to analysis due to sample matrix effects (e.g. chemical interference, colour, turbidity, electrical conductivity) or due to the elevated concentration of one or more analytes in the sample. This will apply to results reported above the increased LOR.

Rick Zolkiewski
General Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2171875-1	L2171875-2	L2171875-3	L2171875-4	L2171875-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	26-SEP-18	26-SEP-18	26-SEP-18	26-SEP-18	26-SEP-18
	Sampled Time	14:00	14:30	13:15	13:15	11:30
	Client ID	2018-09-01	2018-09-02	2018-09-03	2018-09-04	2018-09-05
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)	449	454	457	454	451
	Hardness (as CaCO3) (mg/L)	157	155	155	155	157
	pH (pH)	8.40	8.40	8.39	8.39	8.37
	Total Suspended Solids (mg/L)	13.8	12.6	12.0	11.8	14.0
	Total Dissolved Solids (mg/L)	250	266	274	267	265
	TDS (Calculated) (mg/L)	259	256	255	256	258
	Turbidity (NTU)	15.2	16.2	16.2	14.7	16.1
Anions and Nutrients	Alkalinity, Bicarbonate (as CaCO3) (mg/L)	109	110	109	110	112
	Alkalinity, Carbonate (as CaCO3) (mg/L)	5.0	4.8	5.2	4.8	3.8
	Alkalinity, Hydroxide (as CaCO3) (mg/L)	<1.0	<1.0	<1.0	<1.0	<1.0
	Alkalinity, Phenolphthalein (as CaCO3) (mg/L)	2.5	2.4	2.6	2.4	<2.0
	Alkalinity, Total (as CaCO3) (mg/L)	114	115	114	115	116
	Ammonia, Total (as N) (mg/L)	0.0098	0.0071	0.0194	0.0100	0.0141
	Bromide (Br) (mg/L)	0.052	0.061	0.058	0.058	0.052
	Chloride (Cl) (mg/L)	56.8	56.7	56.8	56.8	56.8
	Fluoride (F) (mg/L)	0.096	0.095	0.095	0.096	0.095
	Nitrate and Nitrite (as N) (mg/L)					
	Nitrate (as N) (mg/L)					
	Nitrite (as N) (mg/L)					
	Total Kjeldahl Nitrogen (mg/L)	1.51	1.48	1.49	1.42	1.47
	Total Nitrogen (mg/L)	1.50	1.49	1.44	1.42	1.45
	Orthophosphate-Dissolved (as P) (mg/L)					
	Phosphorus (P)-Total (mg/L)	0.116	0.105	0.106	0.138	0.118
	Phosphorus (P)-Total Dissolved (mg/L)	0.0159	0.0152	0.0143	0.0168	0.0160
	Silicate (as SiO2) (mg/L)					
	Sulfate (SO4) (mg/L)	29.1	29.1	29.2	29.1	29.1
	Anion Sum (meq/L)	4.50	4.50	4.50	4.50	4.52
	Cation Sum (meq/L)	4.64	4.57	4.54	4.57	4.60
	Cation - Anion Balance (%)	1.6	0.8	0.4	0.7	0.9
Organic / Inorganic Carbon	Total Organic Carbon (mg/L)	13.0	11.4	11.2	11.2	12.0
Total Metals	Aluminum (Al)-Total (mg/L)	0.0086	0.0067	0.0089	0.0051	0.0097
	Antimony (Sb)-Total (mg/L)	0.00143	0.00142	0.00139	0.00139	0.00136
	Arsenic (As)-Total (mg/L)	0.0846	0.0835	0.0854	0.0820	0.0795
	Barium (Ba)-Total (mg/L)	0.0328	0.0313	0.0326	0.0326	0.0300
	Beryllium (Be)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Bismuth (Bi)-Total (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2171875-6	L2171875-7	L2171875-8	L2171875-9	L2171875-10
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	26-SEP-18	26-SEP-18	26-SEP-18	25-SEP-18	26-SEP-18
	Sampled Time	10:00	11:00	10:00	18:00	11:30
	Client ID	2018-09-06	2018-09-07	2018-09-08	2018-09-09	2018-09-10
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)	453	454	452	<2.0	<2.0
	Hardness (as CaCO3) (mg/L)	154	156	157	<0.50	<0.50
	pH (pH)	8.38	8.42	8.44	5.62	5.60
	Total Suspended Solids (mg/L)	13.6	13.0	10.2	<3.0	<3.0
	Total Dissolved Solids (mg/L)	270	254	266	<10	<10
	TDS (Calculated) (mg/L)	255	257	258	<1.0	<1.0
	Turbidity (NTU)	13.7	15.8	15.1	<0.10	<0.10
Anions and Nutrients	Alkalinity, Bicarbonate (as CaCO3) (mg/L)	110	111	109	<1.0	<1.0
	Alkalinity, Carbonate (as CaCO3) (mg/L)	4.6	5.2	6.0	<1.0	<1.0
	Alkalinity, Hydroxide (as CaCO3) (mg/L)	<1.0	<1.0	<1.0	<1.0	<1.0
	Alkalinity, Phenolphthalein (as CaCO3) (mg/L)	2.3	2.6	3.0	<2.0	<2.0
	Alkalinity, Total (as CaCO3) (mg/L)	115	116	115	<1.0	<1.0
	Ammonia, Total (as N) (mg/L)	0.0138	0.0094	0.0150	<0.0050	<0.0050
	Bromide (Br) (mg/L)	<0.050	0.059	0.058	<0.050	<0.050
	Chloride (Cl) (mg/L)	56.7	56.7	56.7	<0.50	<0.50
	Fluoride (F) (mg/L)	0.094	0.095	0.095	<0.020	<0.020
	Nitrate and Nitrite (as N) (mg/L)					
	Nitrate (as N) (mg/L)					
	Nitrite (as N) (mg/L)					
	Total Kjeldahl Nitrogen (mg/L)	1.52	1.45	1.43	<0.050	<0.050
	Total Nitrogen (mg/L)	1.54	1.46	1.48	0.051	0.031
	Orthophosphate-Dissolved (as P) (mg/L)					
	Phosphorus (P)-Total (mg/L)	0.101	0.098	0.091	<0.0020	<0.0020
	Phosphorus (P)-Total Dissolved (mg/L)	0.0153	0.0141	0.0178	<0.0020	<0.0020
	Silicate (as SiO2) (mg/L)					
	Sulfate (SO4) (mg/L)	29.1	29.1	29.1	<0.30	<0.30
	Anion Sum (meq/L)	4.51	4.52	4.51	<0.10	<0.10
	Cation Sum (meq/L)	4.54	4.59	4.64	<0.10	<0.10
	Cation - Anion Balance (%)	0.4	0.7	1.4	0.0	0.0
Organic / Inorganic Carbon	Total Organic Carbon (mg/L)	11.2	11.9	12.1	<0.50	<0.50
Total Metals	Aluminum (Al)-Total (mg/L)	0.0061	0.0067	0.0062	<0.0030	<0.0030
	Antimony (Sb)-Total (mg/L)	0.00141	0.00137	0.00141	<0.00010	<0.00010
	Arsenic (As)-Total (mg/L)	0.0858	0.0842	0.0827	<0.00010	<0.00010
	Barium (Ba)-Total (mg/L)	0.0322	0.0319	0.0318	<0.00010	<0.00010
	Beryllium (Be)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Bismuth (Bi)-Total (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2171875-11	L2171875-12	L2171875-13	L2171875-14	L2171875-15
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	26-SEP-18	26-SEP-18	26-SEP-18	26-SEP-18	26-SEP-18
	Sampled Time	14:00	14:30	13:15	13:15	11:30
	Client ID	2018-09-01 ROUTINE 2	2018-09-02 ROUTINE 2	2018-09-03 ROUTINE 2	2018-09-04 ROUTINE 2	2018-09-05 ROUTINE 2
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)					
	Hardness (as CaCO3) (mg/L)					
	pH (pH)					
	Total Suspended Solids (mg/L)					
	Total Dissolved Solids (mg/L)					
	TDS (Calculated) (mg/L)					
	Turbidity (NTU)					
Anions and Nutrients	Alkalinity, Bicarbonate (as CaCO3) (mg/L)					
	Alkalinity, Carbonate (as CaCO3) (mg/L)					
	Alkalinity, Hydroxide (as CaCO3) (mg/L)					
	Alkalinity, Phenolphthalein (as CaCO3) (mg/L)					
	Alkalinity, Total (as CaCO3) (mg/L)					
	Ammonia, Total (as N) (mg/L)					
	Bromide (Br) (mg/L)					
	Chloride (Cl) (mg/L)					
	Fluoride (F) (mg/L)					
	Nitrate and Nitrite (as N) (mg/L)	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051
	Nitrate (as N) (mg/L)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
	Nitrite (as N) (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Total Kjeldahl Nitrogen (mg/L)					
	Total Nitrogen (mg/L)					
	Orthophosphate-Dissolved (as P) (mg/L)	0.0051	0.0047	0.0050	0.0068	0.0046
	Phosphorus (P)-Total (mg/L)					
	Phosphorus (P)-Total Dissolved (mg/L)					
	Silicate (as SiO2) (mg/L)	12.7	12.2	12.7	12.1	11.5
	Sulfate (SO4) (mg/L)					
	Anion Sum (meq/L)					
	Cation Sum (meq/L)					
	Cation - Anion Balance (%)					
Organic / Inorganic Carbon	Total Organic Carbon (mg/L)					
Total Metals	Aluminum (Al)-Total (mg/L)					
	Antimony (Sb)-Total (mg/L)					
	Arsenic (As)-Total (mg/L)					
	Barium (Ba)-Total (mg/L)					
	Beryllium (Be)-Total (mg/L)					
	Bismuth (Bi)-Total (mg/L)					

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2171875-16	L2171875-17	L2171875-18	L2171875-19	L2171875-20
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	26-SEP-18	26-SEP-18	26-SEP-18	25-SEP-18	26-SEP-18
	Sampled Time	10:00	11:00	10:00	18:00	11:30
	Client ID	2018-09-06 ROUTINE 2	2018-09-07 ROUTINE 2	2018-09-08 ROUTINE 2	2018-09-09 ROUTINE 2	2018-09-10 ROUTINE 2
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)					
	Hardness (as CaCO3) (mg/L)					
	pH (pH)					
	Total Suspended Solids (mg/L)					
	Total Dissolved Solids (mg/L)					
	TDS (Calculated) (mg/L)					
	Turbidity (NTU)					
Anions and Nutrients	Alkalinity, Bicarbonate (as CaCO3) (mg/L)					
	Alkalinity, Carbonate (as CaCO3) (mg/L)					
	Alkalinity, Hydroxide (as CaCO3) (mg/L)					
	Alkalinity, Phenolphthalein (as CaCO3) (mg/L)					
	Alkalinity, Total (as CaCO3) (mg/L)					
	Ammonia, Total (as N) (mg/L)					
	Bromide (Br) (mg/L)					
	Chloride (Cl) (mg/L)					
	Fluoride (F) (mg/L)					
	Nitrate and Nitrite (as N) (mg/L)	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051
	Nitrate (as N) (mg/L)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
	Nitrite (as N) (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Total Kjeldahl Nitrogen (mg/L)					
	Total Nitrogen (mg/L)					
	Orthophosphate-Dissolved (as P) (mg/L)	0.0046	0.0043	0.0042	<0.0010	<0.0010
	Phosphorus (P)-Total (mg/L)					
	Phosphorus (P)-Total Dissolved (mg/L)					
	Silicate (as SiO2) (mg/L)	12.1	12.6	12.0	<0.50	<0.50
	Sulfate (SO4) (mg/L)					
	Anion Sum (meq/L)					
	Cation Sum (meq/L)					
	Cation - Anion Balance (%)					
Organic / Inorganic Carbon	Total Organic Carbon (mg/L)					
Total Metals	Aluminum (Al)-Total (mg/L)					
	Antimony (Sb)-Total (mg/L)					
	Arsenic (As)-Total (mg/L)					
	Barium (Ba)-Total (mg/L)					
	Beryllium (Be)-Total (mg/L)					
	Bismuth (Bi)-Total (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2171875-1	L2171875-2	L2171875-3	L2171875-4	L2171875-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	26-SEP-18	26-SEP-18	26-SEP-18	26-SEP-18	26-SEP-18
	Sampled Time	14:00	14:30	13:15	13:15	11:30
	Client ID	2018-09-01	2018-09-02	2018-09-03	2018-09-04	2018-09-05
Grouping	**Analyte**					
WATER						
Total Metals	Boron (B)-Total (mg/L)	0.029	0.028	0.029	0.029	0.028
	Cadmium (Cd)-Total (mg/L)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
	Calcium (Ca)-Total (mg/L)	37.9	37.5	38.0	37.7	36.4
	Cesium (Cs)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Chromium (Cr)-Total (mg/L)	0.00018	0.00011	0.00040	<0.00010	0.00013
	Cobalt (Co)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Copper (Cu)-Total (mg/L)	0.00145	0.00141	0.00152	0.00134	0.00134
	Iron (Fe)-Total (mg/L)	0.015	0.012	0.013	<0.010	0.015
	Lead (Pb)-Total (mg/L)	0.000068	<0.000050	<0.000050	<0.000050	<0.000050
	Lithium (Li)-Total (mg/L)	0.0062	0.0062	0.0061	0.0062	0.0060
	Magnesium (Mg)-Total (mg/L)	12.7	12.6	12.6	11.8	11.8
	Manganese (Mn)-Total (mg/L)	0.0292	0.0285	0.0289	0.0275	0.0275
	Mercury (Hg)-Total (mg/L)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
	Molybdenum (Mo)-Total (mg/L)	0.000268	0.000247	0.000233	0.000238	0.000238
	Nickel (Ni)-Total (mg/L)	0.00055	0.00053	0.00053	<0.00050	<0.00050
	Phosphorus (P)-Total (mg/L)	0.104	0.101	0.090	0.082	0.091
	Potassium (K)-Total (mg/L)	4.22	4.26	4.09	4.11	4.01
	Rubidium (Rb)-Total (mg/L)	0.00258	0.00259	0.00272	0.00257	0.00247
	Selenium (Se)-Total (mg/L)	<0.000050	0.000060	<0.000050	<0.000050	0.000059
	Silicon (Si)-Total (mg/L)	5.71	5.66	5.69	5.61	5.61
	Silver (Ag)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Sodium (Na)-Total (mg/L)	29.4	28.8	29.6	28.3	27.0
	Strontium (Sr)-Total (mg/L)	0.0989	0.0947	0.0945	0.0932	0.0940
	Sulfur (S)-Total (mg/L)	11.0	10.6	11.2	10.9	10.6
	Tellurium (Te)-Total (mg/L)	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
	Thallium (Tl)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Thorium (Th)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Tin (Sn)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Titanium (Ti)-Total (mg/L)	0.00034	<0.00030	<0.00030	<0.00030	0.00030
	Tungsten (W)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Uranium (U)-Total (mg/L)	0.000585	0.000561	0.000548	0.000524	0.000524
	Vanadium (V)-Total (mg/L)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
	Zinc (Zn)-Total (mg/L)	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
	Zirconium (Zr)-Total (mg/L)	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060
Dissolved Metals	Dissolved Metals Filtration Location	FIELD	FIELD	FIELD	FIELD	FIELD
	Calcium (Ca)-Dissolved (mg/L)	42.3	41.8	41.8	41.8	42.2
	Magnesium (Mg)-Dissolved (mg/L)	12.5	12.4	12.3	12.4	12.5

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2171875-6	L2171875-7	L2171875-8	L2171875-9	L2171875-10
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	26-SEP-18	26-SEP-18	26-SEP-18	25-SEP-18	26-SEP-18
	Sampled Time	10:00	11:00	10:00	18:00	11:30
	Client ID	2018-09-06	2018-09-07	2018-09-08	2018-09-09	2018-09-10
Grouping	**Analyte**					
WATER						
Total Metals	Boron (B)-Total (mg/L)	0.029	0.029	0.029	<0.010	<0.010
	Cadmium (Cd)-Total (mg/L)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
	Calcium (Ca)-Total (mg/L)	38.6	38.8	37.7	<0.050	<0.050
	Cesium (Cs)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Chromium (Cr)-Total (mg/L)	<0.00010	0.00021	<0.00010	<0.00010	<0.00010
	Cobalt (Co)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Copper (Cu)-Total (mg/L)	0.00140	0.00141	0.00137	<0.00050	<0.00050
	Iron (Fe)-Total (mg/L)	0.011	0.012	0.010	<0.010	<0.010
	Lead (Pb)-Total (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
	Lithium (Li)-Total (mg/L)	0.0063	0.0062	0.0062	<0.0010	<0.0010
	Magnesium (Mg)-Total (mg/L)	12.5	12.3	12.0	<0.0050	<0.0050
	Manganese (Mn)-Total (mg/L)	0.0303	0.0267	0.0290	<0.00010	<0.00010
	Mercury (Hg)-Total (mg/L)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
	Molybdenum (Mo)-Total (mg/L)	0.000229	0.000235	0.000252	<0.000050	<0.000050
	Nickel (Ni)-Total (mg/L)	0.00053	<0.00050	<0.00050	<0.00050	<0.00050
	Phosphorus (P)-Total (mg/L)	0.086	0.103	0.090	<0.050	<0.050
	Potassium (K)-Total (mg/L)	4.21	4.23	4.07	<0.050	<0.050
	Rubidium (Rb)-Total (mg/L)	0.00258	0.00259	0.00258	<0.00020	<0.00020
	Selenium (Se)-Total (mg/L)	<0.000050	0.000060	<0.000050	<0.000050	<0.000050
	Silicon (Si)-Total (mg/L)	5.86	5.79	5.58	<0.10	<0.10
	Silver (Ag)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Sodium (Na)-Total (mg/L)	29.3	28.9	28.2	<0.050	<0.050
	Strontium (Sr)-Total (mg/L)	0.0966	0.0942	0.0963	<0.00020	<0.00020
	Sulfur (S)-Total (mg/L)	11.0	11.2	10.9	<0.50	<0.50
	Tellurium (Te)-Total (mg/L)	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
	Thallium (Tl)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Thorium (Th)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Tin (Sn)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Titanium (Ti)-Total (mg/L)	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
	Tungsten (W)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Uranium (U)-Total (mg/L)	0.000556	0.000554	0.000537	<0.000010	<0.000010
	Vanadium (V)-Total (mg/L)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
	Zinc (Zn)-Total (mg/L)	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
	Zirconium (Zr)-Total (mg/L)	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060
Dissolved Metals	Dissolved Metals Filtration Location	FIELD	FIELD	FIELD	FIELD	FIELD
	Calcium (Ca)-Dissolved (mg/L)	41.6	41.9	42.3	<0.050	<0.050
	Magnesium (Mg)-Dissolved (mg/L)	12.2	12.4	12.5	<0.10	<0.10

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2171875-11	L2171875-12	L2171875-13	L2171875-14	L2171875-15
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	26-SEP-18	26-SEP-18	26-SEP-18	26-SEP-18	26-SEP-18
	Sampled Time	14:00	14:30	13:15	13:15	11:30
	Client ID	2018-09-01 ROUTINE 2	2018-09-02 ROUTINE 2	2018-09-03 ROUTINE 2	2018-09-04 ROUTINE 2	2018-09-05 ROUTINE 2
Grouping	**Analyte**					
WATER						
Total Metals	Boron (B)-Total (mg/L)					
	Cadmium (Cd)-Total (mg/L)					
	Calcium (Ca)-Total (mg/L)					
	Cesium (Cs)-Total (mg/L)					
	Chromium (Cr)-Total (mg/L)					
	Cobalt (Co)-Total (mg/L)					
	Copper (Cu)-Total (mg/L)					
	Iron (Fe)-Total (mg/L)					
	Lead (Pb)-Total (mg/L)					
	Lithium (Li)-Total (mg/L)					
	Magnesium (Mg)-Total (mg/L)					
	Manganese (Mn)-Total (mg/L)					
	Mercury (Hg)-Total (mg/L)					
	Molybdenum (Mo)-Total (mg/L)					
	Nickel (Ni)-Total (mg/L)					
	Phosphorus (P)-Total (mg/L)					
	Potassium (K)-Total (mg/L)					
	Rubidium (Rb)-Total (mg/L)					
	Selenium (Se)-Total (mg/L)					
	Silicon (Si)-Total (mg/L)					
	Silver (Ag)-Total (mg/L)					
	Sodium (Na)-Total (mg/L)					
	Strontium (Sr)-Total (mg/L)					
	Sulfur (S)-Total (mg/L)					
	Tellurium (Te)-Total (mg/L)					
	Thallium (Tl)-Total (mg/L)					
	Thorium (Th)-Total (mg/L)					
	Tin (Sn)-Total (mg/L)					
	Titanium (Ti)-Total (mg/L)					
	Tungsten (W)-Total (mg/L)					
	Uranium (U)-Total (mg/L)					
	Vanadium (V)-Total (mg/L)					
	Zinc (Zn)-Total (mg/L)					
	Zirconium (Zr)-Total (mg/L)					
Dissolved Metals	Dissolved Metals Filtration Location					
	Calcium (Ca)-Dissolved (mg/L)					
	Magnesium (Mg)-Dissolved (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2171875-16	L2171875-17	L2171875-18	L2171875-19	L2171875-20
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	26-SEP-18	26-SEP-18	26-SEP-18	25-SEP-18	26-SEP-18
	Sampled Time	10:00	11:00	10:00	18:00	11:30
	Client ID	2018-09-06 ROUTINE 2	2018-09-07 ROUTINE 2	2018-09-08 ROUTINE 2	2018-09-09 ROUTINE 2	2018-09-10 ROUTINE 2
Grouping	**Analyte**					
WATER						
Total Metals	Boron (B)-Total (mg/L)					
	Cadmium (Cd)-Total (mg/L)					
	Calcium (Ca)-Total (mg/L)					
	Cesium (Cs)-Total (mg/L)					
	Chromium (Cr)-Total (mg/L)					
	Cobalt (Co)-Total (mg/L)					
	Copper (Cu)-Total (mg/L)					
	Iron (Fe)-Total (mg/L)					
	Lead (Pb)-Total (mg/L)					
	Lithium (Li)-Total (mg/L)					
	Magnesium (Mg)-Total (mg/L)					
	Manganese (Mn)-Total (mg/L)					
	Mercury (Hg)-Total (mg/L)					
	Molybdenum (Mo)-Total (mg/L)					
	Nickel (Ni)-Total (mg/L)					
	Phosphorus (P)-Total (mg/L)					
	Potassium (K)-Total (mg/L)					
	Rubidium (Rb)-Total (mg/L)					
	Selenium (Se)-Total (mg/L)					
	Silicon (Si)-Total (mg/L)					
	Silver (Ag)-Total (mg/L)					
	Sodium (Na)-Total (mg/L)					
	Strontium (Sr)-Total (mg/L)					
	Sulfur (S)-Total (mg/L)					
	Tellurium (Te)-Total (mg/L)					
	Thallium (Tl)-Total (mg/L)					
	Thorium (Th)-Total (mg/L)					
	Tin (Sn)-Total (mg/L)					
	Titanium (Ti)-Total (mg/L)					
	Tungsten (W)-Total (mg/L)					
	Uranium (U)-Total (mg/L)					
	Vanadium (V)-Total (mg/L)					
	Zinc (Zn)-Total (mg/L)					
	Zirconium (Zr)-Total (mg/L)					
Dissolved Metals	Dissolved Metals Filtration Location					
	Calcium (Ca)-Dissolved (mg/L)					
	Magnesium (Mg)-Dissolved (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2171875-1	L2171875-2	L2171875-3	L2171875-4	L2171875-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	26-SEP-18	26-SEP-18	26-SEP-18	26-SEP-18	26-SEP-18
	Sampled Time	14:00	14:30	13:15	13:15	11:30
	Client ID	2018-09-01	2018-09-02	2018-09-03	2018-09-04	2018-09-05
Grouping	**Analyte**					
WATER						
Dissolved Metals	Potassium (K)-Dissolved (mg/L)	4.5	4.3	4.3	4.3	4.3
	Sodium (Na)-Dissolved (mg/L)	31.9	31.1	30.8	31.2	31.2

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2171875-6	L2171875-7	L2171875-8	L2171875-9	L2171875-10
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	26-SEP-18	26-SEP-18	26-SEP-18	25-SEP-18	26-SEP-18
	Sampled Time	10:00	11:00	10:00	18:00	11:30
	Client ID	2018-09-06	2018-09-07	2018-09-08	2018-09-09	2018-09-10
Grouping	**Analyte**					
WATER						
Dissolved Metals	Potassium (K)-Dissolved (mg/L)	4.2	4.3	4.4	<2.0	<2.0
	Sodium (Na)-Dissolved (mg/L)	31.1	31.3	31.8	<2.0	<2.0

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2171875-11	L2171875-12	L2171875-13	L2171875-14	L2171875-15
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	26-SEP-18	26-SEP-18	26-SEP-18	26-SEP-18	26-SEP-18
	Sampled Time	14:00	14:30	13:15	13:15	11:30
	Client ID	2018-09-01 ROUTINE 2	2018-09-02 ROUTINE 2	2018-09-03 ROUTINE 2	2018-09-04 ROUTINE 2	2018-09-05 ROUTINE 2
Grouping	**Analyte**					
WATER						
Dissolved Metals	Potassium (K)-Dissolved (mg/L)					
	Sodium (Na)-Dissolved (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2171875-16	L2171875-17	L2171875-18	L2171875-19	L2171875-20
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	26-SEP-18	26-SEP-18	26-SEP-18	25-SEP-18	26-SEP-18
	Sampled Time	10:00	11:00	10:00	18:00	11:30
	Client ID	2018-09-06 ROUTINE 2	2018-09-07 ROUTINE 2	2018-09-08 ROUTINE 2	2018-09-09 ROUTINE 2	2018-09-10 ROUTINE 2
Grouping	**Analyte**					
WATER						
Dissolved Metals	Potassium (K)-Dissolved (mg/L)					
	Sodium (Na)-Dissolved (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Matrix Spike	Arsenic (As)-Total	MS-B	L2171875-1, -10, -2, -3, -4, -5, -6, -7, -8, -9
Matrix Spike	Barium (Ba)-Total	MS-B	L2171875-1, -10, -2, -3, -4, -5, -6, -7, -8, -9
Matrix Spike	Calcium (Ca)-Total	MS-B	L2171875-1, -10, -2, -3, -4, -5, -6, -7, -8, -9
Matrix Spike	Magnesium (Mg)-Total	MS-B	L2171875-1, -10, -2, -3, -4, -5, -6, -7, -8, -9
Matrix Spike	Manganese (Mn)-Total	MS-B	L2171875-1, -10, -2, -3, -4, -5, -6, -7, -8, -9
Matrix Spike	Potassium (K)-Total	MS-B	L2171875-1, -10, -2, -3, -4, -5, -6, -7, -8, -9
Matrix Spike	Sodium (Na)-Total	MS-B	L2171875-1, -10, -2, -3, -4, -5, -6, -7, -8, -9
Matrix Spike	Strontium (Sr)-Total	MS-B	L2171875-1, -10, -2, -3, -4, -5, -6, -7, -8, -9
Matrix Spike	Silicate (as SiO2)	MS-B	L2171875-15

Qualifiers for Individual Parameters Listed:

Qualifier	Description
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ALK-TITR-VA	Water	Alkalinity Species by Titration	APHA 2320 Alkalinity

This analysis is carried out using procedures adapted from APHA Method 2320 "Alkalinity". Total alkalinity is determined by potentiometric titration to a pH 4.5 endpoint. Bicarbonate, carbonate and hydroxide alkalinity are calculated from phenolphthalein alkalinity and total alkalinity values.

ANIONS-N+N-CALC-VA	Water	Nitrite & Nitrate in Water (Calculation)	EPA 300.0

Nitrate and Nitrite (as N) is a calculated parameter. Nitrate and Nitrite (as N) = Nitrite (as N) + Nitrate (as N).

BR-L-IC-N-VA	Water	Bromide in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

CARBONS-TOC-VA	Water	Total organic carbon by combustion	APHA 5310B TOTAL ORGANIC CARBON (TOC)

This analysis is carried out using procedures adapted from APHA Method 5310 "Total Organic Carbon (TOC)".

CL-IC-N-VA	Water	Chloride in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

EC-PCT-VA	Water	Conductivity (Automated)	APHA 2510 Auto. Conduc.

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

EC-SCREEN-VA	Water	Conductivity Screen (Internal Use Only)	APHA 2510

Qualitative analysis of conductivity where required during preparation of other tests - e.g. TDS, metals, etc.

F-IC-N-VA	Water	Fluoride in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

HARDNESS-CALC-VA	Water	Hardness	APHA 2340B

Hardness (also known as Total Hardness) is calculated from the sum of Calcium and Magnesium concentrations, expressed in CaCO3 equivalents. Dissolved Calcium and Magnesium concentrations are preferentially used for the hardness calculation.

HG-T-CVAA-VA	Water	Total Mercury in Water by CVAAS or CVAFS	EPA 1631E (mod)

Water samples undergo a cold-oxidation using bromine monochloride prior to reduction with stannous chloride, and analyzed by CVAAS or CVAFS.

IONBALANCE-VA	Water	Ion Balance Calculation	APHA 1030E

Cation Sum, Anion Sum, and Ion Balance (as % difference) are calculated based on guidance from APHA Standard Methods (1030E Checking Correctness of Analysis). Because all aqueous solutions are electrically neutral, the calculated ion balance (% difference of cations minus anions) should be near-zero.

Cation and Anion Sums are the total meq/L concentration of major cations and anions. Dissolved species are used where available. Minor ions are included where data is present. Ion Balance is calculated as:

Ion Balance (%) = [Cation Sum-Anion Sum] / [Cation Sum+Anion Sum]

MET-DIS-ICP-VA	Water	Dissolved Metals in Water by ICPOES	EPA SW-846 3005A/6010B

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United

Reference Information

States Environmental Protection Agency (EPA). The procedure involves filtration (EPA Method 3005A) and analysis by inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B).

MET-T-CCMS-VA | Water | Total Metals in Water by CRC ICPMS | EPA 200.2/6020A (mod)

Water samples are digested with nitric and hydrochloric acids, and analyzed by CRC ICPMS.

Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.

N-T-COL-VA | Water | Total Nitrogen in water by Colour | APHA4500-P(J)/NEMI9171/USGS03-4174

This analysis is carried out using procedures adapted from APHA Method 4500-P (J) "Persulphate Method for Simultaneous Determination of Total Nitrogen and Total Phosphorus" and National Environmental Methods Index - Nemi method 5735.

NH3-F-VA | Water | Ammonia in Water by Fluorescence | J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NO2-L-IC-N-VA | Water | Nitrite in Water by IC (Low Level) | EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

NO3-L-IC-N-VA | Water | Nitrate in Water by IC (Low Level) | EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

P-T-PRES-COL-VA | Water | Total P in Water by Colour | APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorus is determined colourimetrically after persulphate digestion of the sample.
Samples with very high dissolved solids (i.e. seawaters, brackish waters) may produce a negative bias by this method. Alternate methods are available for these types of samples.

Arsenic (5+), at elevated levels, is a positive interference on colourimetric phosphate analysis.

P-TD-PRES-COL-VA | Water | Total Dissolved P in Water by Colour | APHA 4500-P Phosphorous

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Dissolved Phosphorus is determined colourimetrically after persulphate digestion of a sample that has been lab or field filtered through a 0.45 micron membrane filter.
Samples with very high dissolved solids (i.e. seawaters, brackish waters) may produce a negative bias by this method. Alternate methods are available for these types of samples.

Arsenic (5+), at elevated levels, is a positive interference on colourimetric phosphate analysis.

PH-PCT-VA | Water | pH by Meter (Automated) | APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PO4-DO-COL-VA | Water | Diss. Orthophosphate in Water by Colour | APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.
Samples with very high dissolved solids (i.e. seawaters, brackish waters) may produce a negative bias by this method. Alternate methods are available for these types of samples.

Arsenic (5+), at elevated levels, is a positive interference on colourimetric phosphate analysis.

SILICATE-COL-VA | Water | Silicate by Colourimetric analysis | APHA 4500-SiO2 E.

This analysis is carried out using procedures adapted from APHA Method 4500-SiO2 E. "Silica". Silicate (molybdate-reactive silica) is determined by the molybdosilicate-heteropoly blue colourimetric method. Arsenic (5+) above 100 mg/L is a negative interference on this test.

SO4-IC-N-VA | Water | Sulfate in Water by IC | EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

TDS-CALC-VA | Water | TDS (Calculated) | APHA 1030E (20TH EDITION)

This analysis is carried out using procedures adapted from APHA 1030E "Checking Correctness of Analyses".
The Total Dissolved Solids result is calculated from measured concentrations of anions and cations in the sample.

TDS-VA | Water | Total Dissolved Solids by Gravimetric | APHA 2540 C - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Dissolved Solids (TDS) are determined by filtering a sample through a glass fibre filter, TDS is determined by evaporating the filtrate to dryness at 180 degrees celsius.

TKN-F-VA | Water | TKN in Water by Fluorescence | APHA 4500-NORG D.

Reference Information

This analysis is carried out using procedures adapted from APHA Method 4500-Norg D. "Block Digestion and Flow Injection Analysis". Total Kjeldahl Nitrogen is determined using block digestion followed by Flow-injection analysis with fluorescence detection.

TSS-VA	Water	Total Suspended Solids by Gravimetric	APHA 2540 D - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Suspended Solids (TSS) are determined by filtering a sample through a glass fibre filter, TSS is determined by drying the filter at 104 degrees celsius.
Samples containing very high dissolved solid content (i.e. seawaters, brackish waters) may produce a positive bias by this method. Alternate analysis methods are available for these types of samples.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 Turbidity

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

2018-09000

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Lab Copy

Jackfish Lake
Chain-of-Custody Record - Analytical Request Form

CoC#: 2018-09000 Created: 24-09-18

From:

Golder Associates - Jackfish
Address: 6925 Century Ave #100 Mississauga, ON, L5N 7K2
Telephone: (905) 561-4444
Contact: Tamara Darwish TDarwish@golder.com

Send Samples For Analysis To:

ALS Group, Yellowknife
Address: 314 Old Airport Rd, Unit 116
Yellowknife, NT X1A 3T3
Phone: (867) 873-5593
Fax: (867) 920-4238
Contact: Rick Zolkiewski
Email: Rick.Zolkiewski@alsglobal.com

eMail Confirmation and Results To:

Please use full distribution list from quote
HMacpherson@golder.com
MMiller@ntpc.com
GAL_EQUIS@golder.com
AHumphries@golder.com
TDarwish@golder.com

Send Original Signed Lab Reports To:

Golder Associates Ltd.
Address: 9, 4905-48 Street
Yellowknife, NT, X1A 3S3
Telephone: (867) 873-6319
Fax: (867) 873-6379
Contact: Haley Macpherson
hmacpherson@golder.com

Send Invoice To:

Golder Associates Ltd.
Address: 6925 Century Ave #100
Mississauga, ON, L5N 7K2
Telephone: (905) 561-4444
Fax: (905) 567-6561
ATTN: Tamara Darwish
TDarwish@golder.com

FIELD SAMPLE INFORMATION

Fields Notes:
Filter and preserve dissolved parameters.

L2171875

Please ensure that there is only one COC per report. Use email confirmation and results list on this COC.

Facilty Code: 183527250

Project # 1894709-8000-8050
Jackfish Baseline Sampling

Quote # Q66233

L2171875-COFC

REQUESTED LAB SUITES (see reverse side for details)

√ = Preserved :
√ = Field Filtered :
√ = 1-Day Rush :

Sample Control Number	Lab Sample ID	Sample Date (dd-mmm-yy)	Sample Time (hh:mm)	Matrix	Laboratory Comments	Sampler Comments	G = Grab or C = Composite	Number of Containers	Routine 1 (pH, conductivity, hardness, alkalinity, tss, tds (measured and calculated), anions, turbidity)	Routine 2 (orthophosphte, NO_2, NO_3, silica)	Total metals	Dissolved metals (major cations Ca, Mg, K, and Na only)	Total mercury	Total Nutrients: TKN, NH3, TOC, TP, TN	Dissolved nutrients: TDP
2018-09-01		26-09-18	14:00	Water			G	1	√	√	√	√	√	√	√
2018-09-02		26-09-18	14:30	Water			G	1	√	√	√	√	√	√	√
2018-09-03		26-09-18	13:15	Water			G	1	√	√	√	√	√	√	√
2018-09-04		26-09-18	13:15	Water			G	1	√	√	√	√	√	√	√
2018-09-05		26-09-18	11:30	Water			G	1	√	√	√	√	√	√	√
2018-09-06		26-09-18	10:00	Water			G	1	√	√	√	√	√	√	√
2018-09-07		26-09-18	11:00	Water			G	1	√	√	√	√	√	√	√
2018-09-08		26-09-18	10:00	Water			G	1	√	√	√	√	√	√	√

Relinquished by (Sampler Signature): Haley	Date/Time: 26/09/18	Company: Golder Associates	Received by (Signature): 11.35 27/9	Company: ALS
Relinquished by (Signature):	Date/Time:	Company:	Received by (Signature):	Company:

		SAMPLE CONDITION (lab use only)	
Sampler (Printed Name): Haley Macpherson	Sample Storage Temperature prior to Shipping (deg. C):	Sample Receipt Temperature (deg. C): 5.6	Samples Received in Good Condition? Yes / No (If no, provide details.)

Lab Copy

Jackfish Lake
Chain-of-Custody Record - Analytical Request Form

CoC#: 2018-09000 Created: 24-09-18

From:

Golder Associates - Jackfish
Address: 6925 Century Ave #100
Mississauga, ON, L5N 7K2
Telephone: (905) 561-4444
Contact: Tamara Darwish
TDarwish@golder.com

Send Samples For Analysis To:

ALS Group, Yellowknife
Address: 314 Old Airport Rd, Unit 116
Yellowknife, NT X1A 3T3
Phone: (867) 873-5593
Fax: (867) 920-4238
Contact: Rick Zolkiewski
Email: Rick.Zolkiewski@alsglobal.com

eMail Confirmation and Results To:

Please use full distribution list from quote
HMacpherson@golder.com
MMiller@ntpc.com
GAL_EQUIS@golder.com
AHumphries@golder.com
TDarwish@golder.com

Send Original Signed Lab Reports To:

Golder Associates Ltd.
Address: 9, 4905-48 Street
Yellowknife, NT, X1A 3S3
Telephone: (867) 873-6319
Fax: (867) 873-6379
Contact: Haley Macpherson
hmacpherson@golder.com

Send Invoice To:

Golder Associates Ltd.
Address: 6925 Century Ave #100
Mississauga, ON, L5N 7K2
Telephone: (905) 561-4444
Fax: (905) 567-6561
ATTN: Tamara Darwish
TDarwish@golder.com

FIELD SAMPLE INFORMATION

Fields Notes:
Filter and preserve dissolved parameters.
Please ensure that there is only one COC per report. Use email confirmation and results list on this COC

Facilty Code: 183527250

Project # 1894709-8000-8050
Jackfish Baseline Sampling

Quote # Q66233

REQUESTED LAB SUITES (see reverse side for details)

	Routine 1 (pH, conductivity, hardness, alkalinity, tss, tds (measured and calculated), anions, turbidity)	Routine 2 (orthophosphte, NO_2, NO_3, silica)	Total metals	Dissolved metals (major cations Ca, Mg, K, and Na only)	Total mercury	Total Nutrients: TKN, NH3, TOC, TP, TN	Dissolved nutrients: TDP
√ = Preserved :			√	√	√	√	√
√ = Field Filtered :				√			√
√ = 1-Day Rush :							

Sample Control Number	Lab Sample ID	Sample Date (dd-mmm-yy)	Sample Time (hh:mm)	Matrix	Laboratory Comments	Sampler Comments	G = Grab or C = Composite	Number of Containers	Routine 1	Routine 2	Total metals	Dissolved metals	Total mercury	Total Nutrients	Dissolved nutrients: TDP
2018-09-09		25-09-18	18:00	Water			G	1	√	√	√	√	√	√	√
2018-09-10		26-09-18	11:30	Water			G	1	√	√	√	√	√	√	√
2018-09-				Water			G	1	√	√	√	√	√	√	√
2018-09-				Water			G	1	√	√	√	√	√	√	√
2018-09-				Water			G	1	√	√	√	√	√	√	√
2018-09-				Water			G	1	√	√	√	√	√	√	√
2018-09-				Water			G	1	√	√	√	√	√	√	√
2018-09-				Water			G	1	√	√	√	√	√	√	√

Relinquished by (Sampler Signature): [signature]	Date/Time: 27/09/18	Company: **Golder Associates**	Received by (Signature): [signature] 11:35 27/9	Company: ALS
Relinquished by (Signature):	Date/Time:	Company:	Received by (Signature):	Company:

Sampler (Printed Name): Haley Macpherson	Sample Storage Temperature prior to Shipping (deg. C):	**SAMPLE CONDITION (lab use only)**
	Sample Receipt Temperature (deg. C): 5.6	Samples Received in Good Condition? Yes / No (If no, provide details.)

Golder Associates Ltd.
ATTN: TAMARA DARWISH
6925 CENTURY AVE #100
MISSISSAUGA ON L5N 7K2

Date Received: 14-DEC-18
Report Date: 07-JAN-19 09:20 (MT)
Version: FINAL

Client Phone: 905-561-4444

Certificate of Analysis

Lab Work Order #: L2210576

Project P.O. #:	NOT SUBMITTED
Job Reference:	1894709-9000-9050 JACKFISH BASELINE SAMPLING
C of C Numbers:	2018
Legal Site Desc:	

Oliver Gregg
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2210576-1	L2210576-2	L2210576-3	L2210576-4	L2210576-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	11-DEC-18	11-DEC-18	11-DEC-18	11-DEC-18	11-DEC-18
	Sampled Time	11:00	12:15	13:00	14:00	14:15
	Client ID	2018-12-01	2018-12-02	2018-12-03	2018-12-04	2018-12-05
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)	463	469	470	476	460
	Hardness (as CaCO3) (mg/L)	166	166	168	167	168
	pH (pH)	8.25	8.25	8.20	8.23	8.14
	Total Suspended Solids (mg/L)	13.4	13.0	12.6	19.0	13.4
	Total Dissolved Solids (mg/L)	299	312	277	300	297
	TDS (Calculated) (mg/L)	265	262	265	267	265
	Turbidity (NTU)	15.8	14.5	13.8	18.4	13.8
Anions and Nutrients	Alkalinity, Bicarbonate (as CaCO3) (mg/L)	112	114	118	119	118
	Alkalinity, Carbonate (as CaCO3) (mg/L)	<1.0	<1.0	<1.0	<1.0	<1.0
	Alkalinity, Hydroxide (as CaCO3) (mg/L)	<1.0	<1.0	<1.0	<1.0	<1.0
	Alkalinity, Phenolphthalein (as CaCO3) (mg/L)	<2.0	<2.0	<2.0	<2.0	<2.0
	Alkalinity, Total (as CaCO3) (mg/L)	112	114	118	119	118
	Ammonia, Total (as N) (mg/L)	0.0114	0.0118	0.0134	0.0105	0.0127
	Bromide (Br) (mg/L)	<0.050	<0.050	<0.050	<0.050	<0.050
	Chloride (Cl) (mg/L)	59.0	59.0	58.5	60.2	58.7
	Fluoride (F) (mg/L)	0.091	0.093	0.090	0.094	0.091
	Nitrate and Nitrite (as N) (mg/L)					
	Nitrate (as N) (mg/L)					
	Nitrite (as N) (mg/L)					
	Total Kjeldahl Nitrogen (mg/L)	1.72	1.78	1.62	1.80	1.42
	Total Nitrogen (mg/L)	1.66	1.64	1.68	1.66	1.39
	Orthophosphate-Dissolved (as P) (mg/L)					
	Phosphorus (P)-Total (mg/L)	0.0965	0.120	0.106	0.115	0.0840
	Phosphorus (P)-Total Dissolved (mg/L)	0.0115	0.0126	0.0118	0.0123	0.0119
	Silicate (as SiO2) (mg/L)					
	Sulfate (SO4) (mg/L)	29.5	29.6	29.6	30.3	29.4
	Anion Sum (meq/L)	4.53	4.57	4.63	4.70	4.63
	Cation Sum (meq/L)	4.90	4.71	4.79	4.73	4.79
	Cation - Anion Balance (%)	3.9	1.5	1.6	0.3	1.7
Organic / Inorganic Carbon	Total Organic Carbon (mg/L)	13.3	13.3	13.0	13.3	12.6
Total Metals	Aluminum (Al)-Total (mg/L)	0.0036	<0.0030	<0.0030	<0.0030	0.0042
	Antimony (Sb)-Total (mg/L)	0.00147	0.00139	0.00145	0.00142	0.00144
	Arsenic (As)-Total (mg/L)	0.0854	0.0850	0.0849	0.0856	0.0836
	Barium (Ba)-Total (mg/L)	0.0333	0.0357	0.0352	0.0356	0.0350
	Beryllium (Be)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Bismuth (Bi)-Total (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2210576-6	L2210576-7	L2210576-8	L2210576-9	L2210576-10
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	12-DEC-18	12-DEC-18	12-DEC-18	13-DEC-18	13-DEC-18
	Sampled Time	11:40	09:30	12:53	11:30	15:00
	Client ID	2018-12-06	2018-12-07	2018-12-08	2018-12-09	2018-12-10
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)	465	<2.0	462	463	<2.0
	Hardness (as CaCO3) (mg/L)	167	<0.50	166	165	<0.50
	pH (pH)	8.21	5.47	8.23	8.22	5.46
	Total Suspended Solids (mg/L)	15.4	<3.0	13.6	14.8	<3.0
	Total Dissolved Solids (mg/L)	301	<10	301	298	<10
	TDS (Calculated) (mg/L)	267	<1.0	266	265	<1.0
	Turbidity (NTU)	15.2	<0.10	15.0	15.7	<0.10
Anions and Nutrients	Alkalinity, Bicarbonate (as CaCO3) (mg/L)	117	<1.0	118	116	<1.0
	Alkalinity, Carbonate (as CaCO3) (mg/L)	<1.0	<1.0	<1.0	<1.0	<1.0
	Alkalinity, Hydroxide (as CaCO3) (mg/L)	<1.0	<1.0	<1.0	<1.0	<1.0
	Alkalinity, Phenolphthalein (as CaCO3) (mg/L)	<2.0	<2.0	<2.0	<2.0	<2.0
	Alkalinity, Total (as CaCO3) (mg/L)	117	<1.0	118	116	<1.0
	Ammonia, Total (as N) (mg/L)	0.0164	<0.0050	0.0171	0.0161	0.0096
	Bromide (Br) (mg/L)	<0.050	<0.050	<0.050	<0.050	<0.050
	Chloride (Cl) (mg/L)	59.1	<0.50	58.8	58.6	<0.50
	Fluoride (F) (mg/L)	0.093	<0.020	0.092	0.090	<0.020
	Nitrate and Nitrite (as N) (mg/L)					
	Nitrate (as N) (mg/L)					
	Nitrite (as N) (mg/L)					
	Total Kjeldahl Nitrogen (mg/L)	1.51	<0.050	1.55	2.06	<0.050
	Total Nitrogen (mg/L)	1.97	<0.030	1.87	2.19	<0.030
	Orthophosphate-Dissolved (as P) (mg/L)					
	Phosphorus (P)-Total (mg/L)	0.0932	<0.0020	0.104	0.156	<0.0020
	Phosphorus (P)-Total Dissolved (mg/L)	0.0123	<0.0020	0.0121	0.0154	<0.0020
	Silicate (as SiO2) (mg/L)					
	Sulfate (SO4) (mg/L)	29.7	<0.30	29.6	29.6	<0.30
	Anion Sum (meq/L)	4.63	<0.10	4.63	4.59	<0.10
	Cation Sum (meq/L)	4.85	<0.10	4.81	4.76	<0.10
	Cation - Anion Balance (%)	2.3	0.0	1.9	1.8	0.0
Organic / Inorganic Carbon	Total Organic Carbon (mg/L)	13.5	<0.50	12.7	13.8	<0.50
Total Metals	Aluminum (Al)-Total (mg/L)	<0.0030	<0.0030	<0.0030	0.0082	<0.0030
	Antimony (Sb)-Total (mg/L)	0.00142	<0.00010	0.00139	0.00139	<0.00010
	Arsenic (As)-Total (mg/L)	0.0861	<0.00010	0.0856	0.0839	<0.00010
	Barium (Ba)-Total (mg/L)	0.0363	<0.00010	0.0356	0.0350	<0.00010
	Beryllium (Be)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Bismuth (Bi)-Total (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2210576-11	L2210576-12	L2210576-13	L2210576-14	L2210576-15
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	11-DEC-18	11-DEC-18	11-DEC-18	11-DEC-18	11-DEC-18
	Sampled Time	11:00	12:15	13:00	14:00	14:15
	Client ID	2018-12-01	2018-12-02	2018-12-03	2018-12-04	2018-12-05
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)					
	Hardness (as CaCO3) (mg/L)					
	pH (pH)					
	Total Suspended Solids (mg/L)					
	Total Dissolved Solids (mg/L)					
	TDS (Calculated) (mg/L)					
	Turbidity (NTU)					
Anions and Nutrients	Alkalinity, Bicarbonate (as CaCO3) (mg/L)					
	Alkalinity, Carbonate (as CaCO3) (mg/L)					
	Alkalinity, Hydroxide (as CaCO3) (mg/L)					
	Alkalinity, Phenolphthalein (as CaCO3) (mg/L)					
	Alkalinity, Total (as CaCO3) (mg/L)					
	Ammonia, Total (as N) (mg/L)					
	Bromide (Br) (mg/L)					
	Chloride (Cl) (mg/L)					
	Fluoride (F) (mg/L)					
	Nitrate and Nitrite (as N) (mg/L)	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051
	Nitrate (as N) (mg/L)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
	Nitrite (as N) (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Total Kjeldahl Nitrogen (mg/L)					
	Total Nitrogen (mg/L)					
	Orthophosphate-Dissolved (as P) (mg/L)	0.0044	0.0057	0.0051	0.0049	0.0046
	Phosphorus (P)-Total (mg/L)					
	Phosphorus (P)-Total Dissolved (mg/L)					
	Silicate (as SiO2) (mg/L)	12.5	12.9	12.9	13.3	12.6
	Sulfate (SO4) (mg/L)					
	Anion Sum (meq/L)					
	Cation Sum (meq/L)					
	Cation - Anion Balance (%)					
Organic / Inorganic Carbon	Total Organic Carbon (mg/L)					
Total Metals	Aluminum (Al)-Total (mg/L)					
	Antimony (Sb)-Total (mg/L)					
	Arsenic (As)-Total (mg/L)					
	Barium (Ba)-Total (mg/L)					
	Beryllium (Be)-Total (mg/L)					
	Bismuth (Bi)-Total (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2210576-16	L2210576-17	L2210576-18	L2210576-19	L2210576-20
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	12-DEC-18	12-DEC-18	12-DEC-18	13-DEC-18	13-DEC-18
	Sampled Time	11:40	09:30	12:53	11:30	15:00
	Client ID	2018-12-06	2018-12-07	2018-12-08	2018-12-09	2018-12-10
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (uS/cm)					
	Hardness (as CaCO3) (mg/L)					
	pH (pH)					
	Total Suspended Solids (mg/L)					
	Total Dissolved Solids (mg/L)					
	TDS (Calculated) (mg/L)					
	Turbidity (NTU)					
Anions and Nutrients	Alkalinity, Bicarbonate (as CaCO3) (mg/L)					
	Alkalinity, Carbonate (as CaCO3) (mg/L)					
	Alkalinity, Hydroxide (as CaCO3) (mg/L)					
	Alkalinity, Phenolphthalein (as CaCO3) (mg/L)					
	Alkalinity, Total (as CaCO3) (mg/L)					
	Ammonia, Total (as N) (mg/L)					
	Bromide (Br) (mg/L)					
	Chloride (Cl) (mg/L)					
	Fluoride (F) (mg/L)					
	Nitrate and Nitrite (as N) (mg/L)	<0.0051	<0.0051	<0.0051	<0.0051	<0.0051
	Nitrate (as N) (mg/L)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
	Nitrite (as N) (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Total Kjeldahl Nitrogen (mg/L)					
	Total Nitrogen (mg/L)					
	Orthophosphate-Dissolved (as P) (mg/L)	0.0046	<0.0010	0.0045	0.0044	0.0137
	Phosphorus (P)-Total (mg/L)					
	Phosphorus (P)-Total Dissolved (mg/L)					
	Silicate (as SiO2) (mg/L)	13.3	<0.50	13.1	12.8	<0.50
	Sulfate (SO4) (mg/L)					
	Anion Sum (meq/L)					
	Cation Sum (meq/L)					
	Cation - Anion Balance (%)					
Organic / Inorganic Carbon	Total Organic Carbon (mg/L)					
Total Metals	Aluminum (Al)-Total (mg/L)					
	Antimony (Sb)-Total (mg/L)					
	Arsenic (As)-Total (mg/L)					
	Barium (Ba)-Total (mg/L)					
	Beryllium (Be)-Total (mg/L)					
	Bismuth (Bi)-Total (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2210576-1	L2210576-2	L2210576-3	L2210576-4	L2210576-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	11-DEC-18	11-DEC-18	11-DEC-18	11-DEC-18	11-DEC-18
	Sampled Time	11:00	12:15	13:00	14:00	14:15
	Client ID	2018-12-01	2018-12-02	2018-12-03	2018-12-04	2018-12-05
Grouping	**Analyte**					
WATER						
Total Metals	Boron (B)-Total (mg/L)	0.033	0.030	0.030	0.030	0.029
	Cadmium (Cd)-Total (mg/L)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
	Calcium (Ca)-Total (mg/L)	40.4	40.0	40.7	41.0	40.6
	Cesium (Cs)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Chromium (Cr)-Total (mg/L)	0.00019	0.00016	0.00016	0.00027	0.00011
	Cobalt (Co)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Copper (Cu)-Total (mg/L)	0.00186	0.00200	0.00183	0.00186	0.00181
	Iron (Fe)-Total (mg/L)	0.012	0.010	<0.010	0.010	0.016
	Lead (Pb)-Total (mg/L)	0.000057	<0.000050	<0.000050	<0.000050	<0.000050
	Lithium (Li)-Total (mg/L)	0.0064	0.0062	0.0063	0.0063	0.0063
	Magnesium (Mg)-Total (mg/L)	13.6	13.5	13.6	13.5	13.4
	Manganese (Mn)-Total (mg/L)	0.0583	0.0724	0.0710	0.0612	0.0708
	Mercury (Hg)-Total (mg/L)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
	Molybdenum (Mo)-Total (mg/L)	0.000246	0.000249	0.000227	0.000251	0.000231
	Nickel (Ni)-Total (mg/L)	0.00064	0.00064	0.00067	0.00064	0.00056
	Phosphorus (P)-Total (mg/L)	0.094	0.100	0.092	0.094	0.086
	Potassium (K)-Total (mg/L)	4.56	4.57	4.38	4.53	4.41
	Rubidium (Rb)-Total (mg/L)	0.00277	0.00291	0.00296	0.00296	0.00261
	Selenium (Se)-Total (mg/L)	<0.000050	0.000053	<0.000050	0.000068	<0.000050
	Silicon (Si)-Total (mg/L)	6.60	6.56	6.51	6.52	6.48
	Silver (Ag)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Sodium (Na)-Total (mg/L)	31.0	30.6	30.5	31.0	30.3
	Strontium (Sr)-Total (mg/L)	0.0948	0.0959	0.101	0.0973	0.0974
	Sulfur (S)-Total (mg/L)	11.7	11.5	11.3	11.1	11.6
	Tellurium (Te)-Total (mg/L)	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
	Thallium (Tl)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Thorium (Th)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Tin (Sn)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Titanium (Ti)-Total (mg/L)	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
	Tungsten (W)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Uranium (U)-Total (mg/L)	0.000585	0.000578	0.000607	0.000594	0.000576
	Vanadium (V)-Total (mg/L)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
	Zinc (Zn)-Total (mg/L)	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
	Zirconium (Zr)-Total (mg/L)	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060
Dissolved Metals	Dissolved Metals Filtration Location	FIELD	FIELD	FIELD	FIELD	FIELD
	Calcium (Ca)-Dissolved (mg/L)	44.2	44.2	44.7	44.5	44.6
	Magnesium (Mg)-Dissolved (mg/L)	13.6	13.4	13.6	13.6	13.9

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2210576-6	L2210576-7	L2210576-8	L2210576-9	L2210576-10
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	12-DEC-18	12-DEC-18	12-DEC-18	13-DEC-18	13-DEC-18
	Sampled Time	11:40	09:30	12:53	11:30	15:00
	Client ID	2018-12-06	2018-12-07	2018-12-08	2018-12-09	2018-12-10
Grouping	**Analyte**					
WATER						
Total Metals	Boron (B)-Total (mg/L)	0.029	<0.010	0.029	0.030	<0.010
	Cadmium (Cd)-Total (mg/L)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
	Calcium (Ca)-Total (mg/L)	40.8	<0.050	40.8	40.7	<0.050
	Cesium (Cs)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Chromium (Cr)-Total (mg/L)	<0.00010	<0.00010	0.00095	0.00017	RRV 0.00011
	Cobalt (Co)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Copper (Cu)-Total (mg/L)	0.00191	<0.00050	0.00189	0.00198	<0.00050
	Iron (Fe)-Total (mg/L)	0.010	<0.010	0.014	<0.010	<0.010
	Lead (Pb)-Total (mg/L)	<0.000050	<0.000050	0.000112	0.000163	<0.000050
	Lithium (Li)-Total (mg/L)	0.0062	<0.0010	0.0063	0.0063	<0.0010
	Magnesium (Mg)-Total (mg/L)	13.3	<0.0050	13.7	13.7	<0.0050
	Manganese (Mn)-Total (mg/L)	0.0817	<0.00010	0.0758	0.0463	RRV 0.00026
	Mercury (Hg)-Total (mg/L)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
	Molybdenum (Mo)-Total (mg/L)	0.000232	<0.000050	0.000228	0.000235	<0.000050
	Nickel (Ni)-Total (mg/L)	0.00062	<0.00050	0.00071	0.00071	<0.00050
	Phosphorus (P)-Total (mg/L)	0.094	<0.050	0.097	0.109	<0.050
	Potassium (K)-Total (mg/L)	4.54	<0.050	4.59	4.60	<0.050
	Rubidium (Rb)-Total (mg/L)	0.00276	<0.00020	0.00286	0.00289	<0.00020
	Selenium (Se)-Total (mg/L)	<0.000050	<0.000050	0.000051	0.000064	<0.000050
	Silicon (Si)-Total (mg/L)	6.52	<0.10	6.45	6.49	<0.10
	Silver (Ag)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Sodium (Na)-Total (mg/L)	31.1	<0.050	31.1	30.5	<0.050
	Strontium (Sr)-Total (mg/L)	0.0946	<0.00020	0.0948	0.0969	<0.00020
	Sulfur (S)-Total (mg/L)	11.2	<0.50	10.9	11.0	<0.50
	Tellurium (Te)-Total (mg/L)	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
	Thallium (Tl)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Thorium (Th)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Tin (Sn)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Titanium (Ti)-Total (mg/L)	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
	Tungsten (W)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Uranium (U)-Total (mg/L)	0.000596	<0.000010	0.000564	0.000580	<0.000010
	Vanadium (V)-Total (mg/L)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
	Zinc (Zn)-Total (mg/L)	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
	Zirconium (Zr)-Total (mg/L)	<0.000060	<0.000060	<0.000060	<0.000060	<0.000060
Dissolved Metals	Dissolved Metals Filtration Location	FIELD	FIELD	FIELD	FIELD	FIELD
	Calcium (Ca)-Dissolved (mg/L)	44.3	<0.050	45.6	45.8	<0.050
	Magnesium (Mg)-Dissolved (mg/L)	13.7	<0.10	12.6	12.4	<0.10

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID Description Sampled Date Sampled Time Client ID	L2210576-11 WATER 11-DEC-18 11:00 2018-12-01	L2210576-12 WATER 11-DEC-18 12:15 2018-12-02	L2210576-13 WATER 11-DEC-18 13:00 2018-12-03	L2210576-14 WATER 11-DEC-18 14:00 2018-12-04	L2210576-15 WATER 11-DEC-18 14:15 2018-12-05
Grouping	**Analyte**					
WATER						
Total Metals	Boron (B)-Total (mg/L)					
	Cadmium (Cd)-Total (mg/L)					
	Calcium (Ca)-Total (mg/L)					
	Cesium (Cs)-Total (mg/L)					
	Chromium (Cr)-Total (mg/L)					
	Cobalt (Co)-Total (mg/L)					
	Copper (Cu)-Total (mg/L)					
	Iron (Fe)-Total (mg/L)					
	Lead (Pb)-Total (mg/L)					
	Lithium (Li)-Total (mg/L)					
	Magnesium (Mg)-Total (mg/L)					
	Manganese (Mn)-Total (mg/L)					
	Mercury (Hg)-Total (mg/L)					
	Molybdenum (Mo)-Total (mg/L)					
	Nickel (Ni)-Total (mg/L)					
	Phosphorus (P)-Total (mg/L)					
	Potassium (K)-Total (mg/L)					
	Rubidium (Rb)-Total (mg/L)					
	Selenium (Se)-Total (mg/L)					
	Silicon (Si)-Total (mg/L)					
	Silver (Ag)-Total (mg/L)					
	Sodium (Na)-Total (mg/L)					
	Strontium (Sr)-Total (mg/L)					
	Sulfur (S)-Total (mg/L)					
	Tellurium (Te)-Total (mg/L)					
	Thallium (Tl)-Total (mg/L)					
	Thorium (Th)-Total (mg/L)					
	Tin (Sn)-Total (mg/L)					
	Titanium (Ti)-Total (mg/L)					
	Tungsten (W)-Total (mg/L)					
	Uranium (U)-Total (mg/L)					
	Vanadium (V)-Total (mg/L)					
	Zinc (Zn)-Total (mg/L)					
	Zirconium (Zr)-Total (mg/L)					
Dissolved Metals	Dissolved Metals Filtration Location					
	Calcium (Ca)-Dissolved (mg/L)					
	Magnesium (Mg)-Dissolved (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2210576-16	L2210576-17	L2210576-18	L2210576-19	L2210576-20
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	12-DEC-18	12-DEC-18	12-DEC-18	13-DEC-18	13-DEC-18
	Sampled Time	11:40	09:30	12:53	11:30	15:00
	Client ID	2018-12-06	2018-12-07	2018-12-08	2018-12-09	2018-12-10
Grouping	**Analyte**					
WATER						
Total Metals	Boron (B)-Total (mg/L)					
	Cadmium (Cd)-Total (mg/L)					
	Calcium (Ca)-Total (mg/L)					
	Cesium (Cs)-Total (mg/L)					
	Chromium (Cr)-Total (mg/L)					
	Cobalt (Co)-Total (mg/L)					
	Copper (Cu)-Total (mg/L)					
	Iron (Fe)-Total (mg/L)					
	Lead (Pb)-Total (mg/L)					
	Lithium (Li)-Total (mg/L)					
	Magnesium (Mg)-Total (mg/L)					
	Manganese (Mn)-Total (mg/L)					
	Mercury (Hg)-Total (mg/L)					
	Molybdenum (Mo)-Total (mg/L)					
	Nickel (Ni)-Total (mg/L)					
	Phosphorus (P)-Total (mg/L)					
	Potassium (K)-Total (mg/L)					
	Rubidium (Rb)-Total (mg/L)					
	Selenium (Se)-Total (mg/L)					
	Silicon (Si)-Total (mg/L)					
	Silver (Ag)-Total (mg/L)					
	Sodium (Na)-Total (mg/L)					
	Strontium (Sr)-Total (mg/L)					
	Sulfur (S)-Total (mg/L)					
	Tellurium (Te)-Total (mg/L)					
	Thallium (Tl)-Total (mg/L)					
	Thorium (Th)-Total (mg/L)					
	Tin (Sn)-Total (mg/L)					
	Titanium (Ti)-Total (mg/L)					
	Tungsten (W)-Total (mg/L)					
	Uranium (U)-Total (mg/L)					
	Vanadium (V)-Total (mg/L)					
	Zinc (Zn)-Total (mg/L)					
	Zirconium (Zr)-Total (mg/L)					
Dissolved Metals	Dissolved Metals Filtration Location					
	Calcium (Ca)-Dissolved (mg/L)					
	Magnesium (Mg)-Dissolved (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2210576-1	L2210576-2	L2210576-3	L2210576-4	L2210576-5
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	11-DEC-18	11-DEC-18	11-DEC-18	11-DEC-18	11-DEC-18
	Sampled Time	11:00	12:15	13:00	14:00	14:15
	Client ID	2018-12-01	2018-12-02	2018-12-03	2018-12-04	2018-12-05
Grouping	**Analyte**					
WATER						
Dissolved Metals	Potassium (K)-Dissolved (mg/L)	4.7	4.4	4.5	4.4	4.6
	Sodium (Na)-Dissolved (mg/L)	33.3	29.6	30.3	29.5	30.0

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2210576-6	L2210576-7	L2210576-8	L2210576-9	L2210576-10
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	12-DEC-18	12-DEC-18	12-DEC-18	13-DEC-18	13-DEC-18
	Sampled Time	11:40	09:30	12:53	11:30	15:00
	Client ID	2018-12-06	2018-12-07	2018-12-08	2018-12-09	2018-12-10
Grouping	**Analyte**					
WATER						
Dissolved Metals	Potassium (K)-Dissolved (mg/L)	4.5	<2.0	4.3	4.2	<2.0
	Sodium (Na)-Dissolved (mg/L)	32.2	<2.0	32.0	30.9	<2.0

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

		Sample ID	L2210576-11	L2210576-12	L2210576-13	L2210576-14	L2210576-15
		Description	WATER	WATER	WATER	WATER	WATER
		Sampled Date	11-DEC-18	11-DEC-18	11-DEC-18	11-DEC-18	11-DEC-18
		Sampled Time	11:00	12:15	13:00	14:00	14:15
		Client ID	2018-12-01	2018-12-02	2018-12-03	2018-12-04	2018-12-05
Grouping	**Analyte**						
WATER							
Dissolved Metals	Potassium (K)-Dissolved (mg/L)						
	Sodium (Na)-Dissolved (mg/L)						

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L2210576-16	L2210576-17	L2210576-18	L2210576-19	L2210576-20
	Description	WATER	WATER	WATER	WATER	WATER
	Sampled Date	12-DEC-18	12-DEC-18	12-DEC-18	13-DEC-18	13-DEC-18
	Sampled Time	11:40	09:30	12:53	11:30	15:00
	Client ID	2018-12-06	2018-12-07	2018-12-08	2018-12-09	2018-12-10
Grouping	**Analyte**					
WATER						
Dissolved Metals	Potassium (K)-Dissolved (mg/L)					
	Sodium (Na)-Dissolved (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Method Blank	Arsenic (As)-Total	MB-LOR	L2210576-1, -2, -3, -4, -5, -6, -8, -9
Matrix Spike	Total Organic Carbon	MS-B	L2210576-1, -10, -2, -3, -4, -5, -6, -7, -8, -9
Matrix Spike	Total Organic Carbon	MS-B	L2210576-1, -10, -2, -3, -4, -5, -6, -7, -8, -9
Matrix Spike	Aluminum (Al)-Total	MS-B	L2210576-1, -10, -7
Matrix Spike	Arsenic (As)-Total	MS-B	L2210576-1, -10, -2, -3, -4, -5, -6, -7, -8, -9
Matrix Spike	Barium (Ba)-Total	MS-B	L2210576-1, -10, -2, -3, -4, -5, -6, -7, -8, -9
Matrix Spike	Barium (Ba)-Total	MS-B	L2210576-1, -10, -7
Matrix Spike	Calcium (Ca)-Total	MS-B	L2210576-1, -10, -2, -3, -4, -5, -6, -7, -8, -9
Matrix Spike	Calcium (Ca)-Total	MS-B	L2210576-1, -10, -7
Matrix Spike	Lithium (Li)-Total	MS-B	L2210576-1, -10, -7
Matrix Spike	Magnesium (Mg)-Total	MS-B	L2210576-1, -10, -2, -3, -4, -5, -6, -7, -8, -9
Matrix Spike	Magnesium (Mg)-Total	MS-B	L2210576-1, -10, -7
Matrix Spike	Manganese (Mn)-Total	MS-B	L2210576-1, -10, -2, -3, -4, -5, -6, -7, -8, -9
Matrix Spike	Manganese (Mn)-Total	MS-B	L2210576-1, -10, -7
Matrix Spike	Potassium (K)-Total	MS-B	L2210576-1, -10, -2, -3, -4, -5, -6, -7, -8, -9
Matrix Spike	Potassium (K)-Total	MS-B	L2210576-1, -10, -7
Matrix Spike	Sodium (Na)-Total	MS-B	L2210576-1, -10, -2, -3, -4, -5, -6, -7, -8, -9
Matrix Spike	Sodium (Na)-Total	MS-B	L2210576-1, -10, -7
Matrix Spike	Strontium (Sr)-Total	MS-B	L2210576-1, -10, -2, -3, -4, -5, -6, -7, -8, -9
Matrix Spike	Strontium (Sr)-Total	MS-B	L2210576-1, -10, -7
Matrix Spike	Sulfur (S)-Total	MS-B	L2210576-1, -10, -7
Matrix Spike	Uranium (U)-Total	MS-B	L2210576-1, -10, -7
Matrix Spike	Total Nitrogen	MS-B	L2210576-7
Matrix Spike	Silicate (as SiO2)	MS-B	L2210576-11, -12, -13, -14, -15, -16, -17, -18, -19, -20

Qualifiers for Individual Parameters Listed:

Qualifier	Description
MB-LOR	Method Blank exceeds ALS DQO. Limits of Reporting have been adjusted for samples with positive hits below 5x blank level.
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.
RRV	Reported Result Verified By Repeat Analysis

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ALK-TITR-VA	Water	Alkalinity Species by Titration	APHA 2320 Alkalinity

This analysis is carried out using procedures adapted from APHA Method 2320 "Alkalinity". Total alkalinity is determined by potentiometric titration to a pH 4.5 endpoint. Bicarbonate, carbonate and hydroxide alkalinity are calculated from phenolphthalein alkalinity and total alkalinity values.

ANIONS-N+N-CALC-VA	Water	Nitrite & Nitrate in Water (Calculation)	EPA 300.0

Nitrate and Nitrite (as N) is a calculated parameter. Nitrate and Nitrite (as N) = Nitrite (as N) + Nitrate (as N).

BR-L-IC-N-VA	Water	Bromide in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

CARBONS-TOC-VA	Water	Total organic carbon by combustion	APHA 5310B TOTAL ORGANIC CARBON (TOC)

This analysis is carried out using procedures adapted from APHA Method 5310 "Total Organic Carbon (TOC)".

CL-IC-N-VA	Water	Chloride in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

EC-PCT-VA	Water	Conductivity (Automated)	APHA 2510 Auto. Conduc.

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

EC-SCREEN-VA	Water	Conductivity Screen (Internal Use Only)	APHA 2510

Qualitative analysis of conductivity where required during preparation of other tests - e.g. TDS, metals, etc.

		Fluoride in Water by IC	EPA 300.1 (mod)

Reference Information

F-IC-N-VA Water

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

HARDNESS-CALC-VA Water Hardness APHA 2340B

Hardness (also known as Total Hardness) is calculated from the sum of Calcium and Magnesium concentrations, expressed in CaCO3 equivalents. Dissolved Calcium and Magnesium concentrations are preferentially used for the hardness calculation.

HG-T-CVAA-VA Water Total Mercury in Water by CVAAS or CVAFS EPA 1631E (mod)

Water samples undergo a cold-oxidation using bromine monochloride prior to reduction with stannous chloride, and analyzed by CVAAS or CVAFS.

IONBALANCE-VA Water Ion Balance Calculation APHA 1030E

Cation Sum, Anion Sum, and Ion Balance (as % difference) are calculated based on guidance from APHA Standard Methods (1030E Checking Correctness of Analysis). Because all aqueous solutions are electrically neutral, the calculated ion balance (% difference of cations minus anions) should be near-zero.

Cation and Anion Sums are the total meq/L concentration of major cations and anions. Dissolved species are used where available. Minor ions are included where data is present. Ion Balance is calculated as:

Ion Balance (%) = [Cation Sum-Anion Sum] / [Cation Sum+Anion Sum]

MET-DIS-ICP-VA Water Dissolved Metals in Water by ICPOES EPA SW-846 3005A/6010B

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedure involves filtration (EPA Method 3005A) and analysis by inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B).

MET-T-CCMS-VA Water Total Metals in Water by CRC ICPMS EPA 200.2/6020A (mod)

Water samples are digested with nitric and hydrochloric acids, and analyzed by CRC ICPMS.

Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.

N-T-COL-VA Water Total Nitrogen in water by Colour APHA4500-P(J)/NEMI9171/USGS03-4174

This analysis is carried out using procedures adapted from APHA Method 4500-P (J) "Persulphate Method for Simultaneous Determination of Total Nitrogen and Total Phosphorus" and National Environmental Methods Index - Nemi method 5735.

NH3-F-VA Water Ammonia in Water by Fluorescence J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NO2-L-IC-N-VA Water Nitrite in Water by IC (Low Level) EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

NO3-L-IC-N-VA Water Nitrate in Water by IC (Low Level) EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

P-T-PRES-COL-VA Water Total P in Water by Colour APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorus is determined colourimetrically after persulphate digestion of the sample.
Samples with very high dissolved solids (i.e. seawaters, brackish waters) may produce a negative bias by this method. Alternate methods are available for these types of samples.

Arsenic (5+), at elevated levels, is a positive interference on colourimetric phosphate analysis.

P-TD-PRES-COL-VA Water Total Dissolved P in Water by Colour APHA 4500-P Phosphorous

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Dissolved Phosphorus is determined colourimetrically after persulphate digestion of a sample that has been lab or field filtered through a 0.45 micron membrane filter.
Samples with very high dissolved solids (i.e. seawaters, brackish waters) may produce a negative bias by this method. Alternate methods are available for these types of samples.

Arsenic (5+), at elevated levels, is a positive interference on colourimetric phosphate analysis.

PH-PCT-VA Water pH by Meter (Automated) APHA 4500-H pH Value

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode

It is recommended that this analysis be conducted in the field.

PO4-DO-COL-VA Water Diss. Orthophosphate in Water by Colour APHA 4500-P Phosphorus

Reference Information

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.
Samples with very high dissolved solids (i.e. seawaters, brackish waters) may produce a negative bias by this method. Alternate methods are available for these types of samples.

Arsenic (5+), at elevated levels, is a positive interference on colourimetric phosphate analysis.

SILICATE-COL-VA	Water	Silicate by Colourimetric analysis	APHA 4500-SiO2 E.

This analysis is carried out using procedures adapted from APHA Method 4500-SiO2 E. "Silica". Silicate (molybdate-reactive silica) is determined by the molybdosilicate-heteropoly blue colourimetric method. Arsenic (5+) above 100 mg/L is a negative interference on this test.

SO4-IC-N-VA	Water	Sulfate in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

TDS-CALC-VA	Water	TDS (Calculated)	APHA 1030E (20TH EDITION)

This analysis is carried out using procedures adapted from APHA 1030E "Checking Correctness of Analyses".
The Total Dissolved Solids result is calculated from measured concentrations of anions and cations in the sample.

TDS-VA	Water	Total Dissolved Solids by Gravimetric	APHA 2540 C - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Dissolved Solids (TDS) are determined by filtering a sample through a glass fibre filter, TDS is determined by evaporating the filtrate to dryness at 180 degrees celsius.

TKN-F-VA	Water	TKN in Water by Fluorescence	APHA 4500-NORG D.

This analysis is carried out using procedures adapted from APHA Method 4500-Norg D. "Block Digestion and Flow Injection Analysis". Total Kjeldahl Nitrogen is determined using block digestion followed by Flow-injection analysis with fluorescence detection.

TSS-VA	Water	Total Suspended Solids by Gravimetric	APHA 2540 D - GRAVIMETRIC

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total Suspended Solids (TSS) are determined by filtering a sample through a glass fibre filter, TSS is determined by drying the filter at 104 degrees celsius.
Samples containing very high dissolved solid content (i.e. seawaters, brackish waters) may produce a positive bias by this method. Alternate analysis methods are available for these types of samples.

TURBIDITY-VA	Water	Turbidity by Meter	APHA 2130 Turbidity

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

2018

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Lab Copy

Jackfish Lake
Chain-of-Custody Record - Analytical Request Form

CoC#: 2018-1200 Created: 21-11-18

From:

Golder Associates - Jackfish
Address: 6925 Century Ave #100 Mississauga, ON, L5N 7K2
Telephone: (905) 561-4444
Contact: Tamara Darwish TDarwish@golder.com

Send Samples For Analysis To:

ALS Group, Yellowknife
Address: 314 Old Airport Rd, Unit 116 Yellowknife, NT X1A 3T3
Phone: (867) 873-5593
Fax: (867) 920-4238
Contact: Rick Zolkiewski
Email: Rick.Zolkiewski@alsglobal.com

eMail Confirmation and Results To:

Please use full distribution list from quote
HMacpherson@golder.com
MMiller@ntpc.com
GAL_EQUIS@golder.com
AHumphries@golder.com
TDarwish@golder.com

Send Original Signed Lab Reports To:

Golder Associates Ltd.
Address: 9, 4905-48 Street Yellowknife, NT, X1A 3S3
Telephone: (867) 873-6319
Fax: (867) 873-6379
Contact: Haley Macpherson hmacpherson@golder.com

Send Invoice To:

Golder Associates Ltd.
Address: 6925 Century Ave Mississauga, ON, L5N 7K2
Telephone: (905) 561-4444
Fax: (905) 567-6561
ATTN: Tamara Darwish
TDarwish@golder.com

Fields Notes:

Filter and preserve dissolved parameters .

Please ensure that there is only one COC per report. Use email confirmation and results list on this COC.

Facilty Code: 183527250

Project # 1894709-9000-9050 **Jackfish Baseline Sampling**

Quote # Q66233

L2210576

L2210576-COFC

FIELD SAMPLE INFORMATION — *REQUESTED LAB SUITES (see reverse side for details)*

√ = Preserved :

√ = Field Filtered :

√ = 1-Day Rush :

Sample Control Number	Lab Sample ID	Sample Date (dd-mmm-yy)	Sample Time (hh:mm)	Matrix		Comments	G = Grab or C = Composite	Number of Containers	Routine 1 (pH, conductivity, hardness, alkalinity, tss, tds (measured and calculated), anions, turbidity)	Routine 2 (orthophosphate, NO_2, NO_3, silica)	Total metals	Dissolved metals (major cations Ca, Mg, K, and Na only)	Total mercury	EPH, CCME PHC	BTEX & F1	Total Nutrients: TKN, NH3, TOC, TP, TN	Dissolved nutrients: TDP	F_1-F_4
2018-12-01		11-DEC-18	11:00	Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√
2018-12-02		11-DEC-18	12:15	Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√
2018-12-03		11-DEC-18	13:00	Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√
2018-12-04		11-DEC-18	14:00	Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√
2018-12-05		11-DEC-18	14:15	Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√
2018-12-				Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√
2018-12-				Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√
2018-12-				Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√
				Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√

Relinquished by (Sampler Signature):	Date/Time: 11-DEC-18 17:15	Company: **Golder Associates**	Received by (Signature): OC 9:30 14/12	Company: ALS
Relinquished by (Signature):	Date/Time:	Company:	Received by (Signature):	Company:
Sampler (Printed Name): EDWARD HUNT	Sample Storage Temperature prior to Shipping (deg. C):	Sample Receipt Temperature (deg. C): 6-5	**SAMPLE CONDITION (lab use only)** Samples Received in Good Condition? Yes / No (If no, provide details.)	

Lab Copy

Jackfish Lake
Chain-of-Custody Record - Analytical Request Form

CoC#: 2018-1200 Created: 21-11-18

From:

Golder Associates - Jackfish
Address: 6925 Century Ave #100 Mississauga, ON, L5N 7K2
Telephone: (905) 561-4444
Contact: Tamara Darwish TDarwish@golder.com

Send Samples For Analysis To:

ALS Group, Yellowknife
Address: 314 Old Airport Rd, Unit 116 Yellowknife, NT X1A 3T3
Phone: (867) 873-5593
Fax: (867) 920-4238
Contact: Rick Zolkiewski
Email: Rick.Zolkiewski@alsglobal.com

eMail Confirmation and Results To:

Please use full distribution list from quote
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AHumphries@golder.com
TDarwish@golder.com

Send Original Signed Lab Reports To:

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Address: 9, 4905-48 Street Yellowknife, NT X1A 3S3
Telephone: (867) 873-6319
Fax: (867) 873-6379
Contact: Haley Macpherson hmacpherson@golder.com

Send Invoice To:

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Address: 6925 Century Ave Mississauga, ON L5N 7K2
Telephone: (905) 561-4444
Fax: (905) 567-6561
ATTN: Tamara Darwish
TDarwish@golder.com

FIELD SAMPLE INFORMATION

REQUESTED LAB SUITES (see reverse side for details)

Fields Notes:

Filter and preserve dissolved parameters

Please ensure that there is only one COC per report. Use email confirmation and results list on this COC.

Facilty Code: **183527250**

Project # **1894709-9000-9050**
Jackfish Baseline Sampling

Quote # **Q66233**

									Routine 1	Routine 2	Total metals	Dissolved metals	Total mercury	EPH, CCME PHC	BTEX & F1	Total Nutrients	Dissolved nutrients	F_2-F_4
√ = Preserved :											√	√	√			√	√	
√ = Field Filtered :												√					√	
√ = 1-Day Rush :																		
Sample Control Number	**Lab Sample ID**	**Sample Date (dd-mmm-yy)**	**Sample Time (hh:mm)**	**Matrix**	**Laboratory Comments**	**Sampler Comments**	**G = Grab or C = Composite**	**Number of Containers**	**Routine 1 (pH, conductivity, hardness, alkalinity, tss, tds (measured and calculated), anions, turbidity)**	**Routine 2 (orthophosphte, NO_2, NO_3, silica)**	**Total metals**	**Dissolved metals (major cations Ca, Mg, K, and Na only)**	**Total mercury**	**EPH, CCME PHC**	**BTEX & F1**	**Total Nutrients: TKN, NH3, TOC, TP, TN**	**Dissolved nutrients: TDP**	**F_2-F_4**
2018-12-06		12-DEC-18	11:40	Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√
2018-12-07		12-DEC-18	09:30	Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√
2018-12-08		12-DEC-18	12:53	Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√
2018-12-				Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√
2018-12-				Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√
2018-12-				Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√
2018-12-				Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√
2018-12-				Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√

Relinquished by (Sampler Signature): [signature]	Date/Time: 18:30 Dec 12/18	Company: **Golder Associates**	Received by (Signature): OG 9.30 14/12	Company: ALS
Relinquished by (Signature):	Date/Time:	Company:	Received by (Signature):	Company:
Sampler (Printed Name): EDWARD HUNT	Sample Storage Temperature prior to Shipping (deg. C):	Sample Receipt Temperature (deg. C): 6.5	**SAMPLE CONDITION (lab use only)** Samples Received in Good Condition? Yes / No (If no, provide details.)	

Lab Copy

Jackfish Lake
Chain-of-Custody Record - Analytical Request Form

CoC#: 2018-1200 Created: 21-11-18

From:

Golder Associates - Jackfish Address: 6925 Century Ave #100 Mississauga, ON, L5N 7K2 Telephone: (905) 561-4444 Contact: Tamara Darwish TDarwish@golder.com	Send Samples For Analysis To: **ALS Group, Yellowknife** Address: 314 Old Airport Rd, Unit 116 Yellowknife, NT X1A 3T3 Phone: (867) 873-5593 Fax: (867) 920-4238 Contact: Rick Zolkiewski Email: Rick.Zolkiewski@alsglobal.com	eMail Confirmation and Results To: Please use full distribution list from quote HMacpherson@golder.com MMiller@ntpc.com GAL_EQUIS@golder.com AHumphnes@golder.com TDarwish@golder.com	Send Original Signed Lab Reports To: **Golder Associates Ltd.** Address: 9, 4905-48 Street Yellowknife, NT, X1A 3S3 Telephone: (867) 873-6319 Fax: (867) 873-6379 Contact: Haley Macpherson hmacpherson@golder.com	Send Invoice To: **Golder Associates Ltd.** Address: 6925 Century Ave Mississauga, ON, L5N 7K2 Telephone: (905) 561-4444 Fax: (905) 567-6561 ATTN: Tamara Darwish TDarwish@golder.com

FIELD SAMPLE INFORMATION

Fields Notes:

Filter and preserve dissolved parameters

Please ensure that there is only one COC per report. Use email confirmation and results list on this COC.

Facilty Code: 183527250

Project # 1894709-9000-9050 Jackfish Baseline Sampling

Quote # Q66233

REQUESTED LAB SUITES (see reverse side for details)

Sample Control Number	Lab Sample ID	Sample Date (dd-mmm-yy)	Sample Time (hh:mm)	Matrix	Laboratory Comments	Sampler Comments	G = Grab or C = Composite	Number of Containers	Routine 1 (pH, conductivity, hardness, alkalinity, tss, tds (measured and calculated), anions, turbidity)	Routine 2 (orthophosphte, NO_2, NO_3, silica)	Total metals	Dissolved metals (major cations Ca, Mg, K, and Na only)	Total mercury	EPH, CCME PHC	BTEX & F1	Total Nutrients: TKN, NH3, TOC, TP, TN	Dissolved nutrients: TDP	F_2-F_4
√ = Preserved :											√		√			√	√	
√ = Field Filtered :												√					√	
√ = 1-Day Rush :																		
2018-12-09		13-DEC-18	11:30	Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√
2018-12-10		13-DEC-18	15:00	Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√
2018-12-				Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√
2018-12-				Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√
2018-12-				Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√
2018-12-				Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√
2018-12-				Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√
2018-12-				Water			G	1	√	[redacted]	√	√	√	√	√	√	√	√

Relinquished by (Sampler Signature): [signature]	Date/Time: 13-DEC-2018 15:10	Company: **Golder Associates**	Received by (Signature):	Company:
Relinquished by (Signature):	Date/Time:	Company:	Received by (Signature):	Company:
Sampler (Printed Name): EDWARD HUNT	Sample Storage Temperature prior to Shipping (deg. C):			

SAMPLE CONDITION (lab use only)

Sample Receipt Temperature (deg. C):	Samples Received in Good Condition? Yes / No (If no, provide details.)

Lab Copy

Jackfish Lake
Chain-of-Custodv Record - Analvtical Reauest Form

CoC#: 2018-1200 Created: 21-11-18

From:

Golder Associates - Jackfish
Address: 6925 Century Ave #100 Mississauga, ON, L5N 7K2
Telephone: (905) 561-4444
Contact: Tamara Darwish TDarwish@golder.com

Send Samples For Analysis To:

ALS Group, Yellowknife
Address: 314 Old Airport Rd, Unit 116 Yellowknife, NT X1A 3T3
Phone: (867) 873-5593 Fax: (867) 920-4238
Contact: Rick Zolkiewski Email: Rick.Zolkiewski@alsglobal.com

eMail Confirmation and Results To:

Please use full distribution list from quote
HMacpherson@golder.com
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GAL_EQUIS@golder.com
AHumphries@golder.com
TDarwish@golder.com

Send Original Signed Lab Reports To:

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Telephone: (867) 873-6319 Fax: (867) 873-6379
Contact: Haley Macpherson hmacpherson@golder.com

Send Invoice To:

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Telephone: (905) 561-4444
Fax: (905) 567-6561
ATTN: Tamara Darwish
TDarwish@golder.com

FIELD SAMPLE INFORMATION

Fields Notes:

Filter and preserve dissolved parameters .

Please ensure that there is only one COC per report. Use email confirmation and results list on this COC.

Facility Code: 183527250

Project # 1894709-9000-9050 Jackfish Baseline Sampling

Quote # Q66233

REQUESTED LAB SUITES (see reverse side for details)

√ = Preserved :

√ = Field Filtered :

√ = 1-Day Rush :

Sample Control Number	Lab Sample ID	Sample Date (dd-mmm-yy)	Sample Time (hh:mm)	Matrix	Laboratory Comments	Sampler Comments	G = Grab or C = Composite	Number of Containers	Routine 1 (pH, conductivity, hardness, alkalinity, tss, tds (measured and calculated), anions, turbidity)	Routine 2 (orthophosphate, NO_3, NO_2, silica)	Total metals	Dissolved metals (major cations Ca, Mg, K, and Na only)	Total mercury	EPH, CCME PHC	BTEX & F1	Total Nutrients: TKN, NH3, TOC, TP, TN	Dissolved nutrients: TDP	F_2-F_4
2018-12-01		11-DEC-18	11:00	Water			G	1	[redacted]	√	[redacted]							
2018-12-02		11-DEC-18	12:15	Water			G	1	[redacted]	√	[redacted]							
2018-12-03		11-DEC-18	13:00	Water			G	1	[redacted]	√	[redacted]							
2018-12-04		11-DEC-18	14:00	Water			G	1	[redacted]	√	[redacted]							
2018-12-05		11-DEC-18	14:15	Water			G	1	[redacted]	√	[redacted]							
2018-12-				Water			G	1	[redacted]	√	[redacted]							
2018-12-				Water			G	1	[redacted]	√	[redacted]							
2018-12-				Water			G	1	[redacted]	√	[redacted]							

Relinquished by (Sampler Signature): [signature]	Date/Time: 11-DEC-18 17:15	Company: Golder Associates	Received by (Signature): OG 9:30 14/12	Company: ALS
Relinquished by (Signature):	Date/Time:	Company:	Received by (Signature):	Company:

Sampler (Printed Name): EDUARDO HUNT	Sample Storage Temperature prior to Shipping (deg. C):	**SAMPLE CONDITION (lab use only)** Sample Receipt Temperature (deg. C): 6-5	Samples Received in Good Condition? Yes / No (If no, provide details.)

Lab Copy

Jackfish Lake
Chain-of-Custody Record - Analytical Request Form

CoC#: 2018-1200 Created: 21-11-18

From:

Golder Associates - Jackfish
Address: 6925 Century Ave #100 Mississauga, ON, L5N 7K2
Telephone: (905) 561-4444
Contact: Tamara Darwish TDarwish@golder.com

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Please use full distribution list from quote
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MMiller@ntpc.com
GAL_EQUIS@golder.com
AHumphries@golder.com
TDarwish@golder.com

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ATTN: Tamara Darwish
TDarwish@golder.com

FIELD SAMPLE INFORMATION

Fields Notes:

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Facilty Code: 183527250

Project # 1894709-9000-9050 Jackfish Baseline Sampling

Quote # Q66233

REQUESTED LAB SUITES (see reverse side for details)

√ = Preserved :
√ = Field Filtered :
√ = 1-Day Rush :

Sample Control Number	Lab Sample ID	Sample Date (dd-mmm-yy)	Sample Time (hh:mm)	Matrix	Laboratory Comments	Sampler Comments	G = Grab or C = Composite	Number of Containers	Routine 1 (pH, conductivity, hardness, alkalinity, tss, tds (measured and calculated), anions, turbidity)	Routine 2 (orthophosphte, NO_2, NO_3, silica)	Total metals	Dissolved metals (major cations Ca, Mg, K, and Na only)	Total mercury	EPH, CCME PHC	BTEX & F1	Total Nutrients: TKN, NH3, TOC, TP, TN	Dissolved nutrients: TDP	F_2-F_4
2018-12-06		12-DEC-18	11:40	Water			G	1	[redacted]	√	[redacted]							
2018-12-07		12-DEC-18	09:30	Water			G	1	[redacted]	√	[redacted]							
2018-12-08		12-DEC-18	12:53	Water			G	1	[redacted]	√	[redacted]							
2018-12-				Water			G	1	[redacted]	√	[redacted]							
2018-12-				Water			G	1	[redacted]	√	[redacted]							
2018-12-				Water			G	1	[redacted]	√	[redacted]							
2018-12-				Water			G	1	[redacted]	√	[redacted]							
2018-12-				Water			G	1	[redacted]	√	[redacted]							

Relinquished by (Sampler Signature):	Date/Time: 18:30 DEC 12/18	Company: **Golder Associates**	Received by (Signature): OC 9:30 14/12	Company: ALS
Relinquished by (Signature):	Date/Time:	Company:	Received by (Signature):	Company:

Sampler (Printed Name): EDWARD HUNT

Sample Storage Temperature prior to Shipping (deg. C):

SAMPLE CONDITION (lab use only)

Sample Receipt Temperature (deg. C): 6.5

Samples Received in Good Condition? Yes / No (If no, provide details.)

Lab Copy

Jackfish Lake
Chain-of-Custody Record - Analytical Request Form

CoC#: 2018-1200 Created: 21-11-18

From:

Golder Associates - Jackfish
Address: 6925 Century Ave #100 Mississauga, ON, L5N 7K2
Telephone: (905) 561-4444
Contact: Tamara Darwish TDarwish@golder.com

Send Samples For Analysis To:

ALS Group, Yellowknife
Address: 314 Old Airport Rd, Unit 116 Yellowknife, NT X1A 3T3
Phone: (867) 873-5593
Fax: (867) 920-4238
Contact: Rick Zolkiewski
Email: Rick.Zolkiewski@alsglobal.com

eMail Confirmation and Results To:

Please use full distribution list from quote
HMacpherson@golder.com
MMiller@ntpc.com
GAL_EQUIS@golder.com
AHumphries@golder.com
TDarwish@golder.com

Send Original Signed Lab Reports To:

Golder Associates Ltd.
Address: 9, 4905-48 Street Yellowknife, NT, X1A 3S3
Telephone: (867) 873-6319
Fax: (867) 873-6379
Contact: Hailey Macpherson hmacpherson@golder.com

Send Invoice To:

Golder Associates Ltd.
Address: 6925 Century Ave Mississauga, ON, L5N 7K2
Telephone: (905) 561-4444
Fax: (905) 567-6561
ATTN: Tamara Darwish
TDarwish@golder.com

FIELD SAMPLE INFORMATION

Fields Notes:

Filter and preserve dissolved parameters.

Please ensure that there is only one COC per report. Use email confirmation and results list on this COC.

Facilty Code: **183527250**

Project # **1894709-9000-9050**
Jackfish Baseline Sampling

Quote # **Q66233**

REQUESTED LAB SUITES (see reverse side for details)

√ = Preserved :
√ = Field Filtered :
√ = 1-Day Rush :

Sample Control Number	Lab Sample ID	Sample Date (dd-mmm-yy)	Sample Time (hh:mm)	Matrix	Laboratory Comments	Sampler Comments	G = Grab or C = Composite	Number of Containers	Routine 1 (pH, conductivity, hardness, alkalinity, tss, tds (measured and calculated), anions, turbidity)	Routine 2 (orthophosphte, NO_2, NO_3, silica)	Total metals	Dissolved metals (major cations Ca, Mg, K, and Na only)	Total mercury	EPH, CCME PHC	BTEX & F1	Total Nutrients: TKN, NH3, TOC, TP, TN	Dissolved nutrients: TDP	F_2-F_4
2018-12-09		13-DEC-2018	11:30	Water			G	1	[redacted]	√	[redacted]							
2018-12-10		13-DEC-2018	15:00	Water			G	1		√								
2018-12-				Water			G	1		√								
2018-12-				Water			G	1		√								
2018-12-				Water			G	1		√								
2018-12-				Water			G	1		√								
2018-12-				Water			G	1		√								
2018-12-				Water			G	1		√								

Relinquished by (Sampler Signature):	Date/Time:	Company:	Received by (Signature):	Company:
[signature]	13-DEC-2018 15:10	**Golder Associates**	OG 9:30 14/12	ALS

Relinquished by (Signature):	Date/Time:	Company:	Received by (Signature):	Company:

Sampler (Printed Name): EDWARD HUNT

Sample Storage Temperature prior to Shipping (deg. C):

SAMPLE CONDITION (lab use only)

Sample Receipt Temperature (deg. C): 6.5

Samples Received in Good Condition? Yes / No (If no, provide details.)

Recheck Analysis Report

Recheck #: **RC45921**
Dept #: **85120**
Dept: **Metals, Analysis, Vancouver**

Due Date: **24-Jan-2019**
Issued By: **Oliver Gregg**
Date Initiated: **17-Jan-2019**
Original Results reported to Client: **Yes**

Recheck Comments:

pH and labels checked.
Sample reprepped in duplicate. Recheck results confirm with original data. No data replaced in LIMS.

RC file a11-2019-0118br

Reason for Recheck

Result appears too high

Sample #	Account Name			Product		Matrix	Original Measure Date		Original Workgroup	Original Analyst
Analyte	Original Result	Units	LOR	Recheck Result	RPD	Recheck Result 2	RPD 2	UCL	Recheck Measure date	Recheck Workgroup
L2210576-8	**Golder Associates Ltd.~Yellowknife**			**MET-T-CCMS-VA**		**Water**	**20-Dec-2018**		**WG2958631**	**AYC**
Chromium (Cr)-Total	0.00095	mg/L	0.0001	0.00101	6.1	0.00101	6.1	20		

Sample Comments:

L2210576-8 VA- W044-046,N264-265,M490,NP23,HG051(CM)

Analyst Comments:

Description of Water Quality Parameters

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TABLES

1.0 WATER QUALITY PARAMETERS

This appendix describes the parameters commonly used to evaluate baseline water quality, and how these parameters are indicative of specific aspects of water quality. Water chemistry in surface waters depends on the interaction of biological, physical and chemical processes. The purpose of this appendix is to provide a general understanding of surface water quality parameters and typical ranges of concentrations observed in surface waters.

1.1 Field Parameters

1.1.1 Potential of Hydrogen (pH)

The potential of hydrogen (pH) is a measure of hydrogen ion concentration in a solution and is expressed on a scale of 0 (acidic) to 14 (alkaline). The greater the hydrogen ion concentration in water, the more acidic it is. Neutral waters have a pH of 7; waters with a pH less than 7 are considered acidic, and those with a pH greater than 7 are considered alkaline (Table 1.1-1; Wetzel 2001). Most aquatic organisms can tolerate waters with a pH between 6.0 and 9.0, as commonly found in many of the natural surface waters in Canada (McNeely et al. 1979). Acid deposition resulting from human activities can lower the pH of a waterbody. High pH values tend to facilitate the solubilization of ammonia, heavy metals, and salts. The precipitation of carbonate salts is enhanced when pH levels are high. Lethal effects of pH on aquatic life occur below pH 4.5 and above pH 9.5 (MELP 1998). During spring freshet, the pH of surface waters can drop to values approximating the pH of precipitation (e.g., 5.1 to 5.4; Schindler 1996). In natural fens and bogs, pH values can be lower than 4.5 (WRS 2004).

Table 1.1-1: Qualitative pH Scale of Surface Waters

Description	pH
Acidic	0 to <7
Neutral	7
basic (alkaline)	>7 to 14

> = greater than; < = less than; pH = potential of hydrogen.
Source: Wetzel (2001).

1.1.2 Dissolved Oxygen

Adequate amounts of dissolved oxygen (DO) are required to support fish and other organisms in lakes and streams (EMAN-North 2005). The solubility of oxygen depends on many factors, including the partial pressure of oxygen in the air, water temperature, water turbulence, mineral content of the water, the ability of the water to exchange freely with the atmosphere, and watershed characteristics (CCME 1999). Photosynthesis and turbulent mixing are the primary processes for the addition of DO to surface waters. Chemical and biological reduction are the main processes that remove DO from surface waters (AEP 1997).

Typical concentrations of DO in surface waters range from non-detectable (close to zero) to 18.4 mg/L (CCME 1999). The solubility of atmospheric oxygen in freshwater ranges from approximately 15 mg/L at 0°C to 8 mg/L at 25°C at sea level (McNeely et al. 1979). The biological effect of low DO concentration depends on the temperature of the water, type of organism, and life stage of the organism (CCME 1999). Sensitivity to low DO is species-specific, but in general, concentrations below 4 mg/L have been shown to produce detrimental effects in several aquatic organisms (DOE 1972).

1.2 Conventional Parameters, Ions and Organic Carbon

1.2.1 Total Suspended Solids

The concentration of all solid particles in the water column is referred to as total suspended solids (TSS). High TSS values can cause direct and indirect stress to aquatic life (CCME 2002; Robertson et al. 2006). The effect of high TSS concentrations on aquatic life depends on the TSS concentration and the duration of exposure (Newcombe and Jensen 1996; Robertson et al. 2006). Aquatic organisms can withstand low levels of TSS for long periods and higher levels for shorter periods (Newcombe and MacDonald 1991). Concentrations of TSS below 25 mg/L are generally not considered harmful to aquatic life (EIFAC 1965; US EPA 1973). In this report, TSS is characterized as low, moderate, or high (Table 1.2-1).

Table 1.2-1: Qualitative Scale of Total Suspended Solids in Surface Waters

Description	Total Suspended Solids (mg/L)
low	<10
moderate	10 to 25
high	>25

> = greater than; < = less than.

1.2.2 Alkalinity

Alkalinity is a measure of water's capacity to neutralize acids. In most cases, alkalinity is equal to bicarbonate minus hydrogen ion, where both are expressed in equivalents (Schindler 1996; Wetzel 2001). Alkalinity provides an indication of a waterbody's sensitivity to acid deposition or its acid neutralizing capacity. Saffran and Trew (1996) presented a scale of surface water lake sensitivity to acidification based on alkalinity (Table 1.2-2).

Table 1.2-2: Scale of Acid Sensitivity Based on Alkalinity in Surface Water Lakes

Acid Sensitivity	Alkalinity or Acid Neutralizing Capacity (mg/L as $CaCO_3$)
high	0
moderate	>10 to 20
low	>20 to 40
least	>40

$CaCO_3$ = calcium carbonate; > = greater than.
Source: Saffran and Trew 1996.

1.2.3 Major Ions

Major ions in surface waters typically include the anions bicarbonate, chloride and sulphate, and the cations calcium, magnesium, potassium and sodium. These may also be expressed in terms of hardness, total dissolved solids (TDS), and specific conductivity, as described below.

Hardness is primarily determined by the presence of calcium and magnesium (McNeely et al. 1979). A scale of water hardness, expressed as mg/L equivalent to calcium carbonate ($CaCO_3$), is provided in Table 1.2-3. The toxicity of many metals decreases as hardness increases (MELP 1998) because of competitive binding of divalent cations (BC ENV 2017; CCME 2003).

Table 1.2-3: Qualitative Scale of Water Hardness in Surface Waters

Description	Hardness (mg/L as $CaCO_3$)
soft	<60
moderately soft	60 to 120
hard	121 to 180
very hard	>180

$CaCO_3$ = calcium carbonate; > = greater than; < = less than.
Source: McNeely et al. 1979, Mitchell and Prepas 1990.

The concentration of TDS is a measure of total ion concentration. The TDS in surface waters is variable and is highly dependent on exchanges from the surrounding land, atmospheric sources, and exchanges between sediments and the water column (Wetzel 2001). Constituents may be used to calculate TDS concentrations analyzed in samples as a check on results for measured TDS concentrations. The method used for analyzing measured TDS is known to produce variability in the results. Waters with considerable calcium, magnesium, and chloride concentrations can form a hygroscopic (i.e., absorbs ambient water) residue that will continue to absorb water under normal laboratory conditions, thereby biasing the measurement higher than actual (Evaristo-Cordero 2011, pers. comm.; APHA 2012). Therefore, estimates of calculated concentrations of TDS (Equation 1) were included in the assessment of TDS concentrations.

$$Calculated\ TDS\ (SM)(mg/L) = (0.6\ x\ Total\ Alkalinity\ as\ CaCO_3) + Na^+ + Mg^+ + K^+ + Ca^{2+} + SO_4^- + Cl^- + NO_3^- + F^- + SiO_3^{2-}$$

[Equation 1]

Where:

SM = standard methods; Na^+ = sodium cation; Mg^+ = magnesium cation; K^+ = potassium cation; Ca^{2+} = calcium cation; $CaCO_3$ = calcium carbonate;SO_4^- = sulphate anion; Cl^- = chloride anion; NO_3^- = nitrate anion (multiply nitrate as nitrogen by 4.427); F^- = fluoride anion; and, SiO_3^{2-} = silicate anion (multiply reactive silica as SiO_2, by 1.266).

Specific conductivity is a measure of the ability of water to conduct electricity and varies with the concentration of charged particles in the water. Thus, the concentration of TDS and specific conductivity are strongly related. Descriptive scales for specific conductivity and TDS are provided in Table 1.2-4.

Table 1.2-4: Qualitative Scale of Total Dissolved Solids in Fresh Surface Waters

Description	Total Dissolved Solids (mg/L)	Specific Conductivity (µS/cm)
low	≤100	≤165
moderate	100 to 500	165 to 830
high	>500	>830

≤ = less than or equal to; > = greater than; µS/cm = microSiemens per centimetre.
Source: Hart et al. 1990, Mitchell and Prepas 1990.

1.2.4 Organic Carbon

Total organic carbon (TOC) comprises particulate and dissolved organic carbon (DOC). Natural waters have concentrations that generally vary from 1 to 30 mg/L (McNeely et al. 1979). The amount of TOC and DOC reaching surface waters varies largely from season to season with growth cycles and discharge rates (Wetzel 2001). Naturally occurring “brown water” lakes and ponds, common in boreal forest areas, generally have higher TOC concentrations (i.e., greater than 20 mg/L). Most TOC and DOC is derived from humic substances and partly degraded plant and animal materials (Ledesma et al. 2012). Concentrations of DOC has been shown to have a protective effect against metal toxicity in aquatic organisms and is being incorporated into the calculation of water quality guidelines for the protection of aquatic life (CCME 2018). In this report, because TOC and DOC closely approximate each other, TOC will be evaluated on a scale described in Table 1.2-5.

Table 1.2-5: Qualitative Scale of Total Organic Carbon in Surface Waters

Description	Total Organic Carbon (mg/L)
low	<5
moderate	5 to 20
high	>20

> = greater than; < = less than; mg/L = milligrams per litre.

1.3 Nutrients and Trophic Status

The main nutrients of concern in most freshwaters are phosphorus and nitrogen. Both are required for plant growth in small amounts. Phosphorus is an essential plant nutrient which, in excess, can cause increased growth of algae and aquatic plants. It is frequently the limiting nutrient, which means that small additions of phosphorus can result in increased productivity. Increased nutrient concentrations may result in excessive algal growth in water (phytoplankton) or on rock substrates (periphyton), which in turn can decrease oxygen levels in water at night and under ice (when respiration exceeds photosynthesis) (Mitchell and Prepas 1990; Wetzel 2001).

Phosphorus concentrations are influenced by geology and soil characteristics, and by the presence of wetlands in the watershed of a lake or stream. Concentrations of TP are generally lower in lakes situated on Precambrian Shield bedrock, and in lakes not affected by anthropogenic inputs (Wetzel 2001). Phosphorus is often measured as three forms: total dissolved phosphorus, which includes only the dissolved fractions of phosphorus, and total phosphorus (TP), which includes both particulate and dissolved forms, and orthophosphate. Orthophosphate (PO_4^{3-}) or soluble reactive inorganic phosphorus, is the primary dissolved form of phosphorus that is readily available to phytoplankton and periphyton.

Natural sources of nitrogen to freshwaters include precipitation from the atmosphere, nitrogen fixation by bacteria in the water and sediments, and inputs from surface and groundwater discharges (Wetzel 2001). Nitrogen can be present in both dissolved (i.e., soluble) and particulate (i.e., attached to or a component of particulate matter) forms in surface waters. Dissolved inorganic forms include nitrate, nitrite, and ammonia, and particulate forms include both organic and inorganic nitrogen. Some forms of nitrogen can be toxic to humans and aquatic life at high concentrations. CCME Drinking Water Guidelines and Water Quality Guidelines for the Protection of Aquatic Life exist for the dissolved inorganic forms of nitrogen (i.e., nitrate, nitrite and ammonia); these guidelines are temperature and pH dependent (CCME 1999), and are intended to protect humans and aquatic life from toxic effects, rather than effects on productivity.

Trophic status can be evaluated by examining the concentrations of nutrients (TP and TN), chlorophyll *a*, and water transparency (Secchi depth). The primary nutrient that often limits phytoplankton growth in lakes is phosphorus (Schindler 1974); therefore, phosphorus is often used to establish overall trophic status. Chlorophyll *a* is the primary photosynthetic pigment contained in phytoplankton, which is why it is often used as a surrogate measure of phytoplankton biomass and production in lakes (Franklin et al. 2012), and is also used frequently to determine trophic status.

The three main classes of trophic status are:

- oligotrophic (nutrient-poor, unproductive systems)
- mesotrophic (moderately productive systems)
- eutrophic (nutrient-rich, highly productive systems)

Vollenweider (1968) developed a classification scheme for lakes using TP, TN, chlorophyll *a*, and Secchi depth (Table 1.3-1). This general classification system is internationally accepted based on analyses of over 200 waterbodies during the international program on eutrophication conducted by the Organization for Economic Cooperation and Development (OECD). While this general classification system is relatively simple, complications can arise due to overlap in the ranges of trophic categories, as well as differences in categorization among constituents.

Table 1.3-1: Trophic Status Classification of Lakes

Trophic Status	Total Phosphorus (mg/L)		Total Nitrogen (mg/L)		Chlorophyll *a* (µg/L)		Secchi Depth (m)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Oligotrophic	0.008	0.003 to 0.018	0.661	0.307 to 1.630	1.7	0.3 to 4.5	9.9	5.4 to 28.3
Mesotrophic	0.0267	0.011 to 0.096	0.753	0.361 to 1.367	4.7	3.0 to 11.0	4.2	1.5 to 8.1
Eutrophic	0.0844	0.016 to 0.386	1.875	0.393 to 6.100	14.3	3.0 to 78.0	2.45	0.8 to 7.0

mg-P/L = milligrams of phosphorus per litre; mg-N/L = milligrams of nitrogen per litre.
Source: Vollenweider (1970).

The Canadian Council of Ministers of Environment (CCME 2004) recommends basing trophic status classification of lakes and streams on TP concentration, and further divides the mesotrophic and eutrophic subdivisions (Table 1.3-2). This additional subdivision was necessary because of the considerable variation that exists in Canadian surface waters above the range observed by OECD (CCME 2004).

Table 1.3-2: Trophic Classification of Canadian Lakes and Rivers Based on Total Phosphorus Trigger Ranges

Trophic Status	Description	Total Phosphorus Trigger Range (mg-P/L)
ultra-oligotrophic	Nutrient-poor, un-productive	<0.004
oligotrophic	Nutrient-poor, of low productivity	0.004 to 0.010
mesotrophic	Moderately productive	0.010 to 0.020
meso-eutrophic	Moderately to highly productive	0.020 to 0.035
eutrophic	Nutrient rich, highly productive	0.035 to 0.100
hyper-eutrophic	Nutrient rich, very highly productive	>0.100

> = greater than; < = less than; mg-P/L = milligrams of phosphorus per litre.
Source: CCME 2004.

1.4 Metals

Metals naturally occur in surface waters in small quantities. Aquatic organisms can be adversely affected by high metal concentrations; however, the level at which metals are toxic to aquatic organisms varies and several environmental factors (e.g., organic matter, hardness, pH) can modify the toxicity of metals (BC ENV 2017). Usually, most metals are associated with suspended sediments and therefore tend to settle out of the water column, which renders them biologically unavailable. Total metal (dissolved metals plus metals associated with suspended particles) and dissolved metal concentrations are provided in this report, but only total metal concentrations are discussed relative to aquatic life guidelines, with the exception of aluminum, iron and zinc, which have guidelines for the dissolved forms.

2.0 REFERENCES

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Description of Water Quality Parameters

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TABLES

1.0 WATER QUALITY PARAMETERS

This appendix describes the parameters commonly used to evaluate baseline water quality, and how these parameters are indicative of specific aspects of water quality. Water chemistry in surface waters depends on the interaction of biological, physical and chemical processes. The purpose of this appendix is to provide a general understanding of surface water quality parameters and typical ranges of concentrations observed in surface waters.

1.1 Field Parameters

1.1.1 Potential of Hydrogen (pH)

The potential of hydrogen (pH) is a measure of hydrogen ion concentration in a solution and is expressed on a scale of 0 (acidic) to 14 (alkaline). The greater the hydrogen ion concentration in water, the more acidic it is. Neutral waters have a pH of 7; waters with a pH less than 7 are considered acidic, and those with a pH greater than 7 are considered alkaline (Table 1.1-1; Wetzel 2001). Most aquatic organisms can tolerate waters with a pH between 6.0 and 9.0, as commonly found in many of the natural surface waters in Canada (McNeely et al. 1979). Acid deposition resulting from human activities can lower the pH of a waterbody. High pH values tend to facilitate the solubilization of ammonia, heavy metals, and salts. The precipitation of carbonate salts is enhanced when pH levels are high. Lethal effects of pH on aquatic life occur below pH 4.5 and above pH 9.5 (MELP 1998). During spring freshet, the pH of surface waters can drop to values approximating the pH of precipitation (e.g., 5.1 to 5.4; Schindler 1996). In natural fens and bogs, pH values can be lower than 4.5 (WRS 2004).

Table 1.1-1: Qualitative pH Scale of Surface Waters

Description	pH
Acidic	0 to <7
Neutral	7
basic (alkaline)	>7 to 14

> = greater than; < = less than; pH = potential of hydrogen.
Source: Wetzel (2001).

1.1.2 Dissolved Oxygen

Adequate amounts of dissolved oxygen (DO) are required to support fish and other organisms in lakes and streams (EMAN-North 2005). The solubility of oxygen depends on many factors, including the partial pressure of oxygen in the air, water temperature, water turbulence, mineral content of the water, the ability of the water to exchange freely with the atmosphere, and watershed characteristics (CCME 1999). Photosynthesis and turbulent mixing are the primary processes for the addition of DO to surface waters. Chemical and biological reduction are the main processes that remove DO from surface waters (AEP 1997).

Typical concentrations of DO in surface waters range from non-detectable (close to zero) to 18.4 mg/L (CCME 1999). The solubility of atmospheric oxygen in freshwater ranges from approximately 15 mg/L at 0°C to 8 mg/L at 25°C at sea level (McNeely et al. 1979). The biological effect of low DO concentration depends on the temperature of the water, type of organism, and life stage of the organism (CCME 1999). Sensitivity to low DO is species-specific, but in general, concentrations below 4 mg/L have been shown to produce detrimental effects in several aquatic organisms (DOE 1972).

1.2 Conventional Parameters, Ions and Organic Carbon

1.2.1 Total Suspended Solids

The concentration of all solid particles in the water column is referred to as total suspended solids (TSS). High TSS values can cause direct and indirect stress to aquatic life (CCME 2002; Robertson et al. 2006). The effect of high TSS concentrations on aquatic life depends on the TSS concentration and the duration of exposure (Newcombe and Jensen 1996; Robertson et al. 2006). Aquatic organisms can withstand low levels of TSS for long periods and higher levels for shorter periods (Newcombe and MacDonald 1991). Concentrations of TSS below 25 mg/L are generally not considered harmful to aquatic life (EIFAC 1965; US EPA 1973). In this report, TSS is characterized as low, moderate, or high (Table 1.2-1).

Table 1.2-1: Qualitative Scale of Total Suspended Solids in Surface Waters

Description	Total Suspended Solids (mg/L)
low	<10
moderate	10 to 25
high	>25

> = greater than; < = less than.

1.2.2 Alkalinity

Alkalinity is a measure of water's capacity to neutralize acids. In most cases, alkalinity is equal to bicarbonate minus hydrogen ion, where both are expressed in equivalents (Schindler 1996; Wetzel 2001). Alkalinity provides an indication of a waterbody's sensitivity to acid deposition or its acid neutralizing capacity. Saffran and Trew (1996) presented a scale of surface water lake sensitivity to acidification based on alkalinity (Table 1.2-2).

Table 1.2-2: Scale of Acid Sensitivity Based on Alkalinity in Surface Water Lakes

Acid Sensitivity	Alkalinity or Acid Neutralizing Capacity (mg/L as $CaCO_3$)
high	0
moderate	>10 to 20
low	>20 to 40
least	>40

$CaCO_3$ = calcium carbonate; > = greater than.
Source: Saffran and Trew 1996.

1.2.3 Major Ions

Major ions in surface waters typically include the anions bicarbonate, chloride and sulphate, and the cations calcium, magnesium, potassium and sodium. These may also be expressed in terms of hardness, total dissolved solids (TDS), and specific conductivity, as described below.

Hardness is primarily determined by the presence of calcium and magnesium (McNeely et al. 1979). A scale of water hardness, expressed as mg/L equivalent to calcium carbonate ($CaCO_3$), is provided in Table 1.2-3. The toxicity of many metals decreases as hardness increases (MELP 1998) because of competitive binding of divalent cations (BC ENV 2017; CCME 2003).

Table 1.2-3: Qualitative Scale of Water Hardness in Surface Waters

Description	Hardness (mg/L as $CaCO_3$)
soft	<60
moderately soft	60 to 120
hard	121 to 180
very hard	>180

$CaCO_3$ = calcium carbonate; > = greater than; < = less than.
Source: McNeely et al. 1979, Mitchell and Prepas 1990.

The concentration of TDS is a measure of total ion concentration. The TDS in surface waters is variable and is highly dependent on exchanges from the surrounding land, atmospheric sources, and exchanges between sediments and the water column (Wetzel 2001). Constituents may be used to calculate TDS concentrations analyzed in samples as a check on results for measured TDS concentrations. The method used for analyzing measured TDS is known to produce variability in the results. Waters with considerable calcium, magnesium, and chloride concentrations can form a hygroscopic (i.e., absorbs ambient water) residue that will continue to absorb water under normal laboratory conditions, thereby biasing the measurement higher than actual (Evaristo-Cordero 2011, pers. comm.; APHA 2012). Therefore, estimates of calculated concentrations of TDS (Equation 1) were included in the assessment of TDS concentrations.

$$Calculated\ TDS\ (SM)(mg/L) = (0.6\ x\ Total\ Alkalinity\ as\ CaCO_3) + Na^+ + Mg^+ + K^+ + Ca^{2+} + SO_4^- + Cl^- + NO_3^- + F^- + SiO_3^{2-}$$

[Equation 1]

Where:

SM = standard methods; Na^+ = sodium cation; Mg^+ = magnesium cation; K^+ = potassium cation; Ca^{2+} = calcium cation; $CaCO_3$ = calcium carbonate;SO_4^- = sulphate anion; Cl^- = chloride anion; NO_3^- = nitrate anion (multiply nitrate as nitrogen by 4.427); F^- = fluoride anion; and, SiO_3^{2-} = silicate anion (multiply reactive silica as SiO_2, by 1.266).

Specific conductivity is a measure of the ability of water to conduct electricity and varies with the concentration of charged particles in the water. Thus, the concentration of TDS and specific conductivity are strongly related. Descriptive scales for specific conductivity and TDS are provided in Table 1.2-4.

Table 1.2-4: Qualitative Scale of Total Dissolved Solids in Fresh Surface Waters

Description	Total Dissolved Solids (mg/L)	Specific Conductivity (µS/cm)
low	≤100	≤165
moderate	100 to 500	165 to 830
high	>500	>830

≤ = less than or equal to; > = greater than; µS/cm = microSiemens per centimetre.
Source: Hart et al. 1990, Mitchell and Prepas 1990.

1.2.4 Organic Carbon

Total organic carbon (TOC) comprises particulate and dissolved organic carbon (DOC). Natural waters have concentrations that generally vary from 1 to 30 mg/L (McNeely et al. 1979). The amount of TOC and DOC reaching surface waters varies largely from season to season with growth cycles and discharge rates (Wetzel 2001). Naturally occurring “brown water” lakes and ponds, common in boreal forest areas, generally have higher TOC concentrations (i.e., greater than 20 mg/L). Most TOC and DOC is derived from humic substances and partly degraded plant and animal materials (Ledesma et al. 2012). Concentrations of DOC has been shown to have a protective effect against metal toxicity in aquatic organisms and is being incorporated into the calculation of water quality guidelines for the protection of aquatic life (CCME 2018). In this report, because TOC and DOC closely approximate each other, TOC will be evaluated on a scale described in Table 1.2-5.

Table 1.2-5: Qualitative Scale of Total Organic Carbon in Surface Waters

Description	Total Organic Carbon (mg/L)
low	<5
moderate	5 to 20
high	>20

> = greater than; < = less than; mg/L = milligrams per litre.

1.3 Nutrients and Trophic Status

The main nutrients of concern in most freshwaters are phosphorus and nitrogen. Both are required for plant growth in small amounts. Phosphorus is an essential plant nutrient which, in excess, can cause increased growth of algae and aquatic plants. It is frequently the limiting nutrient, which means that small additions of phosphorus can result in increased productivity. Increased nutrient concentrations may result in excessive algal growth in water (phytoplankton) or on rock substrates (periphyton), which in turn can decrease oxygen levels in water at night and under ice (when respiration exceeds photosynthesis) (Mitchell and Prepas 1990; Wetzel 2001).

Phosphorus concentrations are influenced by geology and soil characteristics, and by the presence of wetlands in the watershed of a lake or stream. Concentrations of TP are generally lower in lakes situated on Precambrian Shield bedrock, and in lakes not affected by anthropogenic inputs (Wetzel 2001). Phosphorus is often measured as three forms: total dissolved phosphorus, which includes only the dissolved fractions of phosphorus, and total phosphorus (TP), which includes both particulate and dissolved forms, and orthophosphate. Orthophosphate (PO_4^{3-}) or soluble reactive inorganic phosphorus, is the primary dissolved form of phosphorus that is readily available to phytoplankton and periphyton.

Natural sources of nitrogen to freshwaters include precipitation from the atmosphere, nitrogen fixation by bacteria in the water and sediments, and inputs from surface and groundwater discharges (Wetzel 2001). Nitrogen can be present in both dissolved (i.e., soluble) and particulate (i.e., attached to or a component of particulate matter) forms in surface waters. Dissolved inorganic forms include nitrate, nitrite, and ammonia, and particulate forms include both organic and inorganic nitrogen. Some forms of nitrogen can be toxic to humans and aquatic life at high concentrations. CCME Drinking Water Guidelines and Water Quality Guidelines for the Protection of Aquatic Life exist for the dissolved inorganic forms of nitrogen (i.e., nitrate, nitrite and ammonia); these guidelines are temperature and pH dependent (CCME 1999), and are intended to protect humans and aquatic life from toxic effects, rather than effects on productivity.

Trophic status can be evaluated by examining the concentrations of nutrients (TP and TN), chlorophyll *a*, and water transparency (Secchi depth). The primary nutrient that often limits phytoplankton growth in lakes is phosphorus (Schindler 1974); therefore, phosphorus is often used to establish overall trophic status. Chlorophyll *a* is the primary photosynthetic pigment contained in phytoplankton, which is why it is often used as a surrogate measure of phytoplankton biomass and production in lakes (Franklin et al. 2012), and is also used frequently to determine trophic status.

The three main classes of trophic status are:

- oligotrophic (nutrient-poor, unproductive systems)
- mesotrophic (moderately productive systems)
- eutrophic (nutrient-rich, highly productive systems)

Vollenweider (1968) developed a classification scheme for lakes using TP, TN, chlorophyll *a*, and Secchi depth (Table 1.3-1). This general classification system is internationally accepted based on analyses of over 200 waterbodies during the international program on eutrophication conducted by the Organization for Economic Cooperation and Development (OECD). While this general classification system is relatively simple, complications can arise due to overlap in the ranges of trophic categories, as well as differences in categorization among constituents.

Table 1.3-1: Trophic Status Classification of Lakes

Trophic Status	Total Phosphorus (mg/L)		Total Nitrogen (mg/L)		Chlorophyll *a* (µg/L)		Secchi Depth (m)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Oligotrophic	0.008	0.003 to 0.018	0.661	0.307 to 1.630	1.7	0.3 to 4.5	9.9	5.4 to 28.3
Mesotrophic	0.0267	0.011 to 0.096	0.753	0.361 to 1.367	4.7	3.0 to 11.0	4.2	1.5 to 8.1
Eutrophic	0.0844	0.016 to 0.386	1.875	0.393 to 6.100	14.3	3.0 to 78.0	2.45	0.8 to 7.0

mg-P/L = milligrams of phosphorus per litre; mg-N/L = milligrams of nitrogen per litre.
Source: Vollenweider (1970).

The Canadian Council of Ministers of Environment (CCME 2004) recommends basing trophic status classification of lakes and streams on TP concentration, and further divides the mesotrophic and eutrophic subdivisions (Table 1.3-2). This additional subdivision was necessary because of the considerable variation that exists in Canadian surface waters above the range observed by OECD (CCME 2004).

Table 1.3-2: Trophic Classification of Canadian Lakes and Rivers Based on Total Phosphorus Trigger Ranges

Trophic Status	Description	Total Phosphorus Trigger Range (mg-P/L)
ultra-oligotrophic	Nutrient-poor, un-productive	<0.004
oligotrophic	Nutrient-poor, of low productivity	0.004 to 0.010
mesotrophic	Moderately productive	0.010 to 0.020
meso-eutrophic	Moderately to highly productive	0.020 to 0.035
eutrophic	Nutrient rich, highly productive	0.035 to 0.100
hyper-eutrophic	Nutrient rich, very highly productive	>0.100

> = greater than; < = less than; mg-P/L = milligrams of phosphorus per litre.
Source: CCME 2004.

1.4 Metals

Metals naturally occur in surface waters in small quantities. Aquatic organisms can be adversely affected by high metal concentrations; however, the level at which metals are toxic to aquatic organisms varies and several environmental factors (e.g., organic matter, hardness, pH) can modify the toxicity of metals (BC ENV 2017). Usually, most metals are associated with suspended sediments and therefore tend to settle out of the water column, which renders them biologically unavailable. Total metal (dissolved metals plus metals associated with suspended particles) and dissolved metal concentrations are provided in this report, but only total metal concentrations are discussed relative to aquatic life guidelines, with the exception of aluminum, iron and zinc, which have guidelines for the dissolved forms.

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APPENDIX D

Plankton Data

Table D-1: Chlorophyll *a* Concentrations in Jackfish Lake During the Open-water Season, 201

Area	Sampling Date	Original Sample (µg/L)	Duplicate Sample (µg/L)	Mean (µg/L)	RPD (%)
K and EDM	29-May-18	30.8	22.0	26.4	33
	10-Jul-18	19.8	28.6	24.2	36
	1-Aug-18	59.2	64.3	61.7	8
	26-Sep-18	13.7	17.9	15.8	26
Mid Lake	30-May-18	34.1	43.9	39.0	25
	10-Jul-18	29.5	33.5	31.5	13
	1-Aug-18	66.5	73.0	69.8	9
	26-Sep-18	18.0	17.9	17.9	1
Northeast Bay	30-May-18	31.8	81.1	56.4	87
	10-Jul-18	26.0	26.2	26.1	1
	1-Aug-18	51.7	54.2	53.0	5
	26-Sep-18	17.7	18.2	18.0	3
Northwest Bay	30-May-18	34.4	30.5	32.4	12
	10-Jul-18	46.9	31.5	39.2	39
	1-Aug-18	64.0	74.5	69.3	15
	26-Sep-18	18.0	17.6	17.8	2
Southwest Bay	30-May-18	59.2	37.8	48.5	44
	10-Jul-18	28.8	35.7	32.3	21
	1-Aug-18	48.3	68.8	58.5	35
	26-Sep-18	16.5	18.3	17.4	10

Note: Highlighted values indicate RPD values >50%. The percentage of RPD values over 50% for th
RPD = relative percent difference; - = not applicable or data not available; n/c = sample not collected

Table D-2: Chlorophyll *c* Concentrations in Jackfish Lake During the Open-water Season, 201

Area	Sampling Date	Original Sample (µg/L)	Duplicate Sample (µg/L)	Mean (µg/L)	RPD (%)
K and EDM	29-May-18	1.54	1.68	1.6	9
	10-Jul-18	0.72	1.47	1.1	68
	1-Aug-18	2.32	3.29	2.8	35
	26-Sep-18	0.55	0.72	0.6	27
Mid Lake	30-May-18	2.86	3.34	3.1	15
	10-Jul-18	1.37	1.49	1.4	8
	1-Aug-18	2.99	3.41	3.2	13
	26-Sep-18	0.62	0.63	0.6	2
Northeast Bay	30-May-18	3.02	4.02	3.5	29
	10-Jul-18	1.65	1.24	1.4	29
	1-Aug-18	2.09	2.40	2.2	14
	26-Sep-18	0.69	0.76	0.7	10
Northwest Bay	30-May-18	2.94	2.73	2.8	7
	10-Jul-18	2.20	2.08	2.1	6
	1-Aug-18	2.46	3.46	3.0	34
	26-Sep-18	0.63	0.71	0.7	12
Southwest Bay	30-May-18	4.09	3.32	3.7	21
	10-Jul-18	0.94	1.69	1.3	57
	1-Aug-18	2.03	2.17	2.1	7
	26-Sep-18	0.64	0.74	0.7	14

Note: Highlighted values indicate RPD values >50%. The percentage of RPD values over 50% for th
RPD = relative percent difference; - = not applicable or data not available; n/c = sample not collected

Table D-3: Total Phytoplankton Abundance (cells/L) in Jackfish Lake, 2018

Major Ecological Group	Taxon	K and EDM 29-May-18 cells/L	K and EDM-DUP 29-May-18 cells/L	Mid Lake 30-May-18 cells/L	Northeast Bay 30-May-18 cells/L	Northwest Bay 30-May-18 cells/L	Southwest Bay 30-May-18 cells/L	K and EDM 10-Jul-18 cells/L	Mid Lake 10-Jul-18 cells/L	Northeast Bay 10-Jul-18 cells/L	Northwest Bay 10-Jul-18 cells/L	Southwest Bay 10-Jul-18 cells/L	Southwest Bay-DUP 10-Jul-18 cells/L
Diatoms	**Bacillariophyta**												
	Nitzschia sp.	-	-	-	66,984	20,932	133,967	-	-	-	-	-	-
	Synedra sp.	47,846	47,846	20,932	-	-	-	-	-	-	-	-	-
	Ulnaria ulna	23,923	-	-	-	-	-	-	-	-	-	-	-
	Navicula sp.	-	-	-	33,492	-	-	-	-	-	-	-	-
	Diatoma tenuis	909,065	909,065	1,046,621	1,507,134	983,824	2,366,759	-	-	-	-	-	-
Total Diatoms		**980,833**	**956,911**	**1,067,554**	**1,607,610**	**1,004,756**	**2,500,727**	**0**	**0**	**0**	**0**	**0**	**0**
Chlorophytes or green algae	**Chlorophyta**												
	Carteria sp.	-	-				-	-	-	-	71,768	-	-
	Chlamydomonas sp.	932,988	789,451	648,905	870,789	586,108	3,215,220	-	55,820	-	-	-	-
	Sphaerocystis sp.	-	-	-	-	-	267,935	-	-	-	-	-	-
	Eudorina sp.	-	-	-	-	167,459	-	-	-	-	-	-	-
	Oocystis sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Desmodesmus sp.	95,691	-	-	-	-	-	-	-	-	-	-	-
	Planktosphaeria sp.	167,459	287,073	-	-	104,662	-	-	-	-	-	-	-
	Monoraphidium sp.	23,923	-	-	-	-	-	-	-	-	-	-	-
	Botryococcus braunii	-	-	-	-	-	-	-	-	-	-	57,415	-
Total Chlorophytes		**1,220,061**	**1,076,525**	**648,905**	**870,789**	**858,229**	**3,483,155**	**0**	**55,820**	**0**	**71,768**	**57,415**	**0**
Chrysophytes or golden algae	**Haptophyta**												
	Chrysochromulina sp.	-	-	20,932	-	-	-	-	-	-	-	-	-
	Ochrophyta												
	Chromulina sp.	-	-	20,932	-	-	-	-	-	-	-	-	-
	Ochromonas sp.	47,846	71,768	41,865	33,492	20,932	44,656	-	-	-	-	-	-
	Dinobryon sp.	-	-	-	-	20,932	44,656	-	-	-	-	-	-
	Kephyrion/Pseudokephyrion sp. complex	-	-	-	-	-	-	-	-	-	-	-	-
	Unknown Chrysophyte	-	-	-	-	-	625,182	-	-	-	-	-	-
Total Chrysophytes		**47,846**	**71,768**	**83,730**	**33,492**	**41,865**	**714,493**	**0**	**0**	**0**	**0**	**0**	**0**
Cryptophytes or cryptomonads	**Cryptophyta**												
	Cryptomonas sp.	47,846	119,614	251,189	334,919	251,189	357,247	44,656	55,820	133,967	215,305	114,829	241,141
	Plagioselmis nanoplanctica	-	-	-	-	-	-	-	-	-	-	-	-
	Katablepharidophyta												
	Katablepharis sp.	71,768	119,614	230,257	100,476	41,865	223,279	44,656	-	89,312	358,842	229,659	-
Total Cryptophytes		**119,614**	**239,228**	**481,446**	**435,394**	**293,054**	**580,526**	**89,312**	**55,820**	**223,279**	**574,146**	**344,488**	**241,141**
Euglenophytes or eugenoids	**Euglenozoa**												
	Euglena sp.	-	-	-	-	-	-	-	-	44,656	-	-	-
Total Euglenophytes		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**44,656**	**0**	**0**	**0**
Cyanobacteria or blue-green algae	**Cyanobacteria**												
	Aphanizomenon sp.	-	-	-	-	-	-	19,745,997	10,438,301	10,252,235	20,999,405	16,240,142	13,865,636
	Dolichospermum sp.	-	-	-	1,674,594	-	-	-	-	-	-	-	-
	Planktothrix cf. agardhii	-	-	-	-	-	-	31,348,395	-	8,573,920	34,448,785	20,095,125	43,726,992
	Planktothrix sp.	350,516,392	354,822,490	221,925,535	421,528,736	269,023,484	339,384,331	777,904,611	957,867,618	694,621,482	1,274,246,220	1,104,657,720	1,333,271,344
	Phormidium sp.	418,648	893,117	3,296,856	33,492	376,784	1,071,740	44,656	279,099	-	-	57,415	-
	Limnothrix sp.	-	-	-	-	-	-	-	-	-	-	-	160,761
	Pseudanabaena sp.	71,768	47,846	439,581	-	-	267,935	2,203,021	-	1,339,675	861,220	3,330,049	3,456,361
	Cyanodictyon sp.	-	-	-	-	418,648	-	-	-	-	-	-	-
	Synechococcus sp.	23,923	23,923	41,865	33,492	41,865	-	-	-	-	-	-	-
	Unknown Cyanobacterial (colonial)	-	-	-	-	-	-	-	-	-	-	-	-
Total Cyanobacteria		**351,030,732**	**355,787,375**	**225,703,837**	**423,270,313**	**269,860,781**	**340,724,006**	**831,246,680**	**968,585,018**	**714,787,312**	**1,330,555,631**	**1,144,380,451**	**1,394,481,094**
Dinoflagellates	**Dinophyta**												
	Gymnodinium sp.	47,846	119,614	146,527	301,427	83,730	223,279	-	-	535,870	143,537	114,829	-
	Peridinium sp.	-	-	-	66,984	83,730	44,656	-	-	-	-	-	-
Total Dinoflagellates		**47,846**	**119,614**	**146,527**	**368,411**	**167,459**	**267,935**	**0**	**0**	**535,870**	**143,537**	**114,829**	**0**
Other flagellated algae	Flagellate algal cell (<10µm in length)	143,537	23,923	230,257	167,459	146,527	-	89,312	-	-	143,537	-	160,761
	Non-flagellate algal cell (<10µm in length)	-	-	-	-	-	-	-	-	-	-	-	-
Total other flagellated algae		**143,537**	**23,923**	**230,257**	**167,459**	**146,527**	**0**	**89,312**	**0**	**0**	**143,537**	**0**	**160,761**
Total phytoplankton abundnace		**353,590,468**	**358,275,343**	**228,362,255**	**426,753,468**	**272,372,671**	**348,270,842**	**831,425,303**	**968,696,657**	**715,591,117**	**1,331,488,619**	**1,144,897,183**	**1,394,882,996**
Taxonomic richness (genus-level; number of taxa)		**15**	**12**	**13**	**13**	**15**	**13**	**6**	**5**	**7**	**7**	**8**	**5**

Major Ecological Group	Taxon	K and EDM 1-Aug-18 cells/L	Mid Lake 1-Aug-18 cells/L	Northeast Bay 1-Aug-18 cells/L	Northwest Bay 1-Aug-18 cells/L	Northwest Bay-DUP 1-Aug-18 cells/L	Southwest Bay 1-Aug-18 cells/L	K and EDM 26-Sep-18 cells/L	Mid Lake 26-Sep-18 cells/L	Mid Lake-DUP 26-Sep-18 cells/L	Northeast Bay 26-Sep-18 cells/L	Northwest Bay 26-Sep-18 cells/L	Southwest Bay 26-Sep-18 cells/L
Diatoms	**Bacillariophyta**												
	Nitzschia sp.	-	-	-	-	-	-	167,459	-	-	-	-	-
	Synedra sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Ulnaria ulna	-	-	-	-	-	-	-	-	-	-	-	-
	Navicula sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Diatoma tenuis	-	-	-	-	-	-	-	-	-	-	-	-
Total Diatoms		**0**	**0**	**0**	**0**	**0**	**0**	**167,459**	**0**	**0**	**0**	**0**	**0**
Chlorophytes or green algae	**Chlorophyta**												
	Carteria sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Chlamydomonas sp.	-	-	-	-	-	-	-	334,919	111,640	-	-	-
	Sphaerocystis sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Eudorina sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Oocystis sp.	-	-	-	-	-	-	7,368,212	8,261,329	-	5,090,765	19,023,385	-
	Desmodesmus sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Planktosphaeria sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Monoraphidium sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Botryococcus braunii	-	-	-	-	-	-	-	-	-	-	-	-
Total Chlorophytes		**0**	**0**	**0**	**0**	**0**	**0**	**7,368,212**	**8,596,248**	**111,640**	**5,090,765**	**19,023,385**	**0**
Chrysophytes or golden algae	**Haptophyta**												
	Chrysochromulina sp.	-	55,820	-	-	-	-	-	111,640	-	-	-	-
	Ochrophyta												
	Chromulina sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Ochromonas sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Dinobryon sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Kephyrion/Pseudokephyrion sp. complex	-	-	-	-	-	-	-	-	111,640	-	-	-
	Unknown Chrysophyte	-	-	-	-	-	-	-	-	-	-	-	-
Total Chrysophytes		**0**	**55,820**	**0**	**0**	**0**	**0**	**0**	**111,640**	**111,640**	**0**	**0**	**0**
Cryptophytes or cryptomonads	**Cryptophyta**												
	Cryptomonas sp.	267,935	55,820	167,459	80,380	125,595	-	502,378	446,558	223,279	133,967	-	401,902
	Plagioselmis nanoplanctica	-	167,459	-	-	-	-	-	-	-	-	-	-
	Katablepharidophyta												
	Katablepharis sp.	267,935	-	-	-	-	-	167,459	558,198	334,919	133,967	937,772	133,967
Total Cryptophytes		**535,870**	**223,279**	**167,459**	**80,380**	**125,595**	**0**	**669,837**	**1,004,756**	**558,198**	**267,935**	**937,772**	**535,870**
Euglenophytes or eugenoids	**Euglenozoa**												
	Euglena sp.	-	-	-	-	62,797	-	-	-	-	-	-	-
Total Euglenophytes		**0**	**0**	**0**	**0**	**62,797**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Cyanobacteria or blue-green algae	**Cyanobacteria**												
	Aphanizomenon sp.	116,594,030	22,045,880	19,048,504	5,684,050	36,242,993	39,029,198	-	-	-	-	-	-
	Dolichospermum sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Planktothrix cf. agardhii	67,519,620	13,620,029	-	20,577,408	16,327,289	22,104,637	-	14,289,867	18,308,892	-	-	-
	Planktothrix sp.	2,108,380,499	1,004,198,045	1,155,469,679	1,305,379,310	1,018,257,655	1,432,782,402	2,953,983,353	1,909,036,861	2,343,873,035	2,500,637,337	1,245,897,741	2,537,880,301
	Phormidium sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Limnothrix sp.	-	-	-	-	-	-	-	-	-	-	-	-
	Pseudanabaena sp.	4,983,591	669,837	893,117	-	313,986	2,176,972	-	-	-	-	-	-
	Cyanodictyon sp.	-	55,820		19,291,320	38,683,115	15,071,344	-	-	8,931,167	-	-	-
	Synechococcus sp.	-	-	-	80,380	62,797	-	-	-	-	-	133,967	-
	Unknown Cyanobacterial (colonial)	-	-	-	-	-	18,314,208	-	-	-	-	-	-
Total Cyanobacteria		**2,297,477,740**	**1,040,589,611**	**1,175,411,299**	**1,351,012,468**	**1,109,887,835**	**1,529,478,760**	**2,953,983,353**	**1,923,326,727**	**2,371,113,093**	**2,500,637,337**	**1,246,031,708**	**2,537,880,301**
Dinoflagellates	**Dinophyta**												
	Gymnodinium sp.	-	-	-	-	-	-	-	111,640	223,279	267,935	-	-
	Peridinium sp.	-	-	-	-	-	-	-	-	-	-	-	-
Total Dinoflagellates		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**111,640**	**223,279**	**267,935**	**0**	**0**
Other flagellated algae	Flagellate algal cell (<10µm in length)	-	-	-	80,380	-	-	-	446,558	223,279	133,967	267,935	-
	Non-flagellate algal cell (<10µm in length)	-	-	-	-	-	-	-	-	-	-	-	133,967
Total other flagellated algae		**0**	**0**	**0**	**80,380**	**0**	**0**	**0**	**446,558**	**223,279**	**133,967**	**267,935**	**133,967**
Total phytoplankton abundnace		**2,298,013,610**	**1,040,868,710**	**1,175,578,759**	**1,351,173,229**	**1,110,076,227**	**1,529,478,760**	**2,962,188,862**	**1,933,597,569**	**2,372,341,128**	**2,506,397,939**	**1,266,260,801**	**2,538,550,139**
Taxonomic richness (genus-level; number of taxa)		**5**	**7**	**4**	**5**	**7**	**4**	**5**	**7**	**7**	**5**	**4**	**3**

Note: Grey shaded cells represent field duplicates.

cells/L = cells per litre; DUP = duplicate; sp. = species; < = less than; > greater than; µm = micrometres; - = not applicable.

Table D-4: Total Phytoplankton Biomass (µg/L) in Jackfish Lake, 2018

Major Ecological Group	Taxon	K and EDM 29-May-18 (µg/L)	K and EDM - DUP 29-May-18 (µg/L)	Mid Lake 30-May-18 (µg/L)	Northeast Bay 30-May-18 (µg/L)	Northwest Bay 30-May-18 (µg/L)	Southwest Bay 30-May-18 (µg/L)	K and EDM 10-Jul-18 (µg/L)	Mid Lake 10-Jul-18 (µg/L)	Northeast Bay 10-Jul-18 (µg/L)	Northwest Bay 10-Jul-18 (µg/L)	Southwest Bay 10-Jul-18 (µg/L)	Southwest Bay - DUP 10-Jul-18 (µg/L)
Diatoms	**Bacillariophyta**												
	Diatoma tenuis	1,571	1,571	1,809	2,605	1,700	4,091	0	0	0	0	0	0
Total Diatoms		**1,571**	**1,571**	**1,809**	**2,605**	**1,700**	**4,091**	**0**	**0**	**0**	**0**	**0**	**0**
Chlorophytes or green algae	**Chlorophyta**												
	Chlamydomonas sp.	707	598	492	660	444	2,435	0	42	0	0	0	0
	Oocystis sp.	0	0	0	0	0	0	0	0	0	0	0	0
Total Chlorophytes		**707**	**598**	**492**	**660**	**444**	**2,435**	**0**	**42**	**0**	**0**	**0**	**0**
Cyanobacteria or blue-green algae	**Cyanobacteria**												
	Aphanizomenon sp.	-	-	-	-	-	-	409	216	212	435	336	287
	Planktothrix sp.	-	-	-	-	-	-	1,019	-	279	1,120	653	1,421
	Planktothrix cf. *agardhii*	11,392	11,532	7,213	13,700	8,743	11,030	25,282	31,131	22,575	41,413	35,901	43,331
	Unknown Cyanobacteria (colonial)	-	-	-	-	-	-	-	-	-	-	-	-
Total Cyanobacteria		11,392	11,532	7,213	13,700	8,743	11,030	26,710	31,347	23,066	42,967	36,891	45,039
Total Phytoplankton Biomass		13,670	13,701	9,513	16,964	10,888	17,556	26,710	31,389	23,066	42,967	36,891	45,039

Major Ecological Group	Taxon	K and EDM 01-Aug-18 (µg/L)	Mid Lake 01-Aug-18 (µg/L)	Northeast Bay 01-Aug-18 (µg/L)	Northwest Bay 01-Aug-18 (µg/L)	Northwest Bay - DUP 01-Aug-18 (µg/L)	Southwest Bay 01-Aug-18 (µg/L)	K and EDM 26-Sep-18 (µg/L)	Mid Lake 26-Sep-18 (µg/L)	Mid Lake - DUP 26-Sep-18 (µg/L)	Northeast Bay 26-Sep-18 (µg/L)	Northwest Bay 26-Sep-18 (µg/L)	Southwest Bay 26-Sep-18 (µg/L)
Diatoms	**Bacillariophyta**												
	Diatoma tenuis	0	0	0	0	0	0	0	0	0	0	0	0
Total Diatoms		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Chlorophytes or green algae	**Chlorophyta**												
	Chlamydomonas sp.	0	0	0	0	0	0	0	254	85	0	0	0
	Oocystis sp.	0	0	0	0	0	0	79	89	0	55	205	0
Total Chlorophytes		**0**	**0**	**0**	**0**	**0**	**0**	**79**	**343**	**85**	**55**	**205**	**0**
Cyanobacteria or blue-green algae	**Cyanobacteria**												
	Aphanizomenon sp.	2,415	457	395	118	751	808	-	-	-	-	-	-
	Planktothrix sp.	2,194	443	-	669	531	718	-	464	595	-	-	-
	Planktothrix cf. *agardhii*	68,522	32,636	37,553	42,425	33,093	46,565	96,004	62,043	76,176	81,270	40,491	82,481
	Unknown Cyanobacteria (colonial)	-	-	-	-	-	1436.5	-	-	-	-	-	-
Total Cyanobacteria		73,132	33,536	37,947	43,211	34,375	49,529	96,004	62,508	76,771	81,270	40,491	82,481
Total Phytoplankton Biomass		73,132	33,536	37,947	43,211	34,375	49,529	96,083	62,850	76,855	81,325	40,696	82,481

Note: Grey shaded cells represent field duplicates.

µg/L = micrograms per litre; DUP = duplicate; sp. = species; cf. = confertim or possibly this species; - = not applicable.

Table D-5: Results of Field Duplicate (Quality Control) Phytoplankon Samples for Jackfish Lake, 2018

Station	Sampling Date	Major Taxonomic Group	Total Abundance (cells/L)		RPD (%)	Bray Curtis Dissimilarity Index
			Original Sample	Duplicate Sample		
K and EDM	29-May-18	Total Diatoms	980,833	956,911	2	0.01
		Total Chlorophytes	1,220,061	1,076,525	13	
		Total Chrysophytes	47,846	71,768	40	
		Total Cryptophytes	119,614	239,228	**67**	
		Total Euglenophytes	0	0	-	
		Total Cyanobacteria	351,030,732	355,787,375	1	
		Total Dinoflagellates	47,846	119,614	**86**	
		Total Other Flagellated Algae	143,537	23,923	**143**	
		Total Phytoplankton	353,590,468	358,275,343	1	
		Taxonomic Richness (No. of taxa)	15	12	22	
Southwest Bay	10-Jul-18	Total Diatoms	0	0	-	0.09
		Total Chlorophytes	57,415	0	**200**	
		Total Chrysophytes	0	0	-	
		Total Cryptophytes	344,488	241,141	35	
		Total Euglenophytes	0	0	-	
		Total Cyanobacteria	1,144,380,451	1,394,481,094	20	
		Total Dinoflagellates	114,829	0	**200**	
		Total Other Flagellated Algae	0	160,761	**200**	
		Total Phytoplankton	1,144,897,183	1,394,882,996	20	
		Taxonomic Richness (No. of taxa)	8	5	46	
Northwest Bay	1-Aug-18	Total Diatoms	0	0	-	0.10
		Total Chlorophytes	0	0	-	
		Total Chrysophytes	0	0	-	
		Total Cryptophytes	80,380	125,595	44	
		Total Euglenophytes	0	62,797	**200**	
		Total Cyanobacteria	1,351,012,468	1,109,887,835	20	
		Total Dinoflagellates	0	0	-	
		Total Other Flagellated Algae	80,380	0	**200**	
		Total Phytoplankton	1,351,173,229	1,110,076,227	20	
		Taxonomic Richness (No. of taxa)	5	7	33	
Mid Lake	26-Sep-18	Total Diatoms	0	0	-	0.10
		Total Chlorophytes	8,596,248	111,640	**195**	
		Total Chrysophytes	111,640	111,640	0	
		Total Cryptophytes	1,004,756	558,198	**57**	
		Total Euglenophytes	0	0	-	
		Total Cyanobacteria	1,923,326,727	2,371,113,093	21	
		Total Dinoflagellates	111,640	223,279	**67**	
		Total Other Flagellated Algae	446,558	223,279	**67**	
		Total Phytoplankton	1,933,597,569	2,372,341,128	20	
		Taxonomic Richness (No. of taxa)	7	7	0	

Note: **Bolded** values failed one or more quality control checks (either the RPD exceeded the 50% criterion, or the Bray-Curtis dissimilarity index exceeded the 0.5 criterion).

cells/L = cells per litre; RPD = relative percent difference; QC = quality control; No. = number; - = not applicable.

Table D-6: Taxonomist Split Phytoplantkon Samples for Jackfish Lake, 2018

Station	Date	Original Abundance (cells/L)	QA Abundance (cells/L)	Percent Agreement (%)
Mid Lake	10-Jul-18	968,696,657	1,140,240,179	85
Southwest Bay	26-Sep-18	2,538,550,139	2,496,350,377	98

QA = quality assurance; cells/L = cells per litre.

APPENDIX E

Benthic Invertebrate Community and Sediment Quality Data

Table E-1: Summary of Sediment Chemistry Quality Control Samples for Jackfish Lake Environmental Monitoring Program, Fall 2018

Parameter	Field Dupicate			Labratory Duplicate		
	JFL-SQ-05	JFL-SQ-05-Dup	RPD (%)	JFL-SQ-02	JFL-SQ-02-Dup	RPD (%)
	%	%		%	%	
TOC	6.1	5.7	7	-	-	-
Sand	29.2	27.2	7	4.1	4.3	5
Silt	58.1	58.2	0	87.9	87.2	1
Clay	12.7	14.6	14	8.0	8.5	6

TOC = total organic carbon; - = not measured.

Table E-2: Benthic Invertebrate Abundance Data (numbers per Ekman grab), NTPC Jackfish Lake Environmental Monitoring Program, Fall 2018

Major Taxonomic Group	Family	Subfamily/Tribe	Genus/Species	JFL-BIC-01			JFL-BIC-02			JFL-BIC-03			JFL-BIC-04			JFL-BIC-05		
				#1	#2	#3	#1	#2	#3	#1	#2	#5	#1	#2	#3	#1	#2	#5
Nematoda	-	-	-	2	3	1	0	0	0	0	0	0	21	20	6	2	4	1
Oligochaeta	Naididae	Naidinae	-	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
		Tubificinae	-	1	0	0	0	0	0	0	0	0	0	1	0	12	21	15
Acari - Hydracarina	Pionidae	-	*Piona* sp.	0	0	0	0	0	0	2	1	0	3	1	1	9	3	6
	Unionicolidae	-	*Neumania* sp.	1	0	0	0	0	0	0	0	0	4	9	16	10	3	4
Cladocera	Daphnidae	-	*Daphnia* sp.	5	0	7	2	0	1	0	2	1	1	5	3	1	1	0
Copepoda - Cyclopoida	Cyclopidae	-	-	1	3	15	0	0	0	2	0	1	0	5	5	4	2	2
Ostracoda	-	-	-	0	0	0	0	0	0	0	0	0	2	0	0	1	7	0
Gastropoda	Valvatidae	-	*Valvata sincera*	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0
Bivalvia	Pisidiidae	-	s/d	0	0	0	0	0	0	0	0	0	0	0	0	0	6	2
			Pisidium sp.	0	0	0	0	0	0	0	0	0	0	0	0	4	7	4
Ephemeroptera	Baetidae	-	*Callibaetis* sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	Caenidae	-	*Caenis* sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Trichoptera	Phryganeidae	-	*Phryganea* sp.	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
Diptera	Chaoboridae	-	*Chaoborus* sp.	4	6	0	22	13	21	8	28	11	0	2	1	1	0	0
	Chironomidae	Tanypodinae	*Procladius* sp.	3	0	8	0	0	0	0	1	0	15	17	10	42	22	32
			Tanypus sp.	0	0	4	0	0	0	0	0	0	24	13	12	56	50	43
		Chironomini	*Chironomus* sp.	35	24	158	3	0	0	8	11	7	88	51	90	64	67	81
			Cryptochironomus sp.	0	0	0	0	0	0	0	0	0	7	6	6	3	1	3
			Cladopelma sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Polypedilum sp.	0	0	1	0	0	0	0	0	0	2	0	1	5	3	5
		Tanytarsini	*Tanytarsus* sp.	0	0	0	0	0	0	0	0	0	3	0	3	9	1	9
TOTAL				**52**	**36**	**196**	**27**	**13**	**22**	**20**	**43**	**20**	**170**	**131**	**155**	**224**	**201**	**208**

- = not identified to this level or taxonomic level not applicable; s/d = small or damaged organism.

Note: Shaded cells indicate taxa that were removed from the dataset (meiofauna or non-benthic) before analysis.

Quality Control Results – Sorting Efficiency

Site	Sorting Efficiency (%)
JFL-BIC-01-2	[1-(0/(36+0))]*100 = 100
JFL-BIC-04-2	[1-(0/(131+0))]*100 = 100

Average Sorting Efficiency – 100%

% sorting efficiency = [1-(# in QC re-sort / (# sorted originally + # QC resort))]* 100

GOLDER

Table E-3: Summary Statistics for Benthic Invertebrate Community Variables, NTPC Jack Fish Lake, Fall 2018

Area	Station	Total Density (org/m^2)	Richness (taxa/station)	Simpson's Diversity Index	Simpson's Evenness Index
K and EMD	JF1-1	1,724	4	0.23	0.32
	JF1-2	1,034	1	-	-
	JF1-3	7,456	6	0.16	0.20
Mean		3,405	4	0.20	0.26
Median		1,724	4	0.20	0.26
Minimum		1,034	1	0.16	0.20
Maximum		7,456	6	0.23	0.32
Count		3	3	2	2
SD		3,525	3	0.05	0.09
SE		2,035	1	0.03	0.06
Mid Lake	JF2-1	129	1	-	-
	JF2-2	0	0	-	-
	JF2-3	0	0	-	-
Mean		43	0	-	-
Median		0	0	-	-
Minimum		0	0	-	-
Maximum		129	1	-	-
Count		3	3	-	-
SD		74	1	-	-
SE		43	0	-	-
Northeast Bay	JF3-1	431	2	0.32	0.73
	JF3-2	560	3	0.27	0.46
	JF3-3	302	1	-	-
Mean		431	2	0.30	0.60
Median		431	2	0.30	0.60
Minimum		302	1	0.27	0.46
Maximum		560	3	0.32	0.73
Count		3	3	2	2
SD		129	1	0.03	0.20
SE		74	1	0.02	0.14
Northwest Bay North	JF4-1	6,378	9	0.61	0.28
	JF4-2	4,267	8	0.68	0.39
	JF4-3	6,034	9	0.56	0.25
Mean		5,560	9	0.61	0.31
Median		6,034	9	0.61	0.28
Minimum		4,267	8	0.56	0.25
Maximum		6,378	9	0.68	0.39
Count		3	3	3	3
SD		1,133	1	0.06	0.07
SE		654	0	0.03	0.04
Southwest Bay	JF5-1	9,310	12	0.80	0.41
	JF5-2	8,361	13	0.79	0.36
	JF5-3	8,835	11	0.77	0.39
Mean		8,835	12	0.78	0.39
Median		8,835	12	0.79	0.39
Minimum		8,361	11	0.77	0.36
Maximum		9,310	13	0.80	0.41
Count		3	3	3	3
SD		475	1	0.02	0.03
SE		274	1	0.01	0.02

org/m^2 = organisms per square metre; SD = standard deviation; SE = standard error; - = not applicable.

APPENDIX F

Fish Habitat and Catch Data

Table F-1: Habitat Summary per Fishing Effort, 2018 Jackfish Lake Environmental Monitoring

Sampling Area	Effort Number	Gear Type	Date	UTM Coordinates (Nad83); Zone 11V				Depth (m)		Substrate		Weather				Vegetation	Comments
				Start Easting	Start Northing	End Easting	End Northing	Min	Max	Dominant(a)	Sub-Dominant(b)	Air Temp (°C)	Cloud Cover (%)	Wind Direction	Wind Speed (km/h)		
East Bay	18-JL-BP-001-001	BP	24-Jul-18	635149	6929023	635127	6929079	1.0	1.0	47% Sand, 53% Silt/Clay	Gravel	19	0	-	light	Grassy, cattails, sedge	Flooded shallows, poor visibility
	18-JL-MT-003-001	MT	26-Jul-18	635140	6929025	635114	6929077	0.50	1.0		-	20	0	S	3	Shallow, grassy, cattails	
	18-JL-MT-003-002	MT	26-Jul-18	635140	6929025	635054	6928930	0.50	1.0		Boulder/Bedrock	20	0	S	3	Shallow, flooded, grasses	
	18-JL-SN-001-001	SN	26-Jul-18	635140	6929065	-	-	0.60	0.70		-	23	2	S	3	Flooded, cattails, sedge, woody debris	Poor visibility
	18-JL-SN-001-002	SN	26-Jul-18	635149	6929046	-	-	0.60	0.70		-	23	2	S	3	Flooded, cattails, sedge, woody debris	Poor visibility
Northeast Bay	18-JL-BP-002-001	BP	25-Jul-18	634619	6929319	634611	6929302	0.25	0.75	8% Sand, 92% Silt/Clay	Boulder/Cobble	18	0	N	17	No vegetation	Moderately steep, poor visibility
	18-JL-GN-004-002	GN	26-Jul-18	634793	6929229	634800	6929285	1.6	2.3		-	23	2	S	3	Cattails, flooded bay, emergent grasses.	
	18-JL-GN-004-001	GN	25-Jul-18	634643	6929359	634657	6929415	0.80	1.3		-	18	0	N	17	Cattails and lily pads	Very poor visibility
	18-JL-MT-002-002	MT	25-Jul-18	634638	6929369	634793	6929223	0.50	1.0		Boulder/Fines	20	0	S	2	Emergent vegetation, heavy cattails	Very poor visibility
Northwest Bay North	18-JL-MT-002-001	MT	25-Jul-18	634544	6929350	634492	6929479	0.40	0.70	99% Silt/Clay	Boulder	20	0	N	17	Flooded marshy bay, cattails and sedges	Very poor visibility
	18-JL-MT-001-003	MT	25-Jul-18	634491	6929486	634544	6929350	1.0	1.0		-	20	0	N	17	Flooded marshy bay, cattails and sedges	Shallow, very poor visibility
	18-JL-GN-002-002	GN	25-Jul-18	634530	6929400	634534	6929342	2.3	3.0		-	20	0	N	17	Flooded grasses, sedges and cattails	Shallow bay
	18-JL-GN-003-001	GN	25-Jul-18	634536	6929398	634466	6929452	3.0	3.8		-	20	0	N	17	Flooded grasses, sedges and cattails	Flooded, very poor visibility
	18-JL-AL-002-001	AL	26-Jul-18	634800	6929285	634399	6929338	1.0	2.5		-	23	2	S	3	Grassy, emergent and submergent vegetation	Some boulders
Southwest Bay	18-JL-MT-001-001	MT	24-Jul-18	634083	6928691	634064	6928599	0.50	1.0	29% Sand, 71% Silt/Clay	-	19	0	-	light	Cattails	Shallow bay
	18-JL-MT-001-002	MT	24-Jul-18	634083	6928691	634064	6928599	1.0	1.0		-	19	0	-	light	Cattails	Shallow bay
	18-JL-GN-001-001	GN	24-Jul-18	634064	6928599	634054	6928642	0.60	1.8		-	19	0	-	light	Cattails	Shallow bay
	18-JL-AL-001-001	AL	24-Jul-18	634111	6928548	-	-	1.2	1.3		-	19	0	-	light	Cattails	Shallow bay
	18-JL-GN-001-002	GN	24-Jul-18	634068	6928558	634096	6928529	0.60	1.5		-	19	0	-	light	Grassy, sedges, and cattails	Shallow, poor visibility
	18-JL-GN-002-001	GN	24-Jul-18	634123	6928524	634157	6928511	3.0	6.0		-	19	0	-	light	Grassy, sedges, and cattails	Shallow, poor visibility
	18-JL-AL-001-003	AL	24-Jul-18	684222	6928883	634159	6928531	1.1	3.0		-	19	0	-	light	Weedy shore	Rock wall, shallow
	18-JL-GN-003-002	GN	25-Jul-18	634423	6928603	634332	6928395	0.4	4.0		-	20	0	N	17	Emergent vegetation	Shallow bay, a drop-off at the rock face
	18-JL-BP-002-002	BP	25-Jul-18	634433	6928615	634381	6928583	0.20	0.60		Boulder/Cobble	18	0	N	17	Some emergent and submergent vegetation	Shallow
	18-JL-MT-003-003	MT	26-Jul-18	634422	6928600	634390	6928584	0.40	0.80		Boulder	20	0	S	3	Flooded emergent and submergent vegetation	Small, shallow bay
West Bay	18-JL-AL-001-002	AL	24-Jul-18	634222	6928883	-	-	3.0	6.0	-	-	19	0	-	light	Some weeds	Rock shore with weedy shallower areas between rockcut
	18-JL-MT-003-004	MT	26-Jul-18	634140	6928950	634143	6929027	1.0	2.0		-	20	0	S	3	Cattails, emergent vegetation	

Notes:
(a) Dominant Substrate is based from Sediment Sampling results , see Section 6.
(b) Sub-Dominant Substrate is based from in-field observations during the fish program. Limited substrate data was collected due to the poor water clarity at the time of the sampling program.
Gear Type: GN = Gill net; BP = Backpack Electrofishing; SN = Seine Net; AL = Angling with Lures; MT = Minnow Traps

Table F-2: Backpack Electrofisher Catch-Per-Unit-Effort (No. of Fish/100 seconds), 2018 Jackfish Lake Environmental Monitoring

Effort #	Backpack Electrofisher Settings				Date	Start Time (hh:mm)	End Time (hh:mm)	Total Electrofishing Time (sec)	Lake Whitefish		Northern Pike		Trout-Perch		All Species	
	Voltage Output (V)	Frequency (Hz)	Duty Cycle (%)	Pulse Width (mS)					# of Fish	CPUE	# of Fish	CPUE	# of Fish	CPUE	# of Fish	CPUE
18-JL-BP-001-001	100	30	12	4	24-Jul-18	13:00	13:20	723	0	0	0	0	0	0	0	0
18-JL-BP-002-001	115	30	12	4	25-Jul-18	12:56	13:10	300	0	0	0	0	0	0	0	0
18-JL-BP-002-002	115	30	12	4	25-Jul-18	16:00	17:00	1,206	0	0	1	0.08	0	0	1	0.08
Total								2,229	0	0	1	0.04	0	0	1	0.04

Notes:
CPUE = catch-per-unit-effort (fish catch per 100 seconds).
Visibility was poor in the lake which created challenging electrofishing conditions

Table F-3: Beach Seine Catch-Per-Unit-Effort (No. of Fish/100m3/hour), 2018 Jackfish Lake Environmental Monitoring

Effort #	Sampling Date	Start Time (hh:mm)	End Time (hh:mm)	Capture Time (hh:mm)	Soak Time (h)	Lake Whitefish		Northern Pike		Trout-Perch		All Species	
						# of Fish	CPUE	# of Fish	CPUE	# of Fish	CPUE	# of Fish	CPUE
18-JL-SN-001-001	26-Jul-18	14:20	14:25	0:05	0.08	0	0	0	0	0	0	0	0
18-JL-SN-001-002	26-Jul-18	14:30	14:35	0:05	0.08	0	0	0	0	0	0	0	0

Notes:
CPUE = catch-per-unit-effort (fish catch per 100 m^2 per hour).

Table F-4: Gill Net Catch-Per-Unit-Effort (No. of Fish/100m2/hour), 2018 Jackfish Lake Environmental Monitoring

Effort #	Net Dimensions						Start Date	Start Time (hh:mm)	End Date	End Time (hh:mm)	Soak Time (hh:mm)	Soak Time (h)	Lake Whitefish		Northern Pike		Trout-Perch		All Species	
	Net Name	Gillnet Length (m)	Net Width (m)	Net Area (m^2)	Mesh Size	Mesh Size (mm)							# of Fish	CPUE	# of Fish	CPUE	# of Fish	CPUE	# of Fish	CPUE
18-JL-GN-001-001	short small-mesh multi-panel r	25	1.8	45	mixed small	11.4, 17.7, 24.2, 37.3	24-Jul-18	11:56	24-Jul-18	14:24	2:20	2.33	0	0	2	1.91	0	0	2	1.91
18-JL-GN-001-002	short small-mesh multi-panel r	25	1.8	45	mixed small	11.4, 17.7, 24.2, 37.3	24-Jul-18	14:12	24-Jul-18	16:10	2:02	2.03	0	0	0	0	0	0	0	0
18-JL-GN-002-001	medium large-mesh multi-pan	50	1.65	82.5	mixed medium	105, 62, 135, 39, 92, 52, 119, 76	24-Jul-18	14:20	24-Jul-18	16:15	1:55	1.92	0	0	0	0	0	0	0	0
18-JL-GN-002-002	medium large-mesh multi-pan	50	1.65	82.5	mixed medium	105, 62, 135, 39, 92, 52, 119, 76	25-Jul-18	11:15	25-Jul-18	13:10	1:55	1.92	1	0.63	1	0.63	0	0	2	1.26
18-JL-GN-003-001	long net	100	1.8	180	medium	56	25-Jul-18	11:30	25-Jul-18	13:30	2:00	2.00	4	1.11	1	0.28	0	0	5	1.39
18-JL-GN-003-002	long net	100	1.8	180	medium	56	25-Jul-18	15:52	25-Jul-18	17:02	1:10	1.17	9	4.27	0	0	1	0.47	10	4.75
18-JL-GN-004-001	medium small-mesh multi-pan	50	1.8	90	mixed small	11.4, 17.7, 24.2, 37.3	25-Jul-18	14:10	25-Jul-18	15:25	1:15	1.25	0	0	0	0	0	0	0	0
18-JL-GN-004-002	medium small-mesh multi-pan	50	1.8	90	mixed small	11.4, 17.7, 24.2, 37.3	26-Jul-18	10:38	26-Jul-18	12:30	2:08	1.13	0	0	1	0.98	3	2.95	4	3.93
Total				795								13.75	14	0.13	5	0.05	4	0.04	23	0.21

Notes:

CPUE = catch-per-unit-effort (fish catch per 100 m^2 per hour).

Table F-5: Minnow Trap Catch-Per-Unit-Effort (No. of Fish/hour), 2018 Jackfish Lake Environmental Monitoring

Effort #	Trap Parameters			Start Date	Start Time (hh:mm)	End Date	End Time (hh:mm)	Soak Time (hh:mm)	Soak Time (h)	Soak Time (h) per Effort	Lake Whitefish		Northern Pike		Trout-Perch		All Species	
	Type of Trap	Number of Traps	Bait Type								# of Fish	CPUE	# of Fish	CPUE	# of Fish	CPUE	# of Fish	CPUE
18-JL-MT-001-001	F	8	CF	24-Jul-18	11:28	24-Jul-18	16:30	5:02	5.03	40.3	0	0	0	0	0	0	0	0
18-JL-MT-001-002	F	8	CF	24-Jul-18	16:30	24-Jul-18	9:52	17:24	17.4	138.9	0	0	0	0	0	0	0	0
18-JL-MT-001-003	F	8	CF	25-Jul-18	10:55	25-Jul-18	15:04	4:09	4.15	33.2	0	0	0	0	0	0	0	0
18-JL-MT-002-001	F	8	CISC	25-Jul-18	15:15	26-Jul-18	10:10	18:05	18.9	151.3	0	0	0	0	0	0	0	0
18-JL-MT-002-002	F	8	CISC	26-Jul-18	10:23	26-Jul-18	14:48	4:25	4.42	35.3	0	0	0	0	0	0	0	0
18-JL-MT-003-001	G	8	CF/CISC	26-Jul-18	12:15	26-Jul-18	15:24	3:09	3.15	25.2	0	0	0	0	0	0	0	0
18-JL-MT-003-002	G	8	CF/CISC	26-Jul-18	12:25	26-Jul-18	15:10	2:45	2.75	22.0	0	0	0	0	0	0	0	0
18-JL-MT-003-003	G	4	CF/CISC	26-Jul-18	12:54	26-Jul-18	15:07	2:13	2.22	8.87	0	0	1	0.11	0	0	1	0.11
18-JL-MT-003-004	G	4	CF/CISC	26-Jul-18	13:05	26-Jul-18	15:06	2:01	2.02	8.07	0	0	0	0	0	0	0	0
Total										463.2	0	0	1	<0.01	0	0	1	<0.01

Notes:
CPUE = catch-per-unit-effort (fish catch per hour); CF= cat food; CISC = Cisco; F = Frabill-type minnow trap; G = Gee-type minnow trap

Table F-6: Angling Catch-Per-Unit-Effort (No. of Fish/Hour Effort/angler), 2018 Jackfish Lake Environmental Monitoring

Effort #	Angling Effort			Sampling Date	Start Time (hh:mm)	End Time (hh:mm)	Angling Time (hh:mm)	Total Angling Time (h)	Lake Whitefish		Northern Pike		Trout-Perch		All Species	
	Number of Rods	Number of Hooks	Tackle Name						# of Fish	CPUE	# of Fish	CPUE	# of Fish	CPUE	# of Fish	CPUE
18-JL-AL-001-001	1	3	RD	24-Jul-18	14:10	14:12	0:02	0.03	0	0	0	0	0	0	0	0.0
18-JL-AL-001-002	1	3	RD	24-Jul-18	14:45	15:00	0:15	0.25	0	0	1	4.0	0	0	1	4.0
18-JL-AL-001-003	1	3	RD	24-Jul-18	15:30	16:05	0:35	0.58	0	0	2	3.4	0	0	2	3.4
18-JL-AL-002-001	2	9	RD/JR	26-Jul-18	10:50	11:42	0:52	1.74	0	0	1	0.29	0	0	1	0.29
Total								2.60	0	0	4	1.5	0	0	4	1.5

Notes:
CPUE = catch-per-unit-effort (fish catch per hour of effort per angler); RD = Red Devil spoon with a barbless treble hook; JR = Jointed Rapala with two barbless treble hooks.

Table F-7: Fish External and Internal Assessment, 2018 Jackfish Lake Environmental Monitoring

Fish Identification Number	Recorder	Cutter	Effort #	Species	Capture Date	Capture Time	Live/Dead	Sacrifice Date	Total Length (mm)	Fork Length (mm)	Total Body Weight (g)	Life Stage	Eyes	Gills	Thymus	Skin	Body Deformities (Y/N)	Fins	Hindgut	Sex	Maturity Stage	Mesenteric Fat	Liver
JL-18-AL-NRPK-K-001	CM	MR	18-JL-AL-001-002	NRPK	24-Jul-18	15:00	Dead	24-Jul-18	586	548	790	A	N	N	0	0	N	0	0	M	22	0	A
JL-18-GN-LKWH-R-004	-	-	18-JL-GN-003-002	LKWH	25-Jul-18	-	Live	-	336	480	2,070	A	-	-	-	-	-	-	-	U	-	-	-
JL-18-GN-LKWH-K-003	MR	CM	18-JL-GN-003-002	LKWH	25-Jul-18	17:02	Dead	25-Jul-18	356	316	510	J	N	N	0	0	N	0	0	U	00	3	A
JL-18-GN-LKWH-K-005	MR	CM	18-JL-GN-003-002	LKWH	25-Jul-18	17:02	Dead	25-Jul-18	361	321	587	J	N	N	0	0	N	0	1	U	00	3	A
JL-18-GN-LKWH-R-001	-	-	18-JL-GN-003-002	LKWH	25-Jul-18	-	Live	-	400	354	700	A	-	-	-	-	-	-	-	U	-	-	-
JL-18-GN-LKWH-K-010	MR	CM	18-JL-GN-003-001	LKWH	25-Jul-18	17:02	Dead	25-Jul-18	444	391	846	J	n/c	n/c	n/c	n/c	n/c	n/c	n/c	U	n/c	n/c	n/c
JL-18-GN-LKWH-K-008	MR	CM	18-JL-GN-003-001	LKWH	25-Jul-18	17:02	Dead	25-Jul-18	515	461	1,730	A	n/c	n/c	n/c	n/c	n/c	n/c	n/c	M	n/c	n/c	n/c
JL-18-GN-LKWH-K-004	MR	CM	18-JL-GN-003-002	LKWH	25-Jul-18	17:02	Dead	25-Jul-18	520	461	1,660	A	N	N	0	0	N	0	1	F	13	3	A
JL-18-GN-NRPK-K-002	MR	CM	18-JL-GN-002-002	NRPK	25-Jul-18	17:02	Dead	25-Jul-18	556	502	771	J	n/c	n/c	n/c	n/c	n/c	n/c	n/c	U	n/c	n/c	n/c
JL-18-GN-NRPK-K-003	MR	CM	18-JL-GN-004-002	NRPK	26-Jul-18	17:02	Dead	26-Jul-18	591	554	900	A	N	N	0	0	N	0	0	M	22	0	A
JL-18-GN-LKWH-K-009	MR	CM	18-JL-GN-002-002	LKWH	25-Jul-18	17:02	Dead	25-Jul-18	542	495	1,840	A	n/c	n/c	n/c	n/c	n/c	n/c	n/c	F	n/c	n/c	n/c
JL-18-GN-LKWH-R-002	-	-	18-JL-GN-003-002	LKWH	25-Jul-18	-	Live	-	544	480	1,940	A	-	-	-	-	-	-	-	U	-	-	-
JL-18-GN-LKWH-K-006	MR	CM	18-JL-GN-003-002	LKWH	25-Jul-18	17:02	Dead	25-Jul-18	556	498	2,190	A	N	N	0	0	N	0	1	F	13	3	A
JL-18-AL-NRPK-R-001	-	-	18-JL-AL-001-003	NRPK	24-Jul-18	-	Live	-	541	488	750	U	-	-	-	-	-	-	-	U	-	-	-
JL-18-AL-NRPK-R-002	-	-	18-JL-AL-001-003	NRPK	24-Jul-18	-	Live	-	621	585	740	U	-	-	-	-	-	-	-	U	-	-	-
JL-18-GN-NRPK-R-001	-	-	18-JL-GN-001-001	NRPK	24-Jul-18	-	Live	-	518	478	670	U	-	-	-	-	-	-	-	U	-	-	-
JL-18-GN-NRPK-R-002	-	-	18-JL-GN-001-001	NRPK	24-Jul-18	-	Live	-	566	534	770	U	-	-	-	-	-	-	-	U	-	-	-
JL-18-GN-NRPK-R-003	-	-	18-JL-GN-003-001	NRPK	25-Jul-18	-	Live	-	561	440	570	A	-	-	-	-	-	-	-	U	-	-	-
JL-18-GN-LKWH-K-002	MR	CM	18-JL-GN-003-002	LKWH	25-Jul-18	17:02	Dead	25-Jul-18	563	513	2,170	A	N	N	0	0	N	0	0	F	13	3	A
JL-18-GN-LKWH-K-007	MR	CM	18-JL-GN-003-001	LKWH	25-Jul-18	17:02	Dead	25-Jul-18	569	515	2,330	A	N	N	0	0	N	0	1	F	13	0	N/A
JL-18-GN-LKWH-K-001	MR	CM	18-JL-GN-003-001	LKWH	25-Jul-18	13:30	Dead	25-Jul-18	569	501	2,430	A	N	N	0	0	N	0	0	M	23	3	A
JL-18-GN-LKWH-R-003	-	-	18-JL-GN-003-002	LKWH	25-Jul-18	-	Live	-	571	510	2,270	A	-	-	-	-	-	-	-	U	-	-	-
JL-18-GN-TRPR-K-004	MR	MR	18-JL-GN-003-002	TRPR	25-Jul-18	17:02	Dead	25-Jul-18	57	53	1.77	U	n/c	n/c	n/c	n/c	N	n/c	n/c	n/c	n/c	n/c	n/c
JL-18-BP-NRPK-R-001	-	-	18-JL-BP-001-003	NRPK	25-Jul-18	-	Live	-	684	637	1,090	J	-	-	-	-	-	-	-	U	-	-	-
JL-18-MT-NRPK-R-001	-	-	18-JL-MT-003-003	NRPK	26-Jul-18	-	Live	-	95	89	8.00	J	-	-	-	-	-	-	-	U	-	-	-
JL-18-AL-NRPK-R-003	-	-	18-JL-AL-002-001	NRPK	26-Jul-18	-	Live	-	610	573	850	A	-	-	-	-	-	-	-	U	-	-	-
JL-18-GN-TRPR-K-001	MR	MR	18-JL-GN-004-002	TRPR	26-Jul-18	17:02	Dead	26-Jul-18	54	49	1.18	U	N	N	0	n/c	N	0	0	M	23	0	A
JL-18-GN-TRPR-K-002	MR	MR	18-JL-GN-004-002	TRPR	26-Jul-18	17:02	Dead	26-Jul-18	72	67	3.45	A	N	N	0	n/c	N	1	0	M	23	0	n/c
JL-18-GN-TRPR-K-003	MR	MR	18-JL-GN-004-002	TRPR	26-Jul-18	17:02	Dead	26-Jul-18	90	82	5.49	A	N	N	0	n/c	N	0	0	M	23	0	A

Notes
Live release fish were examined only for length and weight due to limited handling time to mitigate stressful environmental conditions
MR = Monica Redmond; CM = Cameron Mackenzie; NRPK= Northern Pike, LKWH= Lake Whitefish, TRPR = Trout-Perch; n/a = Non-applicable; n/c = the information was not collected due to time constraints; - = the information was not collected because it was not necessary
Life Stage: A= Adult, J= Juvenile, U= Unknown
Eyes: N= No aberrations; good "clear" eye
Gills: N= Normal; no apparent aberrations
Thymus: 0= No hemorrage
Skin: 0= No aberrations
Fins: 0= No active erosion
Hindgut: 0= Normal; no inflammation or reddening, 1= Slight inflammation or reddening
Sex: M= Male, F= Female, U= Unknown
Maturity: 00= Unknown sex and stage; 22= Early stage development, male; 13= Late stage development, female; 23= Late stage development, male;
Mesenteric Fat: 0= None, 3= >50%
Spleen: B= Normal; Black, very dark red, or red
Gall Bladder: 0 = Normal

Table F-7: Fish External and Internal Assessment, 2018 Jackfish Lake Environmental Monitoring

Spleen	Gall Bladder	Gall Bladder Fullness (%)	Bile Colour	Kidney	Parasites	Stomach Fullness (%)	Liver Total Weight (g)	Gonad Total Weight (g)	Otolith (Y/N)	Pectoral Fin Ray LEFT (Y/N)	Scales (Y/N)	Age Archive	Tissue (Y/N)	Cleithera (Y/N)	Condition Factor (*K*)	Comments
B	Not found	n/a	-	N	0	0	3.829	1.549	N	Y	Y	Y	Y	Y	0.48	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.9	-
B	Not found	N/A	-	N	0	90	4.678	n/c	Y	Y	Y	Y	N	N	1.6	No tissue harvest due to unlike size, gonad not collected due to immature status
B	0	50	Dark green	N	0	100	4.95	n/c	Y	Y	Y	Y	N	N	1.8	No tissue harvest due to unlike size, gonad not collected due to immature status
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.6	-
n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	N	N	Y	Y	N	N	1.4	End of day - minimal dissection only
n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	N	N	Y	Y	Y	N	1.8	End of day - minimal dissection only
B	Not found	N/A	-	N	0	90	22.375	109.318	Y	Y	Y	Y	Y	N	1.7	Puffy vent
n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	N	N	Y	Y	Y	Y	0.61	End of day - minimal dissection only
B	-	-	-	-	-	-	-	-	N	Y	N	Y	Y	Y	0.53	End of day - minimal dissection only
n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	N	N	Y	Y	Y	N	1.5	End of day - minimal dissection only
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.8	-
B	Not found	N/A	-	N	0	80	32.785	140.093	Y	Y	Y	Y	Y	N	1.8	Photos of gonads
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.65	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.37	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.61	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.51	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.67	-
B	Not found	N/A	-	N	0	90	30.130	116.556	Y	Y	Y	Y	Y	N	1.6	Stomach contents consisted of invertebrates
B	Not found	N/A	-	N	0	100	32.100	120.858	Y	Y	Y	Y	Y	N	1.7	
B	Not found	N/A	-	N	0	100	22.924	321.284	Y	Y	Y	Y	Y	N	1.9	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.7	-
n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	n/c	1.2	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.42	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.1	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.45	-
n/c	n/c	n/c	n/c	n/c	0	75%	0.016	0.027	N	N	N	N	N	N	1.0	No ageing structures collected for analyses due to unlike size
n/c	n/c	n/c	n/c	N	0	25%	n/c	0.223	N	N	N	N	N	N	1.2	No ageing structures collected for analyses due to unlike size
n/c	n/c	n/c	n/c	N	0	25%	0.033	0.278	N	N	N	N	N	N	1.0	No ageing structures collected for analyses due to unlike size

Notes
Live release fish were examined only for length and weight due to limited handling time to mitigate stressful environmental conditions
MR = Monica Redmond; CM = Cameron Mackenzie; NRPK= Northern Pike, LKWH= Lake Whitefish, TRPR = Trout-Perch; n/a = Non-applicable; n/c = the information was not collected due to time constraints; - = the information was not collected because it was not necessary
Life Stage: A= Adult, J= Juvenile, U= Unknown
Eyes: N= No aberrations; good "clear" eye
Gills: N= Normal; no apparent aberrations
Thymus: 0= No hemorrage
Skin: 0= No aberrations
Fins: 0= No active erosion
Hindgut: 0= Normal; no inflammation or reddening, 1= Slight inflammation or reddening
Sex: M= Male, F= Female, U= Unknown
Maturity: 00= Unknown sex and stage; 22= Early stage development, male; 13= Late stage development, female; 23= Late stage development, male;
Mesenteric Fat: 0= None, 3= >50%
Spleen: B= Normal; Black, very dark red, or red
Gall Bladder: 0 = Normal

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REPORT

2018 Discharge Quality Report

Jackfish Lake Generating Facility

Submitted to:

Matthew Miller
Senior Environmental Licensing Specialist
Heath, Safety and Environment
Northwest Territories Power Corporation
4 Capital Drive, Hay River, NWT X0E 0R6

Submitted by:

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18109589

February 2019

Distribution List

1 electronic copy - Golder Associates Ltd.

1 electronic copy - Northwest Territories Power Corporation

Executive Summary

The Northwest Territories Power Corporation (NTPC) owns and operates the Jackfish Lake Generating Facility (Jackfish Facility), located on the northeast shore of Jackfish Lake in Yellowknife, Northwest Territories. The Jackfish Facility provides electricity to the North Slave communities of Yellowknife, Behchokǫ̀, Dettah and Ndilǫ when the demand exceeds the capacity of the Snare and Bluefish Hydroelectric facilities, or during planned outages.

The use of water from Jackfish Lake by the Jackfish Facility engine cooling systems is regulated under a water license which expires later in 2019. NTPC will apply for a new water licence for the Jackfish cooling systems in early 2019. To support the water licence renewal process, NTPC developed and implemented a one-year environmental monitoring program in 2018. Relevant results from the 2018 environmental program are summarized in this report to determine the potential for effects to water quality and temperature in Jackfish Lake due to the Jackfish Facility, and to provide recommendations on the requirement of discharge limits, either for water quality parameters or temperature, for inclusion in the Water Licence.

Setting water quality or temperature discharge limits for the Jackfish Facility is not recommended. Based on screening of the 2018 dataset herein, combined with the findings from Golder (2019), discharges from the Jackfish Facility are not affecting parameter concentrations in Jackfish Lake, with the possible exception of copper in the immediate vicinity of the discharges. Consistent gradients in water quality concentrations were not observed and no clear changes in water quality in Jackfish Lake have occurred relative to previous water quality surveys.

Study Limitations

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TABLES

FIGURES

ACRONYM LIST

Acronym	Definition
CWQG	Canadian Water Quality Guidelines
DL	detection limit
Golder	Golder Associates Ltd.
Jackfish Facility	Jackfish Lake Generating Facility
NTPC	Northwest Territories Power Corporation
NWT	Northwest Territories

UNITS OF MEASURE

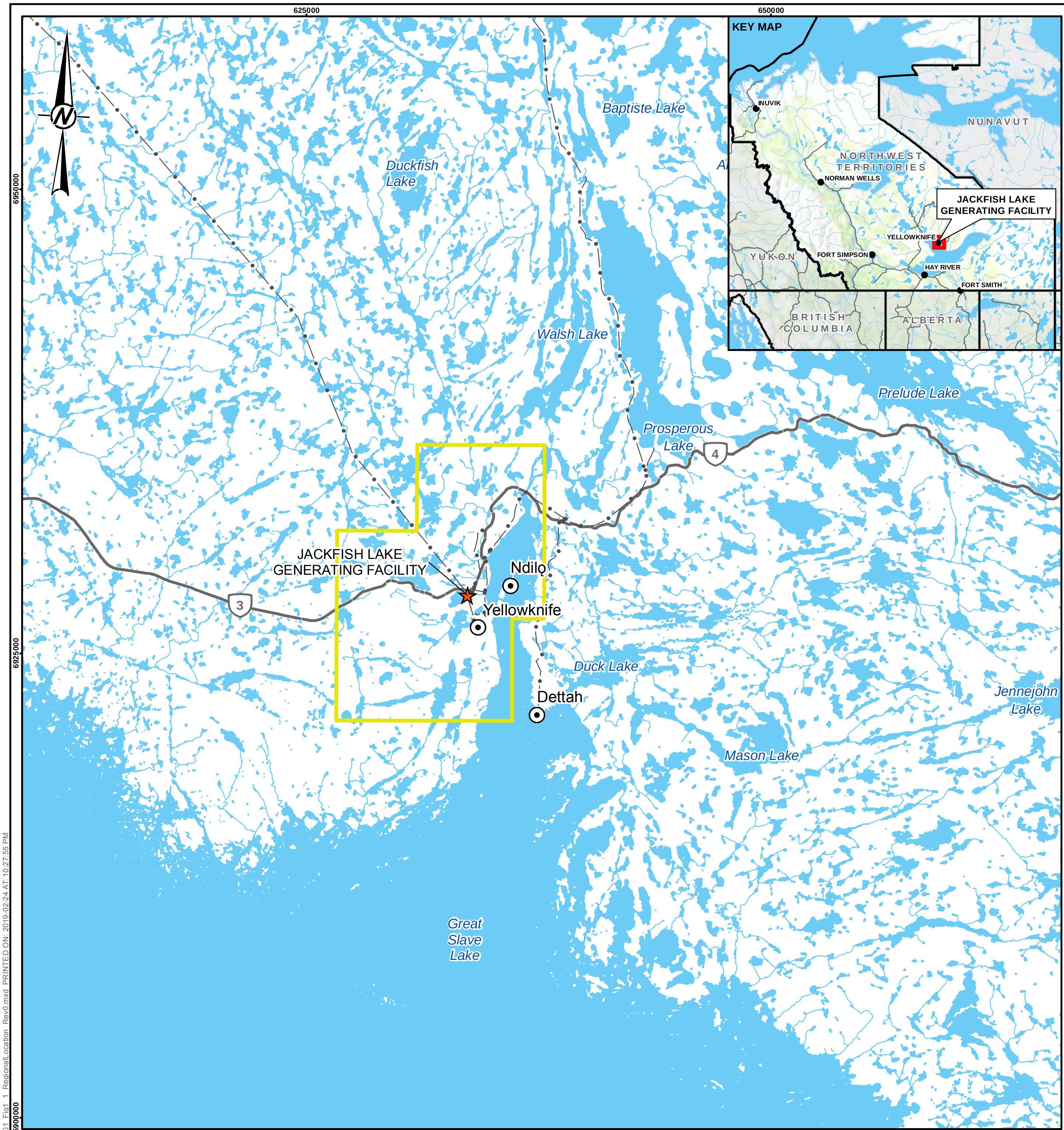
Unit	Definition
%	percent
°C	degrees Celsius
m	metre
mg	milligram
mg/L	milligrams per litre
mg-N/L	milligrams per litre as nitrogen

1.0 INTRODUCTION

The Northwest Territories Power Corporation (NTPC) owns and operates the Jackfish Lake Generating Facility (Jackfish Facility), located on the northeast shore of Jackfish Lake in Yellowknife, Northwest Territories (Figure 1-1). The Jackfish Facility provides electricity to the North Slave communities of Yellowknife, Behchokǫ̀, Dettah and Ndilǫ when the demand exceeds the capacity of the Snare and Bluefish Hydroelectric facilities, or during planned outages. The Jackfish Facility has three different diesel power plants; CAT Plant, EMD Plant, and K-Plant (Figure 1-2). Each plant has a closed- loop engine cooling system that withdraws water from, and discharges water back to, Jackfish Lake. When operation of the Jackfish Facility is required, it is generally of short duration; most electrical generation for the North Slave Electrical system is from Snare or Bluefish Hydro (NTPC 2019).

The use of water from Jackfish Lake by the Jackfish Facility is regulated under Water Licence N1L1-1632 (MVLWB 1995). Water Licence N1L1-1632 was issued in 1995 and expires at the end of 2019. The current water licence does not include water quality limits or sampling requirements for water discharged from the Jackfish Facility to Jackfish Lake. The absence of these requirements is likely because there are no additives during water circulation, and evaporation is expected to be negligible due to a closed system.

The current water licence does not require environmental monitoring of Jackfish Lake. NTPC developed and implemented a one-year environmental monitoring program in 2018 to support the renewal application, and to support subsequent monitoring under the new water licence (Golder 2019). The program was generally focused on Jackfish Lake, but supplemental water samples and temperature data were collected from the Jackfish Facility intakes and discharges. This discharge quality report provides a summary of the Jackfish Facility discharge water quality and temperature, and provides recommendations on the requirements for discharge limits, either for water quality parameters or temperature, for inclusion in the Water Licence.



LEGEND

- ★ PROJECT LOCATION
- ⊙ COMMUNITY
- ACTIVE TRANSMISSION LINE
- HIGHWAY
- WATERCOURSE
- WATERBODY
- YELLOWKNIFE MUNICIPAL BOUNDARY

0 5 10

1:300,000 KILOMETRES

REFERENCE(S)

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DATUM: NAD 83 PROJECTION: UTM ZONE 11

CLIENT
NORTHWEST TERRITORIES POWER CORPORATION

PROJECT
JACKFISH LAKE ENVIRONMENTAL MONITORING

TITLE
REGIONAL LOCATION

CONSULTANT
GOLDER

YYYY-MM-DD	2019-02-24
DESIGNED	TL
PREPARED	PS/LB
REVIEWED	AS
APPROVED	TH

PROJECT NO.	CONTROL	REV.	FIGURE
1894709		0	1-1

REFERENCE(S)
AERIAL PHOTO PROVIDED BY CLIENT, 2018.

CLIENT
NORTHWEST TERRITORIES POWER CORPORATION

PROJECT
JACKFISH WATER LICENCE RENEWAL

TITLE
JACKFISH LAKE GENERATING STATION 2018

CONSULTANT
GOLDER

YYYY-MM-DD	2019-02-22
DESIGNED	TL
PREPARED	AA
REVIEWED	AS
APPROVED	TH

PROJECT NO.	CONTROL	REV.	FIGURE
1894709		0	1-2

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1.1 Objectives

The objectives of this report were to:

- Review the 2018 water quality and temperature data from the Jackfish Facility discharges and Jackfish Lake to determine the potential for effects to water quality and temperature in Jackfish Lake.
- Provide recommendations on the requirement of discharge limits, either for water quality parameters or temperature, for inclusion in the Water Licence.

1.2 Report Organization

The discharge quality report is organized into two main sections; Section 2 describes the results of the discharge water quality evaluation, including:

- parameters considered in the review and a description of the screening process used to determine whether parameter concentrations in the discharges from the Jackfish Facility have the potential to affect water quality in Jackfish Lake (Sections 2.1 and 2.2)
- a summary of the water quality evaluation (Section 2.3)
- recommendations (Section 2.4).

Section 3 describes the results of the discharge temperature evaluation, including:

- a summary of water temperatures of the discharges and Jackfish Lake (Section 3.1)
- fish temperature tolerances (Section 3.2)
- recommendations (Section 3.3).

Section 4 provides a list of references cited in the report.

2.0 WATER QUALITY

2.1 Methods

Water quality data collected in 2018 from the Jackfish Facility discharges and from Jackfish Lake (Figure 2-1) were reviewed, and a screening process was completed to determine whether the discharges from the Jackfish Facility have the potential to affect water quality in Jackfish Lake. The 2018 water quality field programs included:

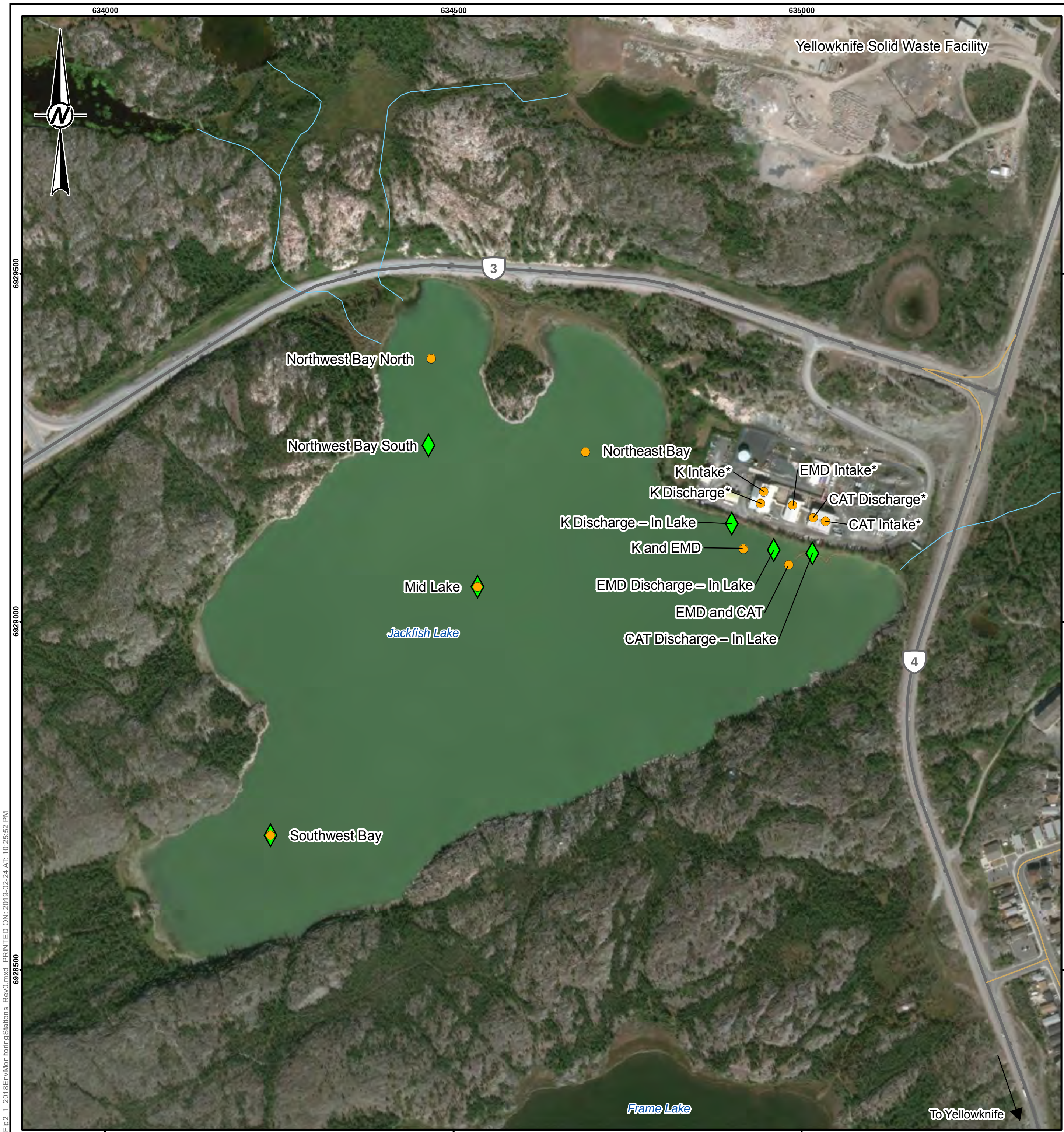
- One sample collected from the CAT discharge and the K discharge in July.
- One sample collected from the CAT intake, K intake, and EMD intake in July.
- Samples collected at seven stations in Jackfish Lake in May, July, August, September, and December.

A detailed description of the 2018 water quality field programs is presented in Golder (2019).

2.1.1 Parameters

The list of parameters analyzed in the 2018 water quality field programs are presented in Table 2-1. Based on a parameter evaluation outlined below, the list of parameters in Table 2-1 was reduced. Parameters were eliminated from Table 2-1 because:

- The parameter does not have Canadian Water Quality Guidelines (CWQG) for the protection of aquatic life, including: total dissolved solids, calcium, magnesium, potassium, sodium, sulphate, total Kjeldahl nitrogen, total phosphorus, antimony, beryllium, bismuth, cesium, cobalt, lithium, manganese, rubidium, strontium, titanium, vanadium, xylenes, F1 (C6-C10)-BTEX, F2 (C10-C16), F3 (C16-C34), F4 (C34-C50), and general organics.
- Hardness, pH, and total organic carbon are exposure and toxicity modifying factors, which influence the toxicity of certain parameters. They were only included in this section of the discharge quality report because they are required to calculate CWQG for total ammonia, aluminum, cadmium, copper, lead, nickel, and zinc.
- There are no activities at the Jackfish Facility expected to change the total suspended solids concentrations and turbidity values of the intake water. Total suspended solids concentrations in Jackfish Lake in 2018 (3.3 to 19.0 mg/L) and in the discharges (7.3 to 15.1 mg/L) were considered low to moderate, and not harmful to aquatic life (Golder 2019). Therefore, the total suspended solids concentrations and turbidity were not included in the final list of parameters.
- Hydrocarbons were not included in the final list of parameters considered herein because concentrations were below detection limits in Jackfish Lake (Golder 2019).
- Water temperature is discussed in Section 3 and was not included in the screening and discussion presented in this section of the discharge quality report.



LEGEND

- TEMPERATURE LOGGER
- WATER QUALITY
- HIGHWAY
- LOCAL ROAD
- WATERCOURSE

0 100 200

1:8,000 METRES

NOTE(S)

*WATER SAMPLES WERE COLLECTED INSIDE FACILITIES; LOCATIONS ARE APPROXIMATE.

REFERENCE(S)

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PROJECTION: UTM ZONE 11 DATUM: NAD 83

CLIENT

NORTHWEST TERRITORIES POWER CORPORATION

PROJECT

JACKFISH LAKE ENVIRONMENTAL MONITORING

TITLE

2018 JACKFISH LAKE ENVIRONMENTAL MONITORING STATIONS

CONSULTANT

GOLDER

YYYY-MM-DD	2019-02-24
DESIGNED	TL
PREPARED	AA
REVIEWED	AS
APPROVED	TH

PROJECT NO.	CONTROL	REV.	FIGURE
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Table 2-1: List of Parameters Analyzed in the 2018 Water Quality Field Programs

Parameters			
Routine	pH	Temperature	Dissolved oxygen
	Specific conductivity	Total alkalinity	Hardness
	Total suspended solids	Turbidity	Total dissolved solids
Major Ions	Calcium	Chloride	Fluoride
	Magnesium	Potassium	Sodium
	Sulphate	Silica	
Nutrients	Total ammonia	Total nitrogen	Nitrate
	Nitrite	Total Kjeldahl nitrogen	Total phosphorus
	Dissolved phosphorus	Orthophosphate	Total organic carbon
Total Metals	Aluminum	Cobalt	Rubidium
	Antimony	Copper	Selenium
	Arsenic	Iron	Silver
	Barium	Lead	Strontium
	Beryllium	Lithium	Thallium
	Bismuth	Manganese	Titanium
	Boron	Mercury	Uranium
	Cadmium	Molybdenum	Vanadium
	Chromium	Nickel	Zinc
Hydrocarbons	Benzene	Xylenes	F3 (C17-C34)
	Ethylbenzene	F1 (C6-C10)-BTEX	F4 (C34-C50)
	Toluene	F2 (C11-C16)	
	Extractable petroleum hydrocarbons (C10-C19)		
	Extractable petroleum hydrocarbons (C19-C32)		
	Total extractable petroleum hydrocarbons (C10-C30)		

Based on the parameter evaluation outlined above, the list of parameters included in the screening process for the Jackfish Facility discharges to Jackfish Lake was:

- Major ions: chloride and fluoride.
- Nutrients: total ammonia, nitrate, and nitrite.

- Total metals: aluminum, arsenic, boron, cadmium, chromium, copper, iron, lead, mercury, molybdenum, nickel, selenium, silver, thallium, uranium, and zinc.

2.1.2 Screening Process

The screening process to determine whether the discharges from the Jackfish Facility have the potential to affect water quality in Jackfish Lake involved two comparisons:

- Parameter concentrations in the Jackfish Facility discharges were compared to 95th percentile concentrations in Jackfish Lake at stations near the Jackfish Facility discharges and at stations far from the Jackfish Facility discharges. The purpose of this comparison was to identify if the potential exists for parameter concentrations in Jackfish Lake to increase above concentrations observed in the lake. Parameter concentrations in the Jackfish Facility discharges that were 20% greater than the 95th percentile concentrations in Jackfish Lake were evaluated further (USEPA 1994).
- Parameter concentrations in the Jackfish Facility discharges and in Jackfish Lake were compared to long-term CWQGs (Table 2-2). The purpose of this comparison was to identify if the potential exists for parameter concentrations in Jackfish Lake to increase above CWQGs as a result of the Jackfish Facility discharges to Jackfish Lake.

Table 2-2: Canadian Water Quality Guidelines

Parameters	Units	Long-term Canadian Water Quality Guidelines[a]
Major Ions		
Chloride	mg/L	120
Fluoride	mg/L	0.12
Nutrients		
Total ammonia	mg-N/L	0.065 - 2.2[b]
Nitrate	mg-N/L	2.93
Nitrite	mg-N/L	0.06
Total Metals[c]		
Aluminum	mg/L	0.1[d]
Arsenic	mg/L	0.005
Boron	mg/L	1.5
Cadmium	mg/L	0.00020 - 0.00024[e]
Chromium	mg/L	0.001
Copper	mg/L	0.0030 - 0.0037[e]
Iron	mg/L	0.3
Lead	mg/L	0.0046 - 0.0061[e]

Table 2-2: Canadian Water Quality Guidelines

Parameters	Units	Long-term Canadian Water Quality Guidelines[(a)]
Mercury	mg/L	0.000026
Molybdenum	mg/L	0.073
Nickel	mg/L	0.12 - 0.14[(e)]
Selenium	mg/L	0.001
Silver	mg/L	0.00025
Thallium	mg/L	0.0008
Uranium	mg/L	0.015
Dissolved Metals		
Zinc	mg/L	0.0046 - 0.013[(f)]

(a) Source: CCME (1999).

(b) The total ammonia CWQG is dependent on temperature and pH. The guideline is calculated based on the individual field pH and temperature measurements for each sample from stations near and far from the Jackfish Facility discharges in 2018. The field measured pH values ranged from 7.9 to 8.9 and the field measured temperatures ranged from 0.88°C and 19.5°C.

(c) In this table, the elements reported as “total metals” includes metalloids such as arsenic and non-metals such as selenium.

(d) The CWQG for total aluminum is dependent on pH: 0.005 mg/L at pH less than 6.5 and 0.1 mg/L at pH equal to or greater than 6.5. The guideline is calculated based on the individual field pH values (7.9 to 8.9) measured at stations near and far from the Jackfish Bay in 2018.

(e) The CWQGs for total cadmium, copper, lead and nickel are dependent on hardness. The guideline is calculated based on the individual hardness measurements for each sample from stations near and far from the Jackfish Facility discharges in 2018. The hardness concentrations ranged from 133 to 167 mg/L as $CaCO_3$.

(f) The CWQG for zinc is dependent on hardness, pH and DOC. The guideline is for the dissolved fraction but was applied to the total fraction as a conservative estimate. DOC was not measured as part of the 2018 baseline monitoring program; therefore, the minimum validated DOC range for the guideline equation (0.3 mg/L) was applied.

mg-N/L = milligrams nitrogen per litre; $CaCO_3$ = calcium carbonate; CCME = Canadian Council of Ministers of the Environment; CWQG = Canadian Water Quality Guidelines; DOC = dissolved organic carbon.

2.2 Data Sources and Limitations

The screening process was based on information collected during the 2018 Jackfish Lake environmental monitoring program (Golder 2019). Parameter concentrations in the Jackfish Facility discharges were based on one sample collected from the CAT discharge and one sample collected from the K discharge in July 2018.

The 95th percentile parameter concentrations in Jackfish Lake at stations near the Jackfish Facility discharges were based on monitoring data collected in May, July, August, September, and December 2018. For the screening process, stations near the Jackfish Facility discharges were: EMD and CAT, and K and EMD. The 95th percentile parameter concentrations in Jackfish Lake at stations far from the Jackfish Facility discharges were also based on monitoring data collected in May, July, August, September, and December 2018. For the screening process, stations far from the Jackfish Facility were: mid, Northeast Bay, Northeast Bay North, and Southwest Bay.

It is recognized that the discharge water quality dataset is limited. The results of the screening process and resultant recommendations are provided with consideration of this data limitation.

2.3 Screening Results

2.3.1 Parameter Concentrations in the Jackfish Facility Discharges Compared to Jackfish Lake at Stations near and far from the Jackfish Facility Discharges

Parameter concentrations in the Jackfish Facility discharges were compared to 95th percentile parameter concentrations in Jackfish Lake at stations near and far from the Jackfish Facility discharges (Table 2-3). If the concentration of a parameter in the discharges was greater than concentrations in Jackfish Lake, this was considered an indication of the potential for the parameter concentration to increase in Jackfish Lake.

A “Yes” in Table 2-3 indicated that the parameter concentration in the discharges was greater than the 95th percentile concentration in Jackfish Lake at stations near and/or far from the discharges. A “No” in Table 2-3 indicated that the parameter concentration in the discharges was less than the 95th percentile concentration in Jackfish Lake at stations near and/or far from the discharges.

Parameter concentrations in the discharges that were 20% greater than the 95th percentile concentrations in Jackfish Lake at stations near the discharges were:

- Total metals: aluminum, copper, iron, lead.

Parameter concentrations in the discharges that were 20% greater than the 95th percentile concentrations in Jackfish Lake at stations far from the discharges were:

- Total metals: aluminum, copper, iron, lead, and zinc.

All instances of elevated discharge concentrations for the parameters listed above were observed in the one sample collected from K discharge on 11 July 2018.

Table 2-3: Comparison of Jackfish Facility Discharge Concentrations to 95th Percentile Concentrations in Jackfish Bay at Stations near and far from the Jackfish Facility Discharges

Parameters	Units	Facility Discharge Concentrations[a]		95th Percentile Concentrations in Jackfish Bay at Stations near the Facility Discharges[b]	95th Percentile Concentrations in Jackfish Bay at Stations far from the Facility Discharges[c]	Are Concentrations in the Facility Discharges > 95th Percentile Concentrations in Jackfish Lake at Stations near the Facility Discharges (Yes/No)?		Are Concentrations in the Facility Discharges > 95th Percentile Concentrations in Jackfish Lake at Stations far from the Facility Discharges (Yes/No)?	
		CAT Discharge	K Discharge			CAT Discharge	K Discharge	CAT Discharge	K Discharge
Major Ions									
Chloride	mg/L	55	55	59	59	No	No	No	No
Fluoride	mg/L	0.09	0.09	0.099	0.098	No	No	No	No
Nutrients									
Total ammonia	mg-N/L	0.0025	0.0025	0.097	0.11	No	No	No	No
Nitrate	mg-N/L	0.0025	0.0025	0.046	0.044	No	No	No	No
Nitrite	mg-N/L	0.0005	0.0005	0.0045	0.004	No	No	No	No
Total Metals[d]									
Aluminum	mg/L	0.0059	0.031	0.0092	0.013	No	**Yes (71%)**	No	**Yes (60%)**
Arsenic	mg/L	0.086	0.086	0.09	0.094	No	No	No	No
Boron	mg/L	0.028	0.028	0.029	0.03	No	No	No	No
Cadmium	mg/L	0.0000025	0.0000025	0.0000025	0.0000025	No	No	No	No
Chromium	mg/L	0.00005	0.00013	0.0006	0.00028	No	No	No	No
Copper	mg/L	0.0028	0.0089	0.007	0.0028	No	**Yes (22%)**	No	**Yes (69%)**
Iron	mg/L	0.013	0.17	0.02	0.035	No	**Yes (88%)**	No	**Yes (79%)**

Table 2-3: Comparison of Jackfish Facility Discharge Concentrations to 95th Percentile Concentrations in Jackfish Bay at Stations near and far from the Jackfish Facility Discharges

Parameters	Units	Facility Discharge Concentrations[(a)]		95th Percentile Concentrations in Jackfish Bay at Stations near the Facility Discharges[(b)]	95th Percentile Concentrations in Jackfish Bay at Stations far from the Facility Discharges[(c)]	Are Concentrations in the Facility Discharges > 95th Percentile Concentrations in Jackfish Lake at Stations near the Facility Discharges (Yes/No)?		Are Concentrations in the Facility Discharges > 95th Percentile Concentrations in Jackfish Lake at Stations far from the Facility Discharges (Yes/No)?	
		CAT Discharge	K Discharge			CAT Discharge	K Discharge	CAT Discharge	K Discharge
Lead	mg/L	0.000025	0.00019	0.00013	0.00012	No	**Yes (33%)**	No	**Yes (39%)**
Mercury	mg/L	0.0000025	0.0000025	0.0000025	0.000013	No	No	No	No
Molybdenum	mg/L	0.00026	0.00028	0.00028	0.00028	No	No	No	No
Nickel	mg/L	0.0006	0.00077	0.0007	0.00073	No	Yes (10%)	No	Yes (5%)
Selenium	mg/L	0.000054	0.000065	0.000059	0.000064	No	Yes (9%)	No	Yes (1%)
Silver	mg/L	0.000005	0.000005	0.000005	0.000005	No	No	No	No
Thallium	mg/L	0.000005	0.000005	0.000005	0.000005	No	No	No	No
Uranium	mg/L	0.00065	0.00067	0.00065	0.00066	No	Yes (3%)	No	Yes (1%)
Zinc	mg/L	0.0015	0.0034	0.0058	0.0022	No	No	No	**Yes (35%)**

(a) Refers to Jackfish Facility discharge concentrations based on monitoring data collected in July 2018 (Golder 2019).

(b) Refers to 95th percentile concentrations in Jackfish Lake based on monitoring data collected in May, July, August, September, and December 2018 at stations EMD and CAT and K and EMD (Golder 2019).

(c) Refers to 95th percentile concentrations in Jackfish Lake based on monitoring data collected in May, July, August, September, and December 2018 at stations mid, Northeast Bay, Northeast Bay North, and Southwest Bay (Golder 2019).

(d) In this table "total metals" includes metalloids such as arsenic and non-metals such as selenium.

mg-N/L = milligrams nitrogen per litre; > = greater than.

2.3.2 Parameter Concentrations in the Jackfish Facility Discharges and Jackfish Lake Compared to Canadian Water Quality Guidelines

Parameter concentrations in the Jackfish Facility discharges and in Jackfish Lake were compared to long-term CWQG to identify parameters with concentrations that may have the potential to cause negative effects to aquatic life in Jackfish Lake (Tables 2-4 and 2-5).

A “Yes” in Tables 2-4 and 2-5 indicated that the parameter concentration in the discharges and in Jackfish Lake was greater than the long-term CWQG, respectively. A “No” in Tables 2-4 and 2-5 indicated that the parameter concentration in the discharges and in Jackfish Lake was less than the CWQG, respectively.

Parameter concentrations in the discharges that were greater than long-term CWQG were:

- Total metals: arsenic and copper.

Parameters with Jackfish Lake concentrations that were greater than long-term CWQG were:

- Total metals: arsenic, copper, and zinc.

There were no exceedances of short-term CWQGs.

Table 2-4: Comparison of Jackfish Facility Discharge Concentrations to Long-term Canadian Water Quality Guidelines

Parameters	Units	Facility Discharge Concentrations[a]		Long-term CWQGs[b]	Are Concentrations in the Facility Discharges > Long-term CWQGs (Yes/No)?	
		CAT Discharge	K Discharge		CAT Discharge	K Discharge
Major Ions						
Chloride	mg/L	55	55	120	No	No
Fluoride	mg/L	0.09	0.09	0.12	No	No
Nutrients						
Total ammonia	mg-N/L	0.0025	0.0025	0.065 – 2.2	No	No
Nitrate	mg-N/L	0.0025	0.0025	2.93	No	No
Nitrite	mg-N/L	0.0005	0.0005	0.06	No	No
Total Metals[c]						
Aluminum	mg/L	0.0059	0.031	0.1	No	No
Arsenic	mg/L	0.086	0.086	0.005	**Yes**	**Yes**
Boron	mg/L	0.028	0.028	1.5	No	No
Cadmium	mg/L	0.0000025	0.0000025	0.00020 - 0.00024	No	No
Chromium	mg/L	0.00005	0.00013	0.001	No	No
Copper	mg/L	0.0028	0.0089	0.0030 - 0.0037	No	**Yes**
Iron	mg/L	0.013	0.17	0.3	No	No
Lead	mg/L	0.000025	0.00019	0.0046 - 0.0061	No	No
Mercury	mg/L	0.0000025	0.0000025	0.000026	No	No
Molybdenum	mg/L	0.00026	0.00028	0.073	No	No
Nickel	mg/L	0.0006	0.00077	0.12 - 0.14	No	No
Selenium	mg/L	0.000054	0.000065	0.001	No	No
Silver	mg/L	0.000005	0.000005	0.00025	No	No
Thallium	mg/L	0.000005	0.000005	0.0008	No	No
Uranium	mg/L	0.00065	0.00067	0.015	No	No
Zinc	mg/L	0.0015	0.0034	0.0046 - 0.013	No	No

(a) Refers to Jackfish Facility discharge concentrations based on monitoring data collected in July 2018 (Golder 2019).
(b) Long-term CWQGs are presented in Table 2-2.
(c) In this table, “total metals” includes metalloids such as arsenic and non-metals such as selenium.
mg-N/L = milligrams nitrogen per litre; CWQG = Canadian Water Quality Guidelines.

Table 2-5: Comparison of Concentrations in Jackfish Bay at Stations near and far from the Jackfish Facility Discharges to Long-term Canadian Water Quality Guidelines

Parameters	Units	Long-term CWQGs[a]	Are Concentrations in Jackfish Lake at Stations near the Facility Discharges > CWQGs (Yes/No)?	Are Concentrations in Jackfish Lake at Stations far from the Facility Discharges > CWQGs (Yes/No)?
Major Ions				
Chloride	mg/L	120	No	No
Fluoride	mg/L	0.12	No	No
Nutrients				
Total ammonia	mg-N/L	0.065 - 2.2	No	No
Nitrate	mg-N/L	2.93	No	No
Nitrite	mg-N/L	0.06	No	No
Total Metals[b]				
Aluminum	mg/L	0.1	No	No
Arsenic	mg/L	0.005	**Yes**	**Yes**
Boron	mg/L	1.5	No	No
Cadmium	mg/L	0.00020 - 0.00024	No	No
Chromium	mg/L	0.001	No	No
Copper	mg/L	0.0030 - 0.0037	**Yes**	No
Iron	mg/L	0.3	No	No
Lead	mg/L	0.0046 - 0.0061	No	No
Mercury	mg/L	0.000026	No	No
Molybdenum	mg/L	0.073	No	No
Nickel	mg/L	0.12 - 0.14	No	No
Selenium	mg/L	0.001	No	No
Silver	mg/L	0.00025	No	No
Thallium	mg/L	0.0008	No	No
Uranium	mg/L	0.015	No	No
Zinc	mg/L	0.0046 - 0.013	No	**Yes**

(a) Long-term CWQGs are presented in Table 2-2. Refer to Golder (2019) for more information on Jackfish Lake water quality.
(b) In this table, the elements reported as "total metals" includes metalloids such as arsenic and non-metals such as selenium.
mg-N/L = milligrams nitrogen per litre; CWQG = Canadian Water Quality Guidelines.

The screening process identified parameters that require further evaluation, particularly from K discharge. Based on the limited dataset, results of the first screening step indicate that parameter concentrations in CAT discharge were similar to concentrations in Jackfish Lake (Table 2-3). However, for K discharge, concentrations of total aluminum, copper, iron, lead, and zinc were notably higher than concentrations in Jackfish Lake (Table 2-3). From the second screening step, arsenic and copper concentrations were measured above CWQGs in the Jackfish Facility discharge or in Jackfish Lake near the discharge. Therefore, total arsenic, aluminum, copper, iron, lead, and zinc are described in more detail below.

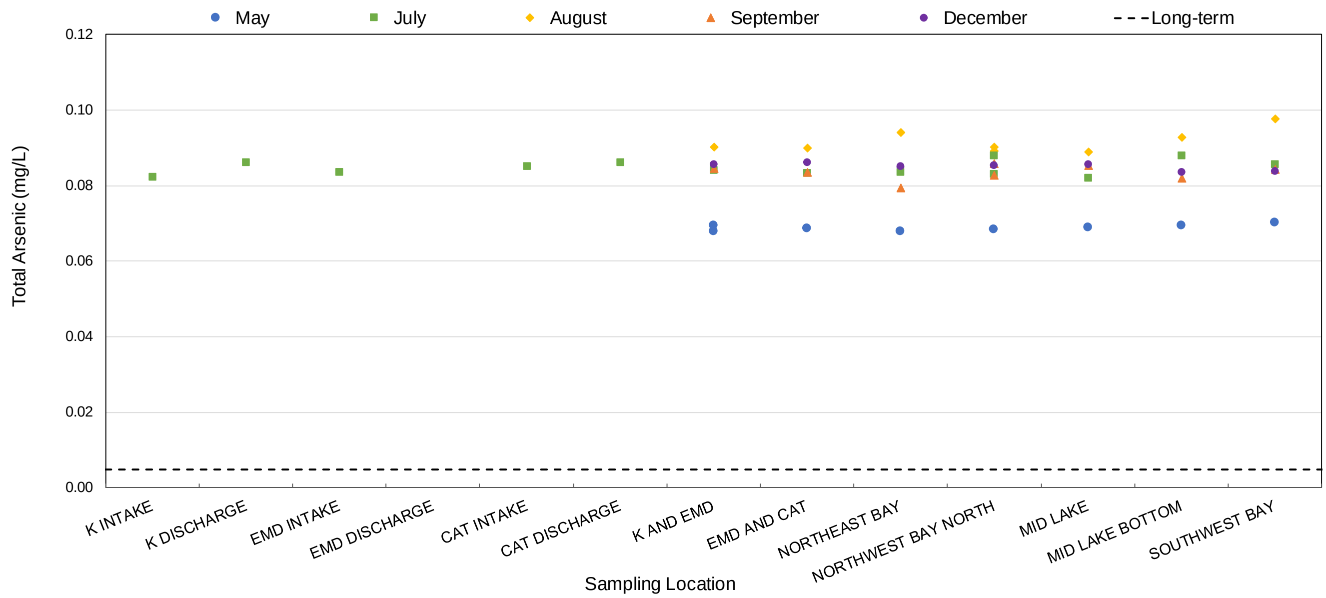
Total arsenic concentrations in Jackfish Lake did not demonstrate a spatial pattern of higher concentrations at stations near the discharges compared to stations far from the discharges (Figure 2-2). Total arsenic concentrations were above the CWQG in the all samples collected from the discharges and from Jackfish Lake in 2018 (Tables 2-4 and 2-5, and Figure 2-2). However, historical samples collected from Jackfish Lake also had total arsenic concentrations greater than the CWQG (Golder 2019). Concentrations of total arsenic are routinely above the CWQG in lakes in and around Yellowknife due to historical contamination from former gold mines in the area (Palmer 2015); therefore, arsenic concentrations in Jackfish Lake are not related to discharge from the Jackfish Facility.

Total aluminum and iron concentrations in the Jackfish Facility discharges were above those measured in Jackfish Lake; however, concentrations in all samples were below CWQGs (Tables 2-4 and 2-5). Total aluminum and iron concentrations in Jackfish Lake also did not demonstrate a spatial pattern of higher concentrations at stations near the discharges compared to stations far from the discharges (Figures 2-3 and 2-4).

Total lead concentrations in May and September at one location near the discharges (i.e., K and EMD) were the highest in Jackfish Lake for those months (Figure 2-5). These results are likely not related to the discharge as higher concentrations of total lead at this location (i.e., K and EMD) were not observed in other months or in the duplicate sample collected in May, which was below the detection limit (DL; Golder 2019, Appendix C.4); total lead concentrations at the other location near the discharges (i.e., EMD and CAT) were consistently below the DL in 2018. Total lead concentrations in Jackfish Lake were below the DL in July and maximum total lead concentrations occurred at stations farther from the discharges in August (i.e., at Northeast Bay) and December (i.e., at Southwest Bay). Additionally, the overall 2018 range in total lead concentrations at K and EMD were within the range of total lead concentrations at Southwest Bay, the station farthest from the discharges.

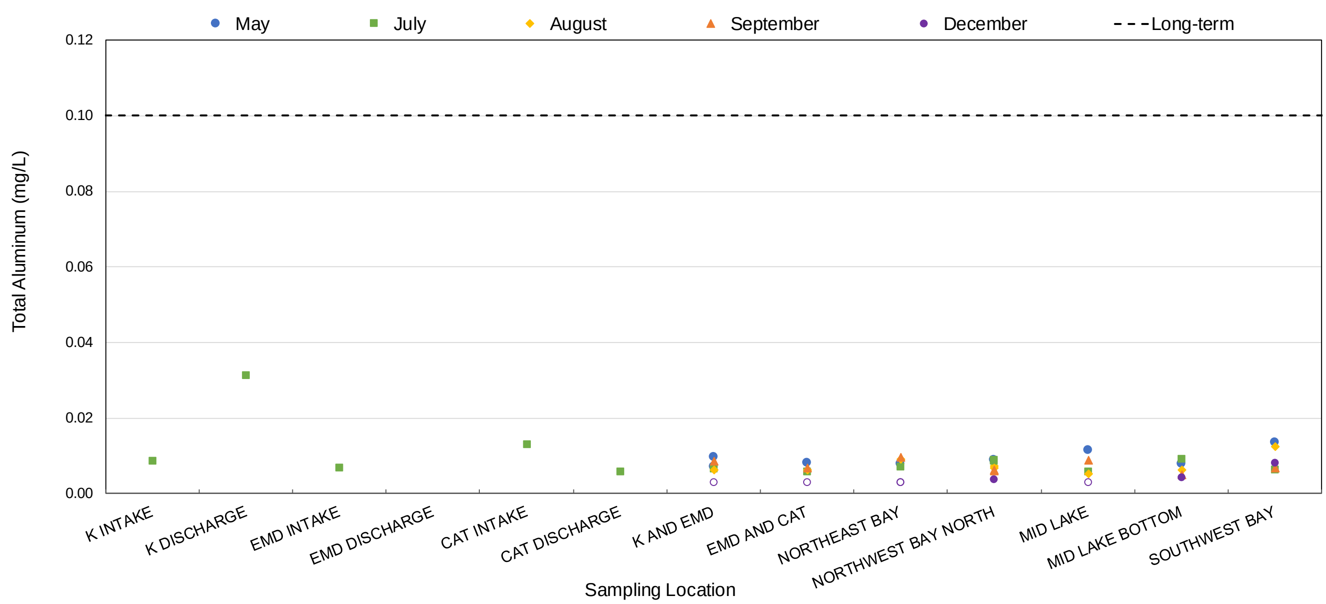
A single total zinc concentration was above the long-term CWQG at a location farthest from the Jackfish Facility discharges (Southwest Bay) (Figure 2-6); this result was likely an anomaly because all but three measured zinc concentrations in Jackfish Lake in 2018 were below the DL (0.003 mg/L). The 2018 total zinc concentrations were within the range of historical total zinc concentrations. No spatial pattern in total zinc concentrations was observed and total zinc concentrations were typically below the DL in Jackfish Lake; therefore, the single total zinc concentration above the long-term CWQG was unlikely related to the Jackfish Facility discharges or of concern to aquatic life.

Figure 2-2: Total Arsenic Concentrations in Intakes, Discharges and Jackfish Lake, 2018



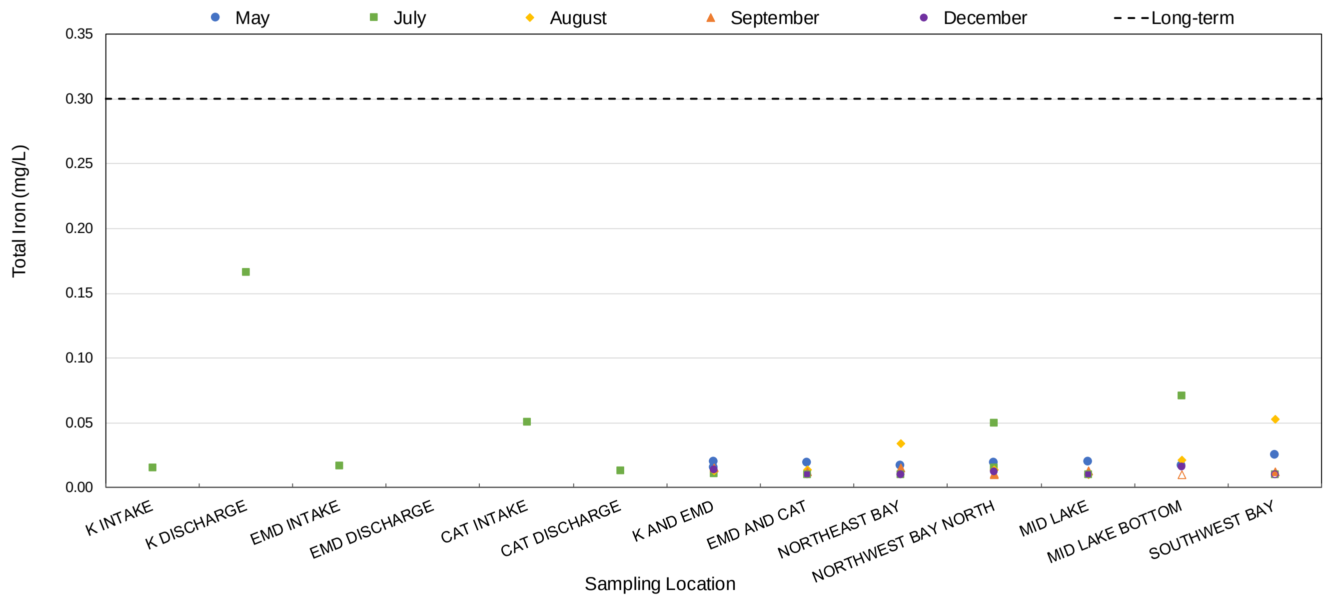
Notes:
All samples were collected at mid-depth with the exception of the intake, discharge and MID-BOTTOM samples; intake and discharge samples were collected as grab samples and MID-BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
The CWQG for total arsenic is 0.005 mg/L.
CWQG = Canadian Water Quality Guidelines for the protection of freshwater aquatic life (CCME 1999); DL = detection limit.

Figure 2-3: Total Aluminum Concentrations in Intakes, Discharges and Jackfish Lake, 2018



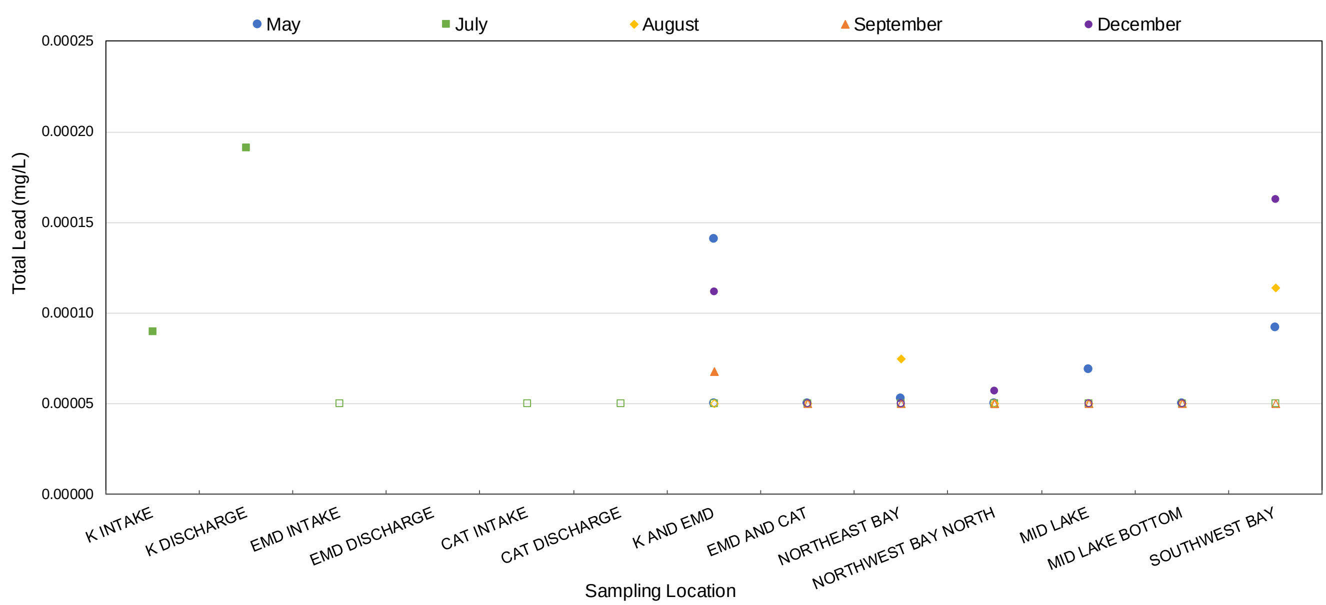
Notes:
All samples were collected at mid-depth with the exception of the intake, discharge, and MID-BOTTOM samples; intake and discharge samples were collected as grab samples and MID-BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
The CWQG for total aluminum is pH dependent. The applicable CWQG (0.100 mg/L), based on 2018 pH field values in Jackfish Lake and intake and discharge stations, is presented. Comparisons to the CWQG for individual samples from 2018 are provided in Golder (2019).
CWQG = Canadian Water Quality Guidelines for the protection of freshwater aquatic life (CCME 1999); DL = detection limit.

Figure 2-4: Total Iron Concentrations in Intakes, Discharges and Jackfish Lake, 2018



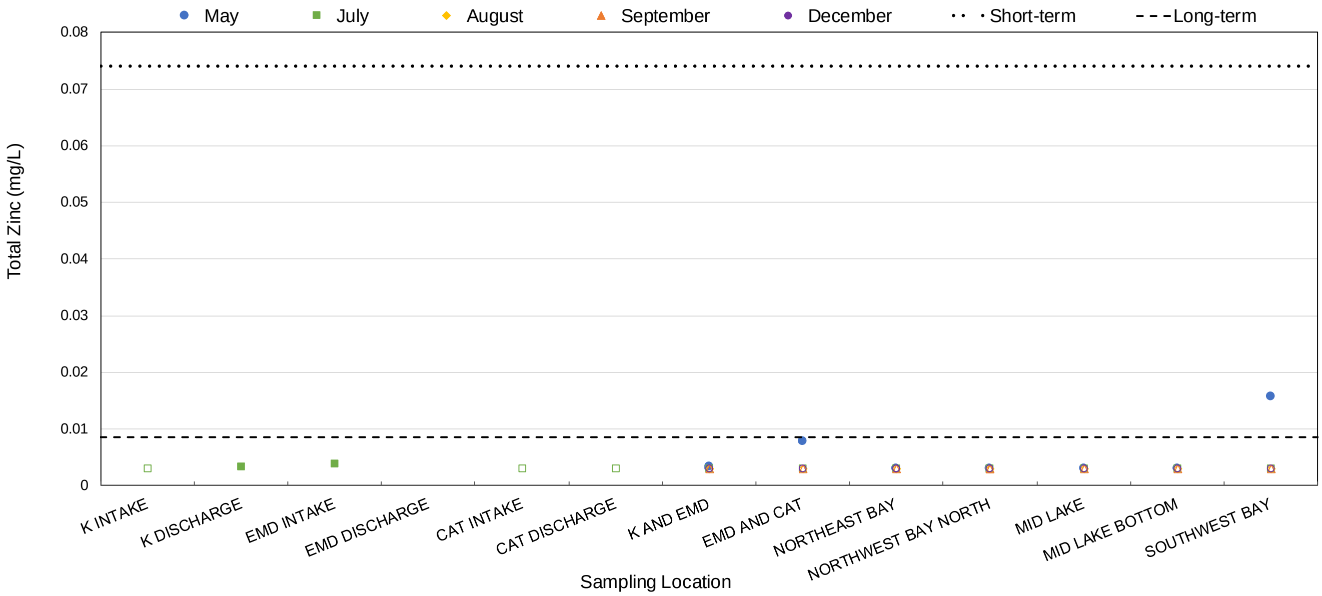
Notes:
All samples were collected at mid-depth with the exception of the intake, discharge, and MID-BOTTOM samples; intake and discharge samples were collected as grab samples and MID-BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
The CWQG for total iron is 0.300 mg/L.
CWQG = Canadian Water Quality Guidelines for the protection of freshwater aquatic life (CCME 1999); DL = detection limit.

Figure 2-5: Total Lead Concentrations in Intakes, Discharges and Jackfish Lake, 2018



Notes:
All samples were collected at mid-depth with the exception of the intake, discharge, and MID-BOTTOM samples; intake and discharge samples were collected as grab samples and MID-BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
The CWQG for total lead is dependent on water hardness. The minimum CWQG (0.0046 mg/L), based on 2018 water hardness values in Jackfish Lake and intake and discharge stations, is not presented.
Comparisons to the CWQG for individual samples from 2018 are provided in Golder (2019).
CWQG = Canadian Water Quality Guideline for the protection of freshwater aquatic life (CCME 1999); DL = detection limit.

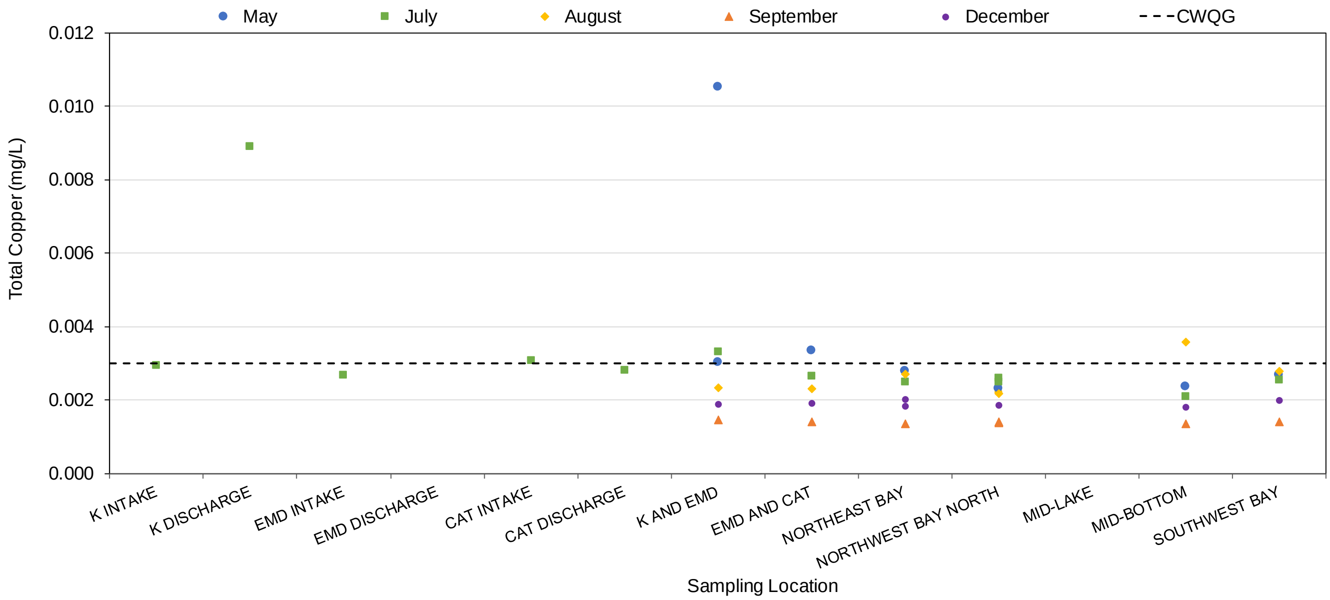
Figure 2-6: Total Zinc Concentrations in Intakes, Discharges and Jackfish Lake, 2018



Notes:
All samples were collected at mid-depth with the exception of the intake, discharge, and MID-BOTTOM samples; intake and discharge samples were collected as grab samples and MID-BOTTOM samples were collected at the bottom.
Concentrations below the DL are shown at the DL as open markers.
The long-term CWQG for zinc is dependent on pH, water hardness, and DOC. The CWQG is for the dissolved fraction but was applied to the total fraction as a conservative estimate. The minimum CWQG (0.009 mg/L), based on 2018 the pH, water hardness and DOC values in Jackfish Lake and intake and discharge stations, is presented.
The short-term CWQG for zinc is dependent on pH, water hardness and DOC. The CWQG is for the dissolved fraction but was applied to the total fraction as a conservative estimate. The minimum CWQG (0.074 mg/L), based on 2018 the pH, water hardness and DOC values in Jackfish Lake and intake and discharge stations, is presented.
Comparisons to the long-term and short-term CWQG for individual samples from 2018 are provided in Golder (2019).
CWQG = Canadian Water Quality Guidelines for the protection of freshwater aquatic life (CCME 1999); DOC = dissolved organic carbon; DL = detection limit.

As described in Golder (2019), spatial patterns of higher concentrations at stations closer to the discharges compared to farther from the discharges were generally not observed, with the possible exception of copper (Figure 8). The concentrations of total copper in the K discharge and in Jackfish Lake at stations near the discharges were above the CWQG in 2018 (Figure 2-7, and Tables 2-4 and 2-5). However, two of the three elevated concentrations near the discharge were marginally above (i.e., by less than 1%) the CWQG, which is considered a conservative benchmark for Jackfish Lake because it does not consider site-specific species or conditions beyond hardness values. The third elevated concentration (0.0105 mg/L), which is well above the hardness-dependent CWQG for the sample (0.0033 mg/L), was notably different than its duplicate sample (0.0030 mg/L) and below the CWQG. The K discharge may be influencing concentrations of total copper in Jackfish Lake at stations near the discharges; however, more data are required to confirm if this is the case, given that the spatial pattern and CWQG exceedance were marginal, and the variability observed in the quality control sample.

Figure 2-7: Total Copper Concentrations in Intakes, Discharges and Jackfish Lake, 2018



Notes:
All samples were collected at mid-depth with the exception of the intake, discharge, and MID-BOTTOM samples; intake and discharge samples were collected as grab samples and MID-BOTTOM samples were collected at the bottom.
The CWQG for total copper is dependent on water hardness. The minimum CWQG (0.0030 mg/L), based on 2018 water hardness values in Jackfish Lake and intake and discharge stations, is presented. Comparisons to the CWQG for individual samples from 2018 are provided in Golder (2019).
CWQG = Canadian Water Quality Guidelines for the protection of freshwater aquatic life (CCME 1999); MID = Mid-Lake.

2.4 Summary and Recommendations

Based on screening of the 2018 dataset herein, combined with the findings from Golder (2019), discharges from the Jackfish Facility are not affecting parameter concentrations in Jackfish Lake, with the possible exception of copper. Consistent gradients in water quality concentrations were not observed and no clear changes in water quality in Jackfish Lake have occurred relative to previous water quality surveys.

Setting water quality discharge limits for the Jackfish Facility is not recommended. There are no additives to the water pumped from Jackfish Lake and through the pipes in the cooling system, and evaporation is expected to be negligible because it is a closed system. It is acknowledged that the comparisons are based on a limited dataset. The CAT discharge and the K discharge were only sampled one time in 2018.

3.0 WATER TEMPERATURE

3.1 Summary of Discharge Effects on Water Temperature

The effects of discharge on water temperatures in Jackfish Lake were examined in the 2018 Environmental Monitoring Study (Golder 2019), during which continuous water temperature measurements were conducted. Temperature measurements were obtained in the vicinity of the CAT, EMD, and K-Plant intake and discharge sites, as well as near-field and far-field in-lake locations, as follows:

- background – at each plant water intake;
- discharge – at each plant discharge point;
- near-field – approximately 500 m from each discharge point;
- far-field – at mid-lake, NW bay (external run-off area), and SW bay (furthest from discharges).

During the Environmental Monitoring Study, elevated lake water temperatures were recorded at the discharge sites relative to the intakes during some plant operating periods (Golder 2019). Some temperature increases were also recorded at the in-lake near-field and far-field locations in response to the thermal discharge. However, through comparison of the range of temperatures measured in the lake to lethal temperatures of the three fish species documented to be present, the study concluded that acute thermal impacts to fish populations were not expected to have occurred for the 2018 operating year.

3.2 Fish Temperature Tolerances

In order to understand potential thermal effects and the protection of the fish populations in Jackfish Lake, temperature tolerances of the three fish species documented to be present (Lake Whitefish, Northern Pike, and Trout-perch) were examined, including temperature tolerances of the various life stages, where available (Table 3-1).

3.2.1 Northern Pike

Spawning/Incubation Period

Northern Pike spawn shortly after ice-out in the early spring followed by a short embryo incubation period before the eggs hatch later in the spring. Potential effects of increased water temperatures during the spring spawning/incubation period include early onset of spawning activity, and water temperatures higher than the tolerance limits for the embryo and larvae life stages. The annual spawning period is considered to extend from May 1 to June 15, based on available information regarding the restricted activity periods for the protection of fish during spawning/incubation periods for the Northwest Territories (NWT) (DFO 2013). During the early portion of this period (i.e., May 1 to 31), in-lake water temperatures should be below 15°C to avoid effects on spawning activity and incubation. During the later portion of this period (i.e., June 1 to 15), in-lake water temperatures should be below 24.8°C to avoid acute effects to embryos/larvae.

Examination of the 2018 water temperature monitoring data (Golder 2019) shows that 2018 plant operations did not affect Northern Pike spawning/incubation activity. Although a spike in facility uptime and discharge water temperature (maximum 26°C on May 12) was recorded during the spawning period, there was no effect on temperatures at any of the in-lake monitoring locations.

Open-Water Period

During the open-water period, when lake temperatures are naturally highest, there is a potential for heated discharge to result in elevated temperatures that may exceed Northern Pike temperature tolerances. To protect all Northern Pike life stages during this period, in-lake water temperatures should be below 29.4°C (lowest Upper Incipient Lethal Temperature – Table 3-1) to avoid effects on fish survival.

The 2018 operating year did not affect Northern Pike during the open-water period, with maximum in-lake water temperatures remaining at or below 23.1°C (optimal for Northern Pike growth), despite discharge temperatures as high as 34.8°C (Golder 2019).

Table 3-1: Temperature Preferences and Tolerances for Fish Species Found in Jackfish Lake

Fish Species	Life Stage	Optimal (˚C)	FTP[a] (ºC)	UILT[b] (ºC)	CTMax [c] (ºC)
Northern Pike	Spawning	4.4 - 12.0	11.5	n/a	n/a
	Embryo/Larvae	9.0 - 15.0	n/a	24.8	32.0
	Fry (young-of-year)	18.0 - 23.0	20.7	31.0	
	Juvenile			33.0	
	Adult			29.4	
Lake Whitefish	Spawning	<6.0	3.1	n/a	n/a
	Embryo	4.9	n/a	-	-
	Fry (young-of-year)	11.9 - 17.0	12.7	26.7	-
	Juvenile			26.6	-
	Adult			23.9	-
Trout-perch	All	10 - 16	-	-	22.9

(a) Final Temperature Preferendum – temperature fish gravitates to within a temperature gradient
(b) Upper Incipient Lethal Temperature (UILT) - lethal temperature for 50% of the population
(c) Critical thermal maxima – temperature at which fish loses equilibrium
Note: n/a = not applicable; - = no data
Source: Edsoll and Rottiers 1976; Jobling 1981; Rast 1988; Casselman and Lewis 1996; Lasenby et al. 2001; Harvey 2009; Hasnain et al. 2010; Hennessey 2011; Environment Canada 2014.

3.2.2 Lake Whitefish

Spawning/Incubation Period

Lake Whitefish spawn in the fall followed by a long incubation period over the winter, with the eggs hatching in the spring as water temperatures increase. Potential effects of increased water temperatures during the fall spawning period include early onset of spawning activity or complete interruption of spawning activity due to the lack of appropriate temperature cues. Hatching of Lake Whitefish eggs is based on the eggs being exposed to a requisite number of degree-days. Therefore, increased temperatures during the fall/winter incubation period could result in poor hatching success, or early hatching followed by poor larvae survival. The annual spawning period is considered to extend from September 15 to October 15 based on the NWT restricted activity period for this species (DFO 2013). During this period, in-lake water temperatures should be below 6°C to avoid effects on spawning activity. To avoid effects on incubation timing and success, increases in in-lake water temperatures during the winter should be avoided or minimized.

Examination of the 2018 water temperature monitoring data (Golder 2019) shows that 2018 plant operations did not affect Lake Whitefish spawning/incubation activity. Although discharge water temperatures up to 26°C were recorded from late September through early December (primarily at the EMD Plant discharge), no temperature effects were observed at any of the in-lake monitoring locations. Background temperatures at the plant intakes were higher than the preferred spawning temperature of less than 6°C in mid-September 2018, indicating that the spawning period for Lake Whitefish in Jackfish Lake would naturally have occurred in late-September or early October, when background temperatures were less than 6°C.

Open-Water Period

During the open-water period, there is a potential for heated discharge to result in elevated temperatures that may exceed Lake Whitefish temperature tolerances. To protect all Lake Whitefish life stages during this period, in-lake water temperatures should be maintained below 23.9°C (lowest UILT – Table 3-1) to avoid effects on fish survival.

The 2018 temperature monitoring data (Golder 2019) shows that in-lake temperatures remained below the 23.9°C tolerance limit for Lake Whitefish, generally remaining at or below 20°C for much of the open-water period, with an open-water peak temperature of 23.1°C. Although the preferred growth range for Lake Whitefish (maximum of 17ºC) was exceeded for a portion of the summer, this was not in response to discharges, with the plant intake temperatures also exceeding 17°C. It would be expected that, during the summer, Lake Whitefish would seek cooler water temperatures found in the deeper portions of the lake.

3.2.3 Trout-Perch

Based on the available temperature criteria for Trout-perch (Table 7), in-lake water temperatures should be maintained below 22.9°C to avoid effects on fish survival.

The 2018 temperature monitoring data (Golder 2019) shows that in-lake temperatures remained at or below 20°C for much of the open-water period, with an open-water peak temperature of 23.1°C. Although the 22.9°C tolerance limit for Trout-perch was exceeded, this occurred only during two brief, isolated periods of facility uptime. In addition, cooler temperatures were measured mid-depth and at the bottom of the lake. Trout-perch are benthopelagic, being known to migrate to deeper (and therefore cooler) waters during the day time (Scott and Crossman 1973) and it is likely that Trout-perch avoided the higher surface temperatures. Temperatures during a portion of the open-water period also exceeded the preferred growth range for Trout-perch (maximum of 16°C); however, this was not in response to discharges, with the plant intake temperatures also exceeding 16°C.

3.3 Summary and Recommendations

Through comparing the range of temperatures measured in the lake to lethal temperatures of Northern Pike, Lake Whitefish, and Trout-perch, the 2018 Environmental Monitoring Study (Golder 2019) concluded that acute thermal impacts to fish populations were not expected to have occurred for the 2018 operating year. At this time, setting temperature criteria for Jackfish Facility discharges is not recommended.

It is, however, recognized that the heated discharge may increase water temperatures such that seasonal effects on fish may occur. It is also acknowledged that the comparisons are based on a limited dataset. It is recommended that additional temperature measurements on Jackfish Facility discharges occur through the Surveillance Network Program, and in-lake through the Aquatic Effects Monitoring Program.

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https://golderassociates.sharepoint.com/sites/33863g/technical work/phase 3000 supporting documents/3030 effluent quality report/ntpc_eqc_report_clean_draft.docx

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