Nalcor Energy – Lower Churchill Project

LCP Aquatic Environmental Effects Monitoring Plan

LCP-PT-MD-9112-EV-PL-0001-01

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Inter-Departmental / Discipline Approval (where required)

Department	Department Manager Approval	Date

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1 PURPOSE

The purpose of this Aquatic Protection and Environmental Effects Monitoring Plan (APEEMP) is to demonstrate how any adverse environmental effects (on aquatic life) of the Lower Churchill River Hydroelectric Generation Project (the Project) will be mitigated, and to set out a program for monitoring the effectiveness of mitigation measures. To comply with regulatory requirements and commitments made in the Environmental Impact Statement (EIS), the Lower Churchill Project's (LCP) APEEMP approach includes consideration of:

- Mitigation objectives – performance objectives in respect of each adverse environmental effect;
- Mitigation – measures planned to achieve the mitigation objectives;
- Metrics and targets – specific, quantifiable, relevant and time constrained;
- Follow-up or Monitoring Programs – how the Project will include follow-up or monitoring surveys to confirm that mitigation strategies are meeting the mitigation objectives; and
- Contingency – plan to be implemented should monitoring reveal that mitigation measures have not been successful.

The LCP's APEEMP builds on existing information and commitments made in the EIS (Nalcor 2009), and conditions of permits and licenses for the Project.

NL Reg. 18/12, also referred to as the *Lower Churchill Hydroelectric Generation Project Undertaking Order* releases the Project from environmental assessment and sets conditions for this release that LCP must meet. The release of the Project from environmental assessment under section 3 is subject to the following conditions:

(a) Nalcor Energy shall abide by all commitments made by it in the Environmental Impact Statement dated February 2009, and all the Environmental Impact Statement Additional Information Requests made by the Lower Churchill Hydroelectric Generation Project Environmental Assessment Panel and consequently submitted by Nalcor Energy, and the submissions made by Nalcor Energy during the panel hearings and, subsequent to the hearings, to the panel, unless one or more of the commitments, or a part of a commitment is specifically waived by the minister;

(e) Nalcor Energy shall prepare and abide by the requirements of environmental effects monitoring plans for all phases of the project, and those plans shall be submitted to and approved by the Minister of Environment and Conservation or the appropriate minister of the Crown before the commencement of an activity which is associated with or may affect one or more of the following matters:

(ii) aquatic

Submission of this EEMP satisfies the condition/requirement in NL Reg. 18/12 that Nalcor Energy prepare and submit to the Minister of Environment and Conservation or the appropriate minister of the Crown, an environmental effects monitoring plan for all phases of the project, before the commencement of an activity which is associated with or may affect the following matters:

(ii) aquatic

2 SCOPE

This plan addresses the required aspects of the aquatic protection and environmental effects monitoring for the design and construction phases of the LCP including Muskrat Falls Generation and the Labrador Transmission Assets (described in Section 6.0).

3 DEFINITIONS

Environmental Assessment: An evaluation of a project's potential environmental risks and effects before it is carried out and identification of ways to improve project design and implementation to prevent, minimize, mitigate, or compensate for adverse environmental effects and to enhance positive effects.

Environmental Management: The management of human interactions with the environment (air, water and land and all species that occupy these habitats including humans).

Environmental Protection Plan: Document outlining the specific mitigation measures, contingency plans and emergency response procedures to be implemented during the construction or operations of a facility.

Environmental Effects Monitoring: Monitoring of overall Project effects to confirm the predictions of EA and to fulfill EA commitments.

Environmental Compliance Monitoring: Monitoring of Project activities to confirm compliance with regulatory requirements and commitments made through the EA process.

4 ABBREVIATIONS & ACRONYMS

CEAA	Canadian Environmental Assessment Act
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CWS	Canadian Wildlife Service
EA	Environmental Assessment
EEMP	Environmental Effects Monitoring Plan
EIS	Environmental Impact Statement
EMP	Environmental Management Plan
EPP	Environmental Protection Plan
ERC	Environment and Regulatory Compliance
Gen	Generation
HSE	Heath Safety and Environment
IBA	Impacts and Benefits Agreement
IPD	Integrated Project Delivery
LTA	Labrador Transmission Asset
LCP	Lower Churchill Project
NE	Nalcor Energy
NL	Newfoundland and Labrador
NLDEC	Newfoundland and Labrador Department of Environment and Conservation
PEEMP	Protection and Environmental Effects Monitoring Plan
RCP	Regulatory Compliance Plan
SARA	Species at Risk Act

5 REFERENCES

LCP-PT-MD-0000-PM-PL-0001-01	LCP Project Execution Plan
LCP-PT-MD-0000-PM-CH-0001-01	LCP Project Charter
LCP-PT-MD-0000-EA-PL-0001-01	LCP Generation Environmental Assessment Commitment Management Plan
LCP-PT-ED-0000-EA-SY-0001-01	Environmental Impact Statement and Supporting Documentation for the Lower Churchill Hydroelectric Generation Project
LCP-SN-CD-0000-EV-PL-0002-01	LCP Project-Wide Environmental Protection Plan
LCP-PT-ED-0000-EV-RG-0001-01	Lower Churchill Project Permit Registry
LCP-PT-MD-0000-SM-ST-0001-01	Post Environmental Assessment Release
LCP-PT-MD-0000-RT-PL-0001-01	Regulatory Compliance Plan
LCP-PT-ED-000-EN-PH-0031-01	Design Philosophy for Environmental Rehabilitation
LCP-PT-ED-0000-EN-PH-0007-01	Design Philosophy for Environmental Mitigation
LCP-PT-MD-0000-HS-PL-0001-01	Health and Safety Plan
LCP-PT-MD-0000-HS-PL-0004-01.	LCP Emergency Response Plan
MFA-PT-MD-0000-EV-PL-0003-01	Ice Formation Environmental Effects Monitoring Plan

6 PROJECT DESCRIPTION

6.1 Muskrat Falls Generation

The Muskrat Falls Generation Project will include the following sub-components which are broken down under the five principal areas of the development:

- 22 km of access roads, including upgrading and new construction, and temporary bridges;
- A 1,500 person accommodations complex (for the construction period); and
- A north roller compacted concrete overflow dam;
- A south rock fill dam;
- River diversion during construction via the spillway;

- 5 vertical gate spillway;
- Reservoir preparation and reservoir clearing;
- Replacement of fish and terrestrial habitat;
- North spur stabilization works, and:
- A close coupled intake and powerhouse, including:
    - 4 intakes with gates and trash racks;
    - 4 turbine/generator units at approximately 206 MW each with associated ancillary electrical/mechanical and protection/control equipment;
    - 5 power transformers (includes 1 spare), located on the draft tube deck of the powerhouse; and
    - 2 overhead cranes each rated at 450 Tonnes

Figure 6.1 Muskrat Falls Generating Facility

6.2 Labrador Transmission Asset (LTA)

LTA consists of the AC transmission line system from Churchill Falls to Muskrat Falls, specifically:

- Churchill Falls switchyard extension;

- Muskrat Falls switchyard;
- Transmission lines from Muskrat Falls to Churchill Falls: double-circuit 315 kV ac, 3 phase lines, double bundle conductor, Single circuit galvanized lattice steel guyed suspension and rigid angle towers; 247 km long;
- 735 kV Transmission Line at Churchill Falls interconnecting the existing and the new Churchill Falls switchyards; and
- Labrador Fibre Project (Nalcor's participation in Aliant led initiative).

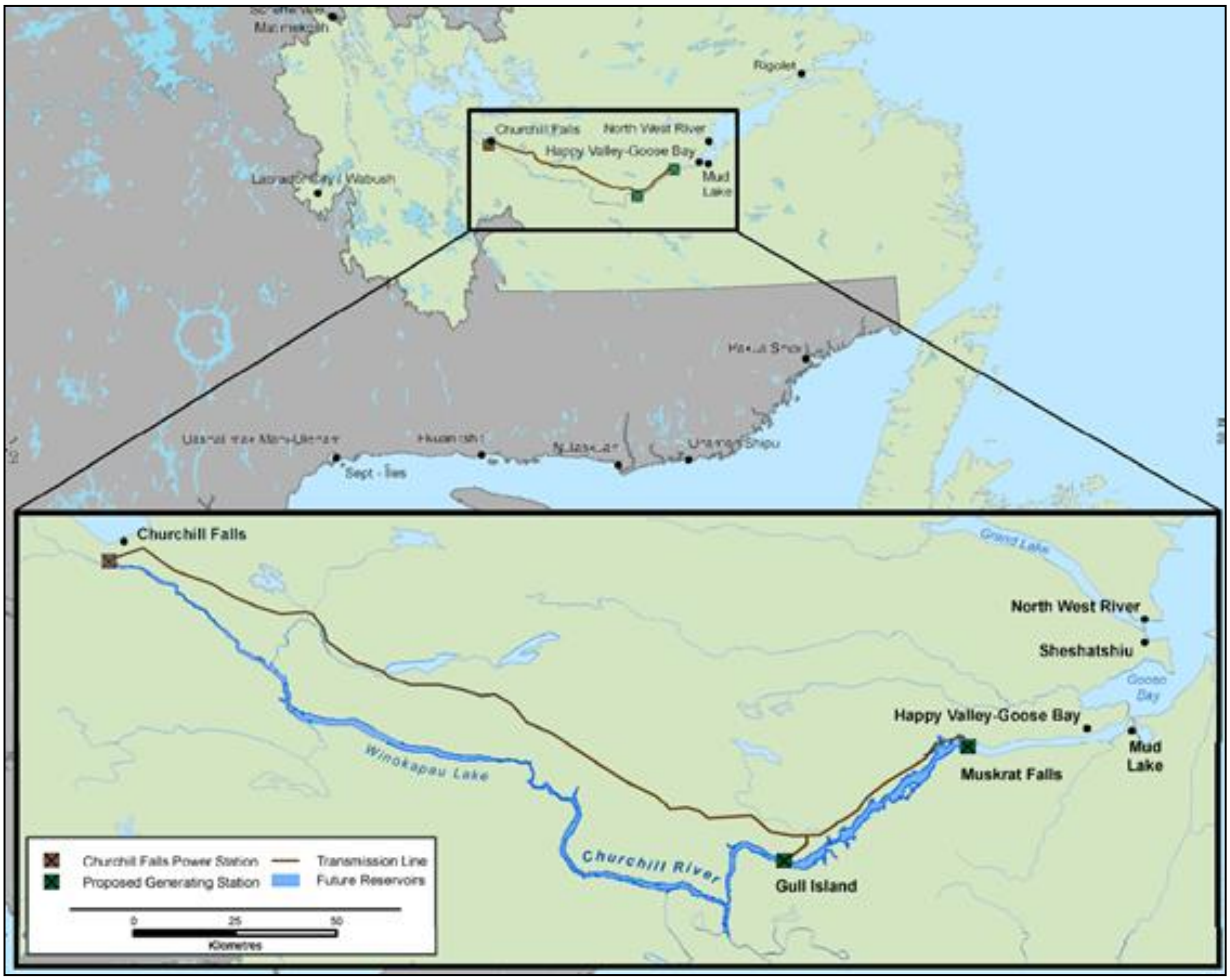

Figure 6.2 Labrador Transmission Asset

7 EEM DESIGN AND METHODOLOGIES

The purpose of an EEM is to confirm predictions of environmental effects that were made during the environmental assessment (EA). An EEM and Fish Habitat Compensation Plan (FHCP) have been developed and submitted to Fisheries and Oceans Canada (DFO) as part of the Fisheries Act Authorization. While the EEM was designed to monitor aquatic environmental predictions outlined during the EA, the FHCP is designed to monitor physical habitat compensation works. Monitoring associated with the FHCP is focused entirely within the Muskrat Falls Reservoir area.

The EEM developed for Fisheries Act Authorization is primarily focused on the area downstream of Muskrat Falls, and includes downstream effects, turbine entrainment and mercury bioaccumulation. The EEM required by the provincial government is an amalgamation of monitoring outlined in the Federal EEM (AMEC 2013a), the FHCP (AMEC 2013b) and others, which effectively covers the entire project area. Where warranted, reference to the federal EEM and FHCP are provided within the text.

Provided below are summaries of the existing environment, predictions made and methodologies that will be employed to monitor predicted parameters. It should be noted that EEM methodologies will follow those outlined in the FHCP where applicable.

7.1 Sampling Schedule

Baseline conditions for many of the parameters included in the EEM, excluding turbine entrainment, will be collected up to impoundment of the reservoir. The sampling frequency is dependent upon the parameter, and details of baseline data collection are presented in the following sections. It should be noted that monitoring of some parameters, including mercury, will begin in 2016 due to flooding to create the diversion head pond.

Completion of the diversion head pond, in 2016 marks the end of baseline data collection, and initiates the post construction EEM monitoring. Table 7.2 shows the schedule for monitoring from 2016 to 2037.

The monitoring programs that have been developed by Nalcor are adaptive in nature and will undergo annual reviews as well as a major review every five years. During reviews, methodologies, schedules (both within year sampling schedule and overall program schedule), sample locations and results will all be investigated. Any adaptations will be identified and discussed with regulators/stakeholders in order to maintain an efficient, inclusive and defensible monitoring program.

7.2 Study Area

Figure 7.1 presents that study area included in the EEM. As mentioned, the EEM is comprised of three major components, each with an associated study area; however, the indicated area on Figure 7.1 encompasses all components.

As indicated on Figure 7.1, Muskrat Falls Reservoir will be sampled for mercury only for the EEM, and turbine entrainment will be focused on the immediate upstream and downstream habitat near the facility. Additional sampling within the Muskrat Falls Reservoir is included in the FHCP. Further details regarding sample sites are provided in the appropriate sections below.

7.3 Downstream Effects

Various environmental parameters will be monitored downstream of Muskrat Falls with a focus on habitat stability, physico-chemical and biological measures of habitat suitability, and fish health. Table 7.1 presents the parameters included in the EEM and the design type that will be utilized for monitoring.

Table 7.1 Summary of Downstream Effects Monitoring Design

Sampling Parameter	Design Type
Habitat Stability	
Bottom Scour (Bathymetry/ADP)	• Before and after comparison • Model Confirmation
Shoreline Erosions (Remote Sensing/GIS)	• Before and after comparison
Ice Cover	• Before and after comparison • Model Confirmation
Habitat Suitability: Physico-Chemical Parameters	
Flow Regime	• Before and after comparison • Model Confirmation
Total Suspended Solids	• Before and after comparison • Control-Impact • Model Confirmation

Total Phosphorus	• Before and after comparison • Control-Impact • Model Confirmation
Salinity/Saltwater Intrusion	• Before and after comparison • Model Confirmation
Water Temperature	• Before and after comparison • Model Confirmation
Habitat Suitability: Biological Measures	
Catch-per-unit-effort	• Before and after comparison
Snorkel Surveys	• Before and after comparison
Population Estimates	• Before and after comparison
Habitat Suitability: Fish Health	
Growth Rates/Condition	• Before and after comparison
Age Demographic	• Before and after comparison
Isotope Trophic Feeding Level	• Before and after comparison

Table 7.2 Monitoring Schedule Following Completion of Head Water Pond

Activity/Task	Monitoring Year																								
	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Downstream Effects Monitoring																									
Bottom Scour (Bathymetry and ADCP)			■			■			■			■			■			■			■				
Shoreline Erosion using Satellite Imaging and GIS			- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -			
Ice Cover			- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -			
Flow Regime	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -			
Total Suspended Sediment	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -			
Total Phosphorus	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -			
Salinity and Salt Water Intrusion	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -			
Water Temperature	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -			
Fish Habitat Utilization (electrofishing, snorkeling, netting)	■		■	■	■		■		■		■		■			■			■			■			
Fish Growth and Condition	■		■	■	■		■		■		■		■			■			■			■			
Fish Age Structure	■		■	■	■		■		■		■		■			■			■			■			
Fish Trophic Feeding Level	■		■	■	■		■		■		■		■			■			■			■			
Seal Abundance	■		■	■	■		■		■		■		■			■			■			■			
Mercury Moniotirng																									
Fish (Downstream and Reservoir)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -			
Seals (Downstream)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -			
Entrainment Monitoring			■	■	■	■	■					■					■					■			
Monitoring Results and Major Program Review								★					★					★					★		

Note: Stars indicate March review of EEMP; solid blocks indicate sampling years for each respective parameter; dashed lines indicate parameters that are samples continuously throughout the EEMP schedule

Figure 7.1 EEM Study area for downstream effects

All Parameters that will be monitored for downstream effects include a comparison of before and after conditions, which require the collection and analysis of baseline data. Various parameters also included modeling for the environmental assessment, predominantly in the physico-chemical parameters and habitat stability. Post-project results from these parameters will be compared to baseline as well as model results to confirm predictions.

7.3.1 Sampling Schedule

Table 7.3 shows a generalized monthly timeline for sampling below Muskrat Falls for each monitoring year. The schedule has taken past sampling programs into consideration (i.e., the majority of past fish sampling has been conducted in August and September). Fish health assessment will occur in conjunction with fish habitat utilization.

As previously mentioned, parameters that are being selected to monitor downstream effects require the collection of baseline data. Baseline data has been collected since 1998 for many of the parameters included in the EEMP, with additional parameters (i.e., habitat stability and fish health) being added to the program as it was developed. Baseline data will continue to be collected until the formation of diversion head pond.

7.3.2 Habitat Stability

The mainstem of the Churchill River below Muskrat Falls is dominated by relatively slow, deep habitat, with substrate being almost entirely comprised of sand (see Table 7.4). Figure 7.2 shows the locations of the lower Churchill River below Muskrat Falls where sand is not the dominant substrate. Acoustic Doppler Current Profiler transects of the river bottom near the Black Rock Bridge (approximately 16 km downstream of Muskrat Falls) have shown that the substrate is mobile in the area (AMEC 2009). This creates an environment that is not favorable for many benthic species of fish and invertebrates, especially those which rely on stable, larger substrate for foraging, refuge or spawning. This also creates an environment that is highly susceptible to bed scour. Shorelines below Muskrat Falls are also dominated by sand. There are isolated areas that show signs of shoreline armoring as a result of erosion. Figure 7.3 shows a typical section of shoreline located below Muskrat Falls.

Table 7.3 Generalized Annual Schedule for Downstream Effects Sampling

Parameter	Month											
	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Habitat Stability												
Bathymetry												
ADCP												
Remote Sensing/GIS												
Ice Dynamics												
Physio-Chemical Parameters												
Flow Regime												
Total Suspended Solids												
Total Phosphorus												
Water Temperature												
Salinity												
Fish Habitat Utilization												
Mainstem/Estuary CPUE												
Snorkel Surveys												
Electrofishing Surveys												
Fish Health												
Growth Rates/Condition												
Age Demographics												
Isotope Feeding Level												

Table 7.4 Summary of Existing Habitat Conditions within the Mainstem below Muskrat Falls

Habitat Classification	Existing Habitat (ha)	Mean Water Velocity (m/s)	Mean Water Depth (m)	Substrate Composition (%)						
				Br	Bo	Ru	Co	Gr	Sa	Mu
Slow	6327.75	0.50 (0.03-0.91)	13.5 (4.9-58.5)	0.0	0.0	9.3	10.0	0.0	80.7	0.0
Fast	48.44	2.45 (0.55-4.35)	8.0 (3.4-12.8)	2.1	12.5	25.1	39.9	5.3	15.1	0.0

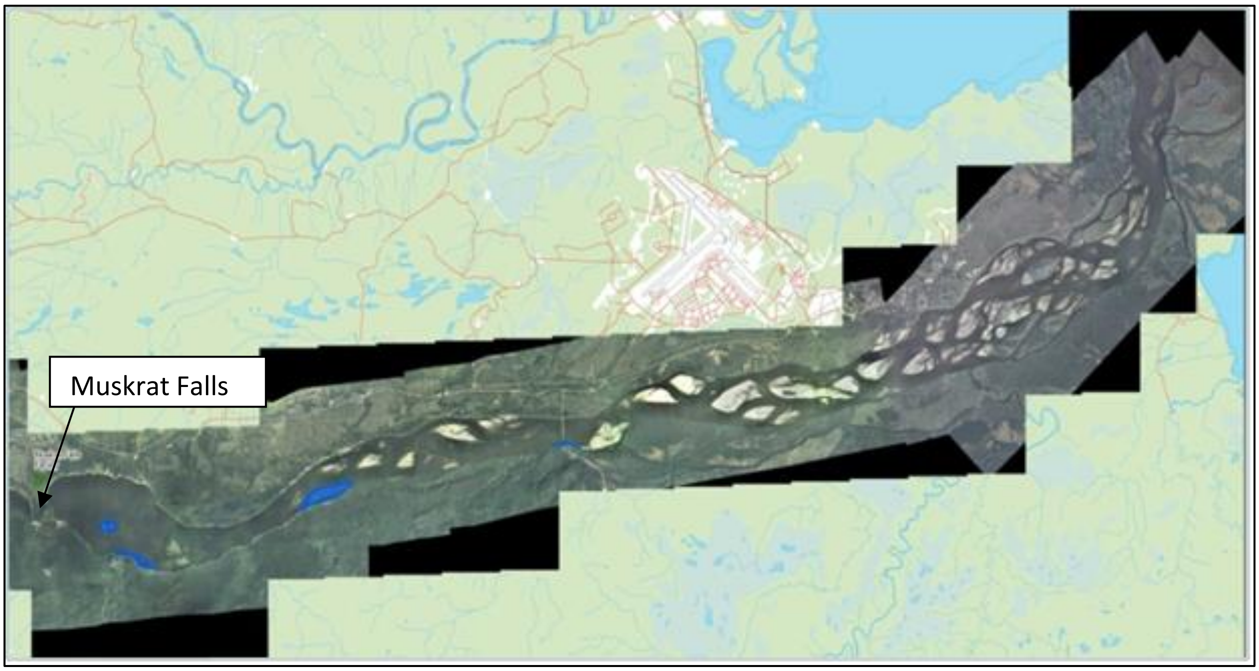

Figure 7.2 Areas where sand is not the dominant substrate (indicated by blue).

Figure 7.3. Typical shoreline below Muskrat Falls

During the winter months, a stable ice cover forms below Muskrat Falls, including Goose Bay and Lake Melville. Ice cover begins in Goose Bay, and proceeds upriver, where it forms a hanging dam, or 'ice rose' immediately below the falls. Typically, ice cover forms in December and break up occurs around April (Hatch 2008).

7.3.2.1 Bottom Scour and Shoreline Erosion

Following the completion of the Muskrat Falls facility, sedimentation and erosion in the reach downstream of Muskrat Falls will be altered. This will be the result of the upstream reservoir and facility acting as a 'sediment trap', and discharging 'sediment starved' water downstream. NHC (2008) modeled the effect of the facility on the bed scour potential below Muskrat Falls. The results of the model are shown in Figure 7.4.

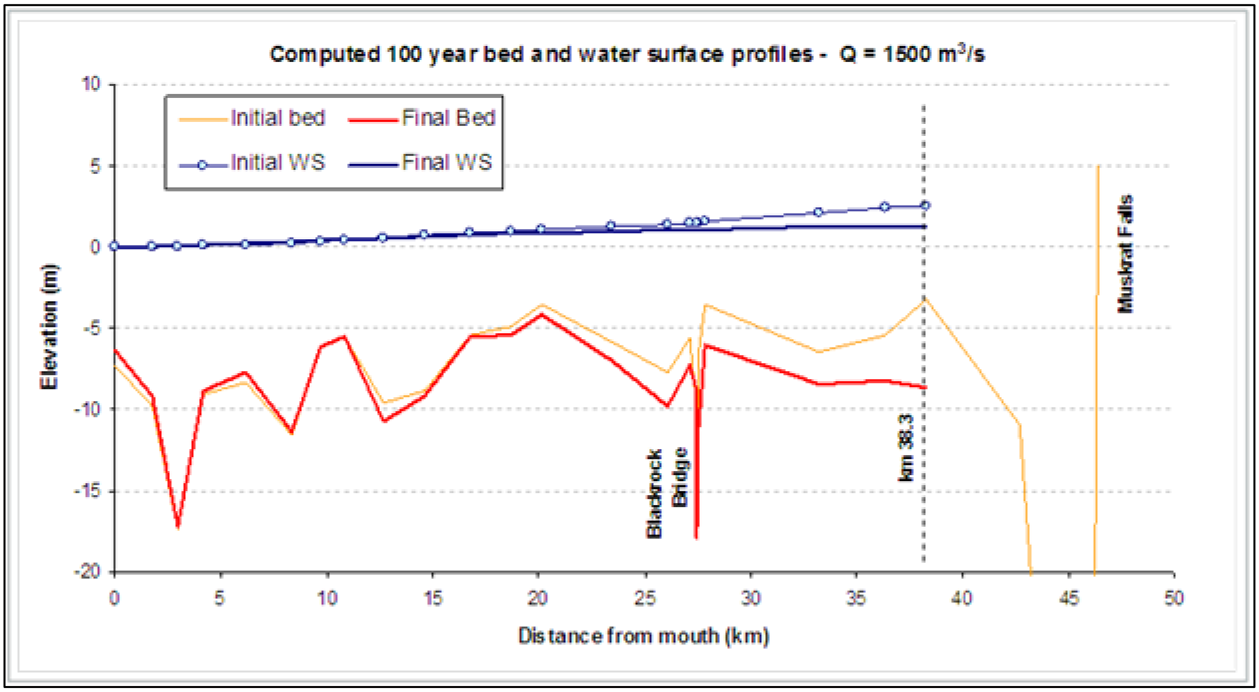

Figure 7.4. Modeled bed scour downstream of Muskrat Falls (NHC 2008)

The model shows that bed scour will increase in the area immediately downstream of Muskrat Falls to approximately 17km downstream of the Blackrock Bridge. Bed elevation immediately downstream of the facility is predicted to be lower by approximately 5m, which is the greatest elevation change predicted. The additional bottom scour will likely lead to additional deposition within the first 10km of the river (from the mouth). It should be noted that the model was run on a 100 year time frame and changes in bed elevation will be slow, on the order of 0.05m/year in the areas of greatest bottom scour potential. However, it could be expected that initial scour will be greater than the overall mean rate.

Aerial photography analysis conducted by NHC (2008) indicated that existing shoreline erosion rates in isolated areas below Muskrat Falls average 2.96m/year. The release of 'sediment starved' water could potentially have the same impacts on shoreline erosion as it does on bottom scour. If the increased bottom scour affects areas near the shoreline, the shoreline will be susceptible to slumping, which would act as the primary factor increasing shoreline erosion downstream of Muskrat Falls. Modeling shows that lateral instability (i.e., slumping) is more likely near the facility, and the effects will gradually diminish downstream.

As a result of the above predictions, bottom scour and bank erosions will both be monitored, employing various methodologies. Bottom scour and erosion rates will also require the collection of baseline data for comparison of pre- and post-project conditions. Sampling for baseline conditions began during the summer of 2013, and will be conducted again in 2015. Following the completion of diversion head pond, further monitoring will follow the schedule presented in Table 7.2.

Bathymetric Mapping

Bathymetric mapping will be used to monitor bottom scour, as well as indicate areas of slumping below Muskrat Falls. Bathymetric mapping has been completed in the plunge pool formed below Muskrat Falls based on survey data collected in 2006 (Figure 7.5).

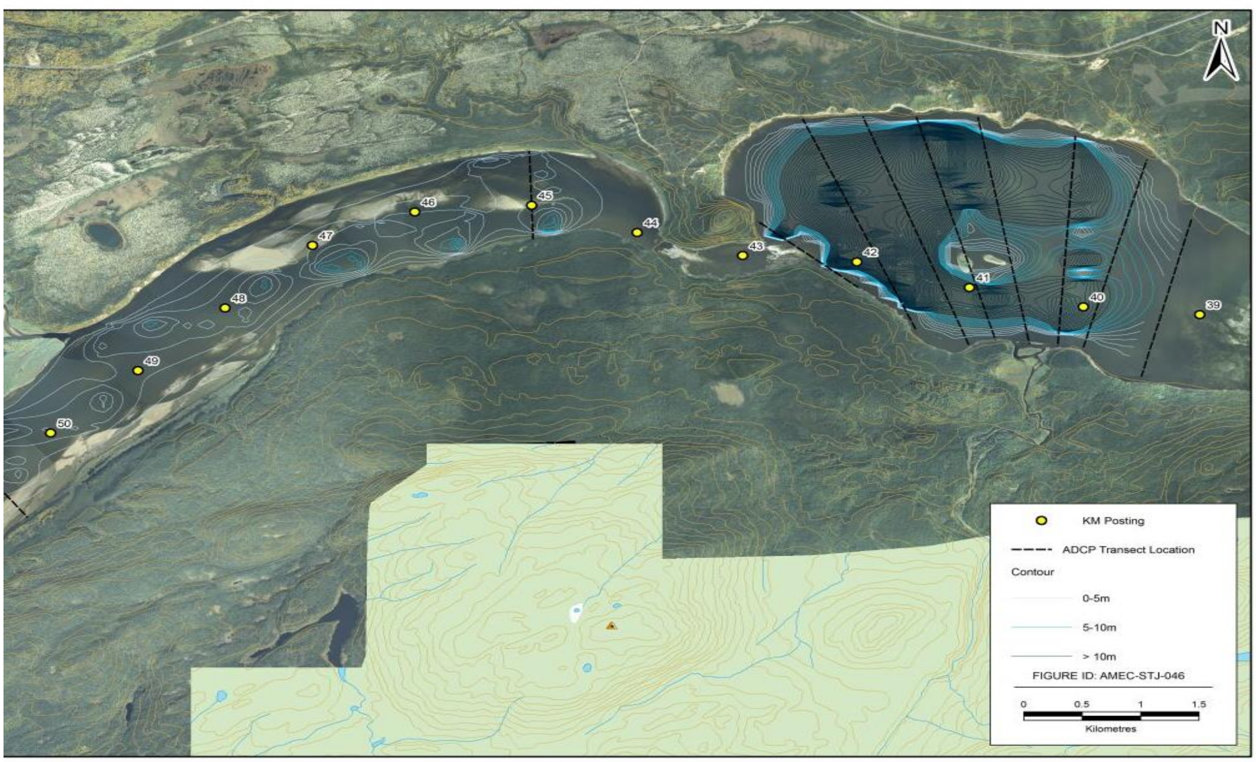

Figure 7.5. Bathymetric contours and ADP transect locations below Muskrat Falls, 2006

In order to collect accurate bathymetric data, extensive coverage with a sonar unit must be obtained. A Lowrance Sonar system will be used which will be connected to an external GPS, and will record a position and water depth every second. Upon completion of the survey, data will be mapped using 3DDfield, a contour generating software package, and ArcGIS. Bathymetric mapping will be completed in the area immediately downstream of Muskrat Falls to Muskrat Island. The extent of bathymetric surveying is chosen to coincide with the areas that are predicted to have the greatest changes as a result of the project (see Figure 7.5). It is anticipated that the collection of bathymetric data beyond Muskrat Island will not occur due to shallow water depths and sand bars, creating a difficult area to collect ample coverage. Shifts in sand bars will be monitored using GIS/satellite imagery analysis (described in section below).

The data collected will be plotted using GIS, which can then be used to make a direct comparison from survey to survey, on an estimated two year frequency for the first ten years. Additional sampling will be determined based on results. Comparisons will be made in regards of the mean and maximum depths as well as the overall bathymetry. As indicated, the comparisons can then be used to indicate areas of increased scour (indicated by greater depths) or deposition (indicated by lesser depths). Additional baseline bathymetry will be required to encompass the greater downstream extent, as well as to assess the bottom scour rates that currently exist within the areas below Muskrat Falls. As mentioned, the substrate composition downstream of Muskrat Falls creates an area that is susceptible to bottom scour, and substrate has been noted as being mobile in past studies (AMEC 2009); therefore, additional baseline bathymetry will likely indicate variations in overall bathymetry since that collected in 2006 (Figure 7.5).

Bathymetric surveys of the areas below Muskrat Falls will be conducted every second year, with the first survey being completed in 2012. Given the slow scour rate that currently exists within the pool downstream of Muskrat Falls, annual bathymetric surveys were determined to be excessive. Following the completion of the diversion head pond, the frequency of bathymetric surveys will follow the schedule presented in Table 7.2.

ADP Transects

Acoustic Doppler Profiler (ADP) will be used to monitor bottom scour along established transect lines in the lower Churchill River. The ADP collects detailed discharge measurements using sound waves, which measure water velocity throughout the water column.

The downstream extent of the ADP transects will focus on the area described for bathymetric mapping. The model from NHC (2008) shows that there is potential for increased deposition at the mouth of the Churchill River; therefore ADP transects will be established there as well. However, as the model shows the increased deposition is minimal, and from year to year, the changes may be undetectable. Through establishing permanent transect locations; a direct comparison of yearly surveys will be conducted. Comparisons of discharge, water velocity and depth along each transect will be compared from survey to survey. ADP transects can also be used to monitor changes in the location of the thalweg which would be indicated by variations in the location of the highest measured velocities.

Similar to the bathymetry, additional baseline will be required to be collected, as the transects that were completed in 2006 will likely have changed, due to the mobile substrate and bottom scour. Baseline ADP sampling will follow a similar schedule as bathymetric surveys, being every second year until the completion of construction. ADP surveys began in the fall of 2013. Following the completion of diversion head pond, the frequency of ADP surveys will follow the schedule presented in Table 7.2. Figure 7.6 shows an example of an ADP data output file, which represents the transect that was completed immediately downstream of Muskrat Falls in 2006 (closest transect line to Muskrat Falls in Figure 7.5).

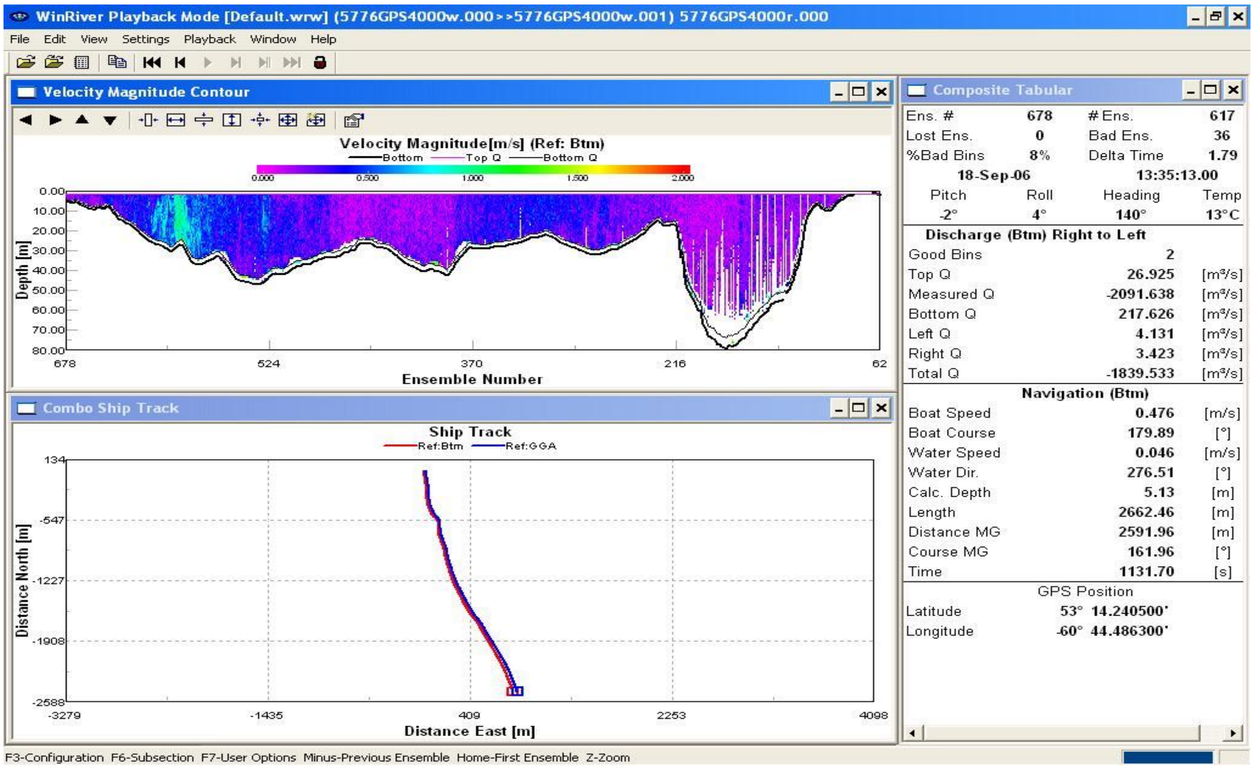

Figure 7.6. ADP data output, below Muskrat Falls, 2006

Remote Sensing and GIS

Shoreline erosion will be measured using remote sensing and GIS. There are two methods which will be employed to assess shoreline erosion; using established transect locations and measuring the water surface area.

Aerial photography will be used to measure the distances from known locations to the shoreline along established transects. Figure 7.7 shows an example of a transect located near the town of Happy Valley-Goose Bay, using photography from 1975 and 2007. Based on the photography, approximately 4m of shoreline have eroded within this transect. Additional transect locations will be developed based on areas of concern (i.e., close to the town of Happy Valley-Goose Bay) and areas with the greatest potential for shoreline erosion (i.e. near Muskrat Falls).

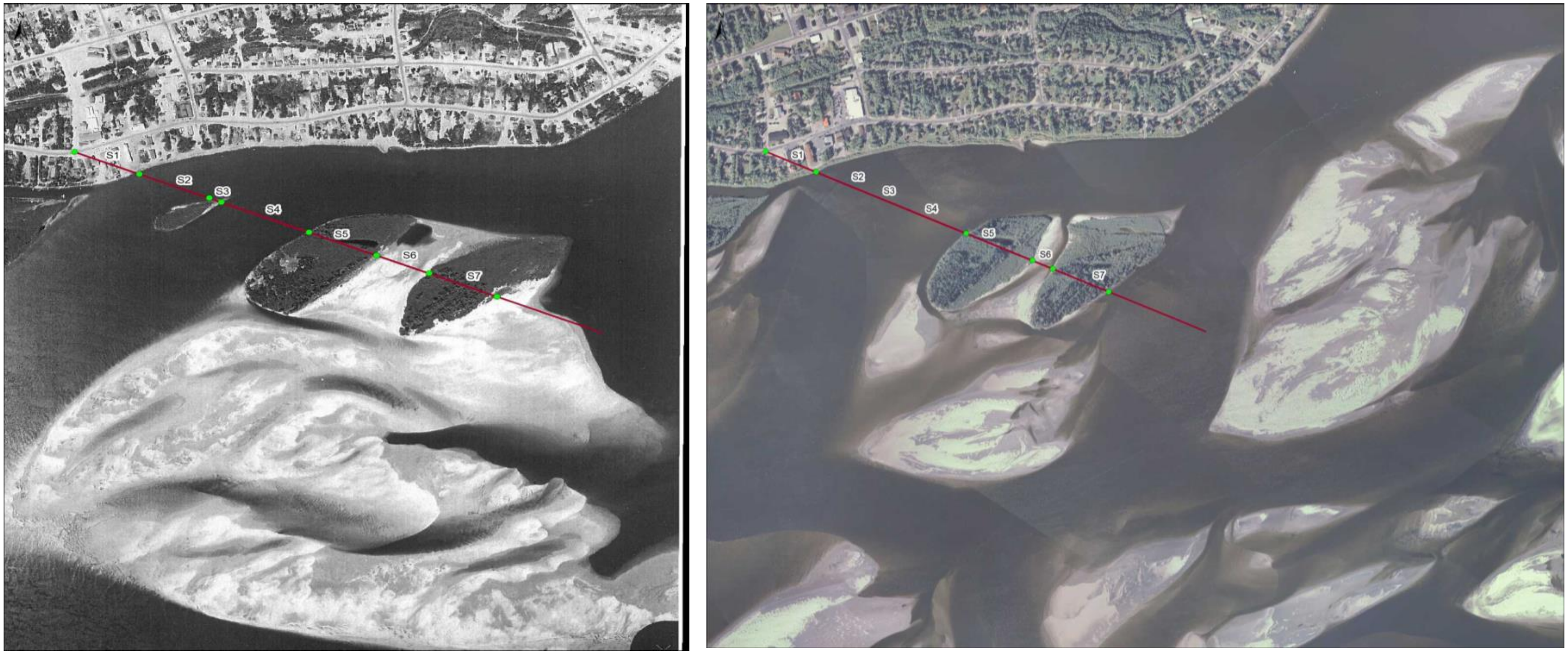

Figure 7.7. Satellite imagery near Goose Bay from 1975 (on left) and 2007 (on right)

The second method to assess the shoreline erosion rate is to measure the boundary of the shoreline and the area of the water's surface in the mainstem of the Churchill River downstream of Muskrat Falls and year to year variations in the surface area can indicate alterations in shoreline erosion patterns. Year to year boundaries will also be overlaid in GIS, which will show areas with greater shoreline erosion rates, as well as areas with shoreline building/deposition.

Upon obtaining satellite imagery from 2013, established transects and overall surface area downstream were analyzed in order to augment the dataset obtained from historic aerial photography. This will continue on an annual basis, and will be used to compare the post project shoreline erosion to pre-project rates. By comparing the baseline to post-project data, variations in the erosion dynamics (i.e. erosion and deposition areas) can be determined.

7.3.2.2 Ice Cover

Hatch (2007) modeled the effect of the project on the development of stable ice cover on the lower Churchill River. The model showed that a stable ice cover would still likely form, however the freeze-up is expected to be delayed by approximately two weeks near the Mud Lake crossing. Likewise, the break-up of the ice cover is expected to be delayed by one week, resulting in the ice cover lasting, on average, one week less than is currently observed. In terms of ice thickness, the area immediately below Muskrat Falls (i.e., the ice rose) is expected to have a large decrease in ice volume, while the areas near Goose Bay and Mud Lake are expected to be comparable to baseline thicknesses (Hatch 2007).

Ice cover will predominantly be monitored using remote video systems, similar to those that are operational near Mud Lake and Grizzle Rapids. Direct measures of ice thickness will be collected in order to augment the data collected using the remote video system. Please see the Ice Formation EEMP (MFA-PT-MD-0000-EV-PL-0003-01) for details regarding this program (Table 7.1).

7.3.3 Habitat Suitability: Physico-Chemical Parameters

Physico-chemical parameters in the lower Churchill River have been monitored for since 2009 through the use of real-time water quality monitoring and since 1998 through collection of water samples for laboratory analysis. Baseline data has been used to develop a database, which describes the physico-chemical environment and assesses the natural variability. As shown in the following sections, many of the parameters being assessed have been shown to be highly variable; however, through statistical analysis, post-project data will be compared to the baseline variability, which will be used to assess environmental effects.

Many of the parameters that have been selected for inclusion in the assessment of the physico-chemical environment are directly, or indirectly, monitored through the use of the real-time water quality (RTWQ) network established by Nalcor and the provincial Department of Environment and Conservation, Water Resources Management Division (WRMD). Figure 7.8 shows the location of RTWQ stations.

Grab samples are obtained throughout the study area and at all RTWQ station locations are considered the primary source of data. RTWQ data is utilized to augment the sampling protocol.

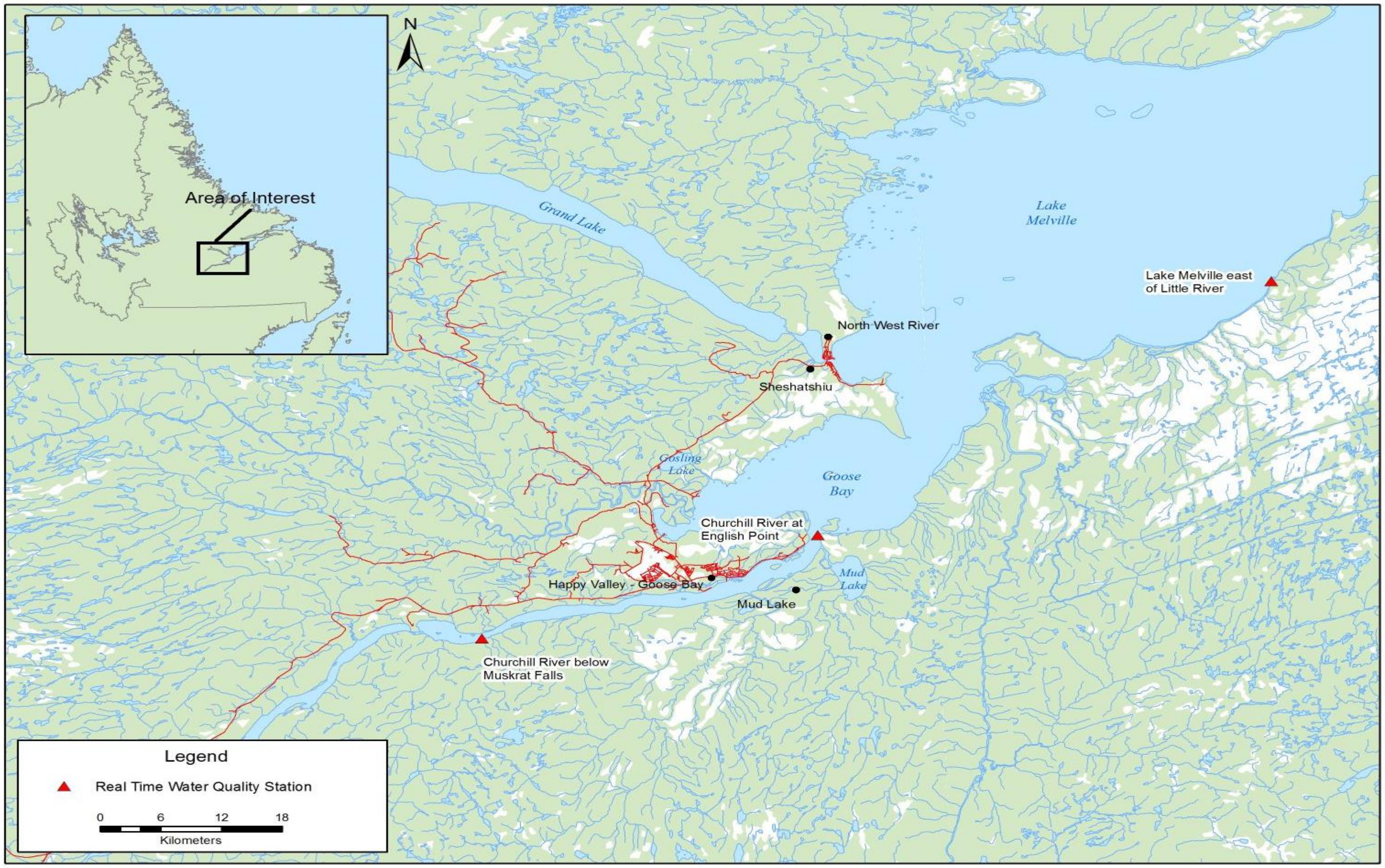

Figure 7.8. Locations of RTWQ Station below Muskrat Falls

7.3.3.1 Flow Regime

The lower Churchill drainage basin is characterized by a well-defined drainage pattern, steep tributary slopes and little natural storage such as lakes and bogs as compared to the upper basin. The mean annual flow (MAF) is estimated to be 1,840m^3/s at Muskrat Falls. The hydrology of the lower Churchill River drainage basin reflects the operation of the existing Churchill Falls facility and regional climate; runoff is seasonal, with inflows being highest in the spring (typically peaking in May or June) and lowest in late winter. Inflows in the remaining lower 23,088km^2 (i.e., the lower Churchill drainage basin) are not controlled, and follow this natural runoff pattern.

The Churchill River has been regulated by the Upper Churchill Falls Facility since 1974, and a Guaranteed Winter Availability Contract (GWAC) was signed in 1998, which imposed more flow regulation through the Upper Churchill Falls Facility. Figure 7.9 shows the existing flow regime downstream of Muskrat Falls since 1998. It should be noted that the hydrograph (Figure 7.9) only includes years since the signing of the GWAC. Despite the regulation imposed by the operation of the Churchill Falls facility, mean daily discharge is still highly variable, in particular during the freshet.

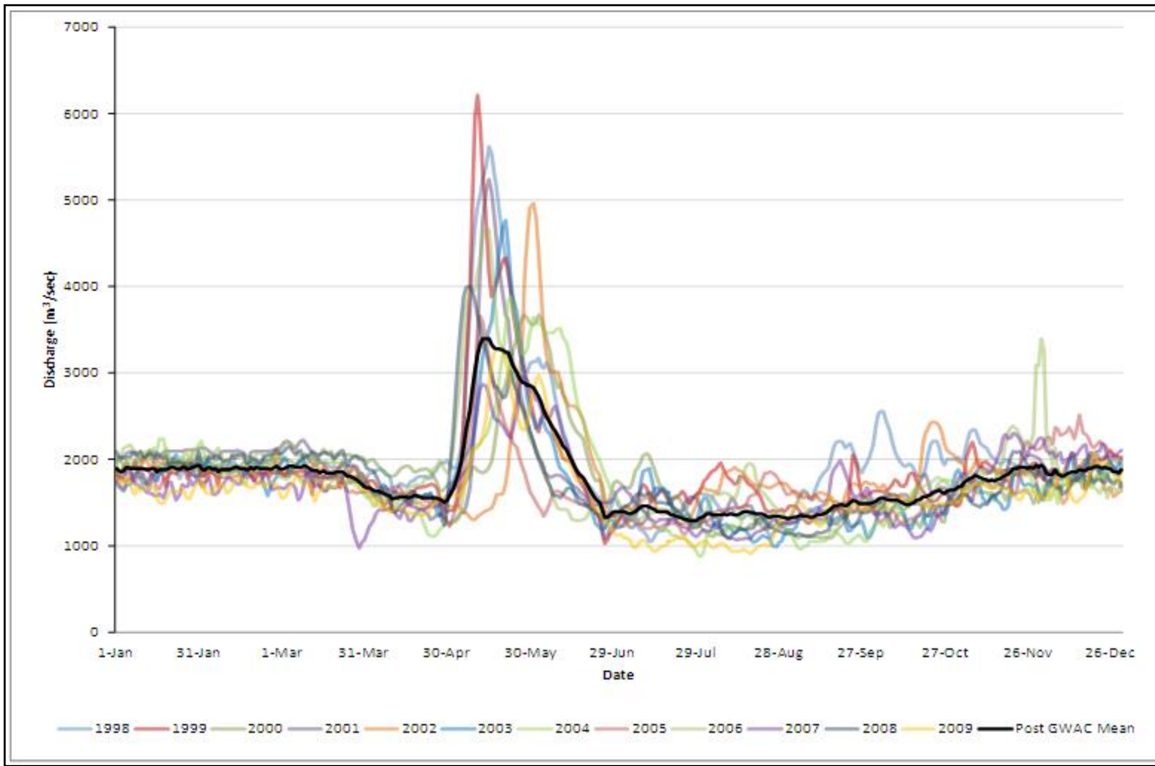

Figure 7.9. Mean daily discharge over Muskrat Falls (Environment Canada Station 03OE001)

The generation facility at Muskrat Falls is being designed as a 'water in-water out' facility, meaning that the reservoir will have limited storage capacity and water residence time. With this type of design, the discharge through the facility will be similar to the existing flow regime. Figure 7.10 shows the mean daily discharge with the upper and lower limits since the signing of the GWAC. This is the anticipated range of flows during operations and will be compared directly to measured flows through the Muskrat Falls powerhouse. Many of the physico-chemical parameters that will be discussed in the following sections are directly related to the flow regime remaining near the existing baseline.

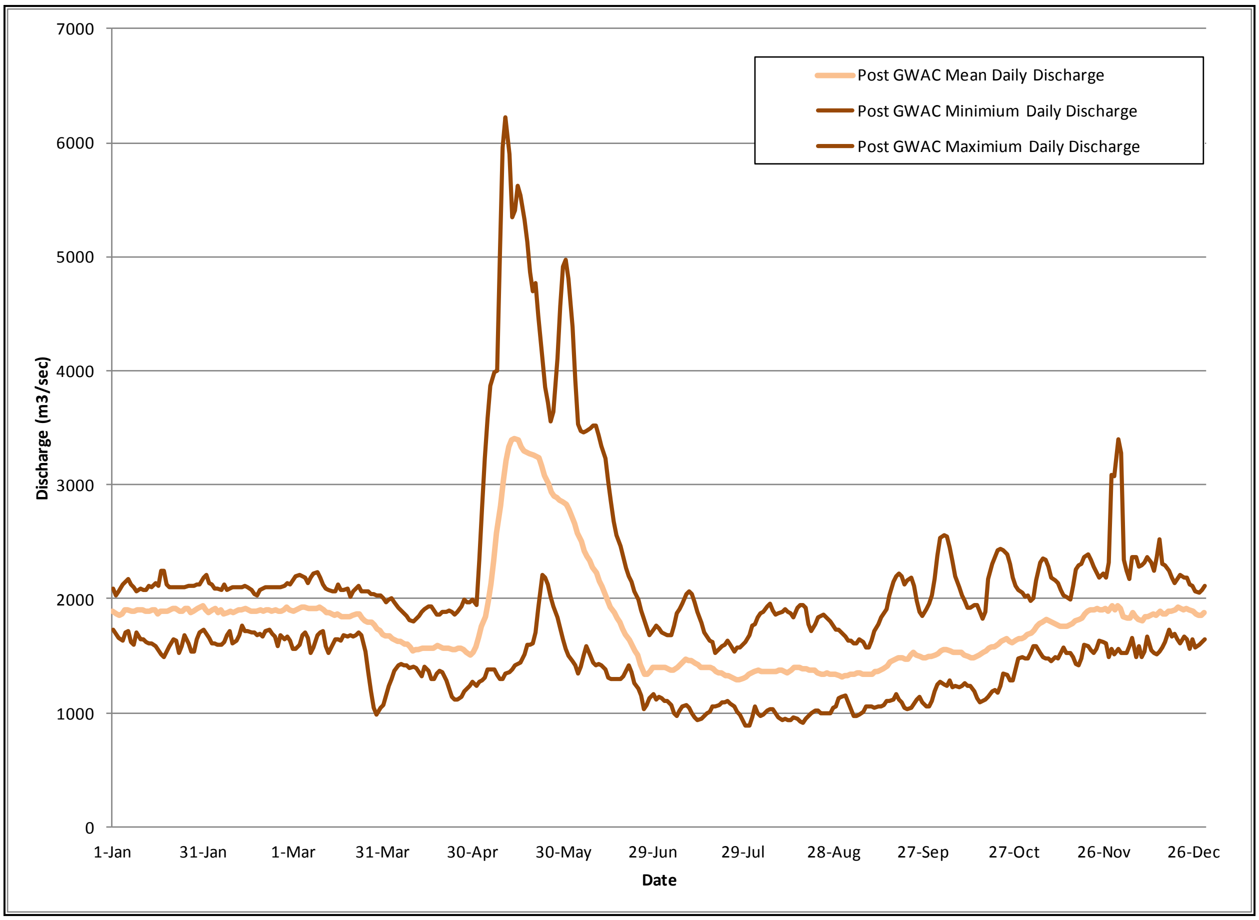

Figure 7.10. Post GWAC discharge variability, Muskrat Falls, 1998-2009 (Environment Canada Station 03OE001)

Discharge measurements have been collected by a gauging station located below Muskrat Falls (maintained by Environment Canada) since the 1960s, providing real-time discharge measures year-round. Following the completion of the Muskrat Falls facility, total discharge from the reservoir will be measured within the powerhouse. This data will be augmented by discharges measured by the gauging station currently in place below Muskrat Falls. Both methods will record discharge year round.

7.3.3.2 Total Suspended Solids

As mentioned in Section 7.3.2.1, the area below Muskrat Falls is susceptible to bed scour and erosion due to the predominantly sandy substrate. This results in high fluctuations in total suspended solids (TSS) that have been measured to range from <1.0 to 127 mg/L, with a mean concentration of 37.8mg/L below Muskrat Falls (Minaskuat 2007). Highest TSS concentrations are associated with the spring run-off (Minaskuat 2007). Table 7.5 shows a summary of TSS measurements collected below Muskrat Falls since 2006.

Table 7.5. Summary of TSS measurements in the mainstem below Muskrat Falls

Sample Year	Sample Duration		Mean Annual TSS Concentration				
	Start	Stop	TSS(mg/L)	Sample Size	TSS Range (mg/L)	Std. Error	95% CI
2006	April 23	Dec 20	33.8	12	<5.0-127.0	10.4	13.4-54.3
2007	Jan 16	Mar 13	58.0	3	<5.0-106.0	24.0	10.9-105.1
2010[1]	June 29	Sept 27	22.0	2	<2.0-41.0	19.0	0.0-59.2
2011[1]	June 23	Oct 12	11.0	5	<2.0-19.0	4.7	5.2-16.8
Total	2006	2011	27.0	22	<2.0-127.0	5.1	17.0-36.9

Sources: Minaskuat 2007, WRMD 2010-2011

1 Only samples above RDL were include in calculations of mean concentrations, standard error and 95% Confidence Intervals. It should be noted that the sampling in 2006-2007 used a lower RDL than sampling in 2010-2011.

Minaskuat (2008) modeled the effect of the Muskrat Falls facility on TSS concentrations throughout the lower Churchill River. The model showed that the reach below Muskrat Falls would likely experience the greatest increase as a result of the project. This will be attributed to the additional bed scour and erosion that is expected, in conjunction with reservoir stabilization. Modeled increases below Muskrat Falls were approximately 25mg/L above mean baseline, and peaked two years following construction. Stabilization of TSS, to near baseline values, is expected to occur 15-20 years post-impoundment and to fall below an increase of 5mg/L in eight years (Figure 7.11). The expected increases in TSS is not predicted to affect fish within the area, as the increases fall within the natural range that has been measured. Given that the post-project flow regime will be similar to existing flow regime, changes in TSS concentrations beyond the mouth of the Churchill River are not predicted (see IR response JRP#166 - CEAA 2011).

The completion of diversion head pond in 2016 will also likely increase TSS, however, the increases associated with diversion head pond will likely fall within the increases that are predicted for the Muskrat Falls Reservoir. The formation of diversion head pond triggers the beginning of post-project monitoring; therefore effects will be considered and compared to baseline.

Analysis for TSS must be completed in a laboratory setting by a CALA certified laboratory. Statistical power analysis showed that 16 samples are required to detect significant statistical variations in water quality. In order to achieve the required number of samples, water sampling will be completed at Grizzle Rapids, in Gull Lake, near the Blackrock Bridge and English Point. These samples will be augmented by data collected by WRMD during the ice free season through monthly calibrations. Samples will be collected just below the water surface, kept cool, and immediately shipped to the lab for analysis. Post-project samples will be collected during the same timeframe from the same locations, and will be compared to the baseline variability (shown in Table 7.5) using standard statistical testing.

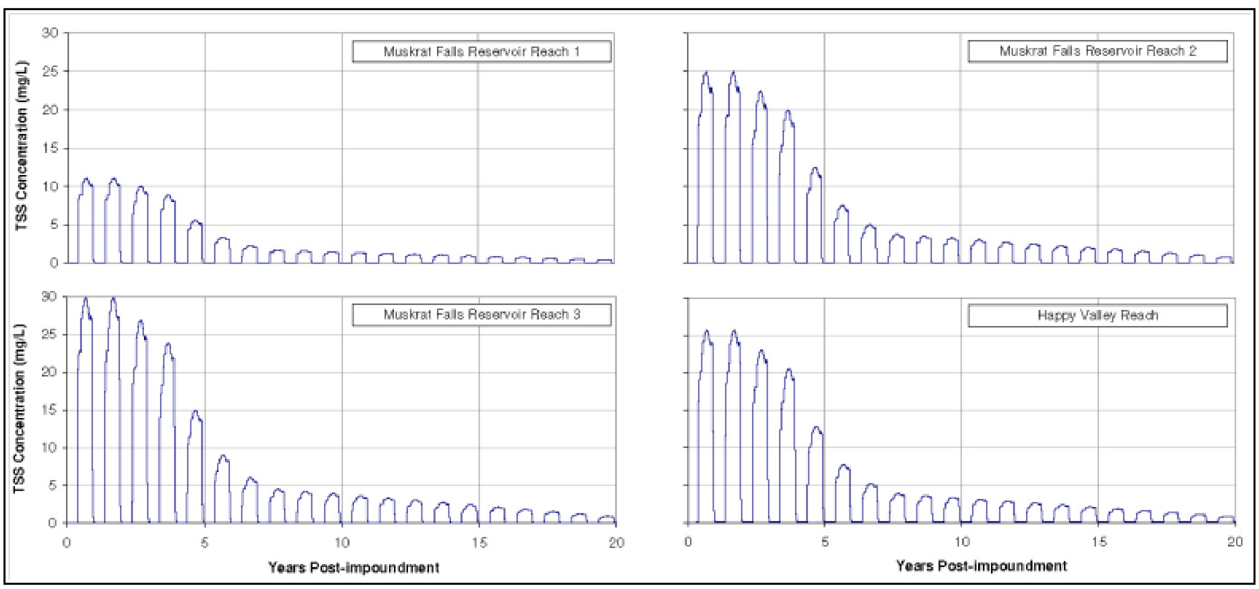

Figure 7.11. Modeled TSS within the Muskrat Reservoir and downstream of Muskrat Falls

Note: Figure presents concentrations above baseline (i.e. a value of 30mg/L indicates an increase of 30 mg/L above baseline)

7.3.3.3 Total Phosphorus

Newly created reservoirs experience an increase in productivity as a result of nutrient input from decomposing terrestrial vegetation. Minaskuat (2008) modeled the effect of the Muskrat Falls facility on the Total Phosphorus (TP) throughout the lower Churchill River, as phosphorus is the limiting nutrient in the majority of freshwater systems. The model results showed that the highest expected increases are in the Muskrat Reservoir and below Muskrat Falls. Concentrations between 0.054 and 0.115 mg/L were predicted using the model (Minaskuat 2008). TP concentrations are also expected to peak two years post-impoundment, however is expected to stabilize faster than TSS; in 10-15 years (Figure 7.12) (Minaskuat 2008). The modeled increases in TP are within the range that could lead to increased fish production, but are below the range that could lead to anoxia as a result of increased algal production.

Similar to TSS, analysis for TP must be completed in a laboratory setting, therefore the RTWQ Network will not be directly used to measure TP. Samples will be collected similar to those described for TSS from Grizzle Rapids, Gull Lake, the Blackrock Bridge and English Point and augmented with water samples collected by WRMD. Table 7.6 shows the variability in baseline TP concentrations to date. As with the other physico-chemical measures, post-project TP will be compared to the baseline variability using standard statistical testing.

TP in Goose Bay and Lake Melville is not expected to be affected by the Muskrat Falls facility. However, monthly samples collected from each RTWQ station during the ice free season will be analyzed for TP as a means of monitoring downstream extent and duration of TP increase.

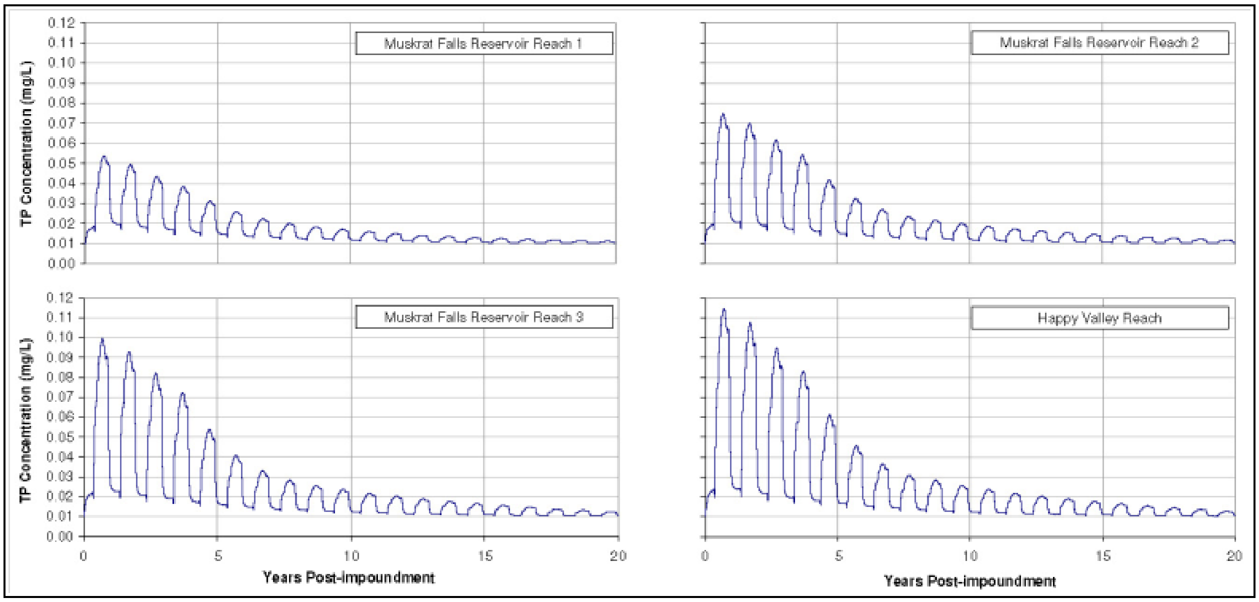

Figure 7.12. Modeled TP within the Muskrat Reservoir and downstream of Muskrat Falls

Note: Figure presents concentrations above baseline (i.e., a value of 0.10mg/L indicates an increase of 0.10 mg/L above baseline)

Table 7.6. Summary of TP measurements in the mainstem below Muskrat Falls

Sample Year	Sample Duration		Mean Annual TP Concentration				
	Start	Stop	TP (mg/L)	Sample Size	TP Range (mg/L)	Std. Error	95% CI
2006	April 23	Dec 20	0.036	12	0.011-0.085	0.006	0.024-0.048
2007	Jan 16	Mar 13	0.102	3	0.075-0.152	0.025	0.052-0.151
2009[1]	June 1	Sept 22	<0.1	5	-	-	-
2010[2]	May 25	Sept 27	0.05	4	<0.01-0.06	0.01	0.03-0.07
2011[2]	June 23	Oct 12	0.03	5	<0.01-0.05	0.01	0.01-0.05
Total[2]	2006	2011	0.04	21	<0.01-0.152	0.01	0.01-0.05

1 All samples collected in 2009 were below the RDL of 0.1mg/L

2 Only samples above RDL were include in calculations of mean concentrations, standard error and 95% Confidence Intervals. It should be noted that the sampling in 2006-2007 used a lower RDL than sampling in 2010-2011.

It should be noted that TSS and TP modeling was completed using bank stability results as a portion of its input data. The bank stability study used qualitative values derived from other locations within Canada with similar soil conditions, as they were not available from within the lower Churchill River area at the time. Subsequent geotechnical soil sampling in 2012 as part of the fish habitat compensation process (AMEC 2010) indicated that the values used in the bank stability study were comparable are therefore applicable. No subsequent changes were made to model results related to bank stability or water quality.

7.3.3.4 Salinity and Saltwater Intrusion

Goose Bay is the western extension of Lake Melville, a tidal lake/fjord along the Labrador coast. Freshwater is supplied by several large rivers, with the Churchill River supplying the majority, creating a layered saline system within Lake Melville. A thin surface layer of relatively fresh water (generally <10 PSU) flows seaward over a denser saline (approximately 25 PSU) bottom layer (Bobbitt and Akenhead 1982; JWEL 2001; AMEC and BAE-NewPlan 2001; Cardosa and deYoung 2002; Oceans 2010). Figure 7.13 shows salinity-depth profiles for sample stations within Goose Bay and Lake Melville, measured in September of 2011. Salinity profiles were completed in the same locations as primary productivity sampling in 2011, and the locations are shown in Figure 7.14. Figure 7.13 shows that a halocline (i.e., a sharp change in salinity within the water column) is present at approximately 15m water depth at Sites 5 and 6, within Goose Bay. It also shows that the further into Lake Melville (Site 3) and the Goose Bay Narrows (Site 4) mixing becomes more uniform, and a halocline is less distinct. This is similar to the salinity profile conducted by JWEL (2001), which found that salinities approached 25 PSU at 25m water depth.

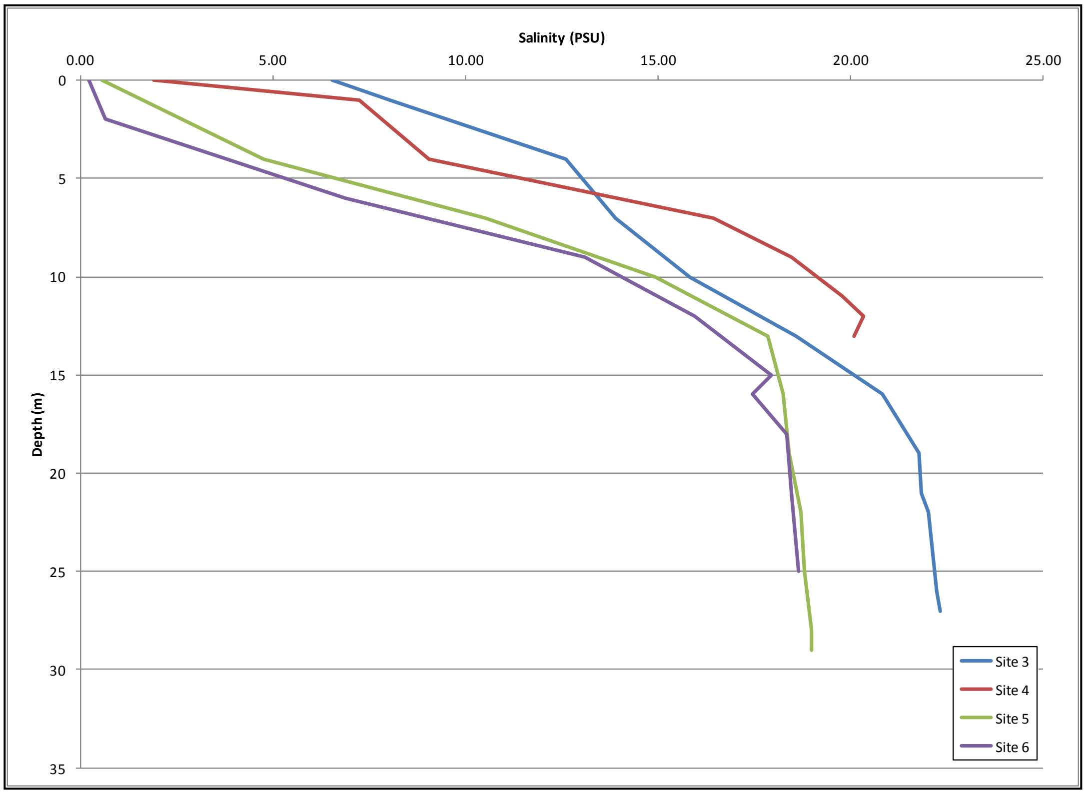

Figure 7.13. Salinity-depth profiles in Goose Bay and Lake Melville (September 2011)

Figure 7.14. Sample locations for salinity profiles, 2011

Post-project flow regime will be similar to the existing flow regime. With similar flows being maintained during operations of the facility, similar freshwater volume will be added to Goose Bay and Lake Melville. Therefore, salinity within the estuarine environment is unlikely to be affected by the facility.

Salinity within Goose Bay and Lake Melville will be monitored through the collection of in situ water sampling, using a HydroLab Surveyor Datasonde DS-5X, which has the capability of measuring salinity in real time. Various other parameters, including; dissolved oxygen, turbidity, pH, specific conductance, and water temperature, will all be collected along vertical profiles. Vertical profiles will be collected from established sampling areas, which will maintain consistency within the database. In situ water quality will be augmented with lab analysis for general chemistry, metals, nutrients and TSS in surface water. Post-project data will be compared to baseline variability using standard statistical testing.

The potential for saltwater intrusion into the lower Churchill River during reservoir filling has been assessed through modeling (Hatch 2008). Results indicate that intrusion is not predicted (Figure 7.15) to occur with a maintenance flow of 552m^3/s (30% MAF).

Saltwater intrusion will be monitored using real-time conductivity data. Based on a complex formula used for conversion of specific conductance to salinity (Perkin and Lewis 1980), a specific conductance value of 14,600uS/cm (at a conservatively low water temperature of 5^{o}C) will be used to indicate a salinity of 14 PSU. At this value, the water is becoming more saline. A water temperature of 5^{o}C was chosen as a conservative value to be used in the conversion equation. Temperature influences the conductivity in that cooler water temperatures create lower conductance. Model results from Hatch (2008) indicate that salinities near the mouth of the Churchill River could reach 14 PSU during reservoir filling. An exceedance of 14,600uS/cm would trigger the potential that saltwater is migrating upriver. If an exceedance occurs at the RTWQ station at the mouth of the lower Churchill River, manual measurements will be completed in order to determine the extent of the intrusion and modify the compensation flow. This monitoring will continue during reservoir filling.

Groundwater

The community of Mud Lake is located approximately 8 km east of the Town of Happy Valley Goose Bay (HVGB), NL, near the mouth of the Churchill River. A channel of the Mud Lake River divides the mainland from an island that is accessible by a foot bridge.

A groundwater sampling program will be implemented in 2014 within Mud Lake to collect baseline conditions. It includes the survey of existing groundwater wells (approximately six in total) at various locations within Mud Lake to gauge water table elevations and salinity/conductivity within each location. This data will be compared against samples taken as part of the monitoring program during and immediately following reservoir filling.

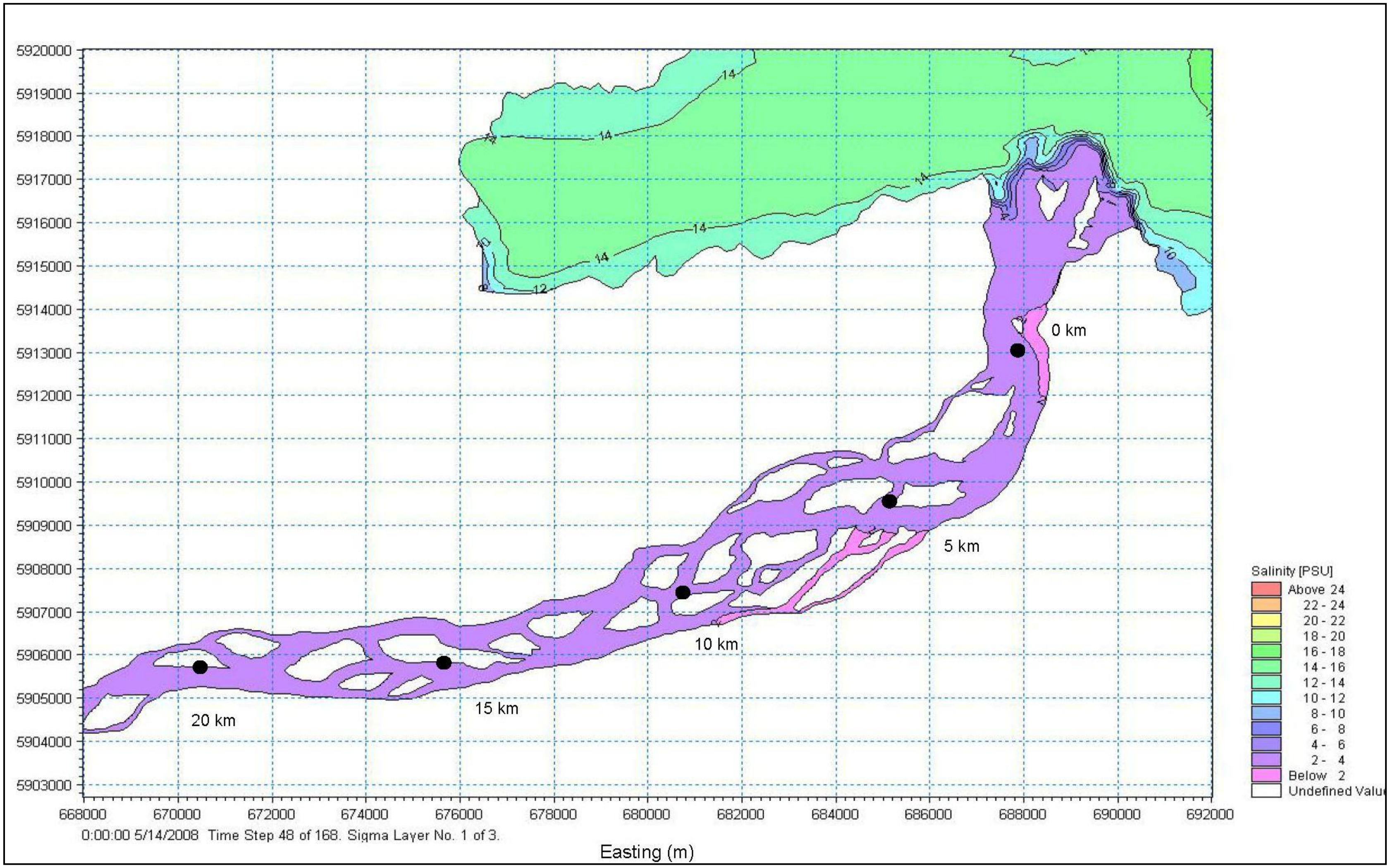

Figure 7.15. Modeled salinities with 30% MAF compensation flow during reservoir filling

7.3.3.5 Water Temperature

Figure 7.16 shows the variability in water temperature that has been measured below Muskrat Falls from 2009 to 2011. Following the development of the Muskrat Falls facility, the thermal regime downstream will be altered, however, it should fall within the natural variability.

The natural range of water temperatures will be unaffected as they are governed by ice formation and the prevailing natural air temperature. However, reservoirs act as thermal sinks, and store and release warmer water during winter months, and cooler water during summer months. Hatch (2007) modeled how the Muskrat Falls Reservoir would influence the water temperature in the reach below Muskrat Falls. It was shown that water temperatures would differ slightly, approximately 0.8-3.2^{o}C cooler in the summer (May to August) and 1.0-2.4^{o}C warmer in the months of September and October. Figure 7.17 shows the results of the model run by Hatch (2007). The formation of the diversion head pond will have a similar effect on water temperature; however, alterations in water temperatures will be within the ranges that have been predicted for the fully impounded Muskrat Falls Reservoir.

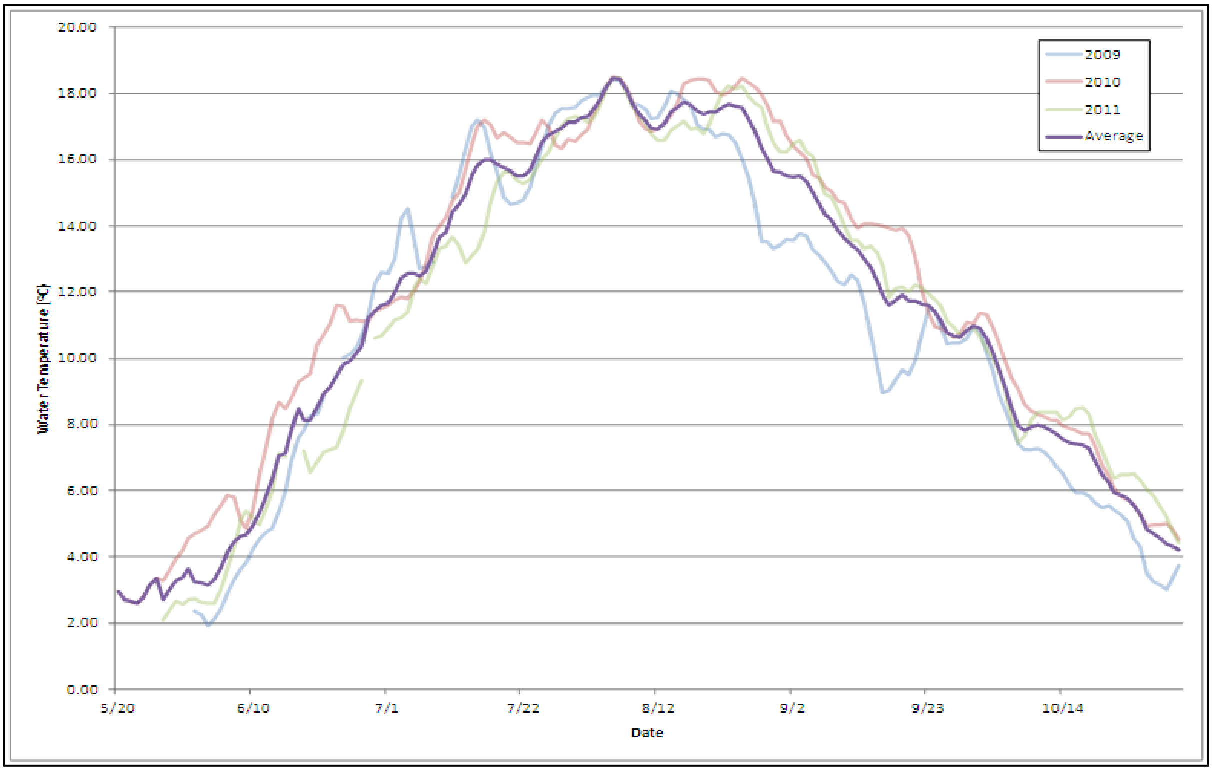

Figure 7.16. Water temperature measured below Muskrat Falls, 2009 to 2011 (data provided by WRMD)

Many biological processes (i.e., spawning or migrations) are temperature dependant. The predicted temperature increases are expected to be within the natural variability that fish within the lower Churchill River have been exposed to under existing conditions. It is unlikely that temperature variations will affect fish productivity or result in delays in life history activities. Water temperature will continue to be monitored post-project via the RTWQ Network.

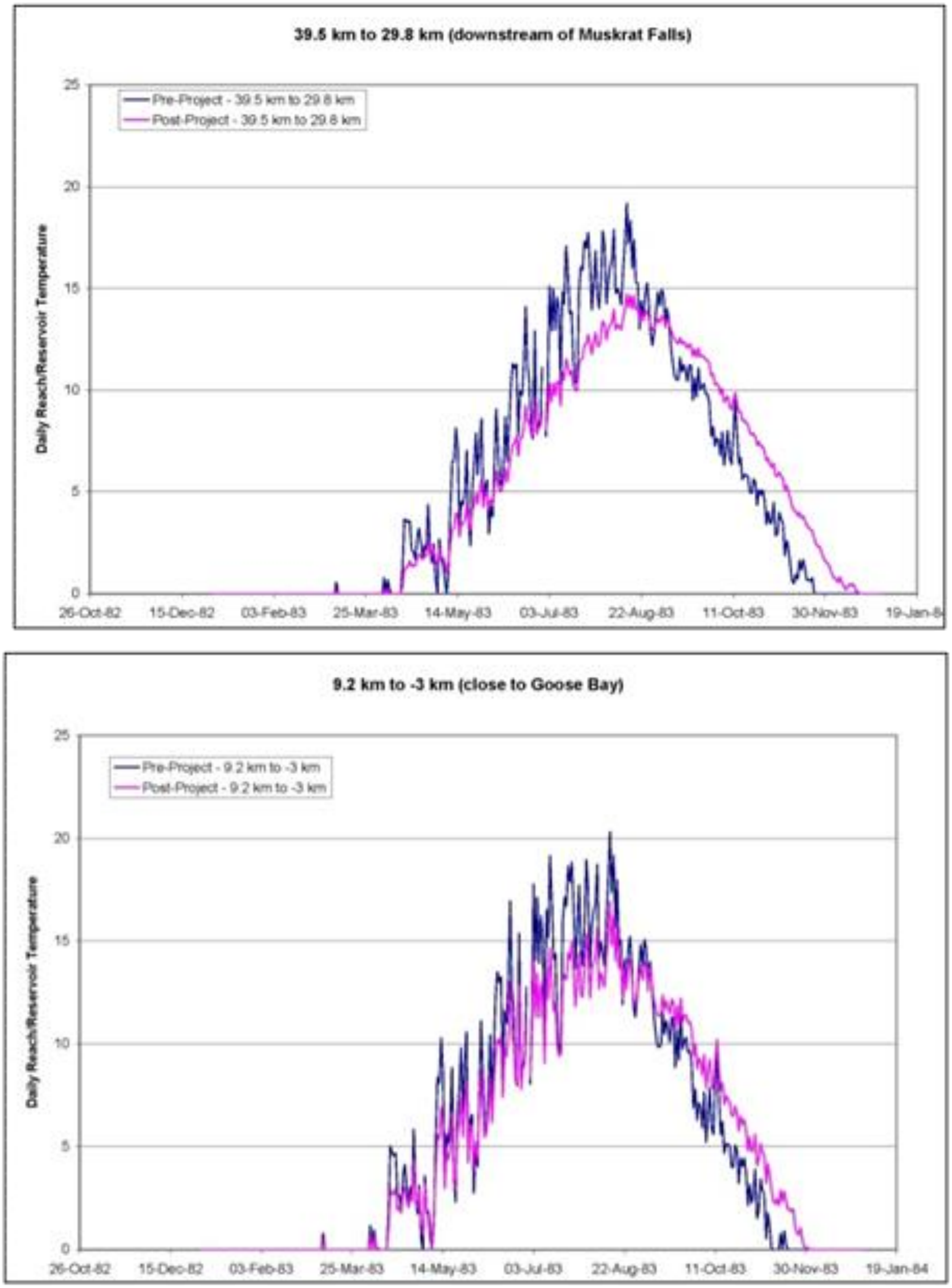

Figure 7.17. Modeled water temperatures below Muskrat Falls

7.3.3.6 Weather/Climate Data

Weather and climate data will be collected at the Muskrat Falls powerhouse as well as at various provincial stations throughout Labrador. This will be used to determine potential effects of climate change on parameters such as water temperature and ice coverage, as required.

7.3.4 Habitat Suitability: Biological Measures

Extensive studies of fish have been completed in the lower Churchill River, Goose Bay and Lake Melville dating back to the 1970s, with field studies for the current project beginning in 1998. Data collected has shown habitat utilization and variations in species distributions throughout the Churchill River system. Table 7.7 shows the species present in the mainstem below Muskrat Falls, Goose Bay and Lake Melville as determined through fisheries surveys (Anderson 1985, AGRA 1998, AMEC 2000, AMEC 2007, AMEC 2010, JWEL 2000, JWEL 2001).

Table 7.7. Summary of fish species present below Muskrat Falls

River Section	Species Presence
Lake Melville	American Plaice, Arctic Cod, Arctic Staghorn Sculpin, Atlantic Herring, Atlantic Poacher, Atlantic Salmon, Tomcod, Capelin, Greenland Cod, Rainbow Smelt, Snakeblenny, Thorny Skate, Threespine, Stickleback, Brook Trout, Winter Flounder, Rock Cod
Goose Bay Estuary	Longnose Sucker, American Plaice, Sand Lance, Arctic Cod, Atlantic Poacher, Atlantic Salmon, Tomcod, Longnose Dace, Lake Chub, Lake Whitefish, Dwarf Lake Whitefish, Round Whitefish, Greenland Cod, Rainbow Smelt, Rock Cod, Snakeblenny, Threespine Stickleback, Winter Flounder, Brook Trout
Section #1 (Goose Bay to Muskrat Falls)	Longnose Sucker, White Sucker, Brook Trout, Lake Whitefish, Dwarf Lake Whitefish, Northern Pike, Lake Chub, Lake Trout, Burbot, Ouananiche/Atlantic Salmon, Three Spine Stickleback, Sculpin, American eel

Note: Species presence compiled from AGRA 1998, AMEC 2000, JWEL 2001, AMEC 2010, and AMEC 2011
Atlantic salmon are present in Goose Bay and Lake Melville during migrations

Catch-per-unit-effort (CPUE) has been used extensively to characterize habitat use by resident species as well as to generate productivity estimates (i.e., biomass). A detailed description is provided in AMEC (2001).

Figure 7.18 shows the fyke net CPUE for each river section. As a means of comparing fish productivity, the CPUE from the Muskrat Reservoir area (Section 2) and above Muskrat Reservoir (Sections 3-5) have been included. As shown, below Muskrat Falls has the lowest CPUE for each species.

The operation of the Muskrat Falls facility is unlikely to affect fish populations located downstream. Variations in fish population dynamics would primarily be driven by variations in physico-chemical parameters discussed above (Section 7.3.3). The models used have shown that the parameters analyzed will likely remain within the natural variation presently within the lower Churchill River.

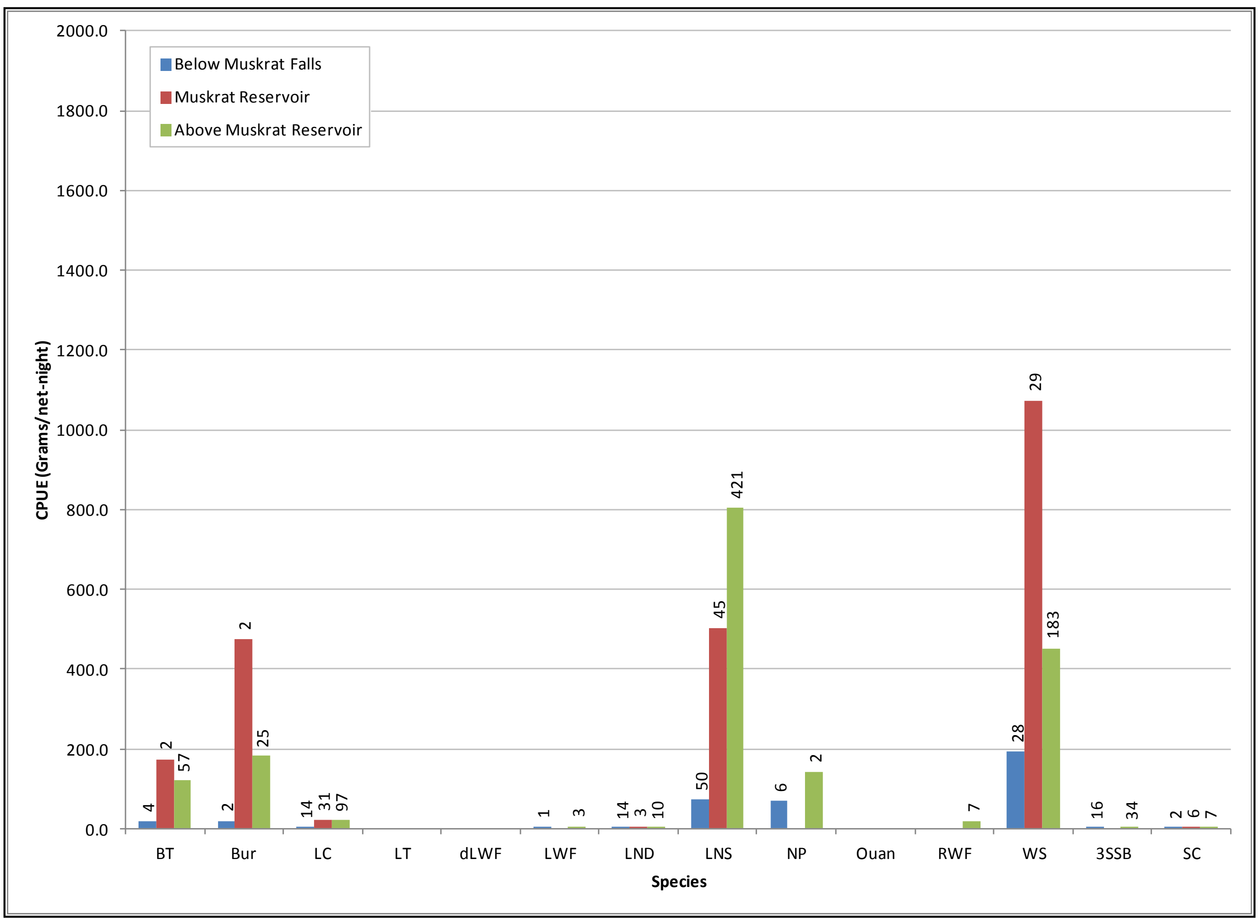

Figure 7.18. Mainstem fyke net CPUE from 1998 to 2010 (numbers above bars indicate the total catch)

Fish monitoring will be conducted within the mainstem below Muskrat Falls, major tributaries and into Goose Bay and Lake Melville. Sampling will rely upon non-lethal sampling techniques, such as fyke nets. Given that gillnetting has been the primary sampling method since 1998, considerations would be given to utilize it during the post-project monitoring program depending upon catch rates with fyke nets. It should also be noted that gillnetting will likely be utilized in order to obtain the necessary numbers of mercury samples (see Section 7.5). Statistical power analysis indicates that fyke net effort required to detect statistically significant declines in CPUE biomass and abundance are 50 and 60 net-nights, respectively, for each habitat type sampled. Therefore, 60 net-nights of effort within each habitat type will be the targeted sample size.

In order to determine locations that would be sampled throughout the EEM, all net locations from 1999 to 2011 were plotted using GIS for Section 1 and Goose Bay Estuary and Lake Melville. Once plotted, ‘zones’ of sampling were identified (Figure 7.19 and 7.20).

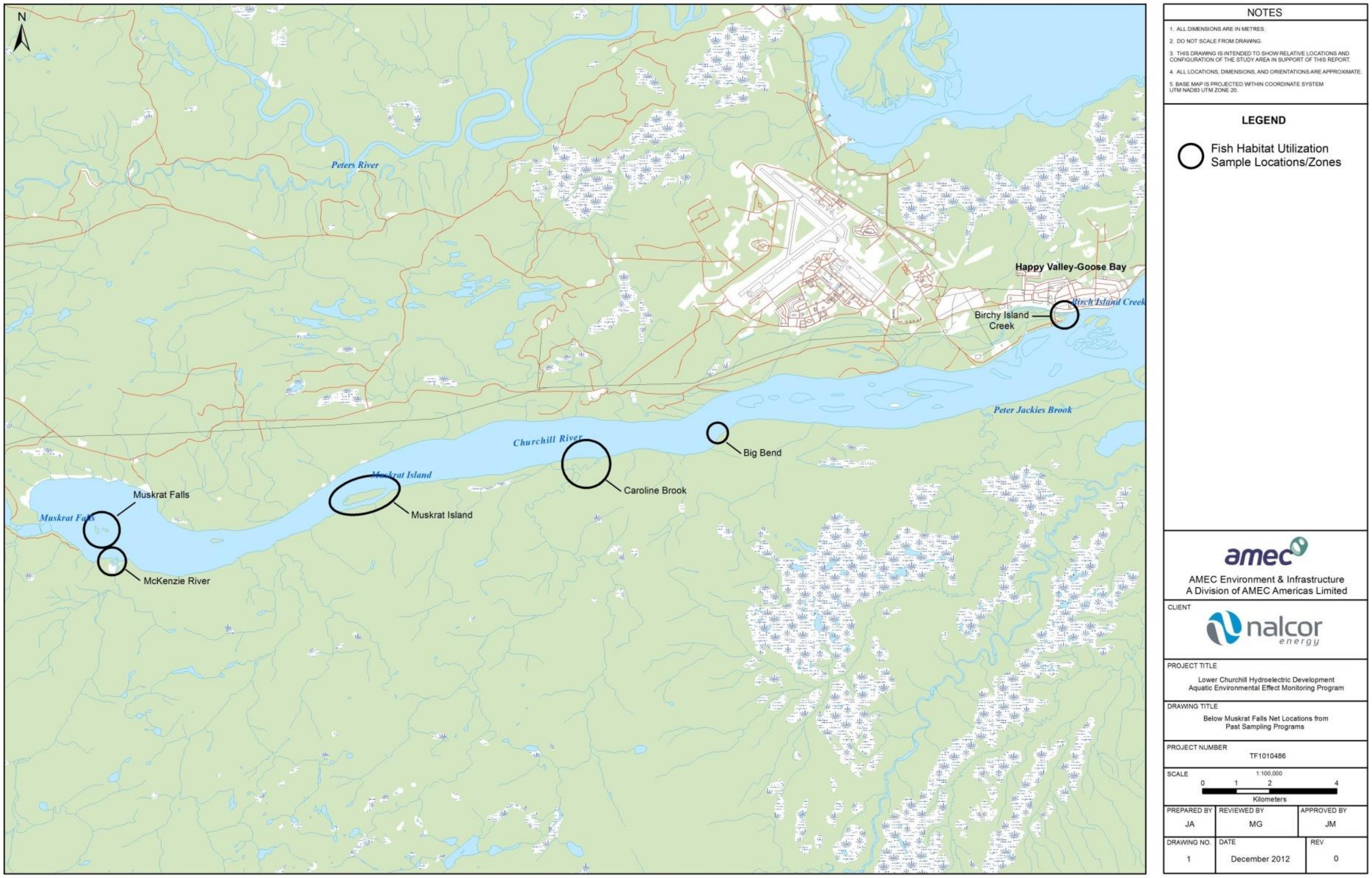

Figure 7.19: Sampling zones below Muskrat Falls

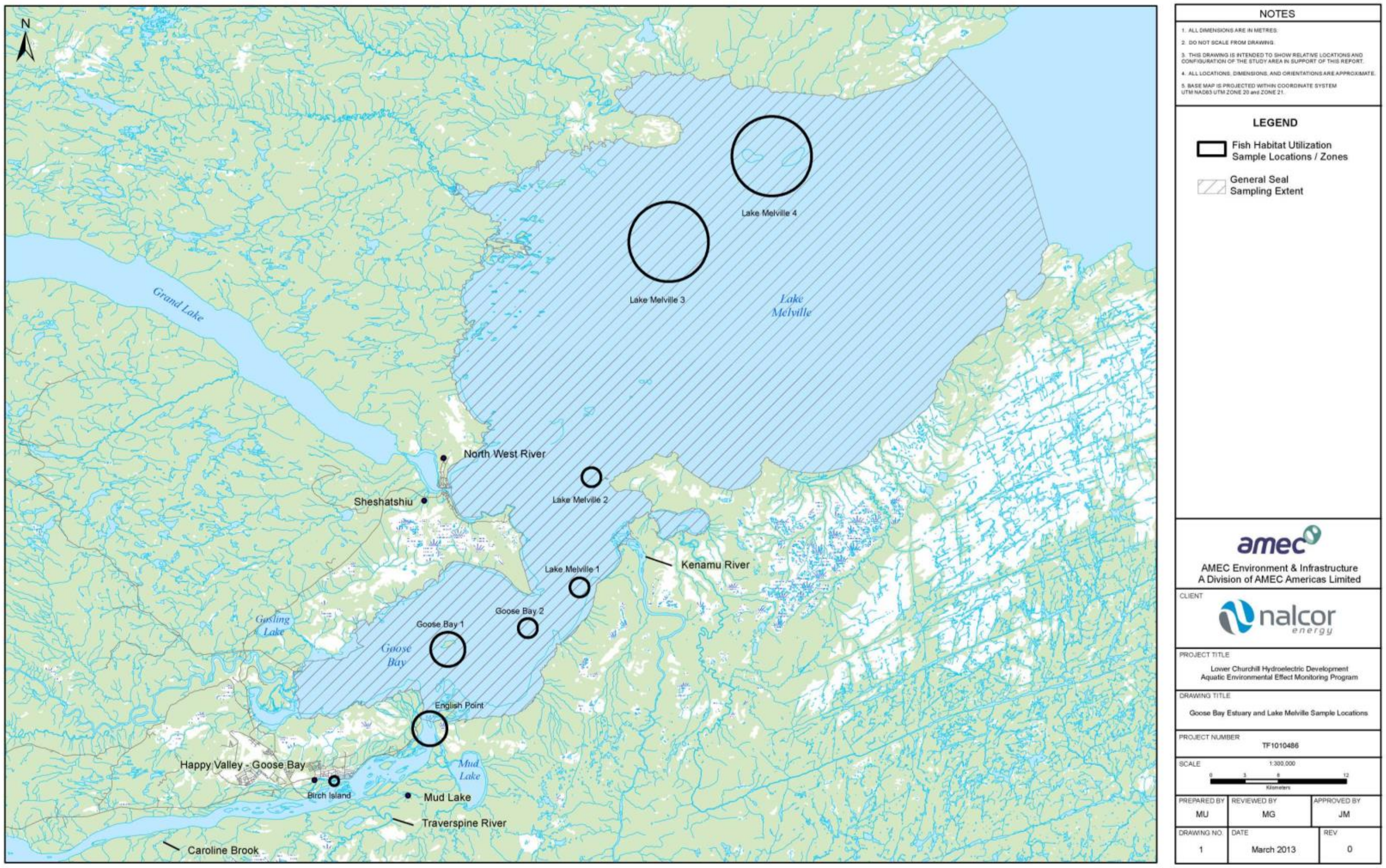

Figure 7.20: Sampling zones in Goose Bay Estuary and Lake Melville

Table 7.8 presents a summary of the data that will be collected using the various live capture methods. The selection of a gear type to be employed will be dependent upon the focus of the particular sampling regime and location of sampling. All fish sampled through fyke netting, gillnetting, electrofishing and angling have been classified by life cycle stage using a length-at-maturity key developed by AMEC (2007; Table 7.9) using fish captured within the lower Churchill River.

Table 7.8. Summary of fish habitat utilization parameters collected by gear type

Parameter	**Fyke Net**	**Electrofisher**	**Angling**	**Snorkel**	**Gill Net**[1]
Species ID	●	●	●	●	●
Length	●	●	●	●[2]	●
Weight	●	●	●		●
Age	●	●	●		●[3]
Population Estimate		●			
Relative Abundance (CPUE)	●	●	●	●	●
Habitat Utilization	●	●	●	●	●
Applicable Habitat Types	Mainstem Tributaries Goose Bay and Lake Melville	Tributaries	Mainstem Tributaries Goose Bay and Lake Melville	Mainstem Tributaries	Mainstem Goose Bay and Lake Melville

1 Gill nets are not a preferred sampling method for the EEM

2 Length estimates will be obtained from snorkeling

3 Bony Age structures as well as scales will be collected from lethally sampled fish

7.3.4.1 Mainstem Habitat Utilization Sampling

As shown in Table 7.8, the mainstem of the lower Churchill River will be sampled using a variety of methods including fyke nets, angling and snorkeling. Provided below are brief descriptions of each. In general, a comparison between baseline data and post-project surveys will be completed to confirm predictions.

Fyke Nets

Fyke nets are a passive, generally non-destructive means of sampling shallow water. Typically, fyke nets are set along the shoreline and allowed to fish overnight. This allows sampling of the dawn and dusk periods when fish are generally more active. Capture data will be used to give species composition, age structure and relative fish densities.

Fyke nets have been deployed in the mainstem below Muskrat Falls as part of baseline characterization. Table 7.10 shows the variability in the fyke net CPUE (grams/net-night), which will be compared to post project catch data. Additional baseline sampling is ongoing. Permanent fyke net locations will be established, and the same locations will be sampled each year. This will ensure consistency in the dataset.

Table 7.9. Size ranges used to determine various life stages (taken from AMEC 2007)

Species	Life stage (mm)		
	YOY Size Range	**Juvenile Size Range**	**Adult Size Range**
Brook Trout	<80	80-200	>200
Lake Trout[1]	<170	170-380	>380
Ouananiche	<80	80-350	>350
Lake Whitefish	<110	110-295	>295
Dwarf Lake Whitefish	<100	100-185	>185
Round Whitefish	<80	80-200	>200
Longnose Dace[1]	<45	45-114	>114
Lake Chub		<127.5	>127.5
Longnose Sucker [2]	<60	60-252	>252
White Sucker [2,3]	<95	95-335	>335
Northern Pike [2,3]	<100	100-573	>573
Burbot [2]	<70	70-350	>350
Threespine Stickleback[2]		<25	>25
Sculpin sp. [2]		<70	>70
Pearl Dace [2]		<75	>75

Reproduced from AMEC 2007

1 Length of YOY referenced from literature

2 Age of maturity referenced from literature, length at that age taken from data collected within the lower Churchill River

3 Size ranges vary depending upon sex of each individual; the conservative value (i.e., greater size range) has been presented, as sex determinations have not been completed during every sampling program.

Fyke nets will be set within the mainstem of the lower Churchill River (Mainstem Slow Habitat) as well as in the major tributaries (i.e., Caroline Brook and McKenzie River, Birchy Creek), which has been sampled during past programs with fyke nets. Each net will be deployed for a duration of at least 16-hours, which encompassed the dusk to dawn periods, when fish movement is generally more prevalent. The basic schedule for each survey location will be as follows:

- Set each fyke net at approximately noon at the selected site and allowed to fish until the next morning (at least 16 hours so that the dusk and dawn time periods will be fished);
- GPS location and habitat data of each fyke net station to be recorded;
- retained fish to be sampled onshore by the crew;
- reset each fyke net; location changes to be based upon daily catch rates and required survey coverage;
- data QA/QC and data transfer/logging completed each evening or as soon as practical.

Table 7.10. Fyke net CPUE variability below Muskrat Falls

Species	Mean CPUE (grams/net-night)	Standard Error	95% Confidence Interval
Brook trout	18.66	3.84	11.14-26.18
Burbot	13.37	13.37	0.00-39.57
Lake chub	4.45	1.42	1.67-7.23
Lake Whitefish	4.72	4.72	0.00-13.96
Longnose dace	0.77	0.77	0.00-2.28
Longnose sucker	227.67	18.96	190.51-264.83
Northern pike	8.30	6.69	0.00-21.40
Sculpin	0.09	0.09	0.00-0.26
Threespine stickleback	1.75	0.74	0.30-3.20
White sucker	202.33	36.51	130.78-273.89

The above procedure will also apply to any gillnets that are set during the program. Figure 7.21 presents a schematic for a typical deployment of both single bag and double bag fyke nets.

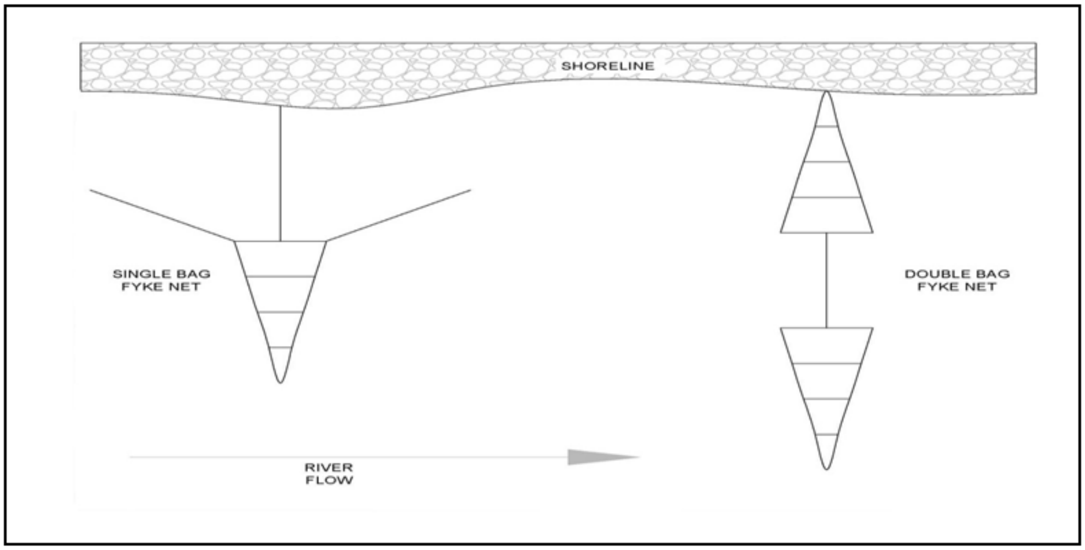

Figure 7.21. Schematic of typical fyke net sets (single and double bags)

Snorkel Surveys

Calibrated snorkel surveys will be used to augment the fyke net CPUE as some life cycle stages are less mobile and not captured using fyke nets. There are several locations below Muskrat Falls that are suitable for snorkel surveys including Muskrat Island, the Blackrock Bridge and the mouths of both Caroline Brook and McKenzie River. In order to maintain consistency, permanent snorkel locations will be established, and repeated on an annual basis. Currently, the locations of the permanent snorkel locations have been established near the Black Rock Bridge and within McKenzie River. Statistical power analysis indicates that a sample effort of 14 snorkel transects, approximately 25m in length, is sufficient to detect statistically significant declines in fish abundance.

Snorkeling will primarily consist of night-snorkeling, which has been shown to be more effective for observing young fish (AMEC 2004; Hagen et al. 2004). It has been shown that over sufficiently short time periods, and if juveniles restrict their movements over a defined area, physically open sites will be treated as closed without introducing significant bias (Pollock 1982; Bohlin *et al.* 1989; Peterson *et al*. 2004).

A team of at least three will be used to complete each station, consisting of one individual snorkeling, one individual measuring habitat parameters and one individual spotting and recording. Upon the observation of a fish, the snorkeler will place a marker (typically a glow stick attached to a small rock or metal bolt) in the location and relay the species, length estimate, substrate type and position within the water column to the recorder. Measurements of water depth and velocity will then be recorded once the snorkeler moves beyond the glow stick location.

Prior to the commencement of snorkel surveys, an assessment of the diver's visual range will be completed. This will allow for a known area to be incorporated into abundance estimates. In order to account for fish that may have been missed by the diver a calibration factor of 3.8 will be applied to observed fish to produce abundance estimates (AMEC 2008). This calibration factor was developed by AMEC (2008) during similar snorkel surveys conducted in Granite Canal.

A database will be constructed of abundance estimates that will allow comparisons of baseline and post-project conditions. Given that the snorkeling will assume a closed population, comparisons can also be made based on spatial proximity to the facility. The collection of baseline snorkel surveys below Muskrat Falls began in the summer of 2012, and surveys will continue on an annual basis until the completion of the facility. Post-project sampling will follow the schedule outlined in Table 7.2.

Angling

Angling will also be used to augment fyke net CPUE as it can sample a wide range of habitat types. All angling will be conducted with barbless hooks in order to minimize stresses to the fish. Handling will also be held to a minimum, however, species, location of capture, length, weight, and scales will be collected.

Benthic Macroinvertebrates

While not included in the federal EEM, benthic macroinvertebrate monitoring has been ongoing below Muskrat Falls and within the Muskrat Falls Reservoir area. Within the mainstem of the lower Churchill River, benthic macroinvertebrates have been collected since 2011 using rock bags; a bait bag filled with artificial substrate. With a consistent volume and size of substrate, variations in the productivity within each sample site can be accurately assessed. Rock bags have been deployed in slow habitat below Muskrat Falls (near the Blackrock Bridge) and in slow and fast habitat above Muskrat Falls (within Gull Lake and near the Gull Lake inflow respectively).

Upon collection, sample will be field preserved, using ethanol or formalin, and shipped to St. John's for identification, numeration and weighing. All invertebrate sample processing will be completed by certified, experienced individuals.

7.3.4.2 *Tributary Habitat Utilization*

Tributaries can also be sampled using the methods outlined for the mainstem, with additional sampling being conducted through electrofishing. Additional baseline on tributary utilization and population estimates will be collected on an annual basis prior to impoundment, and will focus on the McKenzie River and Caroline Brook.

Electrofishing

Tributary habitat utilization will be sampled through the completion of electrofishing stations. Electrofishing stations will be a combination of full quantitative stations (for population estimates, species presence/absence, and habitat utilization and index stations (species presence/absence and habitat utilization. In past studies, the software package MicroFish ver. 3.0 (Van Deventer and Platts 1989) has been used to calculate population estimates; however, estimates cannot be generated accurately with low catches. As a result, abundance and biomass estimates will also be calculated using the Zippin removal method (FSA package for R (http://www.rforge.net/FSA/InstallFSA.R); R Development Core Team 2010). The approach will be applied to abundance and biomass of all fish species combined to help overcome issues associated with low catch rates of many species. From these combined values, estimates for each species will be calculated based on their proportional representation of the total catch. Preliminary testing and simulations of this approach provide improved estimates in fish communities with low abundance, even when species and size-specific catch biases were incorporated into the model. In order to keep the data consistent, all population estimates have been, and will continue to be standardized to one habitat unit (100m^2). Handling will be held to a minimum, however, species, location of capture, length, weight, and scales will be collected.

Within the area downstream of Muskrat Falls, only the McKenzie River has undergone complete quantitative electrofishing, producing population estimates. These were completed in both 1998 and 2011. Table 7.11 shows the variability in the population estimates produced to date. Due to low catch rates of brook trout, burbot and round whitefish, population estimates cannot be calculated, although baseline sampling is ongoing. Statistical power analysis indicates that a sample effort of four electrofishing stations is sufficient to detect statistically significant declines in fish biomass and abundance.

Table 7.11. Mean population estimates from the McKenzie River (1998 and 2011).

Species	Total Catch	Mean Population Estimate[1]	Standard Error	95% Confidence Interval
Brook Trout	4	-	-	-
Burbot	1	-	-	-
Longnose Dace	72	4.3	7.5	0.0-12.8
Longnose Sucker	29	27.7	26.6	0.0-57.7
Round Whitefish	1	-	-	-
Sculpin	148	36.7	27.6	5.4-67.9

[1] Population estimates have been standardized to one habitat unit (100m^2)

Fyke Nets

In deeper tributary sections, or at tributary mouths, fyke net capture data will be used to augment habitat utilization and species presence/absence. Capture data will be used to give a species composition, age structure and relative fish densities. During 2011, fyke nets were used to sample Caroline Brook and the mouth of the McKenzie River. Figure 7.22 shows the CPUE to date for each location. Similar to the mainstem, a sample size of 60 net-nights will be targeted.

Angling and Snorkeling

Similar to the mainstem, angling and snorkeling will also be conducted within the tributaries. As discussed, snorkeling will primarily occur near the mouths of tributaries, while angling can occur in any accessible reach. It should be noted that angling was conducted in Caroline Brook during 2011, however, it yielded no fish. Baseline data collection will continue until impoundment. Similar sample sizes indicated above are targeted within the tributaries; that is, 14 snorkel transects. Angling will be completed to augment sample data sets relative to species presence, length, weight, and aging.

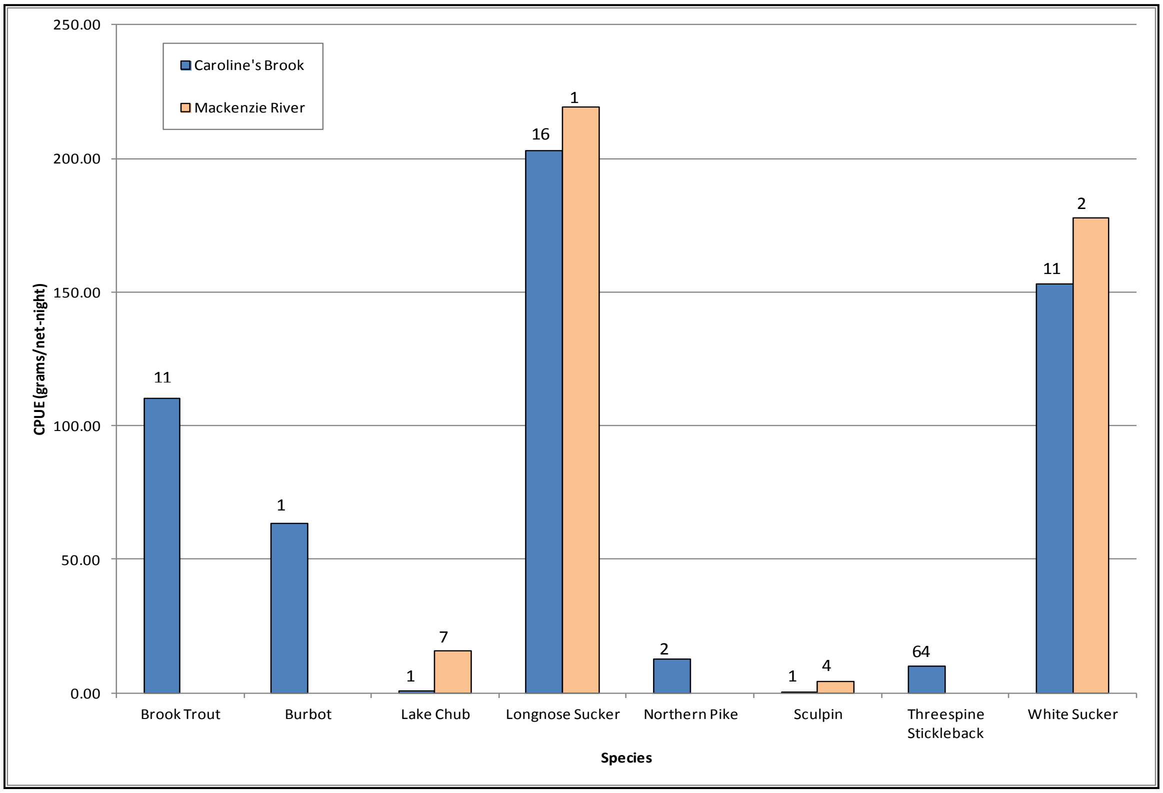

Figure 7.22. Tributary fyke net CPUE, September 2011

Caroline Impoundment Benthic Macroinvertebrates

Monitoring benthic macroinvertebrates in tributaries has also been completed since 2011 using rock bags, as discussed in Section 7.3.4.1. Rock bags have been placed in McKenzie River, Lower Brook, Edwards Brook and Pinus River for durations of approximately three months and one year. Placing rock bags within these tributaries will continue throughout the EEM program.

Tributary rock bag data is currently also being augmented with kick netting. Kick netting involves the agitation of substrate in an upstream zig zag pattern for three minutes (EC 2012). The kick net is placed downstream and benthic macroinvertebrates that become dislodged travel downstream and are captured within the net. Similar to the rock bags, samples will be field preserved using ethanol or formalin. Sample processing (i.e., identification, numeration and weighing) will be conducted by certified, experienced individuals.

7.3.4.3 Goose Bay and Lake Melville Habitat Utilization

Sampling in Goose Bay and Lake Melville has relied upon gillnets, otter trawls (AMEC 2012, JWEL 2000) and beach seining (JWEL 2000). As mentioned, the EEM will primarily focus on non-destructive means of sampling. Therefore, within Lake Melville and Goose Bay, fyke nets, beach seines and otter trawls will continue to be the primary means of sampling. Gill nets and angling may be employed if sample locations are deemed unsuitable for live capture methods. In the instance of using either of these sampling methods, precautions would be made to minimize lethal sampling (i.e., tended gill nets, barbless hooks). Further baseline sampling will utilize live capture methods in order to develop sampling consistency within the dataset. This will allow for meaningful comparisons of catch rates between baseline and post-project datasets.

Collection of further baseline will occur on an annual basis until the completion of Head Pond in 2016. Following this, the sampling of habitat utilization within Goose Bay and Lake Melville will follow the schedules presented in Tables 7.1 and 7.2.

Seal Habitat Utilization

Ice dynamics are considered the primary pathway that could affect seal habitat utilization. As mentioned previously, ice dynamics area not expected to be altered as a result of the project, with the exception of a lag in freeze up and break up within the mainstem. Ice thicknesses and cover are expected to be similar to that which is currently observed below Muskrat Falls and in Goose Bay and Lake Melville. However, seal habitat utilization, as well as mercury monitoring (discussed in Section 7.5.5) has been included in the EEM. Provided below are the methodologies that will be employed to assess seal habitat utilization.

A seal abundance and distribution survey was completed in 2007 (Sikumiut 2007) within the Goose Bay and Lake Melville regions. Methodologies utilized during the initial 2007 baseline study will be followed in order to maintain consistency within the dataset and comparability. Transect locations will be predetermined prior to the commencement of the field program. Transect widths will be 500m, and transect centers will be 2km apart. All associated GIS files will be loaded onto a handheld GPS to ensure the predetermined locations area followed as closely as possible.

For logistical reasons, as well as ease of counting a helicopter will be utilized (Sikumiut 2007) as opposed to a fixed-winged aircraft (Lunn et al. 1997; Kingsley et al. 1985).

During the survey, the aircraft will hold an altitude of approximately 150m and maintain a speed of approximately 180km/h (Sikumiut 2007, Lunn et al. 1997; Kingsley et al. 1985). A four person crew (including the pilot) will be utilized, with two acting as rear observers and one as forward observer and data recorder. In order to maintain a consistent distance to be surveyed, a calibration exercise will be conducted at the beginning of the first day of the survey. The helicopter will hover at approximately 150m height, and a piece of tape will be placed on the window to indicate 250m linear distance, using markings on the runway near the base as a guide (Sikumiut 2007, Lunn et al. 1997). Given that the calibration exercise will be observer specific, the same positions will be maintain for each crew member during the duration of the program.

Prior to the surveys in Goose Bay Estuary and Lake Melville, a reconnaissance flight of the Churchill River will be flown to observe the presence of harbour seals. Upon commencement of the survey, all seal observations will be recorded including any incidental observations of seals outside the 250m; however these observations will not be included in any further calculations or abundance estimates. Constant communication will be maintained among the two observers and the recorder to minimize the chance of a ‘double recording’. For each observation, a GPS waypoint, species identification, and if the seals are in groups, will be recorded. Within Goose Bay Estuary and Lake Melville, typically ringed seals and harp seals are present.

Observations will be plotted in GIS to show the distribution of seals throughout the EEM study area. Various statistical analyses will also be conducted as per Lunn et al. (1997) and Sikumiut (2007).

As mentioned, the primary pathway for interaction between seals and the project would be through variations in ice cover or formation. Therefore, surveys of seal habitat utilization will primarily occur during the whelping season. Anecdotal observations of seals during other portions of the sampling program required for this EEM will also be recorded and used to augment the dataset.

Seals within the Goose Bay and Lake Melville area have also been included in baseline mercury analysis (discussed in Section 7.5.4). Locations and species of seal sampled during this portion of the program will be used to augment data collected during aerial surveys. During past sampling programs, the collection of seals for mercury analysis has been conducted by a local hunter during the annual seal hunt. Variations in the timing and location of the hunt will be communicated from field personnel. Various biological measurements will be collected on site, including; length and weight estimates, and identification to species. GPS coordinates of the harvested animal will also be collected, as well as the completion of a visual inspection of stomach contents. Stomach contents will be identified to finest taxonomic level possible in the field. Aging structures (canine teeth) will also be collected for age determination.

7.3.5 Habitat Suitability: Fish Health

Sampling of fish health will primarily rely upon non-lethal sampling techniques. Table 7.12 shows a summary of the fish health parameters that will be collected for each gear type. Mercury sampling is included within the table, and a detailed discussion is presented in Section 7.5. Sampling of fish health will coincide with sampling for fish habitat utilization. Statistical power analysis indicates that fish health parameters require various sample sizes depending on species and parameter to detect a significant decrease in value. Therefore, the largest sample size necessary to detect a statistically significant decrease will be used as the target for every species; 40 fish of each species per habitat type.

Table 7.12. Summary of fish health parameters collected by gear type

Parameter	Fyke Net	Electrofisher	Angling	Snorkel	Gill Net[1]
Growth Rate/Condition	●	●	●		●
Age[2]	●	●	●		●
Isotope Trophic Level	●	●	●		●
Stomach Contents	●		●		●
Fecundity[3]	●		●		●
Mercury[3]	●		●		●

1 Gill nets are not a preferred sampling method for the EEM
2 Secondary aging structures (see below)
3 Requires lethal sampling

7.3.5.1 Growth Rate/Condition

Growth rates will be assessed using length-at-age, which has been collected in the lower Churchill River since 1998. Condition factors will be used in conjunction with the length-at-age data in order to determine fish condition over time. A condition factor is a length-weight relationship calculated using the formula (Ricker 1975):

$$K = \frac{wt * 10^5}{l^3}$$

Where: K= condition factor

wt= weight (g)

l= length (mm)

A salmonid with a condition factor of 1.00 or greater is described as being in better condition than one with a condition factor of less than 1.00. The use of 1.00 as a means of determining condition in non salmonid fish may not be accurate, in particular for species with differing body shapes, such as northern pike or burbot. In these instances, condition factors will be compared on temporal scales using baseline variability.

Smaller fish often have errors associated with the calculation of condition factors. Likewise, instrument error can also affect the data. In order to account for this, two measures will be used;

- Fish smaller than 80mm in length will be removed, as slight errors in the weights of these individuals could skew the results.
- Ranges will be calculated using three standard deviations of the mean for each species, and values outside of the calculated range will be removed from further analysis. This will be completed for each species in order to account for varying body types.

Length-at-age is calculated using Duncan's equation in order to obtain an estimate of the body-scale constant (Duncan 1980). Back-calculated length-at-age will be used to assess the growth rates at specific ages. Length-at-age will be calculated from samples collected below Muskrat Falls, including Goose Bay estuary and Lake Melville, as described in Section 7.3.4, and will be compared to baseline variability assessed using data collected since 1998. As an example, Figure 7.23 shows the variability in length-at-age for lake whitefish sampled within Section 1, below Muskrat Falls, to date.

Aging structures will be collected below Muskrat Falls into Goose Bay and Lake Melville during habitat utilization sampling. A comprehensive age-size relationship will be completed using the baseline data that has been collected to date for the mainstem of the lower Churchill River. Additional baseline back-calculated length-at-age will be added to the existing database to further develop and refine the relationship.

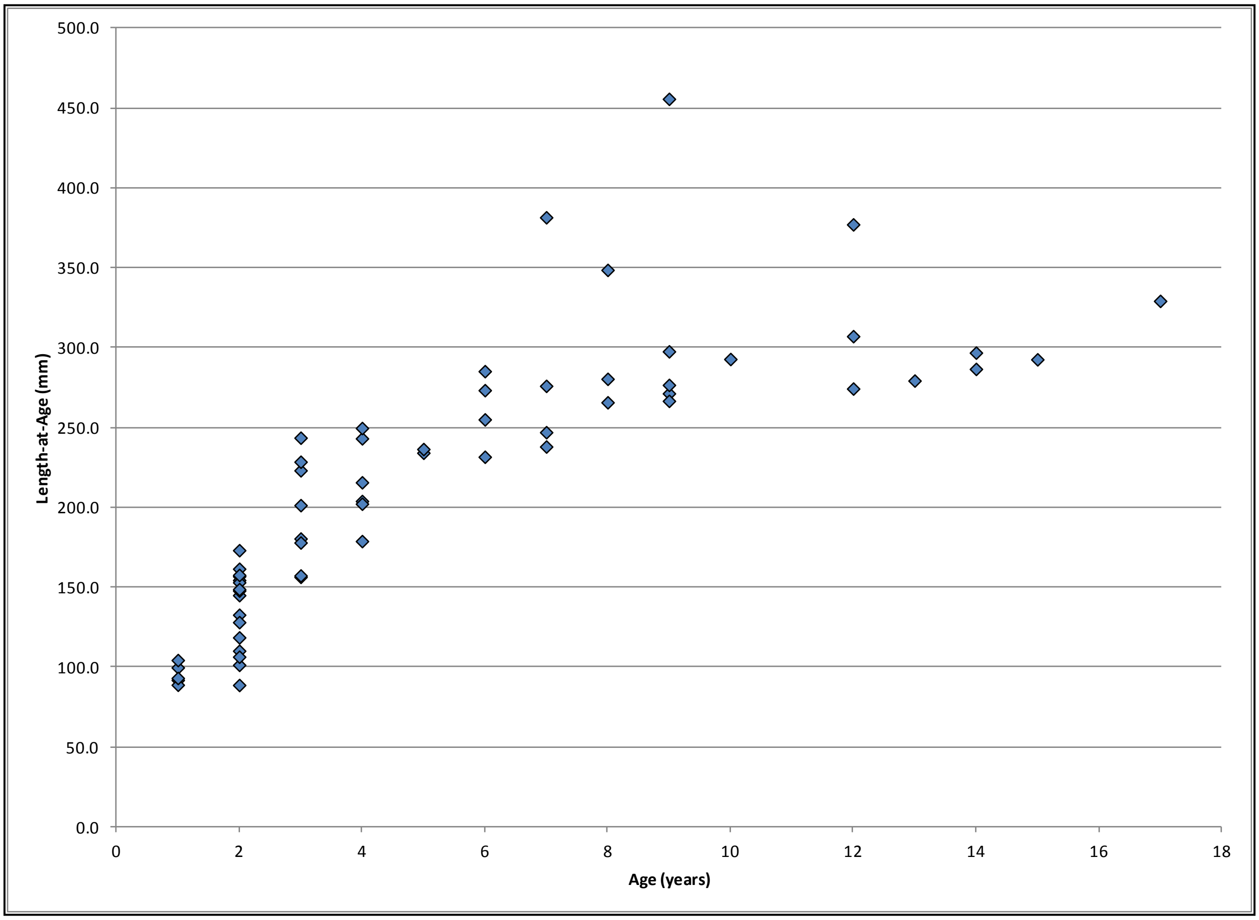

Figure 7.23. Lake whitefish back calculated length-at-age from Section 1, 1998-2011

In past programs, length-at-age has been determined using primary (bony) aging structures which require lethal sampling. A correlation between primary and secondary (scales) aging structures is being determined in order to utilize live capture sample techniques and continue length-at-age determinations. Further delineation of this correlation will be assessed following the collection of additional baseline data and before post-project monitoring. While statistical power analysis indicates that up to 40 individuals of a species will be required to detect as statistically significant decrease in growth rate, all fish collected during baseline that are aged using both bony structures and scales will be included in this analysis of ages using both structures.

7.3.5.2 Age Demographics

Age demographics (i.e., the age class distribution) are indicators of fish population health. Post project population ages will be compared to baseline, which will determine whether the population is changing, and can also show inferences of recruitment (i.e., changes in the proportion of younger year classes). For example, Figure 7.24 shows the age demographic for lake whitefish below Muskrat Falls, using data to date.

Aging structures will be collected and analyzed by experienced personnel (currently sent to University of New Brunswick (UNB) for preparation and analysis). Each structure will be examined for annual growth patterns. Similar to other aging studies, all annular rings are assumed to represent one year of fish growth (as per Ryan 1980) for all species aged (Cooper 1951; Lagler 1956; Ambrose 1983; Chen 1969; Wheeler 1977; Beamish and Harvey 1969; Scott and Crossman 1973; Bruce and Parsons 1976).

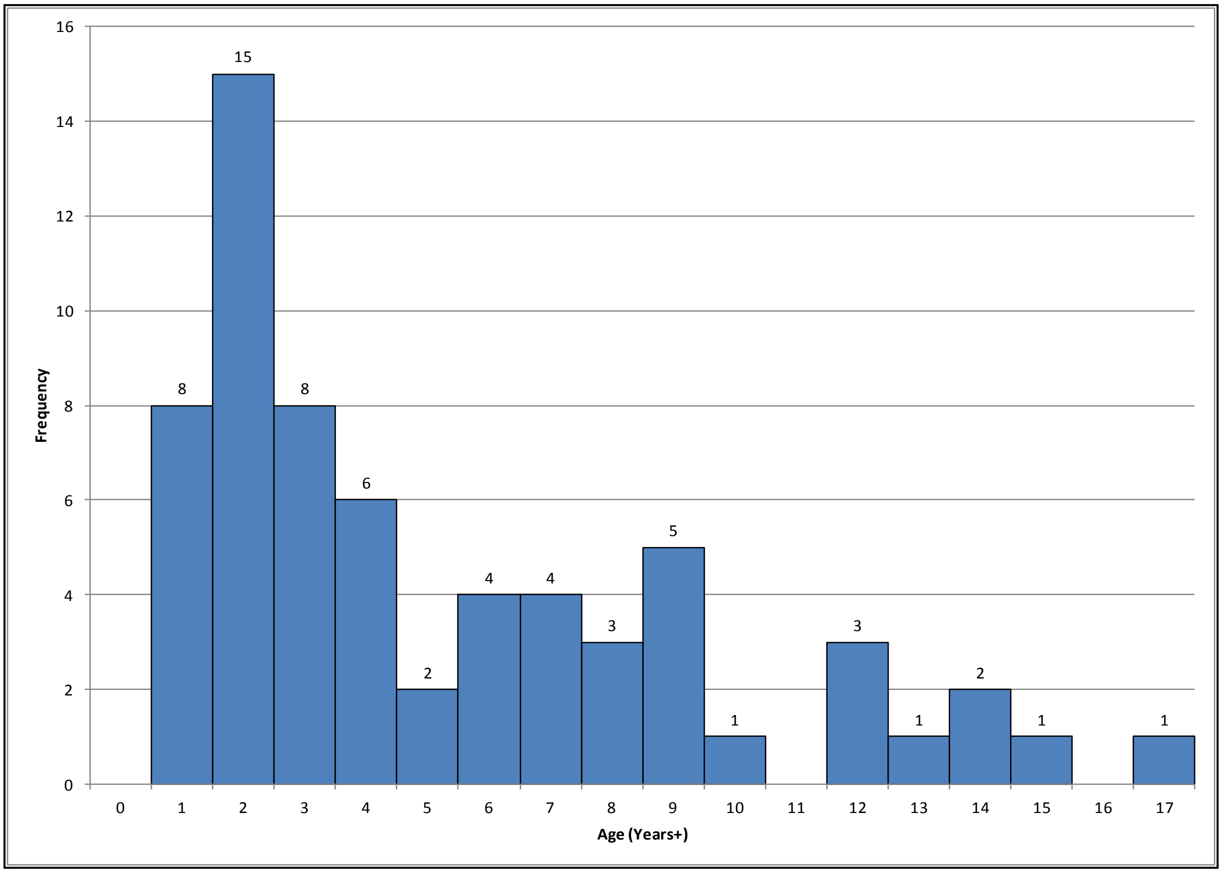

Figure 7.24. Age demographic of lake whitefish sampled in the mainstem below Muskrat Falls (numbers above bars indicate total catch that has been aged)

7.3.5.3 Isotope Trophic Feeding Level

Analysis of fin clips to determine stable isotope ratios has been conducted in the lower Churchill River, Goose Bay and Lake Melville since 2010. Isotope rations are used to determine trophic feeding level of various species and life-stages. Fin clips will be collected from all fish sampled and analyzed for stable isotope (^{13}C and ^{15}N) ratios. The ratios can be used to determine a trophic position, the presence of anadromy within certain species below Muskrat Falls, as well as the habitat that is predominantly utilized (Jardine et al. 2003). Isotope analysis will be included in future monitoring programs as a means of assessing trophic changes following the development of the Muskrat Falls facility (Schetagne et al 2003). It is also being used in conjunction with mercury data in order to assess the downstream extent of mercury accumulation.

Fins clips will be collected, placed in a Ziploc bag or glass vial, and frozen as early as possible. All isotope analyses to date have been conducted by the Stable Isotopes in Nature Laboratory (SINLab) at UNB.

As a means of augmenting the trophic feeding level, stomach contents will also be collected from any fish that is lethally sampled. Stomach samples will be catalogued and frozen for future analysis, should it be required. Additional samples of food sources (e.g., benthic macroinvertebrates, molluscs, algae) are also being collected to augment the dataset and document lower trophic signatures.

By plotting mean isotope ratios, a generalized trophic hierarchy will be developed. In order to determine variations in the post-project environment, in regards to feeding level, standard errors of the $\delta^{15}N$ isotope will be plotted. As an example, Figure 7.25 shows the standard errors of the $\delta^{15}N$ isotope in species sampled in Section 1 of the lower Churchill River to date. As shown, brook trout and burbot are at the higher trophic feeding levels, while white suckers are the lowest.

Isotope analysis can also provide data on the habitat that is primarily utilized by fish, as well as providing an indication of the use of marine habitats (i.e. Goose Bay Estuary or Lake Melville). While the $\delta^{15}N$ ratio indicates the trophic level, the $\delta^{13}C$ indicates the habitat utilized. Similar methods will be employed to compare the post-project data with baseline (i.e., standard error), to compare whether variations are present in the habitats utilized (Figure 7.26).

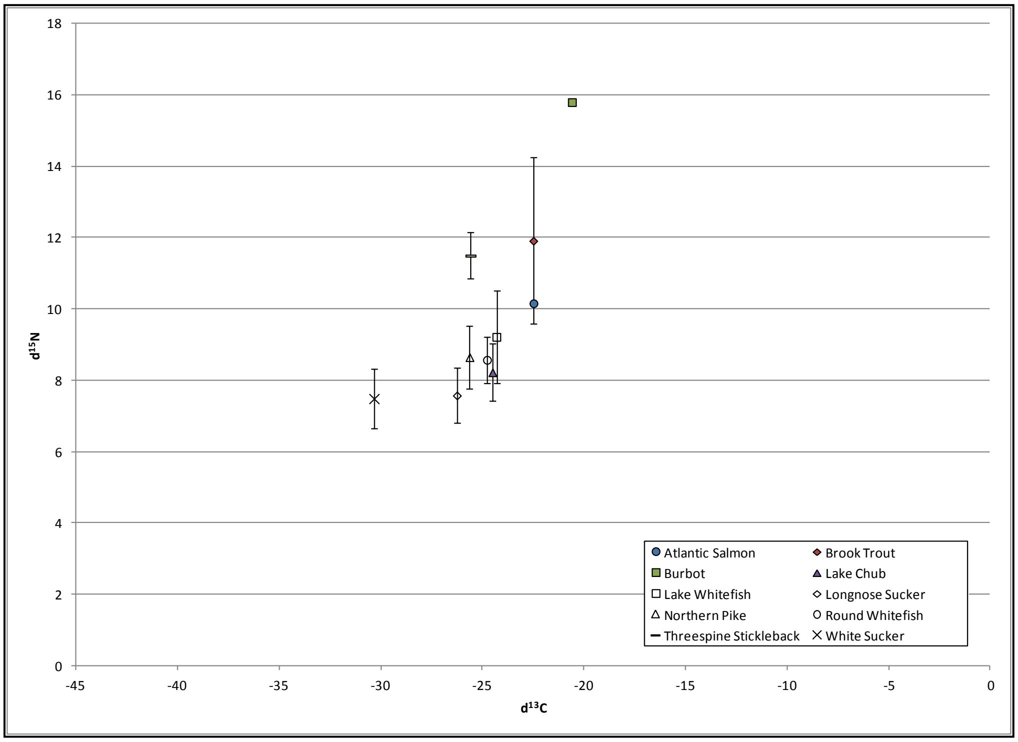

Figure 7.25. Standard errors of δ15N isotope in fishes below Muskrat Falls.

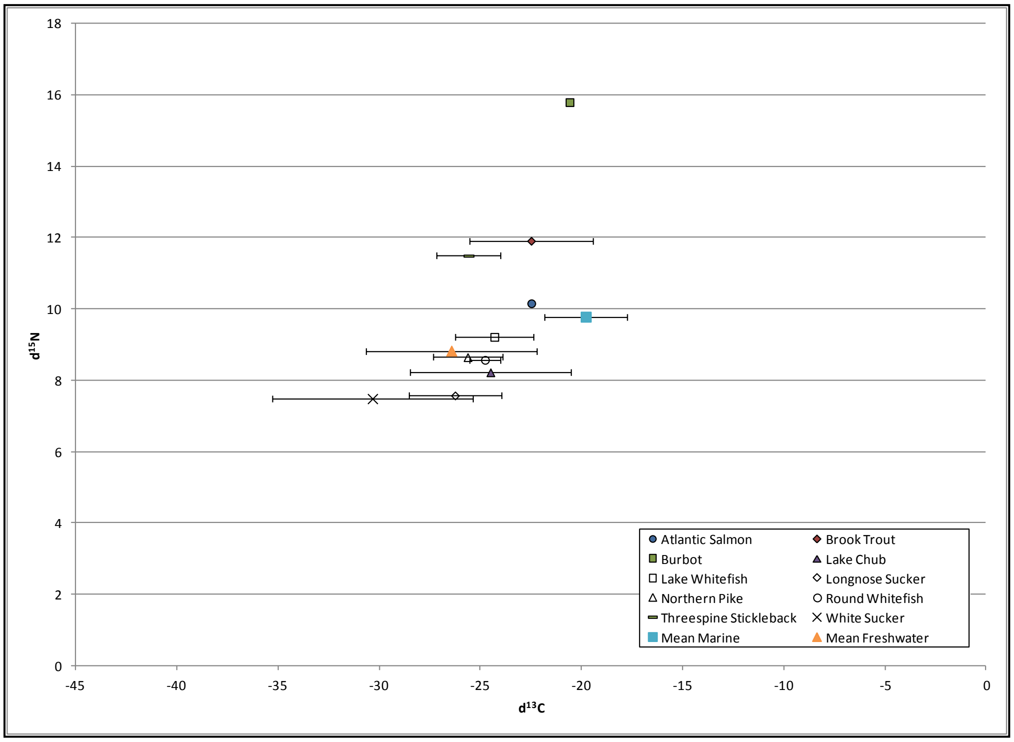

Figure 7.26. Standard errors of δ13C isotope in fishes within the mainstem below Muskrat Falls

7.4 Turbine Entrainment

Fish passage through turbines within the Muskrat Falls facility is expected to be minimal, given that Muskrat Falls is currently a complete obstruction to fish upstream movement (refer to IR#s JRP.51 and JRP.52; Anderson 1985; JWEL 2001).

Turbines that are proposed for the Muskrat Falls Facility are Kaplan type, which are seen as more 'fish-friendly' turbines (Cada 2001). Bell et al. (1967, cited in Ruggles and Collins 1981), reviewed numerous hydroelectric facilities, with different operating regimes and turbine configurations. Survival rates of fish passing through Kaplan turbines ranged from 75.8 to 98.0 percent, with a mean survival rate of 86.0 percent. Various models were developed to estimate both survival (Headrick 1998) and injury rates (Turnpenny 1998) through axial type turbines (Kaplan or Propeller). Results of these models, as they pertain to the Muskrat Falls facility, are shown in Table 7.13.

Table 7.13. Estimates of Turbine Mortality and Injury at Muskrat Falls

Life Cycle Stage	Mortality Rate (%)	Injury Rate (%)
Juvenile (<150mm)	6.0	6.0
Adult (150-550mm)	14.0	22.0

Baseline data collection for turbine entrainment will be limited to assessing sampling methods for capturing and/or detecting fish that might pass through the Muskrat Falls turbines in order to assess injury and mortality rates and injury mechanisms. Direct capture of fish currently passing over the falls has been determined to be unnecessary, as results from this would not be comparable to post-project sampling regimes. Therefore, turbine entrainment will be monitored primarily using a prediction confirmation concept (i.e., results of post-project sampling will be compared to modeled injury and mortality rates presented in Table 7.13).

7.4.1 Study Area

The study area will focus on the area within 200m upstream (near the turbine intakes) and 500m downstream (within the tailrace) of the Muskrat Falls facility.

7.4.2 Sample Schedule

Sampling for turbine entrainment will coincide with periods of increased fish movement, during spring to early summer and early fall. Sampling will occur in late June to early July, during bathymetric and ADP surveys and be repeated again in September, during fish habitat utilization surveys. Sampling for turbine entrainment will be conducted in the years indicated on Table 7.2.

7.4.3 Sampling Turbine Entrainment

Monitoring of turbine entrainment will be adaptive in nature, and will begin with an initial study to estimate the number of fish being injured or killed while travelling through the turbines. The results of the initial study will determine the level of action that will be required for subsequent sampling programs. Figure 7.27 presents a management flow chart that will be utilized for turbine entrainment sampling.

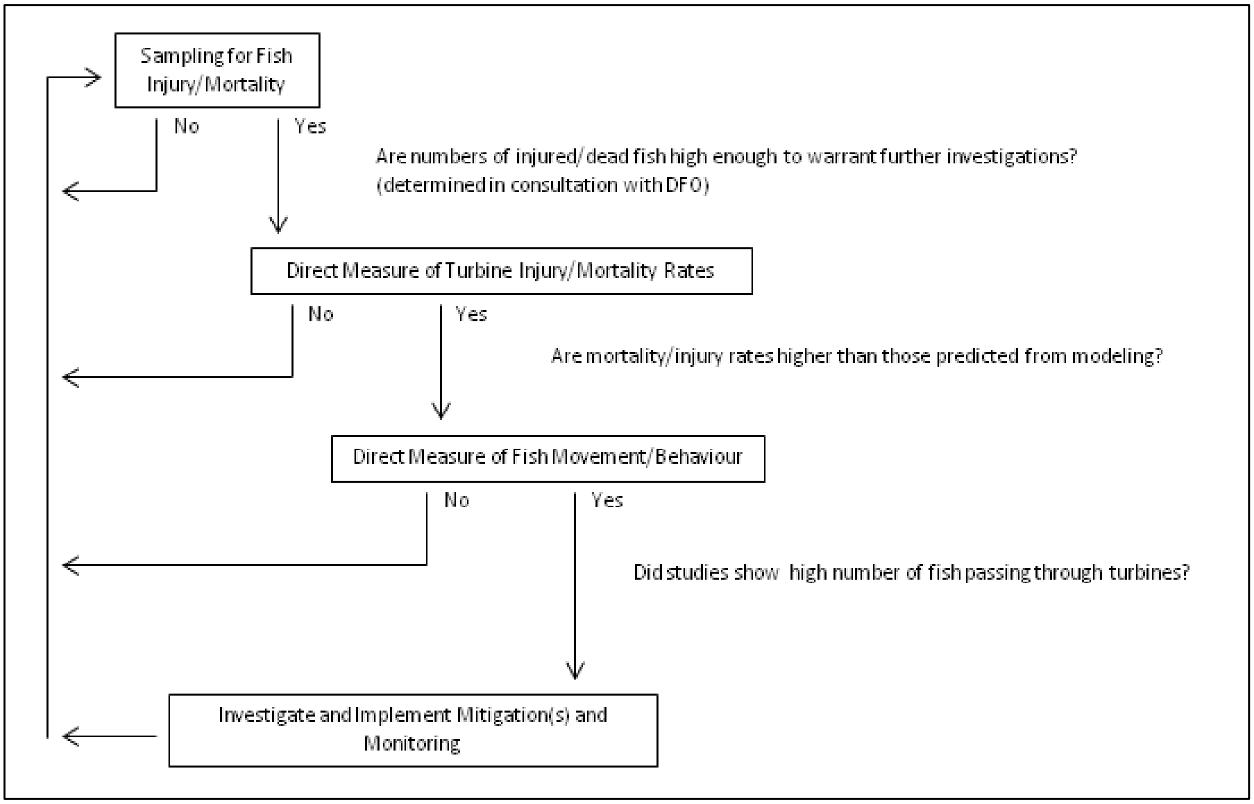

Figure 7.27. Adaptive management decision making for turbine entrainment

With a lack of an established upstream and downstream migration over Muskrat Falls (refer to IR#s JRP.51 and JRP.52; Anderson 1985; JWEL 2001), a relatively low number of fish are expected to be naturally attracted to the upstream penstock and entrained; however, fish may still swim within the calmer water of the reservoir near the penstock intake and potentially become inadvertently entrained. An overall estimate of the number of fish that are being injured/killed will require a sampling regime that can intercept fish as they move/hang up below the tailrace. The number of fish captured that show signs of distress/injury as well as mortalities, if high, will trigger further investigations into the rate of injury and mortality. All injuries/mortality monitoring results will be reported to DFO and, in consultation with them, a determination to conduct additional surveys will be determined. While injury and mortality rates have been modeled for the Muskrat Falls facility, this initial study does not take into account the total number of fish passing through the turbine. If the number of injured/dead fish is high, additional studies will be implemented to determine more precise injury/mortality rates, and provide more detailed analysis of the numbers of fish moving through the turbines. Provided below are methods that will be employed.

An initial study in order to assess injury and mortality of fish below the tailrace will be conducted using a modified otter trawl, plankton tow and/or gillnets. The sample gear will be passed through the tailrace for a predetermined sample time. Upon completion, the gear will be checked for injured or dead fish. The back end of the trawl will be constructed of fine mesh to allow the sampling of fish that are injured or killed during turbine passage. Any injured fish that are captured will be live released, provided that the injuries noted are not severe enough to kill the fish. In addition to sampling the water column, surveys will be conducted along the shoreline near the tailrace to determine if injured/dead fish can be detected onshore as currents and back-eddies may accumulate debris.

Should the initial surveys produce high records of dead/injured fish, additional studies will be conducted, following the management flow charts shown in Figure 7.27.

During the 2012 sampling program, an assessment of using an otter trawl/plankton tow below Muskrat Falls was completed. The field crew deployed both gear types near Muskrat Falls and drove the boat at low speed for varying distances. The methods both appeared feasible; however no fish were observed during the trials. Further investigations were completed during a blast monitoring program in late fall of 2013. During the monitoring, back eddies and notable “debris fields” were identified and marked. These areas are where injured/killed fish would likely gather.

7.4.3.1 Direct Measure of Fish Injury/Mortality

Direct measure of fish injury/mortality rates will be assessed using balloon tags (similar to HI-Z Turb’N Tag; US Patent No. 4,970,988) when the number of injured/dead fish captured below the tailrace is determined to be high. Fish lengths and weights will be recorded for each candidate fish and tags will be attached. Tagged fish will be released into the penstock and allowed to travel through the turbines and into the tailrace. Balloon tags are constructed of a water soluble material, which contains capsules of reactants. Once reactants are activated, a gas is released, and the balloon inflates. The inflated balloon allows for easier observation and collection of fish following turbine passage. Upon collection, the each fish will be assessed for injury, injury mechanisms will be identified (See IR #51 for a discussion of injury mechanisms associated with turbine passage) and detailed survival rates will be calculated and compared to those predicted.

As a means of accurately assessing the survival and injury rates that would occur within the facility, particular species will be selected for balloon tags. Species will likely include:

- Bottom feeder (white or longnose sucker)
    - Suckers are plentiful within the areas above and below Muskrat Falls, and are typically hearty species for handling. Abundance and bottom locomotion make suckers a good candidate species for entrainment studies.
- Salmonid (brook trout, ouananiche, lake whitefish)
    - With the exception of lake whitefish, salmonids are not plentiful within the Muskrat Reservoir area, or the area downstream. Lake whitefish are also not a hearty species, and generally do not respond well to handling.

As mentioned above, a direct measure of injury and survival rates will be assessed if the results from the initial survey warrant additional effort. The candidate species mentioned above can also be changed to match the species which are observed being injured/killed during the initial study.

7.4.3.2 Direct Measure of Fish Movement

If injury or mortality rates are determined to be higher than expected, an additional study will be implemented to determine the number of fish that are coming in contact with the turbines. In order to do this, a radio telemetry program will be initiated.

Again, candidate species will be selected, and will likely consist of suckers and salmonids as discussed above. Fish will be sampled from within the reservoir, and radio telemetry tags will be surgically implanted. The purpose of this program would not be to track movements within the reservoir, but would be focused on tracking fish that may come in contact with the turbines, therefore a fixed receiver would be installed near the penstock. However, additional receivers could be deployed if additional monitoring would be beneficial to the Fish Habitat Compensation Plan (AMEC 2012).

Data will be recovered and plotted in GIS which will show the movements of fish around the dam and through the turbines.

7.4.3.3 Investigate and Implement Mitigations

Following the completion of additional studies, should they be required, mitigations will be investigated and implemented.

Means of mitigation have been acquired through a literature review, and therefore are considered to be in preliminary stages for considerations of project engineers. Numerous mitigations have been assessed including the use of audible and visual deterrents (i.e., strobe lights or low frequency sounds), the use of screening over the turbine intakes, or the construction of electrical barriers within the area of the intake (Whitney et al. 1997).

As a precaution, chains will be attached to log booms when they are installed immediately after impoundment. Additional mitigations, such as those stated above, will be assessed further should they be required.

7.5 Mercury Bioaccumulation

Mercury bioaccumulation within, and downstream of, newly created reservoirs is a known occurrence (Schetagne et al. 2003) as a result of the decomposition of flooded terrestrial vegetation. While methylmercury is the more biologically available form, total mercury is measured as a more conservative indicator as it includes and accounts for all forms present.

Transport of mercury via water into Goose Bay and Lake Melville was modeled (Oceans 2012). The results showed minimal increases within Goose Bay. Figure 7.28 shows the predicted total mercury concentration in water, five months following impoundment. Monitoring of mercury accumulation is being focused on tissues from fish and seals within the Lower Churchill River, Goose Bay and Lake Melville. Any measured increases in fish and seal tissue would be of greater concern due to the direct potential interaction with user groups. Additional baseline water and sediment samples will be collected to augment baseline and to provide information related to post-reservoir comparisons; however; they are not anticipated to be required on a regular basis.

Bioaccumulation of mercury in river reaches downstream of hydroelectric developments is a known phenomenon; therefore relying solely on a before and after comparison of mercury concentrations is not considered an appropriate means of monitoring environmental effects. Post-project mercury concentrations will therefore be compared to modeled results as well as baseline data in conjunction with literature from similar hydroelectric developments. While baseline data has been collected since 2001, it has been for the purpose of developing the model used to predict post-project concentrations.

7.5.1 Study Area

Figure 7.1 presents the study area for mercury sampling. The study area extends from Gull Island to Lake Melville (i.e., within the Muskrat Falls reservoir and downstream out to Goose Bay/Lake Melville area). Sampling of mercury in fish upstream of the Muskrat Falls reservoir area will be completed during baseline studies for the Gull Island facility, and will not be included in the EEM for Muskrat Falls. Sampling of fish unaffected by the project (i.e., outside of the lower Churchill River watershed) is not considered necessary throughout post-project monitoring at this time as increases will be compared to existing baseline and model predictions. As reservoir stabilization continues and mercury concentrations decline and approach existing baseline, sampling outside the watershed may be warranted to determine whether baseline has shifted in the region due to external factors. The decision to sample outside the Churchill River watershed will be determined during the major program reviews as indicated in Table 7.2.

7.5.2 Sampling Schedule

Sampling of mercury in fish will coincide with the sampling for fish habitat utilization in August and September. Sampling of ringed seals will take place during the annual seal harvest, as in past sample years, during April and May.

Sampling for mercury will occur on an annual basis until the visible peak and decline in concentration is observed. An analysis will then be conducted, and additional monitoring will occur with an efficient schedule.

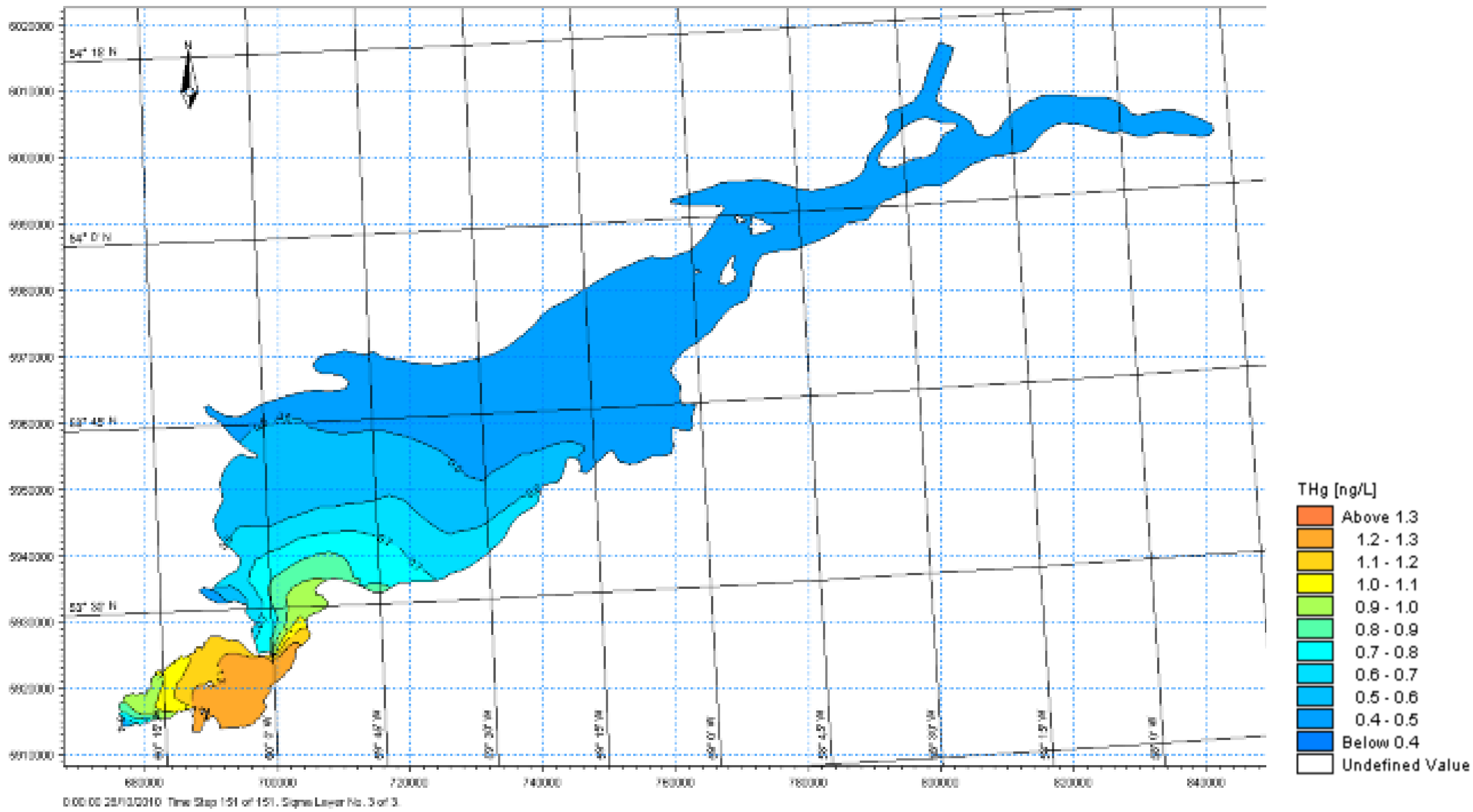

Figure 7.28. Predicted total mercury concentration (ng/L) in waters within Goose Bay and Lake Melville, 5 months following impoundment

7.5.3 *Mercury in Fish Tissue*

Analysis for mercury body burden typically requires lethal sampling; sampling methods will be determined according to target species. Studies conducted for other hydroelectric developments have shown that top predators will show the highest increases in mercury body burden. Within the Churchill River, this would be specific to lake trout, northern pike and burbot. Target species have been selected on modeled results and species of recreational and commercial importance. Table 7.14 shows the breakdown of target species that were assigned for additional sampling. As mentioned, lake whitefish and suckers (both white and longnose) have been shown to have high increase in mercury below hydroelectric development due to a shift in trophic feeding level. These species will also be identified as target species for post-project sampling.

Baseline total mercury concentrations in fish have been collected over a 13 year period (since 1999) and actual concentrations at the time of impoundment may be different. Therefore additional fish samples will be collected and analyzed for mercury body burden during pre-impoundment in order to continue collection of mercury concentrations and to collect as much data as possible from each fish captured (especially those lethally collected). Statistical power analysis indicates that a sample size of 30 fish per species, per area is sufficient to detect statistically significant increases in mercury.

Fish/flesh samples will be collected for subsequent mercury analysis as per Scruton et al. (1994). A 50g flesh sample will be obtained from under the dorsal fin of each sampled fish. If fish are smaller than 51mm or 50 grams in total weight, they will be kept as whole fish samples, with the gut removed. Each sample will be kept on ice and frozen as soon as possible. Parameters recorded for all fish retained for mercury analysis will include:

- length (fork length to the nearest millimetre);
- weight (to the nearest 0.1g);
- aging structure; and,
- stomach contents (preserved and to be later analyzed if required).

Samples collected to date have been sent to Maxxam Analytical (Maxxam), a Canadian Association for Laboratory Accreditation (CALA) certified laboratory for analysis of total mercury. The method to be used for mercury analysis is based upon that found in Analytical Methods Manual, Environment Canada, Ottawa, Inland Waters, 1979, Method NAQUADAT no. 80601 (Method 2).

Figure 7.29 shows the mean mercury concentrations that have been measured in the mainstem below Muskrat Falls to date, while Figure 7.30 shows mean mercury concentrations measured in Goose Bay and Lake Melville. Error bars on the graph indicate the standard error of the dataset. It should be noted that only one burbot has been sampled to date for mercury below Muskrat Falls, therefore there is no standard error reflected. Likewise, Atlantic herring, dwarf lake whitefish and round whitefish have only been sampled once in Goose Bay and Lake Melville.

Table 7.14. Mercury target species.

Species	Recommended Location of Sampling	Adult Fish Length Desired
Lake Trout	Muskrat Falls Reservoir area Below Muskrat Falls	600mm
Northern Pike	Muskrat Falls Reservoir area Below Muskrat Falls	700mm
Longnose Sucker	Muskrat Falls Reservoir area Below Muskrat Falls Goose Bay Lake Melville	400mm
Brook Trout	Muskrat Falls Reservoir area Below Muskrat Falls Goose Bay Lake Melville	300mm
Atlantic salmon	Muskrat Falls Reservoir area Below Muskrat Falls Goose Bay Lake Melville	300mm
Lake Whitefish	Muskrat Falls Reservoir area Below Muskrat Falls Goose Bay Lake Melville	300mm
White Sucker	Muskrat Falls Reservoir area Below Muskrat Falls Goose Bay Lake Melville	400mm

Rainbow Smelt	Below Muskrat Falls Goose Bay Lake Melville	200mm
Tomcod	Goose Bay Lake Melville	200mm

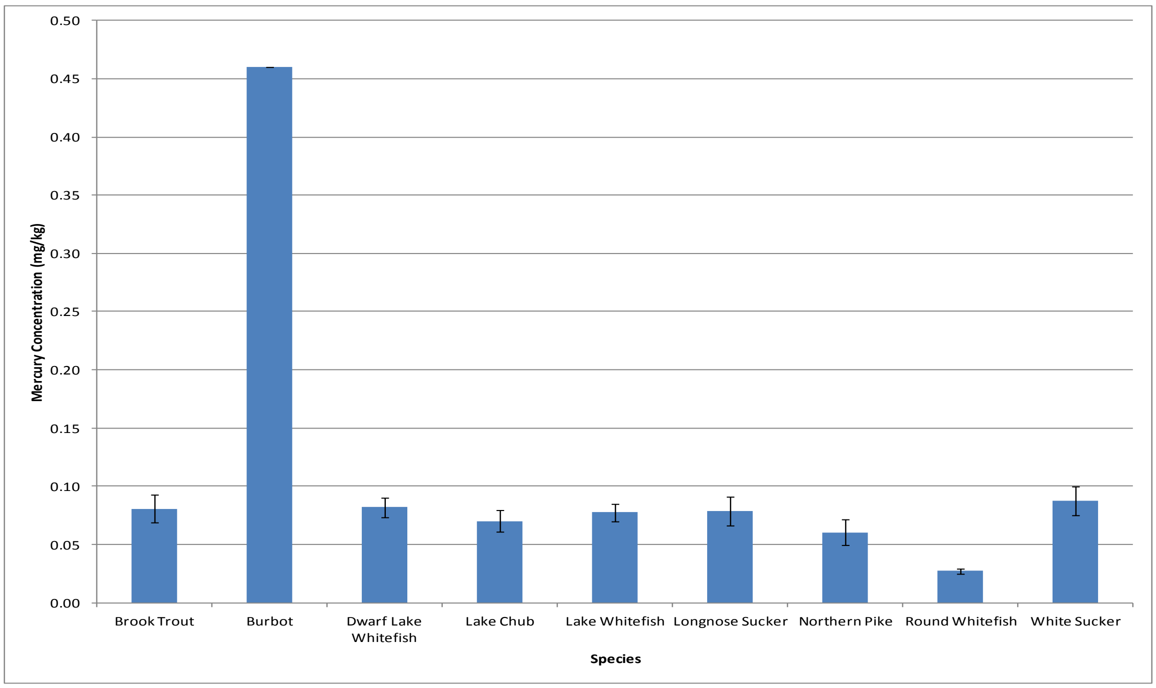

Figure 7.29. Mean mercury concentrations in the mainstem below Muskrat Falls

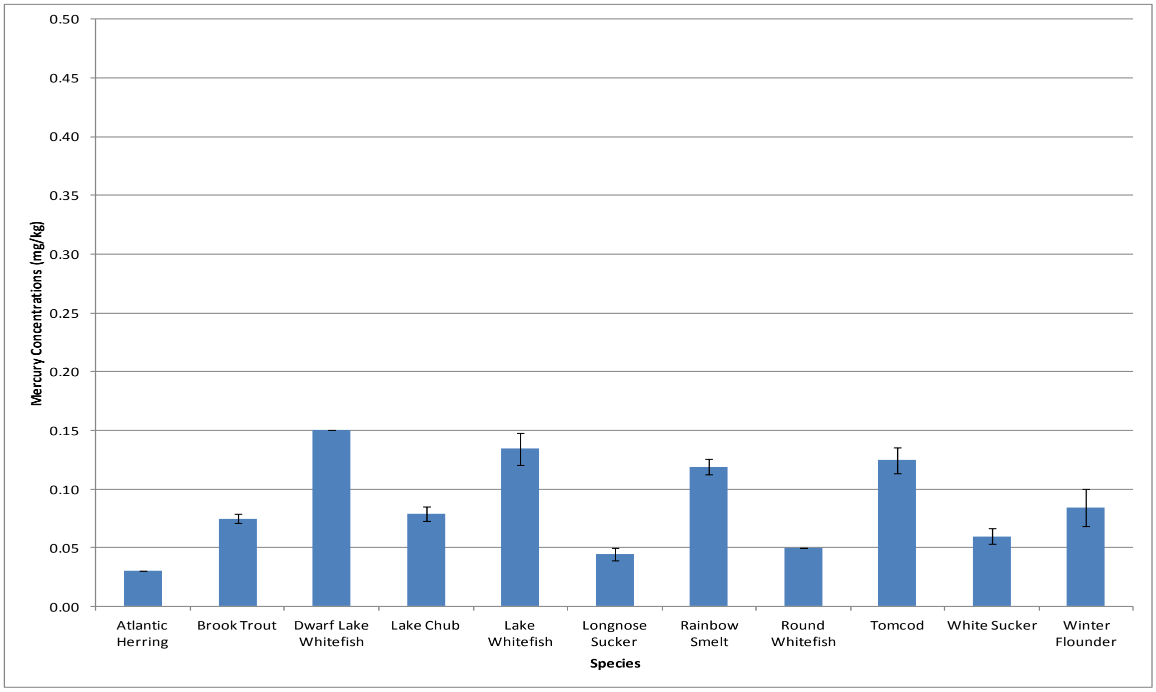

Figure 7.30. Mean mercury concentrations in Goose Bay and Lake Melville

As mentioned, the capture method employed for mercury will be dependent upon the target species. Target species will also determine the sample locations. It should be noted that fish which are sampled lethally for mercury will also have primary aging structures, fecundity and stomach analysis conducted.

7.5.4 Mercury in Seal Tissue

Collection of seal samples began in 2011 and has occurred in conjunction with the annual traditional seal hunt. Only ringed seals (*Pusa hispida*) have been collected during this program, as it is the species that is most relied upon as a food source for people within the Upper Lake Melville area. Measurements of the animal upon harvesting will be collected, as well as samples for laboratory analysis. Similar to fish, a total sample of 30 animals will be targeted per year based on statistical power analysis.

A sample of muscle will be collected for analysis as well as teeth to determine the age of each animal sampled. Each muscle sample will be collected near the tail of the animal. Each sample will be at least 15 grams in weight and collected without any blubber attached. Samples will be cooled on ice in the field, and later frozen prior to shipping to a CALA certified laboratory for analysis. Teeth have been noted as the prime structure for aging of seals (Mansfield 1991, Dehn et al. 2007, Chambellant and Ferguson 2009) with the lower canine teeth providing the most accurate age determination (Mansfield 1991). Upon processing, a lower canine tooth (or a proportion of the lower jaw) will be removed from each animal and frozen until the field portion of the program is completed. Aging of the teeth has been completed by Sir Stanford Flemming College to date using methods as described by Stewart et al. (1996).

Various measurements will also be collected from the animal at the time of capture, including estimates of length (nose to tail) and weight. GPS coordinates will be recorded in order to assess the spatial distribution of ringed seals. A description of stomach contents and measure of blubber thickness will also be recorded.

Seals will also be analyzed for trophic feeding pattern by stable isotopes (as described for fish) and stomach content analysis. Isotope ratios from muscle biopsies provide an indication of the seal's diet and habitat usage over a longer period of time, while the isotope ratios from the stomach contents indicate the trophic level and habitat usage of the last food source. A small muscle biopsy (as per Noren et al. 2005) will be collected through an incision in the blubber from each animal. Samples of the stomach contents will also be collected, provided there is food within the stomach, and also sent for isotope analysis. All muscle biopsies to date have been sent to the SINLab at UNB for analysis.

Isotope ratios will be used to aide in the determination of trophic feeding level of ringed seals in Lake Melville and Goose Bay estuary, and whether they are utilizing fish from the Churchill River, or a more marine source, as a food source.

Table 7.15 provides a summary of the mercury analysis collected in 2011. Baseline data is ongoing with a total of 30 seals collected in 2012.

Seal sampling will continue to occur during the annual seal hunt by a licensed guide. Sampling parameters (i.e., mercury in muscle and liver, aging and trophic feeding pattern) will remain constant during each subsequent sampling year.

Table 7.15. Summary of ringed seal mercury concentration (2011)

Sample ID	Mercury Concentration (mg/kg)	Age (years)
Ringed Seal #1	0.19	8+
Ringed Seal #2	0.09	1+
Ringed Seal #3	0.10	0+

Ringed Seal #4	0.09	0+
Ringed Seal #5	0.39	2+
Ringed Seal #6	0.05	0+
Ringed Seal #7	0.35	0+
Ringed Seal #8	0.13	0+
Ringed Seal #9	0.23	1+
Ringed Seal #10	0.06	0+
Ringed Seal #11	0.11	0+
Ringed Seal #12	0.19	0+
Ringed Seal #13	0.32	1+
Ringed Seal #14	0.16	0+

8 REPORTING

An annual report for each prescribed monitoring year will be produced on the results of the monitoring program. The report will be submitted to DFO for information and review. This EEM report will be submitted to all required regulators including the provincial Department of Environment and Conservation by March 31 of the following year to allow for data to be analyzed and presented in time for review and incorporation of any revisions to subsequent sampling or analysis.

As shown in the schedule presented in Table 7.2, a review of the monitoring program will be conducted every five years. The results of the review will be submitted to regulators with the annual monitoring report for that year.

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