Keeyask Generation Project

Aquatic Effects Monitoring Plan

KEEYASK
Hydropower Limited Partnership

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KEEYASK GENERATION PROJECT AQUATIC EFFECTS MONITORING PLAN

Prepared by

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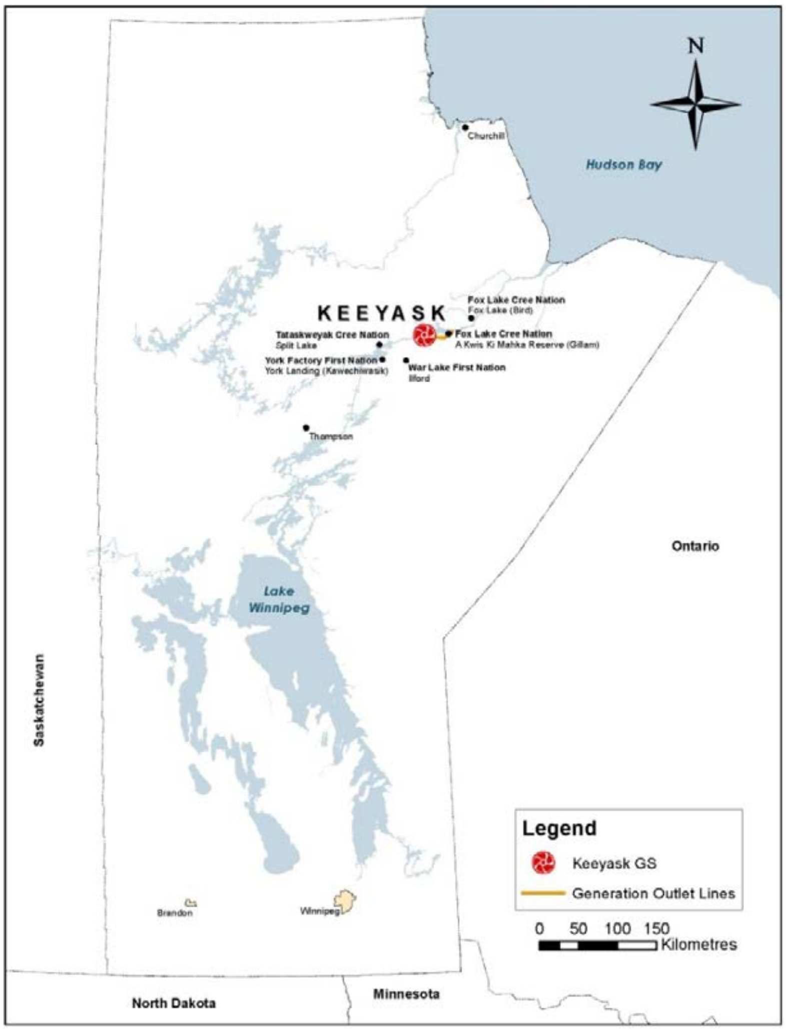
PREFACE

KEEYASK ENVIRONMENTAL PROTECTION PROGRAM

An Environmental Protection Program (the Program) has been developed to mitigate, manage and monitor potential environmental effects described in the *Keeyask Generation Project: Response to EIS Guidelines* during the construction and operation phases of the Keeyask Generation Project (the Project) shown on Map 1. The Program includes a collection of plans grouped in the following categories: Environmental Protection Plans, Environmental Management Plans, and Environmental Monitoring Plans.



Map 1: Location of Keeyask Generation Project

Figure 1 lists all of the plans included in the Program. It also demonstrates how the Program will be managed. The Keeyask Hydropower Limited Partnership (the Partnership) has delegated authority to Manitoba Hydro to manage construction and operation of the Project including implementation of the Program. The organizational structure of the Partnership for this aspect of the Project includes a Monitoring Advisory Committee (MAC), which includes participants from each of the Keeyask Cree Nations (KCNs) and Manitoba Hydro. Manitoba Hydro will be guided on the implementation of the Program by the MAC, the Partnership Board of Directors and ongoing discussion with Regulators.

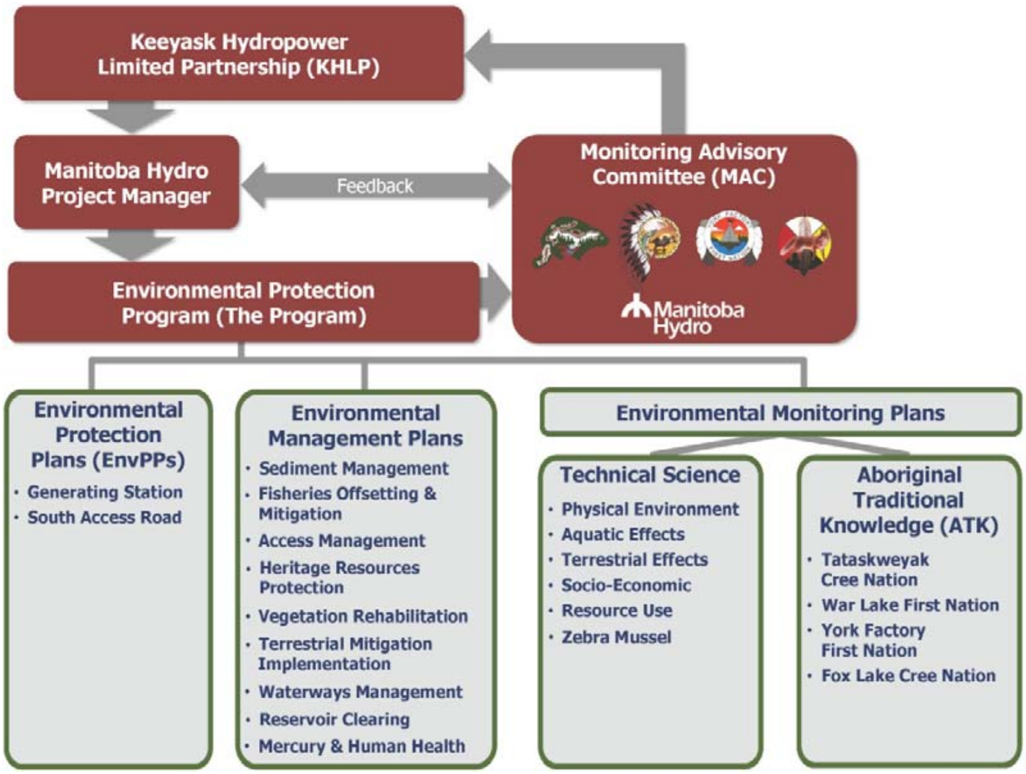


Figure 1: Environmental Protection Program

The Environmental Protection Plans (EnvPPs) provide detailed, site-specific environmental protection measures to be implemented by the contractors and construction staff to minimize environmental effects from construction of the generating station and south access road. They are designed for use as reference documents providing the best management practices to meet or exceed regulatory requirements. EnvPPs are organized by construction activity, highlighting measures to reduce the impact of a specific work activity (e.g., tree clearing or material placement in water). Contractors' compliance with the EnvPPs is a contractual obligation. Under Manitoba Hydro's construction site management, a Site Environmental Lead will be responsible for monitoring compliance and determining when corrective actions are required.

The Environmental Management Plans focus on minimizing effects on specific environmental parameters. They outline specific actions that must be taken during construction and in some cases into the operational phase to mitigate Project effects. The management plans include monitoring to determine success of the actions taken and to determine other actions that need to be undertaken (adaptive management). Implementation of these plans will involve Manitoba

Hydro's staff, the KCNs, specialized consultants and contractors under the direction of the Project Manager.

The Environmental Monitoring Plans are designed to measure the actual effects of the Project, test predictions or identify unanticipated effects. During the course of the environmental assessment, numerous requirements for monitoring were identified. There will be both technical science monitoring and Aboriginal Traditional Knowledge (ATK) monitoring undertaken. The technical science monitoring will be conducted by Manitoba Hydro and specialized consultants contracted by Manitoba Hydro, who will in turn hire members of the KCNs to work with them to fulfil the monitoring activities. Manitoba Hydro will also have contracts with each of the KCNs to undertake ATK monitoring of the project.

The activities that occur and the results generated from the Environmental Protection Program will be discussed at MAC meetings. The MAC is an advisory committee to the Partnership Board of Directors and will review outcomes of the programs and, if appropriate provide advice and recommendations to the Partnership on additional monitoring or alternative mitigation measures that may be required. The MAC will provide a forum for collaboration among all partners. On behalf of the Partnership, the MAC will also ensure that the outcomes of the Environmental Protection Program are communicated more broadly on an annual basis to Members of the KCNs, regulators and the general public.

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1.0 INTRODUCTION

This document describes the Aquatic Effects Monitoring Plan (AEMP) for the Keeyask Generation Project (the Project), a 695 megawatt (MW) hydroelectric generating station and associated facilities at Gull Rapids on the lower Nelson River in northern Manitoba immediately upstream of Stephens Lake. The Project will be located entirely within the Split Lake Resource Management Area. The Project is approximately 725 kilometres (km) northeast of Winnipeg, 35 km upstream of the existing Kettle Generating Station, where Gull Lake flows into Stephens Lake, 60 km east of the community of Split Lake, 180 km east-northeast of Thompson and 30 km west of Gillam (Map 1-1).

The Keeyask Generation Project: Response to EIS Guidelines, completed in June 2012, provides a summary of predicted effects and planned mitigation for the Project. Technical supporting information for the aquatic environment, including a description of the environmental setting, effects and mitigation, and a summary of proposed monitoring and follow-up programs is provided in the Keeyask Generation Project Environmental Impact Statement: Aquatic Environment Supporting Volume (AE SV).

The AE SV describes existing conditions and predicted environmental effects to the aquatic environment, including Valued Environmental Components (VECs). The AEMP describes monitoring that will provide information to:

- Determine if the effects assessment predictions in the AE SV are correct;
- Determine the effectiveness of mitigation/offsetting measures;
- Assess the need for additional mitigation/offsetting measures if initial measures are not adequate;
- Determine the effectiveness of any additional/adapted measure(s); and
- Confirm compliance with regulatory requirements set out in Project approvals documentation.

Monitoring activities focus on primary effects to key components of the environment rather than addressing all potential changes to the aquatic environment as described in the AE SV. Monitoring described in this AEMP meets the conditions in Manitoba *Environment Act* Licence No. 3107 (MEAL) and the Authorization under the *Fisheries Act* issued (FAA)for the Keeyask Project.

The study area includes the reach of the Nelson River from the Kelsey Generating Station (GS) to the Kettle GS, as well as waterbodies immediately adjacent to the Nelson River (Map 1-2). Monitoring will be focused on the reach of the river from approximately 3 km downstream of the outlet of Clark Lake to approximately 3 km downstream of Gull Rapids (i.e., the inlet of Stephens Lake), where direct changes to water levels and flows are expected. Selected components will also be monitored upstream of this reach (in Split Lake) and downstream of this reach (in Stephens Lake). Monitoring for the water quality and mercury in fish flesh components will periodically extend downstream to the Nelson River estuary to address concerns that inputs to the water at the Project site could be carried downstream (see Water Quality Section).

The Keeyask Fisheries Regulatory Review Committee (KFRRC) is a committee of representatives from the Keeyask Hydropower Limited Partnership, Manitoba Conservation and Water Stewardship (Fisheries Branch) (MCWS), and Fisheries and Oceans Canada (DFO; Terms of Reference for the KFRRC are provided in Appendix 1A). The KFRRC will review monitoring results and determine whether the Partnership is in compliance with fisheries-specific regulatory requirements outlined in the FAA and in the MEAL and whether adaptive management measures may be required. Monitoring results will be discussed to identify any required modifications to the monitoring plan and/or the mitigation and offsetting measures as specified in environmental approvals for the Project. The review will also consider whether monitoring results indicate that the Fisheries Management Objectives (FMOs; Appendix 1B) developed by MCWS for the Keeyask Project are being met and, if not, what changes to mitigation and offsetting measures may be required. The KFRRC will fulfill the role of the Lake Sturgeon Advisory Committee, as set out in Clause 21 of the MEAL. The AEMP is adaptive with provisions to modify monitoring programs and mitigation measures, if and as required, based on comparisons to benchmarks that have been identified for specific indicators. The approach to establishing a benchmark varies among components of the monitoring program and is described in the proceeding sections. In general, benchmarks were set in relation to changes or levels of indicators that could be indicative of negative effects. For many indictors, an “early warning” level was identified, which would indicate potential negative changes and trigger a review and possible adjustment of the monitoring to ensure that the program is sensitive enough to detect changes of concern. An “ecologically significant” benchmark was chosen as the level at which no adverse effect is expected based on assessment results presented in the AE SV, conditions in similar environments, or professional judgement; however, if levels of the indicator move beyond this benchmark, then the potential for adverse effects exists. Passing the ecologically significant benchmark results in further investigation to determine whether changes to mitigation measures are warranted. For some indicators (e.g., water quality parameters during the operation period), management measures to reduce effects are not possible; in such instances, the response to exceedance of a benchmark could consist of further analysis, including of biological components. Where widely accepted guidelines exist (e.g., comparison of water quality parameters to the Manitoba Water Quality Standards, Objectives and Guidelines) these were used as benchmarks. However, in most instances, no widely accepted guidelines exist to provide the basis for the establishment of benchmarks; in these instances, levels were identified based on the range of natural variation observed in similar environments, results of modeling, and/or professional judgement.

Benchmarks provided in this AEMP should be considered preliminary, and may be modified as additional information becomes available, as part of an adaptive management approach.

During the construction phase, monitoring results will be reviewed to determine whether adjustments need to be made to either the temporal and/or spatial scope of sampling, and to provide feedback to Project personnel if alterations to mitigation measures are required. During the operation phase, monitoring results will provide the basis for modifications to sampling plans (e.g., reduction if effects are not observed, design changes if effects are not adequately recorded by existing plan), and the modification or implementation of additional mitigation and/or offsetting measures, if required. While operation monitoring may continue twenty-five or more years following impoundment of the reservoir, the monitoring timeframe for particular components will be reduced if there are no observed effects, or if results indicate a more rapid stabilization. An integrated review of all aquatic monitoring results after monitoring is completed for three years of impoundment will determine whether changes to the monitoring program are required in the short term. The Keeyask Monitoring Advisory Committee (MAC) will discuss the AEMP monitoring results and possible need for adjusting monitoring based on the results observed, throughout construction and operation.

Annual reports on monitoring conducted under the AEMP will be provided in accordance with the FAA and MEAL. A synthesis report, which will form the basis for decisions about the nature of monitoring in the period 10-25 years after impoundment, will be prepared after 10 years of post-impoundment monitoring.

In addition to results from monitoring activities described within this AEMP, results from components of the Physical Environmental Monitoring Plan (PEMP) and the Instream Construction Sediment Management Plan (SMP) will be used to: (i) describe effects to the aquatic environment; and (ii) interpret results from various monitoring activities in the AEMP. Appendix 1C summarizes relevant information that will be obtained from the PEMP and SMP. The Coordinated Aquatic Monitoring Program (CAMP), a program conducted jointly by MCWS and Manitoba Hydro, includes the collection of environmental data at several locations in northern Manitoba that may be affected by the Project or that will provide useful context for interpreting changes observed in the area affected by the Project. CAMP sampling locations are provided in Appendix 1C.

The following sections of this document describe monitoring that will be conducted for the following components of the aquatic environment:

- Water Quality (VEC) (Section 2.0);
- Aquatic Habitat (Section 3.0);
- Aquatic Macroinvertebrates (Section 4.0);
- Fish Community (Walleye, Northern Pike and Lake Whitefish are VEC species) (Section 5.0);
- Lake Sturgeon (VEC) (Section 6.0); and
- Mercury in Fish Flesh (Section 7.0).

A summary of pathways of effect, planned mitigation/offsetting, residual effects and monitoring for each component of the aquatic environment can be found in Table 1-1.

A greater level of detail is provided for Lake Sturgeon monitoring than for the more standard monitoring associated with other components of the aquatic environment. This is because there is less certainty associated with the potential effects of the Project to Lake Sturgeon populations, the current low numbers of Lake Sturgeon in the region, the cultural importance of this species, and the need to fully understand Project effects so that effective adaptive management measures can be implemented as the Project progresses.

2.0 WATER QUALITY

2.1 INTRODUCTION

Water quality will be monitored during the construction and operation phases of the Keeyask Generation Project and, as described in Section 2.3, monitoring results will be evaluated to inform adaptive management decisions. The monitoring program has been designed to address key pathways of effect and predictions presented in the Keeyask Generation Project Aquatic Environment Supporting Volume (AE SV) with the overall objective of monitoring and evaluating water quality in relation to the protection of aquatic life (PAL). The water quality monitoring program forms an important foundation of the overall AEMP, as the results of this monitoring component will be considered within the biological monitoring components.

Subsequent sections in this introduction provide: (i) a summary of the assessment provided in the AE SV, including a description of pathways of effect, a summary of assessment results, and proposed mitigation and offsetting measures (Section 2.1.1); and (ii) an overview of benchmarks that will be considered in the interpretation of the monitoring results (Section 2.1.2).

Monitoring activities are described in Section 2.2, as follows:

- Section 2.2.1 Monitoring during the construction period; and
- Section 2.2.2 Monitoring during the operation period.

Although there are similarities between monitoring programs during construction and operation, due to fundamental differences in terms of the potential effects of the Project, the programs are presented separately.

Section 2.3 provides the adaptive management framework outlining the proposed process for interpreting and assessing monitoring results, including integration of results with other monitoring activities described in this AEMP. This section also describes the process whereby monitoring results will be considered in terms of action levels to determine the need and type of follow-up activities, including: (i) modification of the monitoring program; (ii) conduct of focused studies; and (iii) implementation of follow-up or mitigation measures.

Additional information beyond that presented in this AEMP, pertinent to monitoring of water quality, includes:

- **Wastewater monitoring**: (i) monitoring of wastewater treatment plant effluent to comply with the Keeyask Infrastructure Project Manitoba Environment Act Licence, Tier 1 Water Quality Standards defined in the Manitoba Water Quality Standards, Objectives and Guidelines and the Wastewater Systems Effluent Regulations under the federal Fisheries Act; and (ii) monitoring effluent from the settling pond(s), water impounded behind cofferdams and concrete washout to confirm compliance with limits provided in the EnvPPs for the Keeyask Generation Project and the Keeyask South Access Road;

- Instream Construction Sediment Management Plan (SMP): the SMP presents a total suspended solids (TSS)/turbidity monitoring program designed to provide near continuous monitoring through the deployment of turbidity loggers upstream and downstream of the construction activities. The SMP forms the foundation of monitoring for the key effects predicted during the construction phase (i.e., increases in TSS related to water diversion and impoundment and to cofferdam placement and removal). SMP monitoring sites will be situated upstream and downstream of instream construction activities; and
- Physical Environment Monitoring Plan (PEMP): the PEMP includes some water quality monitoring during the construction and operation periods. Specifically, the PEMP includes monitoring of dissolved oxygen (DO), water temperature, turbidity, TSS, measures of carbon, and total dissolved gas pressure.

The water quality monitoring program described herein is intended to supplement information collected under the aforementioned programs. Information gathered though wastewater monitoring, the SMP, and the PEMP will be considered in the reporting phase.

2.1.1 ASSESSMENT SUMMARY

A summary of Project-related pathways of effect, mitigation and offsetting measures, residual effects and monitoring is provided in Table 2-1. The following sections provide a brief summary of the pathways of effect through which the Project may potentially affect water quality and a summary of the assessment results, as presented in the AE SV.

2.1.1.1 PATHWAYS OF EFFECT

Potential effects of the Project on water quality were assessed based on analysis of the following possible pathways of effect:

- Inputs of TSS during Project construction, including instream construction activities and point source discharges;
- Discharge of wastewaters (i.e., treated sewage effluent, concrete equipment washout water, dewatering of cofferdams, etc.) to surface waters;
- Blasting;
- Non-point sources (e.g., runoff from work areas);
- Leachate from rock stockpiles and structures containing rock exposed to surface waters/drainage (e.g., dam);
- Accidental spills/releases;

- Changes in the water regime: changes in water levels, flows, velocities, depths, and residence times may affect mixing, reaeration, accumulation, cycling or losses of substances from the reservoir, and thermal regimes;
- Changes in the ice regime: changes in the spatial extent of open-water areas and/or timing of freeze- up and break-up may affect reaeration (and therefore DO concentrations) and/or light availability;
- Flooding of terrestrial habitat: decomposition of flooded organic materials may affect DO, pH, nutrients (phosphorus and nitrogen), organic carbon, colour, and/or metals; and
- Erosion and sediment transport/deposition: effects on shoreline erosion and sedimentation processes may affect TSS and water clarity.

2.1.1.2 ASSESSMENT RESULTS AND MITIGATION/OFFSETTING MEASURES

Residual effects of the Project on water quality were described in the AE SV for the construction and operation periods. Mitigation/offsetting measures to minimize effects on water quality include:

- Sediment/erosion control measures and implementation of the SMP;
- Treatment of wastewaters prior to discharge to surface waters;
- Avoidance of use of ammonium nitrate fuel oils (ANFOs) in water or in areas that will come into contact with water;
- Conduct of construction activities in-the-dry where feasible;
- Implementation of the Environmental Protection Plan;
- Implementation of the Reservoir Clearing Plan to reduce the quantity of flooded organic materials; and
- Selection of the 159 m reservoir elevation to reduce the proportion of newly flooded area in the reservoir, thereby reducing areas with degraded water quality and reducing potential effect to water quality along the mainstem.

CONSTRUCTION PERIOD

Key residual effects of the Project on water quality during the construction period are:

- Increased concentrations of TSS during instream construction (*e.g.*, cofferdam placement and removal), with the largest increases occurring immediately downstream of construction; and
- Increased concentrations of substances in effluents in the immediate receiving environment.

The primary effect of the Project during the construction phase is related to increases in TSS. Specifically, the Project is expected to cause increases in TSS during critical periods of river management and cofferdam placement/removal. Other pathways of effect (*i.e.*, discharge of point sources) are expected to result in highly localized and negligible to small effects (*e.g.*, wastewater effluent) on water quality.

OPERATION PERIOD

Predicted effects of Project operation are expected to be greatest in flooded, isolated backbays in the reservoir, with small changes expected along the main flow of the Nelson River (upstream in thereservoir and downstream of the GS). In brief, flooded backbays are expected to experience reduced DO concentrations (notably in winter under ice cover), lower pH, reduced water clarity, and increased concentrations of nutrients, colour, TSS/turbidity, total dissolved solids (TDS)/conductivity, organic carbon, and metals. These effects will be greatest during the initial years after impoundment of the reservoir to the full supply level (FSL) and will decline notably thereafter. Water quality conditions in these backbays are expected to stabilize within ten to fifteen years.

Small and few changes in water quality are expected along the main flow of the Nelson River, either upstream of the GS in the reservoir or downstream of the GS. The primary effect on water quality along the main flow of the river is predicted to be reductions in TSS concentrations in the reservoir and for several kilometres downstream in Stephens Lake. Some variables that are correlated to TSS, such as total phosphorus (TP) and some metals, may also slightly decrease in these areas in association with deposition of suspended solids.

2.1.2 IDENTIFICATION OF BENCHMARKS

Benchmarks for the water quality monitoring program have been identified for key water quality indicators (Table 2-2). Key indicators were identified as those most likely to be affected by the Project, for which there is the greatest risk for direct effects on aquatic life, and for which there are objectives or guidelines for the PAL. An assessment of baseline water quality data for the local study area is presented in Appendix 2A.

Benchmarks for key indicators were derived based on four approaches:

- **Approach 1**: For key indicators where Manitoba water quality objectives or guidelines for PAL (Manitoba Water Stewardship [MWS] 2011) are available and the indicator (mean of open-water season) is within the PAL objectives or guidelines under baseline conditions, the MB PAL guideline/objective was identified as the benchmark. For illustrative purposes, site-specific water quality objectives have been calculated based on the baseline mean water hardness for those metals for which the objectives are based on water hardness (cadmium, chromium, copper, lead, nickel and zinc) and the most stringent baseline conditions for pH and temperature for calculating ammonia objectives. For DO, the most stringent objectives for the open-water and ice-cover periods will be used as the benchmarks. The intent is to derive actual site-specific objectives using measured water quality during the monitoring period, where applicable.

- **Approach 2**: Where the mean concentration of a water quality indicator exceeds PAL objectives or guidelines under baseline conditions (*i.e.*, aluminum and iron), the benchmarks were defined as the 95th percentile of the baseline water quality conditions. Baseline water quality conditions have been defined using data collected within the local study area, which ranges from Clark Lake to the Kettle Generating Station. Only sites that were located on the main flow of the Nelson River were included and benchmarks were derived using data collected during the open-water season. Summary statistics for this dataset are presented in Table 2-2. Should additional data be acquired prior to construction, the summary statistics and associated 95th percentiles may be updated and incorporated into the monitoring benchmarks.
- **Approach 3**: For TP, the narrative Manitoba guidelines for TP were not used since mean and median concentrations of TP in the local study area exceed the MB narrative guideline for lakes, ponds, reservoirs and tributaries at the point where they enter such bodies of water under current conditions. Instead, triggers identified in the phosphorus guidance framework for management of freshwater systems developed by the Canadian Council of Ministers of the Environment (CCME 1999; updated to 2014) have been applied for this parameter; use of these triggers as benchmarks is also consistent with the assessment approach presented in the AE SV. This approach applies to two triggers: (i) a shift in trophic status, in this instance from eutrophic to hypereutrophic (see Table 2-3); and/or (ii) an increase in TP of 50% relative to background (see Table 2-2). The lower of these two triggers (*i.e.*, 50% increase) has been adopted as the benchmark; and
- **Approach 4**: For chlorophyll *a*, the benchmark was developed through consideration of baseline water quality conditions and trophic classification schemes in the scientific literature (Table 2-4). Currently the study area is classified as mesotrophic based on mean chlorophyll *a* concentrations (open-water season; Table 2-4). The calculated average boundary between maximum mesotrophic and minimum eutrophic status from the scientific literature is 8.8 µg/L (Table 2-5). This concentration is between the 90th (8.0 µg/L) and 95th percentiles (10.0 µg/L) of the baseline data set. Therefore, the 95th percentile of the baseline data (*i.e.*, 10.0 µg/L) was identified as the benchmark.

2.2 MONITORING ACTIVITIES TO DETECT CHANGE

The following describes the general background, approach, and methods for monitoring water quality during the construction phase until impoundment to the FSL and for the first ten years of operation after full impoundment. A summary schedule for all monitoring activities in relation to Project construction and operation, and the implementation of mitigation measures is provided in Figure 2-1.

2.2.1 MONITORING DURING THE CONSTRUCTION PERIOD

The following section provides a description of water quality monitoring during the construction phase, which is in addition to the monitoring referred to in Section 2.1. The monitoring program described below is based on the current Project construction schedule and timing of sampling may change if the construction schedule is modified in the future.

Water quality monitoring during construction focuses on activities that will increase TSS and related variables in the Nelson River and Stephens Lake, but is also intended to detect unforeseen effects and provide a means for adaptive management. The monitoring described below will provide monitoring information for a broader suite of water quality variables, in addition to TSS, over the construction phase. The overall objective of construction monitoring is to record the net effect of various construction activities on a suite of water quality parameters along the mainstem of the Nelson River.

2.2.1.1 KEY QUESTIONS

The primary effect of the Project during the construction phase is related to increases in TSS. Specifically, the Project is expected to cause increases in TSS during critical periods of river management and cofferdam placement/removal (see Table 2-6). Other pathways of effect (*i.e.*, discharge of point sources) are expected to result in highly localized and negligible to small effects (*e.g.*, discharge of concrete batch plant effluent). Key questions that will be addressed include:

- Has the Project resulted in exceedances of water quality objectives or guidelines for the protection of aquatic life?
- What were the magnitude and spatial extent of effects of construction on water quality?

2.2.1.2 STUDY DESIGN AND DATA ANALYSIS

EXISTING DATA

Water quality has been measured at a total of 41 sites from the inflows to Split Lake to the Nelson River estuary as part of the Keeyask Generation Project environmental studies program (Map 2-1). Sampling was conducted four times in the open-water season (roughly monthly) in 2001 through 2004 and 2009 at a number of sites in the regional study area. Winter monitoring has been conducted at sites that were accessible and deemed safe in the late winters of 2001, 2002, 2004, and 2009. Additional targeted studies (*e.g.*, Access Road stream crossing baseline sampling) have also been conducted in the study area and data collected through these studies will be used where applicable, within the monitoring program.

Additional water quality data have been collected as part of Manitoba and Manitoba Hydro’s Coordinated Aquatic Monitoring Program (CAMP), which was initiated in 2008, in Split Lake, Stephens Lake, the Limestone Forebay, the Lower Nelson River in the vicinity of the potential Conawapa GS, Assean Lake, and the Hayes River. This program is on-going and data collected as part of this program may be used as an additional source of information regarding monitoring during Project construction and operation.

Lastly, data collected under the PEMP and SMP, notably monitoring of TSS and turbidity, will be considered within the AEMP. Specifically, SMP results will be reviewed and results of the water quality monitoring program conducted under the AEMP will consider this information in the overall interpretation of effects to water quality.

STUDY DESIGN

The construction monitoring program is designed to facilitate comparisons of water quality spatially (*i.e.*, upstream and downstream of construction activities) to delineate Project-related effects. Specifically, the program is designed to facilitate statistical comparisons of water quality in a reference area to water quality monitored downstream of construction activities (*i.e.*, areas that are predicted to be most affected by the Project); this area is defined as the local study area (Map 2-2). The reference area will be an area located upstream of Project activities in the lower Nelson River.

In addition, water quality will be periodically monitored at single stations downstream of Stephens Lake to the Nelson River estuary to determine the extent of effects during instream construction in this area; this area is referred to as the regional study area (Map 2-2).

Sampling will be more intensive in the local study area in the vicinity of construction activities (*i.e.*, Gull Rapids and downstream into Stephens Lake). Specifically, water quality monitoring will include monitoring at replicate sites upstream and downstream of construction activities in the local study area, with additional monitoring conducted at a number of sites downstream of the local study area at single sampling sites within the regional study area.

The objective of monitoring during the construction period is to determine if the Project caused or contributed to exceedances of benchmarks (Table 2-2) and to confirm predictions in the AE SV (summarized in Section 2.1.1.2 and in Table 2-1).

DATA ANALYSIS

Data analysis will focus upon key indicators measured in the local study area where replicates will be collected. Comparisons to benchmarks will be done to identify the potential for adverse effects on aquatic biota. Means of each key indicator measured during a sampling period and for the open-water season collectively will be compared to the associated benchmark.

For each key indicator that exceeds a benchmark, a statistical comparison between upstream and downstream sampling areas will be undertaken for each sampling event, and potentially for the open- water season collectively. Data will be first evaluated for normality and equal variance and where the assumptions are met, will be compared through an Analysis of Variance (ANOVA) and a Tukey's test ($\alpha = 0.05$). Where these assumptions are not met, even with standard data transformations, non- parametric analyses will be applied such as the Kruskal-Wallis test followed by the Dunn's multiple pairwise comparisons procedure ($\alpha = 0.05$). Values that are reported below the analytical detection limit will be assigned a value of one half the detection limit.

Data may also be compared to baseline water quality data for the local and/or regional study area to assist with providing additional confidence and context for the monitoring results. Where statistical differences are noted, available regional water quality data will be evaluated to determine the spatial extent of effects.

Correlation analyses and linear regression may also be undertaken to assist with data interpretation and to extrapolate over a broader temporal scale. For example, correlations between TSS and other key indicators, in association with SMP monitoring results, may be undertaken to assist with evaluating potential changes in water quality indicators that may have occurred outside of the water quality sampling periods.

Hydrocarbon data will be screened upon receipt of monitoring results from the analytical laboratory to identify if there is an indication of potential contamination; results will be evaluated for occurrence of detections and comparisons to Manitoba Water Quality Standards, Objectives, and Guidelines (MWQSOGs) for PAL (MWS 2011) where available.

Supporting water quality indicators (*i.e.*, parameters for which there are no PAL objectives or guidelines but may be indicative of general changes in water quality, such as conductivity), will also be evaluated in the reporting phase to assess potential temporal trends.

2.2.1.3 PARAMETERS

Surface water samples will be collected and submitted to an analytical laboratory accredited under the Canadian Association for Laboratory Accreditation Inc. (CALA) for analysis of the parameters indicated in Table 2-7, which include key and supporting indicators. With the exception of benzene, toluene, ethylbenzene, and xylene (BTEX) and F1-F4 hydrocarbons, which will only be measured at sites immediately upstream and downstream of construction activities, all of the parameters listed in Table 2-7 will be measured at each site (*i.e.*, regional and local study areas). *In situ* measurements of pH, temperature, specific conductance/conductivity, turbidity, DO, and water depth will also be collected from each site.

Current laboratory analytical detection limits (ALS Laboratories, Winnipeg, MB) for the parameters identified are also provided in Table 2-7. However, analytical detection limits may vary in relation to the on-going process of method improvement and ensuring that test results are not misrepresented.

Detection limits may decrease as new methodologies and technologies are implemented or may increase to address sample matrix interferences, when sample dilutions are required, or as dictated by the accreditation process.

2.2.1.4 SAMPLING SITES

As described in Section 2.2.1.2, the monitoring program will incorporate monitoring at single sampling sites over the regional study area and monitoring at replicate sampling sites immediately upstream and downstream of construction activities within the local study area

(Map 2-3). Regional sampling sites include Stephens Lake North and sites downstream of Stephens Lake along the lower Nelson River (Map 2-4).

Sampling in the local study area will include replicate sites located in an area upstream of construction activities (as close as feasible without being influenced by construction) and two areas downstream of construction activities. The first downstream area (referred to as "near-field") will be located as close as feasible downstream of all construction activities considering safety and logistics. It is anticipated that the near field area may be relocated over the construction period in accordance with construction activities. The second downstream area (referred to as "far-field"), will be located upstream of the Kettle GS. Five sites will be randomly selected within polygons of 250 m in length and bounded by water depth (> 5 m), distance from shore (> 100 m), and in consideration of SMP logger locations. These boundaries were identified to ensure sites will be located in relatively deep areas even under low water levels and to avoid nearshore areas where localized differences in water quality may occur (e.g., localized shoreline erosion), while also being sufficiently large to accommodate five sampling sites with sufficient separation (i.e., minimum of 20 m separation between sites). The precise location of sites in the vicinity of construction activities will be confirmed during the initial monitoring in 2014. With the possible exception of replicate sites selected in the near-field sampling area, sampling sites are expected to remain the same throughout monitoring activities during the construction period.

The proposed number of replicate sites that will be monitored in the upstream and downstream areas is five. An initial *a priori* statistical power analysis was completed for selected key water quality indicators to determine the appropriate level of sampling effort (i.e., the number of sites per area) required for the conduct of a reasonably statistically robust sampling design (Appendix 2A). Additional power analyses may be completed prior to construction and/or operation to refine the study design and to reassess sample sizes after acquisition of additional water quality data during the construction period and/or if modifications are warranted in the future (*e.g.*, to address changes in MWQSOGs).

2.2.1.5 SAMPLING FREQUENCY AND SCHEDULE

An overview of the monitoring schedule for the construction period is presented in Table 2-6. The precise timing and frequency of sampling will be adjusted upon finalization of the construction schedule and details. The program includes monitoring four times in the open-water season (roughly monthly between June and September/early October) and once in late winter in each year of construction. Precise timing of the monitoring will consider instream construction activities and predictions regarding increases in TSS in the lower Nelson River; efforts will be made to conduct monitoring during periods of peak increases in TSS to capture the period with the highest magnitude of effect[1].

[1] Note that monitoring as part of the Sediment Management Plan will provide continuous data on turbidity/TSS during periods of instream construction.

Monitoring will be conducted in the local study area during each of these monitoring periods. Additional monitoring in the regional study area will be conducted during three periods when TSS is predicted to increase by more than 5 mg/L (as a 24-hour rolling average in the fully mixed river) due to construction (Table 2-6, Map 2-1). These periods are:

- Central Dam Stage 1 Cofferdams;
- South Dam Stage II Cofferdam Construction; and
- Powerhouse Unit 1 Commissioning.

2.2.1.6 FIELD AND LABORATORY METHODS

In situ measurements will be collected using calibrated field meters. Samples of water will be collected by directly filling sample bottles (provided by the analytical laboratory) at approximately 30 cm below the surface at all sites. Samples for laboratory analysis will be submitted to an analytical laboratory accredited under CALA.

A Quality Assurance/Quality Control (QA/QC) plan will be developed prior to program implementation and will outline the planning, implementation, and assessment procedures to be used in order to apply specific QA/QC activities and criteria to the AEMP. In brief, the QA/QC plan will include QA/QC samples (i.e., trip blanks, field blanks, site replicates), sampling protocols, and data handling procedures.

2.2.1.7 BENCHMARKS

A description of the approach for derivation of water quality benchmarks is provided in Section 2.1.2 and benchmarks for key water quality indicators are presented in Table 2-2. Appendix 2A presents the results of a review of baseline water quality data, which was used as the foundation for benchmark development and for conduct of *a priori* power analyses.

2.2.2 MONITORING DURING THE OPERATION PERIOD

This section presents the design, rationale, and methods for surface water quality monitoring during the operation phase of the Project. It is expected that the details of the operation monitoring program will be re-examined prior to commencement of the operation period, as additional data are acquired during the construction period. Specifically, the construction monitoring program will generate additional data that will augment the baseline dataset, which could in turn increase the rigour of the operation monitoring program (*i.e.*, statistical power). Further, reconsideration of benchmarks identified herein should be undertaken prior to operation to consider lessons learned during construction monitoring and evolution of scientific information such as water quality guidelines.

2.2.2.1 KEY QUESTIONS

Key questions that will be addressed through water quality monitoring during the operation phase are:

- Does Project operation cause or contribute to exceedances of water quality objectives or guidelines for the protection of aquatic life?
- What are the magnitude and spatial extent of effects of operation on water quality?
- Are changes in water quality consistent with predictions in the AE SV (Table 2-1)?
- Are there seasonal differences in effects on water quality?
- How does water quality vary over time?

2.2.2.2 STUDY DESIGN AND DATA ANALYSIS

STUDY DESIGN

The objective of operation monitoring will be to determine if the Project caused or contributed to exceedances of benchmarks (Table 2.2) and to confirm predictions in the AE SV (summarized in Section 2.1.1.2 and in Table 2-1). The study design for the operation period is similar to the design described in Section 2.2.1.2 for construction monitoring. In brief, monitoring will be conducted in areas upstream of the reservoir, within the reservoir and downstream of the reservoir in Stephens Lake (*i.e.*, the local study area). The study design will facilitate comparisons of water quality during the operation period to baseline data as well as spatially within the study area. The study design will also facilitate tracking of water quality conditions over time (*i.e.*, evaluation of trends).

Water quality monitoring during the operation phase is focussed upon the Keeyask reservoir and Stephens Lake (i.e., the local study area), which incorporate the predicted spatial extent of effects on water quality during operation (Map 2-5). The north basin of Stephens Lake is relatively isolated from the main flow of the Nelson River that runs along the southern area of the lake (i.e., the mainstem of the lower Nelson River) and will be monitored to confirm the predictions that this area will not be affected by the Project and to provide additional reference area monitoring information.

Periodic monitoring downstream of Stephens Lake in the regional study area (Map 2-4) will also be included to confirm the impact assessment predictions that water quality in this area will not be affected; monitoring downstream to the Nelson River estuary will be conducted in Year 1 of operation when effects of the Project on water quality are expected to be the greatest. Results of the Year 1 monitoring will be reviewed in the context of the adaptive management framework (Section 2.3.1) to determine the need for future monitoring downstream of Stephens Lake.

EXISTING DATA

See Section 2.2.1.2 for a description of existing water quality data.

DATA ANALYSIS

Data analysis will focus upon key indicators measured in the local study area where replicates will be collected. Comparisons to benchmarks will be done to identify the potential for adverse effects on aquatic biota. Key indicators measured during a sampling period and for the open-water season collectively will be compared to the associated benchmark. Data may also be compared to baseline water quality data for the local and/or regional study area to assist with providing additional confidence and context for the monitoring results. For sampling areas with replicate sites, the means of a key indicator measured during each sampling period will be compared to the benchmark. Where sampling is conducted at a single site (i.e., north arm of Stephens Lake, the Kettle GS, sites downstream of the Kettle GS, and reservoir backbays), comparisons to the benchmarks will be done for individual data points and for the open-water season means.

For each key indicator that exceeds a benchmark, a statistical comparison between upstream and downstream sampling areas located along the mainstem of the Nelson River will be undertaken for each sampling event, and potentially for the open-water season collectively. Statistical comparisons will be conducted for areas in which replicate samples are collected. Data will be first evaluated for normality and equal variance and where the assumptions are met, will be compared through an ANOVA and a Tukey's test ($\alpha = 0.05$). Where these assumptions are not met, even with standard data transformations, non-parametric analyses will be applied such as the Kruskal-Wallis test followed by the Dunn's multiple pairwise comparisons procedure ($\alpha = 0.05$). Values that are reported below the analytical detection limit will be assigned a value of one half the detection limit. Where statistical differences are noted, regional water quality data (e.g., data collected downstream of Stephens Lake) will also be evaluated to evaluate the spatial extent of effects.

Data collected from backbays in the reservoir will be compared to water quality measured in the mainstem of the reservoir, using the same statistical approaches indicated for analysis of data collected along the mainstem of the Nelson River. Water quality monitoring results collected at sites without replicate sampling will be qualitatively assessed for indications of Project effects.

Monitoring results will also be compared to predictions presented in the AE SV (Table 2.1). These comparisons will serve to confirm assessment predictions in terms of the nature, direction, magnitude, spatial extent, and duration of predicted effects. Trend analyses will be included to track temporal changes in conditions.

Supporting water quality indicators (i.e., parameters for which there are no PAL objectives or guidelines but may be indicative of general changes in water quality such as conductivity), will also be evaluated in the reporting phase to assess potential spatial and temporal trends.

2.2.2.3 PARAMETERS

The monitoring program will include collection of samples for laboratory analysis and measurement of *in situ* water quality variables. Laboratory variables will include pH/alkalinity, nutrients, TSS/turbidity, true colour, organic carbon, metals, and conductivity/TDS (see Table 2-8 for details). Table 2-8 presents a list of laboratory water quality parameters and current analytical detection limits (ALS Laboratories, Winnipeg, MB). *In situ* parameters will include temperature, pH, DO, turbidity and conductivity and Secchi disk depth where velocities are low.

2.2.2.4 SAMPLING SITES

In the local study area, sampling sites will be located in areas on the main flow of the river and representative backbays in the reservoir, areas in Stephens Lake (including the southern and northern areas of the lake), and a reference area located upstream of the hydraulic zone of influence of the Project (Map 2-5). During the first year of operation monitoring, water quality sampling will also include monitoring at single sites on the lower Nelson River downstream of Stephens Lake to the estuary

(*i.e.*, regional monitoring); if no effects are observed, this sampling will be scaled back in future years.

Like the construction monitoring plan, monitoring during operation will include a combination of single sampling sites and sampling at replicate sites in the local study area; following completion of the first year of monitoring, the number of replicate sites will be reassessed and may be modified after that time. It is anticipated this review may include application of the adaptive management assessment framework and, potentially, power analyses.

Monitoring will include sampling at five replicate sites at an upstream area (*i.e.*, Clark Lake; upstream of the hydraulic zone of influence), which will serve as the reference area, two areas in the reservoir, and two areas downstream of the GS in Stephens Lake (Map 2-5). Single sampling sites will include the north arm of Stephens Lake, a site just upstream of the Kettle GS, the Long Spruce and Limestone GS forebays, and additional sites downstream along the lower Nelson River.

In addition to sampling the mainstem of the reservoir and Nelson River, four representative backbays will be included in the operation monitoring program (Backbays 4, 8, 11, and 12; Map 2-5). Water quality was predicted to be the most affected due to the combined effects of peatland disintegration and flooding in Backbays 4, 8, and 11. In addition, these backbays capture the areas predicted to be most affected by peatland disintegration (Backbay 8) and by flooding (Backbay 4). Backbay 12 is the largest backbay and portions will experience substantial effects to water quality; this backbay is also important to the fish community (Section 5.0).

Like monitoring on the mainstem of the Nelson River, five sites will be sampled in each backbay for the variables listed in Table 2-8*. In situ* measurements of pH, conductivity, temperature, DO, and turbidity may also be collected at additional sites to examine spatial variability in conditions in the backbays. The intent is to evaluate water quality overall in these areas, but to also provide a measure of spatial variability and mixing (*i.e.*, what is the spatial extent of water quality effects). Following the first year of monitoring, the results will be reviewed to determine which backbays will be monitored thereafter and if modifications to the sampling program are warranted (*e.g.*, change in the number or location of sampling sites). Specifically, it is anticipated that modifications to the program may be suggested based on the occurrence and locations of benchmark exceedances, comparisons to EIS predictions, power analyses, and/or consideration of monitoring results for other components.

2.2.2.5 SAMPLING FREQUENCY AND SCHEDULE

Water quality will be monitored annually for the first three years of Project operation. As indicated in Section 1.0, a review in the fourth year of operation will identify whether the sampling frequency can be reduced at some locations. However, it is anticipated that monitoring will continue annually at some locations for the first ten years of operation. Sampling frequency will include four sampling periods in the open-water season (over the period of June-October) and one sampling period in late winter (*i.e.*, February/March) during the initial three years of operation. As Project operation is predicted to cause notable decreases in DO in isolated flooded backbays in winter, a second winter sampling event to measure DO will be conducted in early winter the first year after full impoundment; results of this winter DO monitoring will be reviewed and considered in terms of modification to the monitoring program in subsequent years.

2.2.2.6 FIELD AND LABORATORY METHODS

In situ measurements will be collected using a calibrated field meter; incremental depth profiles of *in situ* parameters will be obtained in low velocity areas, including but not limited to lentic areas of the reservoir and lakes. Samples of water will be collected by directly filling sample bottles (provided by the analytical laboratory) at approximately 30 cm below the surface at all sites. Samples will also be collected at approximately 1 m above the sediments using a van Dorn or Kemmerer water sampler at sites located in flooded backbays and the site in the north arm of Stephens Lake. See Section 2.2.1.6 for a description of QA/QC plan development.

2.2.2.7 BENCHMARKS

Key water quality indicators and benchmarks for the operation period are presented in Table 2-2. Indicators and benchmarks are consistent with those for the construction monitoring program with the exception that methylmercury is included for the operation period. Methylmercury is included as a key indicator for the operation period due to its direct linkage with flooding of terrestrial organic material.

See Section 2.1.2 for a description of rationale and methods for selection of key indicators and benchmarks.

2.3 MANAGEMENT RESPONSE FRAMEWORK

2.3.1 ADAPTIVE MANAGEMENT ASSESSMENT FRAMEWORK

During the Project construction period, the primary mechanism through which adaptive management will be implemented is through the SMP and monitoring of point sources as described in the EnvPP. As the key effect of Project construction identified in the AE SV is the potential for increased TSS, the SMP will provide the primary framework for monitoring the key impact pathway and subsequent implementation of adaptive management measures. In particular, the SMP has been designed to provide a means for monitoring this key pathway of effect through use of turbidity loggers and as such, will provide a means for rapid assessment of changes and subsequent implementation of adaptive management.

The water quality monitoring program that will be implemented during construction and operation is intended to provide a means for monitoring effects to water quality parameters other than TSS (although TSS will also be monitored during the water quality monitoring program) specifically to monitor for potential unforeseen effects and subsequently provide a mechanism for adaptive management.. The intent of the adaptive management framework is to provide a means for identifying potential changes in water quality that may be harmful to aquatic biota. A management response framework is presented in Figure 2-2.

Data will first be subject to QA/QC review, graphical examinations (e.g., box and/or scatter plots), and initial screening (e.g., identification of outliers). Data will then be compared to benchmarks as identified in Table 2-2 (Step 1). If a benchmark is not exceeded, the assessment will proceed to Response Level 1 – trend analysis. In this instance, key indicators will be described and tracked over time to assess whether there is an upward or downward trend that may suggest escalating effects. Trend analysis will be a key assessment tool for the operation period as it will provide a means for confirming the duration of effects identified in the AE SV.

If a benchmark is exceeded, the assessment will proceed to Step 2 – determination of whether there is a statistical difference between upstream and downstream areas (i.e., control-impact), between backbay and reservoir mainstem areas (i.e., spatial differences), and/or relative to baseline conditions (before-after). If a statistical difference is not observed, the assessment will proceed to Response Level 1.

Where statistical differences are identified for key indicators, the assessment will proceed to Step 3 in which a determination of cause (i.e., is the difference Project-related) will be undertaken. By design, the program will provide information to speak to this question (i.e., upstream versus downstream comparisons). However, additional analyses that may be undertaken could include:

- Evaluation of timing and locations of construction activities and comparisons to water quality monitoring results (e.g., do the timing and locations of construction activities coincide with observed changes in water quality?);

- Evaluation of data to identify potential spatial patterns in water quality and the potential role of the Project in observed differences;
- Evaluation of data collected under the SMP and wastewater effluent monitoring;
- Evaluation of water quality data collectively, which may suggest cause;
- Consideration of local, non-Project related activities/influences that may affect water quality; and/or
- Review of regional water quality data to evaluate if similar changes have occurred in other areas that may not be Project-related.

If the observed difference is determined to be not Project-related, the assessment will proceed to Response Level 1. If it is concluded that the change is due to or likely due to the Project, the assessment will proceed to Response Level 2.

2.3.1.1 RESPONSE LEVEL 1

Response Level 1 will include trend analyses and general descriptions of the monitoring results. It is noted that temporal trends will not be discernible until several years of data are obtained.

2.3.1.2 RESPONSE LEVEL 2

It is important to identify *a priori* that data will be considered for individual indicators but the overall assessment and subsequent actions that may be undertaken under Response Level 2 will consider changes to various water quality indicators individually as well as collectively. Actions that will be undertaken or considered under Response Level 2 include:

- Conduct trend analysis;
- Compare results to predictions in the AE SV (Table 2-1);
- Investigate contribution of the Project to the observed effect(s);
- Evaluate spatial and temporal extent of the observed effect(s);
- Consider results of biological monitoring (*e.g.,* does the area where a benchmark exceedance is exceeded support fish spawning);
- Determine need for additional monitoring and/or focused study;
- Evaluate potential sources/causes and potential for continued contributions/effects;
- Consider regional information on the indicators of concern for assisting with interpretation of results; and
- Consider mitigation/management and determine next steps and/or additional follow-up action that may be required/warranted.

Comparison to predictions in the AE SV is considered critical as the AE SV identified several construction periods associated with major instream activities that are likely to result in exceedances of the chronic PAL objective for TSS. Similarly, exceedances of some benchmarks were predicted for backbays in the Keeyask reservoir, primarily during the initial years of operation. For monitoring during the operation period, the analyses will be more focused on tracking trends in water quality over time to confirm predictions; specifically, a key objective of the operation monitoring program will be to confirm the predictions that effects will be greatest in the first year of impoundment, with decreases thereafter.

Monitoring data will be compared to benchmarks, which are largely PAL objectives and guidelines, to screen for potential adverse effects on aquatic life. However, it is emphasized that exceedances of some PAL objectives or guidelines were predicted in the AE SV for flooded backbays; therefore, a key component of the management response framework is not only comparisons to benchmarks, but also comparisons to predictions in the AE SV (Table 2-1).

Consideration of the results of biological monitoring is also critical, as this information will provide the means for assessing ecological relevance of the observed changes in water quality and ultimately the appropriate management response. Follow-up monitoring and/or focused studies could be undertaken to provide detailed, site-specific information on effects to the aquatic environment.

Lastly, it should be noted that there are inherent limitations in options for management actions associated with the Project during the operation period. The primary pathway of effect to water quality is flooding of terrestrial habitat and this pathway cannot be mitigated.

Review of the monitoring program and benchmarks will be undertaken throughout the implementation of the construction and operation monitoring programs with the expressed intent to provide a mechanism for modification as data are acquired.

3.0 AQUATIC HABITAT

3.1 INTRODUCTION

Aquatic habitat provides the environment in which aquatic biota live, as defined by water depth, velocity and substratum, as well as structure, including non-living and living (rooted plants) components.

Monitoring of Project-related changes to aquatic habitat will occur within the area of direct effect (Clark Lake to Stephens Lake reach, Map 1-2). Monitoring will record changes over time in existing aquatic habitat that is altered by the Project (e.g., increased water levels); document the evolution of flooded terrestrial habitat into productive aquatic areas; and assess conditions on structures constructed to offset habitat loss.

Information related to aquatic habitat will also be collected as part of the PEMP, including water level, depth, and velocity measurements at site specific locations to support aquatic habitat monitoring. Other activities in the PEMP, such as monitoring ice regime, erosion of mineral and peat shorelines, and rate sediment deposition, will be used to complement the aquatic habitat monitoring program.

No monitoring of aquatic habitat prior to impoundment of the reservoir to the full supply level will be undertaken. Potential effects on substrate composition related to the deposition of sediments released during instream construction will be assessed during the initial round of monitoring after the reservoir is impounded and instream construction is complete. Likewise, habitat changes due to water level changes that begin in the reservoir during construction will be monitored after impoundment is complete.

A monitoring program will identify whether debris is accumulating in the mouths of tributary streams, which could block access by large-bodied fish, and provide for the removal of that debris. These activities will occur in coordination with the Waterways Management Program, and are not discussed further in this AEMP.

The remaining sections of this introduction provide a summary of the aquatic habitat assessment (Section 3.1.1) and a discussion of benchmarks applicable to aquatic habitat (Section 3.1.2).

Monitoring activities to detect change are described in Section 3.2, as follows:

- Section 3.2.1 Development of nearshore and aquatic macrophyte habitat;
- Section 3.2.2 Deep water substrate composition; and
- Section 3.2.3 Monitoring of sensitive and constructed habitat.

Section 3.3 describes the management response framework for the aquatic habitat assessment.

3.1.1 ASSESSMENT SUMMARY

A summary of Project-related pathways of effect, mitigation and offsetting measures, residual effects and monitoring is provided in Table 3-1.

This section first summarizes the pathways of effect and predicted residual effects to aquatic habitat for the operating period of the Project, once the appropriate mitigation measures are applied. Monitoring activities to record the development of nearshore and deep water habitat, and assess sensitive and constructed habitat, are also summarized.

RESERVOIR

Impoundment of Gull Lake to form the Keeyask reservoir creates a pathway of effect where water levels rise and water velocity decreases. The principal residual effect predicted for the Nelson River and tributary creeks in the AE SV was an increase in silt deposition for much of the inundated area. No changes were predicted up river of present day Gull Lake where changes in depth and velocity were predicted to be relatively small. The substrate in the main channel of the river is expected to remain as it is today.

The flooding of terrestrial areas creates several pathways of effect that arise from the creation of lentic habitat. Residual effects predicted within the newly flooded area include peat resurfacing, formation of peat islands, and deposition of large areas of silt which was land before the Project. The wetted perimeter of the reservoir creates pathways of effect that operate within relatively short timescales. Predicted residual effects near the water's edge result from water level variation and wave action that, over time, is expected to develop into a silt free nearshore zone, except in flooded creek mouths. Some of the nearshore zone of the reservoir will become rooted macrophyte habitat. Another residual effect is the creation of bay habitat where a fine organic substrate will underlie humic water masses surrounded by peatlands. Reservoir-wide residual effects were predicted for the ice regime. This included changes in ice cover and timing of ice-on and ice-off.

DOWNSTREAM OF THE KEEYASK GS

Operation of the Keeyask GS is expected to create two main pathways of effect for the aquatic habitat of the downstream environment. The first change may arise from alteration of the path and magnitude of flow during powerhouse operation. Operations will realign the path of the main flow more to the south side of the channel. The predicted residual effect is a loss of lotic habitat along the north bank about

1 km below the tailrace where new lentic habitat is expected to form. The second predicted pathway of effect is the loss of the hanging ice dam. It is thought that the hanging ice dam during winter prevented deposition from occurring in the lentic habitat that otherwise was present during summer. Consequently, the interaction of both pathways may create a new area of deposition along the north bank where it did not exist before.

No change to substrate composition in Stephens Lake is expected due to sediments during construction or as a result of flow changes during the daily operations of the GS. The Physical Environment studies suggest that a thin layer of sediment will be transported and deposited in the river more than 4 km below the GS as a result of construction. These materials are expected to sort by size during the early period of operation, as has been observed today. No change in substrate composition is expected. Daily water level variation will increase due to Keeyask GS operations but this daily range will be sufficiently small that no measurable change to habitat is predicted.

OVERVIEW OF MONITORING

The objective of the monitoring is to confirm predictions in the AE SV (outlined above and summarized in Table 3-1), and to monitor the ongoing changes in the reservoir relative to Stephens Lake. In doing so, any differences between predicted and observed effects may require adaptive management to maintain the long-term goals (*e.g.*, presence of specific types of habitat upstream and downstream of the GS).

The design of the monitoring program aims to: (i) validate predictions in the AE SV regarding the type, rate, magnitude, direction, and sequences of change of habitat as it develops over time, and (ii) to monitor the areas impacted by flooding with comparison to proxy/reference areas. The types of comparisons employed are the Before/After and Impact/Reference designs. Three programs will record the predicted residual and null effects over time.

1. Development of nearshore and aquatic macrophyte habitat – this program will provide the first detailed study of the rate that nearshore habitats form in a sub-arctic reservoir, and will provide an understanding of the variables that force and maintain habitat distributions (*e.g.*, sediment boundaries, macrophyte distributions, effects of water level variation). The post-Project data will be compared to baseline data and reference sites in Stephens Lake.
2. Deep water substrate composition – this program will monitor the state of deep water substrates in water depths greater than 3 m in the reservoir and below the GS. In the reservoir, the pattern of silt sedimentation in the pre-flood river channel and the development of substrate in flooded terrestrial habitat will be compared to post-Project substrate maps presented in the AE SV. The river channel below the GS will also be examined to determine whether new deposition occurs in a relatively small area along the north bank, and to confirm that no changes in substrate composition are occurring in young-of-the-year (YOY) Lake Sturgeon habitat at the inlet to Stephens Lake.
3. Monitoring of sensitive and constructed habitat(s) - the state of habitats considered sensitive for YOY Lake Sturgeon will be monitored with emphasis near the entrance to present-day Gull Lake, the existing habitat used in the side channel around Caribou Island, and below the GS. Constructed Walleye and Lake Whitefish spawning habitats in the reservoir, Lake Sturgeon spawning habitat at the tailrace, and Lake Whitefish spawning habitat near Stephens Lake, will be compared to their design criteria to ensure that the structures provide habitat with the intended characteristics.

3.1.2 IDENTIFICATION OF BENCHMARKS

The use of a benchmark in a monitoring study implies that a reference condition exists or a threshold value is available to help to guide the adaptive management aims of a program over time. Unfortunately, benchmarks are not available for the aquatic habitat of similar reservoirs; reservoirs in similar physiographic and climactic settings are few, the net result of the changes tends to be site specific, and no reservoirs provide precisely the same conditions to provide a reference site. Consequently, the aim of the aquatic habitat monitoring program is to collect the information that will enable comparisons to assess the status and trends over time. The approach is based on the Before-After Control-Impact (BACI) design, with the caveat that a control site is unavailable so Stephens Lake will serve as a reference site that is similar, but not exactly like, the impacted site. The main types of comparisons will be:

- Before and after comparisons - data from the monitoring program will be compared to data collected from the existing environment and/or to the expected condition based on either inference or modelling;
- Use of proxy sites (*i.e.*, reference sites) that provide similar reference conditions from which to base comparisons;
- Trends over time; and
- Design criteria for constructed habitat.

The current understanding of habitat distributions in the reservoirs of the lower Nelson River mostly coincides with the onset of the Keeyask Project environmental studies, when the reservoirs were more than 20 years old. As a result, the before and after comparisons that will be undertaken early in the Keeyask reservoir's development will sometimes be qualitative and descriptive as this will be the first detailed monitoring of this type. Comparisons to reference sites in Stephens Lake will be quantitative and area-based as the reservoir ages, heterogeneity decreases, and habitat develops.

The state of knowledge available at the time specific monitoring activities are conducted will be used to refine monitoring in comparison to techniques used at the time of the environmental assessment. This will also be the case for technologies used to map habitat. In lieu of benchmarks the general approach will be to follow trends over time, and assess if unanticipated change occurs. If so, adaptive management may include an increase in the frequency of monitoring to determine if the condition of the habitat of concern is a short-term (*e.g.*, result of a storm) or long-term state. Discrepancies in observed versus predicted habitat will be considered in the assessment of the fish community and Lake Sturgeon to inform whether additional measures are required.

Habitats constructed for offsetting habitat loss, as well as sensitive habitats, will be evaluated relative to the design criteria known today (*e.g.*, suitable velocity distribution for Lake Sturgeon spawning), and also consider the state of knowledge at that time. The intent will be to verify that the constructed habitat continues to have the intended structure, and performs the desired function, for species over time.

3.2 MONITORING ACTIVITIES TO DETECT CHANGE

The following describes the general background, approach, and methods for monitoring aquatic habitat. A summary schedule for all monitoring activities in relation to Project operation and the implementation of mitigation measures is provided in Figure 3-1.

3.2.1 DEVELOPMENT OF NEARSHORE AND AQUATIC MACROPHYTE HABITAT

The components of the nearshore and aquatic macrophyte habitat program are listed in Table 3-2. This table provides an overview of the variables to measure, the sampling design, and sampling frequency and schedule.

Data collected in shallow water areas (less than 3 m) will be used to monitor changes in flooded areas that develop into new nearshore and macrophyte habitat as the Keeyask reservoir ages. These data will also be compared to reference data from the flooded area of Stephens Lake, which is considered a future proxy for the Keeyask reservoir at about 25 years after flooding. When the Keeyask reservoir is about 25 years old, the post-Project predictions of potential macrophyte habitat and the actual area occupied by macrophytes will be compared to the observed monitoring data. Changes observed during monitoring will be quantified and linked to other components of the aquatic environment, including benthic macroinvertebrates and fish.

KEY QUESTIONS

Upstream of the GS, the development of nearshore habitat and areas suitable for aquatic macrophytes depends primarily on changes in water level, exposure, the type and distribution of pre-flood soils, the boundary between humic and turbid water masses, and the processes of erosion, transport, and deposition of sediments. Generally, it is the rate of habitat development in the early years of the reservoir that is most uncertain.

The key questions for this monitoring component are:

- How will nearshore habitat develop in the Keeyask reservoir?
- How will aquatic macrophyte habitat develop in the Keeyask reservoir?
- How precise were the predictions in the AE SV (Table 3-1)?

STUDY DESIGN AND DATA ANALYSIS

Habitat changes in the reservoir will be addressed using two methods: (i) high resolution remote sensing to provide a “big picture” measure of change; and (ii) detailed aerial and boat-based surveys to provide information on changes at specific sampling points.

REMOTE SENSING

Changes in the shape of the reservoir and the rate of shoreline changes can exert a strong control on the availability and quality of future nearshore habitat. High resolution satellite remote sensing will be used to track reservoir changes using optical and microwave frequencies. Imaging will be most frequent in the first three years, when changes to shorelines are expected to occur at the highest rate, with reduced frequency from years four to ten as the rate of change decreases, and occasional frequency thereafter.

This imaging program will also capture the distribution of humic and turbid water masses in the reservoir, which will affect the amount of suspended sediment available for deposition and the long-term development of substrate (see Section 3.2.1.4).

AERIAL AND BOAT-BASED SURVEYS

Development of nearshore habitat will be monitored using a stratified random study design. The main types of flooded terrestrial soils will be partitioned (i.e., deep peat, thin peat overlaying mineral soils, and mineral soils) by water mass types (i.e., turbid, humic from local peatland drainage) over a range of surface wave energy conditions and zones of daily water level variation. Macrophyte data will be collected to document their vertical distribution over time with particular emphasis on the factors that control the upper and lower limits of their distribution. The intent is to understand the initial flooded condition, the forces that form and maintain the habitat over time, and the response resulting from the development of habitat. In Stephens Lake, the reference sites will be studied to develop a statistical distribution of macrophyte presence along the elevation gradient in the intermittently exposed zone (IEZ) and permanently wetted zone (PWZ) which will be related to the water surface level variation, light regime, and sediment boundaries.

Existing Data

Shoreline and elevation data were developed for the future Keeyask reservoir area as presented in the Keeyask Generation Project Physical Environment Supporting Volume (PE SV).

Nearshore and aquatic macrophyte surveys documented habitat criteria in the flooded areas of Stephens Lake during 2005-2007 (Cooley et al. 2009; Larter and Cooley 2010). These investigations were based on physical environment studies that classified pre-flood soil types located within Stephens Lake today, and classified how the soils change after flooding (e.g., peat resurfacing and transport) (ECOSTEM Ltd. 2013). The rate of light extinction in the main types of water masses and euphotic depths were estimated (Cooley and Dolce 2008). Data were collected along more than 500 transects in the west end of Stephens Lake where conditions are similar to those expected in the proposed reservoir, and the pre-flood conditions are known. The area of potential macrophyte habitat for Year 30 was estimated using a predictive model that employed Discriminant Analysis. Species seldom fully occupy the entire potential habitat available. In Stephens Lake, two detailed study areas showed that the macrophytes occupied about 10% of the available potential habitat (Larter and Cooley 2010).

Data Analysis

Changes in reservoir geometry, the water's edge boundaries representing the perimeter of the reservoir, islands, and mobile peat will be extracted from the microwave imagery using an approach developed specifically for this reservoir (Larter 2010). Multivariate methods will be used to classify the surface water mass distribution from the optical data. The extracted features will form a time series dataset to show shoreline recession and any changes in the location of the boundaries that separate the water masses.

Nearshore topographic profile data collected by boat-based sampling will describe the elevation and slope profile, the antecedent water level variation on the profile, and substratum types. For transects with occasional rooted macrophytes present, the GPS location (sub-meter) will be recorded and the species of plant(s) will be noted. The surface area of the plant beds will be captured with high-resolution satellite images from the reference sites in Stephens Lake. These reference sites selected from Stephens Lake will follow the same stratified random design and field methods applied to the Keeyask reservoir. Comparisons between the Keeyask reservoir and the reference sites in Stephens Lake will help to determine if the vertical zonation of plants, or lack thereof, is a result of habitat instability (*e.g.*, peat resurfacing), water surface regime, or both.

3.2.1.1 PARAMETERS

Satellite imaging parameters will include the measurement of microwave backscatter (*i.e.*, sigma naught) for water's edge data, and multi-band optical wavelength data to capture the surface characteristics of the water masses (interval data, 16 bit precision).

Parameters for the nearshore area will include bed elevation (m), water surface elevation (m), substrate type (Wentworth mineral classes + organic), substrate composition (percent grain size fraction), aquatic macrophyte species composition and abundance, water level variation data (+/-0.1 m), and the ratio of the area occupied to the potential habitat available. Acoustic bottom typing information will use parameters derived from the acoustic waveform data which may include measurements based on the magnitude and duration of the echo (*e.g.*, hardness and roughness), or alternatively, by assessment of the shape of the echo.

3.2.1.2 SAMPLING SITES

Sampling sites along the shoreline of the Keeyask reservoir will be identified according to the study design (Section 3.2.1.2) in order to monitor the nearshore area, and the development of aquatic macrophyte habitat on both mineral and fine organic substrates (Map 3-1). Sites will also include several representative backbays (in zones 4, 8, and 12; Map 2-5) that are being sampled in the water quality, benthic invertebrate and fish community monitoring programs to provide an integrated record of biological response to habitat development in flooded areas. Downstream of the GS, studies of macrophyte occupation in Stephens Lake will continue to document the vertical zonation of plants with respect to the water regime. The evolution of rooted macrophyte habitat will be monitored at three to five reference sites in Stephens Lake.

3.2.1.3 SAMPLING FREQUENCY AND SCHEDULE

Monitoring studies will begin when the reservoir attains the FSL for the first time.

Three satellite images from each platform will be acquired during the open-water period (spring, summer, and fall) during each of the first three years. Image captures for the first ten years will be annual, but frequency may be reduced if the annual rate of change is small.

Nearshore habitat sampling will occur in each of the first three years after attaining FSL, and then at least once every three years until ten years post-impoundment. Monitoring may continue at a reduced frequency until 25 years post-impoundment, if nearshore habitat continues to evolve after the initial 10 years. Aquatic macrophyte surveys and nearshore habitat sampling will occur at the same time, although the macrophyte habitat may take up to 15 years to develop, depending on site conditions. Aquatic macrophyte surveys and satellite imaging will target mid-to-late summer when plant growth is most evident.

Sampling of aquatic macrophyte habitat in Stephens Lake will occur concurrently with sampling in the reservoir, although it may be at a lower frequency, depending on results.

3.2.1.4 FIELD AND LABORATORY METHODS

Sites will be selected during boat-based reconnaissance according to the study design (Section 3.2.1.2). Each site visited during the first survey will be large enough to allow for replication of transects to assess local heterogeneity of the substrate. Surveys at these sites will be repeated over time using the same measures to describe the development of nearshore habitat as the Keeyask reservoir ages. Transects will be perpendicular to the shoreline and will extend below the maximum recorded photic zone (relative to the minimum operating level of 158 m) to document any changes in topographic profile and bed composition. Substrate composition, water velocity, water surface elevation, and bed elevation along each transect will be sampled using GPS and hydro-acoustic technology. The entire set of replicate transects will be classified at high detail using acoustic bottom typing software and geographic information systems. Side scan sonar, which provides images of the bottom, will be the primary means for assessing local heterogeneity in bottom composition. Ponar and/or Ekman dredge samples will validate the sonar data.

Macrophyte sampling will begin when the early signs of growth are visible in the reservoir. Transects will target areas where plants are growing. Sampling at these sites (and new ones that develop) over time will be compared to the existing multivariate distribution that describes plant occupation in the potential habitat. Satellite remote sensing will document the change in the location, shape, and area of aquatic macrophyte beds and the associated nearshore area (see Larter and Cooley 2010 and Appendix 3B of the AE SV for methods). Helicopter reconnaissance will compare the observations made by boat at the nearshore field sites (for plants and optical characteristics of the water masses) to other areas around the reservoir as it ages, as well as, to validate the remote sensing imagery. Later, possibly fifteen years after impoundment to FSL, remote sensing and validation with a helicopter (methods consistent with those used during environmental assessment studies; see Appendix 3C of the AE SV) may be used to determine the areas occupied by plants relative to the potential habitat that is available. When the Keeyask reservoir attains a ratio of occupied to potential aquatic macrophyte habitat similar to that of Stephens Lake, or when changes within the system subside (*i.e.*, no appreciable change in the area occupied by plants over time), the monitoring program will be discontinued.

3.2.1.5 BENCHMARKS

The primary uncertainty with respect to the nearshore habitat predictions is the rate at which habitat develops. Changes can be grouped into three key periods of time. Many of the predicted large magnitude changes will occur within the first three years after FSL is reached. Four to ten years after impoundment, the physical processes in the reservoir continue at accelerated but slower than initial rates. Later, after ten to fifteen years, the physical processes in areas of the reservoir begin to slow, and the long-term habitat patterns expected in shallow water areas of the reservoir should emerge. Collectively, the changes during the first three years provide the basis for many predicted states later in the reservoirs' development.

If unanticipated changes are observed, the stratified random approach will be revised to adapt and refocus effort. For example, if macrophyte colonization during the first 15 years is not developing as expected, results of the PEMP and AEMP studies (including water regime) will be reviewed for causality. Concurrent observation of macrophyte beds in Stephens Lake will be undertaken and may help to determine whether the observed changes are unique to the Keeyask reservoir.

3.2.2 DEEP WATER SUBSTRATE COMPOSITION

Monitoring of substrate composition in deep water (greater than 3 m) will be conducted as there is the potential for it to change over time in the Keeyask reservoir and downstream of the GS. The components of this program are listed in Table 3-3. This table provides an overview of the variables to measure, the sampling design, and sampling frequency and schedule.

3.2.2.1 KEY QUESTIONS

The evolution of substrate composition in deep water within the newly formed reservoir depends mostly on the pattern of water velocities that develop within the reservoir, and how the processes of erosion, transport, and deposition in the river channel maintain or alter the existing substrate.

Potential effects on aquatic habitat downstream of the GS include the deposition of fine sediments over existing cobble and gravel substrate in the channel area and the existing sand lens in upper Stephens Lake.

The key questions for this monitoring component are:

- How will substrate composition change over time in deep water in the Keeyask reservoir and downstream of the GS (including in the area of existing YOY Lake Sturgeon habitat in Stephens Lake)?
- How many years into the operation period will it take for substrate boundaries to form?
- Will fines (sand/gravel) deposit below the Birthday Rapids area in slow lotic habitat (*i.e.*, will new YOY Lake Sturgeon habitat form in the reservoir)?
- Will fines (sand/gravel) deposit in the area near the entrance to present day Gull Lake (*i.e.*, will new YOY Lake Sturgeon habitat form in the reservoir)?
- How precise were the post-Project models that predicted the long-term deep water substrate distributions?

3.2.2.2 STUDY DESIGN AND DATA ANALYSIS

Changes to the distribution of the substrate in deep water is indicative of alteration to the hydraulics and the ability of the river to transport materials along the bed. Changes to the substrate may be considered as positive or negative to biota. From a modelling standpoint, however, it is easier to predict high magnitude changes for materials that are abundant (*e.g.*, silt superimposition) than it is for smaller more localized effects where material availability is sparse, or uncertain (*e.g.*, deposition of sand/gravel). Consequently, this study design not only assesses high magnitude changes resulting from siltation of rocky deep water habitat, but also attempts to sample areas where new YOY habitat may develop at scales that could not be modelled in the AE SV.

A systematic sampling design will direct the sampling of substrate in select areas of the Keeyask reservoir and below the GS. Four main areas of interest will be monitored using cross-sectional sampling during the operation phase (Map 3-2). Birthday Rapids, the first area of interest, will be monitored to learn if fines (sand/gravel) are depositing in new slower lotic areas along the edges of the channel below the rapids. Similarly, the second area near the entrance to Gull Lake, will be monitored to learn if fines are depositing in the main channel. If sand and gravel are more available than was predicted by the PE SV studies, then Lake Sturgeon YOY habitat may develop. The third area of interest is located near the present outlet of Gull Lake and along the north channel of Caribou Island. The deposition of silt at the outlet of Gull Lake after flooding is not expected, and transport of sand/gravel from the upper reservoir is unlikely. This area does not meet the criteria currently understood to comprise YOY Lake Sturgeon habitat, but may offer an alternate opportunity for mitigation at the entrance of Gull Lake. Sand and gravel is presently abundant around the area of interest by Caribou Island where some suitable YOY habitat is expected to remain. Substrate composition will also be monitored downstream of the Keeyask GS and into Stephens Lake due to its importance to YOY and sub-adult Lake Sturgeon.

The study design is similar for the habitat above and below the dam. Generally, substrate validation methods that retrieve a physical sample will be the primary means for interpreting substrate change. Acoustic bottom typing or substrate imaging approaches will be used as supporting methods. Acoustic bottom classification from vertical beam sonar will be used over larger areas to delineate substrate boundaries. At the onset of monitoring, however, vertical beam bottom typing will not be used in the deep water areas of the reservoir; echo responses will be heterogeneous and difficult to validate. Vertical beam classification methods will be used in areas where silt does not accumulate, or later when the thin layers of sediment become sufficiently thick to block the bottom echo caused by the materials below. The design of the acoustic surveys in the reservoir will be consistent with that below the GS, although in flooded areas they will be phased in over time when the methods are known to be valid.

The substrate composition survey design below the GS will capture the material size gradient that transitions from coarse boulder and cobble to gravel and sand, then to silt (Map 3-2). Determination of substrate composition for sites that are gravel or smaller (i.e., where sub-adult Lake Sturgeon were most often caught) will be based on physical samples retrieved for particle size analysis. The local heterogeneity of substrate materials will be assessed. Remote sensing methods, such as vertical beam or side scan sonar, will be used throughout the area of interest. Sites selected for sonar and validation in the main channel within Gull Lake and Stephens Lake will be a sub-set of those presented in the AE SV (Appendix 3A, map 3A- 2 and map 3A- 4). New systematic sites will be included where change is expected, or is uncertain.

EXISTING DATA

Aquatic habitat data were collected mainly between 2003–2007, with some additional data collected from relatively small areas in later years for specific information requirements. The primary baseline data include water depth, bed and water surface elevation, substratum type, water velocity, water levels, macrophyte habitat, and studies of fish habitat use. These data span the hydraulic zone of influence of the Project and flooded areas of Stephens Lake, the latter of which is a proxy for the future reservoir. The primary baseline datasets describing the existing environment were provided in the AE SV (Section

3.0 , maps 3-6 to 3-16), and the results of modelling to predict post-Project conditions are presented in AE SV maps 3-24 to 3-35.

Data Analysis

Data analysis will include the classification of Ponar grab samples. These data will be combined with the field classifications taken from the weighted sounding line results, from hard-bottomed areas.

Collectively, these data are the primary substrate classifications that validate the acoustic studies. The vertical beam acoustic bottom typing data will utilize supervised classification methods (Appendix 3A of the AE SV). This approach involves the development of a library of acoustic signatures for a set of predicted bottom types, which may precede the field survey. Several methods are suited to process the multivariate echo data. Discriminant Analysis is one such approach that supports cross validation to determine agreement between observed and predicted substrate classes. The acoustic data will be partitioned into “test” and “model” groups. The acoustic model will be derived using the data only from the “model” group, which will predict the substrate class for all observations. The percent agreement of the model will be assessed using cross-tabulation of the observed and predicted classes from the independent “test” group not used to build the model.

When validation of the Project predictions is required, the post-Project modelling datasets will be used (AE SV maps 3-24 to 3-35), or the underlying data observed in the field will be used if required (AE SV maps 3A-1 to 3A-4).

3.2.2.3 PARAMETERS

Parameters will include bed elevation (m), water surface elevation (m), substrate type (Wentworth mineral classes + organic), substrate composition (percent grain size fraction and Phi units), and water level variation data (+/-0.1 m). Acoustic bottom typing information will use parameters derived from the acoustic waveform data which may include measurements based on the magnitude and duration of the echo (*e.g.*, hardness and roughness), or alternatively, by assessment of the shape of the echo.

3.2.2.4 SAMPLING SITES

Most of the cross sections in the deep water areas of the Keeyask reservoir will be located between the entrance of present-day Gull Lake and the GS (Map 3-2). Sampling will occur in areas that are presently aquatic habitat and in flooded terrestrial habitat. Bottom samples will be taken along these cross sections at a subset of the sites sampled to describe the existing environment (see Maps 3A-2 and 3A-3 in Appendix 3A of the AE SV for channel sampling distribution). Site selection in flooded areas will be based on the substrate composition distribution predictions for 25 years post-impoundment. The results of water velocity sampling, conducted as part of the PEMP in support of habitat monitoring, will be used to select substrate composition sampling sites. Some of the flooded areas will be sampled at greater density to ensure that sampling captures the depositional boundaries. This will validate the development of potential substrate boundaries that change from hard to soft, or kept the existing substrate type. Downstream of the GS, substrate composition will be monitored at cross sections at an interval similar to that used to describe the existing environment. The areas sampled will be sufficiently large to ensure expected patterns of residual effect are captured even if the Project models are biased. Vertical beam acoustic and side scan sonar will be used in detail in the areas shown in Map 3-2, where possible. Some of these areas will include smaller, new, sensitive, and constructed habitats (Section 3.2.3).

3.2.2.5 SAMPLING FREQUENCY AND SCHEDULE

During the first three years of operation, annual reservoir substrate composition surveys will be conducted within the original channel of the Nelson River. Six years post-impoundment, the monitoring program will be extended to include spatial sampling of all flooded habitat in the reservoir, with the exception of those areas already considered by the nearshore surveys described in Section 3.2.1.1. This spatial survey will occur at least once every three years until a review takes place of the overall program ten years post-impoundment. The frequency of monitoring after this time will be determined based on the results of the substrate composition surveys and PEMP studies.

Substrate composition sampling below the Keeyask GS will be conducted in spring and late summer in the first three years after impoundment. If substrate composition at that time is different from what was present in the existing environment, the next sampling period will be scheduled to follow a relatively high magnitude flow event. If the substrate composition forms a pattern unlike that observed in the existing environment, even after a high flow event, and it no longer provides the same habitat function and use to aquatic biota, then measures to provide alternate habitat will be developed.

3.2.2.6 FIELD AND LABORATORY METHODS

Acoustic methods (vertical, side scan, and/or Didson) will be used to document substrate at individual sites and along cross-sections. Ponar grab samples collected to validate acoustic sampling of soft substrates will undergo particle size analysis at a certified laboratory, from which Phi grain size units will be determined. In the field, substrate heterogeneity and any vertical layering will be assessed. Each Ponar grab will be classified in two ways based on a visual assessment: extent of mixing (homogenous or heterogeneous), and the intactness of the surface layer, including a description of any silt sediment apparent or measured. Particular care will be taken to keep the surface of the sample intact where possible, which will be photographed. Samples with two or more well defined layers will have sub- samples taken from each layer. This method will distinguish samples that are layered from those that are not.

Acoustic sampling will be the primary means of classifying the substrate at sites that are hard-bottomed and do not yield a Ponar sample; hard substrates will be validated by dragging a weighted sounding line down the river along the transects. This method can also address heterogeneity of hard-bottomed areas, as it permits the detection of pockets of fines within larger areas of coarse material.

3.2.2.7 BENCHMARKS

As with the development of nearshore habitat, the benchmark will be compared to predicted post-Project conditions outlined in section 3.1.1. If substrate does not develop as anticipated, or if areas change where no change is expected, these results will be considered within the biological assessment to determine whether adaptive management is required.

3.2.3 MONITORING OF SENSITIVE AND CONSTRUCTED HABITAT

A specific monitoring program will assess effects of the Project on habitats that are sensitive due to their importance for Lake Sturgeon (specifically spawning and YOY habitat) where the assessment has identified uncertainty with respect to post-Project conditions, as well as, conditions on habitats constructed as part of the offsetting plan. Table 3-4 provides a list of the program components, including an overview of the variables to measure, the sampling design, and sampling frequency and schedule.

The objectives of the program are to:

- Monitor aquatic habitat criteria (*i.e.*, substrate, water depth, and velocity) at sensitive sites where spawning Lake Sturgeon habitat exists today, or where new potential habitat may develop in the post- Project environment. The existing habitat areas are found at Long Rapids, Birthday Rapids, and the area below the spillway;
- Monitor aquatic habitat criteria (*i.e.*, substrate, water depth, and velocity) at sensitive sites where YOY and sub-adult Lake Sturgeon habitat is known today, or where new potential habitat may develop during operation. These areas may be found at Birthday Rapids, the entrance to Gull Lake, lower Gull Lake, the channel north of Caribou Island, and in Stephens Lake about 4–7 km below Gull Rapids; and
- Monitor aquatic habitat criteria (*i.e.*, substrate, water depth velocity) at constructed spawning habitats in the Keeyask reservoir, tailrace, along the south shore downstream of the GS, and at the former haul road site along the north shore channel.

3.2.3.1 KEY QUESTIONS

A summary of effects is provided below to support the Key Questions for the Sensitive and Constructed habitats.

SENSITIVE HABITAT

Keeyask GS operations will affect Lake Sturgeon spawning habitat at two sites. At Birthday Rapids, the water depth and velocity will change, and although turbulent flows may persist, the white water habitat will no longer be present. It is uncertain if Lake Sturgeon will continue to spawn here, or move upstream to Long Rapids. Depth, substrate, and velocity sampling will be undertaken in the area of Long Rapids and Birthday Rapids to confirm suitable habitat remains there during the period of operation. For Lake Sturgeon downstream of the GS, Gull Rapids will no longer be available. A spawning shoal will be constructed below the GS tailrace at a location and with design criteria to provide suitable habitat for spawning.

In the reservoir, there will be a reduction in the type of habitat thought to be suitable for YOY Lake Sturgeon (*i.e.*, low water velocity over sand/gravel substrate). Post-Project models suggest: (i) new YOY habitat may not develop at the entrance to Gull Lake due to a lack of sand deposition, and (ii) most of the existing YOY habitat located near Caribou Island will be lost.

During operation, water velocity will slow notably as flows enter Gull Lake; a post-Project substrate model predicts that silt will not deposit. Results of physical environment studies, however, suggest that sand and gravel may not be available to deposit in this low velocity hydraulic habitat, so the existing cobble/boulder substrate would remain.

Although the velocity appears to be suitable for YOY at the entrance to Gull Lake, the available YOY habitat is not. Substrate model outputs also predict that some of the existing suitable YOY habitat found near Caribou Island today may persist during operation. It remains unclear, however, if larval Lake Sturgeon would drift to this location given the altered flows in the reservoir.

The key questions for the sensitive habitat monitoring are:

- Will Birthday Rapids and the area below the spillway (when it is in operation) continue to provide spawning habitat for Lake Sturgeon?
- Will sand and gravel transport through the riverine reach of the reservoir and deposit downstream of Birthday Rapids and/or the entrance to Gull Lake to create suitable YOY Lake Sturgeon habitat?
- If sand and gravel do not deposit near the entrance to Gull Lake what are the substrate conditions that develop?

Results of this program will be considered in close connection with the YOY Lake Sturgeon program, which will address habitat use by sturgeon in this reach (Section 6.3.2).

CONSTRUCTED HABITAT

Constructed habitat upstream and downstream of the Keeyask GS will not function as intended if sediment/algae accumulate on its surface, or if the anticipated water movements (*i.e.*, waves, water level variation, velocity) do not meet the specified habitat design criteria.

The site-specific considerations for constructed rocky habitat in the reservoir influence the long-term area and quality of habitat built. The reservoir will actively transport sediment downstream to form a depositional boundary at an elevation where wave energy, water level variation, and the effects of slope no longer transport material. Rocky habitat constructed near islands within the reservoir will have a wide range of exposure. This can affect mixing depth by surface waves. Sites with lower exposure will have sediment boundaries in relatively shallow water compared to those with wide exposure in the reservoir. Spawning shoals downstream of the Keeyask GS may also create a “sediment shadow” as a response to deflecting current, depending on the design of the shoal and its location in the flow. Measurement of water velocity across the surface of the shoal can validate the actual habitat area available over a range in river discharges, as modelled by Manitoba Hydro.

The key question for constructed habitat monitoring is:

- Will monitoring data collected from the constructed spawning habitat (*i.e.*, water velocity and depth, and substrate) in the reservoir, near the tailrace, and along the south and north shore downstream of the GS confirm that the extent and surface area continue to meet design criteria over time?

3.2.3.2 BENCHMARKS

The design criteria for the constructed habitat were described in sections 4.1.2 to 4.1.6 of the FOMP. These will serve as benchmarks for the assessment.

3.2.3.3 STUDY DESIGN AND DATA ANALYSIS

Changes to substrate composition in habitats that are sensitive, or constructed, will be monitored as part of the substrate composition sampling program described in Section 3.2.2. Given that the sites targeted by this specific effects program are relatively small, the monitoring data collected from these locations may be of a higher spatial (and possibly temporal) resolution. The extent of the area of interest will initially be based on post-Project model results. If the predicted area of interest is over-or-under estimated, this program will not miss the observed effect given that the area of interest is within the larger area where substrate composition will be monitored (Section 3.2.2). For example, if the extent of silt deposition for YOY habitat in the area of Caribou Island is greater than predicted, then the full extent of the area could be determined from the substrate monitoring program.

Before and after comparisons will be undertaken for constructed habitat. The initial state of the constructed habitat will be captured prior to wetting using high-resolution laser scanning methods tied to kinematic Global Positioning Systems. This will create a highly dense point array of surface elevations of the structure and immediate surrounding area. After immersion, the laser “point cloud” data will be compared to acoustic transects deployed on, and in the area of, the constructed habitat.

EXISTING DATA

Survey transects and point sample locations used to develop substrate maps are shown in AE SV maps 3A-2 to 3A-4. The amount and quality of YOY habitat currently present in the Keeyask area, as estimated using Habitat Suitability Index (HSI) methods, are shown in AE SV maps 6-14 to 6-16 and 6-47 to 6-49.

DATA ANALYSIS

Substrate composition in sensitive habitats (*e.g.*, areas where YOY Lake Sturgeon presently occur in Gull Lake and Stephens Lake), and in areas that may become suitable for YOY Lake Sturgeon based on changes in velocity (*e.g.*, the inflow to Gull Lake), will be monitored to assess whether they remain/become suitable habitat. See Section 3.2.2.3 for a detailed description of the substrate composition data that will be collected, and analyses undertaken.

Constructed habitat will be monitored to confirm that the cobble/boulder structures meet the specified habitat design criteria. The actual area of created habitat will be calculated based on the area that meets the design criteria outlined in sections 4.1.2 to 4.1.6 of the FOMP. For the reservoir, this would include the area of habitat available above the upper depth limit of silt sedimentation. The spawning shoals below the GS will be assessed to determine how well the design criteria (*i.e.*, depth, velocity, and substrate) are met over their entire surface.

3.2.3.4 PARAMETERS

Monitoring sensitive and constructed habitats will require data collection of the following parameters: bed elevation; water surface elevation; water velocity; and substrate composition and heterogeneity (percent grain size fraction, and Phi units). A photographic/imaging record will be developed for each site where samples or constructed habitat is visible. Measurement of substrate heterogeneity will also be undertaken where applicable (Section 3.2.2.6).

3.2.3.5 SAMPLING SITES

Monitoring will be conducted at sites of existing sensitive habitats (*e.g.*, areas where YOY sturgeon presently occur in Gull Lake and Stephens Lake) and in areas that may become sensitive habitat such as the entrance to present day Gull Lake (Map 3-3). Sampling will also be conducted at constructed habitats upstream and downstream of the Keeyask GS. This will include deep and shallow spawning shoals constructed upstream of the Keeyask GS for use in 2020, the sturgeon spawning structure constructed near the Keeyask GS tailrace also for use in 2020, and the Lake Whitefish spawning shoal constructed downstream of the GS in 2021.

3.2.3.6 SAMPLING FREQUENCY AND SCHEDULE

After the reservoir is impounded, and sensitive and constructed habitats are built, the habitats will be monitored annually for three years, starting after the first unit is in service. Monitoring after the initial three year period would occur at least once every three years until ten years post-impoundment. Monitoring may continue at a reduced frequency after this time, depending upon results. If unforeseen effects are detected at any of the constructed aquatic habitat sites, the frequency of monitoring at those specific sites will increase.

3.2.3.7 FIELD AND LABORATORY METHODS

Specific effects monitoring of substrate change will employ techniques previously described in Section 3.2.2.7, depending on site conditions. For example, deep water sites would rely more on side-scan sonar images given that the deployment of Didson acoustic imaging is more difficult at greater depth. Water surface elevation, water velocity, and sediment deposition will be measured at the constructed habitats.

3.2.3.8 BENCHMARKS

Habitat criteria measured at areas predicted to be suitable for Lake Sturgeon spawning will be compared to criteria identified in the Lake Sturgeon HSI model presented in the AE SV to estimate total area and suitability. If suitable areas are less than those identified in the AE SV and if monitoring of Lake Sturgeon indicates a lack of suitable spawning habitat (Section 6.3.3), then the implementation of measures to create additional suitable habitat will be undertaken.

Similarly, for YOY Lake Sturgeon habitat, results of surveys will be compared to criteria identified in the Lake Sturgeon HSI, which was presented in the AE SV to estimate total area, and compared to the total area identified in the AE SV, and identified during review by DFO (45 ha in the reservoir). The criteria for habitat suitability may be modified from that reported in the AE SV if the state of knowledge at the time of the monitoring identifies other criteria important for YOY sturgeon. If suitable areas are less than indicated and monitoring of YOY sturgeon (Section 6.3.2) indicates a lack of suitable habitat, contingency measures to create habitat will be implemented.

With respect to constructed habitats, if measurements indicate that design criteria are not met, then the need to modify existing constructed habitat will be investigated. In addition, if a measurable and persistent layer of material finer than sand develops on the constructed spawning habitats, further investigations will be initiated to address this problem.

3.3 MANAGEMENT RESPONSE FRAMEWORK

3.3.1 ADAPTIVE MANAGEMENT RESPONSE FRAMEWORK

The introduction of this AEMP refers to adaptive management as a tool to address Project concerns identified through monitoring. The objective of the adaptive management response framework for aquatic habitat is to establish a decision-making approach to determine whether: (i) habitat (including constructed habitats) in the post- Project environment is as predicted in the AE SV; and (ii) if not, whether additional mitigation is required. As discussed in the preceding sections, there are no widely accepted benchmarks for aquatic habitat; instead, post-Project habitat will be compared to predicted habitat to determine whether there are any major discrepancies, and constructed habitats will be compared to design criteria set out in the FOMP.

3.3.2 INTEGRATED ANALYSIS OF MONITORING RESULTS

Understanding the residual effects of the Project on aquatic habitat will be determined by integrating results of all the monitoring activities. Continued monitoring of the developed habitat and its occupation by species (monitoring for biota described in sections 4.0, 5.0 and 6.0) will show how the reservoir evolves, enable an assessment of the validity of predictions, and provide for direct comparisons to reference sites in Stephens Lake. Additional mitigation with respect to aquatic habitat will also need to consider whether the monitoring of biota indicates that the habitat is limiting or not suitable.

3.3.3 DECISION FRAMEWORKS – MODIFICATION OF MITIGATION AND OFFSETTING MEASURES

Monitoring of habitat will be iterative over time as sampling proceeds and data accumulate to show trends. During this time, comparisons of the monitoring data to predictions in the AE SV (as summarized in Section 3.1.1 and Table 3-1), or to proxy sites, may identify new information. Consequently, a long-term monitoring plan may need to adapt and change over time for reasons that include:

- Uncertainty at the time the problem is defined (*i.e.*, change in the state of knowledge over time);
- Data are incomplete or are biased;
- The reference site selected for comparison to the impacted site continues to change; and
- A technical inability to model a process well despite having a good conceptual model of the problem.

Decision frameworks have been developed to guide the path of choices that may be needed to adapt the program and identify whether additional mitigation is required over time. Assessment from an adaptive management perspective is expected with respect to the following topics:

- Differences between the observed nearshore/offshore data and the state of environment predicted by the models in the AE SV (i.e., Before/After comparison);
- Differences between the area occupied and the depth distribution of potential rooted macrophyte habitat in the Keeyask reservoir and Stephens Lake (i.e., Impacted/Reference or proxy site comparison);
- The need for the implementation of contingency measures to create YOY habitat in relation to the quantity and quality of habitat considered suitable for Lake Sturgeon YOY in the post-Project environment where there is uncertainty regarding the full range of criteria that define their habitat (i.e., Before/After comparison) and where available habitat may be in areas too small for reliable modelling (post-Project observation and monitoring);
- The need for the implementation of measures to create conditions suitable for spawning Lake Sturgeon in the reservoir; and
- Differences between the design criteria of the artificial spawning shoals and observations after being wetted (i.e., Before/After comparison).

An assessment of changes in the state of knowledge for each of these topics will be considered and updated, as necessary, over time. Any unanticipated effects of the Project will be included (*i.e.*, where no effect was predicted but an effect occurred). The physical processes responsible for development and maintenance of habitat generally are understood. The largest uncertainties moving forward are: (i) the rate of habitat development; and (ii) if YOY habitat for Lake Sturgeon will form in the reservoir.

These topics can be considered using decision frameworks for: (i) the habitat of the nearshore and offshore areas (Sections 3.2.1 and 3.2.2); and (ii) the Sensitive and Constructed habitats (Section 3.2.3).

3.3.3.1 NEARSHORE AND OFFSHORE HABITAT DECISION FRAMEWORK

The decision framework for the nearshore and offshore habitat studies is shown in Figure 3-2. The first question is whether the pattern of observation is consistent with the expected results. This is a "reference condition" or "benchmark" of the current understanding of sample distributions to which all monitoring data is compared. If observed results are not as expected, then the analysis proceeds to determine: (i) whether results are within an expected range of variation, which may in time, achieve predicted results; and (ii) whether the observed discrepancy from predicted habitat has consequences for the biota. Ultimately, the need to implement further mitigation will be dependent on not meeting the overall objectives of sustainable fish populations

3.3.3.2 SENSITIVE AND CONSTRUCTED HABITAT DECISION FRAMEWORK

The decision framework for Sensitive and Constructed Habitat is shown in Figure 3-3. The first question is whether the habitats meet the criteria established in the AE SV in terms of area of habitat, water velocity, depth, and substrate characteristics. As discussed in preceding sections, the criteria applied to "suitable" habitats, as described in the AE SV, may be updated if the state of knowledge at the time of monitoring indicates a change in the understanding of habitat suitability. This is most likely to apply to YOY Lake Sturgeon habitat, given that this life stage is currently the focus of considerable scientific research.

If established criteria are not met, then the analysis will proceed to determine whether the observed results may be related to the sampling approach. Certain environments, such as the spawning structure at the tailrace, may be difficult to sample and the ability to establish whether criteria are being met may be limited. The analysis would also consider whether any deficiencies in the constructed habitat are affecting the biota, in particular the sustainability of fish populations. Measures to modify sensitive or constructed habitat will be considered if effects to the sustainability of fish populations are observed.

4.0 BENTHIC MACROINVERTEBRATES

4.1 INTRODUCTION

Monitoring of benthic macroinvertebrates (i.e., benthos) will occur during construction and operation. In general, sampling locations will remain as consistent as possible throughout the construction and operation phases to facilitate comparisons with data collected during both (Map 4-1).

Benthic macroinvertebrates are standard indicators of ecological integrity used in bio-monitoring programs worldwide. Similar to most biological indicators, macroinvertebrate community metrics (i.e., indices) are particularly valuable as they integrate environmental conditions over time. Benthic macroinvertebrates are also an important food source for fish and integral in describing the quality of fish habitat available for key life stages.

The monitoring program for benthic macroinvertebrates relies upon a combination of statistical comparisons and professional judgement. Effects will be determined through comparison of data to upstream reference sampling sites (e.g., upstream-downstream comparisons in relation to relatively site- specific construction activities) and to pre-Project data (i.e., baseline data).

Sections in this introduction provide: a summary of the assessment provided in the AE SV, including a description of the pathways of effects and a summary of assessment results; and, an overview of the development of the benchmark that will be considered in the benthic macroinvertebrate monitoring program.

Section 4.2 provides a detailed description of the following monitoring activities:

- Section 4.2.1 Biological effects of predicted TSS increase during construction; and
- Section 4.2.2 Biological effects of predicted aquatic habitat and water quality changes during operation.

Section 4.3 provides the adaptive management framework outlining the proposed process for interpreting results of benthic macroinvertebrate monitoring activities, including integration of results with other monitoring activities described in the AEMP. This section also describes the process whereby monitoring results will be considered in terms of the proposed benchmark to determine the need for follow-up activities, specifically the need to modify the monitoring program.

4.1.1 ASSESSMENT SUMMARY

A summary of Project-related pathways of effect, mitigation and offsetting measures, residual effects and monitoring is provided in Table 4-1. The following sections provide a brief summary of the pathways of effect through which the Project may potentially affect benthic macroinvertebrates and a summary of the assessment results, as presented in the AE SV.

4.1.1.1 PATHWAYS OF EFFECT

The AE SV considered the following pathways of effect during construction and operation of the Project:

- Changes to water quality, such as increases in concentration of TSS and related variables (*e.g.*, turbidity). It is expected that measures to protect water quality will reduce the likelihood of any measurable effects on the benthic macroinvertebrate community;
- Dewatering of habitat in Gull Rapids;
- Deposition of sediments in Stephens Lake. This is not expected to affect benthic macroinvertebrates as the total amount of sediments deposited is predicted to be very small (less than 0.6 cm thickness over the period of construction) and the composition of bottom substrate will not be changed;
- The alteration of existing habitat and the creation of new habitat due to flooding;
- A reduction in medium and high water velocity habitat upstream of the GS due to reservoir creation. Although water velocity is being reduced and water depth is increasing in areas of the reservoir, water flow is expected to be adequate (relatively short water residence time; low to high velocity aquatic habitat present) through the mainstem to produce and maintain a somewhat comparable density of drifting invertebrates;
- A conversion of existing hard gravel, cobble, and boulder substrates to softer silt/clay substrates due to sedimentation in the reservoir;
- An increase in the frequency of water level fluctuations due to GS operations;
- A conversion of tributary habitat to bays due to flooding; and changes in surface water quality in off- current areas, particularly bays (*e.g.*, flooding and peat disintegration are expected to cause decreases in DO concentrations in portions of shallow, flooded bays of the reservoir with poor mixing and long water residence times in the open-water and ice-cover seasons);
- An alteration of flow patterns, water velocities, and depths in the portion of the Nelson River from the GS to the inlet of Stephens Lake; and
- A reduction in the extent and severity of ice scour in the portion of the Nelson River from the GS to the inlet of Stephens Lake. However, available information suggests that disturbance of habitat induced by ice breakup and scour is temporary.

4.1.1.2 ASSESSMENT RESULTS

The impoundment of the Nelson River at Gull Rapids will produce large changes in the benthic macroinvertebrate community, both within the reservoir and the Nelson River immediately downstream of the GS.

A large increase in the abundance of benthic macroinvertebrates is expected in the reservoir in the long- term in response to the increased availability of aquatic habitat (creation of flooded areas and expansion of deep water habitat as water levels increase). The increase in benthic invertebrate abundance may be accompanied by a change in the community composition in the lower portions of the reservoir from that typical of riverine aquatic habitat to one more characteristic of slower flowing water (i.e., resembling portions of Stephens Lake). Flooding and peatland erosion/disintegration are expected to cause decreases in DO concentrations in localized areas (i.e., in a small portion of the shallow, flooded bays of the reservoir characterized as having poor mixing and long water residence times) during the open-water and ice-cover seasons. The effects are expected to be moderate-term in duration (i.e., the first 10–15 years post-impoundment), but in highly isolated shallow areas where organic substrates persist and/or where floating peat islands are present, the duration of effects may be long-term (i.e., longer than 25 years).

Greater effects to DO in the reservoir will occur in winter; a larger area will be affected, the magnitude of DO depletion will be greatest, and the duration of the effects will be longest. Anoxic and hypoxic conditions are expected to develop in shallow areas over flooded terrestrial habitat with limited mixing with the mainstem during the ice-cover season. The low DO conditions are expected to limit invertebrate colonization to a few resilient groups (e.g., chironomids) in the localized affected areas.

The reduction in fast water (high velocity) and hard substrate at rapids due to flooding, dewatering, and/or footprint of the GS, and conversion of tributary habitat to bays, will result in a reduction in the abundance of macroinvertebrates favouring this type of aquatic habitat.

4.1.2 IDENTIFICATION OF BENCHMARKS

Unlike water or sediment, where protection of aquatic life guidelines may be used to develop triggers or thresholds for effects assessment, there are no universal benchmarks for biological variables such as abundance or diversity. Rather, the magnitude of change or difference relative to expected conditions must be used to establish appropriate benchmark(s) or critical effects size(s) (CESs) for biological variables.

Metal mining technical guidance for Environmental Effects Monitoring (EEM; EC 2012) identifies CESs for a benthic macroinvertebrate (BMI) metric as multiples of within-reference-area standard deviations (*i.e.*, ±2 standard deviations [SDs]). Confirmed effects are based on the results of two consecutive surveys Recent and ongoing monitoring programs in northern Canada have identified effects sizes and/or benchmarks for the benthos using different approaches. For the Diavik Diamond Mine, a significant adverse effect as it relates to aquatic biota was defined in the environmental assessment as a change in fish population(s) that is greater than 20% (Government of Canada 1999). This effect must have a high probability of being permanent or long-term in nature and must occur throughout the receiving environment (Lac de Gras). The “Significance Thresholds” for BMI, therefore, are related to impacts that could result in a change in fish population(s) that is greater than 20% (Golder 2014). Azimuth (2012) recommended the application of a 20% effect size as a monitoring "trigger" and a 50% effect size as a monitoring "threshold" for benthic macroinvertebrate metrics (*i.e.*, total abundance and richness), where effect size refers to a change or difference relative to BACI. They further note that the terms "threshold" and "trigger" are intended to be applied less strictly for biological variables, relative to chemical variables such as water or sediment quality, due to the inherent natural variability in biological parameters and the need to consider the cause of any observed statistical "changes" in the biological communities. The rationale provided for the identification of the 20% and 50% criteria is "to maintain a transparent (fixed) effect size that is more likely to be ecologically relevant." Where natural variability is high, use of two standard deviations for benthic invertebrate metrics could potentially mean that large and ecologically- relevant effects could occur to some endpoints without being higher than the CES. On the other hand, the limitation of using percentage change to define the CES for a metric when variability is high is reduced statistical power to detect change. Integral to this discussion is the importance of considering the variability in existing data in identifying appropriate CESs.

With respect to the Project, development of a benchmark(s) or CES(s) for the benthic macroinvertebrate community that are adequately sensitive and ecologically appropriate considered the following:

- Natural variability in existing benthic macroinvertebrate metrics;
- Limitations of the baseline data set (*i.e.*, a more statistically robust study design has only been implemented in study area waterbodies since 2010 as part of the CAMP); and
- Literature in which benchmarks or CESs for benthic macroinvertebrate metrics have been adopted or identified, such as AEMPs for the Diavik Diamond Mine (Golder 2014) and Meadowbank (Azimuth 2012) projects.

An initial *a priori* power analysis (see Appendix 4A) was completed for select benthic macroinvertebrate community metrics (based on an assessment of variability to identify more robust metrics) to:

- Provide a preliminary analysis of the power of the existing data set to be used as the foundation for detecting post-Project change (*i.e.*, Before-After comparisons); and
- Explore samples sizes (*i.e.*, number of replicate stations within a waterbody or area of a waterbody) required for detecting pre-defined levels of change.

The power of the existing data set in Split Lake to be able to detect a post-Project change in the mean of ±25% is high for the metrics investigated, with the exception of total macroinvertebrate abundance in the intermittently exposed nearshore aquatic habitat type (see Table 4A-17). Based on guidance provided in the Metal Mining EEM document (EC 2012) and the scientific literature, and experience with other AEMPs (*e.g.*, Azimuth 2012), an effect size of ±50% change in the mean of a metric (proposed benthic macroinvertebrate AEMP benchmark) is likely most appropriate to use (*i.e.*, realistically achievable with a well-designed program). However, an effect size of ±25% may be achievable for certain metrics with comparatively reduced levels of variability. In before-after comparisons of metrics, the power to detect differences is greater when there are more monitoring events in the before and after periods included in the analysis. Overall, it is expected that the benthic macroinvertebrate AEMP will be capable of detecting larger effects in a short time period, but will require a longer time period to detect more subtle changes.

4.2 MONITORING ACTIVITIES TO DETECT CHANGE

The following describes the general background, approach, and methods for monitoring benthic macroinvertebrates during the construction phase until impoundment to the FSL and for the first ten years of operation after full impoundment. A summary schedule for all monitoring activities in relation to Project construction and operation, and the implementation of mitigation measures is provided in Figure 4-1.

4.2.1 BIOLOGICAL EFFECTS OF PREDICTED TSS INCREASE

Construction monitoring will specifically address the biological effects of predicted increases in TSS on the benthic community due to in-stream work on the Nelson River and will complement the water quality program (Section 2.0). Monitoring of benthic macroinvertebrates will occur immediately downstream of instream construction activities related to the Keeyask GS where effects, should they be measureable, will be greatest ("construction" locations listed in Table 4-2 and shown in Map 4-1). A series of potentially affected locations extending further downstream will be monitored depending on water quality results (*i.e.*, Long Spruce Forebay, Limestone Forebay and downstream of Limestone GS). Benthic macroinvertebrates will also be assessed upstream of instream activities in unaffected waterbodies, such as the Burntwood River (First Rapids to Split Lake) and Split Lake (based on sampling conducted as part of CAMP).

4.2.1.1 KEY QUESTIONS

As discussed in the AE SV, construction-related activities have the potential to affect benthic macroinvertebrates through effects to water quality, dewatering of habitat in Gull Rapids, and the deposition of sediments in Stephens Lake.

The results of benthic monitoring programs will be used to assess the biological effects of predicted increase in TSS due to instream work on the Nelson River (intended to complement the water quality monitoring described in Section 2.0) and sediment deposition in Stephens Lake. The key questions that monitoring during construction will address are:

- To what degree will benthic invertebrate abundance and/or community composition change during construction activities in comparison to either upstream or pre-Project conditions?
- Are there any unexpected effects on benthic macroinvertebrates that may be related to GS construction activities?

STUDY DESIGN AND DATA ANALYSIS

The benthic macroinvertebrate sampling uses a modified sampling design, which was adjusted from the sampling program used for the environmental studies (last conducted in 2006) based on input from regulators and experience gained from the CAMP and Wuskwatim AEMP monitoring programs. The proposed AEMP sampling design is comparable to the current CAMP design, such that data generated by the latter program may be used for AEMP reporting. Sampling areas (*i.e.*, polygons, see Map 4-1) will be stratified by water depth and constrained by other aquatic habitat attributes (*e.g.*, substrate type, presence/absence of aquatic plants, water velocity, *etc.*) such that sampling areas represent the predominant habitat type(s) within each waterbody and/or those habitat type(s) with predicted effects as defined in the AE SV. Sampling conducted in fall 2013 (pre-construction) was based on a sampling design refined during AEMP design in an attempt to minimize the inherent variability within the benthic invertebrate data. Results will be directly comparable to data collected during the construction period. The modifications from the sample design used for the environmental assessment studies will increase the statistical power of the data and comparability to other regional programs (e.g., CAMP, Wuskwatim AEMP).

The study design is a hybrid that incorporates elements of both the BACI and gradient designs. A BACI design consists of one or more control (or reference) locations to which an exposure (or reference) area is compared, both before and after an impact is deemed to have occurred. A gradient design refers to a series of sampling locations extending away from a potential source of effect (e.g., increase in TSS due to instream work), to a sufficient distance downstream that allows use of the farthest location as a reference (i.e., where an effect is no longer detected). Sampling locations along the gradient should represent different exposure levels (e.g., within the mixing zone vs. fully mixed river condition).

EXISTING DATA

Multiple years of data to assess benthic macroinvertebrate abundance, community composition, and distribution have been collected in Split Lake , the Clark Lake to Gull Rapids reach of the Nelson River, and Stephens Lake between 1997 and 2006 to assess the potential effects of the Project on the benthos (Lawrence and Fazakas 1997; Fazakas and Zrum 1999; Zrum and Neufeld 2001; Zrum and Bezte 2003; Zrum and Kroeker 2003; Juliano and Neufeld 2004, 2005; Sotiropoulos and Neufeld 2004; Neufeld 2007; and Capar 2008). Additional baseline data were collected in fall 2013 to augment the existing database and improve its utility for post-Project comparisons.

As part of the CAMP, benthic macroinvertebrate data have been collected in the following waterbodies:

- Burntwood River (First Rapids to Split Lake) since 2011 (every three years);
- Split Lake since 2009 (annually);
- Stephens Lake since 2009 (every three years);

- Limestone Forebay since 2010 (every three years); and
- Lower Nelson River downstream of the Limestone GS since 2010 (annually).

This program is ongoing and data collected will be reviewed and may be used to augment the baseline dataset and/or as an additional source of information regarding monitoring during Project construction and operation.

Data collected during the PEMP and SMP, notably monitoring of TSS and turbidity, will be considered within the AEMP. Specifically, SMP results will be reviewed and results of the benthic macroinvertebrate monitoring program conducted under the AEMP will consider this information in the overall interpretation of effects on the benthos.

DATA ANALYSIS

The hybrid design allows for the statistical testing for effects in the area immediately downstream of construction activities, upstream and downstream of the operating GS, and provides an estimate of the spatial extent of potential effects. Potential Project-related effects will be evaluated through statistical comparisons of benthic macroinvertebrate community descriptors (*i.e.*, metrics) between reference and exposure locations during each sampling event and to pre-Project baseline data.

Although all metrics will be reviewed, data analysis may focus upon key metrics (see Section 4.2.1.3) and comparisons to the proposed benchmark (*i.e.*, ±50% change in the mean of a metric in comparison to reference locations and/or baseline data) will be done to identify the potential for adverse effects on the benthic macroinvertebrate community. For each metric that exceeds the benchmark, a statistical comparison between reference and exposure locations and/or baseline data will be undertaken. Prior to statistical analyses, macroinvertebrate metrics are tested for normality and homogeneity of variances and where the assumptions are met, will be compared through a t-test or an Analysis of Variance (ANOVA) with Bonferroni pairwise comparison ($\alpha = 0.05$). Where these assumptions are not met, non-parametric analyses will be applied such as the Mann-Whitney U-test or Kruskal-Wallis test followed by Dunn's multiple pairwise comparisons procedure ($\alpha = 0.05$). When data are non-normal, non-parametric tests are more powerful than parametric ones, *i.e.*, non-parametric analyses may be able to detect significant differences in the data when parametric analyses would not (Zar 1999). Non-parametric analyses are performed on ranks of the data and therefore do not require transformation of data; thus, all analyses will be performed on the raw data. All analyses are performed using a current version of XLStat Version.

4.2.1.2 PARAMETERS

Benthic invertebrate community descriptors (*i.e.*, metrics) are calculated for each sample and included in the data analysis. Abundance metrics are determined based on the mean for each aquatic habitat type sampled within a polygon and may include:

- Total invertebrate density; and

- Abundance or density of major groups (*e.g.*, Amphipoda, Oligochaeta, Chironomidae, Ephemeroptera, Trichoptera, Plecoptera, Pisidiidae, and Gastropoda).

Composition metrics are also determined based on the mean 'characteristic' for each aquatic habitat type sampled within a polygon. Composition metrics may include:

- Percent Ephemeroptera;
- Percent Ephemeroptera, Plecoptera, and Trichoptera taxa (EPT Index) (Sullivan et al. 2004);
- Ratio of EPT/Chironomidae;
- Percent of total organisms made up of Oligochaeta and Chironomidae; and

Simpson's Diversity (Environment Canada 2012) index provides an estimate of the probability that two individuals in a sample belong to the same species. The higher the index (0 to 1), the less likely it is that two individuals belong to the same species, *i.e.*, likely the higher the diversity (Magurran 1988, 2004). However, it is important to keep in mind that this index is not itself a diversity and it is highly nonlinear. Diversity indices attempt to summarize the relative abundance of various taxa. An index may provide more succinct information about benthic macroinvertebrate communities than abundance or richness alone. Simpson's Diversity index de-emphasizes rare taxa, while highlighting common taxa and evenness among taxa (*i.e.*, similarity of population sizes of different species) (Mandaville 2002).

Lastly, richness metrics may include:

- Total richness (total number of taxa per aquatic habitat in a polygon at the lowest practical level of identification; provides a measure of the diversity and is indicative of the level of disturbance) (Barbour *et al.* 1999; Klemm *et al.* 2002; Resh *et al.* 1997); and
- Richness of each Ephemeroptera, Plecoptera, and Trichoptera (EPT).

The variability of numerous benthic macroinvertebrate metrics measured during the CAMP were evaluated and described to assist with identifying the most robust metrics for further statistical exploration and consideration under the AEMP (see Appendix 4A). Three less variable metrics identified through this process as key metrics for the purposes of benchmark comparisons were:

- Total macroinvertebrate abundance;
- Simpson's Diversity Index; and
- Total taxonomic richness.

Coefficients of Variation (COVs) for the composition and richness metrics were typically less than 20% for each habitat type in Split Lake and were therefore identified for further analysis; exceptions included Simpson's Diversity Index (nearshore: 2011) and taxonomic richness (offshore: 2009, 2010) (see Tables 4A-9 and 4A-13). COV for total macroinvertebrate abundance (Table 4A-1) was somewhat higher in comparison, particularly in the nearshore aquatic habitat type, but this metric was retained as it is among the most commonly used indicators for the status of the benthic macroinvertebrate community in waterbodies.

4.2.1.3 SAMPLING SITES

To the extent possible and where feasible, sampling locations are selected such that sampling conducted pre-Project and during construction will be comparable, with monitoring conducted near established baseline sampling sites. Benthos will be assessed at: two reference sampling areas, including the Burntwood River (First Rapids to Split Lake) and Split Lake (data collected as part of CAMP for both waterbodies); and three potentially affected areas in a gradient downstream of Gull Rapids, including the Nelson River (3 km downstream of Keeyask), Stephens Lake (11 km downstream of Keeyask), and Stephens Lake (25 km downstream of Keeyask; data collected as part of CAMP) (Table 4-2; Map 4-1). At each area, grab samples will be collected from nearshore predominantly wetted and offshore habitat types. The following locations were sampled in 2013 specifically to supplement the baseline data available to assess potential construction effects (Map 4-1):

- Nelson River downstream of Gull Rapids (within 3 km - inlet to Stephens Lake); and
- Stephens Lake South 11 km downstream of Gull Rapids.

If water quality effects are detected downstream of the Kettle GS during any given construction monitoring year, additional sampling of benthic macroinvertebrates in this area may be proposed for that fall to determine the extent of potential downstream effects on this community due to instream construction activities.

4.2.1.4 SAMPLING FREQUENCY AND SCHEDULE

Benthic macroinvertebrate monitoring will be conducted annually in the fall during instream construction. If notable increases in TSS concentrations do not occur during the first four years of construction (i.e., up to and including spillway commissioning), the spatial extent or frequency of this sampling program may be reduced.

4.2.1.5 FIELD AND LABORATORY METHODS

Benthic macroinvertebrates will be sampled with a petite Ponar dredge (0.023 m2 opening) in flowing water environments with typically firmer, mixed/heterogeneous sediments or with an Ekman dredge (0.023 m2 opening) in standing water environments with typically softer, homogeneous sediments in predominantly wetted shallow (predominantly wetted [PW] nearshore) and deep water (offshore) habitats. Samples will be sieved through a 500 µm sieve bucket. A sample will also be collected at each benthic replicate station to characterize the general type of sediments in terms of organic content and particle size composition.

Based on the analysis of existing data (see Appendix 4A), five replicate stations per aquatic habitat type for each sampling area (i.e., polygon) will be sampled. Within each sampling area, samples are collected from the nearshore in predominantly wetted (PW) habitat and in the deeper offshore (OS) habitat. For PW habitat, water depths of >1 to 3 m, areas with consistent water movement (i.e., standing water, low water velocity), and homogeneous substrate are targeted; areas with aquatic macrophyte beds are avoided. For the OS, sampling sites are constrained by the same habitat attributes, with the exception of water depth, which is >3 to 10 m. The spatial extent of a polygon is at least 100 m x 100 m, and large enough to adequately accommodate five replicate stations. The locations of the five replicate stations are established by field crews and selected based on specific habitat attributes (i.e., water depth, substrate type, absence of aquatic plants, water velocity) and the spatial separation criteria outlined in the Metal Mining Technical Guidance for Environmental Effects Monitoring (EEM; EC 2012). By EEM definition, a replicate station is a specific, fixed sampling location within an area that can be determined, recognized, re-sampled and defined quantitatively (i.e., UTM position and a written description allow for the same replicate station to be sampled in subsequent years). The geographic extent of each replicate station is minimally 10 m x 10 m and separated from other replicate stations by at least 20 m. Within the habitat type(s), a replicate station consists of three randomly collected benthic invertebrate sub-samples; the sub-samples are composited to provide a single descriptor value from each station. Field sub-samples are collected using a random number table and from designated sampling locations around an anchored boat within the 10 m x 10 m replicate station area.

For each field sub-sample/grab, the Ekman/petite Ponar will be slowly lowered until it rests on the bottom to prevent shock waves that could physically move or disturb organisms and sediment from beneath the sampler. The Ekman/petite Ponar rope will be then pulled gently, closing the Ekman/petite Ponar jaws. The Ekman/petite Ponar will be slowly raised, to minimize turbulence, and the sample will be immediately placed into a pail. An acceptable sample will require that the jaws be completely closed upon retrieval. If the jaws are not completely closed the sample will be discarded into a bucket (and disposed of once sampling is completed) and the procedure is repeated. All sampling equipment will be rinsed before sampling at the next site.

At the laboratory, samples from all locations will be rinsed with water through a 500 µm sieve and sorted under a 3X magnifying lamp. The invertebrates will be transferred to 70% ethanol prior to being identified to the appropriate taxonomic level. A Leica Mz125 microscope (maximum 100x magnification) and reference texts from Clifford (1991), Merritt and Cummins (1996), Peckarsky *et al.* (1990), Smith (2001), Stewart and Stark (2002), and Wiggins (2004) will be used for taxonomic identification. Scientific names used follow the Integrated Taxonomic Information System (ITIS 2014) classification.

Invertebrates are identified to major group (subclass, order, or family) and Ephemeroptera are identified to genus. A qualified invertebrate taxonomist will performs all invertebrate identification and enumeration, with 10% of samples submitted to an external taxonomist for QA/QC purposes.

A QA/QC plan will be developed prior to program implementation and will outline the planning, implementation, and assessment procedures to be used to apply specific QA/QC activities and criteria to the AEMP. In brief, the QA/QC plan will include QA/QC procedures, detailed sampling protocols, and data handling procedures.

4.2.1.6 BENCHMARKS FOR ANALYSIS OF TSS INCREASES

Although all metrics will be reviewed, data analysis may focus upon three key metrics (see Section 4.2.1.3) and comparisons to the proposed benchmark (*i.e.*, ±50% change in the mean of a metric in comparison to reference locations and/or baseline data) will be done to identify the potential for adverse effects on the benthic macroinvertebrate community. For each metric that exceeds the benchmark, a statistical comparison between reference and exposure locations and/or baseline data will be undertaken.

Potential effects of construction-related activities on the downstream benthic macroinvertebrate community will be assessed by:

- Investigating statistically significant changes over time in metrics used to describe the community at each affected polygon in comparison to any observed changes over time at unaffected polygons, for the same aquatic habitat types sampled; and
- Relating any observed statistically significant changes over time in benthic community metrics in sampled aquatic habitat types at affected polygons to changes in the input of total TSS (*i.e.*, relating any changes to construction effects).

The response of the benthos to increases in TSS will be assessed annually and reported on in comparison to changes in water quality downstream of instream construction activities. For example, significant decreases in metrics between baseline and a construction monitoring year that will be expected to be negatively affected by increases in TSS include a decrease in Ephemeroptera abundance, percent EPT, and Pisidiidae abundance.

The current variability of river flow results in variations in the concentrations of suspended sediments and their deposition in the Project area. As a result, the current benthic macroinvertebrate community should be able to withstand very short-term increases (*i.e.*, days to a few weeks) in suspended and benthic sediments with negligible (*i.e.*, non-detectable), long-term negative effects.

4.2.2 BIOLOGICAL EFFECTS OF PREDICTED AQUATIC HABITAT AND WATER QUALITY CHANGES

For the Clark Lake to Gull Rapids reach of the Nelson River, operation monitoring of the benthic macroinvertebrate community will assess the biological effects of predicted flooding, sedimentation, increased frequency of water level fluctuations, and changes in surface water quality in bays. Downstream of the Keeyask GS, operation monitoring will assess the biological effects of predicted alteration of flow, as well as water velocities and depths (where sampling is feasible), and a reduction in ice scour. Additional baseline data were collected in fall 2013 to augment the existing database and improve its utility for post- Project comparisons. It is expected that the details provided in the following sections will be reviewed prior to commencement of the operation period as additional data and understanding are acquired during the construction period.

Benthic macroinvertebrate monitoring during operation includes the area from the GS upstream to the base of Long Rapids and downstream through Stephens Lake-South (Table 4-2; Map 4-1).

The benthic macroinvertebrate community will also be monitored upstream of the GS in unaffected waterbodies, such as the Burntwood River (First Rapids to Split Lake) and Split Lake., and in areas of Stephens Lake (*i.e.*, O'Neill Bay and Stephens Lake-North) that will continue to provide a useful proxy to assist in assessing effects of the Project.

4.2.2.1 KEY QUESTIONS

Upstream of the GS, benthic sampling will be designed to assess the biological effects of predicted flooding, sedimentation, increased frequency of water level fluctuations, and changes in surface water quality in bays. The key questions that will be addressed through benthic macroinvertebrate monitoring during operation are:

- Has an area-wide, large increase in benthic macroinvertebrate abundance, and a change in community composition, occurred in the long term in response to the increased availability of aquatic habitat and changes in substrates?
- Are benthic macroinvertebrate abundance and/or distribution in littoral habitat negatively affected by the increased frequency of water level fluctuations?
- Do low DO concentrations in areas of flooding and peat disintegration result in initially low levels of benthic abundance and richness? What is the ultimate abundance of benthos in the long term if DO depletion continues to occur during the winter months?
- Are there any unexpected effects on benthic macroinvertebrates that may be related to GS operation?

Downstream of the GS, benthic sampling will be designed to assess the biological effects of predicted alteration of flow, as well as water velocities and depths (where sampling is feasible), and a reduction in ice scour. The key questions that will be addressed through benthic macroinvertebrate monitoring during operation are:

- Have irregular flow patterns contributed to a reduction in benthic macroinvertebrate taxa richness?
- Has reduced ice scour in littoral habitat contributed to any change to the abundance and/or distribution of benthos?
- Are there any unexpected effects on benthic macroinvertebrates that may be related to GS operation?

4.2.2.2 STUDY DESIGN AND DATA ANALYSIS

The sampling design and data analysis for benthic macroinvertebrate monitoring will follow that described in Section 4.2.1.2.

4.2.2.3 PARAMETERS

Parameters are described in Section 4.2.1.3.

4.2.2.4 SAMPLING SITES

Throughout operation, benthic macroinvertebrates will be monitored at four reference areas and seven potentially affected areas. The reference areas include the Burntwood River, Split Lake, Stephens Lake-O’Neil Bay, and Stephens Lake-North (sampling in all areas, with the exception of Stephens Lake-O’Neil Bay, will be completed through CAMP) (Table 4-2; Map 4-1). Four potentially affected areas upstream of Keeyask will be monitored including Nelson River-Mainstem, Nelson River-Back Bay (minimally flooded tributary), Nelson River-Back Bay (Seebeesis Creek), and Gull Lake (Map 4-1). Three potentially affected sites downstream of Keeyask will be monitored including the Nelson River (3 km downstream of Keeyask), Stephens Lake (11 km downstream of Keeyask), and Stephens Lake (25 km downstream of Keeyask; sampling to be completed through CAMP) (Table 4-2; Map 4-1). At each sampling location, a kick/sweep sample will be collected from the nearshore intermittently exposed zone habitat type, and grab samples will be collected from each of the nearshore predominantly wetted habitat type and offshore habitat type (with a few exceptions where not all three habitat types are available within a polygon). Where feasible, sampling stations utilized during construction monitoring will also be sampled during operation, with the addition of stations in newly created habitat (selected so as to be representative of the predominant habitat types within the reservoir) or to address specific Project-related effects (*e.g.*, bays within shallow, flooded areas that experience DO depletion). Sites representative of the flooded backbays and mainstem areas in the reservoir will be monitored across multiple AEMP components (water quality, aquatic habitat, lower trophic levels, and fish community) to allow for an integrated analysis of observed changes (see Section 2.2.2.4 for further discussion). The following locations were sampled in 2013 specifically to supplement the baseline data available to assess potential Project-related effects (Map 4-1):

- Nelson River Mainstem near upstream extent of Gull Lake;
- Nelson River Back Bay minimally flooded tributary (unnamed creek D/S of Nap Creek);
- Nelson River Back Bay flooded tributary (Seebeesis Creek);
- Gull Lake;
- Nelson River downstream of Gull Rapids (within 3 km - inlet to Stephens Lake);
- Stephens Lake South 11 km downstream of Gull Rapids; and
- Stephens Lake O'Neil Bay.

Following the first year of monitoring, results from multiple AEMP components will be reviewed to determine which bay(s) will be monitored thereafter and if modifications to the sampling program will be warranted (*e.g.*, change in the number or location of replicate stations).

4.2.2.5 SAMPLING FREQUENCY AND SCHEDULE

Benthic monitoring will be conducted annually in the fall each year for the first three years after full supply level is reached. Monitoring will then occur at least once every three years until ten years post- impoundment. A review conducted at that time will determine the need for and frequency of sampling after this time.

4.2.2.6 FIELD AND LABORATORY METHODS

Based on the analysis of existing data (see Appendix 4A), five replicate stations per aquatic habitat for each sampling polygon will be sampled. Within each sampling location, a kick/sweep samples will be collected from the nearshore intermittently exposed zone habitat type, and grab samples will be collected from each of the nearshore predominantly wetted habitat type and offshore habitat type (with a few exceptions where not all three habitat types are available within a polygon). The spatial extent of polygons, establishment of replicate stations, definition of a replicate station, geographic extent of a replicate station, and number/handling of field sub-samples are as described in Section 4.2.1.6.

Benthos will be sampled in the intermittently exposed portion of the littoral zone (*i.e.*, nearshore IEZ) with a travelling kick/sweep net ($\leq$ 500 µm mesh net bag and a 305 x 254 mm frame opening). Each replicate station would consist of a timed 3-minute composite sample using a zigzag travelling kick/sweep approach in a perpendicular direction from the water's edge to a maximum of 1 m water depth (width of zigzag will be approximately 1 m). In predominantly wetted shallow- and deep water habitats, benthos will be sampled as described in Section 4.2.1.6. A sample will also be collected at each replicate station to characterize the general type of sediments in terms of organic content and particle size composition.

See Section 4.2.1.6 for a description of laboratory methods and QA/QC plan development.

4.2.2.7 BENCHMARKS FOR ANALYSIS OF HABITAT CHANGES

Although all metrics will be reviewed, data analysis may focus upon key metrics (see Section 4.2.1.3) and comparisons to the proposed benchmark (*i.e.*, ±50% change in the mean of a metric in comparison to reference locations and/or baseline data) will be done to identify the potential for adverse effects on the benthic macroinvertebrate community. For each metric that exceeds the benchmark, a statistical comparison between reference and exposure locations and/or baseline data will be undertaken.

Potential effects of operation-related changes in aquatic habitat and water quality parameters on the benthic macroinvertebrate community will be assessed by:

- Investigating statistically significant changes over time in metrics used to describe the community at each affected polygon in comparison to any observed changes over time at unaffected polygons, for the same aquatic habitat types sampled; and
- Relating any observed statistically significant temporal changes in benthic community metrics, at affected polygons, to changes in aquatic habitat and water quality parameters.

Response(s) of the benthos to the following will be assessed and reported on in comparison to changes in aquatic habitat and water quality parameters:

- Predicted flooding, sedimentation, increased frequency of water level fluctuations, and changes in surface water quality in bays upstream of the GS; and
- Predicted alteration of flow, as well as water velocities and depths (where sampling is feasible), and a reduction in ice scour downstream of the GS.

4.3 MANAGEMENT RESPONSE FRAMEWORK

4.3.1 ADAPTIVE MANAGEMENT ASSESSMENT FRAMEWORK

Benthic macroinvertebrate data will be assessed during each year of monitoring, and would follow the proposed management framework as outlined in Figure 4-2 and described below.

4.3.1.1 STEP 1 – COMPARISON TO BENCHMARK

Step 1 will involve preparing the BMI data for analysis (*i.e.*, conversion of number of macroinvertebrates to density), calculation of metrics for each replicate station, preliminary review of data through graphical presentations (*e.g.*, box plots) to visually assess the occurrence of extreme outliers and potential spatial and/or yearly differences, and calculation of summary statistics. Data will then be compared to the benchmark (change in the mean of ±50% as described in Section 4.1.2); if the benchmark is not exceeded the assessment would proceed to Response Level 1 (temporal analysis). In this instance, more robust metrics will be plotted graphically or in table format to facilitate visual analysis of changes over time and assessment of whether there is an upward or downward change that may suggest mounting effects.

4.3.1.2 STEP 2 – STATISTICAL EVALUATION OF DATA RELATIVE TO REFERENCE AND/OR BASELINE

If the benchmark is exceeded, the assessment would proceed to Step 2 – determination of whether there is a statistical difference between upstream and downstream areas (*i.e.*, control-impact) and/or relative to baseline conditions (*i.e.*, before-after). If a statistical difference was not observed, the assessment would proceed to Response Level 1.

4.3.1.3 STEP 3 – DETERMINE IF EFFECTS ARE PROJECT RELATED

Where statistical differences are identified for any metric with an exceedance of the benchmark, the assessment would proceed to Step 3 in which an investigation of cause (*i.e.*, whether the difference is Project-related) will be undertaken. By design, the program will provide information to address this question. However, additional analyses that could be undertaken may include the following:

- Evaluation of timing and locations of construction activities;
- Evaluation of data collected under the SMP;
- Consideration of local, non-Project related activities/influences that may affect water quality or aquatic habitat, and subsequently the aquatic biota; and
- Review of regional benthic macroinvertebrate data (*e.g.*, CAMP, Wuskwatim AEMP) to evaluate if similar changes have occurred in other areas that may not be Project-related.

If the observed difference(s) is determined to be not Project-related, the assessment would proceed to Response Level 1. If it is determined that the Project was likely contributing to the observed change(s), the assessment would proceed to Response Level 2.

As for water quality (Section 2.3.1), it is important to identify *a priori* that data will be considered for individual metrics, but the overall assessment and subsequent activities that may be undertaken under Response Level 2 would consider changes to various benthic macroinvertebrate community metrics individually as well as collectively. Activities to be undertaken or considered under Response Level 2 may include the following:

- Temporal analysis;
- Compare to predictions in the AE SV (Table 4-1);
- Evaluate contribution of the Project to the effect;
- Evaluate spatial and temporal extent of the observed effects;
- Consider results of water, sediment, aquatic habitat, and other biological monitoring (i.e., assess ecological relevance of the observed changes);
- Determine the need for additional monitoring and/or focused study(ies) to provide site-specific information on the effects to the environment;
- Evaluate potential sources/causes and potential for continued contributions/effects;
- Consider regional information (*i.e.*, data from CAMP) on the metrics of concern to assist with interpretation of AEMP results; and
- Consider mitigation/management and determine next steps and/or additional follow-up action(s) that may be required.

Review of the monitoring program and benchmark will be undertaken throughout the implementation of the AEMP with the intent to provide a mechanism for modification(s) as data are acquired over time.

4.3.2 INTEGRATED ANALYSIS OF MONITORING RESULTS

Relationships among benthic macroinvertebrate community metrics, environmental variables (*e.g.*, surface water and sediment quality parameters), and other biotic components (*e.g.*, fish community descriptors) may be explored using:

- Spearman rank correlation coefficients (evaluate correlations between metrics; ADDINSOFT 2013);
- Regression plots of paired metrics (evaluate potentially significant relationships between metrics); and

Multivariate analyses (summarize the structure of the macroinvertebrate community and potential relationships with corresponding environmental conditions or other factors that may influence the community).

5.0 FISH COMMUNITY

5.1 INTRODUCTION

Monitoring Project effects on the fish community and the success of mitigation/off-setting measures will focus on three fish species selected as VECs for the Project: Walleye, Lake Whitefish, and Northern Pike. The overall objective of mitigation and offsetting is to maintain existing fish populations to support a sustainable fishery, which is consistent with the Fisheries Management Objectives for the Project (Appendix 1B). Lake Sturgeon may also be recorded in the studies described in this section; however, targeted monitoring for Lake Sturgeon is described in Section 6.0.

Components of fish community monitoring will be conducted during both the construction and operation phases of the Project in the Nelson River and associated tributaries between Clark Lake and the Keeyask GS (the Keeyask area) and in Stephens Lake (Map 1-2). Fish species composition and abundance monitoring, described in Section 5.2.1, will also be conducted in Split Lake under the CAMP, and will be used as an upstream comparative waterbody. Several components of monitoring are proposed to continue for 15-20 years following the start of construction in 2014, while other components that are focused on assessing the effectiveness of mitigative measures may only be conducted for one or two years following impoundment in 2019.

Subsequent sections in this introduction provide: (i) a summary of the assessment provided in the AE SV, including a description of pathways of effect, a summary of assessment results, and proposed mitigation and offsetting measures (Section 5.1.1); and (ii) an overview of benchmarks (action levels) that will be considered in the interpretation of the monitoring results (Section 5.1.2).

Monitoring activities are described in Section 5.2, as follows:

- Section 5.2.1 Species composition and abundance monitoring;
- Section 5.2.2 Monitoring use of existing and created spawning habitat;
- Section 5.2.3 Movement/habitat use monitoring;
- Section 5.2.4 Turbine mortality;
- Section 5.2.5 Monitoring of fish stranding following spill events; and
- Section 5.2.6 Monitoring fish winterkill in the vicinity of Little Gull Lake.

Section 5.3 provides the adaptive management framework outlining the proposed process for interpreting and assessing monitoring results, including integration of results with other monitoring activities described in this AEMP. This section also describes the process whereby monitoring results would be considered in terms of action levels to determine the need and type of follow-up activities, including: (i) modification of the monitoring program; (ii) conduct of focused studies; and (iii) implementation of additional mitigation and/or offsetting measures.

5.1.1 ASSESSMENT SUMMARY AND IDENTIFICATION ACTION LEVELS FOR MONITORING ACTIVITIES

A summary of Project-related pathways of effect, mitigation and offsetting measures, residual effects and monitoring is provided in Table 5-1. The following sections provide a brief summary of the pathways of effect through which the Project may potentially affect the fish community and a summary of the assessment results, as presented in the AE SV.

5.1.1.1 PATHWAYS OF EFFECT

Potential effects of the Project on the fish community were assessed based on analysis of the following possible pathways of effect:

- Injury or mortality due to stranding of fish when cofferdams are dewatered, entrainment of fish in intake pipes for water used for construction, blasting effects, and water quality effects from instream activities, malfunctions, or accidental spills;
- Reduction of spawning activity during construction due to disturbance (from noise, vibrations, *etc.*) and habitat loss/alteration;
- Loss of spawning and feeding habitat and the loss of an upstream movement corridor as a result of the flooding and dewatering of portions of Gull Rapids;
- An increase in numbers of fish leaving the reservoir (present day Gull Lake) due to the relatively rapid changes in water levels and water velocities in Gull Lake during Stage II construction and impoundment and a decrease in water velocity at Birthday Rapids after impoundment;
- Changes to fish use of aquatic habitat in Stephens Lake due to sediment deposition during construction;
- Changes in downstream movement of larval, juvenile, and adult fish due to the creation of the reservoir and presence of the GS structures (*i.e.*, dam, spillway, trash racks and turbines);
- Injury and mortality of fish moving downstream past the trash racks and turbines or over the spillway, as well as stranding in the dewatered area after spillway operation is ceased;
- Potential changes to fish use of the river reach immediately downstream of Gull Rapids due to channeling flow through the GS and cycling of flows;
- Changes in upstream movement of adult fish at Gull Rapids due to the presence of the GS structures;

- Habitat changes in the reservoir due to changes in water levels and flow that will result in the loss or alteration of existing habitats (tributaries, rapids, littoral) and creation of new habitats. Some of these habitats (*e.g.*, littoral) will be of lower quality due to the increased frequency of water level fluctuations in the reservoir. These habitat changes will result in changes of the production of aquatic plants, invertebrates and forage fish;
- Changes in water quality (TSS and DO) in backbay areas of the reservoir, in particular during the first ten years of impoundment; and
- Potential increase in mortality of VEC species due to increased domestic and recreational harvest.

5.1.1.2 ASSESSMENT RESULTS, MITIGATION / OFFSETTING MEASURES

DOWNSTREAM OF GULL RAPIDS / GENERATING STATION

Potential fish mortality during construction due to stranding during cofferdam dewatering, entrainment in water intake pipes, blasting, and effects to water quality will be mitigated through measures including: instream construction timing windows to protect spring spawning fish; fish salvage; adherence to guidelines for intake screens and blasting; and treatment of effluents. These measures are expected to effectively avoid effects to fish and no targeted monitoring is planned. A small amount of habitat, in channels created in the last decade by erosion as a result of ice dams along the north shore of the Nelson River downstream of Gull Rapids, will also be filled in during construction of haul roads to allow access to borrow sites; these haul road crossings will be removed at the end of construction. Fish movement along the channels will be maintained by providing culverts in the haul road crossings; no targeted monitoring is planned.

Water quality may be affected by instream construction and point and non-point discharges downstream of the construction site. Effects to water quality are being managed to minimize effects (Section 2.1.1) and no specific monitoring of the fish community in relation to water quality changes is planned.

During the construction period, a reduction/loss of natural recruitment downstream of the GS is expected due to a loss of spawning habitat in Gull Rapids and disturbances associated with construction activities. Fish populations in Stephens Lake that spawn primarily in Gull Rapids are predicted to experience a short-term decrease in cohort strength during the years that the GS is being built. During operation, a constructed spawning shoal, located in the tailrace of the GS, and a Lake Whitefish spawning shoal, located on the south shore downstream of the GS (FOMP Section 4.1.5 and 4.1.6), are expected to provide sufficient spawning habitat for fish that spawn primarily in this area of Stephens Lake.

Monitoring of fish species composition and abundance and of existing and created spawning habitat will document how fish populations respond to the loss of Gull Rapids and the effectiveness of created spawning habitat. These are described in sections 5.2.1 and 5.2.2, respectively. No long-term negative effects to VEC fish populations are predicted.

Creation of the reservoir may reduce the number of larval fish drifting from the Keeyask area downstream into Stephens Lake, as reduced water velocities will likely result in a higher proportion of drifting larvae being retained in the reservoir. The change in species composition and abundance will be monitored both upstream and downstream of the GS. This change is permanent and cannot be mitigated.

The ability of Gull Rapids to function as an upstream movement corridor will be lost for fish populations in Stephens Lake. Based on analysis of existing information, habitat for each life history stage of all VECs will be present both upstream and downstream of the GS after construction. In addition, analysis in the AE SV supported the conclusion that fish populations in Stephens Lake would not be adversely affected by the loss of access to habitat in Gull Lake. However, in its review of the AE SV, DFO identified uncertainty with respect to this conclusion. This uncertainty will be addressed through a collaborative process by the KFRRC to determine whether mitigation of effects to upstream movement through the provision of upstream fish passage is required. Monitoring to describe fish movements in Stephens Lake is described in Section 5.2.3.

Similarly, the AE SV concluded that mortality of Walleye, Northern Pike and Lake Whitefish passing by the turbines or over the spillway of the GS would not affect the sustainability of populations upstream and downstream of the GS. Direct measurement of injury and mortality during experimental passage past the turbines and over the spillway is planned for Walleye and potentially Northern Pike and Lake Whitefish (Section 5.2.4).

Following operation of the Keeyask GS spillway, fish could potentially become stranded within isolated pools in the spillway after the water recedes. This potential source of fish mortality will be mitigated through the provision of escape channels that will allow fish to move into Stephens Lake. Monitoring the effectiveness of this mitigative measure is described in Section 5.2.5.

The minor changes in habitat associated with the downstream transport of fines in the river channel between the GS and Stephens Lake are not expected to affect fish populations. Targeted monitoring of substrate in this reach is described in sections 3.2.1 and 3.2.2 of this document. Sedimentation in this area of Stephens Lake during construction is not expected to affect substrate composition since deposition will consist of like material (i.e., sand will deposit over sand and silt over silt).

Gull Lake/Keeyask Reservoir

Impoundment of the Keeyask Reservoir will alter fish habitat in the Birthday Rapids to Gull Rapids reach of the Nelson River. The relatively rapid increase in water level immediately after impoundment and corresponding decrease in water velocity in the reservoir and at Birthday Rapids could increase numbers of fish leaving the reservoir. Once FSL is reached, existing river, lake and tributary habitat will be changed as a result of increased water depth and decreased water velocities, characteristic of the newly established Keeyask Reservoir. Habitat changes between Long Rapids and Birthday Rapids will be of small extent; there are no anticipated changes to water velocity and substrate and only a small change to water depth.

Fish habitat in the newly flooded areas of the reservoir will potentially be of lower quality due to low DO conditions during winter, shoreline instability, and the absence of aquatic plants for the first years after impoundment. As conditions evolve, these areas will develop into suitable feeding habitat for many fish species and spawning habitat for species such as Northern Pike. Over the long-term, it is predicted that there will be an increase in the fish abundance in the reservoir. The composition of the fish community will shift towards species guilds that prefer lacustrine (e.g., Walleye) rather than riverine (e.g., Longnose Sucker) conditions. Monitoring the response of the fish community to these habitat changes is described in Section 5.2.1.

Some existing spawning sites for Lake Whitefish and Walleye in the reservoir (e.g., inlet of Gull Lake, constriction in Gull Lake upstream of Caribou Island) will be altered, but these will be replaced by spawning habitat created at nearby locations (FOMP Section 4.1.2). The effectiveness of created spawning habitat and use of existing spawning habitat in the post-Project environment will be monitored to confirm that spawning habitat is available (Section 5.2.2).

Fish movements downstream from the Keeyask reservoir to Stephens Lake will be possible through the Keeyask GS via either the turbines or spillway. Fish movements within the reservoir and Stephens Lake, as well as upstream out of the reservoir, and downstream past the GS will be monitored (Section 5.2.3). Results of this monitoring component will be used to determine the proportion of tagged fish moving through the Keeyask GS. Mortality of fish moving through the turbines will be directly estimated through a turbine mortality study focused on Walleye, and potentially Lake Whitefish and Northern Pike (Section 5.2.4).

During winter there is potential that low oxygen levels in the Keeyask reservoir may develop in the vicinity of present day Little Gull Lake. Under normal circumstances, fish could move into areas of the reservoir with suitable oxygen levels. However, there is concern that during winter the section of the Keeyask reservoir surrounding Little Gull Lake could freeze to the bottom and isolate fish in Little Gull Lake. To mitigate this potential effect, the central portion of existing channels will be deepened to provide egress channels and allow fish to leave this area if low oxygen levels develop. Monitoring the effectiveness of this mitigative measure is described in Section 5.2.6.

It is not known whether construction of the Keeyask GS will cause a change (either increase or decrease) in the harvest of Walleye, Northern Pike and Lake Whitefish. No targeted monitoring is planned.

The need to modify planned mitigation and offsetting measures will be determined through the adaptive management process set out in Section 5.3.

OVERVIEW OF MONITORING

Monitoring that will address specific effects has been noted above; however, monitoring to support the overall objective of maintaining populations of Walleye, Northern Pike and Lake Whitefish upstream and downstream of the GS is best understood as an integrated program as follows:

1. Fish species composition and abundance monitoring (Section 5.2.1) – maintaining fish populations to support sustainable fisheries for each VEC fish species is the overall objective. Catch-per-unit- effort (CPUE), as determined by standardized index gillnetting, will be used as the primary indicator. CPUE of small-bodied fish species will be monitored to confirm that suitable foraging and rearing areas exist in the post-Project environment. In addition, condition factor and growth rate data on large and small-bodied species will be recorded.
2. Use of existing and created spawning habitat (Section 5.2.2) – spawning will be monitored to confirm that suitable spawning areas (existing and created habitat) exist post-Project.
3. Movement/Habitat use monitoring (Section 5.2.3) – movement studies on adult Walleye and Lake Whitefish are being conducted to provide estimates of movement through Gull Rapids prior to construction of the GS, estimates of passage through the GS once constructed, estimates of emigration from the reservoir, the frequency of GS encounters and use of specific habitats (*e.g.*, spawning). Monitoring will provide supporting information to assess potential changes to fish abundance in the Keeyask reservoir.
4. Turbine and spillway mortality (Section 5.2.4) – VEC fish species will be experimentally introduced into a turbine of the Keeyask GS to determine injury and mortality rates of fish, by size and species. Turbines have been designed to provide 90 %or greater survival for fish less than 500 mm in length. Survival rates for larger fish are not known but are expected to be greater than recorded in previous studies (65-80%) (AE SV Appendix 1A). Mortality rates for fish passing over the spillway may also be estimated.
5. Monitoring of fish stranding in the Keeyask GS spillway following spill events (Section 5.2.5) – following a spill event, monitoring will occur in the Keeyask GS spillway to determine if channels constructed to prevent fish stranding, and allow fish to escape into Stephens Lake, are functioning as predicted.
6. Monitoring fish winterkill in the vicinity of Little Gull Lake (Section 5.2.6) – To mitigate the potential for winter kill in this area, egress channels will be constructed prior to impoundment. Immediately after ice-off, monitoring will be conducted to assess whether winterkill of adult large-bodied fish occurred.

5.1.2 IDENTIFICATION OF BENCHMARKS

The approach to adaptive management for the aquatic environment will be based on a collaborative effort of the KFRRC as described in Section 1 of this AEMP. To assist in determining when adaptive management measures need to be implemented, preliminary benchmarks comprising three action levels have been identified, as follows (Table 5-2):

1. Early warning trigger – generally defined as a change in a negative direction in an indicator; this action level will provide an alert that further analysis may be required to determine if unanticipated negative effects are occurring.
2. Ecologically significant benchmark - defined as a change/level of an indicator that suggests that a negative effect, sufficient to threaten the overall Project objective of maintaining

existing VEC fish populations to support sustainable fisheries, is occurring. No widely accepted benchmarks exist for fish populations; the benchmarks proposed in Table 5-2 are based on the current understanding of Walleye, Lake Whitefish, and Northern Pike in the Keeyask area and professional judgement.

3. Conservation objective – defined as being indicative of Walleye, Lake Whitefish, and Northern Pike fish populations that are achieving the Project objective of maintaining the existing fish populations to support sustainable fisheries.

Table 5-2 provides a list of action levels that will be considered on an annual basis in interpretation of the results of monitoring activities. These action levels are initial starting points for the monitoring program and may be refined as the program proceeds. It should be noted that, as described in Section 5.2, specific monitoring activities may provide information related to indicators in addition to those listed in Table 5-2. However, action levels have only been identified for the indicators listed in Table 5-2 as these are the most useful in addressing the overall goal of maintaining VEC fish populations and assessing the effectiveness of mitigation/offsetting measures.

The six components of the monitoring program will consider action levels for selected indicators, as follows:

- Fish Species Composition and Abundance – This component of monitoring will consider the following indicators: VEC fish species CPUE, condition factor and growth rate; and CPUE and species richness of small-bodied fish species. The program is based on a comparison of data collected prior to construction of the Project with those collected during Project operation.

CPUE is a sufficiently sensitive metric to track changes to fish populations; however, initially post- impoundment CPUE is expected to decline in the Keeyask reservoir due to the doubling of the wetted area and potential movement of fish into newly flooded areas that will be difficult to sample. A 50% reduction in CPUE in comparison to pre-Project levels for three consecutive monitoring cycles (9 years) after impoundment was selected as the ecologically significant benchmark. The conservation objective is maintenance of existing VEC populations to support sustainable fisheries.

For condition factor and growth, a statistically significant decline was identified as the early warning trigger and an ecologically significant change was considered as a decline of 25% in these values.

Indicators for the small-bodied fish community, which includes juveniles of large-bodied species, include species richness and a measure of total abundance and abundance of the main species.

- Use of existing and newly created spawning habitat –The indicators that will be used are the presence of pre-spawn or spawning Northern Pike, Walleye and Lake Whitefish in the vicinity of existing or created spawning habitat and the presence of larval Lake Whitefish.

- Movement monitoring – Results of movement monitoring will assist in assessing the need for downstream fish protection measures and upstream fish passage. The early warning trigger that a change in the frequency of downstream movements has occurred is an observed increase in the frequency of movement of VEC species (measured by both acoustically tagged and Floy-tagged VEC species) above that of the existing level (less than 5% annually). The ecologically significant benchmark was set as a rate greater than 10% annually for any one of the three VEC species.
- Turbine mortality monitoring - turbines at the Keeyask GS have been designed to incorporate features to minimize rates of fish injury and mortality. Based on the specifications of turbines installed in the Keeyask GS, the survival rate of fish up to 500 mm in length is expected to be greater than 90%. There are two benchmarks for this monitoring component. Any mortality of acoustically tagged fish that encounters the Keeyask GS will provide an early warning trigger. The ecologically significant benchmark for both tagged and test fish will be mortality above 10% for fish smaller than 500 mm and 50% for fish greater than 500 mm.
- Monitoring fish stranding in the Keeyask GS Spillway – Action levels were selected as an early warning trigger of 50 dead large bodied fish, the ecologically significant benchmark is greater than 200 dead large bodied fish, and the conservation objective is less than 50 dead fish.
- Fish winterkill in the vicinity of Little Gull Lake - Action levels were selected as an early warning trigger of 50 dead large bodied fish, the ecologically significant benchmark is greater than 200 dead large bodied fish, and the conservation objective is less than 50 dead fish.

5.2 MONITORING ACTIVITIES TO DETECT CHANGE

A summary schedule for all monitoring activities in relation to project construction and operation, and the implementation of mitigation and offsetting measures is provided in Figure 5-1.

5.2.1 FISH SPECIES COMPOSITION AND ABUNDANCE MONITORING

The goal of fish species composition and abundance monitoring is to determine if changes occur to relative abundance (measured using CPUE), condition, and growth of large-bodied fish species and CPUE of small-bodied fish species. Data analysis will be focused on, but not limited to, Northern Pike, Walleye and Lake Whitefish, the three VEC fish species selected for the Keeyask Project. For each of the above listed indicators, before and after comparisons will be made to data collected pre-Project (*i.e.*, 2001–2014). Monitoring will be conducted annually in

Split Lake (under CAMP), and annually in the Keeyask reservoir and Stephens Lake immediately following impoundment for a period of two or three years and every three years thereafter (Maps 5-1, 5-2 and 5-3). Change will be determined through statistical and qualitative comparisons to benchmarks established based on pre-Project data and/or expert opinion.

5.2.1.1 KEY QUESTIONS

Fish populations in the Clark Lake to Kettle GS reach of the Nelson River are expected to be affected by the Keeyask Project through several pathways (Section 5.1.1.1).

The key questions for this monitoring component are as follows:

- Will the abundance (CPUE) and species composition of the fish communities in the Keeyask reservoir and Stephens Lake change as a result of construction and operation of the Project?
- For the three VEC species, will a biologically relevant (and statistically significant) change in condition factor or growth be observed in the Keeyask reservoir and Stephens Lake in comparison to pre-Project conditions?
- Will the abundance of small-bodied fish captured in small mesh gillnets set in the Keeyask reservoir and Stephens Lake change following construction of the Project?

5.2.1.2 STUDY DESIGN AND DATA ANALYSIS

EXISTING DATA

Fish community data were collected in Split Lake, Gull Lake, and Stephens Lake in 2001, 2002, 2003 (Stephens Lake only), and 2009 using standard gang and small mesh index gillnets (Remnant *et al.* 2004; Johnson and Parks 2005; Holm 2010; Dunmall *et al.* 2004; Holm and Remnant 2004; Pisiak 2005a,b).

DATA ANALYSIS

A before-after-control-impact (BACI) study design will be used to detect change in a number of fish community metrics in the Clark Lake to Keeyask GS reach, as well as Split Lake and Stephens Lake, including: (a) CPUE of large-bodied fish species as measured by standard gang index gillnets; (b) condition factor of VEC fish species (controlling for fish length); (c) where sample sizes permit, length- at-age for three year old fish, and/or young fish (*i.e.*, approximately less than7 years of age), and growth of young fish as measured by Galluci and Quinn's growth parameter ω (Galluci and Quinn 1979); and (d) CPUE of small-bodied fish species captured in small mesh index gillnets. Standardized index gillnetting data will enable CPUE, condition factor, and length-at-age calculations for each VEC fish species. In addition, small mesh gillnets will be attached to every third standard index gillnet to generate the small- bodied species CPUE data.

The variability in the catch and composition of fish species captured in gillnets means that several levels of assessment are required. Initial assessments of the pre-Project baseline data suggest that these data are not normally distributed, meaning comparisons are restricted to nonparametric methods. For example, the likelihood of CPUE values for both large- and small-bodied fish can be determined using the baseline data that have been fitted to a distribution in XLStat (Addinsoft 2006). Standard methods will be used to test distribution fit and whether monitoring data are expected based on the fitted baseline distributions (*e.g.*, Akaike's Information Criterion or AIC, Mann-Whitney U-test, Kolmogorov-Smirnov test).

Determining whether CPUE values fit the baseline data will be determined using the Mann-Whitney U- test and evaluating the likelihood of observing the monitoring data given the baseline distribution. Power of the Mann-Whitney U-tests will be determined post hoc once the monitoring data have been fitted to a distribution. This approach provides a reliable and defensible estimate of the statistical power of the Mann-Whitney U-test, given the data. Analyses will be run with random deviates from the fitted distributions (baseline and monitoring) using PopTools Addin (Hood 2010) for Microsoft Excel. All iteration-based analyses will be built using Excel macros written in Visual Basic for Applications.

Community composition will be compared to existing baseline data to determine whether the post- Project monitoring data fall within the expected variation. Incidence-abundance curves of existing baseline data will be used to assess the incidence and abundance of fish species during the monitoring period. Annual frequency of occurrence of fish species in the baseline data will also be used to assess annual variation in composition and allow appropriate assessment of the composition during the monitoring period.

Condition factor, length-at-age relationships and the growth parameter ω will also be evaluated for fish species using metrics (length, weight, age) collected during the index gillnetting programs. The statistical analysis employed will depend on a number of factors, but Analysis of Variance (ANOVA), Analysis of Covariance (ANCOVA), and/or a mixed model approach will be used to compare post-Project data with pre-Project information to determine if change is occurring.

5.2.1.3 PARAMETERS

Similar to pre-Project studies, fish will be captured using standard index gang gillnets and small mesh index gillnets, enumerated by species, and sampled for length and weight. In addition, sex, state of maturity, and external condition (deformities, erosion, lesions, and tumours [DELTs]) will be recorded from the catch. Age and mercury samples will also be collected from a subsample of the catch.

Catch data will be analyzed to generate CPUE values and frequency of occurrence histograms. Condition factor, length-at-age and growth of young fish as measured by Dalluci and Quinn's growth parameter ω (Galluci and Quinn 1979) will be calculated by species and the CPUE of the small-bodied fish community will be calculated.

5.2.1.4 SAMPLING SITES

Sampling in Split and Stephens lakes will generally occur at sites established during baseline studies (Map 5-1, 5-3). Sampling sites within the Keeyask reservoir following construction of GS will be identified based on major habitat types, which is consistent with site selection methods used during baseline studies (preliminary sites shown in Map 5-2).

5.2.1.5 SAMPLING FREQUENCY AND SCHEDULE

Monitoring will be conducted annually in Split Lake under CAMP. Monitoring of Stephens Lake will be conducted under CAMP in August 2015 and 2018. Monitoring of Gull Lake/Keeyask reservoir will be conducted in August 2015 and potentially 2018. After impoundment in late 2019, two or three consecutive years of monitoring will be conducted in both the Keeyask reservoir and Stephens Lake to record the response of the fish community to the newly formed reservoir and loss of Gull Rapids. Monitoring of the Keeyask reservoir and Stephens Lake will commence on a three year rotation in 2024. In 2029, the need for additional monitoring will be decided upon by the KFRRC (Figure 5-1).

5.2.1.6 FIELD AND LABORATORY METHODS

A total of 10–16 gillnet sites will be set in each waterbody to collect pertinent catch and biological data. All sites will be sampled with bottom set standard gang index gillnets and at every third set location a small mesh index gillnet will be attached to the standard gang index gillnet.

All captured fish will be enumerated by species, measured for fork length (FL) and/or total length, and weighed. For VEC species, a subsample based on length intervals will be aged to provide data for the catch- and length-at-age and analyses.

Utilizing pre-Project data collected in the Keeyask study area, an *a priori* non-parametric power analysis indicated that the power to detect small changes (*i.e.*, an increase or decrease of 10% or 25%) in VEC species CPUE values will be quite low unless a prohibitively large number of sites are sampled. However, the power analysis did indicate that the power to detect a large decline in Northern Pike and Walleye CPUE (*i.e.*, greater than or equal to 50%) will be high (greater than 80% power), assuming 10-16 sites are sampled. The ability to detect changes in Lake Whitefish CPUE will be slightly lower than Northern Pike or Walleye, due to the smaller numbers of whitefish caught and higher variation around whitefish catches. However, 10-16 sites will be adequate to assess large changes in Lake Whitefish CPUE.

5.2.1.7 BENCHMARKS

STANDARD INDEX GILLNET CPUE FOR VECS (LAKE WHITEFISH, NORTHERN PIKE, WALLEYE)

The key indicator that will be used to provide the benchmark for large-bodied fish species will be CPUE. This parameter was selected as the key indicator as it has been calculated in 2001/2002, 2002/2003, and 2009 from Gull and Stephens lakes, respectively, and for multiple years in Split Lake. Mean CPUE will be calculated, allowing the direct statistical assessment of the difference between sequential estimates as well as the relative statistical power for a given percentage decrease.

The fish community is not expected to change immediately after FSL is reached as short term monitoring (*i.e.*, less than 4 years) has been demonstrated to not detect changes in fish communities immediately after impoundment (Quinn and Kwak 2003). Rather, a lag response is expected, whereby changes in the fish populations and communities are expected to occur gradually after Project completion, and may not be detectable for a considerable period of time (Findlay and Bourdages 2000). As a result, CPUE benchmarks that are statistically and/or biologically relevant will be difficult to ascertain, as changes will have to be large to be detectable, and/or possibly require many years of monitoring before being detected.

In addition to the long periods of time required to fully realize change, selecting a CPUE action benchmark is tenuous as variation around CPUE is typically high, and can vary widely between gillnet sites, waterbodies, and years. For example, Lake Whitefish, Northern Pike, and Walleye CPUE estimates (log transformed) from pre-Project standard index gillnetting conducted between Clark Lake and Gull Rapids varied considerably between years (2001, 2002 and 2009), especially for the smaller numbers of Lake Whitefish, with calculated coefficient of variation (CV) values equal to 74%, 29% and 24%, respectively. Lake Whitefish CPUE varied from a low of one fish caught/100 m of net/24 hours in 2002 to a high of 2.4 fish caught/100 m of net/24 hours in 2009, a change of 140%. Similar results were observed for Northern Pike CPUE estimates (min = 2.7 in 2009, max = 10.3 in 2002; a 74% decrease between 2002 and 2009) and Walleye CPUE estimates (min = 3.1 in 2009; max = 6.3 in 2001; a decrease of 103% between 2001 and 2009).

Needless to say, fish CPUE can vary considerably from year to year, and results from a prospective assessment of the nonparametric power to detect decreases in Lake Whitefish, Northern Pike and Walleye CPUE reflect this somewhat, as a decrease greater than 50% can be detected with high power and a reasonable sample size (*i.e.*, greater than 80%; Figure 5-2). As a result, the action benchmark for this component of monitoring, determined *a priori*, will be a 50% decrease from pre-Project estimates recorded for at least three consecutive monitoring cycles (*i.e.*, 9 years). The power analysis used here assumed that the standard error is the same for each decrease shown in Figure 5-2. Thus, a *post hoc* power analysis will be used once the actual standard error is estimated for each monitoring sample period.

CPUE values will be reviewed annually to determine whether changes to the fish community have occurred as predicted (Table 5-1). If results show significant differences from the predictions, then the results of other monitoring programs will be reviewed to determine likely cause/effect relationships and whether actions can be taken to mitigate unpredicted effects.

CONDITION FACTOR

Similar to CPUE, condition factor (K) is not expected to change immediately after FSL is reached, but rather a lag response is expected whereby changes in the aquatic environment will translate into changes in fish condition gradually after Project completion. Therefore, change may not be detectable for a considerable period of time.

Mean condition factor will be calculated for each VEC species (controlling for fish length) and compared with pre-Project data. Appropriate statistical analyses will be run to detect change. Depending on the number of fish caught, the early warning trigger, determined *a priori*, will be a statistically significant decrease in K for any of the three VEC fish species from pre-Project estimates recorded for two consecutive monitoring cycles (*i.e.*, 6 years). The action benchmark will be an observed 25% decline in K, for any one species, over two consecutive monitoring cycles.

LENGTH-AT-AGE/GROWTH OF YOUNG FISH AND CPUE OF SMALL-BODIED FISH

Length-at-age/growth of young fish will assist in determining if the Project has altered the quality of rearing and foraging habitats, or productivity at the lower trophic levels. The early warning trigger will be a statistically significant decrease in length-at-age for three-year old fish, and the growth parameter ω for young fish. If sample sizes are insufficient to utilize one cohort, then young fish, determined to be approximately less than 7 years of age will be used to increase the sample size. Mean fork length-at-age 3 will be calculated for each VEC species and compared with pre-Project data. Appropriate statistical analyses will be run to detect change. For length-at-age data, 95% confidence intervals and an appropriate ANOVA or mixed model analysis will assess mean difference in length, comparing pre- and post-Project mean length. Similarly, von Bertalanffy growth curves (Ricker 1975) will be fit to estimate ω, and 95% confidence intervals and an appropriate ANOVA or mixed model analysis will be used to assess differences in ω, comparing pre- and post-Project. The action benchmark will be an observed 25% decline in growth rate, for any one species, over two consecutive monitoring cycles.

Given that each VEC species is reliant to some extent on small-bodied fish present in the Keeyask area as a food resource, the assessment of small-bodied species caught in small mesh index gillnets will be assessed. For the early warning trigger, a statistically significant decrease in small-bodied species CPUE will be used.

All of the same issues associated with using VEC species CPUE likely apply to small-bodied species CPUE (*i.e.*, high variation, considerable time to realize effects, *etc.*). Although no *a priori* power analysis was done to establish the power to detect change in small-bodied species CPUE, results are expected to be similar to those observed for VEC species. As a result, an action benchmark will be a 50% decrease from pre-Project estimates or a decline in species richness, recorded for at least three consecutive monitoring cycles (*i.e.*, 9 years).

5.2.2 USE OF EXISTING AND CREATED SPAWNING HABITAT

Monitoring existing and created spawning habitat will be conducted to confirm the prediction in the AE SV that suitable spawning habitat for each VEC fish species will exist both upstream and downstream of the GS in the post-Project environment. Spawning will be confirmed by the observation of pre-spawn of spawning Walleye and Lake Whitefish and larval Lake Whitefish in the vicinity of existing and created spawning habitat. Reservoir tributary confluences and back bays will be monitored during spring to confirm that Northern Pike continue to spawn in these areas.

5.2.2.1 KEY QUESTIONS

Construction of the Keeyask GS and creation of the Keeyask reservoir will alter existing spawning habitat for each VEC fish species at Birthday Rapids, Gull Rapids, and throughout the reservoir. Constructed spawning shoals in the reservoir, in Stephens Lake and in the tailrace of the Keeyask GS are expected to be used by Walleye and Lake Whitefish (FOMP sections 4.1..2, 4.1.5 and 4.1.6; see maps 5-4, 5-5 and 5-6).

The key questions for this monitoring component are as follows:

- Does suitable spawning habitat exist upstream and downstream of the Keeyask GS for each VEC fish species in the post-Project environment?
- Will Northern Pike continue to spawn in tributary confluences and back bays of the Keeyask reservoir?
- Will Walleye and Lake Whitefish use existing or created spawning habitat in the Keeyask reservoir, immediately downstream of the GS and in Stephens Lake?

5.2.2.2 STUDY DESIGN AND DATA ANALYSIS

EXISTING DATA

Several studies were conducted in the Keeyask area between 2001 and 2004 to identify spawning habitat for VEC fish species (Remnant *et al.* 2004; Johnson and Parks 2005; Bretecher *et al.* 2007; Johnson 2007). Similar studies were conducted concurrently in the reach of the Nelson River below Gull Rapids (Pisiak *et al.* 2004; Pisiak 2005a, b; MacDonald 2007). Results of these studies suggest that Northern Pike spawn in tributary confluences and backbays of the Keeyask area. Walleye, however, were found to spawn in the Nelson River mainstem and spawning sites were identified in the vicinity of Birthday Rapids, the inlet to Gull Lake and on the rocky shorelines of Caribou Island. Pre-spawn Lake Whitefish in the Keeyask area were captured in the riverine section of the Nelson River between Birthday Rapids and Gull Lake, suggesting that spawning occurred within this reach. Gull Rapids was found to provide important spawning habitat for Walleye and Lake Whitefish in Stephens Lake.

DATA ANALYSIS

To determine the location of spawning habitat for Walleye in the post-Project environment, a combination of boat-electrofishing and gillnetting will be conducted during spring in the vicinity of existing or created spawning habitat both upstream and downstream of the GS. Boat-electrofishing and short duration gillnet sets will be conducted in back bays and tributary confluences to confirm that Northern Pike are spawning in these areas. Identifying Lake Whitefish spawning areas will be more difficult in the Keeyask area, due to the relatively low abundance of this species. Neuston tows will be conducted in the Keeyask reservoir shortly after ice-off to confirm that Lake Whitefish spawned upstream of the GS post-Project. Downstream of the GS, boat electrofishing will be conducted during fall in the vicinity of the tailrace spawning structure and the Lake Whitefish spawning shoal to determine if Lake Whitefish are spawning in these areas.

5.2.2.3 PARAMETERS

Numbers of VEC species captured in pre-spawn and spawning condition (boat electrofishing or backpack electrofishing), and numbers of Lake Whitefish larvae captured in neuston tows will be the two parameters of interest.

5.2.2.4 SAMPLING SITES

During spring, boat electrofishing and short duration gillnet sets will be conducted in representative backbays/tributary confluences in the Keeyask area to confirm that Northern Pike continue to spawn in these areas (within zones 4, 7, 8, 11, 12 and 13, Map 2-5). Sampling for pre-spawn and spawning Walleye will be conducted in natural and constructed spawning habitat in the Keeyask reservoir and downstream. Neuston tows will be conducted in the Keeyask reservoir in the vicinity of constructed spawning shoals and in areas suspected to support spawning habitat in the existing environment to capture larval Lake Whitefish.

During fall, boat-electrofishing and gillnetting will be conducted at the tailrace spawning structure and at the Lake Whitefish spawning shoal to capture pre-spawn and spawning Lake Whitefish.

5.2.2.5 SAMPLING FREQUENCY AND SCHEDULE

Sampling will occur during the first two years after full supply level is attained. Spring sampling for Northern Pike, Walleye and larval Lake Whitefish will be conducted in May and June, while fall sampling for Lake Whitefish will be conducted in September and October. Exact dates of sampling will vary annually and correspond with the time that water temperatures are within the preferred range of spawning or hatching for each species. Neuston sampling will be initiated as soon as the reservoir is virtually ice-free.

5.2.2.6 FIELD AND LABORATORY METHODS

Electrofishing gear will be comprised of a Smith-Root GPP 5.0 electrofisher with dual boom 0.91 m diameter Smith-Root UAA-6 Umbrella anodes mounted approximately 2.0 m apart. The electrofisher will be set at 15 pulses per second/3.5 amps/500 volts, proven to be effective in the Nelson River. The electrofishing crew will consist of one boat driver and two netters at the bow of the boat, one each on the port and starboard sides.

A modified neuston sampler (Mason and Phillips 1986, Mota *et al.* 2000) will be used to sample for larval Lake Whitefish. All captured larvae will be enumerated and identified to species either in the field or in the laboratory.

5.2.2.7 BENCHMARKS

Monitoring will confirm whether existing and created spawning habitat in the reservoir and downstream of the GS are being used by the VEC species. Absence of VEC species in pre-spawn or spawning condition, or larval Lake Whitefish, captured during their respective sampling programs, will act as the early warning trigger. In absence of statistical benchmarks, the ecologically significant benchmark will be the absence of pre-spawn/spawning fish, or larval Lake Whitefish, observed for two consecutive monitoring cycles. The conservation objective for this monitoring component will be the capture of spawning VEC species in several areas of the reservoir and downstream of the GS and similar numbers of larval Lake Whitefish compared to the existing environment.

Results of this monitoring component, when combined with CPUE data, will provide an indication that suitable spawning habitat exists or does not exist in the post-Project environment. If data indicate that spawning habitat does not exist, then adaptive management measures will be decided upon in consultation with MCWS and DFO. Measures may include development of additional spawning habitat at alternate locations, or improvement of existing structures.

5.2.3 MOVEMENT / HABITAT USE MONITORING

Northern Pike movement will be monitored by mark-recapture of Floy-tagged fish, whereas movement studies on Walleye and Lake Whitefish will be more detailed, involving both mark-recapture and acoustic telemetry. Lake Whitefish and Walleye were selected for more detailed monitoring because both species are known to spawn in the vicinity of Gull Rapids, they are species of commercial and domestic importance, and they are known to pass both upstream and downstream through Gull Rapids. Following construction of the GS and impoundment of the Keeyask reservoir, coarse-scale movements of Walleye and their use of habitat in the reservoir will be monitored to describe habitat use, distribution (*i.e.*, are fish using the upper, middle, or lower end of the reservoir) and coarse-scale movement patterns.

Coarse-scale movement/habitat use monitoring during construction/operation will involve the following types of data collection:

- Continued monitoring of the acoustic transmitters (three-year battery life) that were applied to 80 Walleye in the Keeyask area and Stephens Lake in 2013. An additional 80 transmitters will be applied in 2016 to continue monitoring during construction;
- Monitoring of acoustic transmitters (three-year battery life) applied to 60 Lake Whitefish (20 upstream of the Keeyask GS and 40 in Stephens Lake) during fall of 2014. An additional 60 transmitters will be applied in 2017;
- Monitoring of acoustic transmitters (three-year battery life) applied to 80 Walleye in the Keeyask reservoir and Stephens Lake during the operation phase for two consecutive 3-year monitoring cycles (2020 and 2023); and

- Monitoring of mark-recapture data from each VEC fish species.

The array of acoustic receivers already in place to monitor movements of acoustically tagged Lake Sturgeon (Section 6.2.4) will be used to monitor movements of acoustically-tagged Walleye and Lake Whitefish.

5.2.3.1 KEY QUESTIONS

Construction of the Project will affect fish movements in the main flow of the Nelson River near the construction site by blocking fish movements with placement of cofferdams, altering flow patterns, and causing disturbances (*i.e.*, blasting) that may increase emigration from the construction area. The broad objective of movement monitoring is to gain a better understanding of movements and habitat use in the Keeyask study area, with particular focus on movements in the vicinity of Gull Rapids, including, but not limited to, upstream and downstream passage.

Specific objectives of monitoring during construction are as follows:

- To quantify the number (or the proportion) of tagged Walleye and Lake Whitefish that move past the construction site; and
- To determine if fish are utilizing habitat in the vicinity of construction activities (particularly during spawning.

Movements and habitat use of Walleye and Lake Whitefish may be affected by operation of the Project, as a result of changes in the water regime (*e.g.*, flooding, reduction in water velocity). Specific objectives of monitoring during operation are as follows:

- To determine what types of habitat Walleye and Lake Whitefish are utilizing in the Keeyask reservoir (*i.e.*, are fish using the upper, middle or lower end of the reservoir);
- To identify what proportion of the fish population moves from the Keeyask reservoir upstream past Birthday and/or Long rapids;
- To assess the frequency of downstream movement through the Keeyask GS, which species/size classes are moving downstream, when are the movements occurring, and to determine mortality; and
- To determine where and what sizes of fish congregate in the fast water environment immediately below the Keeyask GS, and whether the species composition/size classes of fish vary by season.

5.2.3.2 STUDY DESIGN AND DATA ANALYSIS

Existing Data

Movements of 54 radio- and 20 acoustic-tagged Walleye, Northern Pike, and Lake Whitefish were monitored in the Nelson River between Clark Lake and Stephens Lake from 2001-2005. These data were presented in three reports: Murray and Barth (2007); Murray *et al.* (2005); and Barth *et al.* (2003).

Acoustic transmitters were applied to 80 Walleye in 2013; 40 upstream and 40 downstream of Gull Rapids, the site of the proposed Keeyask GS (Hrenchuk and Barth 2014b).

Between 1999 and 2012, Floy-tags were applied to approximately 5,500 Walleye, 7,900 Northern Pike, and 1,700 Lake Whitefish in the Keeyask area, Split Lake and Stephens Lake and their tributaries (Barth *et al.* 2004; Holm *et al.* 2005; Holm 2006, 2007a,b,c, 2009, 2010, 2011, 2012, 2013). Recapture information continues to be collected from these fish.

DATA ANALYSIS

The array of acoustic receivers already in place to monitor Lake Sturgeon movements (Section 6.2.4) will be used to monitor movements of acoustically tagged Walleye and Lake Whitefish. Receivers have been set to maximize the detection distance of each receiver and optimize spatial coverage of the study area, accounting for the potential for long distance upstream or downstream movements. Presently, receivers are set in low velocity areas in Clark Lake, below sets of rapids (Long Rapids and Birthday Rapids), in off-current areas of the Nelson River, in Gull Lake, in off-current areas within Gull Rapids, in Stephens Lake, immediately downstream of the Kettle GS and approximately 2 km upstream of the Long Spruce GS (see Section 6.2.4). Depending on how construction of the GS alters flow patterns upstream and downstream of the GS, additional receivers may be set near the construction site to provide additional data.

Additional stationary receivers will be deployed following impoundment to monitor the frequency and mode (spillway or turbines) of downstream fish passage through the GS, and to provide a determination of survival following passage. Acoustically tagged fish moving downstream through the GS will be detected by stationary receivers on the upstream side of the GS, and, if the fish survives passage, will be relocated by receivers on the downstream side of the GS. Tagged fish detected by the stationary receivers on the upstream side of the GS, which are not subsequently detected by either the upstream or downstream stationary receivers, will be assumed to have suffered mortality. Presently, it is unknown if acoustic telemetry will be capable of discerning whether a fish moved downstream through the GS via the turbines or spillway, but given the distance between the intakes of the two structures, it is likely that receivers can be positioned to make this distinction with reasonable confidence.

It should be noted that tags that are never detected are considered defective and excluded from data analyses, as are tags that consistently emit a signal but do not move for an extended period of time (indicative of tag loss/mortality). Tagged fish may also be harvested, which will reduce the sample size of tagged fish in the area.

Additional data on the movements of fish in the Keeyask reservoir will be collected by marking Walleye, Lake Whitefish and Northern Pike larger than 250 mm FL with Floy-tags. The intent of applying Floy- tags to these three species in the reservoir is to provide additional information on the frequency of fish movements out of the reservoir, either downstream through the Keeyask GS, or upstream into Split Lake. Marked fish will be recaptured by local fishermen, commercial fishermen and/or during biological studies such as index gillnetting conducted in the Keeyask reservoir, Split, Stephens and Assean lakes, Lake Sturgeon gillnetting conducted in the Upper

Split Lake Area, the Keeyask reservoir and in Stephens Lake as well as other studies described as part of this AEMP. The proportion of tagged (marked) and unmarked fish captured will be recorded for all biological studies. A mark-recapture history will be generated for each fish captured during the operation phase. Individual recapture histories will be compared to pre-Project data. This will provide a descriptive comparison of the frequency and extent of movement between the pre-Project environment and movement during operation.

5.2.3.3 PARAMETERS

Although the questions being addressed during construction and operation are somewhat different, the parameters being addressed have been combined for the two phases of the Project. Additionally, as discussed in the previous section, acoustic transmitters will be applied to Walleye and Lake Whitefish twice during construction (2013/2014 and 2017/2018) and to Walleye for two consecutive cycles during operation (2020 and 2023). Floy-tags will be applied to Walleye, Lake Whitefish, and Northern Pike. The following metrics will be examined:

- Number and proportion of acoustic and Floy-tagged fish that remain upstream of the construction site during construction or remain in various reaches of the Keeyask reservoir during operation;
- Number and proportion of acoustic and Floy-tagged fish that use habitat in the immediate vicinity of construction activities (*e.g.*, foraging in/near Gull Rapids)/Keeyask GS;
- Number and proportion of acoustic and Floy-tagged fish that move downstream over Gull Rapids/Keeyask GS into Stephens Lake or beyond;
- Number and proportion of acoustic-tagged Walleye and Lake Whitefish that move upstream through Gull Rapids during construction; and
- Number and proportion of acoustic and Floy-tagged fish that move upstream from Gull Lake/Keeyask Reservoir into the Split Lake area or beyond.

To the extent possible, movement data will be interpreted by fish species, size, age and state of maturity. This information may identify spawning areas, foraging areas and/or overwintering areas. Seasonal movement information such as distance moved, and proportional distribution will be calculated for each acoustically tagged fish.

5.2.3.4 SAMPLING SITES

In 2013, 40 Walleye were tagged within 2 km of the downstream end of Gull Rapids and 40 Walleye were tagged 7.5 to 15 km upstream of Gull Rapids. Because Lake Whitefish will be more difficult to capture and keep alive during the tagging process, a combination of electrofishing and short duration gillnet sets will be used. Lake Whitefish will be tagged downstream of Gull Rapids, if possible. However, should insufficient numbers of Lake Whitefish be captured in this area, alternate locations will be considered including the North and South Moswakot rivers and Ferris Bay. Lake Whitefish do not comprise a large component of the fish community of Gull Lake and, based on previous experience, it is likely to be difficult to capture sufficient numbers of Lake Whitefish for statistical analysis.

Once tags applied to Walleye in 2013 and Lake Whitefish in 2014 have expired (3 years), additional transmitters will be applied. A total of 80 Walleye will be tagged, with approximately half of this total being tagged upstream of the construction site and half in Stephens Lake. A total of 60 Lake Whitefish will be tagged of which, due to the expected difficulty in capturing Lake Whitefish in Gull Lake mentioned above, approximately 20 fish will be tagged upstream of Gull Rapids and 40 fish will be tagged in Stephens Lake. Stationary acoustic receivers will be deployed throughout the Nelson River between Clark Lake and the Long Spruce GS. Additional receivers may be installed to monitor fish movements in the vicinity of the construction site. Once the reservoir has been filled, additional receivers will be deployed immediately upstream of the GS near both the spillway and powerhouse. Stationary receivers will be pulled out during winter in the riverine sections of the Keeyask reservoir.

To apply Floy-tags to fish in the Keeyask reservoir during operation, boat electrofishing will be conducted in the upper, middle and lower sections of the Keeyask reservoir. Sampling will be conducted to provide adequate spatial representation of Floy-tagged fish within each reservoir section. Recapture of Floy-tagged fish will occur during sampling conducted as part of CAMP in the Burntwood River below First Rapids and Split, Assean, and Stephens lakes, Lake Sturgeon gillnetting in the Upper Split Lake Area, Keeyask reservoir and Stephens Lake and/or other biological monitoring studies described in this AEMP.

5.2.3.5 SAMPLING FREQUENCY AND SCHEDULE

Three-year transmitters were applied to Walleye in 2013 and the same type of transmitters will be applied to Lake Whitefish during fall 2014. Fall has been selected as the period to implant transmitters because Lake Whitefish are in the best condition during fall and therefore more likely to survive the tagging process.

Because the lifespan of the acoustic transmitters that are of appropriate size for the fish species of interest is three years, transmitters will be applied to fish at three years intervals. During construction transmitters will be applied to Walleye and Lake Whitefish twice (2013 and 2014; 2016 and 2017 for Walleye and Lake Whitefish, respectively). During operation monitoring, new transmitters will be applied to Walleye twice (2020 and 2023), thus providing six years of monitoring data.

To capture fish for Floy-tagging, boat electrofishing and gillnets (set for a short duration) will be employed for 14-day periods, during spring and fall, annually, for three years in the late construction/early operation monitoring period. The need for applying additional tags would be reassessed during the four year review.

5.2.3.6 FIELD AND LABORATORY METHODS

Acoustic transmitters will be applied to Lake Whitefish during September to ensure that they are in the best condition possible prior to tag implantation. Prior to tag implantation, fish will be captured by electrofishing or in gillnets. Gillnets will be checked every one to two hours; fish will be removed from the net as soon as possible after capture, with minimal handling (*e.g.*, cutting of the net, if necessary). All Lake Whitefish will be measured for FL (± 1 mm) and weight (± 25 g). Fish in good physical condition, and a minimum weight of 400 g, will be chosen for tagging. To the extent possible, fish of various sizes and sexes will be selected.

Fish will be anaesthetized in clove oil, and a V13 acoustic transmitter (manufactured by VEMCO) will be surgically implanted into the body cavity through a small mid-ventral incision. The incision will be stitched closed, and the fish held until equilibrium and locomotory function have returned. Fish will be released at the site of capture. Fish will be tagged at various locations upstream and downstream of the construction site to provide adequate spatial representation.

A 50+ receiver VR2W array, that includes seven “gates” is currently being used to monitor movements of Walleye and Lake Sturgeon within the Keeyask study area (Hrenchuk 2014). For reference, “gates” refer to simultaneous use of two or more acoustic receivers oriented perpendicular to the primary flow axis to provide complete coverage for a cross section of river. In practice, this should result in 100% detection of passing fish and allow for directionality of movements to be determined (determined to be 95% effective in 2013) (Hrenchuk 2014). Movements of tagged fish will be monitored over the three-year life span of the transmitters throughout the open-water and, to a lesser extent, during the ice covered season (it is not feasible to monitor in some locations due to ice scouring). The methodologies employed will achieve a high level temporal resolution associated with large scale movements between or through key locations (*i.e.*, Gull Rapids).

Boat electrofishing and gillnets (set for a short duration) will be used to collect fish for Floy-tagging. Electrofishing gear will be comprised of a Smith-Root GPP 5.0 electrofisher with dual boom 0.91 m diameter Smith-Root UAA-6 Umbrella anodes mounted approximately 2.0 m apart. The electrofisher will be set at 15 pulses per second/3.5 amps/500 volts, proven to be effective in the Nelson River. The electrofishing crew will consist of one boat driver and two netters at the bow of the boat, one each on the port and starboard sides. Gillnets will be composed of twisted nylon mesh, with stretched mesh sizes ranging from 76 mm (3”) to 127 mm (5”). Floy-tags will be applied to each fish species between the basal pterygiophores of the dorsal fin using a Dennison Mark II tagging gun.

5.2.3.7 BENCHMARKS

Movement data will be reviewed prior to key events (*e.g.*, initiation of cofferdam construction, blasting) and annually. If movement data indicate that a large number of VEC species fish are aggregating close to planned construction activity and may be at risk, then mitigation measures to reduce the risk may be considered.

There is only one specific benchmark set for this monitoring component, relating to the frequency of downstream passage of adult VEC species. The early warning trigger was selected as an increase in movements of fish passing downstream through the GS above the existing level (less than 5%). The ecologically significant benchmark is an observed downstream movement of greater than 10% of the tagged fish, while the conservation target is to maintain rates of movement similar to what is observed in the existing environment.

How movement information will be used within the management framework and how the information will be used to determine the need for fish passage is further discussed in Section 5.3.

5.2.4 TURBINE MORTALITY

Turbines at the Keeyask GS have been designed to incorporate features to minimize rates of fish injury and mortality. Although low rates of injury and mortality are expected, a study to assess the effects on Walleye, Northern Pike, and, if possible, Lake Whitefish passed through turbines at the Keeyask GS will be conducted. Data will be used to determine the accuracy of mortality rate predictions provided in the AE SV. Fish movement data (discussed in Section 5.2.3) will also be used as an early warning trigger and to assess turbine mortality rates. Mortality rates for fish passing over the spillway may also be estimated using methodologies similar to those discussed in Section 5.2.4.6.

5.2.4.1 KEY QUESTIONS

The key questions for the turbine mortality study are as follows:

- What are the rates of injury and mortality for adult Walleye, Northern Pike, and Lake Whitefish?
- Within a species, is there a relationship between fish length and turbine effects?

5.2.4.2 STUDY DESIGN AND DATA ANALYSIS

EXISTING DATA

Turbine mortality studies were conducted at the Kelsey GS in 2006 and 2008 (North/South Consultants Inc. [NSC] and Normandeau Associates Inc. 2007, 2009). These studies reported that the survival rate was greater than 75% for Walleye with a mean length of 428 mm and Northern Pike greater than 450 mm.

DATA ANALYSIS

The approach outlined in the sections below is based on the Kelsey GS studies cited above; however, alternate approaches to estimating turbine and spillway mortality at the Keeyask GS will be evaluated in consultation with MCWS and DFO.

To estimate the rates of injury and mortality of fish during passage through a turbine at the Keeyask GS, Walleye, Northern Pike, and Lake Whitefish (if adequate numbers can be captured) will be experimentally passed through one turbine in sufficient numbers to make statistically valid predictions of 48-hour survival (NSC and Normandeau Associates Inc. 2007, 2009). Control fish will be released immediately downstream of the GS. Fish will be captured in the vicinity of the Keeyask GS, marked with HI-Z (balloon) and radio tags, and released into the turbine intake. Following release into the turbine, tagged fish will be recaptured downstream of the GS, injuries assessed, and survival calculated after a 48-hour holding period.

5.2.4.3 PARAMETERS

Following turbine passage, parameters by fish species and size-class include injury rate, and 48-hour survival rate.

5.2.4.4 SAMPLING SITES

Fish will be passed through a turbine at the Keeyask GS. To the extent possible, fish used in the study will be captured downstream of the GS.

5.2.4.5 SAMPLING FREQUENCY AND SCHEDULE

The study will be conducted in June of the third year that the first turbine unit is operational.

5.2.4.6 FIELD AND LABORATORY METHODS

Walleye, Northern Pike, and Lake Whitefish will be captured in the vicinity of the Keeyask GS, using a variety of non-lethal methods, and held in holding pools for 24 hours. Only fish in excellent condition following 24 hours of holding will be considered as treatment or control fish. Treatment fish will be intentionally passed through a turbine. Fish passed into the turbine will be released at three depths (shallow, mid, and deep). Control fish (*i.e.*, fish not passed through the turbine, but otherwise treated identical to experimental fish) will be released directly into the tailrace downstream of the GS through a flexible plastic tube. Approximately 120 fish of each species will be tested (30 fish at each of three separate turbine release points and 30 control fish).

Prior to release as either treatment or control fish, fish will be measured for FL, and marked with HI-Z (balloon) tags and external radio-tags. These tags allow for the retrieval and assessment fish condition within minutes of their release. Upon retrieval, fish condition will be classified as either clean, injured, or mortality. Injuries will be further classified by type and severity. Live fish will be transferred to holding pools for 48 hours. Fish will be further assessed for injury and mortality at 24 hours and again at

48 hours, after which the live fish will be released.

5.2.4.7 BENCHMARKS

Based on movement data collected from acoustically-tagged Walleye, Lake Whitefish (described in the previous section 5.2.3), and Lake Sturgeon (described in Section 6.2.4), any indication that passage through the Keeyask has resulted in mortality will act as the early warning trigger for this monitoring component.

Using the formula developed by Franke *et al.* (1997), the predicted survival rate is greater than 90% for fish less than 500 mm in length passing through the turbines installed in the Keeyask

GS. This will be the benchmark against which turbine mortality rates will be assessed. As illustrated in Table 5-2, survival of less than 50% of fish greater than 500 mm has also been considered as an ecologically significant benchmark. If data indicate that the prediction is incorrect, adaptive management measures will be decided upon in consultation with MCWS and DFO.

5.2.5 FISH STRANDING FOLLOWING SPILL EVENTS

Following spill events, or periods of water level fluctuation in Stephens Lake, the number, size and location of isolated spillway pools in the Keeyask GS spillway that do not connect to Stephens Lake, will be identified. Fish may become stranded in these isolated pools, resulting in mortality due to increased water temperatures, freezing during winter and/or depletion of dissolved oxygen. Fish will be captured within these spillway pools (fish capture methods contingent on size, shape, morphology, and depth of pools) to determine the species composition, abundance and size of fish stranded, as well as period of the year and size and duration of spill events that may influence fish stranding. This potential source of fish mortality will be mitigated through the construction of channels that connect the spillway pools to Stephens Lake under all water levels. Channels are planned to be constructed in the dry prior to operation of the spillway.

5.2.5.1 KEY QUESTIONS

Spillway operation and fluctuating water levels in Stephens Lake have the potential to create isolated pools in the Keeyask GS spillway that could result in fish mortality. Channels will be constructed to mitigate this potential source of fish mortality and ensure proper drainage that allows fish to escape into Stephens Lake. Monitoring will confirm that the channels are effective at reducing/preventing significant fish mortality.

The key question for monitoring are as follows:

- Are fish being stranded in the spillway of the Keeyask GS following a spill event?
- Are the constructed channels effective at allowing fish to escape back into Stephens Lake following a spill event at the Keeyask GS?

5.2.5.2 STUDY DESIGN AND DATA ANALYSIS

DATA ANALYSIS

Given that the location and characteristics (depth, shape, morphology) of spillway pools and the connecting channels that ensure drainage will not be known until after the GS has been constructed, establishing a study design is impossible at present. However, the main objective of this monitoring component will be to determine the extent of fish stranding, and the effectiveness of drainage channels following a variety of different water level and spillway flow scenarios (*i.e.*, spill volume, duration, number of spillway gates opened, as well Stephens Lake water levels). Sampling will aim to determine where, when and what types of fish, by size class, and sex and maturity status are being stranded, as well as the location, number and size of isolated pools that are not being effectively drained by connecting channels.

5.2.5.3 PARAMETERS

Parameters include the number, species composition, size, sex and state of maturity of fish stranded in the spillway pools. Additional information associated with each spill event, including the amount of flow that passed through the spillway, the duration of the spill, the tailrace water level, and the time of year, will be used to provide context for the stranding results.

5.2.5.4 SAMPLING SITES

Monitoring will be conducted in isolated spillway pools between the Keeyask GS spillway and Stephens Lake.

5.2.5.5 SAMPLING FREQUENCY AND SCHEDULE

Sampling will be conducted following spill events and periods of water level fluctuation in Stephens Lake during the first two years of operation (Figure 5-1). The frequency and schedule of sampling will be determined on an annual basis, dependent upon the frequency of spillway use and Stephens Lake water level fluctuation. The duration of the program will depend on range of spill events that occur.

5.2.5.6 FIELD AND LABORATORY METHODS

Upon termination of a spill event or water level fluctuation event in Stephens Lake, sampling will be conducted within isolated spillway pools using the optimal non-lethal capture methodology (*i.e.*, short set gillnets, backpack electrofishing, dipnetting), that depending on physical characteristics, may vary by pool. Captured fish will be enumerated by species, measured for FL (mm), and released into the Nelson River downstream of the GS.

5.2.5.7 BENCHMARKS

The conservation objective associated with this component of monitoring is to reduce the stranding of fish in the spillway such that less than 50 large-bodied fish are stranded annually. The ecologically significant benchmark is the capture of greater than 200 stranded large-bodied fish per year within isolated spillway pools.

5.2.6 FISH WINTERKILL IN THE VICINITY OF LITTLE GULL LAKE

Flooding associated with impoundment of the Keeyask Reservoir will inundate Little Gull Lake. As described in Section 5.4.2.2.4 of the AE SV, low oxygen levels may develop in this area during ice covered periods due to a lack of flow through, long periods of ice cover, and long residence times. Although low oxygen conditions will be characteristic of many areas of the reservoir during winter, this area is of particular concern due to predictions that shallow sections of flooded land on either end of present day Little Gull Lake will freeze to the bottom and potentially prevent fish from escaping, resulting in fish winterkill. To mitigate this potential negative effect on fish, escape channels will be constructed that connect Little Gull Lake to the Nelson River, allowing fish a way to escape from low oxygen conditions should they develop. To determine whether this measure is effective in preventing winterkill, surveys will be conducted in spring immediately after ice-off.

5.2.6.1 KEY QUESTIONS

The key question for winterkill monitoring in the vicinity of Little Gull Lake is:

- Are the escape channels in the vicinity of Little Gull Lake effective in preventing winterkill in this portion of the reservoir?

5.2.6.2 STUDY DESIGN AND DATA ANALYSIS

EXISTING DATA

A fish inventory of Little Gull Lake was conducted using seine nets in summer 2002 (Richardson and Holm 2005). Results indicated that the fish community consisted of two forage species, Fathead Minnow and Brook Stickleback, species that are generally adapted to low DO conditions.

DATA ANALYSIS

Not applicable for this monitoring component.

5.2.6.3 PARAMETERS

Each dead large-bodied fish will be counted and, if possible, measured.

5.2.6.4 SAMPLING SITES

Monitoring will be conducted along the length of the entire shoreline in the area of Little Gull Lake.

5.2.6.5 SAMPLING FREQUENCY AND SCHEDULE

Sampling will be conducted immediately after ice-off during the first 2 years of operation.

5.2.6.6 FIELD AND LABORATORY METHODS

All dead fish will be identified to species and counted.

5.2.6.7 BENCHMARKS

Monitoring will confirm that escape channels are functioning as expected. If more than 200 dead fish are observed along the shorelines of the reservoir in the area of Little Gull Lake that likely resulted from low oxygen conditions during winter, then adaptive management measures will be decided upon in consultation with MCWS and DFO.

5.3 MANAGEMENT RESPONSE FRAMEWORK

5.3.1 ADAPTIVE MANAGEMENT ASSESSMENT FRAMEWORK

The introduction of this AEMP describes the KFRRC, which will oversee adaptive management to address Project concerns identified through monitoring. The adaptive management frameworks described below outline the steps whereby monitoring results will be reviewed in reference to benchmarks to determine whether unanticipated changes are occurring and, if so, whether adjustments to planned mitigation and offsetting measures are required.

As illustrated in Figure 5-3 through Figure 5-12, results of monitoring activities described in the preceding sections will be reviewed to determine whether the benchmark identified as the trigger for additional assessment has been crossed. If not, results will be reported and reviewed by the KFRRC; at this point the KFRRC has the option to determine that benchmarks or monitoring program need to be modified, even if the benchmarks identified in this AEMP have not been exceeded. If a benchmark is exceeded, then a multi-step assessment will be conducted. If there is a concern that an observed change may affect the sustainability of a fish population, then the next step is to determine whether additional mitigation or offsetting measures are required and, if so, whether contingency measures have been previously identified. If no contingency measures to address a particular issue have been *a priori*, then further studies would need to be identified and implemented. These studies would likely involve further biological investigations, to better define the problem and identify potential solutions. Depending on the type of solutions that are identified, engineering studies and evaluations may be required to design potential offsetting measures. If a large investment is required, then a complete cost/benefit analysis.

5.3.2 INTEGRATED ANALYSIS OF MONITORING RESULTS

Overall effects to the fish community will be determined by integrating results of all the monitoring components. Continued monitoring of VEC fish populations will confirm the long-term sustainability of fisheries for VEC fish species in the Keeyask area and Stephens Lake. As shown in Figure 5-3, CPUE will be a key input into long-term decisions regarding the need for additional mitigative measures.

Monitoring condition factor and growth will assist in verifying predictions in the AE SV that post-Project habitat would be suitable for foraging (Figure 5-4 and Figure 5-5). The abundance of small-bodied fish will also be assessed (Figure 5-6). Monitoring existing and created spawning habitat will provide an indication of where the VEC fish species are spawning in the post-Project environment and results will be used to assess the success of created spawning habitats (Figure 5-7). Fish movement monitoring will provide important supporting information for determining the causes of potential adverse effects in relation to adult abundance, condition and growth and provide input into the consideration of fish passage (Figure 5-8). The need for downstream fish protection will in part be based on results of movement monitoring of acoustically tagged fish (Figure 5-8) and turbine effects studies (Figure 5-9 and 5-10).

Results of monitoring the effectiveness of escape channels built to mitigate winterkill in Little Gull Lake and stranding in the spillway will address two other potential sources of mortality (Figure 5-11 and Figure 5-12).

5.3.3 MODIFICATION TO MITIGATION AND OFFSETTING MEASURES

Adaptive management for the Project will be guided by the KHLP's commitment to maintain sustainable fisheries for Walleye, Lake Whitefish and Northern Pike upstream and downstream of the station. If monitoring indicates that populations of these species cannot support sustainable fisheries, then further investigations will be undertaken to identify possible reasons and potential solutions. There currently are three major types of mitigation/offsetting measures that could be subject to modification through adaptive management:

4. Spawning habitat – measures to modify constructed habitat in the reservoir, and downstream of the GS near the tailrace, north shore and south shore;
5. Methods to reduce fish mortality through improving spillway connective channels, or escape channels from Little Gull Lake; and
6. Fish passage – potential provision of downstream protection (barrier to reduce passage at the turbines) and provision of upstream passage.

5.3.3.1 DETERMINATION OF THE NEED TO MODIFY SPAWNING HABITAT

Development of the Keeyask Reservoir will alter spawning habitat upstream of the GS for each VEC fish species, while permanent alteration of Gull Rapids will eliminate spawning habitat for Lake Whitefish and Walleye at the rapids, though other locations will remain downstream of the GS, in Stephens Lake and in tributaries. If the monitoring described in Section 5.2.2 does not locate spawning VEC fish species upstream or downstream of the GS in predicted post-Project spawning habitats, then further investigation and results of other monitoring components would be required to determine: (i) if spawning is not occurring; and, (ii) if the reduction in spawning habitat is affecting the fish population.

Based on the evolution of the fish community in other reservoirs of the Nelson River, Walleye and Northern Pike populations generally increase. For this reason, it was predicted that spawning habitat for these two species will be abundant in the reservoir post-Project. Lake Whitefish however, will be more difficult to monitor, due to their low abundances in the reservoir. If larval Lake Whitefish are absent from Neuston tows in the reservoir, and CPUE of Lake Whitefish is found to be declining, then additional mitigative measure will be considered to enhance Lake Whitefish spawning areas.

5.3.3.2 IMPROVEMENT OF SPILLWAY CONNECTIVE CHANNELS AND/OR ESCAPE CHANNELS FROM LITTLE GULL LAKE

Should monitoring results indicate that large-bodied fish are suffering mortality due to stranding in the spillway (Section 5.2.5) or winterkill in Gull Lake (Section 5.2.6), the feasibility of modifications to either the connective channels or escape channels would be investigated.

5.3.3.3 DETERMINATION OF THE NEED FOR FISH PASSAGE

With respect to fish passage, three possible scenarios have been identified where fish passage could contribute to sustainable fisheries:

7. Permanent loss of adults by downstream emigration from the Keeyask reservoir is greater than the population in the reservoir can sustain.

The solution to this problem would depend on the age of fish moving and their fate as they pass by the station. If emigration is occurring at young life stages that readily survive passage downstream, then provision of upstream fish passage would provide fish the opportunity to return upstream. If larger fish are emigrating, then their route of downstream passage and any mortality associated with passage, particularly past the turbines, would need to be assessed. If substantial numbers of large fish are moving and a large proportion are dying during passage, then methods of fish protection would need to be investigated (see #2). If large fish are passing safely downstream, then an alternate approach would be to provide upstream passage.

It should be noted that provision of upstream passage would not necessarily address loss of fish from the Keeyask reservoir, since large fish may not move upstream through the passage facilities. This would be assessed based on ongoing monitoring of fish movements, and it may be determined that upstream passage is not appropriate.

8. The loss to the upstream and downstream populations as a result of mortality during passage past the station is threatening the sustainability of the upstream and/or downstream populations. If mortality is greater than sustainable levels, then the implementation of a measure to protect fish during downstream passage, or prevent them from moving downstream would be considered. A barrier to prevent passage of large fish would increase the upstream population but not the downstream population.
9. There may be as yet unidentified benefits to providing fish passage.

Both results of monitoring and developments in the understanding of VEC fish species ecology may indicate an unidentified role of large-scale movements in maintaining populations in the long term that would be relevant to the consideration of fish passage.

Section 6.3.4 provides additional discussion of fish passage in relation to Lake Sturgeon, which is also relevant to species considered in this section.

6.0 LAKE STURGEON

6.1 INTRODUCTION

Monitoring effects of the Project and success of mitigation and offsetting measures on Lake Sturgeon populations will require the continuation of several sampling programs initiated during the environmental assessment studies in 2001. Components of the Lake Sturgeon monitoring program that begin during the construction phase will be continued into the operation phase, and potentially continue for decades thereafter. The goal for Lake Sturgeon mitigation set out in the AE SV, which is consistent with the Project-specific Fisheries Management Objectives (Appendix 1B), is to develop self-sustaining populations upstream and downstream of the GS. Mitigation and monitoring will continue until this goal is achieved. Monitoring programs will also address the need for modifications/additions to mitigation and offsetting measures described in the Keeyask Fisheries Offsetting and Mitigation Plan (FOMP).

Similar to pre-Project studies, monitoring will be conducted in the following general areas (Map 6-1):

1. The Upper Split Lake area (including the Nelson River between the Kelsey GS and Split Lake, the Grass River between Witchai Lake Falls and the Nelson River, the Burntwood River from First Rapids to Split Lake, and the Odei River between First Falls and its confluence with the Burntwood River);
2. The Keeyask area, the Nelson River between the outlet of Clark Lake and Gull Rapids, and the site of the future Keeyask reservoir; and
3. Stephens Lake, specifically the section of the Nelson River downstream of the Keeyask GS to the Kettle GS.

The remaining sections of this introduction provide the following:

- Section 6.1.1 - a summary of the assessment provided in the AE SV, including a description of pathways of effect, a summary of assessment results, proposed mitigation and offsetting measures; and an overview of monitoring; and
- Section 6.1.2 - an overview of proposed benchmarks relevant to the implementation of adaptive management in response to monitoring results.

Section 6.2 “Monitoring Activities to Detect Change” describes the following four programs related to Lake Sturgeon:

- Section 6.2.1 Adult population estimation and biological metric monitoring;
- Section 6.2.2 Juvenile population and year-class strength monitoring;
- Section 6.2.3 Spawn monitoring; and
- Section 6.2.4 Movement monitoring.

It should be noted that several aspects of fish community monitoring, such as spillway stranding (Section 5.2.3.4), also address potential effects to Lake Sturgeon.

Section 6.3 provides the adaptive management framework outlining the proposed process for interpreting results of Lake Sturgeon monitoring activities, including integration of results with other monitoring activities described in this AEMP. This section also describes the process whereby monitoring results will be considered in terms of benchmarks identified in Section 6.1.2 to determine the need for follow-up activities, including: (i) modification of the monitoring program; (ii) implementation of other types of monitoring activities; (iii) implementation of identified contingency measures (as described in the FOMP); and (iv) identification of the need for and evaluation of other options to modify mitigation and offsetting measures.

6.1.1 ASSESSMENT SUMMARY

A summary of Project-related pathways of effect, mitigation and offsetting measures, residual effects and monitoring is provided in Table 6-1. The following sections provide a brief summary of how the pathways of effect through the Project may potentially affect Lake Sturgeon and a summary of the assessment results, as presented in the AE SV.

6.1.1.1 PATHWAYS OF EFFECT

Potential effects of the Project on Lake Sturgeon were assessed based on analysis of the following possible pathways of effect:

- Disruption of spawning activity during construction due to disturbance (from noise, vibrations, *etc.*) and habitat loss/alteration;
- Loss of spawning habitat and the loss of an upstream movement corridor as a result of the flooding and dewatering of portions of Gull Rapids and the presence of the GS structure;
- Changes in downstream movement of larval, juvenile, and adult sturgeon due to the creation of the reservoir and presence of the GS structures (*i.e.*, dam, spillway, trash racks and turbines);
- Injury and mortality of sturgeon moving downstream past the trashracks and turbines or over the spillway, as well as stranding in the dewatered area after spillway operation is ceased;
- Potential changes to sturgeon use of the river reach immediately downstream of Gull Rapids due to channeling flow through the GS and cycling of flows;
- Changes to sturgeon use of aquatic habitat in Stephens Lake due to sediment deposition during construction;
- An increase in numbers of sturgeon leaving the reservoir (present day Gull Lake) due to the relatively rapid changes in water levels and water velocities in Gull Lake during Stage II construction and impoundment and a decrease in water velocity at Birthday Rapids after impoundment;

- Changes in sturgeon use of the Birthday Rapids to Gull Rapids reach due to increased water levels and decreased flow that will result in the loss or alteration of existing habitat (in particular YOY habitat in Gull Lake) and creation of new habitat;
- A decrease in attraction to and use of spawning habitat at Birthday Rapids, given the predicted habitat alterations (*i.e.*, the loss of white water due to the small increase in depth and small reduction in water velocity); and
- Potential increase in mortality due to an increase in harvest.

6.1.1.2 ASSESSMENT RESULTS, MITIGATION / OFFSETTING MEASURES, AND MONITORING OVERVIEW

DOWNSTREAM OF GULL RAPIDS / GENERATING STATION

Potential mortality of sturgeon during construction as a result of stranding during cofferdam dewatering, entrainment in water intake pipes, blasting, and effects to water quality will be mitigated through measures including: adherence to instream construction timing windows, fish salvage, adherence to guidelines for intake screens and blasting, and treatment of effluents. These measures are expected to effectively avoid adverse effects to the Lake Sturgeon population and no targeted monitoring is planned.

During the construction period, a reduction/loss of natural recruitment downstream of the GS is expected due to loss of spawning habitat in Gull Rapids. Stocking of sturgeon into Stephens Lake (FOMP Section 4.1.7) is expected to mitigate potential effects to the overall population. Use of Gull Rapids for spawning during construction will be inferred from results of movement monitoring and recruitment monitoring.

During operation, the tailrace spawning shoal, cofferdam remnants downstream of the GS, and sections of the river immediately downstream of the spillway when it is in operation, are expected to provide sufficient spawning habitat to support a self-sustaining sturgeon population in Stephens Lake (FOMP Section 4.1.5). Augmentation of the Stephens Lake population will continue by stocking during the initial period of operation until a viable population size is reached, such that there will be sufficient spawners present to sustain the population. Continued monitoring of adult movements during operation will indicate whether fish are present in the region of the river with constructed spawning habitat. In addition, the areas where spawning fish are expected to congregate will be sampled to the extent feasible to determine the abundance of spawning fish. Monitoring of recruitment of young fish will provide the most effective measure of whether successful spawning is occurring downstream of the GS.

The minor changes in habitat in the river channel between the GS and Stephens Lake are not expected to affect the Lake Sturgeon population due the presence of other similar habitat in the vicinity. Young-of- the-year habitat in the river channel and at the inlet to Stephens Lake is expected to remain suitable, as no deposition of fine material over sand or gravel is predicted. Recruitment monitoring will assist in confirming whether suitable habitat is present.

Creation of the reservoir is expected to retain any larval sturgeon that may be currently drifting downstream from spawning locations near Birthday Rapids, over Gull Rapids, and into Stephens Lake. The contribution of young sturgeon spawned upstream of Gull Rapids relative to those spawned in Gull Rapids, to the existing Stephens Lake population is not known; however, given that few adult sturgeon are present in Stephens Lake, juvenile fish currently in Stephens Lake may have drifted in as larvae from upstream spawning locations. After impoundment, larval sturgeon are not expected to drift through the reservoir due to low water velocity, and any input that occurs under existing conditions would no longer occur. Stocking is expected to provide an alternate source of sturgeon to Stephens Lake to compensate for the potential loss of drifting sturgeon that may have been born at spawning sites upstream of Gull Rapids. In the long term, after a viable population is established in Stephens Lake, it is expected that recruitment from sturgeon within Stephens Lake would maintain the population.

Based on analysis of existing information, the conclusion in the AE SV was that the loss of access to habitat in Gull Lake will not affect the Stephens Lake population because habitat required to fulfill all life history stages will be present post-Project. In addition, stocking will increase the numbers of sturgeon such that, in the long term, sufficient sturgeon are present to spawn each year. However, in its review of the assessment, DFO identified uncertainty with respect to this conclusion. This uncertainty will be addressed through a collaborative process to determine whether mitigation of effects to upstream movement through the provision of upstream fish passage is required (Section 6.3).

Similarly, the assessment concluded that mortality of Lake Sturgeon passing by the turbines or over the spillway of the GS would not prevent the development of self-sustaining Lake Sturgeon populations upstream or downstream of the GS. Direct measurement of injury and mortality during experimental passage past the turbines is planned for Walleye and potentially Northern Pike and Lake Whitefish (Section 5.6), but there is no plan to use Lake Sturgeon as a test fish. Results of these studies will provide some information on potential mortality rates for smaller sturgeon. The rate of downstream movement of Lake Sturgeon in the reservoir and potential mortality will be estimated from movement studies.

Stranding of fish in the spillway after a spill will be mitigated through provision of escape channels from isolated pools or other measures; the effectiveness of this measure will be determined through surveys after spillway operation (Section 5.2.5). The need for additional fish protection measures will be determined through the adaptive management process set out in Section 6.3, based on an assessment of whether observed mortality is preventing the establishment of self-sustaining populations.

GULL LAKE / KEEYASK RESERVOIR

The potential loss of older sub-adults and adult Lake Sturgeon from Gull Lake due to emigration during construction and the initial years of impoundment cannot be prevented. Overall population numbers will be maintained through stocking, though this would not immediately replace older year classes in the reservoir. Monitoring of sturgeon movements would indicate whether a large proportion leave the reservoir. Although effects to the adult population present in the reservoir cannot be directly mitigated, stocking will assist in recovering the population.

Impoundment will change the habitat in the Birthday Rapids to Gull Rapids reach. The creation of a greater area of low velocity, deep water habitat is predicted to result in a net gain of foraging habitat for sub-adult and adult sturgeon. Young-of-the-year habitat found in the reach of Gull Lake north of Caribou Island will be altered by the Project and is predicted to be less suitable for YOY sturgeon.

Further, due to changes in water velocity, the dynamics of lake sturgeon larval drift are expected to change and as such it is expected that larvae will no longer drift to this location. Post-Project, suitable YOY habitat is predicted to exist at the inlet to Gull Lake, which is also predicted to be the primary location that larval sturgeon would settle out. However, it is not certain whether the substrate will be suitable; therefore, a contingency measure has been developed to create reservoir YOY habitat by the placement of sand on the river bottom if natural conditions are indeed unsuitable (FOMP Section 4.1.4). Monitoring the abundance and condition of adult Lake Sturgeon in the Keeyask reservoir will confirm predictions of suitable foraging habitat in the reservoir. The suitability of YOY habitat will be addressed through monitoring recruitment and distribution of wild-hatched and stocked fish.

Birthday Rapids is a known Lake Sturgeon spawning location. Impoundment of the Keeyask reservoir will lead to increased water levels that will submerge Birthday Rapids; water velocity and depth will continue to be suitable for sturgeon spawning but white water will likely no longer be present. As Lake Sturgeon prefer to spawn at sites with white water, it is unknown whether Lake Sturgeon will continue to spawn at Birthday Rapids post-impoundment. Given the uncertainty with Lake Sturgeon use of this area, monitoring will be conducted post-Project. In the event that Lake Sturgeon no longer spawn in this vicinity, a contingency plan has been developed to create hydraulic features that would be attractive to spawning sturgeon (FOMP Section 4.1.3); the process and timeline for determining whether such activities need to be undertaken is set out in Section 6.3.

It is not known whether construction of the Keeyask GS will cause a change (either increase or decrease) in the domestic harvest of Lake Sturgeon. However, given that access to the existing population in Gull Lake will be facilitated by construction of the access road, which will be open to the public after construction is complete, a conservation awareness program, highlighting the vulnerability of this population, is planned. Harvest of sturgeon will not be monitored; however, results of adult population monitoring provide an indirect measure of mortality (including mortality attributed to domestic harvest).

The AE SV concluded that a potential response of Lake Sturgeon to GS construction could be the loss of adults in Gull Lake and potentially Stephens Lake through emigration. However, in the long-term, no adverse effects in the area directly affected by the Project are expected due to offsetting measures to provide habitat for all life history stages and the implementation of an extensive stocking program. After a viable population has been established through stocking, and constructed habitat is functioning as intended, populations will be self-sustaining. Stocking will not be required in perpetuity. Similarly, an overall increase in the number of sturgeon in the Kelsey GS to Kettle GS reach of the Nelson River is expected in the long-term as a result of population augmentation due to stocking.

OVERVIEW OF MONITORING

Monitoring that will address specific effects have been noted above; however, monitoring to support the overarching conclusions of creation of self-sustaining populations upstream and downstream of the GS and a long-term increase in sturgeon numbers is best understood as an integrated program as follows:

1. Adult population (Section 6.2.1) – this monitoring activity includes estimation of the number of adult sturgeon, the trajectory of population growth, survival, and condition. Adult population size is the ultimate endpoint of the monitoring program since the goal of proposed mitigation and offsetting measures is to establish an adult population with numbers and an age structure that indicates a long term viable population (assuming a carefully managed harvest as per the FMOs). In addition to the number of fish and age structure (based on length), condition factor will be monitored to provide an indication that suitable foraging areas remain post-Project.
2. Juvenile population monitoring (Section 6.2.2) – monitoring of the juvenile population will be primarily based on measurement of recruitment of young (age 0–10 years) fish. Recruitment is being monitored in part because changes in the adult population will not be observed for many years after effects to spawning and/or recruitment of young fish occur. Monitoring of young fish allows early detection of potential changes to the future size of the adult population. Recruitment monitoring is also being conducted because it will provide information on natural recruitment, the success of constructed spawning habitat, and the need to apply contingency measures for the creation of spawning and YOY habitat in the Keeyask reservoir. Growth rates and condition factor will be calculated to address questions as to whether food and appropriate conditions for feeding are present. Recruitment monitoring will also provide immediate information on the fate of stocked fish and inform adjustment of the stocking program, if necessary.
3. Spawn monitoring (Section 6.2.3) – this is one component of the recruitment question and also one of the direct linkages to effects of the Project. The presence of adult fish during the spawning season in predicted locations of spawning habitat supports the prediction that spawning habitat will be available.. No statistical benchmark will be applied to this monitoring activity, since recruitment of young fish (discussed in the preceding point) provides the ultimate measure of the success of spawning.
4. Movement monitoring (Section 6.2.4) – movement studies on adult and sub-adult fish are being conducted to provide supporting information for the three indicators listed above. Monitoring will provide information to assess potential changes to the adult population size due to emigration and mortality (*i.e.*, natural, harvests and by passage past the GS), changes in growth and condition due to habitat use (*i.e.*, what areas are the fish using?), and use of specific habitats (*e.g.*, spawning).

6.1.2 IDENTIFICATION OF BENCHMARKS

The approach to adaptive management for the aquatic environment will be based on a collaborative effort of the KFRRC as described in Section 1 of this AEMP. To assist in determining when adaptive management measures need to be implemented, preliminary benchmarks comprising three action levels have been identified, as follows (Table 6-2):

1. Early warning trigger – generally defined as a statistical change of an indicator in a negative direction, this action level will provide an alert that further analysis may be required to determine if unanticipated negative effects are occurring;
2. Ecologically significant benchmark - defined as a change in an indicator that may indicate that a negative effect, threatening the long-term objective of developing a sustainable Lake Sturgeon population, is occurring. No widely accepted "ecologically significant benchmarks" have been developed for Lake Sturgeon populations; the benchmarks proposed in Table 6-2 are based on the current understanding of Lake Sturgeon in the Keeyask area and professional judgement. In particular, the results of the population viability analysis completed in late 2013 (Nelson 2013) at the request of DFO were used to identify levels of indicators that might indicate increased risk to the recovery of the population as an initial benchmark that will be modified as additional information becomes available.
3. Conservation objective – defined as a level/change in an indicator that indicates that a positive effect, moving the population towards the long-term objective of a self-sustaining population, is occurring. As with the ecologically significant benchmarks, there is no widely accepted definition of what levels of indicator constitute a population in recovery. Levels were developed based on the current understanding of sturgeon in the Keeyask area, and professional judgement based on conditions observed at other locations in northern Manitoba.

Table 6-2 provides a list of action levels that will be considered on an annual basis in interpretation of the results of monitoring activities. These action levels are initial starting points for the monitoring program and may be refined as the program proceeds. It should be noted that, as described in Section 6.2, specific monitoring activities may provide information related to indicators in addition to those listed in Table 6-2. However, action levels have only been identified for the indicators listed in Table 6-2 as these are the most amenable to statistical analysis, are the most useful in addressing the overall goal of developing sustainable Lake Sturgeon populations, and effective in assessing mitigation/offsetting measures. Table 6- 2 also defines a "recovery target" which provides the level of each parameter that is expected when the population is "recovered". It is anticipated that the numbers provided in Table 6-2 will change as a better understanding is developed of what constitutes a self-sustaining sturgeon population in northern Manitoba. For example, the number of adult spawning females identified by DFO in the Lake Sturgeon recovery potential assessment (Vélez-Espino, L.A. and Koops, M.A. 2009) was used to estimate a total population; however, it is known that sturgeon in northern Manitoba live longer than the maximum age identified by DFO (55 years) and therefore, the DFO estimate is not applicable to Manitoba. To assist in understanding the implications of monitoring results to the long-term recovery of the Lake Sturgeon population, the population viability analysis model developed at the request of DFO in fall 2013 (Nelson 2013), will be refined as additional information is obtained and revised model outputs will be created periodically as part of the adaptive management approach (Section 6.3).

The four components of the monitoring program will consider action levels for selected indicators, as follows:

1. Adult Population – Four indicators will be compared to benchmarks: population estimate; population trajectory; condition; and survival. The program is based on monitoring that was initiated in 2001 and occurs in alternating years in the Upper Split Lake area and the Keeyask area (Birthday Rapids to Gull Rapids reach). Results will be compared to data collected during the pre-construction period.

The population estimate is not sufficiently sensitive to provide an action level; however, it will be used to determine whether the recovery target defined by DFO in the Recovery Potential Assessment has been reached.

The population trajectory is a sensitive metric that provides an effective short term measure of changes in the population. A 2.5% decrease relative to today’s population trajectory of 1.013 (which would increase the risk that the population is in decline) was selected as the early warning trigger. A population trajectory of less than 1 for three consecutive monitoring cycles was selected as an ecologically significant benchmark as the population would clearly be in decline. The conservation objective is based on an increase in the current population trajectory, such that the population would clearly be increasing.

Changes to condition factor provide a short term indicator of change that can be related to factors such as food availability (e.g., condition of Lake Sturgeon in Lake Winnebago varies with the abundance of shad (Koenigs pers. Comm. 2014). For condition factor, a statistically significant decline of fish within several size classes greater than 800 mm FL will provide an early warning that a change is occurring. The ecologically significant benchmark was identified as a decline below the condition factor of fish observed in the lower Nelson River. This population of Lake Sturgeon, defined as “healthy” by Cleator *et al*. (2010), has a mean condition factor lower than that of fish in Gull Lake. Given the range of condition factors observed in Manitoba, the conservation objective was selected as being within the range observed in northern Manitoba, which is also the long-term recovery target.

The MARK model used to estimate population size and population trajectory also calculates a survival rate. Changes in survival rate will be used to assess effects of factors such as harvest and mortality associated with downstream passage. The early warning trigger for survival is a decrease to levels less than seen in the existing environment (87%), while the ecologically significant benchmark was identified in the population viability analysis (82.5%). The conservation objective is an increase in the existing survival rate and the recovery target will be based on the survival rate identified in the population viability analysis as being sustainable for a “recovered” population.

2. Juvenile Population – The juvenile (ages 1–10) population program will consider the following indicators: year class strength (as measured by CPUE) and condition. Monitoring will continue to determine whether additional year classes based on fish hatched in the Nelson River (apart from 2008) are observed and whether stocking is increasing the size and frequency of successful year classes.

The early warning trigger for juvenile year class strength (as defined by CPUE), after stocking has been initiated, is a CPUE less than observed in the upper Nelson River at Sea Falls. This location was chosen since it is the most similar environment to Keeyask where stocking is occurring, and stocked fish have exhibited high survival for several years. An ecologically significant benchmark would be not observing any juveniles (apart from the 2008 year class) for two monitoring cycles, since that would indicate that the survival of stocked fish was poor. The preliminary recovery objective is a CPUE equal to or greater than the CPUE observed at Sea Falls, and the long-term recovery target is an age distribution similar to the Slave Falls Reservoir, which has been identified as a healthy population (Cleator *et al.* 2010); limited data on year-class strength in healthy sturgeon populations precludes identification of metrics associated with a “healthy” population in northern Manitoba.

The action levels for condition for juveniles are based on the same criteria as identified for adults.

3. Spawn monitoring – This program will use two indicators: presence of adult fish (as measured by CPUE during spring spawning surveys) and the number of current year spawners. In the reach of the Nelson River from Clark Lake to Gull Rapids, where adult fish have been captured every spring that sampling occurred, the early warning trigger is the absence of any adult fish in the reach. The ecologically significant benchmark is the absence of fish for three consecutive monitoring cycles at locations (both in the reservoir and Stephens Lake) where adults should be present. The conservation objective is the observation of one or more adult fish, and the long-term recovery target is a CPUE similar to that observed at other mainstem spawning sites on the Nelson River.

The number of current year spawners is the second indicator. Monitoring for spawning in the reservoir (Long Rapids to the GS) post-Project will compare the frequency of spawning fish to that observed in the existing environment. Given the small size of the spawning population downstream of Gull Rapids and the infrequent capture of spawning fish since studies began in 2001, successful spawning downstream of the GS may not be observed until stocked fish mature to spawn (over 25 years from now). The presence of spawning fish will be used an important input into the assessment of the success of the constructed spawning structure and suitability of habitat in the reservoir, in conjunction with recruitment of young fish. Each of the action levels is the same (observation of mature fish) and the long-term recovery target is ten mature males each year.

4. Movement monitoring – Movement studies are being conducted to provide information to interpret results for other monitoring activities and, as such, no specific benchmarks are identified for much of the program. However, indicators to address effects of passage past

the GS have been selected: downstream movement of adults past the GS; mortality of adults during passage past the GS; downstream movement of sub-adults (the sub-adult category includes older juveniles); and mortality of sub-adults.

For both the adults and sub-adults, the early warning trigger for movements is an increase above the existing environment, while the ecologically significant benchmark is an increase above the level identified in the population viability analysis. With respect to mortality during passage past the GS, the early warning trigger is an increase above an estimate for existing GSs, while the ecologically significant benchmark is an increase above that included in the PVA analysis. The conservation objectives and recovery targets are values within the range observed at other GSs in Manitoba, since no evidence of adverse effects to populations due to mortality at existing facilities has been documented.

Rationale and details of benchmarks are provided in relation to specific monitoring programs described in subsequent sections. Section 6.3 describes the use of action levels in adaptive management for Lake Sturgeon.

6.2 MONITORING ACTIVITIES TO DETECT CHANGE

A summary schedule for all monitoring activities in relation to Project construction and operation, and the implementation of mitigation and offsetting measures is provided in Figure 6-1.

6.2.1 ADULT POPULATION MONITORING

Data collected during adult population monitoring will be used to identify potential changes in abundance and condition factor. Change will be determined through statistical and qualitative comparison of monitoring data to benchmarks developed through analyses of similar data sets collected during environmental studies initiated in 2001.

6.2.1.1 KEY QUESTIONS

Lake sturgeon populations in the Kelsey GS to Kettle GS reach of the Nelson River are vulnerable due to small population sizes and limited recruitment. Population estimates have been developed for the Upper Split Lake area population and the Keeyask area population, based on mark and recapture studies initiated in 2001. Over a similar time period, substantive effort was made to establish an abundance estimate for the Stephens Lake population, however, too few adult Lake Sturgeon were captured to facilitate a meaningful quantitative estimate.

The key questions for this monitoring component are as follows:

- Is there a biologically relevant (and statistically significant) change in the rate of population growth for the Upper Split Lake area population, and the Keeyask area population?

- Is there a biologically relevant (and statistically significant) change in survival for the Upper Split Lake area population, and the Keeyask area population?
- Is mortality during passage through the GS (via turbines or spillway or due to impingement on the trashracks) significantly affecting the Lake Sturgeon population?
- Is the abundance/CPUE of adult Lake Sturgeon in Stephens Lake changing?
- Is there a biologically relevant (and statistically observable) change in the condition factor of Lake Sturgeon?
- In the long term, is there a measureable effect on population growth due to stocking?
- In the long term, are Lake Sturgeon populations in all three areas considered sustainable based on the size of the adult population and the population viability analysis?

6.2.1.2 STUDY DESIGN AND DATA ANALYSIS

EXISTING DATA

Multiple years of population and biological metric data have been collected in the Upper Split Lake area, the Clark Lake to Gull Rapids reach of the Nelson River, and in Stephens Lake since 2001 (Barth and Mochnacz 2004; Barth 2005; Barth and Murray 2005; Barth and Ambrose 2006; Barth and MacDonald 2008; MacDonald 2008; MacDonald 2009; MacDonald and Barth 2011; Hrenchuk and McDougall 2012; Hrenchuk 2013). In the Upper Split Lake area and the Keeyask area, 542 and 502 individual adult Lake Sturgeon have been captured since studies began in 2001 (includes all fish captured to 2013). In Stephens Lake however, only 98 adults have been captured.

Population, survival, and lambda (population growth) estimates were developed for the Upper Split Lake Area and the Keeyask area based on data collected from 2001 to 2011 (Nelson and Barth (2012).

Estimates (2001–2008) for the Keeyask area adult population ranged from 344 to 1,275 fish with the most recent estimate (2008) being 643 individuals (95% CI's: 343–1,177 individuals). Survival and lambda estimates were 0.87 (95% CI's: 0.83–0.96) and 1.01 (95% CI's: 0.94–1.09), respectively. Estimates (2001– 2009) for the Upper Split Lake area population were also relatively low, ranging from 183 to

654 individuals with the most recent estimate (2009) being 585 individuals. Survival and lambda estimates were 0.94 (95% CI's 0.82–0.98) and 1.10 (95% CI's: 1.02–1.19), respectively. Population estimates could not be generated for Stephens Lake due to the small number of adult size sturgeon greater than 833 mm (FL) captured.

DATA ANALYSIS

Appendix 6A provides a description of the statistical terms used in the following discussion of the population analysis.

Data collected during monitoring in the Upper Split Lake area and in the Keeyask area will be typical of mark-recapture studies in fisheries science. Sampling will be conducted with comparable effort, using similar gear types, over comparable time-periods, across multiple years. Variability in population estimates will reflect annual variation in spring temperatures and discharges, the variable spawning intervals of Lake Sturgeon, and the variation in recapture probability of individual fish. The precision of the estimates tends to improve over time as more fish are added to the tagged population and as mortality due to harvest is incorporated based on resource user tag returns.

Mark-recapture data will be collected over a 5-6 week period during the spring of each study year. Each year will be divided into spawning and post-spawning intervals. The spawning and post-spawning intervals will be defined based on a combination of sex and maturity data collected from individual sturgeon and water temperature, as opposed to calendar dates.

In order to analyze the mark-recapture dataset, an encounter history will be constructed for each tagged fish based on spawning and post-spawning intervals. Individual capture and recapture histories will be used to develop quantitative estimates of survival, lambda, and abundance. Only adult sturgeon (greater than 833 mm FL1) will be included in the analysis.

Several different population model variants exist, but most can be classified as either closed or open models. Closed models assume there are no births, deaths, immigration, or emigration between sample periods, while open models assume that these processes occur. To estimate population size, survival and lambda, a hybrid model called Robust Design (Kendall 2001), which combines elements of closed and open population models, will be used. This model was selected because of the extended length of the time-period involved (*i.e.*, over ten years), the variable spawning interval, and the collection of additional data that will improve the precision of the estimate. The key difference between the Robust Design from a classic open model (e.g., Jolly-Seber model) is that there may be multiple capture occasions

(i.e., secondary sampling occasions, in this study post-spawning sampling periods) between survival periods (primary samples, in this study between annual surveys conducted at the spawning sites) as opposed to just one capture occasion. The secondary sampling periods are spaced closely in time to the primary sampling period and it is assumed that the population is closed during this time (i.e., no births, death, immigration, or emigration between sampling periods that occur within a year). In this case, the secondary sampling (post-spawn sampling) will be conducted immediately following the primary sampling (spawn sampling). The closed part of the model allows both an estimate of abundance and the probability that an animal is captured at least once during the secondary samples, termed the probability of recapture. The mean abundance estimate reflects the number of adult sized Lake Sturgeon in the sample area during the study period. The open part of the model is the time between primary sample occasions (i.e., between spawn occasions in this study). This period is long enough that gains (births and immigration) and losses (deaths and emigration) to the population occur, and therefore the primary samples are used to estimate survival, population growth (lambda), emigration, and immigration parameters similar to a classic open model.

The immigration and emigration parameters measure the degree of movement and detection among years, and provide an estimate of the proportion of sturgeon temporarily available for capture.

Immigration and emigration (gamma' and gamma") are modeled as either random or markovian. Under the Robust Design model, the population is assumed to be closed between secondary sample occasions and open between primary sample occasions. Because population estimates may be subject to violations of the closure assumption between the primary and secondary sampling periods, the closure assumption will be tested using the CloseTest application (Stanley and Burnham 1999). The CloseTest application is a statistical software package (Stanley and Burnham 1999) that uses the Chi-squared statistic to test the Jolly-Seber model against no mortality (NM) and no recruitment (NR), both of which indicate a violation of the closure assumption. Therefore, two separate Chi-squared tests will be used to test the closure assumption, one testing for additions to the population between time j and time j+1 and one testing for losses from the population between time j-1 to time j. The mark-recapture estimates may be confounded by variables such as spawning periodicity, inter-annual variation in river flows, and harvest during the spring; for these reasons, tests for statistical significance in the closure test will be considered at alpha = 0.01.

To assess the long-term trend in abundance, a Burnham Lambda variant of the Jolly-Seber model will be used to estimate both abundance and population growth. This particular variant of the Jolly-Seber adds new individuals to the population indirectly by modeling the rate of population growth (lambda λ) between time intervals. The Lambda parameter provides a measure of population growth since the first year, with values less than 1 indicating population decline, a value of 1 indicating equilibrium, and values greater than 1 indicating population growth. Formulations to assess λ were developed by Burnham (1991) and Pradel (1996). The difference between the two variants is that the Pradel-λ method is conditional upon individuals being seen, while the Burnham method is not. The Burnham Jolly-Seber method thus includes an estimate for population size at the first time-period. Therefore, as previously discussed, the mean local population estimates reflect the number of adult sized Lake Sturgeon in the sample area during the study period; however, the mean regional population estimate for any single time-period is the mean local abundance estimate divided by 1-gamma (immigration/emigration). Thus, the smaller the gamma the closer the local abundance estimate reflects the regional population size. Akaike's information criterion is a standard model selection tool that weights models based on their fit with the average model and selects the best model based on information theory. This tool was used to select the model that described the best fit with the data from each population.

In Stephens Lake, development of a population estimate has not been possible due to the small number of fish captured. Changes in abundance will be based on CPUE values calculated from data collected during spring gillnetting programs using similar gear types at similar sampling sites over similar time- periods as programs conducted periodically since 2001. This comparison will be descriptive (*i.e.*, no statistical analysis) due to the small sample sizes. In addition, individual encounter histories will be developed to record the fate of all tagged sturgeon; given that a substantial portion of the sub-adults and adults in Stephens Lake population are tagged (approximately 40% of all captured adults have been previously tagged), this will provide a semi-quantitative assessment of changes to sturgeon numbers.

Changes to the condition factor of adult Lake Sturgeon in the Upper Split Lake area and the Keeyask area will be assessed by comparing pre-Project data to data collected during the construction phase. Appropriate parametric or non-parametric statistical tests will be used to determine if a change has occurred. Stephens Lake sample sizes may be too low to allow for detection of subtle changes associated with condition factor.

6.2.1.3 PARAMETERS

As described in the preceding section, individual capture and recapture histories will be used to develop quantitative estimates of survival, lambda, and abundance. Long-term trends in abundance will be assessed by modeling the rate of population growth (λ) between time intervals.

Biological metrics such as length and weight will be collected from each sturgeon captured, enabling calculation of Fulton's condition factor (K) (Ricker 1975). Calculation of this metric will allow for direct, quantitative, comparisons (analysis of variance if parametric, Kruskal-Wallis if non-parametric) among similar sized fish captured pre-Project. For analysis, condition will be calculated by length class intervals (the length class intervals will be selected based on size ranges that show similar condition). Length- weight regressions and size-frequency histograms will also be generated for descriptive purposes. Ageing structures will not be collected from sturgeon greater than 833 mm FL due to ageing inaccuracies associated with ageing larger, older fish, and as such, length-at-age comparisons for adult Lake Sturgeon will not be possible.

6.2.1.4 SAMPLING SITES

Sampling sites will be comprised of both spawning areas and areas distant from spawning areas. The number of gillnetting sites, location of gillnetting sites, and amount of gillnetting effort will be comparable to previous studies to enable direct quantitative comparisons among years. As suitable Lake Sturgeon sampling sites are determined partially by water levels and flows, Post-Project sampling locations may be shifted due to changes in these variables. Maps 6-2, 6-3, and 6-4 provide an example of how sampling locations are distributed within each study area on an annual basis.

6.2.1.5 SAMPLING FREQUENCY AND SCHEDULE

Sampling will be conducted during spring over a three-week marking phase and a three-week recapture phase in alternating years between study locations (*e.g.*, the Upper Split Lake area during odd numbered years and the Keeyask area and Stephens Lake during even years). The sampling program is being conducted in alternate years at each location to reduce disturbance to sturgeon during the spawning period (the same individual is frequently captured multiple times during the six week sampling program), which was a key concern to members of

Tataskweyak Cree Nation. Given that rapid changes to the adult population are not expected, this sampling frequency is expected to be adequate to track long-term change.

6.2.1.6 FIELD AND LABORATORY METHODS

Large mesh gillnets (8, 9, 10, and 12 inch, equal effort by mesh size) will be used to capture sturgeon. Each fish captured will be measured, weighed, examined for previously applied Floy-tags, and marked with a Floy-tag and PIT tag (Passive Integrated Transponder) if previously unmarked. A sample of fin tissue (approximately 1 cm square) will be collected from each fish and archived to permit genetic analyses at a later date, if required[2].

6.2.1.7 BENCHMARKS

The key indicator variable that will be used to provide the benchmark for adult Lake Sturgeon population estimation will be the population trajectory, or λ. This parameter was selected as the key indicator variable since it will be calculated every two years for each of the Upper Split Lake Area population and the Keeyask area sturgeon populations, and is calculated with 95% confidence intervals that surround the estimate, allowing a direct statistical assessment of the difference between sequential estimates as well as the relative statistical power for a given percentage decrease.

Results from pre-Project monitoring suggest λ values slightly greater than 1 for each population with annual 95% confidence intervals that include 1. The early warning trigger for this component of monitoring is determined *a priori* as a 2.5% decrease from the existing value that is recorded for two consecutive population estimate cycles for either population (*i.e.*, 4 years) (see Management Framework in Section 6.3). Figure 6-2 illustrates the distribution of λ equal to 1.03 (the current estimate of λ), assuming a log normal distribution, and sequential decreases in λ (1%, 2.5%, 5%, and 10%). A decrease of 2.5% was selected as the early warning trigger because with a 2.5% decline there is an approximately 50% probability that the population is in decline. Figure 6-3 illustrates the probability of detecting changes in λ; a decrease of 2.5% can be detected more readily than a change of 1% but less readily than a change of 10%. The analysis used here assumes that the standard error is the same for each decrease shown in Figures 6-2 and 6-3. A *post hoc* power analysis will be used once the actual population estimate standard error is estimated for each monitoring period.

It should be noted however, that although the confidence intervals (95%) surrounding λ, and the λ value, provide an indication of the trajectory of the population, Lake Sturgeon are not recruited into this population estimate for at least 15 years. Therefore, a change in λ (positive or negative) for at least the initial 15 years of monitoring will indicate changes to the adult population that occur prior to the offsetting measures of the Project coming into effect. Because offsetting measures are focused on improving recruitment, the success or failure of these strategies will

[2] The genetic structure of adult Lake Sturgeon in the lower Nelson River has been documented; however, archived samples of adult sturgeon will enable further analysis (if required, outside of the scope of the AEMP) to determine the origin of specific sturgeon as well as address potential future questions about the population genetic structure prior to stocking.

not manifest themselves in the adult population, and thus be measurable through this component of monitoring for approximately 15 years.

For the Stephens Lake population, insufficient sturgeon were captured pre-Project to calculate a population estimate. Therefore, data on absolute numbers of individuals captured, and mean CPUE, will enable a qualitative assessment (i.e. are numbers increasing or decreasing) of how the adult population is responding to construction and operation of the GS and, over time, the success of mitigative measures.

In terms of condition factor, mean K across 50 mm size class intervals of Lake Sturgeon greater than 800 mm FL will be calculated from each of the three aforementioned populations and compared with pre- Project data. If statistically significant differences are observed, the assessment will consider condition in other northern environments to determine if the change is biologically relevant.

6.2.2 JUVENILE POPULATION MONITORING

For the purposes of this AEMP, juvenile sturgeon are defined as being between one and ten years of age. Sampling may also capture YOY sturgeon (less than one year old) and older sub-adults (approximately 10–20 years old). Analyses will also consider these age groups, but the primary focus will be on sturgeon one to ten years of age given that these can be reliably captured in the sampling gear employed (unlike YOY sturgeon which are not fully recruited by the fall sampling period), can be reliably aged to identify year-class (unlike older sturgeon), and provide a rapid indication of the success of spawning and YOY survival, the two life history stages for which the greatest uncertainty exists for Keeyask Project.

Data collected during juvenile population monitoring will be used to assess cohort strength, identify changes in condition factor, determine whether natural reproduction is occurring, determine the need for YOY habitat creation and enable an evaluation of the stocking program. Juvenile population monitoring will be conducted in the Upper Split Lake area, the Keeyask area, and in Stephens Lake.

6.2.2.1 KEY QUESTIONS

As previously discussed, Lake Sturgeon populations in the Kelsey GS to Kettle GS reach of the Nelson River are vulnerable due to small population sizes and limited recruitment. Successful sampling for juvenile (age 0–10 year old) Lake Sturgeon began in 2008 in the Keeyask area. Since that time, year-class strength indices, using two methods, have been calculated for the Keeyask area and Stephens Lake based on data collected in 2010, 2011, and 2012. In addition, sampling has been conducted in the Upper Split Lake area for young sturgeon in 2011 and 2012.

The key questions for monitoring the juvenile population are as follows:

- Does recruitment of wild sturgeon occur upstream and/or downstream of the GS during construction?
- Does recruitment of wild sturgeon occur upstream and/or downstream of the GS during operation?
- Does spawning habitat need to be created/modified (if recruitment of wild fish is not observed)?
- What is the survival rate of stocked sturgeon?
- What is the proportion of hatchery-reared to wild recruits within a cohort (*i.e.*, how successful is the stocking program)?
- Is there a biologically meaningful (and statistically significant) change in condition factor and growth of juvenile sturgeon during construction or operation?
- Do stocking rates need to be adjusted?
- Where in the reservoir and in Stephens Lake will YOY rearing habitat be located, and will the distribution of YOY and juvenile Lake Sturgeon change following reservoir creation?
- Does additional YOY habitat need to be created in the reservoir or in Stephens Lake?

6.2.2.2 STUDY DESIGN AND DATA ANALYSIS

A multi-mesh gillnetting study will be conducted targeting juvenile Lake Sturgeon. Gillnetting sites will provide adequate spatial representation of each study area, the Upper Split Lake area, the Keeyask area and Stephens Lake, to account for potential differences in the distribution and abundance of Lake Sturgeon size- and age-classes.

EXISTING DATA

Prior to 2008, little was known about the ecology of YOY (classified as sturgeon measuring less than 200 mm FL) and sub-adult (classified as sturgeon measuring from 200 to 833 mm FL) sturgeon in the Nelson River. Gillnetting studies conducted in 2008 in Gull Lake were the first to capture and document

habitat use of YOY Lake Sturgeon in the Nelson River. These studies also identified habitats preferred by sub-adult sturgeon, previously not documented. Since 2008, several studies have increased the understanding of YOY and sub-adult sturgeon abundance, habitat use, condition, growth, year-class strength and factors influencing year-class strength in the Keeyask area (MacDonald 2009; Michaluk and MacDonald 2010; Henderson *et al.* 2011; Henderson and Pisiak. 2012; Henderson *et al.* 2013). Further, data on young Lake Sturgeon were collected in the Upper Split Lake area (*i.e.*, the Burntwood River and the Nelson River between the Kelsey GS and Split Lake) in 2011 and 2012 (Henderson and Pisiak 2012; Henderson *et al.* 2013). These and other recent studies conducted in large riverine systems, indicate that juvenile habitat is essentially defined by the presence of deep water habitat, with spatial distribution patterns likely being driven by coarse-scale spawning site selection and patterns of larval drift

(Barth *et al.* 2011; McDougall *et al.* 2013a, b). For reference, since studies began in 2001, 232, 453 and 212 Lake Sturgeon measuring less than 833 mm have been captured in the Upper Split Lake area, the Keeyask area, and in Stephens Lake, respectively.

DATA ANALYSIS

Each captured Lake Sturgeon will be classified as either "wild' or "hatchery-reared" (all hatchery-reared fish will be marked prior to release) and the proportion of each within each cohort will be calculated.

Two methods of year-class strength analyses, referred to as Johnson's and Kimura's methods, will be used to estimate cohort strength (Johnson 1957; Kimura 1988). Cohorts older than 10 years of age will not be included in the analysis as older sturgeon might be of large enough size that they are less susceptible to capture in mesh sizes(1–6") and aging error increases once Lake Sturgeon have reached approximately 14 years of age (Bruch *et al.* 2009). Furthermore, exclusivity of deep water habitat use becomes less certain as Lake Sturgeon attain larger sizes and begin to exhibit behaviours more characteristic of adults. Young-of-the-year fish will also be excluded from the analysis because they are likely underrepresented in the catch due to their small size and potential limited range of movement.

To calculate year-class strength using Johnson's method, the sum of the relative yearly contribution (in percent) for each year-class represented over a three-year sampling period will determined. This number will then be divided by the result of the cumulative mean relative yearly contribution (in percent) of all year-classes in the sample at the corresponding ages. Year-class strength will also be calculated using Kimura's method where CPUE values are calculated for each cohort captured during the three-year study period and pooled. The resulting data will be entered into a two-way ANOVA, with sampling year and cohort as factors, and then a comparison of least-squares means will be conducted. Pairwise correlations between YCSI ranks (Johnson's method) and values (Kimura's method) and occurrence of instream construction activities, Nelson River historical water levels, total precipitation, and air temperature for months typically corresponding to spawn, egg incubation, hatch, and larval drift (*i.e.*, May, June, and July) will also be analyzed. The latter variables will address questions on abiotic factors that may influence Lake Sturgeon year-class strength in this area.

Growth rate and mean condition factor of sturgeon measuring less than 800 mm FL captured during monitoring, will be compared (analysis of variance if parametric, Kruskal-Wallis if non-parametric) to conspecifics of similar size/age-classes captured pre-Project.

6.2.2.3 PARAMETERS

To determine origin (hatchery-reared or wild), each Lake Sturgeon captured will be inspected for a mark (marking method for sturgeon released as fingerlings has not been definitively determined yet) and a small genetics sample (to allow for parentage identification via high-resolution genetics) will be collected from each fish to act as a fail-safe should marks be unrecognizable. Further, survival rates of sturgeon stocked as fingerlings or yearlings will be calculated, and will influence future stocking initiatives related to the relative numbers of each life stage stocked.

Condition factor and length-at-age will be calculated from individual sturgeon from each area sampled. CPUE and relative abundance of each cohort (*i.e.*, year-class strength indices) will be calculated from the catch data from each sampling area.

If possible, the mark/recapture data will be used to generate an age-structured recruitment model, however, this type of analysis has not be conducted before on juvenile/sub-adult Lake Sturgeon.

6.2.2.4 SAMPLING SITES

Approximately 40 gillnet sampling sites will be selected in each sampling location (*i.e.*, Upper Split Lake, Keeyask area and in Stephens Lake). Sampling sites will be located exclusively in the deep water habitat. For an example of sampling sites from previous years in the Keeyask area and Stephens Lake refer to Maps 6-5 and 6-6.

6.2.2.5 SAMPLING FREQUENCY AND SCHEDULE

Recruitment monitoring will occur annually in the Keeyask area and in Stephens Lake. Sampling will be conducted every two years in the Upper Split Lake area. Sampling will occur during the fall to minimize fish mortality and facilitate accurate ageing.

6.2.2.6 FIELD AND LABORATORY METHODS

Each gillnet will be composed of twisted nylon and five panels of: 1, 2, 3, 5 and 6 inch stretched mesh (25, 51, 76, 127 and 152 mm). Each panel of mesh will be 25 yds. (22.9 m) long and 2.7 yds. (2.5 m) deep.

Gillnets will be distributed throughout a sampling area (see Maps 6-5 and 6-6) in deep water habitats, with criteria for deep water varying somewhat by location. In general, 8 m can be viewed as the minimum depth criteria in the Nelson River. Sampling locations will be recorded using a Garmin Etrex GPS receiver (Garmin International, Inc., Olathe, KS). Water depth will be measured using a PiranhaMax Series 150 Portable Sonar (Humminbird, Eufaula, AL) and water temperature will be measured daily using a hand-held thermometer (± 0.5°C). The orientation of each gillnet will be dependent on water velocity. In low (0.20 – 0.49 m/s) or moderate (0.50 – 1.49 m/s) water velocities, nets will be set parallel to flow and in standing (0.00 – 0.19 m/s) velocities set perpendicular to flow. Gillnets will be set overnight and checked approximately every 24 hours, weather permitting.

Captured fish will be measured, weighed, and marked with an individually numbered Floy-tag and PIT tag. For ageing purposes, a segment of the first ray of the left pectoral fin (approximately 1 cm2), immediately distal to the fin articulation, will be removed from all captured Lake Sturgeon. Fin ray segments collected in the field will be placed in individually numbered envelopes, air dried, and brought back to the North/South Consultants Inc. laboratory for subsequent ageing. For age determination, each fin ray segment will be mounted in epoxy and thin-sectioned with a low speed, precision jewellers saw (Struers Minitom; Struers Inc., Cleveland, Ohio). The sections will then be fixed on glass slides with Cytoseal-60 (Thermo Scientific, Waltham, Massachusetts) mounting medium and examined under a dissecting microscope (30–40x magnification). Without prior knowledge of fish length or weight, three readers will assign ages by counting visible annuli under reflected light. If readers assign different ages to a fish, either the modal age will be chosen or, in rare cases, the median age.

A small tissue sample will be collected from each captured fish for genetic analysis. Stocked fish will likely have been previously marked prior to release from the hatchery (note: marking technique for different life stages has not been finalized) and the genetics sample will be used as a backup to confirm whether or not fish retained the mark following release.

6.2.2.7 BENCHMARKS

Juvenile Lake Sturgeon abundance provides the most reliable indicator of year-class strength. Data collected from the Keeyask area and Stephens Lake have indicated that under existing conditions, recruitment is erratic and that a strong year class was only observed in one (2008) of ten year-classes from 2002–2012 (Figure 6-4). Erratic recruitment is also characteristic of healthy populations, though the frequency of strong year classes is greater than in the Keeyask area. For example, data collected from the “healthy” population in the Slave Falls reservoir, using the same standardized gillnetting method used during Keeyask studies, indicated that strong year-classes occurred six times more frequently relative to those in the Keeyask area and Stephens Lake (Figure 6-4). The benchmark, to achieve through recruitment of both wild and stocked fish, is a distribution of year-classes similar to a “healthy” lake sturgeon population (*i.e.*, the Slave Falls Reservoir population).

Results of monitoring in the Keeyask area will be considered in terms of observed frequency and abundance of young sturgeon in both the existing environment and post-Project environment using the Slave Falls Reservoir population as a reference “healthy” population. The CPUE distributions in Figure 6-4 are fitted with a gamma distribution, which is a two-parameter family of continuous probability distributions (the exponential distribution and chi-squared distribution are special cases of the gamma distribution). The observed distribution will be recalculated after each monitoring cycle because as more data are collected, the underlying distribution of observed juvenile CPUE values will be further refined. The analysis will include all juvenile sturgeon, both wild and stocked.

Figure 6-5 provides an example of how a shift in the distribution of CPUE from the Keeyask area to those observed in the Slave Falls Reservoir requires an approximate 300% increase in the mean CPUE. The statistical power to detect increases in CPUE of juvenile sturgeon is highest for increases of 100% or more (Figure 6-6).

Absent (or very weak) year-classes, can indicate an early warning trigger that wild spawning is not occurring, YOY rearing habitat may not be suitable, or that stocking is not successful. However, the recruitment of the wild population is so low at present, that monitoring absent year classes in the wild population would not provide the necessary information. Monitoring the stocked cohorts, however, would indicate if the level of stocking is resulting in consistent cohorts to achieve future reproducing adults and the target cohort distribution. As indicated in Table 6-2, the early warning trigger for year-class strength for the juvenile population is a CPUE less than that measured at the Nelson River below Sea Falls, where several years of successful stocking (defined as the survival of stocked fish) have been observed. The ecologically significant benchmark is the absence of recorded juveniles less than three years of age after two monitoring cycles. Given that the 2008 year class in the Keeyask area has been recorded in every sampling year that it was present, it is felt that the sampling approach has a high probability of capturing at least some juvenile sturgeon if they are present.

Similar to adult sturgeon, mean K (condition factor) across 50 mm size class intervals of Lake Sturgeon, measuring less than 800 mm FL, will be calculated from each of the three populations and compared with pre-Project data. The benchmark used will be a statistically significant difference with 90% power. The current length-at-age for Keeyask Lake Sturgeon indicates sub-adults are fast growing and robust at age, therefore decreases in condition factor for sub-adult Lake Sturgeon will indicate that changes in the system are having an impact on growth.

6.2.3 SPAWN MONITORING

To address uncertainty regarding the response of Lake Sturgeon to altered spawning habitat, gillnetting surveys will be conducted in the vicinity of potential spawning sites at Long Rapids, Birthday Rapids, and downstream of the Keeyask GS (constructed spawning habitat) to locate congregations of spawning Lake Sturgeon. These surveys will be conducted on a biennial basis in conjunction with population estimation monitoring. Results will aid in identifying areas that are being used for spawning and will allow for an assessment of the relative abundance of sturgeon frequenting each spawning area.

6.2.3.1 KEY QUESTIONS

Spawn monitoring will attempt to identify spawning locations and assess numbers of spawning adults. Spawn monitoring will address the following key questions:

- Are spawning adults present in the Keeyask reservoir and Stephens Lake?
- Where (on a coarse-scale) do Lake Sturgeon spawn in the post-Project environment?
- Will contingency measures be needed to create conditions suitable and attractive for spawning sturgeon at Birthday Rapids?
- Will Lake Sturgeon in Stephens Lake be attracted to, and spawn on, the tailrace spawning structure or below the spillway?; and
- Will modifications to the spawning structure downstream of the Keeyask GS be required?

6.2.3.2 STUDY DESIGN AND DATA ANALYSIS

EXISTING DATA

Spring large mesh gillnetting studies have been conducted to identify spawning areas and congregations of spawning sturgeon in the Upper Split Lake area, the Keeyask area, and in Stephens Lake since environmental studies began in 2001 (Barth and Mochnacz 2004; Barth 2005; Barth and Murray 2005; Barth and Ambrose 2006; Barth and MacDonald 2008; MacDonald 2008; MacDonald 2009; MacDonald and Barth 2011; Hrenchuk and McDougall 2012; Hrenchuk 2013). First Rapids on the Burntwood River was identified as a spawning site in 2001 based on the capture of males in pre-spawn condition and the capture of larval sturgeon in drift nets (Barth and Mochnacz 2004). Long Rapids was identified as a spawning area based on the capture of pre-spawn and ripe males and the capture of a larval Lake Sturgeon in a drift net set upstream of Birthday Rapids in 2003 (Barth and Murray 2005 and Hrenchuk 2013). Similarly, current-year spawning sturgeon have been captured in the vicinity of Birthday Rapids and Gull Rapids during several years of study (Hrenchuk 2013).

DATA ANALYSIS

In the pre-Project environment, Lake Sturgeon are known or suspected to have spawned in the vicinity of Long Rapids, Birthday Rapids, and Gull Rapids. However, due to the relatively small size of the populations upstream and downstream of the GS, and the spawning periodicity of Lake Sturgeon, spawning may not occur at each of these locations every year. Due to uncertainties regarding the response of spawning sturgeon to altered habitat conditions upstream and downstream of the Keeyask GS, monitoring will be conducted to determine whether sturgeon continue to spawn at Long and Birthday rapids and whether they use the constructed spawning habitat below the Keeyask GS. Given the habitat alterations that will occur in the study area, it is possible that sturgeon may require some time to locate new spawning habitat and encounter partners following construction of the GS.

If it is determined that habitat modifications are necessary in the vicinity of Birthday Rapids or downstream of the Keeyask GS, monitoring will be continued at specific locations until suitable conditions have been created that allow sturgeon to spawn successfully, alternative mitigation measures are implemented, or learned spawning site fidelity has time to establish. This component of monitoring will, to the extent possible, attempt to locate spawning areas while not disturbing the spawning fish (*i.e.*, repeatedly catch the same fish in gillnets).

Data analysis will include a comparison of the number of adult sturgeon captured during the spring spawning period with previous years. The presence of current year spawners will be recorded, to the extent feasible. Current-year spawning males are easy to identify due to the presence of milt. Current-year females, however, are more difficult to identify.

Additional information on potential spawning locations will be provided by acoustic telemetry (see Section 6.2.4). Manual acoustic tracking will be conducted daily for a week prior to, and during, the spawning period (as determined by water temperature), to identify the location of acoustically-tagged sturgeon that may be spawning in the current year.

6.2.3.3 PARAMETERS

Catch-per-unit-effort, sex ratio, reproductive readiness, and standard biological data (lengths and weight) will be recorded. All captured unmarked sturgeon will be marked with both a uniquely numbered Floy- tag and a uniquely numbered PIT tag to allow for future identification, and the generation of mark- recapture encounter history and movement data.

6.2.3.4 SAMPLING SITES

Gillnets will be set in close proximity to suspected spawning and/or staging locations (Map 6-7). Long Rapids, the vicinity of Birthday Rapids, and downstream of the GS will be targeted. Other potential spawning sites between the outlet of Clark Lake and Gull Lake will also be assessed, particularly if there is evidence that Long Rapids and Birthday Rapids are not being utilized.

6.2.3.5 SAMPLING FREQUENCY AND SCHEDULE

Gillnetting surveys will be conducted on a biennial basis in conjunction with population estimation monitoring during construction and operation of the GS.

6.2.3.6 FIELD AND LABORATORY METHODS

Large mesh gillnets (8, 9, 10, and 12 inches) will be set in close proximity to suspected spawning locations during spring, when water temperatures range from 8–13°C. Gillnets will be checked every 24 hours and all captured fish will be measured for length and weight and assessed for sex and state of maturity. If warranted (as decided by the KFRRC), the sex of each suspected spawning female will be assessed based on internal examination through a small incision in the body cavity, to allow for direct observation of eggs. The incision will be closed using degradable suture material. Habitat characteristics (*i.e.*, water depth, water velocity, and substrate) associated with each gillnetting site will be documented.

6.2.3.7 BENCHMARKS

No statistical benchmarks will be developed for the abundance of spawning sturgeon given the low number of spawners observed in the existing environment. However, spawning will be assessed based on two qualitative indicators: (i) presence of adults during spawning period; and (ii) presence of fish that will spawn in the current year, as discussed in Section 6.1.2 and presented in Table 6-2.

The need to modify spawning habitat in either the reservoir or the Keeyask GS tailrace spawning structure will be based in part on the presence/absence of adults and continued evidence of no wild recruits in the Keeyask reservoir or Stephens Lake (see Section 6.2.2). Decisions to modify habitat would follow the step-wise procedure described in the adaptive management framework (Section 6.3).

Based on data collected from 2001 to 2012 in the Keeyask area and in Stephens Lake, significant recruitment to these Lake Sturgeon populations occurred in only one of 10 years (2008) from 2001 to 2011; several year-classes have been continually absent from juvenile gillnet catches (Henderson *et al.* 2013). For this reason, wild recruitment is unlikely to be successful. Should analyses of gillnetting results suggest that sturgeon are congregating to spawn annually at Long Rapids, Birthday Rapids, or at the tailrace spawning structure, and wild recruitment is continually not observed, then the need for modifications to spawning or YOY habitat will be examined (see Section 6.3).

6.2.4 MOVEMENT MONITORING

Movement monitoring will be conducted to determine if disturbances associated with construction and operation alter habitat use and coarse-scale movement patterns of sub-adult and adult sturgeon upstream and/or downstream of the Project. Monitoring results will assist in identifying the use of key habitats (*i.e.*, spawning, rearing, and foraging) during construction and operation, the potential vulnerability of sturgeon to activities at the construction site (*i.e.*, if sturgeon utilize the immediate vicinity of the construction site they may be vulnerable to stranding during dewatering), and the potential for increased emigration following impoundment. Movement data will also contribute to the assessment of the need for fish protection at the GS for fish moving downstream and for upstream fish passage.

Coarse-scale movement/habitat use monitoring will involve the following three types of data collection:

- Movement data collected from the recapture of Floy-tagged Lake Sturgeon tagged during mark- recapture studies described above (population estimation monitoring, Section 6.2.1), or from individuals marked during environmental studies conducted from 2001–2013. These data will be collected from the Upper Split Lake area, Keeyask area, and Stephens Lake;
- Continued monitoring of 60 acoustic transmitters (10-year battery life) applied to adult Lake Sturgeon in the Keeyask area and Stephens Lake in 2011 and 2012. Additional acoustic transmitters will be applied to fish throughout the construction period and the initial decade of operation to continue to provide movement data until the early 2030s; and
- Continued monitoring of 40 acoustic transmitters (4-year battery life) applied to sub-adult Lake Sturgeon in the Keeyask area and Stephens Lake in 2013. After these transmitters have expired, additional transmitters will be applied until the mid-2020s.

As discussed below, both monitoring activities and durations of specific studies may be adjusted based on results.

6.2.4.1 KEY QUESTIONS

The key questions for coarse-scale movement/habitat use monitoring are as follows:

- Will disturbances associated with construction alter coarse-scale movement/habitat use upstream and/or downstream of the construction site;
- Are sturgeon using habitat in the immediate vicinity of the construction site?

- Will the frequency of long-distance movements (and subsequent downstream emigration/entrainment) by sub-adult and adult Lake Sturgeon increase during construction and operation of the Project?
- Will there be a statistically significant change in the proportional distribution of sub-adult and adult Lake Sturgeon following reservoir creation (*i.e.*, will there be a population level shift in distribution patterns following reservoir creation)?
- Are sturgeon congregating in the vicinity of spawning habitat downstream of the GS during the spawning season or are they moving elsewhere downstream of the GS?
- Are fish moving downstream past the GS and, if so, is there an indication that they have survived passage?

6.2.4.2 STUDY DESIGN AND DATA ANALYSIS

EXISTING DATA

Lake Sturgeon mark-recapture data have been collected in the Upper Split Lake area, Keeyask area, and Stephens Lake from 2001 through 2013 (Barth and Mochnacz 2004; Barth 2005; Barth and Murray 2005;

Barth and Ambrose 2006; Barth and MacDonald 2008; MacDonald 2008; MacDonald 2009; MacDonald and Barth 2011; Hrenchuk and McDougall 2012; Hrenchuk 2013). Similar data sets have been established for sub-adult Lake Sturgeon in the Upper Split Lake area, Gull Lake, and Stephens Lake from 2008–2012 (MacDonald 2009; Michaluk and MacDonald 2010; Henderson *et al.* 2011; Henderson and Pisiak 2012; Henderson *et al.* 2013).

Since 2011, movements of 60 acoustically tagged adult sturgeon have been monitored in the Nelson River between Clark Lake and the Long Spruce GS. These data have been presented in Hrenchuk and McDougall (2012), Hrenchuk and Barth (2013), and Hrenchuk *et al.* (2014).

Coarse- and fine-scale movements and habitat utilization of 20 sub-adult Lake Sturgeon tagged in Stephens Lake were monitored using acoustic telemetry. Movements of these fish were tracked from spring 2011 to fall 2012 (McDougall *et al.* 2013a, b).

In fall 2013, 40 acoustic transmitters were applied to sub-adult Lake Sturgeon, 20 in each of Gull and Stephens lakes (Hrenchuk and Barth, 2014a).

DATA ANALYSIS

Mark-recapture

A mark-recapture history will be generated for each sturgeon captured during population estimation monitoring (Section 6.2.1) and recruitment monitoring (Section 6.2.2). Individual recapture histories will be compared to pre-Project data. This will provide a descriptive comparison of the frequency and extent of movement between the pre-Project environment and movement during the construction and operation phases.

Acoustic Telemetry

As previously discussed, acoustic transmitters with a 10-year battery life were applied to 60 adult Lake Sturgeon in the Nelson River between Clark Lake and the Kettle GS in 2011 and 2012. In addition, 40 transmitters were applied to sub-adult Lake Sturgeon during fall 2013. Data collected from these transmitters during construction will be compared to movements of the same fish prior to construction. Tags that are never detected are considered defective and excluded from data analyses, as are tags that consistently omit a signal but do not move for an extended period of time (indicative of tag loss/mortality). Tagged sturgeon may also be harvested, which will reduce the sample size of tagged fish in the area.

These data will enable comparisons among movement patterns (*i.e.*, typical distances and spatial patterns associated with spawning and foraging) and will indicate the relative utilization of the different reaches of the Nelson River. Range and rate of movement tends to expand as sub-adults grow; this will be taken into consideration while interpreting the movement pattern results. From a broader movement perspective, individual based approaches such as home-range (linear river kilometers [rkm] and/or XY minimum convex polygons), coarse-scale utilization distributions (by season), and residency at receivers (see Shaw *et al.* 2013), will also be investigated.

Population based approaches such as proportional distribution (see McDougall 2011), and capture- recapture estimates of spatial utilization (see Danancher *et al.* 2004) could also be incorporated depending on the nature of the data collected. Proportional distribution analysis will be conducted to compare spatial utilization patterns of tagged Lake Sturgeon pre-Project and during the construction phase. To facilitate this analysis, each individual receiver's river kilometre distance from Gull Rapids/the Keeyask GS will be measured using ArcGIS (Environmental Systems Research Institute, Redlands, California). A translation table will then be generated in Excel to assign receiver distances to all detections. A positioning algorithm, adapted from McDougall *et al.* (2013a), will be employed to calculate the average detection distance of each individual fish, based on a four hour interval according to the following equation:

$$\overline{D}_{\Delta t} = \frac{\sum_{i=1}^{n} R_i D_i}{\sum_{i=1}^{n} R_i}$$

Where: n = the number of receivers in the array;

Ri = the number of detections at the ith receiver during the ΔT time period; and

Di = the linear river kilometre distance of the ith receiver from Gull Rapids.

Proportional distributions of tagged Lake Sturgeon within binned river sections, spaced every five rkm with the Keeyask GS axis representing zero rkm, will be calculated based on a four hour interval. If data are missing, interpolation of positions will be conducted considering all spatiotemporal data available, based on the assumption that fish remain in the bin section in which they were last detected until they are next positioned (McDougall *et al.* 2013a, b).

Acoustic telemetry studies will continue during the operation period. In addition to the analyses described above, movement data will be examined to determine whether sturgeon are congregating at spawning habitat during spring, where they are feeding, their rate of emigration, and their rate of downstream movement past the GS.

6.2.4.3 PARAMETERS

Mark-recapture

Distance(s) between the initial capture and recapture location(s) will be calculated for each marked Lake Sturgeon that is subsequently recaptured. Movements among populations will be reported.

Acoustic Telemetry

For each acoustically-tagged fish, total distance moved, extent of distance moved (range in rkm), proportional distribution (days/rkm or zone), monthly movement range, and seasonal movement range, will be determined. Similar to what has been presented in Hrenchuk and McDougall (2012) and Hrenchuk and Barth (2013), coarse-scale movements of sub-adults and adults will be described in terms of rkm distance, with the Gull Rapids/Keeyask GS axis representing a distance of zerorkm. The area located downstream of Gull Rapids (*i.e.*, Stephens Lake, Long Spruce Forebay) was considered positive (+) distance from Gull Rapids, while the area located upstream (*i.e.*, Gull and Clark lakes) is considered negative (-) distance. Numbers and/or proportion of acoustically tagged Lake Sturgeon that: remain in the area in which they are tagged (Gull Lake or Stephens Lake); use habitat in the immediate vicinity of construction activities (*e.g.*, spawning in Gull Rapids); move downstream over Gull Rapids into Stephens Lake or beyond; move upstream through Gull Rapids during construction; and move upstream into the Split Lake area or beyond, will be reported.

6.2.4.4 SAMPLING SITES

Mark-recapture

Sampling to mark and recapture adult and sub-adult Lake Sturgeon will occur at gillnetting sites selected during population estimation and biological metric monitoring and recruitment monitoring (Section 6.2.1 and Section 6.2.2, respectively).

Acoustic telemetry

Capture and release locations for sturgeon implanted with acoustic transmitters are described for adults and sub-adults in Hrenchuk and McDougall (2012) and Hrenchuk and Barth (2014a), respectively.

During construction, acoustic receivers will generally be located at the same sites as those established during the same study conducted from 2011–2013 (Map 6-8) though some locations may need to be modified due to construction activities. In general, acoustic receivers have been set in low velocity areas between Clark Lake and the Long Spruce GS to maximize spatial coverage and the detection range of each acoustic receiver. Receiver "gates" have also been established at five transects in the Nelson River between Clark Lake and the Kettle GS (see Fish Community, Section 5).

Once FSL has been reach, habitat characteristics in the Keeyask area will change, most notably immediately upstream of the Project. Additional stationary receivers will be added to the existing array in the reservoir to ensure spatial coverage of the increased quantity of wetted area.

6.2.4.5 SAMPLING FREQUENCY AND SCHEDULE

Mark-recapture

Floy-tags will be applied and recaptured sturgeon will be recorded in conjunction with the adult population monitoring. For a description of the sampling frequency and schedule, refer to Section 6.2.1 (population estimation monitoring) and recruitment monitoring (Section 6.2.2).

Acoustic telemetry

Fish that will be tracked during construction will have been implanted with transmitters prior to the start of construction; however, if several tags are lost, the need to apply additional tags will be evaluated and tags will be applied during spring (adult) and fall (sub-adult) population and recruitment studies. Due to the 10-year battery-life of the transmitters applied to adult sturgeon, movement monitoring will occur throughout the construction phase, into the operation phase. Transmitters in sub-adults will expire after four years. Once these tags have expired, new transmitters will be applied to monitor fish during the latter part of the construction phase, including impoundment and the initial operating period.

6.2.4.6 FIELD AND LABORATORY METHODS

Mark-recapture

Floy-tags will be applied during the population estimation studies (Section 6.2.1).

Acoustic telemetry

Acoustic transmitters will have been applied to fish prior to the start of construction and, as discussed in the preceding section, additional transmitters may be applied (for implantation methods, see Hrenchuk and McDougall (2012) and Hrenchuk and Barth (2014a).

An array of 50+ acoustic receivers will be deployed in the Nelson River between the outlet of Clark Lake and the Long Spruce GS during the open-water period (Map 6-8), and a portion of the receivers will be deployed throughout the winter (Map 6-9). Stationary acoustic receivers (VEMCO model VR2W) will be (and are currently being) used to continuously monitor tagged adult and sub-adult Lake Sturgeon in the Keeyask area, Stephens Lake, and (when fish move downstream of the Kettle GS) the Long Spruce Forebay. Stationary receivers deployed during the open-water period will be affixed to custom moorings and surface floats will be attached to each mooring to facilitate retrieval. The geographic position of each receiver will be recorded using a handheld GPS receiver, and the depth at each site will be recorded using a fishfinder.

To monitor movements during winter, stationary receivers will be affixed to a custom moorings (~25 kg) designed to maintain stability in the current and eliminate receiver sway (Figure 6-7). Moorings will be equipped with a 2 m long loop of airline cable attached to a buoy. From an anchored boat, the receiver/mooring will be lowered to the river bottom using a rope to ensure proper orientation. When deployed, the hydrophone of each receiver will be situated approximately 1 m above the river bottom and oriented toward the surface. To retrieve receivers previously deployed throughout the winter, a sonar will be used to locate submerged acoustic receivers based on a characteristic signature produced by the moorings and suspended buoy (McDougall *et al.* 2013a, b). Once located, a 2 m long rake (15 cm tine spacing) will be lowered to the bottom and back-trolled until the buoy or airline cable attached to each receiver mooring is snagged. Once snagged, each receiver will be raised to the surface and data will be downloaded using Vemco VUE software.

Manual tracking will be conducted periodically from a boat using a handheld receiver. Tracking will be conducted in areas of calm water, out of the main river channel, spaced approximately every 1 km to facilitate overlapping coverage.

6.2.4.7 BENCHMARKS

Movement studies will be conducted to provide information to interpret results for other monitoring activities and, as such, no specific benchmarks are identified for studies that determine changes of distribution within the reservoir and Stephens Lake. However, action levels to implement mitigation to address effects of passage past the GS have been selected: downstream movement of adults past the GS; mortality of adults during passage past the GS; downstream movement of sub-adults (the sub-adult category includes older juveniles); and mortality of sub-adults.

The action levels described in Table 6-2 are based on: changes from existing conditions (early warning trigger); the inputs used for the population viability analysis (as an indication of potential risk to the population); and observed movements at other GSs. Given the extremely low rate of downstream movement observed in the existing environment and at most GSs, comparisons will be qualitative rather than based on statistical analysis. All results will be considered in conjunction with statistically based changes in the Lake Sturgeon adult population. Population trajectory is the key variable in assessing whether mortality and/or loss due to emigration as a result of downstream movements/mortality during passage past the GS, is presenting a risk to the long term sustainability of Lake Sturgeon populations in the reservoir and Stephens Lake.

6.3 MANAGEMENT RESPONSE FRAMEWORK

6.3.1 ADAPTIVE MANAGEMENT ASSESSMENT FRAMEWORK

The introduction of this AEMP describes the KFRRC, which will oversee an adaptive management process as a tool to address Project concerns identified through monitoring. The adaptive management framework describes the steps whereby monitoring results will be reviewed in reference to benchmarks to determine whether unanticipated changes are occurring and whether adjustments to planned mitigation and offsetting measures are required (Figure 6-8). As illustrated in Figure 6-8, results of monitoring activities described in the preceding sections will be reviewed to determine whether the benchmark identified as the trigger for additional assessment has been crossed. If not, results will be reported and reviewed by the KFRRC; at this point the KFRRC has the option to determine that benchmarks or monitoring program need to be modified, even if the benchmarks identified in this AEMP have not been reached. If a benchmark is exceeded, then a multi-step assessment will be conducted.

The initial step will be to determine whether the duration or frequency of benchmark exeedence has been passed. As described below, several of the benchmarks will require action only if more than one monitoring cycle has shown that the benchmark is crossed. However, even if the benchmark has not been crossed for the required number of instances to trigger further action, a trend analysis will be conducted to assess whether the observed result is a result of natural variation or indicative of worsening conditions.

If the required time has been met, the next step will be further analysis involving other monitoring results, both from the Lake Sturgeon program and other monitoring activities, to determine whether not meeting the benchmark indicates a problem. Considering all monitoring results together will be essential for developing a complete understanding of effects of the Project on Lake Sturgeon. If monitoring activities are resulting in differing conclusions, then a review of monitoring activities will be conducted to determine whether the program requires adjustment.

In the event that there is general agreement among monitoring results that an issue exists, the analysis would continue to assess whether the overall objective, of developing/maintaining a sustainable Lake Sturgeon population, is being affected. If not, then the benchmarks will be reviewed and adjusted to provide a more realistic indicator of the sensitivity of the population. If an issue is identified with the long-term sustainability of the sturgeon population, then existing contingency measures will be reviewed, and implemented as appropriate.

If no contingency measures to address a particular issue have been identified, then further studies would need to be identified and implemented. These studies would likely involve further biological investigations, to better define the problem and identify potential solutions. Depending on the type of solutions that are identified, engineering studies and evaluations may be required to design potential offsetting measures. If a large investment is required, then a complete cost/benefit analysis.

6.3.2 INTEGRATED ANALYSIS OF MONITORING RESULTS

Overall effects to sturgeon populations will be determined by integrating results of all the core components. Continued monitoring of the adult population will indicate the long-term status of the population and be directly comparable to the overall goal of mitigation (creation of a self-sustaining population). As shown in Figure 6-9, estimates of the adult population will be a key input into long-term decisions regarding the need for measures to mitigate mortality (including downstream fish protection) and emigration from the reservoir to Stephens Lake (*e.g.*, upstream passage). Monitoring the condition of adult sturgeon will assist in verifying predictions that habitat post-Project will be suitable for foraging, as well as indicating whether in the long term, population densities are too high (Figure 6-10).

Juvenile population monitoring will provide the most immediate indication of effects to spawning, YOY, and rearing habitat, which were identified in the AE SV as the most sensitive life history stages and the target of habitat creation measures (Figure 6-11 through Figure 6-13). Monitoring the abundance and condition of juveniles will also provide initial results on the success of the stocking program. As discussed in Section 6.2.2, stocked sturgeon will be marked so that they can be distinguished from wild hatched sturgeon. Assessment of the success of spawning habitat would depend on the capture of wild hatched sturgeon; however, good survival and growth of stocked sturgeon would indicate that habitat for young sturgeon is suitable. Condition factor will be used as an input into the assessment of whether habitat conditions are suitable as well as to determine whether overstocking is occurring.

Surveys for spawning adult sturgeon and studies of movements will provide important supporting information for determining the causes of potential adverse effects in relation to adult abundance and condition, and recruitment and condition, of sub-adult sturgeon.

A population viability analysis model for the Keeyask Project will provide one method of assessing integrated results of monitoring. The model will be updated with results of monitoring (*e.g.*, estimates of juvenile sturgeon survival and growth in the reservoir) and population projections re-run to determine whether effects of the Project are increasing the risk to the long-term viability of the sturgeon population. The model will also provide one method of assessing relative risks/benefits of modifications to mitigation measures (*e.g.*, change in stocking rates, delay in implementing or modifying habitat creation measures).

6.3.3 MODIFICATION TO MITIGATION AND OFFSETTING MEASURES

As described in Section 6.3.1, adaptive management for the Project will be guided by the KHLP's commitment to develop self-sustaining sturgeon populations upstream and downstream of the station. If monitoring results and interpretation of those results in consultation the KFRRC indicates that such populations are not developing, then as set out in Section 6.3.1, further investigations will be undertaken to identify possible reasons and potential solutions. There currently are four major types of mitigation/offsetting measures that could be subject to modification through adaptive management as follows:

1. Spawning habitat – measures to create appropriate hydraulic conditions in the vicinity of Birthday Rapids and modifications to constructed spawning habitat at tailrace;
2. YOY habitat – potential need for habitat modification in Keeyask reservoir and confirmation that habitat in Stephens Lake will remain suitable;
3. Stocking – potential adjustments to number of fish stocked, age of fish stocked, and locations of stocking; and
4. Fish passage – potential provision of downstream protection (barrier to reduce passage at the turbines) and provision of upstream passage.

6.3.3.1 DETERMINATION OF THE NEED TO MODIFY SPAWNING HABITAT

Spawning habitat must be present upstream and downstream of the GS to achieve the objective of creating long-term self-sustaining Lake Sturgeon populations. Successful spawning habitat requires the following:

- The presence of enough adult Lake Sturgeon in the vicinity such that sufficient fish mature in each year to form a viable spawning cohort to be attracted to the spawning habitat;
- Conditions that are suitable for spawning sturgeon, including cues to attract spawning fish and the presence of off-current refuges close to high velocity areas;
- Suitable water velocity, depth and substrate for egg deposition and survival, including survival of larval fish prior to drift; and
- Suitable YOY habitat downstream of the spawning site that can be reached by drifting larval sturgeon.

If the assessment described in Section 6.3.2 identifies that the amount or quality of spawning habitat either upstream or downstream of the GS is preventing successful recruitment, then further investigations will be required to determine the issue and potential solutions.

Potential issues and means to address them are as follows:

1. Inadequate numbers of adult sturgeon.

The absence of observed spawning in Gull Rapids in the existing environment has been attributed to the small numbers of Lake Sturgeon in Stephens Lake. This situation will continue for many years, and may not be substantially improved until stocked fish mature to spawn (if sturgeon are stocked into Stephens Lake in 2015, then mature fish could be present in 2040). There is also currently good representation of the 2008 age class – these fish would mature in about 2033 but whether a single year class can create a viable spawning population is not known.

2. Conditions not appropriate for adult spawners.

Lake Sturgeon appear to be attracted to specific areas to spawn, and cues often include the presence of white water or other hydraulic features (*e.g.*, presence of a barrier) as well as the presence of off- current refuges close to areas of high velocity. Movement studies will assist in determining the response of sturgeon to spawning habitat both upstream and downstream of the GS since it will be possible to determine the general areas in which the sturgeon are moving during the spawning season. Gillnetting in areas where sturgeon are expected to aggregate prior to moving into fast water habitat to spawn will also indicate whether mature sturgeon are present.

If monitoring indicates that sturgeon are not congregating in relation to spawning habitat, then further analysis will be conducted to determine where they are, if they are using alternate habitat, or if suitable habitat is not present. Depending on the results, modifications to create suitable cues will be undertaken.

3. Water velocity, depth, and substrate are not suitable for egg deposition and survival, including survival of larval fish prior to drift.

Unsuitable conditions, due to factors such as growth of algae, have been one reason that spawning structures have not been successful in some areas. In the event that spawning sturgeon are observed using habitat and no recruitment is observed, conditions on the spawning structure will be investigated. Work will include examination of velocity, depth, and substrate (to the extent feasible). The placement of eggs mats, to better understand egg deposition and the fate of eggs, will also be considered, if feasible.

Appropriate measures to correct the problem will need to be developed after the problem is identified. Given the design of the spawning structure, no issues with velocity, depth and substrate are anticipated at present.

4. Suitable YOY habitat.

The absence of recruitment may also be due to the lack of suitable YOY habitat in areas accessible to drifting larval fish. The suitability of YOY habitat for fall fingerlings or yearlings can be indirectly assessed through stocking of sturgeon onto habitats where it is expected that drifting larval fish would also settle. Good survival and growth of these fish will suggest that substrate conditions and food availability are suitable, though it is possible that younger fish require more specific conditions. The location of where drifting fish settle will need to be established through detailed measurements of velocity during the period when drift is expected. These results will be analyzed in relation to the known velocity and depth conditions for YOY habitat in other areas and the existing environment.

Appropriate contingency measures will depend on the issue that is identified. The KHLP has developed a plan for the placement of sand in the river bottom, if monitoring indicates that YOY habitat is not suitable due to the absence of sand.

6.3.3.2 DETERMINATION OF THE NEED TO MODIFY YOUNG-OF-THE-YEAR HABITAT

Young-of-the-year habitat must be present upstream and downstream of the GS to achieve the objective of creating long-term self-sustaining Lake Sturgeon populations. Successful YOY habitat requires the following:

- The presence of enough adult Lake Sturgeon in the vicinity such that sufficient fish mature in each year to form a viable spawning cohort to produce larval fish that could settle on the habitat;
- Appropriate spawning habitat at a location upstream of the YOY habitat such that drifting larval sturgeon would reach the YOY habitat;
- Suitable water velocity, depth, and substrate for the settling of larval fish and their subsequent survival; and
- Suitable conditions for other factors that may affect the survival of YOY, such as the presence of food items in conditions appropriate for foraging, density of older sturgeon (intra-specific competition), and other fish species (predation and inter-specific competition).

The first two requirements listed above will be addressed in the evaluation of spawning habitat and the presence of mature sturgeon, described in Section6.3.3.1. With respect to the second two requirements, the best indicator of the presence of suitable YOY habitat is a record of wild-hatched YOY or yearling sturgeon captured during the juvenile sturgeon monitoring program. However, given that only one successful year-class with persistent representation in the juvenile monitoring program has been produced since the early 2000s, the frequency of successful natural recruitment is too low to provide a useful monitoring tool. Only in the future, when the number of mature sturgeon increases, potentially when the 2008 year class matures or when the first stocked sturgeon mature (2033 and 2039, respectively), will there be a greater likelihood that natural recruitment will be detected.

In the absence of natural recruitment, two indirect measures will be used as a test of the suitability of YOY habitat:

1. Measurement of physical conditions at the location where YOY sturgeon are expected to settle, based on the rapid decrease in velocity similar to that seen at the locations where YOY are observed in Gull and Stephens lakes; and
2. Survival of stocked sturgeon.

Measurement of physical conditions

In the fourth year after initial impoundment (2023), when the period of initial rapid change in the reservoir is largely complete, water depth, velocity, and substrate will be mapped at the entrance to present day Gull Lake. Other areas further downstream, including at the existing YOY habitat, will be mapped if measured velocity post-Project indicates that larval drift may continue further into the reservoir than expected. Conditions in areas of potential YOY habitat will be compared to:

3. Criteria set out in the YOY HSI model developed in the AE SV;
4. Conditions in documented YOY habitat pre-Project in Gull and Stephens lakes; and
5. Conditions where wild hatched YOY or yearling sturgeon are captured in other environments in Manitoba, including the Burntwood River and the Winnipeg River.

Physical conditions in the YOY habitat will be considered suitable if conditions are similar to any of the locations listed above, or other areas where YOY habitat is documented in the next decade. If physical conditions are not considered suitable, then the Phase I construction of YOY habitat (sand placement) will be conducted in 2024 (Figure 6-1).

SURVIVAL OF STOCKED STURGEON

Stocking is anticipated to release both fingerling and yearling fish. Survival of immediate post larval fish in YOY habitat cannot be tested with stocked fish since natural mortality at this life stage is high; however, the survival of fish stocked in late summer will indicate whether habitat for older YOY is suitable. Survival of fish will indicate that conditions in the habitat as a whole, both with respect to physical characteristics and the biological factors listed above, are suitable. Three releases of stocked fish will be conducted prior to concluding whether or not conditions are suitable for YOY sturgeon based on this measure (2027). Detection of any surviving stocked sturgeon in the area will be considered as evidence that the habitat is suitable. If no surviving stocked fish are observed by 2027, YOY habitat will be constructed the following year (Figure 6-1).

It should be noted that juvenile monitoring may detect wild hatched fish in the reservoir and this would provide evidence that habitat is suitable for YOY. In addition, as sturgeon currently in the reservoir mature, the likelihood that natural spawning will produce a successful year class will increase, and provide additional information as to the suitability of YOY habitat.

6.3.3.3 DETERMINATION OF THE NEED TO MODIFY THE STOCKING PLAN

Recruitment monitoring will be capable of assessing the success of stocking (defined by survival of stocked fish, several years post-release). The presence of recruits, their abundance and condition will be considered in evaluating whether stocking rates need to be adjusted. Under existing conditions, strong year classes occur rarely in the Keeyask area. Erratic recruitment has also been observed in healthy populations, although the frequency of strong year classes is much higher than in the Keeyask area.

Results of monitoring in the Keeyask area will be considered in terms of observed frequency and abundance of young sturgeon in both the Keeyask area prior to construction of the GS and in the Winnipeg River (which was defined during DFO's Recovery Potential Assessment for

Lake Sturgeon as a healthy population with a stable or increasing trajectory (Cleator *et al.* 2010)).

Condition factor will be compared to pre-Project data in the Keeyask area as well as the range of condition factors observed in northern Manitoba to determine whether any changes of concern are occurring.

Recruitment monitoring results will be reviewed annually, although one-year lags associated with analysis are expected (*i.e.*, YOY tend to be under represented in sub-adult survey methods because they are less susceptible to capture in the gear). If stocking is unsuccessful (*i.e.*, if recruitment of stocked fish has not occurred three years into the operation phase), adaptive management measures will be decided upon in consultation with MCWS and DFO. Measures may include stocking a higher proportion of larger sized fish, changing release locations, or increasing the number of fish stocked. Conversely, if survival of stocked fish is found to exceed estimates and stocking rates are too high (which is conceivable, given this has occurred in other localities), potential action will consist of reducing the number of fish stocked, perhaps by skipping years.

6.3.3.4 DETERMINATION OF THE NEED FOR FISH PASSAGE

With respect to fish passage, four possible scenarios have been identified where fish passage could contribute to the development of self-sustaining populations:

1. Permanent loss of sturgeon by downstream emigration from the Keeyask reservoir is greater than the population in the reservoir can sustain.

The solution to this problem would depend on the age of fish moving and their fate as they pass through the station. If emigration is occurring at young life stages that readily survive passage downstream, then provision of upstream fish passage will provide sturgeon with the opportunity to return upstream. If larger fish are emigrating, then their route of downstream passage and any mortality associated with passage, particularly past the turbines, will need to be assessed. If substantial numbers of large sturgeon are moving and a large proportion are dying during passage, then methods of fish protection will need to be investigated. If large fish are passing safely downstream, then an alternate approach will be to provide upstream passage.

It should be noted that provision of upstream passage will not necessarily address loss of fish from the Keeyask reservoir, since sturgeon may not move upstream through the passage facilities. The potential use of upstream fish passage facilities to provide adult fish that have moved downstream, from the Keeyask reservoir with the opportunity to return to the reservoir, will be assessed based on ongoing monitoring of fish movements. It may be determined that the provision of upstream fish passage is not an appropriate mitigation measure for this effect (for example, if fish that have moved downstream do not aggregate at locations below the generating station where they appear to be seeking to move upstream).

2. Habitat to support all life history stages cannot be created in Stephens Lake.

If spawning structures, including any subsequent alterations based on monitoring, ultimately fail to produce successful recruitment in Stephens Lake as a result of issues associated with the quality of spawning habitat, quality and quantity of YOY habitat, or other unforeseen factors, then another option will be to provide an effective upstream and downstream link between the reservoir and Stephens Lake. This will allow sturgeon to spawn and rear in the reservoir upstream, and use Stephens Lake as foraging habitat for sub-adult and adult fish. This option will require that sturgeon readily use upstream passage facilities and that large sturgeon are able to move readily and safely downstream.

It should be noted that provision of upstream passage and allowing sturgeon to move downstream (for example via the spillway) may not result in the desired use of Stephens Lake as foraging habitat, since sturgeon may not ascend through a fish passage facility. Few passage structures have been successful in passing Lake Sturgeon over a high head dam.

3. The sturgeon population in Stephens Lake increases to the point that providing the opportunity to disperse upstream is considered desirable.

Provision of upstream passage could allow sturgeon to leave Stephens Lake; however, it is not known how many will disperse upstream rather than downstream. In addition, it is not known whether upon reaching the reservoir, if fish would continue to move upstream or return to Stephens Lake.

4. There may be as yet unidentified benefits to providing fish passage.

Both results of monitoring and developments in the understanding of Lake Sturgeon ecology may indicate a hitherto unidentified role of large-scale movements in maintaining populations in the long term.

Section 1 of this AEMP sets out the collaborative process that will be used to determine at a future date whether fish passage is required for the Keeyask Project. For each of the possible reasons to implement fish passage listed above, it is recognized that a multi-phase process, consisting of the following steps, will be required:

1. Additional biological investigations to address uncertainties listed above. These may include implementation of a trap and transport program to determine the response of fish to being moved from downstream of the GS to upstream in the reservoir;
2. Engineering and biological investigations to refine the conceptual design of fish passage and determine the best approach. These investigations could include monitoring of fish movements at the generating station, to better design fish passage facilities that successfully pass Lake Sturgeon both upstream and downstream;
3. An evaluation of other options to develop and support sustainable Lake Sturgeon populations. This evaluation would consider the results of enhancement activities conducted elsewhere in Manitoba; and
4. An overall evaluation considering environmental, technical, and economic factors to determine the best approach, given the technologies that are available at that time.

7.0 MERCURY IN FISH FLESH

7.1 INTRODUCTION

Monitoring of mercury levels in fish will be conducted during the operation phase of the Project. Mercury concentrations are expected to increase during the first years after full impoundment and reach peak levels in species such as Walleye and Northern Pike in three to seven years. Monitoring will be conducted in the Keeyask reservoir, Stephens Lake, Split Lake, and the Aiken River (to address York Factory First Nations concerns). Sampling may also extend downstream (*i.e.*, Long Spruce Forebay), depending on the extent of observed increases in Stephens Lake (see below).

7.1.1 ASSESSMENT SUMMARY

The Project has the potential to increase fish mercury concentrations during construction and operation in response to the disturbance and flooding of wetlands and terrestrial soils associated with construction activities and the creation of the reservoir (Table 7-1).

Expected effects to mercury concentrations in fish flesh are as follows:

- Mercury concentrations in Lake Whitefish, Northern Pike, and Walleye from the Keeyask reservoir will increase to approximately three to five times the pre-impoundment levels recorded in 2002– 2006; after reaching maxima three to seven years post construction, concentrations will decline in the long-term, but they may remain higher than pre-Project levels for up to 30 years; and
- Mercury concentrations in Lake Whitefish, Northern Pike, and Walleye from Stephens Lake will increase to approximately two times the pre-impoundment levels observed in 2001–2005; these maxima will decline over the long-term, but concentrations may remain higher than pre-Project levels for up to 25 years in areas close to the riverine corridor within Stephens Lake.

7.1.2 IDENTIFICATION OF BENCHMARKS

The following benchmarks will be used for comparison with monitored fish mercury concentrations:

- Predicted maximum mercury concentrations for Lake Whitefish, Northern Pike, and Walleye from the Keeyask reservoir and Stephens Lake;

- The 0.5 ppm total mercury Health Canada standard for commercial marketing of freshwater fish in Canada (Health Canada 2007a, b), which also represents the Manitoba guideline for mercury in fish for the protection of human consumers (MWS 2011);
- A 0.2 ppm total mercury guideline instituted as a “safe consumption limit” for people eating “large quantities of fish” for subsistence purposes (Wheatley 1979; see more detailed rationale below); and

The 0.033 ppm methylmercury Canadian and Manitoba tissue residue guidelines of for the protection of wildlife consumers of aquatic biota (CCME 2000; MWS 2011).

7.2 MONITORING ACTIVITIES TO DETECT CHANGE

The following describes the general background, approach, and methods for mercury in fish flesh monitoring. A summary schedule for all monitoring activities in relation to Project construction and operation, and the implementation of mitigation measures is provided in Figure 7-1.

7.2.1 KEY QUESTIONS

Several Project-related impacts are associated with potential increases in the release of mercury to the aquatic environment, as well as increased bioaccumulation. Upstream of the GS, these impacts include: flooding of terrestrial habitats and wetlands; conversion of intermittently wetted to permanently wetted habitat; and disintegration and decomposition of peatlands. Downstream of the GS, mercury concentrations in fish flesh could increase due to the downstream transport of methylmercury in water (including suspended particular matter) and potentially in lower trophic level organisms (*i.e.*, zooplankton and drifting benthic invertebrates) from the Keeyask reservoir. In addition, there is the potential for fish that accumulate mercury in the Keeyask reservoir to move upstream into Split Lake and downstream into Stephens Lake. Monitoring of mercury concentrations in fish muscle during Project operation is aimed at evaluating potential increases in mercury relative to baseline conditions (*i.e.*, looking for increases relative to pre-operation phase), to concentrations predicted in the AE SV (Section 7.2.4.2.2, Table 7-1), and to benchmarks related to the health of animal and human consumers of fish.

Large-bodied fish species that will be sampled for muscle mercury are Lake Whitefish, Northern Pike, and Walleye. These species were selected for historic reasons (*i.e.*, these species were commonly sampled in historic studies), because of their economic importance (they are harvested commercially and domestically), and in the case of Northern Pike and Walleye, because they are top predators and are, therefore, at the greatest risk for bio-magnification of mercury. Tissue samples from incidental Lake Sturgeon mortalities will also be collected and submitted for mercury analysis. In addition to these large-bodied, long- lived fish, 1-year old (1+)

Yellow Perch will be sampled for the analysis of mercury. Yellow Perch are widespread and abundant prey fish for Northern Pike and Walleye in the study area and, because they do not undertake extensive movements, are suitable indicators of “local” methylmercury production and bioaccumulation. The young perch may also provide insights regarding annual changes in the supply of mercury to the ecosystem.

Key questions that will be addressed through monitoring mercury in fish muscle during the operation phase are:

- What are the maximum mercury concentrations in the muscle of target fish species during operation of the Project in comparison to pre-Project levels and in relation to reference waterbodies?
- When (*i.e.*, how many years after the start of operation) are the maxima reached?
- How long does it take for fish mercury concentrations to return to background levels or to be stable at a new background level (considering potential temporal patterns in fish mercury in reference waterbodies)?
- Will the Project result in fish mercury concentrations that exceed existing standards and guidelines regarding human health or guidelines for the protection of wildlife consumers of aquatic life?

7.2.2 STUDY DESIGN AND DATA ANALYSIS

Existing Data

Fish mercury concentrations from Gull Lake were measured in 1982, and in four years between 1999 and 2006 (KHLP 2012). Concentrations in Northern Pike (0.51 ppm) and Walleye (0.78 ppm) in 1982 were significantly higher than in 2001-2006 (range of standardized means for both species: 0.19-0.26 ppm).

Lake Whitefish had similar concentrations of 0.06-0.08 ppm in the three years (1999, 2001, and 2002) mercury was analyzed for the species. Mercury levels in Yellow Perch were the lowest (0.023-0.029 ppm) of all fish species when measured in the central portion of Gull Lake in 2003 and 2004.

Stephens Lake has an extensive and long-term (1981-2012) record on fish mercury concentrations (see summaries in Bodaly *et al.* 2007; Jansen 2010a). The most recent concentrations are available for young Yellow Perch in 2003 (Jansen and Strange 2007a) and for large-bodied species in 2013 (CAMP 2014; CAMP *unpub. data*). Concentrations in Lake Whitefish (0.19 ppm), Northern Pike (1.05 ppm), and Walleye (1.76 ppm) from Stephens Lake were highest when first sampled (second sample for whitefish) more than 10 years after construction of the Kettle GS formed Stephens Lake 1970. Since then, mercury levels have declined substantially and significantly, reaching lows of 0.03, 0.18, and 0.20 ppm in the three species, respectively, in 2005. Except for these minima, which were significantly lower compared to all other means for pike and Walleye, concentrations in these two species have fluctuated between 0.26 and

0.34 ppm, and 0.26 and 0.41 ppm, respectively, since 2001. Because of their relative small variability (standard errors were generally less than 12% of the mean), occasional significant differences existed between one or two of the means, indicating that sample sizes between 18 and 76 fish were sufficient to detect even subtle differences in mercury concentrations (also see below, results for the Aiken River). For whitefish, concentrations have fluctuated from 0.046 to 0.070 ppm since 2004 (except for 2005), without a significant difference. The only sufficiently-sized sample of mercury concentration in Yellow Perch from Stephens Lake exists for 2003, when concentrations were 0.052 ppm, significantly higher than for Gull Lake in 2003 and 2004 (see above).

Split Lake has one of the most long-term and complete record of fish mercury concentrations of any waterbody in Manitoba (and Canada). Results for samples from individual fish exist for 27 years between 1972 and 2013 and concentrations from commercial (composite) samples are available for 1970. Results for large-bodied species have been compiled in several summary publications (Bodaly *et al.* 2007; Jansen and Strange 2007a; Jansen 2010a). The most recent data on mercury concentrations in fish from Split Lake were collected in 2010 (CAMP 2014) and 2013 (CAMP *unpub. data*).

Mean mercury concentrations in Northern Pike and Walleye from Split Lake have fluctuated greatly over the 20-year period from 1970-1990 without showing any trends that could be attributed to the operation of either the LWR which was completed in 1976 or the CRD which went into full operation in 1977 (also see Bodaly *et al.* 2007). Maximum mean concentrations for non-commercial samples (*i.e.*, excluding 1970) were observed in 1982 for both Northern Pike (0.52 ppm) and Walleye (0.75 ppm). These maxima were not significantly different from means recorded in many sampling years between 1973 and 1990. Starting in 1990, mercury concentrations began to decrease almost linearly (at least in pike and Walleye) and by 2005, concentrations of 0.18 ppm in Northern Pike, 0.12 ppm in Walleye, and 0.03 ppm in Lake Whitefish were the lowest measured throughout the historic record for each species. Since then, mercury concentrations have fluctuated strongly, particularly in pike and Walleye, at levels mostly significantly higher compared to 2005.

Monitoring of fish mercury concentrations in Split Lake and Stephens Lake (South basin) under CAMP is ongoing and the results will be used for AEMP reporting.

Mercury levels in Northern Pike and Walleye from the Aiken River have been measured in nine years between 1978 and 1998. However, sample size was small (three to eight fish) for those years, generally not allowing calculation of length standardized means. Adequate samples were obtained for the same two species in five years from 2002-2012 when fish were often collected from two separate locations, York Landing and Ilford (Jansen and Strange 2007a, 2009; Jansen 2010b, 2012).

Mercury concentrations of pike captured at York Landing or Ilford have ranged from 0.25–0.40 ppm between 2002 and 2012, without a significant difference either between locations for the same year or between years for the same location. Mercury concentrations in Walleye from York Landing have also been relatively steady from 2002–2012, ranging from 0.19–0.28 ppm. However, because of the very small variability of these concentrations (standard errors were 6-11% of the mean, sample size 37–51 fish), the lowest mean was significantly different from the two highest means. Walleye from Ilford showed similar small variability in mean mercury concentrations that ranged from 0.22–0.35 ppm for samples of 38–50 fish. The highest mean (measured in 2012) was significantly different from the other three means recorded from 2002–2009.

Mercury concentrations in Lake Whitefish, Northern Pike, and Walleye from the Long Spruce forebay have been measured in seven years between 1985 and 2003. Mean standardized concentrations were highest in Northern Pike (0.70 ppm) and whitefish (0.175 ppm) when first measured eight years after the completion of the Long Spruce Generating Station in 1977 (Swanson 1986; the values for pike and Walleye are reversed in Table 11 of the document); maximum concentrations in Walleye (0.64 ppm) were recorded in 1986 (Swanson and Kansas 1987), nine year after the start of operations. Thereafter, concentrations declined steadily in pike and Walleye, reaching the lowest values (0.23 and 0.24 ppm, respectively) of the entire record in 2003, when last measured. These means were significantly different from all means up to 1993. Lake Whitefish reached their lowest mercury concentrations in 1993, the mean (0.073 ppm) being significantly different from those recorded for 1985–1989, but not compared to the following sampling years, 1996 and 2003.

Data Analysis

Based on recommendations from earlier Manitoba fish mercury monitoring programs (*i.e.*, "Program for Monitoring of Mercury Concentrations in Fish in Northern Manitoba Reservoirs" [MMMR]; Jansen and Strange 2007a; Strange and Bodaly 1999) and in agreement with the target sample size under CAMP, 36 individuals of the three large-bodied species (Lake Whitefish, Northern Pike, and Walleye) will be collected from each waterbody for mercury analysis. The number and the size distribution of the whitefish, pike, and Walleye available for mercury analysis will be recorded and evaluated during fish capture to obtain a distribution representing all available size classes (see Strange and Bodaly 1999 for an example). Fish mercury concentrations mainly increase with fish age (length). A well size-stratified sample ensures that the range in mercury concentrations within a fish population is adequately represented. A maximum of 25 one-year-old Yellow Perch will be collected. A smaller sample size is justified because due to the positive relationship between mercury concentration and fish age, variability in the mean concentration within a cohort of fish is much reduced compared to the sample mean of the entire population. Perch age will be primarily estimated based on their size distribution, recognizing that these fish will measure between 60–90 mm at the end of their second growing season. Only perch of a length close to the upper and lower limits of the size distribution will be aged (see below). The actual number of fish from each species to be analyzed will largely depend on their availability within the different waterbodies and it is expected that numbers will occasionally differ from the target sample size. Only Northern Pike and Walleye will be collected from the Aiken River.

Mean mercury concentrations will be length-standardized to facilitate comparisons between samples of fish collected from the same location or between samples of fish obtained from different waterbodies over time. Standard lengths have been designated as 350, 550 and 400 mm for Lake Whitefish, Northern Pike, and Walleye, respectively (Strange and Bodaly 1999; CAMP 2014). A standard length of 100 mm will be applied to Yellow Perch. In addition to arithmetic means, standardized means will be calculated from unique regression equations for each species and waterbody based on the analysis of logarithmic transformations of mercury concentrations in muscle and fish FLs using the following relationship:

Log10[Hg] = a + b (Log10L)

Where: [Hg] = muscle mercury concentration (µg/g);

L = fork length (mm);

a = Y-intercept (constant); and

b = slope of the regression line (coefficient).

Differences in species-specific standardized mean mercury concentrations between waterbodies or years (including existing data for pre-Project years) will be established based on their 95 percent confidence limits with a non-overlap indicating a significant difference between means. In those cases where the relationship between mercury concentration and fish length is not significant (and length standardization is not applicable), appropriate parametric or non-parametric statistical tests will be used to compare arithmetic means. In particular, means will be compared between pre- and post-Project years, and between measured and predicted post-Project means (see AE SV Section 7.2.4.2.2). Maximum post- Project mercury concentrations will be considered attained for a species if standardized means (or arithmetic means if the relationship between fish length and mercury content is not significant) are not statistically different for three consecutive sampling periods (*i.e.*, 1 year for fish from the Keeyask reservoir and Stephens Lake; every 3 years for other waterbodies) or are significantly lower in the sampling period following two sampling periods of similar concentrations. Stable post-Project concentrations at the end of the declining phase will be considered attained for a species if standardized (or arithmetic) means are not statistically different for three consecutive sampling periods.

7.2.3 PARAMETERS

The primary parameter of concern for this monitoring program is the concentration of total mercury in fish skeletal muscle from the following species: Lake Whitefish, Northern Pike, Walleye, and Yellow Perch. Information on supporting biological variables will also be collected from these species, including: FL, total weight, sex, maturity, and age (for limitations regarding ageing Yellow Perch see Section 7.2.2.2). Some of the smallest perch may not provide a muscle sample sufficient for the weight requirement by the analytical laboratory, and a matrix containing some skin and bones may be analyzed.

7.2.4 SAMPLING SITES

Samples will be collected from fish captured during the conduct of the fish community monitoring program (Section 5.0) in Keeyask reservoir, Stephens Lake, and Split Lake. In the unlikely event that the target sample sizes of fish for mercury analysis are not captured during the fish community monitoring program, some additional sampling or sampling in a different location of a waterbody may be necessary to meet the minimum sample size requirements. Pike and Walleye from the Aiken River will also be sampled under the AEMP (Map 7-1).

If substantial increases (*i.e.*, 10% higher than predicted concentrations) are observed in Stephens Lake, the fish mercury monitoring program will be extended further downstream on the Nelson River by sampling within the Long Spruce Forebay. In this case, samples for mercury analysis could not be obtained from the fish community core program and sampling sites for a fish mercury program will be established based on information from previous sampling for fish mercury in 1996 and 2003. Fish mercury monitoring is also conducted by MCWS and Manitoba Hydro under CAMP at several sites in the region (see Table 1C-1).

7.2.5 SAMPLING FREQUENCY AND SCHEDULE

The periodicity of fish mercury monitoring will depend on the waterbody and Project time periods. During the operation phase, monitoring will proceed yearly in the directly affected waterbodies (*i.e.*, Keeyask reservoir, Stephens Lake) until maximum fish mercury concentrations are reached (Figure 7-1). Thereafter, monitoring of mercury levels will be conducted every three years until concentrations have reached pre-Project levels or are considered stable at a new background level. To decide if a new background mercury concentration should be considered for any of the monitoring species, results will also be compared to lakes from other Manitoba fish mercury monitoring programs (*i.e.*, CAMP). For those waterbodies not hydrologically affected by the Project (*i.e.*, Split Lake, Aiken River), monitoring will proceed at a 3-yearly interval throughout the operation phase until fish mercury concentrations have reached pre-Project concentrations or are considered stable at a new background level in the Keeyask reservoir (Figure 7-1).

Whenever possible, fish will be collected concurrently with the sampling of the fish community in the summer (Section 5.0). Northern Pike and Walleye from the Aiken River, a waterbody not part of fish community sampling will be collected in spring at ice-off.

7.2.6 FIELD AND LABORATORY METHODS

A sub-sample (36 Northern Pike, Walleye, and Lake Whitefish, and up to 25 one-year-old Yellow Perch) of fish collected as part of the fish community core monitoring program (Section 5.2.1) that are fresh and in good condition will be processed for mercury analysis. Upon capture, large-bodied fish will be measured for FL (±1 mm) and total weight (±1 g), examined internally to determine sex and maturity (not Yellow Perch; see below), and bony structures will be removed for age analysis. Dorsal spines will be taken from Walleye, cleithra from Northern Pike, and otoliths from Lake Whitefish and Yellow Perch for age determination.

A sample of axial muscle (fillet) with skin attached weighing approximately 10-60 g will be removed from each large-bodied fish anterior to the caudal (tail) fin, wrapped in cling wrap, placed into a plastic bag, and frozen for later mercury analysis at a CALA-accredited analytical laboratory. Juvenile Yellow Perch will not be dissected in the field but will be placed individually into labeled mercury-free plastic bags and stored on ice before freezing. In the laboratory, perch will be partially thawed, measured (±1 mm FL) and weighed (±0.1 g). All internal organs, the head (dorso-ventral oblique cut to just posterior of the pelvic girdle), and the tail (at the caudal peduncle) will be removed). Otoliths will be taken for age determination of selected individuals from the limits of the perch size distribution (see section 7.2.2.2). The remaining carcass, including skin and bones will be weighed (±0.01 g), wrapped in cling wrap, placed in a Ziploc® bag, and refrozen before submission to the analytical laboratory.

Total mercury analysis at the CALA-approved laboratory will be performed using internal protocols and procedures. The QA/QC program includes the analysis of different standard (certified) reference materials with each sample run, and the submission of duplicate samples to a second analytical laboratory to evaluate inter-laboratory differences.

7.3 MANAGEMENT RESPONSE FRAMEWORK

Fish mercury concentrations will be assessed during each year when sampling occurs. The assessment would follow a management response framework similar to that outlined for several other monitoring components (*e.g.*, Figure 4-2).

Step 1 involves the statistical analysis of the data, including the relationship between fish length and mercury concentration and, if warranted, the length standardization of mean concentrations for each species and waterbody. Mean (arithmetic or standardized) mercury concentrations will then be statistically compared to benchmarks (see section 7.1.2) and if a benchmark is not exceeded the assessment will proceed to Response Level 1 (temporal analysis). For this, the results for a particular monitoring year will be evaluated in the context of the entire available time series of mercury concentrations for a particular species and waterbody, especially the years identified as being representative of “current” conditions pre- Project. Such an analysis may reveal an increasing trend in mercury concentrations even though a particular benchmark has not yet been exceeded, indicating, for example, that an exeedence can be expected in the near future. Also, results for a particular lake will be compared to fish mercury concentrations from several other AEMP waterbodies and CAMP reference lakes to establish if a mean represents an outlier or is part of a consistent temporal trend across waterbodies.

If a benchmark is statistically exceeded, the assessment proceeds to Step 2 which consists of an investigation of cause (*i.e.*, is the exceedance Project-related). By design, the program will provide information to speak to this question. However, additional analyses that could be undertaken may include:

- Evaluation of data collected under the physical environment monitoring program (*e.g.*, on peatland disintegration, water level fluctuations in the Keeyask forebay); and
- Review of regional fish mercury data (*e.g.*, CAMP, Wuskwatim AEMP) to evaluate if similar changes have occurred in other areas that may not be Project-related.

If the observed difference(s) is determined to be not Project-related, the assessment proceeds to Response Level 1. If it is determined that the Project was likely contributing to the observed change(s), the assessment proceeds to Response Level 2. Activities to be undertaken or considered under Response Level 2 may include:

- Temporal analysis;
- Comparison to predictions in the AE SV (other than those that represent benchmarks, Table 7-1);
- Evaluate contribution of the Project to the effect;
- Evaluate spatial and temporal extent of the observed effects;
- Consider results of water, sediment, aquatic habitat, and other biological monitoring (*i.e.*, assess ecological context of the observed changes);
- Evaluate potential sources/causes and potential for continued contributions/effects;
- Consider regional information (*i.e.*, data from CAMP) on fish mercury concentrations to assist with interpretation of AEMP results; and
- Consider mitigation/adaptive management and determine next steps and/or additional follow-up action(s) that may be required.

A review of the monitoring program will be undertaken throughout the implementation of the AEMP with the intent to provide a mechanism for modification(s) as data are acquired over time.

The sharing of data and information from the different monitoring components is an integral part of the AEMP. Because of the linkages between fish mercury concentrations and human health, the timely dissemination of information between disciplines is critical. To this end, confirmed results from fish mercury monitoring will be provided, as soon as they are available, to the KHLP's Monitoring Advisory Committee and Mercury and Human Health Risk Management Planning Group. As noted in the Socio- Economic Monitoring Plan, the timely provision of the most current fish mercury concentrations will provide the basis for updates to the "Human Health Risk Assessment" and safe consumption recommendations, both of which are components of the "Mercury and Human Health Risk Management Plan" for the Keeyask Generation Project.

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9.0 TABLES AND FIGURES

Table 1-1: Summary of pathways of effect, planned mitigation/offsetting, residual effects and monitoring for (A) water quality, (B) aquatic habitat, (C) benthic macroinvertebrates, (D) the fish community, (E) Lake Sturgeon, and (F) mercury in fish flesh. Haul road shoal = Downstream north spawning habitat (FOMP Section 4.1.1); Spawning – Reservoir = Reservoir – spawning shoals (FOMP Section 4.1.2); Spawning – Birthday R. = Reservoir – hydraulic features near Birthday Rapids (FOMP Section 4.1.3); YOY – reservoir = Reservoir – YOY Lake Sturgeon habitat (FOMP Section 4.1.4); Spawning – tailrace = Downstream of GS – tailrace spawning shoal (FOMP Section 4.1.5); Spawning – south shore = Downstream of GS – south shore spawning shoal (FOMP Section 4.1.6).

A

Potential Pathway of Effect	Mitigation: Sediment and Erosion Control Measures	Mitigation: Effluent Treatment	Mitigation: Site selection/capping of materials	Mitigation: Blasting Management Plan	Mitigation: Little Gull Lake Egress Channel	Mitigation: Forebay Clearing Plan	Mitigation: Pre-testing of materials	Mitigation: Construction in-the-dry	Mitigation: Spill response and Environmental Protection Programs	Predicted Effect after Mitigation/Offsetting Measures	Monitoring: Construction Water Quality Monitoring (AEMP 2.2.1): Gull/Lower Nelson River/Reservoir	Construction Water Quality Monitoring: Stephens Lake	Construction Water Quality Monitoring: Downstream of Stephens Lake	Operation Water Quality Monitoring (AEMP 2.2.2): Gull/Reservoir	Operation Water Quality Monitoring: Stephens Lake	Operation Water Quality Monitoring: Downstream of Stephens Lake
Instream construction activities and water management and potential for increases in total suspended solids in the Nelson River and Stephens Lake.	x							x		Increases in TSS downstream of construction activities.	x	x	x			
Discharge of point sources (e.g., treated sewage effluent).		x								Highly localized effects on water quality in the immediate vicinity of effluent discharges.	x	x	x			
Placement of excavated materials in the future reservoir.			x							Negligible effect on water quality after mitigation.	x	x	x			
Runoff from access roads, camp site, work areas and other cleared lands, including potential inputs via groundwater.	x									Negligible effect on water quality after mitigation.	x	x	x			
Blasting.				x				x		Negligible effect on water quality after mitigation.	x	x	x			
Placement of excavated materials on cofferdams, main dam, and other structures (potential for acid leachate generation).							x			Negligible effect on water quality after mitigation.	x	x	x			
Placement of concrete in surface waters.								x		Negligible effect on water quality after mitigation.	x	x	x			
Accidental spills and releases of hazardous substances.									x	Negligible effect on water quality after mitigation.	X	x	x			
Flooding of terrestrial habitat and changes in water levels/flows/residence times.					x	x				Increases in nutrients, colour, turbidity, conductivity, and metals and decreases in pH and dissolved oxygen in flooded backbays in the reservoir. Effects to the mainstem of the reservoir will be negligible to small for most conditions. TSS will decrease in the long-term due to increased sedimentation in the reservoir. TSS will decrease in the southwestern portion of Stephens Lake over the long term.				x	x	x
Mineral soil erosion/erosion and peat re-surfacing during operation.										TSS will increase in flooded backbays during the initial years of operation, with effects being larges in the first year of operation and declining rapidly thereafter. Negligible effects in mainstem of the reservoir.				x	x	x

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B

Potential Pathway of Effect	Mitigation / Offsetting: Spawning – reservoir (KAFA 13.1.2)	Mitigation / Offsetting: Spawning – tailrace (KAFA 13.1.5)	Mitigation / Offsetting: Spawning – south shore (KAFA 13.1.6)	Mitigation / Offsetting: YOY - Reservoir (KAFA 13.1.4)	Predicted Effect after Mitigation/Offsetting Measures	Monitoring: Nearshore Habitat (AEMP 3.2.1): Stephens Lake	Monitoring: Nearshore Habitat (AEMP 3.2.1): Gull/Reservoir	Monitoring: Offshore Habitat (AEMP 3.2.2): Stephens Lake	Monitoring: Offshore Habitat (AEMP 3.2.2): Gull/Reservoir	Monitoring: Sensitive/Constructed Habitat (AEMP 3.2.3): Stephens Lake	Monitoring: Sensitive/Constructed Habitat (AEMP 3.2.3): Gull/Reservoir
Habitat changes from Long Rapids to Birthday Rapids as a result of minor changes in water depth will result in negligible changes to velocity and no effects to substrate.					Minor changes are not expected to affect habitat.						
Habitat changes at Birthday Rapids due to the small increase in depth and small reduction in velocity may result in the loss of whitewater.					Habitat will remain as high velocity, hard substrate, and similar range of depths. The loss of white water may require implementation of contingency measures to create hydraulic features attractive to spawning sturgeon in the vicinity of Birthday Rapids.						X
Loss of Gull Rapids due to GS structure and dewatering.		X	X		Loss of rapids offset partly by creation of up to 5 ha of spawning habitat for Lake Sturgeon and Walleye downstream of the generating station and creation of 0.1 ha spawning shoal for Lake Whitefish on the south bank of the Nelson River near Stephens Lake.					X	
Alteration of habitat in the 4 km of river immediately downstream of Gull Rapids due to channeling flow through the generating station and cycling at the station.					Habitat predicted to remain generally similar in terms of depth, velocity and substrate with the exception of the development of an area of deposition along north bank below GS.	X		X			
Habitat changes to the river, tributary stream, and lake habitat between Birthday Rapids and Gull Rapids as a result of increased water depth and decreased velocity.	X			?	Large (average of 6 m) increase in depth and decrease in velocity with deposition of fine sediments over areas of coarse sediment. Loss of existing macrophyte beds.				X		X
Alteration of substrate in Stephens Lake due to sediment deposition during construction.					Monitoring of substrate is proposed to verify no effect.			X		X	
Creation of new aquatic habitat through the flooding of terrestrial areas.					Long term creation of 5,100 ha of productive fish habitat. Monitoring proposed to track changes in nearshore and offshore areas, including development of macrophyte habitat and macrophyte colonization.		X		X		

Table 1-1: Summary of pathways of effect, planned mitigation/offsetting, residual effects and monitoring for (A) water quality, (B) aquatic habitat, (C) benthic macroinvertebrates, (D) the fish community, (E) Lake Sturgeon, and (F) mercury in fish flesh. Haul road shoal = Downstream north spawning habitat (FOMP Section 4.1.1); Spawning – Reservoir = Reservoir – spawning shoals (FOMP Section 4.1.2); Spawning – Birthday R. = Reservoir – hydraulic features near Birthday Rapids (FOMP Section 4.1.3); YOY – reservoir = Reservoir – YOY Lake Sturgeon habitat (FOMP Section 4.1.4); Spawning – tailrace = Downstream of GS – tailrace spawning shoal (FOMP Section 4.1.5); Spawning – south shore = Downstream of GS – south shore spawning shoal (FOMP Section 4.1.6).

C

Potential Pathway of Effect	Mitigation / Offsetting: Sediment Management Plan (KAFA 9.1.5)	Mitigation / Offsetting: Spawning – reservoir (KAFA 13.1.2)	Mitigation / Offsetting: Spawning – tailrace (KAFA 13.1.5)	Mitigation / Offsetting: Spawning – south shore (KAFA 13.1.6)	Predicted Effect after Mitigation/Offsetting Measures	Monitoring: BMI (AEMP 4.2) Stephens Lake	Monitoring: BMI (AEMP 4.2) Gull/Reservoir
Changes to water quality, such as increases in concentration of TSS and related variables (*e.g.*, turbidity).	X				No long term effect to the benthic macroinvertebrate community due to the implementation of a Sediment Management Plan (SMP) for in-stream construction.	X	X
Dewatering of habitat in Gull Rapids.			X	X	Long term effect resulting in a reduction in the abundance of benthic macroinvertebrates favouring this type of aquatic habitat and a change in the macroinvertebrate community composition. Effect partially offset by creation of rocky shoal habitat downstream of the GS and on the south bank of the Nelson River near Stephens Lake.		
Deposition of sediments in Stephens Lake.	X				No long term effect to the benthic macroinvertebrate community due to minor nature of predicted changes.	X	
Loss of existing habitat and the creation of new habitat due to flooding.		X			Long term effect resulting in a reduction in the abundance of benthic macroinvertebrates favouring this type of aquatic habitat and a change in the macroinvertebrate community composition. Effect partially offset by creation of rocky shoal habitat upstream of the GS.		X
Reduction in medium and high water velocity habitat upstream of the GS due to reservoir creation.					Long term effect resulting in a large increase in the abundance of benthic macroinvertebrates and a change in the community composition.		X
Conversion of existing hard gravel, cobble, and boulder substrates to softer silt/clay substrates due to sedimentation in the reservoir.		X			Long term effect resulting in a reduction in the abundance of benthic macroinvertebrates favouring this type of aquatic habitat and a change in the macroinvertebrate community composition. Effect partially offset by creation of rocky shoal habitat upstream of the GS.		X
Increase in the frequency of water level fluctuations due to GS operations.					Long term effect in isolated nearshore areas resulting in a reduction in the abundance of benthic macroinvertebrates favouring this type of aquatic habitat and a change in the macroinvertebrate community composition.	X	X
Conversion of tributary habitat to bays due to flooding, and changes in surface water quality in off-current areas, particularly bays (*e.g.*, flooding and peat disintegration are expected to cause decreases in DO concentrations in portions of shallow, flooded bays of the reservoir with poor mixing and long water residence times in the open water and ice-cover seasons).					Moderate to long term effect during open water season in isolated nearshore areas resulting in a reduction in the abundance of benthic macroinvertebrates favouring this type of aquatic habitat and a change in the macroinvertebrate community composition. Greater effects will occur in the winter where a larger area will be affected, the magnitude of DO depletion will be greatest, and the duration of effects would be longest. The low DO conditions are expected to limit invertebrate colonization to a few resilient groups (*e.g.,* chironomids) in the localized affected areas.		X
Alteration of flow patterns, water velocities, and depths in the portion of the Nelson River from the GS to the inlet of Stephens Lake.					No long term effect to the benthic macroinvertebrate community due to minor nature of predicted changes.	X	X
Reduction in the extent and severity of ice scour in the portion of the Nelson River from the GS to the inlet of Stephens Lake.					Long term effect resulting in an increase in the abundance of benthic macroinvertebrates favouring this type of aquatic habitat and a change in the macroinvertebrate community composition.	X	

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D

Potential Pathway of Effect	Mitigation / Offsetting: Instream timing windows (KAFA 9.1.1.1)	Fish Salvage (KAFA 9.1.1.2)	Provision of fish passage at culverts (KAFA 9.1.2)	End of pipe screening guidelines/blasting guidelines (KAFA 9.1.3, 9.1.4)	Water quality management (KAFA 9.1.5)	Egress channels in Little Gull Lake	Escape channels in spillway	Upstream fish passage	Turbine design	Haul road – shoals and channel (KAFA 13.1.1)	Spawning – reservoir (KAFA 13.1.2)	Spawning – tailrace (KAFA 13.1.5)	Spawning – south shore (KAFA 13.1.6)	Predicted Effect after Mitigation/Offsetting Measures	Monitoring: No targeted monitoring	Fish Species Composition and Abundance (AEMP 5.3.1): Split Lake	Keeyask Area	Stephens Lake	Use of created and existing spawning habitat (AEMP 5.3.2): Keeyask Area	Stephens Lake	Movement and habitat Use Monitoring (AEMP 5.3.3): Keeyask Area	Stephens Lake	Turbine Mortality (AEMP 5.3.4): Stephens Lake	Fish Stranding Following Spill Events: Stephens Lake	Fish Winterhill in Little Gull Lake: Keeyask Area
Dewatering of cofferdams.	X	X												Negligible effect to fish populations due to fish salvage.							X	X			
Temporary causeways to borrow sites.			X							X				No effect due to passage/ additional habitat.								X			
Entrainment of fish in intake pipes.				X										No effect due to adherence to DFO guidelines.	X										
Blasting.				X										No significant effect to fish populations.							X	X			
Changes to water quality due to instream construction, reservoir creation and flooding.	X				X	X								Effects to fish habitat upstream and downstream of GS. During instream construction, increases in TSS could affect fish in Stephens Lake. During operation fish could be affected in backbays due to oxygen depletion.			X	X			X	X			X
Disturbance of spawning in Gull Rapids by construction	X													Potential reduction in year class strength during construction.			X	X			X	X			
Loss of Gull Rapids due to dewatering.								X				X	X	Loss of spawning habitat not expected to affect populations due to presence of other spawning habitat in Stephens Lake and construction of spawning shoals. Loss of movement corridor not expected to affect population but will be assessed and addressed, if required, through provision of fish passage.			X	X		X	X	X			
Alteration to fish emigration to Stephens Lake.								X	X					No effect expected due to small number of fish currently moving downstream.				X			X	X	X		
Fish injury and mortality at turbines, spillway .								X	X					No effect expected due to small number of fish currently moving downstream.									X		
Fish stranding in the spillway.							X							No effect due to creation of escape channels.										X	
Alteration of habitat due to GS cycling.														No effect due to minimal change in water levels.	X										
Alteration of habitat in Stephens Lake due to sedimentation from construction.														Deposition of additional fines (< 0.6 cm) in areas that are already composed of the same substrate.	X										
Decreased water velocities at Birthday Rapids after impoundment.														Potential for increased movements out of Gull Lake; potential movement of spawners to upstream locations.		X	X	X	X		X				
Habitat changes to the river, tributary stream and lake habitat between Birthday and Gull rapids as a result of increased water depth and decreased velocity.														Changes in spawning and foraging habitat, with potential reduction in rocky shoals in lower reservoir. Shifts in fish distribution are expected but no long term decline in abundance.			X	X	X	X	X				
Habitat changes from Long Rapids to Birthday Rapids as a result of minor changes in water depth that will result in negligible changes to velocity and no effects to substrate.														No effect.							X				
Creation of new aquatic habitat as the result of flooding of terrestrial land, primarily surrounding present-day Gull Lake.														Long-term creation of 5,100 ha of aquatic habitat.			X	X							
Harvest by the construction workforce and after construction by resource users.														No effect expected due to fisheries management.	X										

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E

	Mitigation / Offsetting									Monitoring									
	Spawning – Birthday R. (KAFA 13.1.3)	Spawning – tailrace (KAFA 13.1.5)	YOY – Stephens L. (KAFA 8.1.11)	YOY – reservoir (KAFA 13.1.4)	Stocking (KAFA 13.1.7)	Fish passage (KAFA 11.1.7)	D/S fish protect. (KAFA 11.1.8)	Offsite stocking (KAFA 13.1.7)		Adult pop. (AEMP 6.2.1) Stephens Lake	Adult pop. (AEMP 6.2.1) Gull/Reservoir	Juvenile pop. (AEMP 6.2.2) Stephens Lake	Juvenile pop. (AEMP 6.2.2) Gull/Reservoir	Spawning (AEMP 6.2.3) Stephens Lake	Spawning (AEMP 6.2.3) Gull/Reservoir	Movement (AEMP 6.2.4) Stephens Lake	Movement (AEMP 6.2.4) Gull/Reservoir	Upper Split Lake Adult pop. (AEMP 6.2.1)	Upper Split Lake Juvenile pop. (AEMP 6.2.2)
Potential Pathway of Effect									**Predicted Effect after Mitigation/Offsetting Measures**										
Disruption of spawning activity due to construction activity at Gull Rapids.					X				No effect to total recruitment due to stocking during construction.			X				X			
Loss of spawning habitat due to GS structure and dewatering of Gull Rapids.		X			X	?			No effect to long term sustainable population in Stephens Lake due to creation of spawning habitat downstream of the GS and stocking to re-establish a viable population.			X		X		X			
Loss of an upstream movement corridor due to GS structure and dewatering of Gull Rapids.						?			No effect to long term sustainable population in Stephens Lake is predicted due to presence of habitat to support all life history stages.	X		X		X		X			
Changes in downstream movement of larval, juvenile, and adult fish due to presence of reservoir/GS structures in former riverine habitat.					X				No effect to long term sustainable population in Stephens Lake due to creation of a self-sustaining population by stocking and presence of habitat to support all life history stages.	X		X				X	X		
Injury and mortality of fish moving downstream past the trashracks and turbines or over the spillway.					X		?		No effect to long term sustainable population in Stephens Lake due to small number of large sturgeon moving and high survival of smaller fish.	X		X					X		
Potential changes to fish use of the river reach immediately downstream of Gull Rapids due to channeling/cycling of flows.									No effect to long term sustainable population in Stephens Lake due to minor nature of predicted changes.	X		X				X			
Changes to fish use of aquatic habitat in Stephens Lake due to sediment deposition during construction.			?						No effect to long term sustainable population in Stephens Lake as no permanent deposition of silt over areas of sand is predicted.	X		X				X			
Increased emigration from reservoir during impoundment and operation.					X	?			Potential short term effect to number of adults in Gull Lake; long term reduction in population due to emigration to establish viable population avoided by stocking.		X		X				X		
Changes in fish use of the Birthday Rapids to Gull Rapids reach due to increased water levels and decreased flow that will result in the loss or alteration of existing habitat (in particular young-of-the-year (YOY) habitat in Gull Lake) and creation of new habitat.				?	X				No effect to long term sustainable population in reservoir due to suitability of foraging habitat in reservoir and development of suitable YOY habitat near inlet of present-day Gull Lake.		X		X				X		
A decrease in attraction to and use of spawning habitat at Birthday Rapids, given the predicted loss of white water.	?				X				No effect to long term sustainable population in reservoir given that stocking will support the population during the initial years of transition and a contingency measure to create features attractive to spawning sturgeon in the vicinity of Birthday Rapids, if required, has been developed.		X		X		X		X		
Potential increase in mortality due to an increase in domestic harvest.									No effect to long term sustainable population in reservoir or Stephens Lake due to measures to inform local resource users of the vulnerability of this sturgeon population.	X	X								
Increase in regional Lake Sturgeon population.								X	Increase in regional Lake Sturgeon population due to stocking in areas where habitat exists but stocks have been depleted by historic over exploitation in a commercial fishery.									X	X

Table 1-1: Summary of pathways of effect, planned mitigation/offsetting, residual effects and monitoring for (A) water quality, (B) aquatic habitat, (C) benthic macroinvertebrates, (D) the fish community, (E) Lake Sturgeon, and (F) mercury in fish flesh. Haul road shoal = Downstream north spawning habitat (FOMP Section 4.1.1); Spawning – Reservoir = Reservoir – spawning shoals (FOMP Section 4.1.2); Spawning – Birthday R. = Reservoir – hydraulic features near Birthday Rapids (FOMP Section 4.1.3); YOY – reservoir = Reservoir – YOY Lake Sturgeon habitat (FOMP Section 4.1.4); Spawning – tailrace = Downstream of GS – tailrace spawning shoal (FOMP Section 4.1.5); Spawning – south shore = Downstream of GS – south shore spawning shoal (FOMP Section 4.1.6).

F

Potential Pathway of Effect	Mitigation / Offsetting	Lower head, reduced flooded area compared to earlier GS designs	Clearing of trees in the flooded zone during winter which minimizing runoff		Predicted Effect after Mitigation/Offsetting Measures	Monitoring	Keeyask Reservoir	Stephens Lake	Split Lake	Aiken River	Longspruce Forebay
Increase in fish mercury concentrations due to increased net methylation rates after reservoir flooding and bioaccumulation of methylmercury in the aquatic food chain. Downstream export of mercury via water and biota from the Keeyask reservoir into Stephens Lake and potentially further downstream.		X	X		Concentrations in lake whitefish, northern pike, and walleye from the Keeyask reservoir will see a large, medium-term increase to approximately three to five times the pre-impoundment levels recorded in 2002–2006; these maximum concentrations will decline in the long-term, but levels may remain higher than pre-Project concentrations for up to 30 years. Concentrations in lake whitefish, northern pike, and walleye from Stephens Lake will increase moderately in the medium-term to approximately two times the pre-impoundment levels observed in 2001–2005; these maximum concentrations will decline over the long-term, but levels may remain higher than pre-Project concentrations for up to 25 years in areas close to the riverine corridor within Stephens Lake.		X	X	X	X	(X)

Table 2-1: Water Quality - summary of pathways of effect, planned mitigation/offsetting, residual effects and monitoring. X = planned activity.

Potential Pathway of Effect	Mitigation: Sediment and Erosion Control Measures	Effluent Treatment	Site selection/capping of materials	Blasting Management Plan	Little Gull Lake Egress Channel	Forebay Clearing Plan	Pre-testing of materials	Construction in-the-dry	Spill response and Environmental Protection Programs	Predicted Effect after Mitigation/Offsetting Measures	Monitoring: Construction Water Quality Monitoring(AEMP 2.2.1): Gull/Lower Nelson River/Reservoir	Stephens Lake	Downstream of Stephens Lake	Operation Water Quality Monitoring(AEMP 2.2.2): Gull/Reservoir	Stephens Lake	Downstream of Stephens Lake
Instream construction activities and water management and potential for increases in total suspended solids in the Nelson River and Stephens Lake.	x							x		Increases in TSS downstream of construction activities.	x	x	x			
Discharge of point sources (e.g., treated sewage effluent).		x								Highly localized effects on water quality in the immediate vicinity of effluent discharges.	x	x	x			
Placement of excavated materials in the future reservoir.			x							Negligible effect on water quality after mitigation.	x	x	x			
Runoff from access roads, camp site, work areas and other cleared lands, including potential inputs via groundwater.	x									Negligible effect on water quality after mitigation.	x	x	x			
Blasting.				x				x		Negligible effect on water quality after mitigation.	x	x	x			
Placement of excavated materials on cofferdams, main dam, and other structures (potential for acid leachate generation).							x			Negligible effect on water quality after mitigation.	x	x	x			
Placement of concrete in surface waters.								x		Negligible effect on water quality after mitigation.	x	x	x			
Accidental spills and releases of hazardous substances.									x	Negligible effect on water quality after mitigation.	X	x	x			
Flooding of terrestrial habitat and changes in water levels/flows/residence times.					x	x				Increases in nutrients, colour, turbidity, conductivity, and metals and decreases in pH and dissolved oxygen in flooded backbays in the reservoir. Effects to the mainstem of the reservoir will be negligible to small for most conditions. TSS will decrease in the long-term due to increased sedimentation in the reservoir. TSS will decrease in the southwestern portion of Stephens Lake over the long term.				x	x	x
Mineral soil erosion/erosion and peat re-surfacing during operation.										TSS will increase in flooded backbays during the initial years of operation, with effects being larges in the first year of operation and declining rapidly thereafter. Negligible effects in mainstem of the reservoir.				x	x	x

Table 2-2: Summary statistics for key water quality indicators and monitoring benchmarks.

	Dissolved Ammonia	Dissolved Nitrate/ nitrite	TP	TSS	pH	Chlorophyll *a*	DO	Aluminum	Arsenic	Cadmium	Chromium	Copper
	(mg N/L)	(mg N/L)	(mg/L)	(mg/L)		(µg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Mean	0.0104	0.0205	0.039	14.3	8.16	5.49	11.35	1.17	0.00124	0.000010	0.0018	0.00291
Median	0.0090	0.0180	0.038	13.5	8.19	5.00	11.16	1.18	0.00122	<0.00001	0.0015	0.00233
Min	0.0010	0.0025	0.018	3.0	7.85	2.00	8.25	0.21	0.00060	<0.00001	<0.001	<0.001
Max	0.0423	0.0680	0.065	28.0	8.41	12.00	16.05	2.53	0.00250	0.000087	0.0120	0.01933
SD	0.0087	0.0171	0.009	4.3	0.14	2.13	1.85	0.53	0.00032	0.000014	0.0018	0.00236
SE	0.0007	0.0015	0.001	0.4	0.01	0.18	0.16	0.06	0.00004	0.000002	0.0003	0.00029
n	135	135	135	134	135	135	130	67	67	39	43	67
95th Percentile	0.0309	0.0519	0.054	22.4	8.35	10.00	14.48	1.98	0.00181	0.000017	0.0028	0.00610
Mean + 2 x SD	0.0278	0.0547	0.056	22.9	8.44	9.76	15.05	2.22	0.0019	0.00004	0.0054	0.00762
COV	83	84	23	30	2	39	16	45	25	-	103	81
# Detects	116	104	135	134	135	135	130	67	67	7	29	66
% Detects	86	77	100	100	100	100	100	100	100	18	67	99
Benchmark Method	MWQSOG	MWQSOG	CCME	MWQSOG	MWQSOG	95^{th} Percentile	MWQSOG	95^{th} Percentile	MWQSOG	MWQSOG	MWQSOG	MWQSOG
Benchmark	0.8960 [1]	2.930	0.058	5/25 mg/L above background	6.5-9	10.00	6.50/9.5	1.98	0.15000	0.00030 [2]	0.097 [2]	0.0106 [2]

Table 2-2: Summary statistics for key water quality indicators and monitoring benchmarks.

	Iron	Lead	Mercury	Methylmercury [3,4]	Molybdenum	Nickel	Selenium	Silver	Thallium	Uranium	Zinc
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Mean	0.87	0.000503	<0.00002	<0.00000005	0.00071	0.0030	<0.001	<0.0001	0.00007	0.00057	<0.01
Median	0.90	<0.0005	<0.00002	<0.00000005	0.00063	0.0022	<0.001	<0.0001	0.00005	0.00058	<0.01
Min	0.21	0.000218	<0.000001	<0.00000005	0.00040	<0.0020	<0.001	<0.0001	0.00005	0.00040	<0.01
Max	1.66	0.001867	0.000033	<0.00000005	0.00630	0.0300	0.0050	0.00070	0.00030	0.00080	0.070
SD	0.33	0.000333	0.000007	-	0.00070	0.0043	0.0006	0.00009	0.00004	0.00009	0.011
SE	0.04	0.000041	0.000001	-	0.00009	0.0005	0.0001	0.00001	0.00001	0.00001	0.002
n	67	67	31	6	67	67	59	59	67	67	51
95th Percentile	1.45	0.000970	0.000030	-	0.00087	0.0055	0.0010	0.00020	0.00010	0.00071	0.016
Mean + 2 x SD	1.53	0.001169	0.000026	-	0.00212	0.0115	0.0018	0.00026	0.00015	0.00075	0.030
COV	38	66	63	-	98	142	98	127	66	15	144
# Detects	67	35	6	0	67	50	4	6	13	67	9
% Detects	100	52	19	0	100	75	7	10	19	100	18
Benchmark Method	95th Percentile	MWQSOG	MWQSOG	MWQSOG	MWQSOG	MWQSOG	MWQSOG	MWQSOG	MWQSOG	MWQSOG	MWQSOG
Benchmark	1.45	0.0038 [2]	0.000026	0.000005	0.073	0.059 [2]	0.0010	0.0001	0.0008	0.0330	0.135 [2]

1. Calculated using the maximum pH and temperature. PAL objectives will be calculated using site-specific pH and temperature measured at the time of monitoring.
2. Calculated using the mean baseline water hardness. Benchmarks will be calculated using site-specific water hardness measured at the time of monitoring.
3. Key indicator for the operation period only.
4. Summary statistics for regional sites sampled in fall 2011.

Table 2-3: CCME phosphorus management guidance framework trophic categorization scheme (CCME 1999; updated to 2014).

Lake Trophic Status: Total phosphorus (µg/L)						Reference
Ultra-oligotrophic	**Oligotrophic**	**Mesotrophic**	**Meso-eutrophic**	**Eutrophic**	**Hypereutrophic**	
<4	4-10	10-20	20-35	35-100	> 100	CCME (1999; updated to 2014)
				Study Area Mean: 39 Median: 38		Keeyask Baseline

Table 2-4: Trophic classification schemes for lakes based on chlorophyll *a*.

Lake Trophic Status: Chlorophyll *a* (µg/L)						Reference
Ultra-oligotrophic	**Oligotrophic**	**Mesotrophic**	**Meso-eutrophic**	**Eutrophic**	**Hypereutrophic**	
<1	<2.5	2.5-8	-	8-25	> 25	OECD (1982) and AENV (2014)
-	Mean: <1.7 Range: 0.3-4.5	Mean: 4.7 Range: 3-11	-	Mean: 14.3 Range: 3-78	Range: 100-150	Wetzel (2001)
-	< 3.5	3.5-9	-	9.1-25	> 25	Nürnberg (1996)
-	<2.6	2.6-6.4	6.4-20	>20		Carlson (1977)
≤2	2-5	5-12	-	12-25	>25	Swedish EPA (2000)
-	<2	2-7	-	7-30	>30	USEPA (2009)
-	<3	3-7	-	7-40	>40	University of Florida (2002)
-	1-3	3-8	-	8-25		Galvez-Cloutier R. and M. Sanchez. (2007)
Mean: <1 Maximum: 2.5	Mean: <2.5 Maximum: 8	Mean: 2.5-8 Maximum: 8-25	-	Mean: 8-25 Maximum: 25-75	Mean: >25 Maximum: >75	Ryding and Rast (1989)
		Study Area Mean: 5.5 Median: 5.0				Keeyask Baseline

Table 2-5: Derivation of the benchmark for chlorophyll *a* based on trophic boundaries.

Reference	Chlorophyll *a* Trophic Boundaries (µg/L)			
	Maximum Oligotrophic	Minimum Mesotrophic	Maximum Mesotrophic	Minimum Eutrophic
OECD (1982) and AENV (2014)	2.5	2.5	8	8
Wetzel (2001)	4.5	3	11	3
Nürnberg (1996)	3.5	3.5	9	9.1
Carlson (1977)	2.6	2.6	6.4	20
Swedish EPA (2000)	5	5	12	12
USEPA (2009)	2	2	7	7
University of Florida (2002)	3	3	7	7
Galvez-Cloutier and Sanchez (2007)	3	3	8	8
Ryding and Rast (1989)	8	8	8	8
Mean	3.79	3.62	8.49	9.12

Table 2-6: Overview of the water quality monitoring schedule for the construction period.

Year	Instream Activity Description	Monitoring Period	Sampling Events	Monitoring Area	AE SV Predictions[1]
2014/2015	Quarry Cofferdam Powerhouse Stage I Cofferdam North Channel Rock Groin North Channel Stage I Cofferdam	June	-	-	
		July	x	Local	Increases in TSS < 5 mg/L in fully mixed river over the period of mid-July through mid-October
		August	x	Local	
		Late September/early October	x	Local	
		February/March	x	Local	
2015/2016	Spillway Stage I Cofferdam Central Dam Stage I Cofferdam	June	x	Local	
		July	x	Local and Regional	Increases in TSS < 5 mg/L for majority of period between mid-July and early October; TSS to increase by up to 8 mg/L in July
		August	x	Local	
		Late September/early October	x	Local	
		February/March	x	Local	
2016/2017	None	June	x	Local	
		July	x	Local	
		August	x	Local	
		Late September/early October	x	Local	
		February/March	x	Local	
2017/2018	Spillway Cofferdam Removal Spillway Commissioning South Dam Stage II Cofferdam Construction	June	x	Local	
		July	x	Local	
		August	x	Local	Increases in TSS < 5 mg/L from Spillway cofferdam removal

Table 2-6: Overview of the water quality monitoring schedule for the construction period.

Year	Instream Activity Description	Monitoring Period	Sampling Events	Monitoring Area	AE SV Predictions[1]
		September/October	x	Local and Regional	Increases of up to 25 mg/L during Spillway commissioning; Increases of up to 15 mg/L during construction of the South Dam Stage II Upstream Rockfill Cofferdam
		February/March	x	Local	
2018/2019	Tailrace Summer Level Cofferdam Construction	June	x	Local	Increases in TSS < 5 mg/L due to South Dam Stage II Upstream and Downstream cofferdam and Tailrace Summer Level cofferdam construction from May to mid-September
		July	x	Local	
		August	x	Local	
		September	x	Local	
		February/March	x	Local	
2019/2020	Tailrace Summer Level Cofferdam repairs Powerhouse Cofferdam Removal Tailrace Summer Level Cofferdam removal Powerhouse Unit 1 Commissioning	June	x	Local	Increase in TSS of 3 mg/L due to removal of the Powerhouse cofferdam from late June to late July
		July	x		
		August	x		
		September/October	x	Local and Regional	Increase in TSS of 7 mg/L due to Tailrace Summer Level cofferdam from early September through early October
		February/March	x	Local	

1. 24-hour rolling average concentrations of TSS in the fully mixed Nelson River

Table 2-7: Laboratory water quality parameters and current analytical laboratory detection limits: construction period.

Parameter	Units	DL	Parameter	Units	DL
Total Kjeldahl nitrogen	mg/L	0.2	Total mercury	ng/L	1
Ammonia	mg/L	0.01	Aluminum	mg/L	0.005
Nitrate/nitrite	mg/L	0.005	Antimony	mg/L	0.0002
Total phosphorus	mg/L	0.001	Arsenic	mg/L	0.0002
Total dissolved phosphorus	mg/L	0.001	Barium	mg/L	0.0002
Total organic carbon	mg/L	1	Beryllium	mg/L	0.0002
Dissolved organic carbon	mg/L	1	Bismuth	mg/L	0.0002
Total suspended solids	mg/L	2	Boron	mg/L	0.01
Turbidity	NTU	0.1	Cadmium	mg/L	0.00001
True Colour	TCU	5	Calcium	mg/L	0.1
Conductivity	µmhos/cm	1	Chromium	mg/L	0.001
Total dissolved solids	mg/L	5	Cobalt	mg/L	0.0002
Hardness	mg/L	0.3	Copper	mg/L	0.0002
pH	Ph units	0.1	Iron	mg/L	0.1
Alkalinity, Total (as $CaCO_3$)	mg/L	1	Lead	mg/L	0.00009
Bicarbonate (HCO_3)	mg/L	3	Magnesium	mg/L	0.01
Carbonate (CO_3)	mg/L	3	Manganese	mg/L	0.0003
Hydroxide (OH)	mg/L	3	Molybdenum	mg/L	0.0002
Chloride	mg/L	0.5	Nickel	mg/L	0.002
Sulphate	mg/L	0.5	Potassium	mg/L	0.02
Chlorophyll *a*/pheophytin *a*	µg/L	0.1	Selenium	mg/L	0.001
			Silver	mg/L	0.0001
Benzene	mg/L	0.0005	Sodium	mg/L	0.03
Toluene	mg/L	0.001	Strontium	mg/L	0.0001
Ethyl benzene	mg/L	0.0005	Thallium	mg/L	0.0001
Xylene	mg/L	0.0005	Thorium	mg/L	0.0001
F1 Hydrocarbons (C6-C10)	mg/L	0.1	Tin	mg/L	0.0002
F2 Hydrocarbons (C10-C16)	mg/L	0.025	Titanium	mg/L	0.0005
F3 Hydrocarbons (C16-C34)	mg/L	0.025	Tungsten	mg/L	0.0001
F4 Hydrocarbons (C34-C50)	mg/L	0.025	Uranium	mg/L	0.0001
			Vanadium	mg/L	0.0002
			Zinc	mg/L	0.002
			Zirconium	mg/L	0.0004

Table 2-8: Laboratory water quality parameters and current analytical laboratory detection limits: operation period.

Parameter	Units	DL	Parameter	Units	DL
Total Kjeldahl nitrogen	mg/L	0.2	Total mercury	ng/L	1
Ammonia	mg/L	0.01	Total methylmercury	ng/L	0.05
Nitrate/nitrite	mg/L	0.005	Aluminum	mg/L	0.005
Total phosphorus	mg/L	0.001	Antimony	mg/L	0.0002
Total dissolved phosphorus	mg/L	0.001	Arsenic	mg/L	0.0002
Total organic carbon	mg/L	1	Barium	mg/L	0.0002
Dissolved organic carbon	mg/L	1	Beryllium	mg/L	0.0002
Total suspended solids	mg/L	2	Bismuth	mg/L	0.0002
Turbidity	NTU	0.1	Boron	mg/L	0.01
True Colour	TCU	5	Cadmium	mg/L	0.00001
Conductivity	µmhos/cm	1	Calcium	mg/L	0.1
Total dissolved solids	mg/L	5	Chromium	mg/L	0.001
Hardness	mg/L	0.3	Cobalt	mg/L	0.0002
pH	Ph units	0.1	Copper	mg/L	0.0002
Alkalinity, Total (as $CaCO_3$)	mg/L	1	Iron	mg/L	0.1
Bicarbonate (HCO_3)	mg/L	3	Lead	mg/L	0.00009
Carbonate (CO_3)	mg/L	3	Magnesium	mg/L	0.01
Hydroxide (OH)	mg/L	3	Manganese	mg/L	0.0003
Chloride	mg/L	0.5	Molybdenum	mg/L	0.0002
Sulphate	mg/L	0.5	Nickel	mg/L	0.002
Chlorophyll *a*/pheophytin *a*	µg/L	0.1	Potassium	mg/L	0.02
			Selenium	mg/L	0.001
			Silver	mg/L	0.0001
			Sodium	mg/L	0.03
			Strontium	mg/L	0.0001
			Thallium	mg/L	0.0001
			Thorium	mg/L	0.0001
			Tin	mg/L	0.0002
			Titanium	mg/L	0.0005
			Tungsten	mg/L	0.0001
			Uranium	mg/L	0.0001

Table 2-8: Laboratory water quality parameters and current analytical laboratory detection limits: operation period.

Parameter	Units	DL	Parameter	Units	DL
			Vanadium	mg/L	0.0002
			Zinc	mg/L	0.002
			Zirconium	mg/L	0.0004

Table 3-1: Aquatic habitat – summary of pathways of effect, planned mitigation/offsetting, residual effects and monitoring. X = planned activity; ? = contingency measure.
Spawning – Reservoir = Reservoir – spawning shoals (FOMP Section 4.1.2); YOY – reservoir = Reservoir – YOY Lake Sturgeon habitat (FOMP Section 4.1.4); Spawning – tailrace = Downstream of GS – tailrace spawning shoal (FOMP Section 4.1.5); Spawning – south shore = Downstream of GS – south shore spawning shoal (FOMP Section 4.1.6).

Potential Pathway of Effect	Mitigation / Offsetting	Spawning - reservoir (KAFA 13.1.2)	Spawning – tailrace (KAFA 13.1.5)	Spawning – south shore (KAFA 13.1.6)	YOY - Reservoir (KAFA 13.1.4)	Predicted Effect after Mitigation/Offsetting Measures	Monitoring	Nearshore Habitat (AEMP 3.2.1)	Stephens Lake	Gull/Reservoir	Offshore Habitat (AEMP 3.2.2)	Stephens Lake	Gull/Reservoir	Sensitive/Constructed Habitat (AEMP 3.2.3)	Stephens Lake	Gull/Reservoir
Habitat changes from Long Rapids to Birthday Rapids as a result of minor changes in water depth will result in negligible changes to velocity and no effects to substrate.						Minor changes are not expected to affect habitat.										
Habitat changes at Birthday Rapids due to the small increase in depth and small reduction in velocity may result in the loss of whitewater.						Habitat will remain as high velocity, hard substrate, and similar range of depths. The loss of white water may require implementation of contingency measures to create hydraulic features attractive to spawning sturgeon in the vicinity of Birthday Rapids.										X
Loss of Gull Rapids due to GS structure and dewatering.			X	X		Loss of rapids offset partly by creation of up to 5 ha of spawning habitat for Lake Sturgeon and Walleye downstream of the generating station and creation of 0.1 ha spawning shoal for Lake Whitefish on the south bank of the Nelson River near Stephens Lake.									X	
Alteration of habitat in the 4 km of river immediately downstream of Gull Rapids due to channeling flow through the generating station and cycling at the station.						Habitat predicted to remain generally similar in terms of depth, velocity and substrate with the exception of the development of an area of deposition along north bank below GS.			X			X				
Habitat changes to the river, tributary stream, and lake habitat between Birthday Rapids and Gull Rapids as a result of increased water depth and decreased velocity.		X			?	Large (average of 6 m) increase in depth and decrease in velocity with deposition of fine sediments over areas of coarse sediment. Loss of existing macrophyte beds.							X			X
Alteration of substrate in Stephens Lake due to sediment deposition during construction.						Monitoring of substrate is proposed to verify no effect.						X			X	
Creation of new aquatic habitat through the flooding of terrestrial areas.						Long term creation of 5,100 ha of productive fish habitat. Monitoring proposed to track changes in nearshore and offshore areas, including development of macrophyte habitat and macrophyte colonization.				X			X			

Table 3-2: Monitoring program summary for the nearshore habitat and macrophyte monitoring program.

Study and Monitoring Area	Effect Type/ Proxy Site/ Mitigation	Observed or Predicted Reference Condition	Measurement Variables	Study Design	Sampling Frequency and Schedule	Action Thresholds	Analysis and Reporting
Shorelines and silt/fine organic material substrate boundary created at the confluence of turbid and humic water masses in flooded bays	Residual Effect	Stephens Lake	Optical and radar remote sensing data, locations of water masses, shoreline position	Systematic/Temporal	Satellite images collected annually during spring, mid-summer, and fall for the first 3 Years. Annual imaging years 4-10. Further activities assessed at that time.	Notable disagreement with predicted initial changes in flooded perimeter may require adaptive response of habitat plan.	Year 1 report - agreement between predicted and observed shorelines for Year 0 and 1, and distribution of water masses. A Year 5 report will summarize the locations of water masses in reservoir, change in habitat geometry of the reservoir, and the available fine organic substrate data.
Development of nearshore area in lentic habitat along margin of Keeyask Reservoir	Residual Effect	Stephens Lake	Bed elevation, water surface elevation, substrate type and composition, macrophyte species composition, water level variation, ratio of area occupied to potential habitat.	Stratified random to locate areas of interest/Systematic within area of interest/Repeated measures over time	Each of the first three years of operation at FSL and every 3 years until Year 10 assessment. Sampling scheduled mid-to-late summer.	Disagreement in the rate of nearshore development with PE studies may require adaptive response of habitat plan.	Year 10 report on development of nearshore area will also provide key assessment of the ability of reservoir to support macrophytes by Year 15, as predicted in the AE SV.
Reference sites to monitor spatial and vertical distribution of macrophytes in potential habitat along margin of Stephens Lake	Proxy Site	Stephens Lake	Same as above	Targeted/Repeated measures on transect over time	First three years of operation and every 3 years until Year 10 assessment. Sampling scheduled late summer. Plant beds targeted based on aerial observations then repeated systematically over time.	Advances regarding the state of knowledge at reference sites will be incorporated during the AEMP	Year 3 report of the proxy macrophyte sites will provide initial key assessment of the role of water level variation, light, and the location of the silt boundary (*i.e.*, based on 3 years of data).
Development of potential macrophyte habitat and colonization in the Keeyask Reservoir	Residual Effect	Keeyask Reservoir/ Stephens Lake	Same as above	Targeted/Repeated measures on transect over time	Potential habitat results from nearshore program. Plant colonization studies start when flights of reservoir show occupation, perhaps during Year 9. Plant beds targeted based on aerial observations then repeated over time.	Disagreement with the state of knowledge from reference sites or ability to colonize may require adaptive management.	Year 15 report on potential macrophyte habitat availability and colonization will provide key retrospective assessment of the AE SV predictions. Report will compare statistical distributions of plant vertical zonation over time between Stephens Lake and Keeyask reservoir.

Table 3-3: Monitoring program summary for the offshore habitat monitoring program.

Study and Monitoring Area	Effect Type/ Proxy Site/ Mitigation	Observed or Predicted Reference Condition	Measurement Variables	Study Design	Sampling Frequency and Schedule	Action Thresholds	Communication
Monitoring Study: Deep Water Substrate Composition Monitoring							
Substrate below Birthday Rapids in or near areas of slower lotic habitat	Site Scale/Not predicted in AE SV	Keeyask Existing Environment Studies	Ponar samples or detection of rocky bed using sounding line, acoustic imaging	Targeted/Repeated measures over time	Each of first three years of operation at FSL and every 3 years until Year 10 assessment.	Assessment in Years 1-3 to learn if sand/gravel deposits, or if not, consider sand/gravel addition year 3. PE team to monitor state of shoreline and assess stability of nearby banks.	Year 6 report will summarize the deep water substrate, depth, and velocity changes and assess validity of AE SV data. Subsequent reporting based on results.
Substrate of Riverine area of Keeyask Reservoir within areas of lotic channel u/s of Gull Lake	No Effect	Keeyask Existing Environment Studies	Ponar samples or detection of rocky bed using sounding line, acoustic imaging	Systematic (replicate Keeyask EE sites)	Each of first three years of operation at FSL and every 3 years until Year 10 assessment. Flooded terrestrial habitat assessed for the first time in Year 6.	Preliminary assessment of silt deposition patterns in deep water lotic channel in Year 3. These observations can be used to support or refute the need for YOY mitigation at Birthday Rapids and entrance to Gull Lake. See PEMP for velocity monitoring during first three years	Year 6 report will summarize the deep water and lotic substrate data and assess validity of AE SV predictions. Subsequent reporting will include flooded terrestrial deep water areas, and will be based on results not later than Year 10.
Substrate of Lotic channel in reservoir near entrance to Gull Lake	Residual Effect	Year 30 Substrate Boundary Model	Acoustic waveform data (hardness, roughness or shape of echo), grain size analysis and Phi units	Systematic/Adaptive with time (replicate Keeyask EE sites)	Each of the first three years of operation at FSL and every 3 years until Year 10 assessment.	See PEMP for velocity and bed load transport monitoring. If predicted and early signs of residual effects are notably different adapt monitoring program.	Information regarding the state of substrate will be reported annually. Reporting on effects will be based on results, or as late as Year 6 assuming results closely mimic AE SV predictions.
Substrate of Lotic habitat below Keeyask GS (< 7 km)	No Effect	Physical Environment Transport Model	Acoustic waveform data (hardness, roughness, or shape of echo), detection of rocky bed with sounding line, grain size analysis and Phi units	Systematic (replicate Keeyask EE sites)	Same as above	Same as above	Same as above

Table 3-4: Monitoring program summary for the Sensitive and Constructed habitat monitoring program.

Study and Monitoring Area	Effect Type/ Proxy Site/ Offset	Observed or Predicted Reference Condition	Measurement Variables	Study Design	Sampling Frequency and Schedule	Action Thresholds	Communication
Sensitive YOY Lake Sturgeon habitat in Stephens Lake	No Effect	Keeyask Existing Environment Studies	Primary metric - grain size fraction. Supported by acoustic bottom typing methods as a secondary method. Acoustic Doppler measurement of water velocity.	Systematic/Temporal	Twice annual (spring, fall) for the first 5 - 10 years of operation, depending on inflow. Should any survey result show clearly that a null effect is not the outcome then PE studies are triggered to better understand the sources, pathways, and fate of unanticipated sediments.	Measurable and persistent layer of silt on sand/gravel observed (*i.e.*, outside of interannual variability before the Project) will trigger PE study of origin and pathways of sediment.	The state of the YOY habitat will be reported annually until the habitat is considered stable, where periodic sampling would follow. Reporting of null or unanticipated effects based on results, or as late as Year 6 for null effect.
Sensitive YOY Lake Sturgeon habitat near Caribou Island	Residual Effect	Year 30 Substrate Boundary Model	Same as above	Systematic/Temporal	Each of the first three years of operation (fall) and every 3 years until Year 10 assessment.	Observation of persistent silt sedimentation in areas near Caribou Island not predicted to be depositional suggest Year 30 model underestimated deposition. Reassess for other sites with similar range of input variables.	Information regarding state of YOY habitat will be reported annually. Reporting on effects will be based on results, or as late as Year 6 if results mimic AE SV predictions.
Constructed Habitat - Spawning Shoals	Offset	Design Criteria in Appendix 1A, AE SV	Survey grade point cloud elevation data at initial time step, vertical beam acoustic elevation, side scan images, DIDSON acoustic video, touch texture of rock surfaces	Systematic/Temporal	Same as above	Observation of persistent silt sedimentation within area intended to satisfy design criteria triggers site assessment of criteria.	Information regarding state of constructed habitat will be reported annually. Reporting on effects will be based on results, or as late as Year 6 if results meet design criteria.

Table 4-1: Benthic invertebrates - summary of pathways of effect, planned mitigation/offsetting, residual effects and monitoring. X = planned activity; BMI = benthic macroinvertebrates. Spawning – Reservoir = Reservoir – spawning shoals (FOMP Section 4.1.2); Spawning – tailrace = Downstream of GS – tailrace spawning shoal (FOMP Section 4.1.5); Spawning – south shore = Downstream of GS – south shore spawning shoal (FOMP Section 4.1.6).

Potential Pathway of Effect	Mitigation / Offsetting: Sediment Management Plan (KAFA 9.1.5)	Mitigation / Offsetting: Spawning – reservoir (KAFA 13.1.2)	Mitigation / Offsetting: Spawning – tailrace (KAFA 13.1.5)	Mitigation / Offsetting: Spawning – south shore (KAFA 13.1.6)	Predicted Effect after Mitigation/Offsetting Measures	Monitoring: BMI (AEMP 4.2) Stephens Lake	Monitoring: BMI (AEMP 4.2) Gull/Reservoir
Changes to water quality, such as increases in concentration of TSS and related variables (*e.g.*, turbidity).	X				No long term effect to the benthic macroinvertebrate community due to the implementation of a Sediment Management Plan (SMP) for in-stream construction.	X	X
Dewatering of habitat in Gull Rapids.			X	X	Long term effect resulting in a reduction in the abundance of benthic macroinvertebrates favouring this type of aquatic habitat and a change in the macroinvertebrate community composition. Effect partially offset by creation of rocky shoal habitat downstream of the GS and on the south bank of the Nelson River near Stephens Lake.		
Deposition of sediments in Stephens Lake.	X				No long term effect to the benthic macroinvertebrate community due to minor nature of predicted changes.	X	
Loss of existing habitat and the creation of new habitat due to flooding.		X			Long term effect resulting in a reduction in the abundance of benthic macroinvertebrates favouring this type of aquatic habitat and a change in the macroinvertebrate community composition. Effect partially offset by creation of rocky shoal habitat upstream of the GS.		X
Reduction in medium and high water velocity habitat upstream of the GS due to reservoir creation.					Long term effect resulting in a large increase in the abundance of benthic macroinvertebrates and a change in the community composition.		X
Conversion of existing hard gravel, cobble, and boulder substrates to softer silt/clay substrates due to sedimentation in the reservoir.		X			Long term effect resulting in a reduction in the abundance of benthic macroinvertebrates favouring this type of aquatic habitat and a change in the macroinvertebrate community composition. Effect partially offset by creation of rocky shoal habitat upstream of the GS.		X
Increase in the frequency of water level fluctuations due to GS operations.					Long term effect in isolated nearshore areas resulting in a reduction in the abundance of benthic macroinvertebrates favouring this type of aquatic habitat and a change in the macroinvertebrate community composition.	X	X
Conversion of tributary habitat to bays due to flooding, and changes in surface water quality in off-current areas, particularly bays (*e.g.*, flooding and peat disintegration are expected to cause decreases in DO concentrations in portions of shallow, flooded bays of the reservoir with poor mixing and long water residence times in the open water and ice-cover seasons).					Moderate to long term effect during open water season in isolated nearshore areas resulting in a reduction in the abundance of benthic macroinvertebrates favouring this type of aquatic habitat and a change in the macroinvertebrate community composition. Greater effects will occur in the winter where a larger area will be affected, the magnitude of DO depletion will be greatest, and the duration of effects would be longest. The low DO conditions are expected to limit invertebrate colonization to a few resilient groups (*e.g.,* chironomids) in the localized affected areas.		X
Alteration of flow patterns, water velocities, and depths in the portion of the Nelson River from the GS to the inlet of Stephens Lake.					No long term effect to the benthic macroinvertebrate community due to minor nature of predicted changes.	X	X
Reduction in the extent and severity of ice scour in the portion of the Nelson River from the GS to the inlet of Stephens Lake.					Long term effect resulting in an increase in the abundance of benthic macroinvertebrates favouring this type of aquatic habitat and a change in the macroinvertebrate community composition.	X	

Table 4-2: A summary of the Keeyask study area waterbodies to be sampled during the AEMP.

Waterbody	Nearshore IEZ (<1m) - kick/sweep [1]	Nearshore PW (1-3m) - grab [2]	Offshore (OS) (3-10m) - grab [2]	Project Effects	Predicted Impact
Affected by the Project					
Nelson River Mainstem: near u/s extent of Gull Lake	5 rep stns [3]	5 rep stns [3]	5 rep stns [3]	Operation	loss/creation of habitat; reduction in med/high water velocity habitat; conversion of substrates due to sedimentation; increase in freq of water level flucs; flooding of tributary habitat; changes in WQ in off-current areas (bays)
Nelson River Back Bay: minimally flooded tributary (unnamed creek D/S of Nap Creek)	5 rep stns	5 rep stns	too shallow	Operation	loss/creation of habitat; reduction in med/high water velocity habitat; conversion of substrates due to sedimentation; increase in freq of water level flucs; flooding of tributary habitat; changes in WQ in off-current areas (bays)
Nelson River Back Bay: flooded tributary (Seebeesis Creek)	5 rep stns	5 rep stns	too shallow	Operation	loss/creation of habitat; reduction in med/high water velocity habitat; conversion of substrates due to sedimentation; increase in freq of water level flucs; flooding of tributary habitat; changes in WQ in off-current areas (bays)
Gull Lake	5 rep stns	5 rep stns	5 rep stns	Operation	loss/creation of habitat; reduction in med/high water velocity habitat; conversion of substrates due to sedimentation; increase in freq of water level flucs; flooding of tributary habitat; changes in WQ in off-current areas (bays)
Nelson River: D/S of Gull Rapids (within 3 km - inlet to Stephens Lake)	5 rep stns	5 rep stns	5 rep stns	Construction; Operation	increased TSS/sedimentation; alteration of flow patterns, water velocities, and depths, reduction in extent/severity of ice scour
Stephens Lake - S: ~11 km D/S of Gull Rapids	5 rep stns	5 rep stns	5 rep stns	Construction; Operation	increased TSS/sedimentation; unexpected D/S effects
Stephens Lake - S: ~25 km D/S of Gull Rapids	use CAMP data	5 rep stns - collect with CAMP	use CAMP data	Construction; Operation	increased TSS/sedimentation; unexpected D/S effects
Unaffected by the Project					
Burntwood River (First Rapids to Split Lake)	use CAMP data	5 rep stns - collect with CAMP	use CAMP data	N/A	N/A
Split Lake	use CAMP data	5 rep stns - collect with CAMP	use CAMP data	N/A	N/A
Stephens Lake - O'Neil Bay	5 rep stns	5 rep stns	too shallow	N/A	proxy for reservoir conditions (back-bays)
Stephens Lake - N	use CAMP data	5 rep stns - collect with CAMP	use CAMP data	N/A	N/A

N/A = not applicable
1. aquatic habitat type sampled during Operation only
2. aquatic habitat type sampled during Construction and Operation
3. replicate stations: for kick/sweep, each replicate station will consist of a timed 3-minute composite sample; for grab, each station will consist of 3 sub-samples
4. Seebeesis Creek (corresponds to Zone 12) was sampled in 2013 to provide baseline data for a tributary predicted to be flooded by the Project

Table 5-1: Fish community - summary of pathways of effect, planned mitigation/offsetting, residual effects and monitoring. X = planned activity. Haul road shoal = Downstream north spawning habitat (KAFA Section 13.1.1 Spawning – Reservoir = Reservoir – spawning shoals (FOMP Section 4.1.2); Spawning – tailrace = Downstream of GS – tailrace spawning shoal (FOMP Section 4.1.5); Spawning – south shore = Downstream of GS – south shore spawning shoal (FOMP Section 4.1.6).

Potential Pathway of Effect	Mitigation / Offsetting: Instream timing windows (KAFA 9.1.1.1)	Fish Salvage (KAFA 9.1.1.2)	Provision of fish passage at culverts (KAFA 9.1.2)	End of pipe screening guidelines/blasting guidelines (KAFA 9.1.3, 9.1.4)	Water quality management (KAFA 9.1.5)	Egress channels in Little Gull Lake	Escape channels in spillway	Upstream fish passage	Turbine design	Haul road – shoals and channel (KAFA 13.1.1)	Spawning – reservoir (KAFA 13.1.2)	Spawning – tailrace (KAFA 13.1.5)	Spawning – south shore (KAFA 13.1.6)	Predicted Effect after Mitigation/Offsetting Measures	Monitoring: No targeted monitoring	Fish Species Composition and Abundance (AEMP 5.3.1): Split Lake	Fish Species Composition and Abundance: Keeyask Area	Fish Species Composition and Abundance: Stephens Lake	Use of created and existing spawning habitat (AEMP 5.3.2): Keeyask Area	Use of created and existing spawning habitat: Stephens Lake	Movement and habitat Use Monitoring (AEMP 5.3.3): Keeyask Area	Movement and habitat Use Monitoring: Stephens Lake	Turbine Mortality (AEMP 5.3.4): Stephens Lake	Fish Stranding Following Spill Events: Stephens Lake	Fish Winterhill in Little Gull Lake: Keeyask Area
Dewatering of cofferdams.	X	X												Negligible effect to fish populations due to fish salvage.							X	X			
Temporary causeways to borrow sites.			X							X				No effect due to passage/ additional habitat.								X			
Entrainment of fish in intake pipes.				X										No effect due to adherence to DFO guidelines.	X										
Blasting.				X										No significant effect to fish populations.							X	X			
Changes to water quality due to instream construction, reservoir creation and flooding.	X				X	X								Effects to fish habitat upstream and downstream of GS. During instream construction, increases in TSS could affect fish in Stephens Lake. During operation fish could be affected in backbays due to oxygen depletion.			X	X			X	X			X
Disturbance of spawning in Gull Rapids by construction	X													Potential reduction in year class strength during construction.			X	X			X	X			
Loss of Gull Rapids due to dewatering.								X				X	X	Loss of spawning habitat not expected to affect populations due to presence of other spawning habitat in Stephens Lake and construction of spawning shoals. Loss of movement corridor not expected to affect population but will be assessed and addressed, if required, through provision of fish passage.			X	X		X	X	X			
Alteration to fish emigration to Stephens Lake.								X	X					No effect expected due to small number of fish currently moving downstream.				X			X	X	X		
Fish injury and mortality at turbines, spillway .								X	X					No effect expected due to small number of fish currently moving downstream.									X		
Fish stranding in the spillway.							X							No effect due to creation of escape channels.										X	
Alteration of habitat due to GS cycling.														No effect due to minimal change in water levels.	X										
Alteration of habitat in Stephens Lake due to sedimentation from construction.														Deposition of additional fines (< 0.6 cm) in areas that are already composed of the same substrate.	X										
Decreased water velocities at Birthday Rapids after impoundment.														Potential for increased movements out of Gull Lake; potential movement of spawners to upstream locations.		X	X	X	X		X				
Habitat changes to the river, tributary stream and lake habitat between Birthday and Gull rapids as a result of increased water depth and decreased velocity.														Changes in spawning and foraging habitat, with potential reduction in rocky shoals in lower reservoir. Shifts in fish distribution are expected but no long term decline in abundance.			X	X	X	X	X				
Habitat changes from Long Rapids to Birthday Rapids as a result of minor changes in water depth that will result in negligible changes to velocity and no effects to substrate.														No effect.							X				
Creation of new aquatic habitat as the result of flooding of terrestrial land, primarily surrounding present-day Gull Lake.														Long-term creation of 5,100 ha of aquatic habitat.			X	X							
Harvest by the construction workforce and after construction by resource users.														No effect expected due to fisheries management.	X										

Table 5-2: Summary of action levels identified for the Fish Community monitoring program. Identified values are preliminary and subject to change as additional information becomes available.

Monitoring Program	Indicator	Action Levels		
		Early Warning Trigger	**Ecologically Significant Benchmark**	**Conservation Objective**
Species Composition and Abundance	CPUE of VEC species	Missing year-classes will provide an indication that recruitment for a particular fish species may be compromised	50% decline in CPUE for three consecutive monitoring cycles after impoundment (9 years). Note: initial decline in CPUE in Keeyask area expected after impoundment due to doubling of area	Maintain existing VEC populations to support sustainable fisheries
	Condition Factor of VEC species	Statistically significant decrease	25% decline for two consecutive cycles (6 years)	Maintain existing condition factor
	Growth rate of VEC species	Statistically significant decrease	25% decline for two consecutive cycles (6 years)	Maintain existing growth rate
	Small-bodied fish	Statistically significant decrease in CPUE of most abundant species	50% decline in CPUE for three consecutive cycles (9 years), decline in species richness	Maintain existing CPUE and species richness
Use of Existing and Newly Created Spawning Habitat	Number of pre-spawn and spawning Walleye	No current year spawners captured during sampling	No pre-spawn or spawning fish observed for 2 consecutive monitoring cycles	Capture spawning Walleye in several areas of the reservoir and downstream of the GS
	Number of pre-spawn and spawning Northern Pike	No current year spawners captured during sampling	No pre-spawn or spawning fish observed for 2 consecutive monitoring cycles	Capture spawning Northern Pike in tributaries and several backbays
	Number of pre-spawn and spawning Lake Whitefish	No current year spawners captured during sampling	No pre-spawn or spawning fish observed for 2 consecutive monitoring cycles	Capture spawning Lake Whitefish in several areas of the reservoir and downstream of the GS
	Number of Lake Whitefish larvae	Capture less than in the existing environment	No larvae are observed for 2 consecutive monitoring cycles	More or similar numbers of larvae relative to the existing environment
Movement Monitoring	Proportion of acoustically or Floy-tagged fish that moved D/S through the GS	Increase above existing level (<5% annually)	> 10% annually	Remain similar to existing environment (< 5% annually)
Turbine Mortality	Mortality of acoustically tagged Walleye. Lake Whitefish or Lake Sturgeon moving downstream that encounter GS	Any suspected mortality	Survival of <90% of tagged fish < 500 mm and <50% of tagged fish >500 mm	Survival of > 90% of tagged fish < 500 mm; Survival > 50% for tagged fish > 500 mm
	Mortality of fish experimentally passed through the GS turbines	Survival of < 90% for fish < 500 mm; 25% mortality of fish > 500 mm during experimental passage	Survival of <90% of fish < 500 mm and <50% of fish >500 mm	Survival of > 90% of fish < 500 mm; Survival > 50% for fish > 500 mm
Fish Winterkill in the Vicinity of Little Gull Lake	Dead large-bodied fish	Presence of 50 dead large-bodied fish	> 200 dead large-bodied fish observed during monitoring	< 50 dead large-bodied fish
Fish Stranding Following Spill Events	Stranded large-bodied fish	Observation of 50 stranded large-bodied fish	Observation of > 200 stranded large-bodied fish	Observation of < 50 stranded large-bodied fish

Table 6-1: Lake Sturgeon - summary of pathways of effect, planned mitigation/offsetting, residual effects and monitoring. X = planned activity; ? = contingency measure. Spawning – Birthday R. = Reservoir – hydraulic features near Birthday Rapids (FOMP Section 4.1.3); YOY – reservoir = Reservoir – YOY Lake Sturgeon habitat (FOMP Section 4.1.4); Spawning – tailrace = Downstream of GS – tailrace spawning shoal (FOMP Section 4.1.5).

Potential Pathway of Effect	Mitigation / Offsetting: Spawning – Birthday R. (KAFA 13.1.3)	Spawning – tailrace (KAFA 13.1.5)	YOY – Stephens L. (KAFA 8.1.1)	YOY – reservoir (KAFA 13.1.4)	Stocking (KAFA 13.1.7)	Fish passage (KAFA 11.1.7)	D/S fish protect. (KAFA 11.1.8)	Offsite stocking (KAFA 13.1.7)	Predicted Effect after Mitigation/Offsetting Measures	Monitoring: Adult pop. (AEMP 6.2.1) Stephens Lake	Adult pop. Gull/Reservoir	Juvenile pop. (AEMP 6.2.2) Stephens Lake	Juvenile pop. Gull/Reservoir	Spawning (AEMP 6.2.3) Stephens Lake	Spawning Gull/Reservoir	Movement (AEMP 6.2.4) Stephens Lake	Movement Gull/Reservoir	Upper Split Lake Adult pop. (AEMP 6.2.1)	Upper Split Lake Juvenile pop. (AEMP 6.2.2)
Disruption of spawning activity due to construction activity at Gull Rapids.					X				No effect to total recruitment due to stocking during construction.			X				X			
Loss of spawning habitat due to GS structure and dewatering of Gull Rapids.		X			X	?			No effect to long term sustainable population in Stephens Lake due to creation of spawning habitat downstream of the GS and stocking to re-establish a viable population.			X		X		X			
Loss of an upstream movement corridor due to GS structure and dewatering of Gull Rapids.						?			No effect to long term sustainable population in Stephens Lake is predicted due to presence of habitat to support all life history stages.	X		X		X		X			
Changes in downstream movement of larval, juvenile, and adult fish due to presence of reservoir/GS structures in former riverine habitat.					X				No effect to long term sustainable population in Stephens Lake due to creation of a self-sustaining population by stocking and presence of habitat to support all life history stages.	X		X				X	X		
Injury and mortality of fish moving downstream past the trashracks and turbines or over the spillway.					X		?		No effect to long term sustainable population in Stephens Lake due to small number of large sturgeon moving and high survival of smaller fish.	X		X					X		
Potential changes to fish use of the river reach immediately downstream of Gull Rapids due to channeling/cycling of flows.									No effect to long term sustainable population in Stephens Lake due to minor nature of predicted changes.	X		X				X			
Changes to fish use of aquatic habitat in Stephens Lake due to sediment deposition during construction.			?						No effect to long term sustainable population in Stephens Lake as no permanent deposition of silt over areas of sand is predicted.	X		X				X			
Increased emigration from reservoir during impoundment and operation.					X	?			Potential short term effect to number of adults in Gull Lake; long term reduction in population due to emigration to establish viable population avoided by stocking.		X		X				X		
Changes in fish use of the Birthday Rapids to Gull Rapids reach due to increased water levels and decreased flow that will result in the loss or alteration of existing habitat (in particular young-of-the-year (YOY) habitat in Gull Lake) and creation of new habitat.				?	X				No effect to long term sustainable population in reservoir due to suitability of foraging habitat in reservoir and development of suitable YOY habitat near inlet of present-day Gull Lake.		X		X				X		
A decrease in attraction to and use of spawning habitat at Birthday Rapids, given the predicted loss of white water.	?				X				No effect to long term sustainable population in reservoir given that stocking will support the population during the initial years of transition and a contingency measure to create features attractive to spawning sturgeon in the vicinity of Birthday Rapids, if required, has been developed.		X		X		X		X		
Potential increase in mortality due to an increase in domestic harvest.									No effect to long term sustainable population in reservoir or Stephens Lake due to measures to inform local resource users of the vulnerability of this sturgeon population.	X	X								
Increase in regional Lake Sturgeon population.								X	Increase in regional Lake Sturgeon population due to stocking in areas where habitat exists but stocks have been depleted by historic over exploitation in a commercial fishery.									X	X

Table 6-2: Summary of action levels identified for the Lake Sturgeon monitoring program. Identified values are preliminary and subject to change as additional information becomes available.

Monitoring Program	Indicator	Action Levels			Recovery Target
		Early Warning Trigger	Ecologically Significant Benchmark	Conservation Objective	
Adult Population	Population estimate	N/A – insufficient sensitivity	N/A – insufficient sensitivity	N/A – insufficient sensitivity	2,065[1]
	Population trajectory	Statistically significant decline (2.5% decrease from current lambda 1.013)	Value of less than 1 for 3 consecutive monitoring cycles	Statistically significant increase (2.5% decrease from current lambda 1.013)	TBD from PVA[2]
	Condition	Statistically significant decline	Decline to below mean value/age class of lower Nelson River population	Remain within range observed in northern Manitoba	Remain within range observed in northern Manitoba
	Survival[3]	Statistically significant decrease below 87%	Decrease to lowest level tested in PVA model (82.5%)	Maintain or increase existing survival (87%)	TBD[4]
Juvenile Population	Year class strength (CPUE)	CPUE and year class strength < observed at Nelson River below Sea Falls	No juveniles < 3 years of age observed in 2 monitoring cycles	CPUE and year class strength ≥ in Nelson River below Sea Falls	Age structure in Slave Falls Reservoir
	Condition	Statistically significant decline	Decline to below mean value observed in juvenile sturgeon in upper Seven Sisters Reservoir[5]	Remain within range observed in northern Manitoba	Remain within range observed in northern Manitoba
Spawn Monitoring	Presence of adult fish	No adult fish in one year in Long Rapids to Birthday Rapids reach	No adult fish for 3 monitoring cycles at locations where adults should be present	Presence of adult fish	Within range observed at Nelson River mainstem spawning sites
	# current year spawners	No current year spawners in Long Rapids to Keeyask GS reach	No current year spawners in Long Rapids to Keeyask GS reach for 3 monitoring cycles	Presence of mature fish (> 0)	Ten mature males
Movement Monitoring	D/S movement of adults from reservoir	Increase above existing level (< 2%/annually)	Loss greater than can be supported as indicated by PVA analysis (> 4.5%)	Remain within range seen at other GSs in Manitoba (< 3% annually)	Remain within range seen at other GSs in Manitoba (< 3% annually)
	Mortality of adults during passage past GS	Increase above observed levels (< 10%)	PVA analysis included 100% mortality so not relevant if movements remain below 4.5%.	Remain within range seen at other GSs in Manitoba (< 10%)	Remain within range seen at other GSs in Manitoba (< 10%)
	D/S movement of sub-adults (200–833 mm) from reservoir	Increase above existing level (< 2%/annually)	Loss greater than can be supported as indicated by PVA analysis (> 4.5%)	Remain within range seen at other GSs in Manitoba (< 15%)	Remain within range seen at other GSs in Manitoba (< 15%)
	Mortality of sub-adults (200–833 mm) during passage past GS	Increase above 3%	Loss greater than can be supported in PVA analysis (sigmoid curve provided by DFO)	Remain within range seen at other GSs in Manitoba (< 10%)	Remain within range seen at other GSs in Manitoba (< 10%)

1. Based on DFO Recovery Potential Assessment.
2. Calculate from Population Variability Analysis (fall 2013).
3. Output of MARK model during population estimation.
4. Output of PVA assuming that DFO RPA target has been reached and stocking discontinued.
5. Only riverine section where sufficient juveniles captured to calculate condition factor.

Table 7-1: Mercury in fish flesh - summary of pathways of effect, planned mitigation/offsetting, residual effects and monitoring. X = planned activity; (X) activity triggered by exceedance of benchmark(s).

Potential Pathway of Effect	Mitigation / Offsetting	Lower head, reduced flooded area compared to earlier GS designs	Clearing of trees in the flooded zone during winter which minimizing runoff		Predicted Effect after Mitigation/Offsetting Measures	Monitoring	Keeyask Reservoir	Stephens Lake	Split Lake	Aiken River	Longspruce Forebay
Increase in fish mercury concentrations due to increased net methylation rates after reservoir flooding and bioaccumulation of methylmercury in the aquatic food chain. Downstream export of mercury via water and biota from the Keeyask reservoir into Stephens Lake and potentially further downstream.		X	X		Concentrations in lake whitefish, northern pike, and walleye from the Keeyask reservoir will see a large, medium-term increase to approximately three to five times the pre-impoundment levels recorded in 2002–2006; these maximum concentrations will decline in the long-term, but levels may remain higher than pre-Project concentrations for up to 30 years. Concentrations in lake whitefish, northern pike, and walleye from Stephens Lake will increase moderately in the medium-term to approximately two times the pre-impoundment levels observed in 2001–2005; these maximum concentrations will decline over the long-term, but levels may remain higher than pre-Project concentrations for up to 25 years in areas close to the riverine corridor within Stephens Lake.		X	X	X	X	(X)

FIGURES

Year

	2014	2015	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	2041	2042	2043	2044	2045
Project																																
Monitoring																																
Construction water quality	+	+	+	+	+	+	+																									
Operation water quality monitoring								+	+	+	+	+	+	+	+	+	+	Post 2030 to be determined based on monitoring results.														

Figure 2-1: Planned schedule for water quality monitoring during Keeyask Generating Station construction (2014-2019); commissioning (2020); and operation (2021+). Plus = conduct monitoring activity; heavy line = end of AEMP.

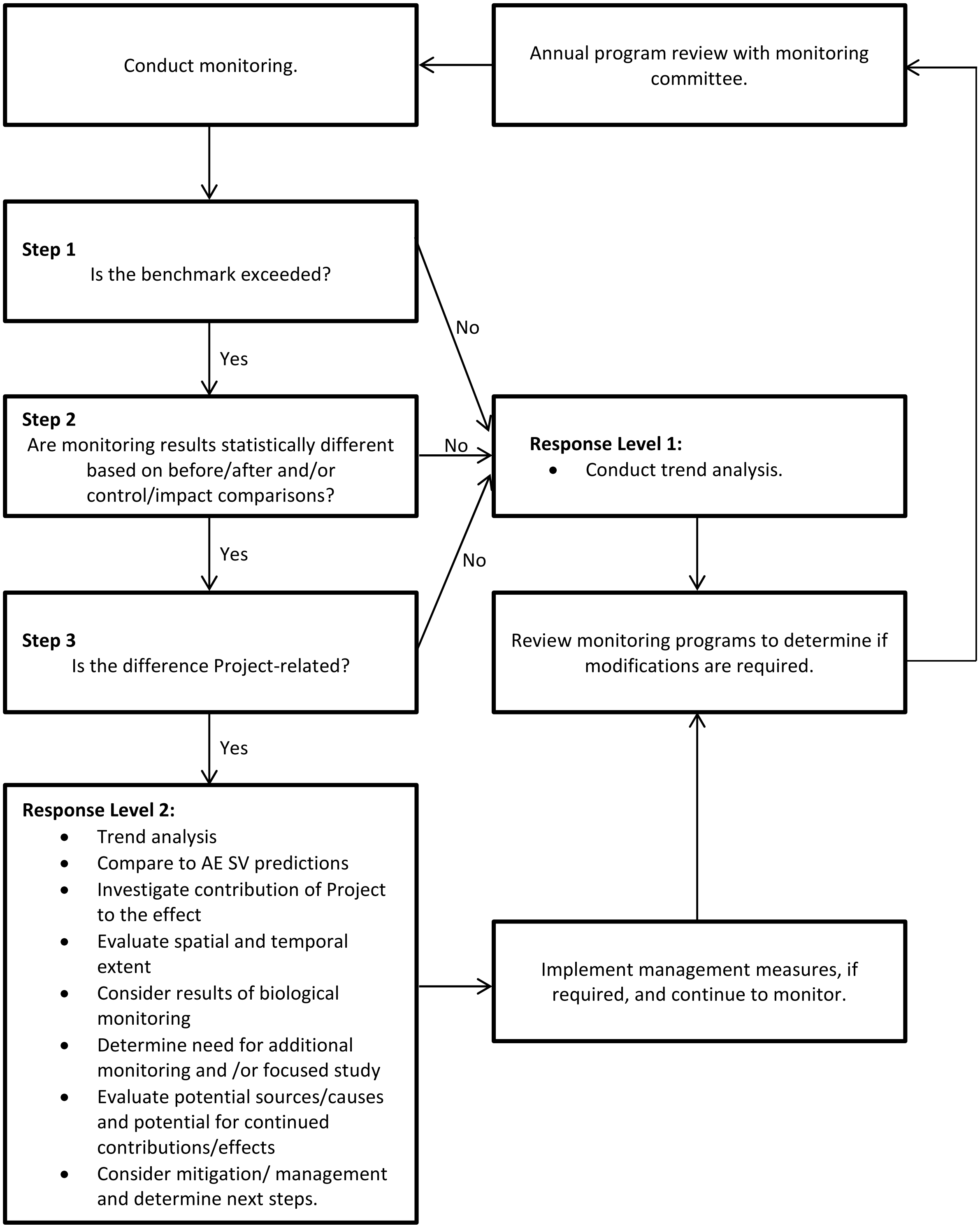


Figure 2-2: Water quality assessment and management response framework.

	2014	2015	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	2041	2042	2043	2044	2045
Project																																
Nearshore Macrophyte Habitat																		Post 2030 to be determined based on monitoring results.														
Remote Sensing							+	+	+	+	+	+	+	+	+	+	★															
Reservoir - Nearshore Surveys							+	+	+			+			+																	
Macrophyte Surveys							+	+	+			+			+		★															
Deep Water Substrate Composition																																
Reservoir							+	+	+			+			+		★															
Downstream of Keeyask GS (< 7 km)							+	+	+	—	—	—	■	—	—	—	—															
Sensitive and Constructed Habitat																																
Reservoir - YOY Habitat							+	+	▲			+			+		★															
Reservoir - North of Caribou Island YOY Habitat Stephens Lake - YOY Habitat							+	▲	+			+			+		★															
Constructed Habitat - Spawning Shoals (Reservoir, Tailrace, North, and South Shore)							+ ▲	+	+			+			+		★															

Figure 3-1: Planned schedule for aquatic habitat monitoring during Keeyask Generating Station construction (2014-2019); commissioning (2020); and operation (2021+). Plus = conduct monitoring activity; solid bar = form of habitat expected to resemble long term state; square = monitoring to follow high-magnitude flow event; star = decision regarding rate of habitat development and timing of subsequent field programs; triangle = monitoring to confirm physical attributes of habitat; heavy line = end of AEMP.

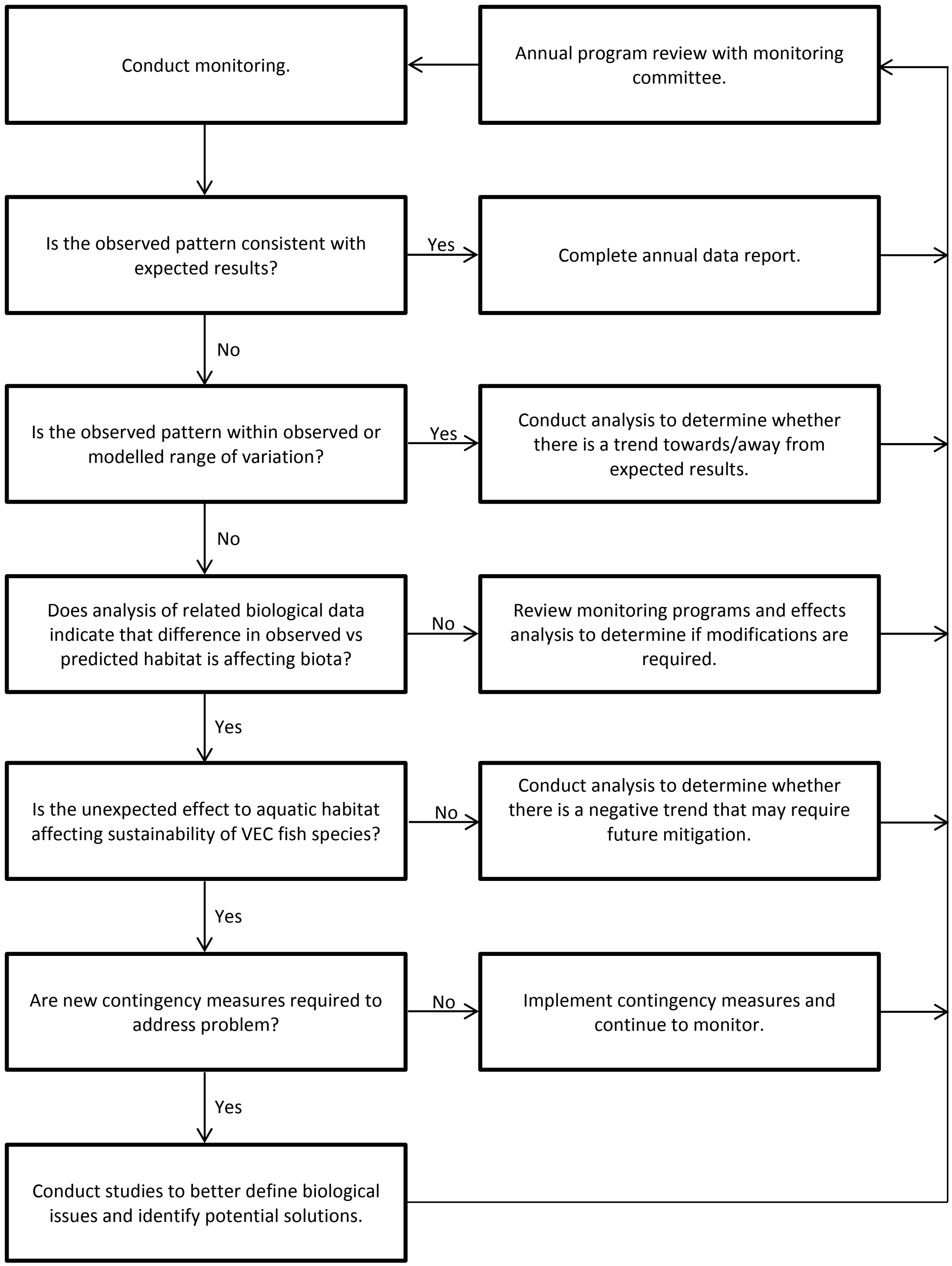


Figure 3-2: Nearshore and offshore habitat management response framework.

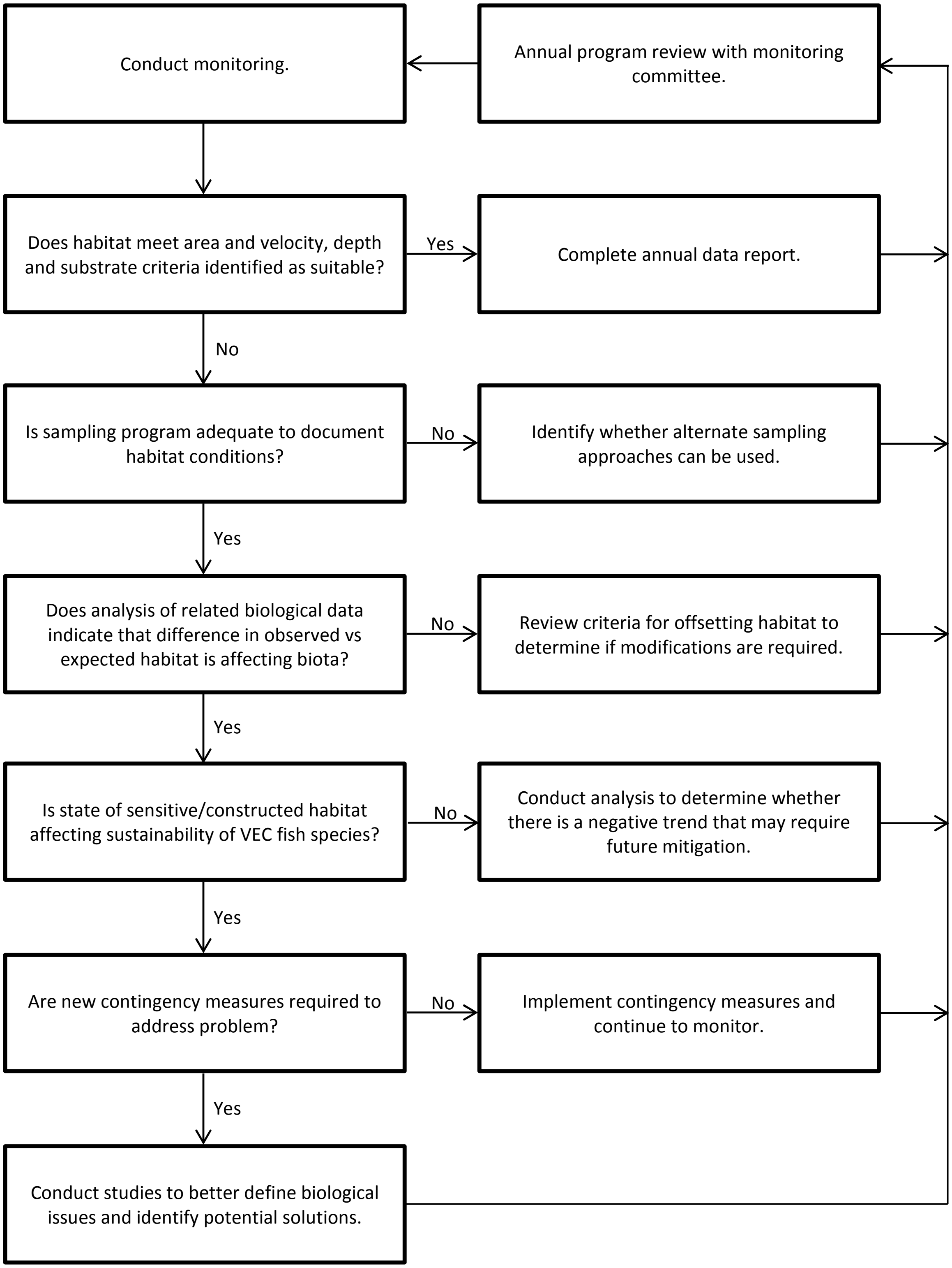


Figure 3-3: Sensitive and constructed habitat management response framework.

	2014	2015	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	2041	2042	2043	2044	2045
Project																																
Project Effects Monitoring																	Post 2030 to be determined based on monitoring results.															
Gull / Reservoir							+	+			+			+																		
Nelson River downstream of GS	+	+	+	+	+	+	+	+			+			+																		
Stephens Lake - South[1]	+	+	+	+	+	+	+	+			+			+																		
Offsite Monitoring																																
Stephens Lake - North[1]							+	+			+			+																		
Stephens Lake - O'Neil Bay							+	+			+			+																		
Split Lake[1]	+	+	+	+	+	+	+	+			+			+																		
Burntwood River[1]		+		+		+	+	+			+			+																		

Notes
1. Site also sampled under CAMP.

Figure 4-1: Planned schedule for benthic macroinvertebrate monitoring during Keeyask Generating Station construction (2014-2019); commissioning (2020); and operation (2021+). Plus = conduct of monitoring activity; heavy line = end of AEMP.

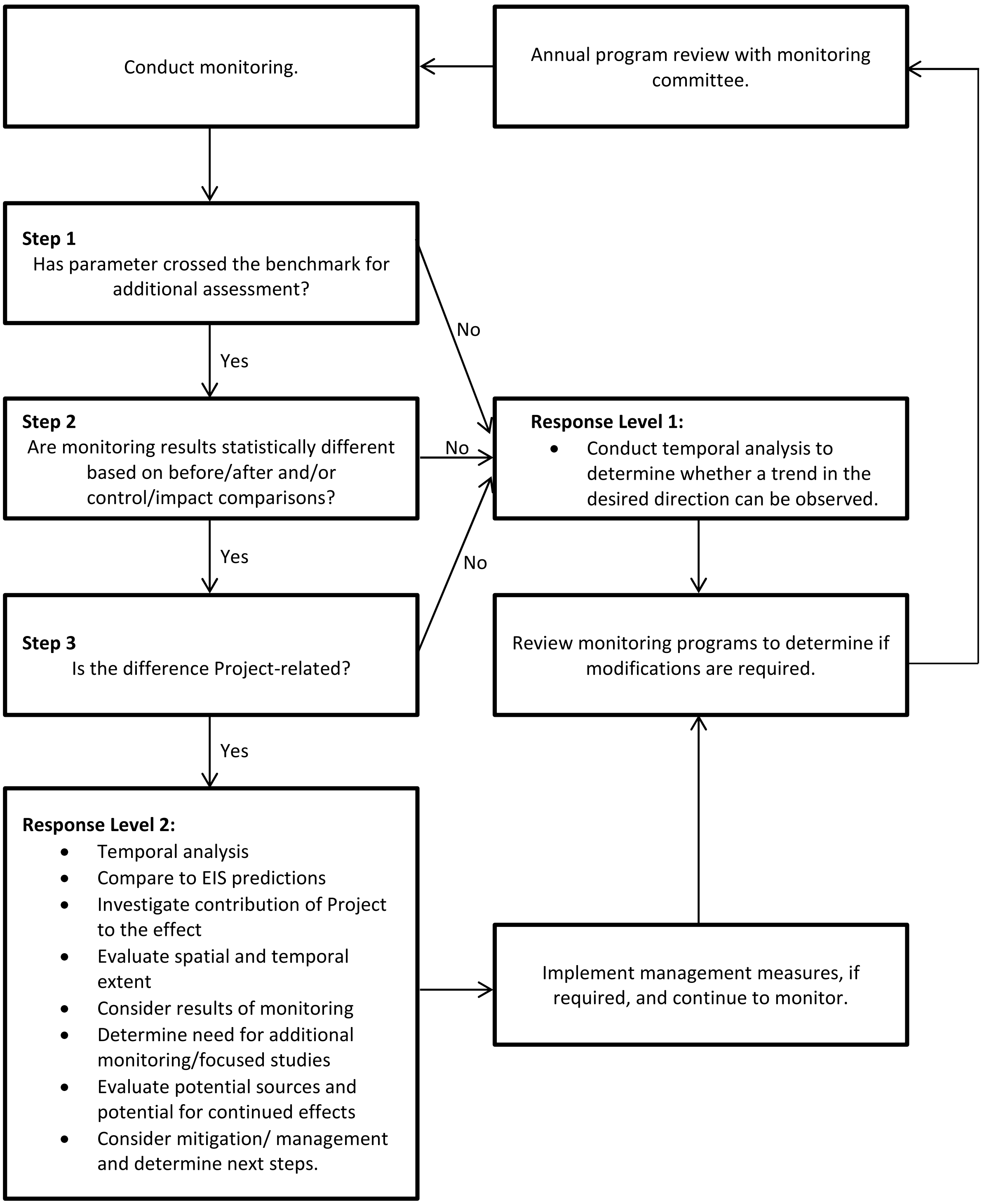
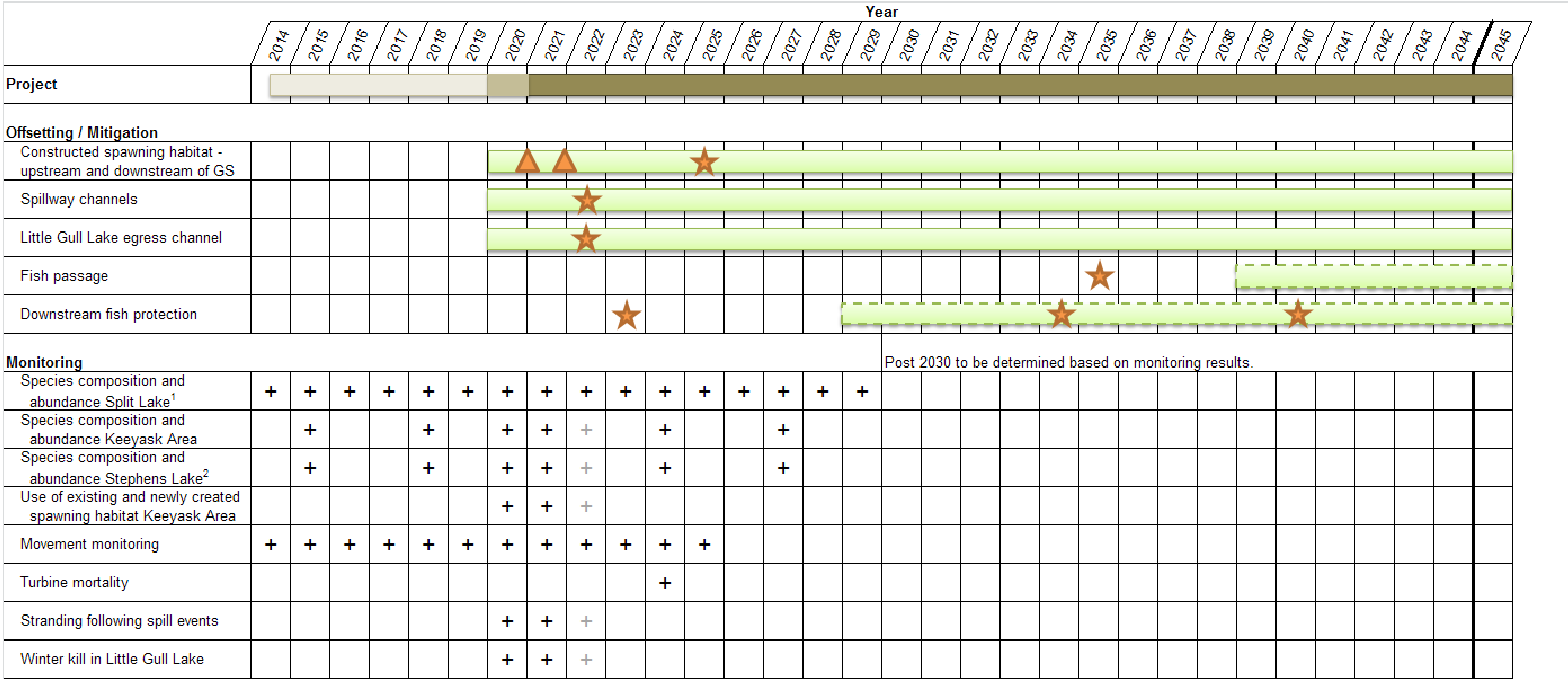


Figure 4-2: Proposed benthic macroinvertebrate response framework.



Notes
1. Sampling under CAMP.
2. Sampled in part under CAMP

Figure 5-1: Planned schedule for the implementation of mitigation/offsetting measures and monitoring for the fish community during Keeyask Generating Stationconstruction (2014-2019); commissioning (2020); and operation (2021+). Solid line = measure will be implemented; triangle = monitoring to confirm physical attributes of habitat; star = decision regarding alteration to mitigation/offsetting based on biological monitoring; plus = conduct of monitoring activity (light colour = potential); heavy line = end of AEMP.

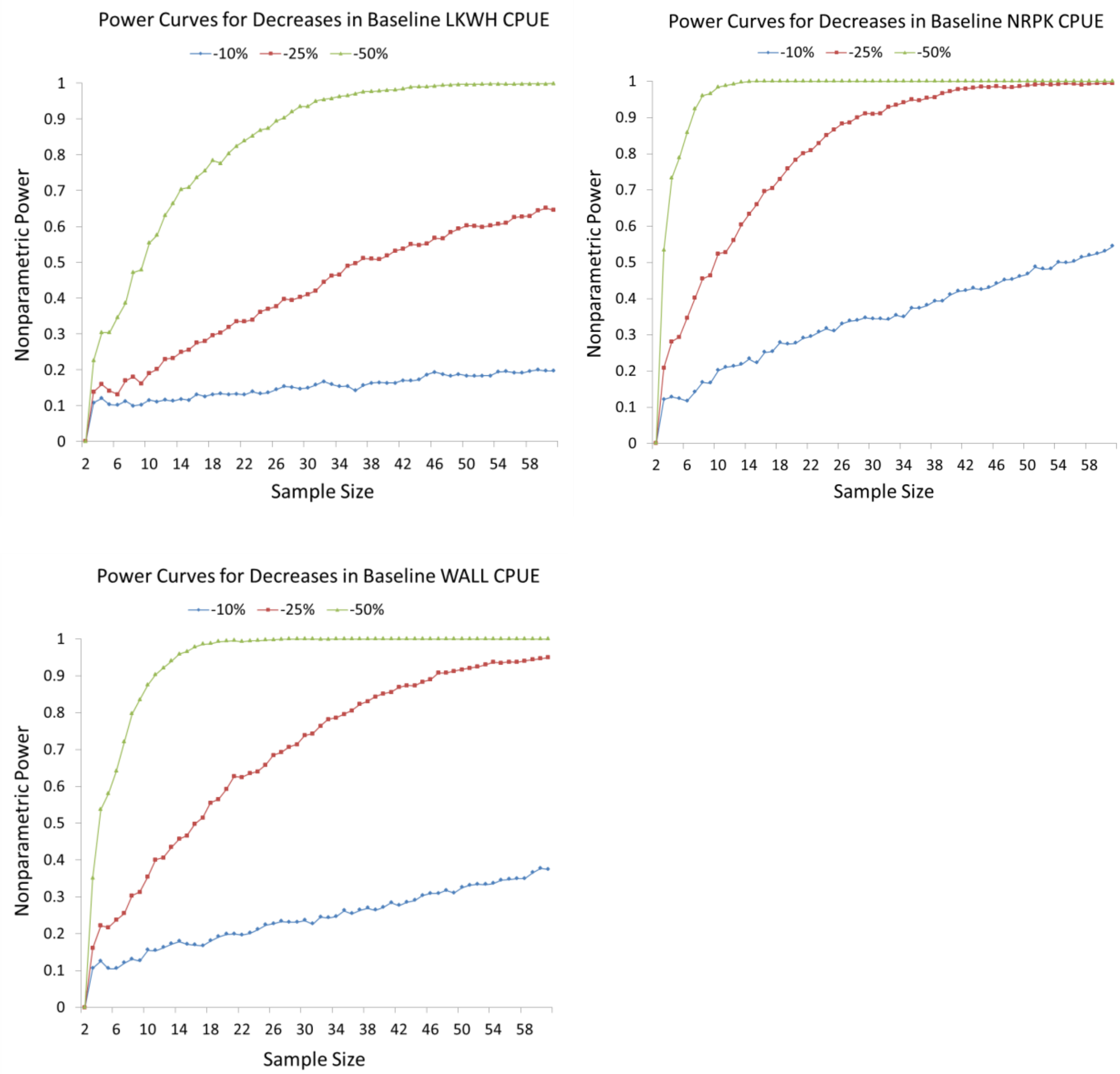


Figure 5-2: Results of prospective non parametric power analysis, graphing non parametric power for a given sample size, assuming decreases of 10%, 25% and 50% in Northern Pike, Lake Whitefish and Walleye CPUE (# fish/100 m of net/24 hrs). Data are from pre-Project gillnetting studies conducted between Clark Lake and Gull Rapids in 2001, 2002 and 2009.

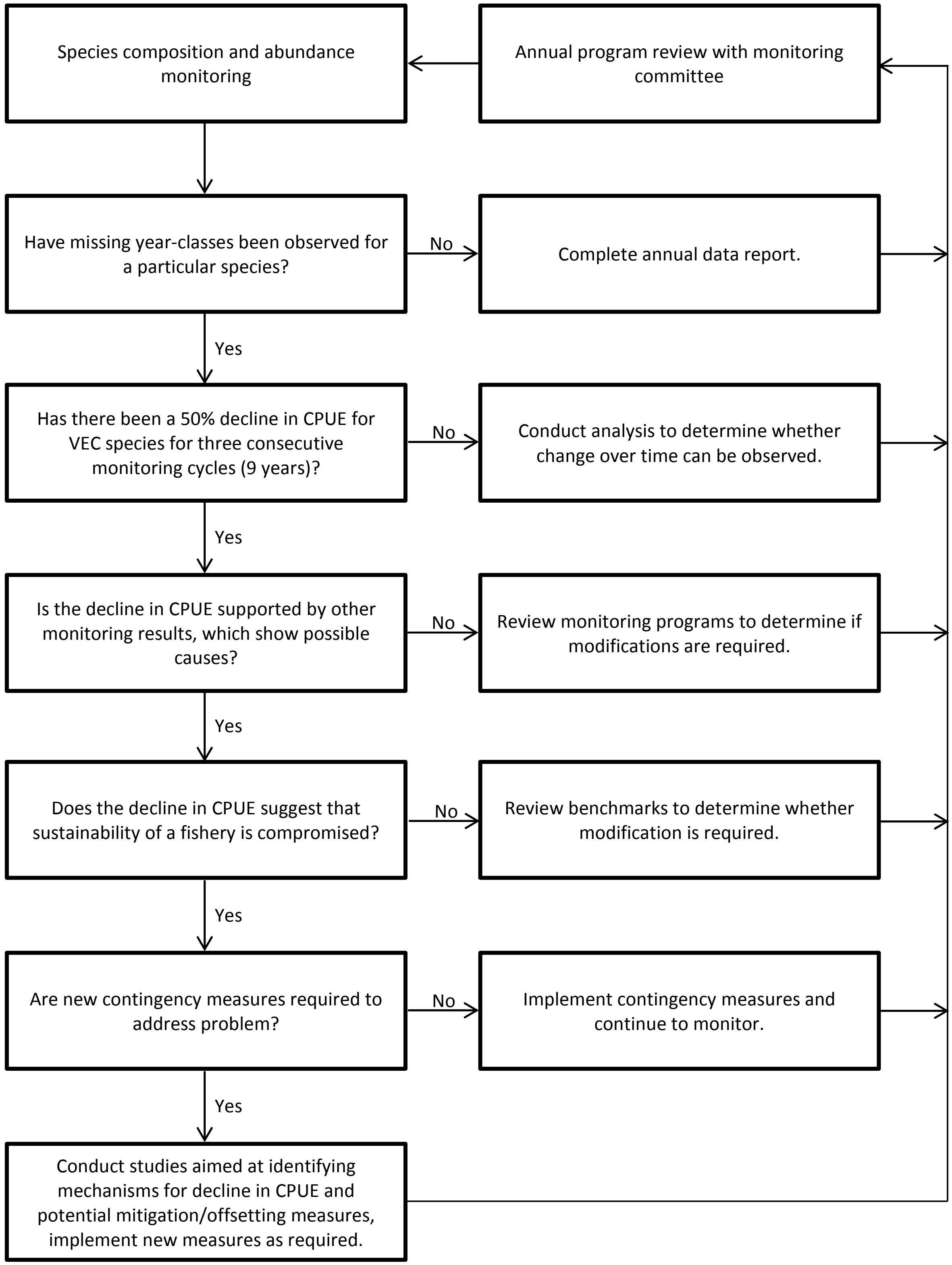


Figure 5-3: Fish species composition and abundance monitoring – CPUE.

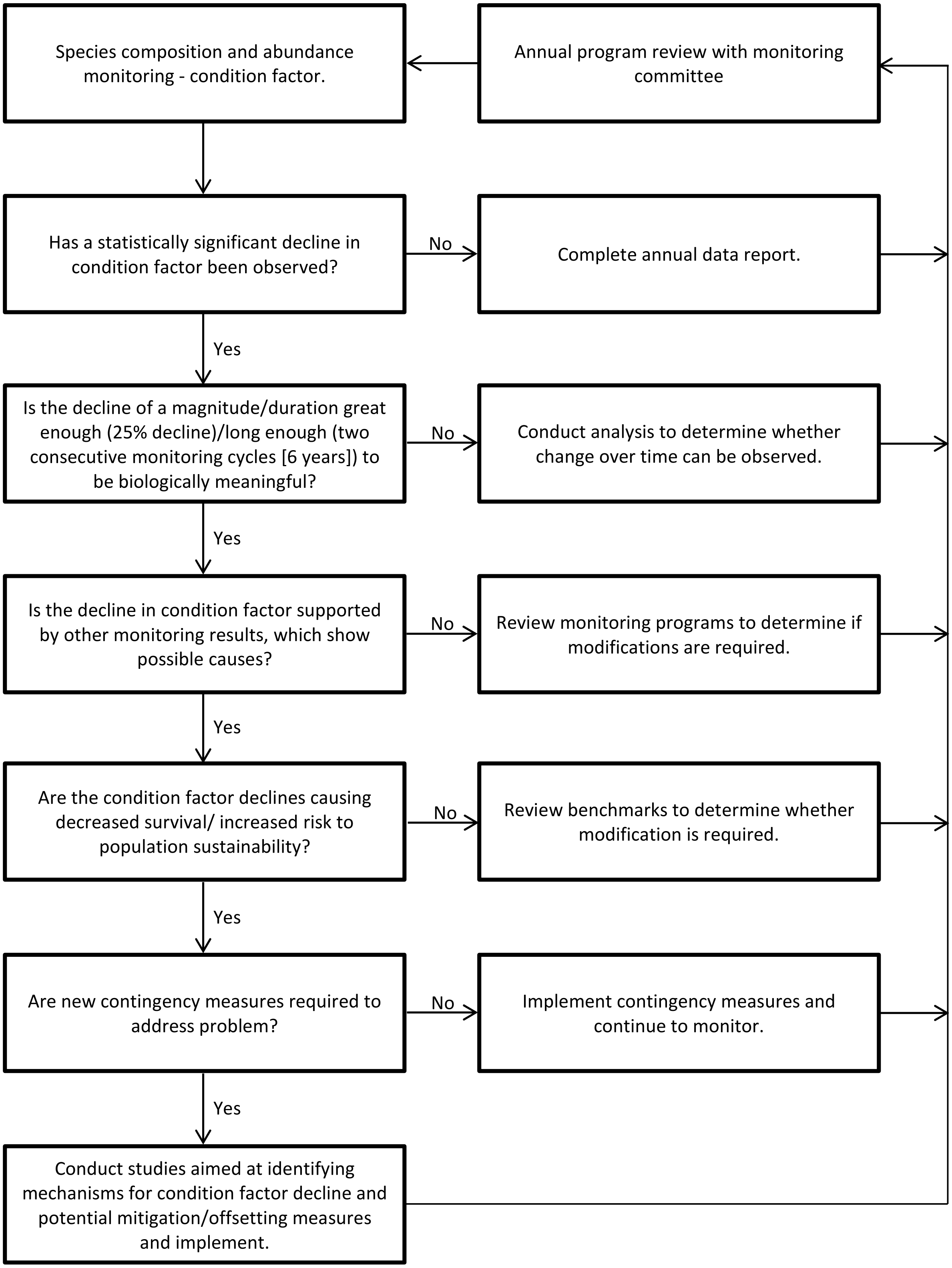


Figure 5-4: Fish species composition and abundance monitoring – condition factor.

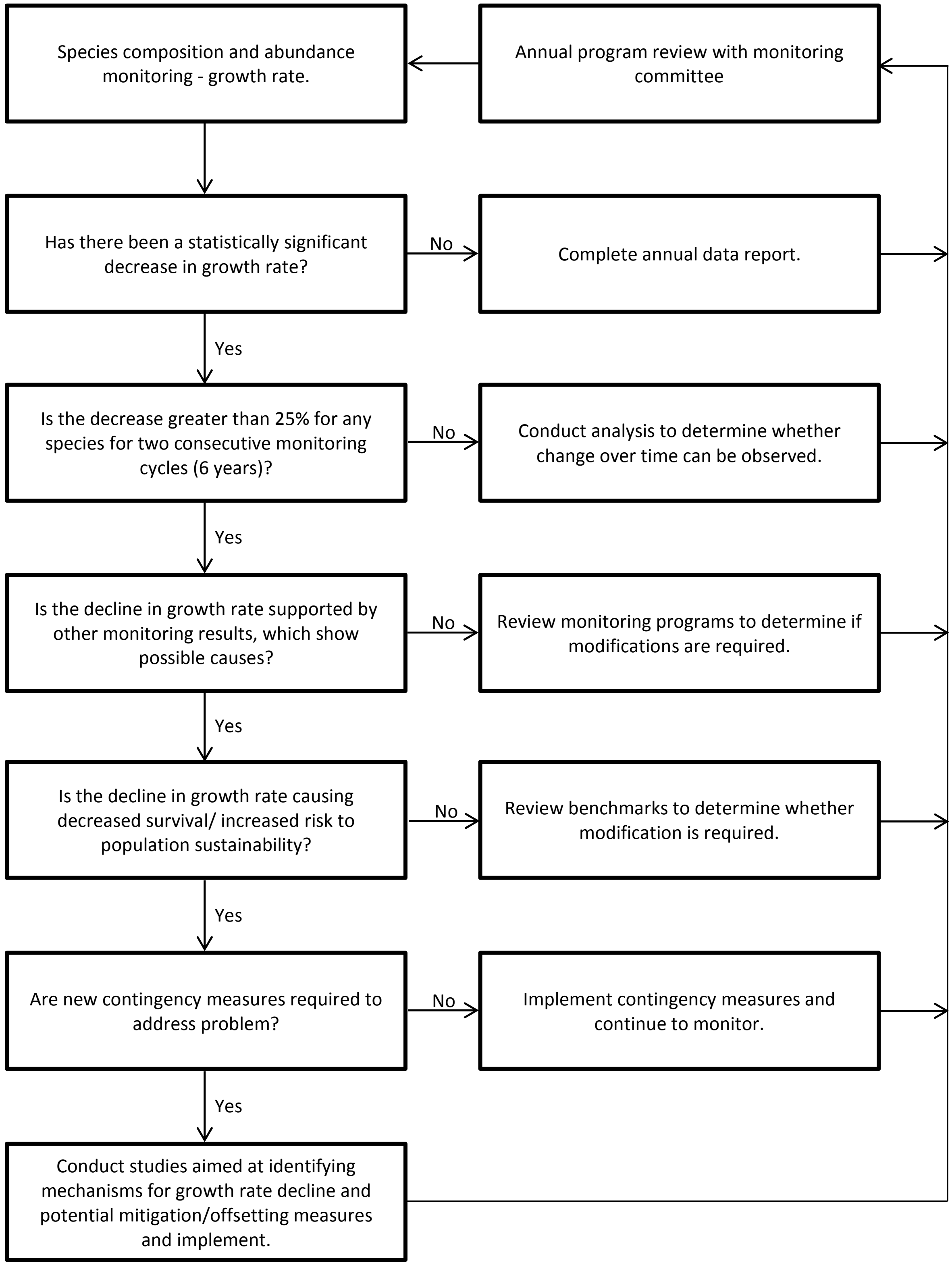


Figure 5-5: Fish species composition and abundance monitoring – growth rate.

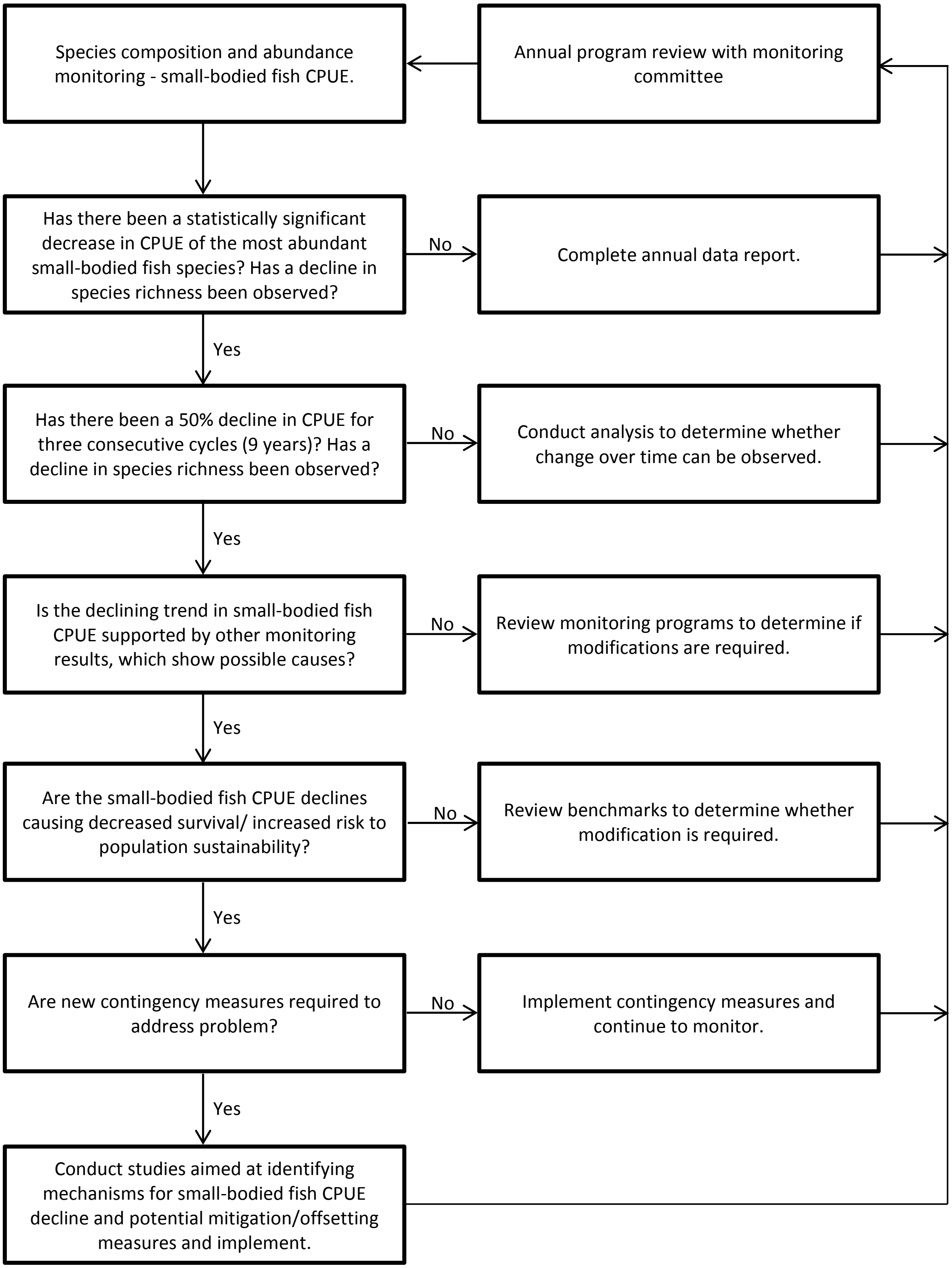


Figure 5-6: Fish species composition and abundance monitoring – small-bodied fish CPUE.

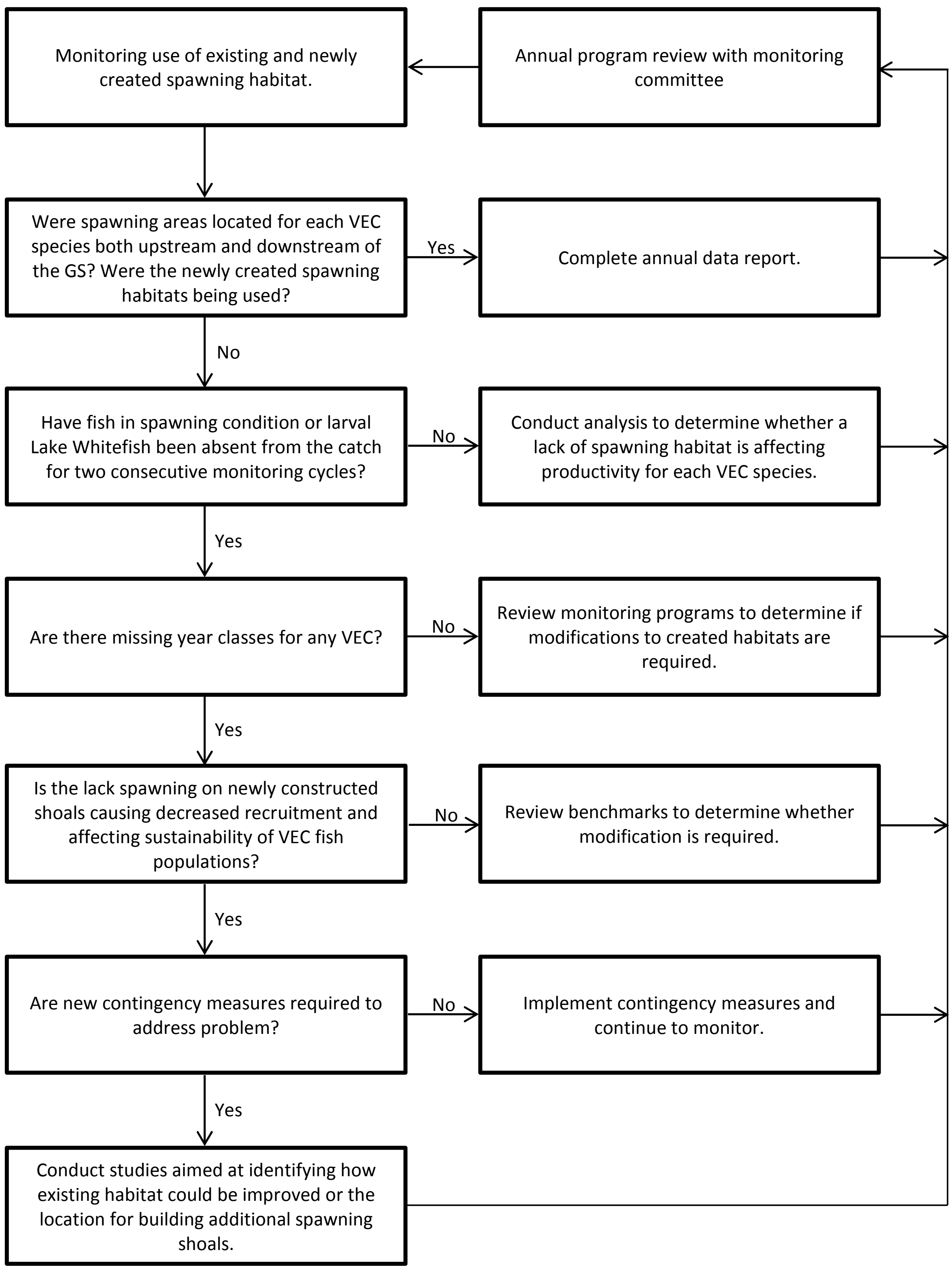


Figure 5-7: Monitoring use of existing and newly created spawning habitat.

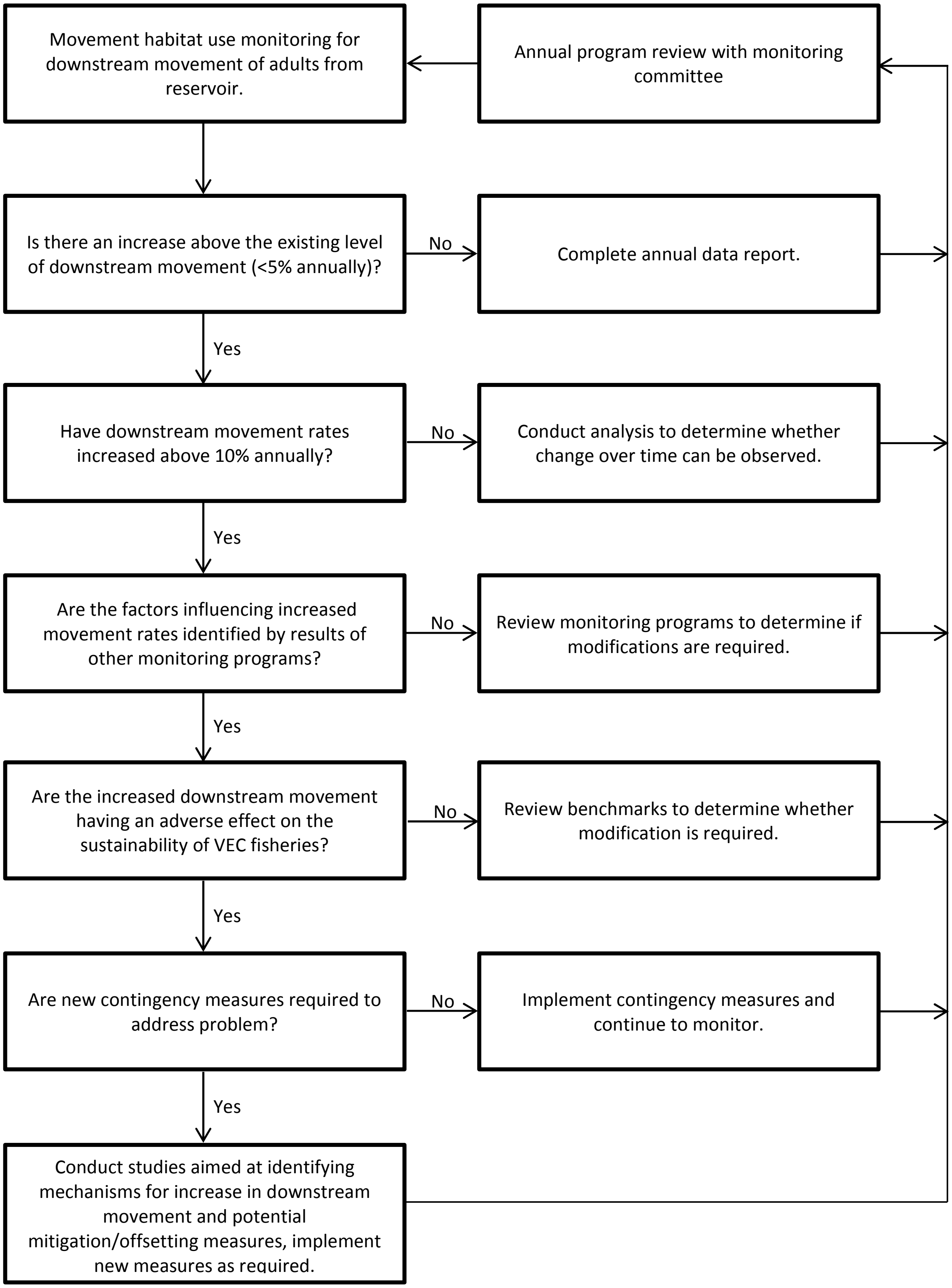


Figure 5-8: Movement monitoring.

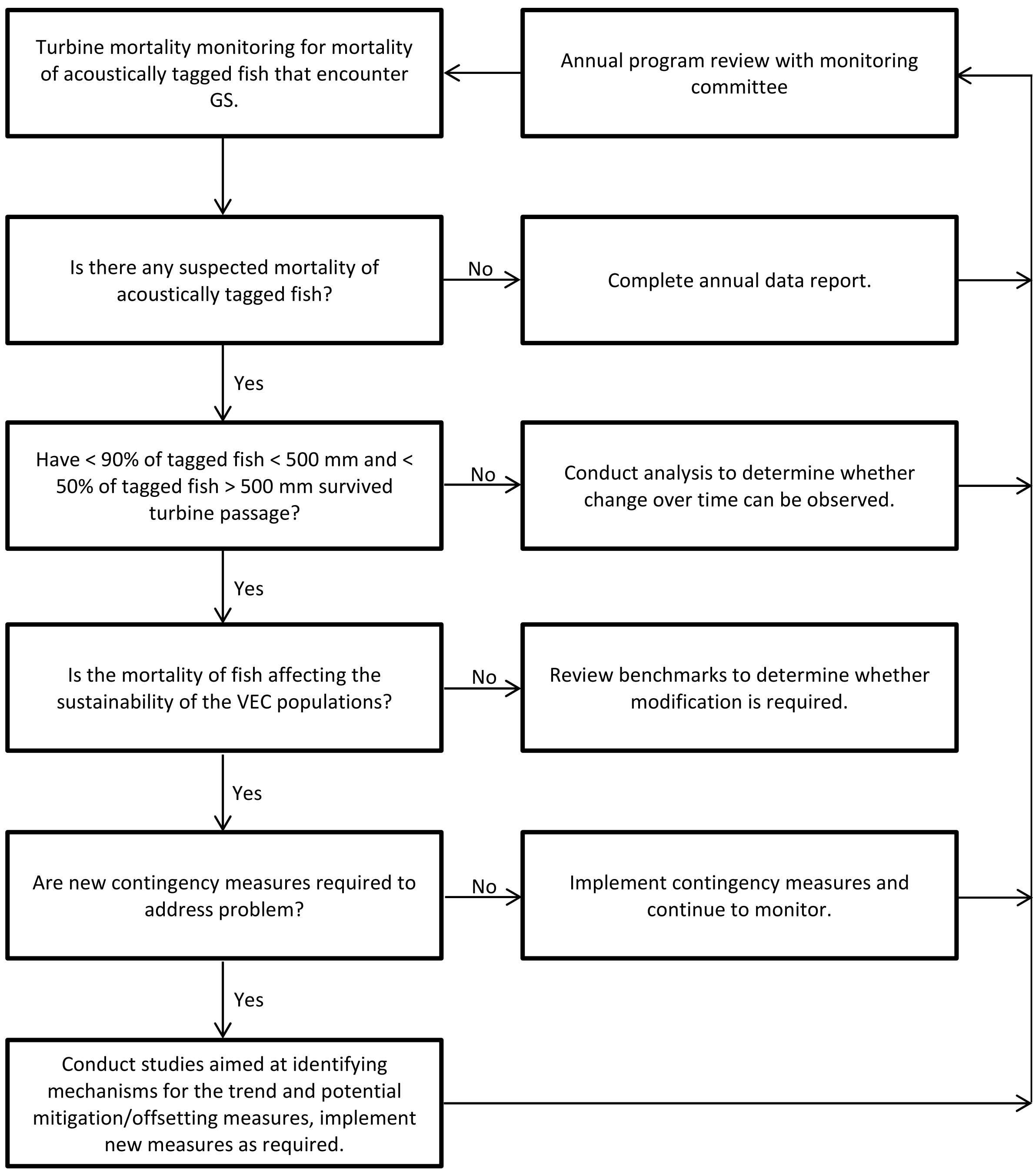


Figure 5-9: Turbine mortality monitoring – mortality of acoustically tagged fish that encounter the GS.

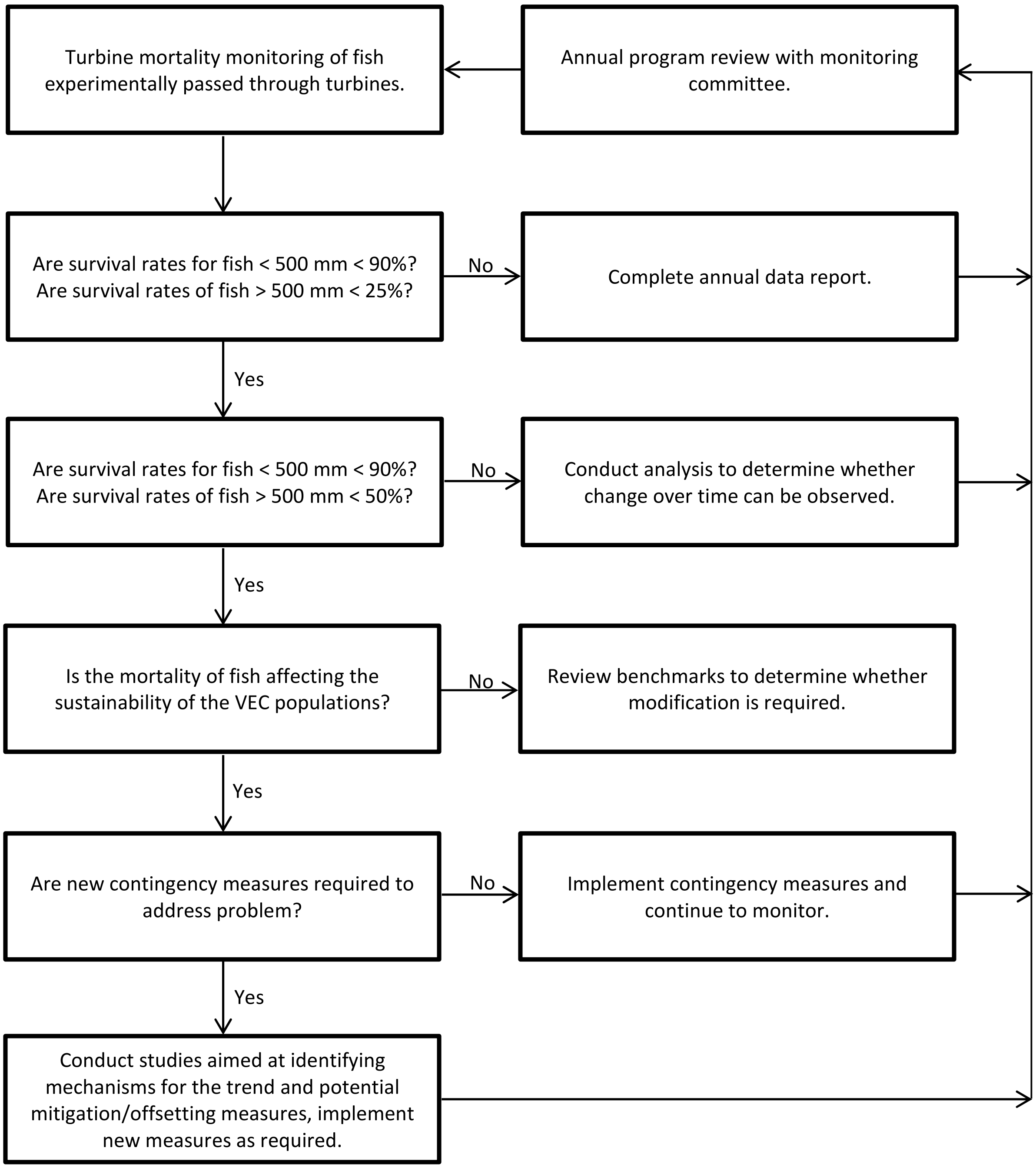


Figure 5-10: Turbine mortality monitoring – mortality of fish experimentally passed through turbines.

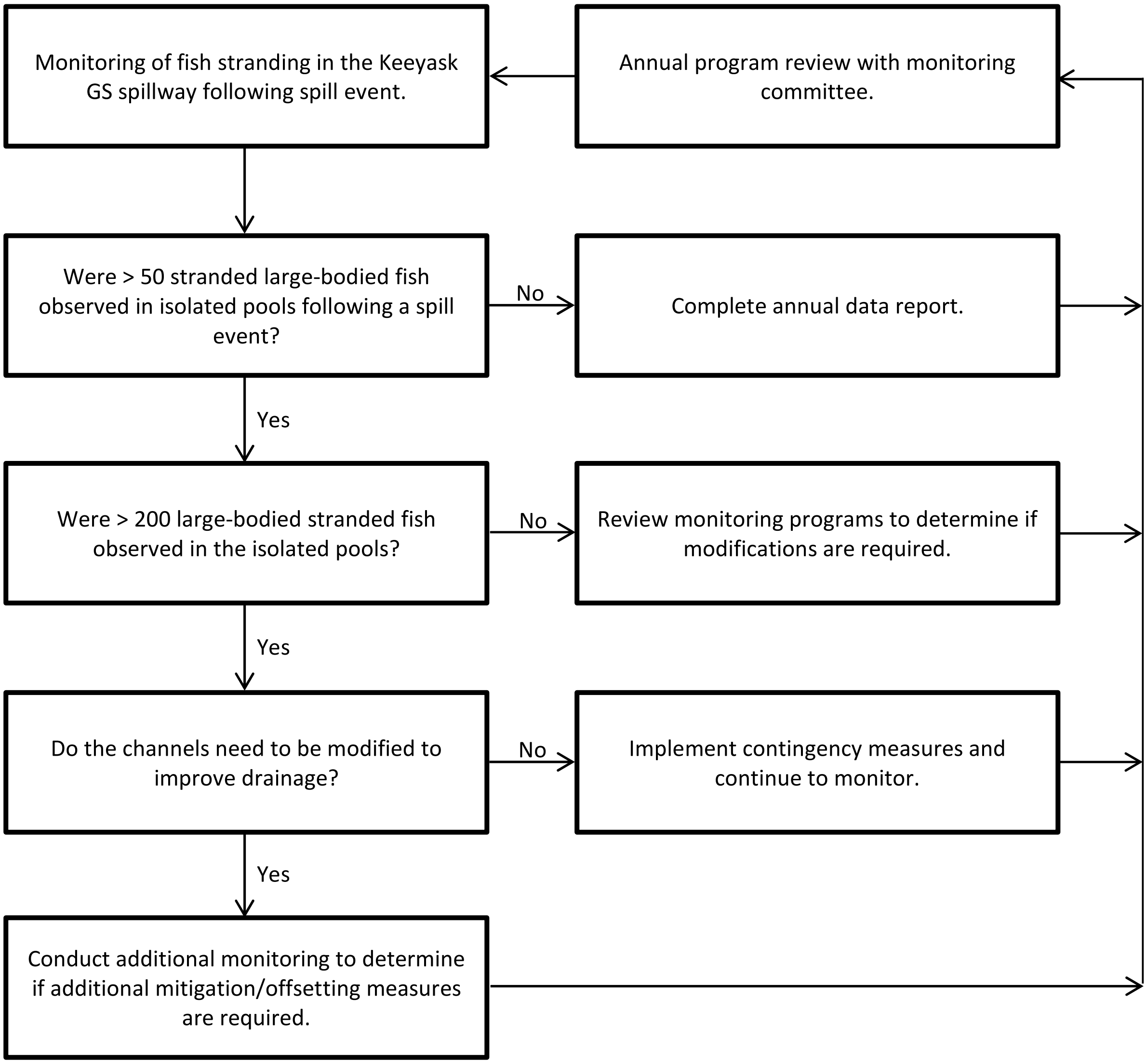


Figure 5-11: Monitoring of fish stranding below the Keeyask GS spillway following spill events.

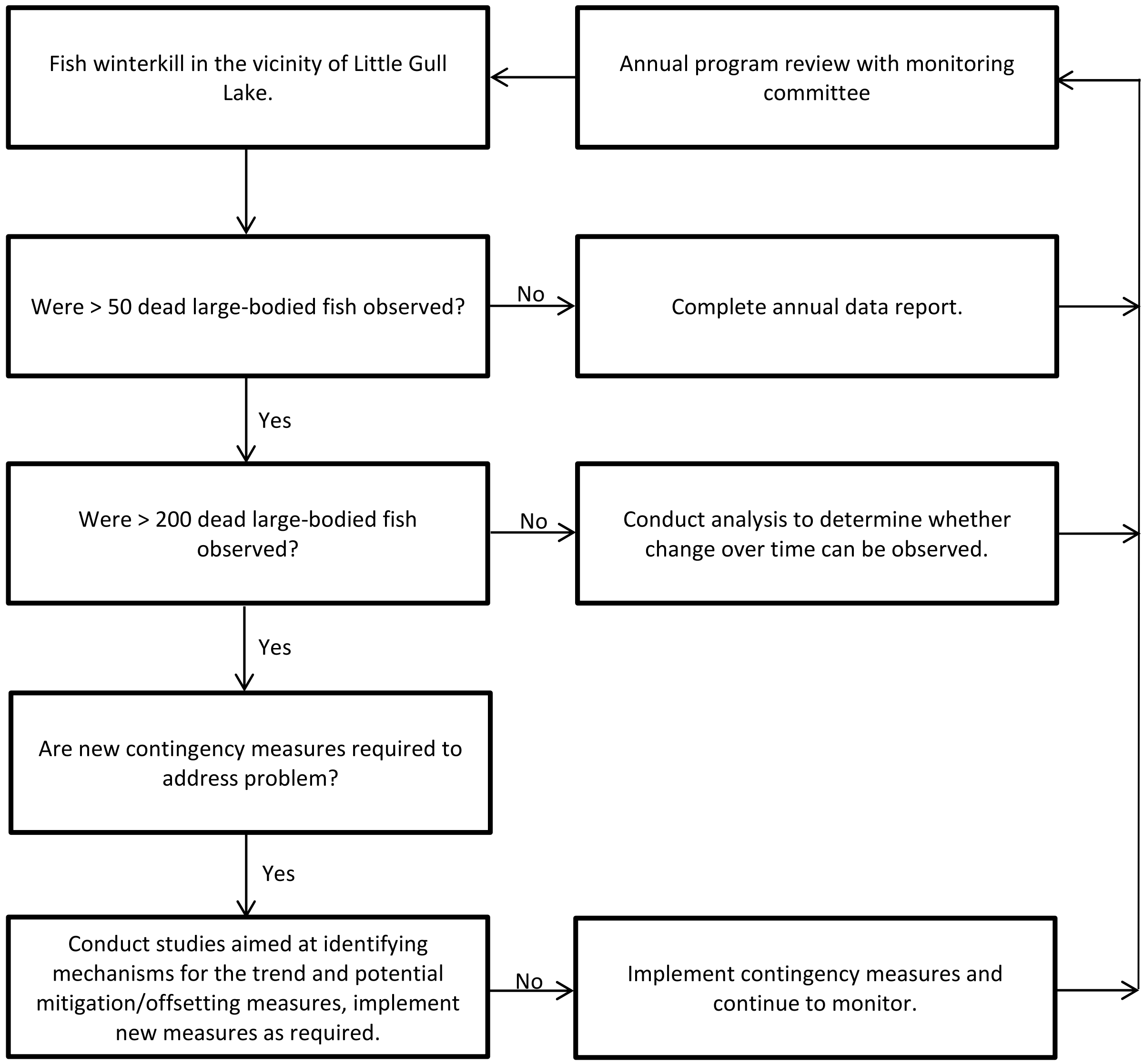
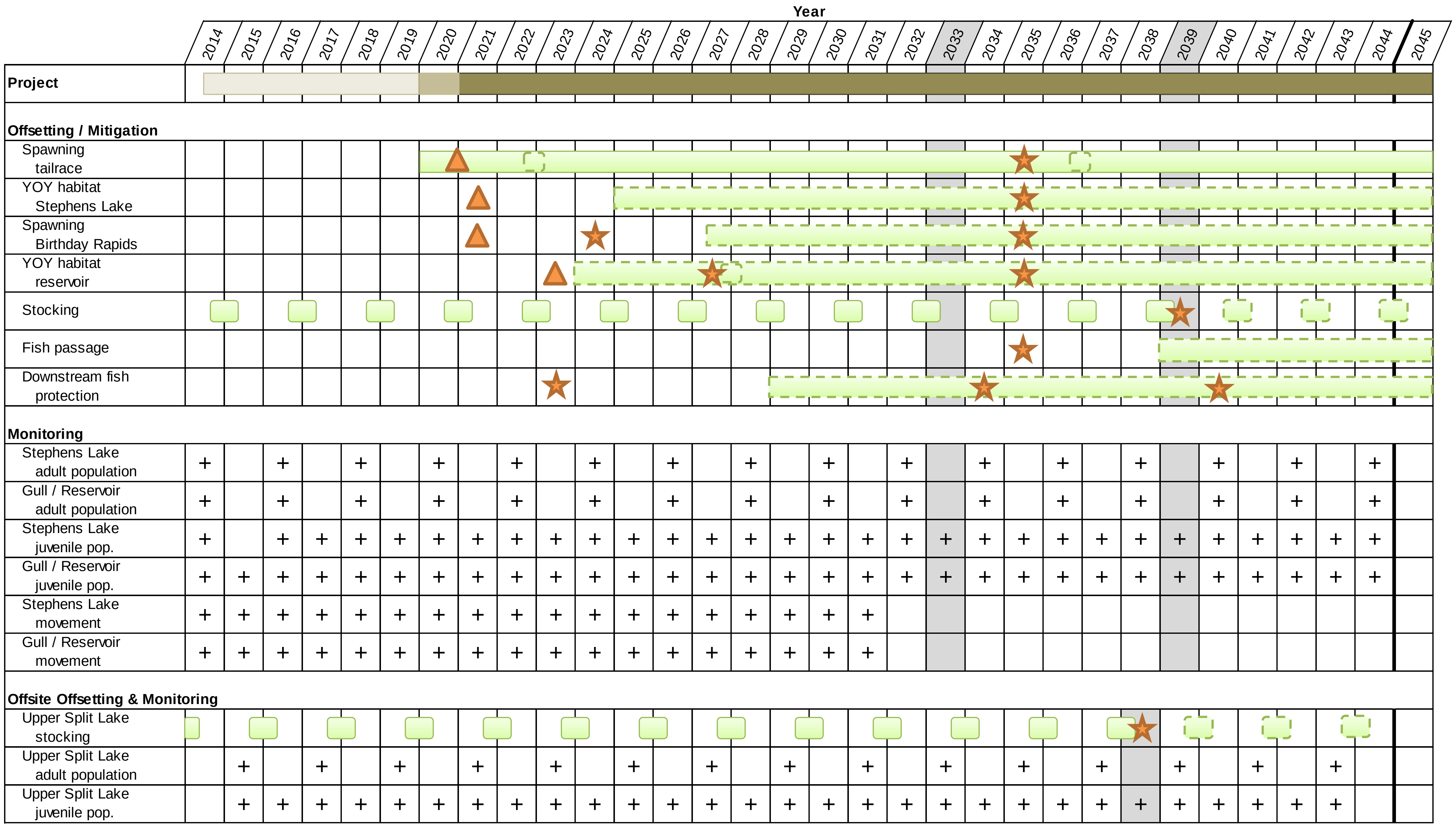


Figure 5-12: Fish winterkill in the vicinity of Little Gull Lake.



Notes:
Grey shading indicates increase in spawning population: 2033 (maturation of 2008 year class) and 2038/2039 (maturation of first stocked fish).

Figure 6-1: Planned schedule for the implementation of mitigation/offsetting measures and monitoring for Lake Sturgeon during Keeyask Generating Station construction (2014-2019); commissioning (2020); and operation (2021+). Solid line = measure will be implemented; dashed line = contingency measure; triangle = monitoring to confirm physical attributes of habitat; star = decision regarding alteration to mitigation/offsetting based on biological monitoring; plus = conduct of monitoring activity; heavy line = end of AEMP.

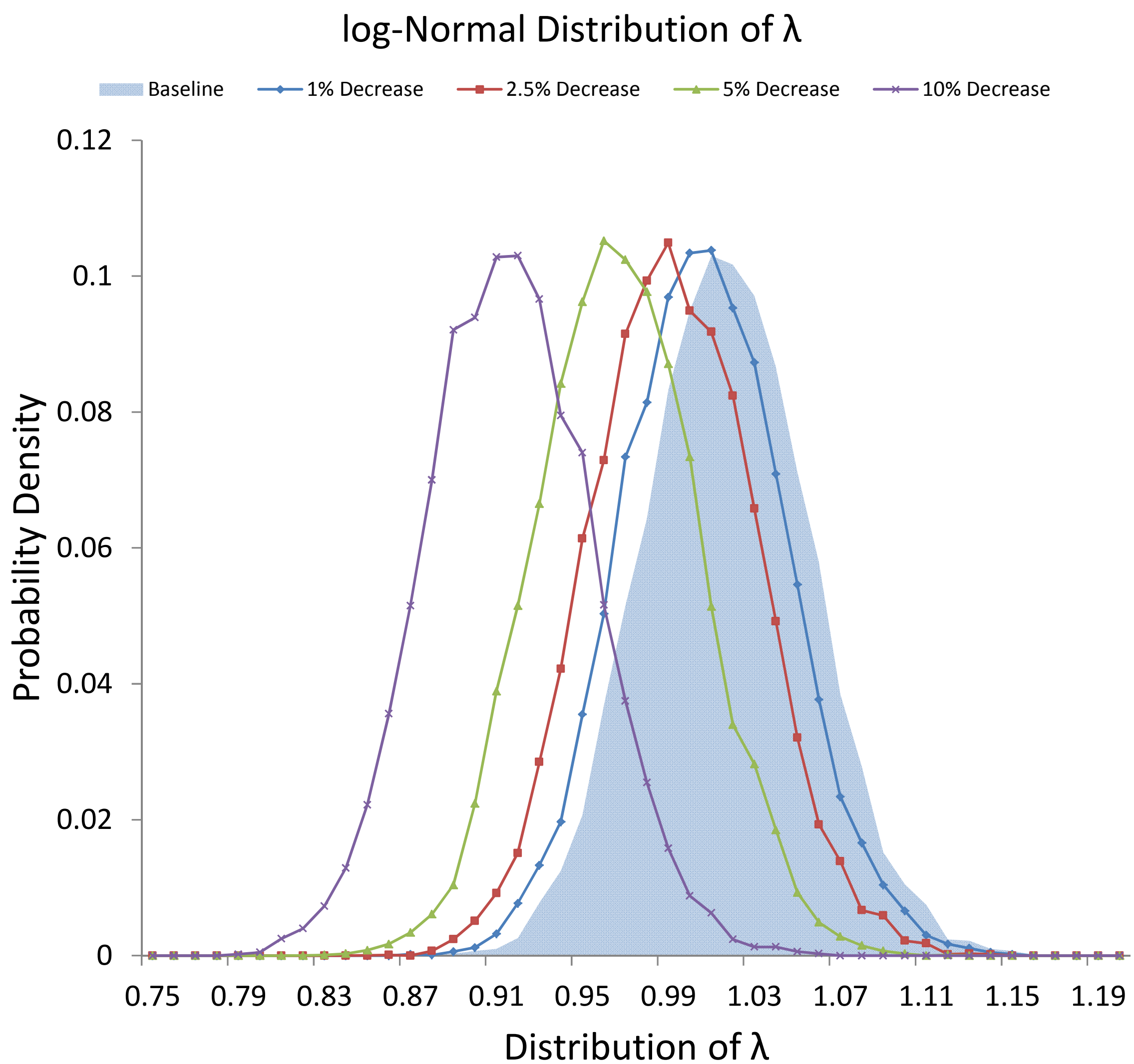


Figure 6-2: Baseline distribution of λ, fitted to a log normal distribution. Sequential decreases in mean λ (assuming same standard error) for 1%, 2.5%, 5%, and 10% are provided).

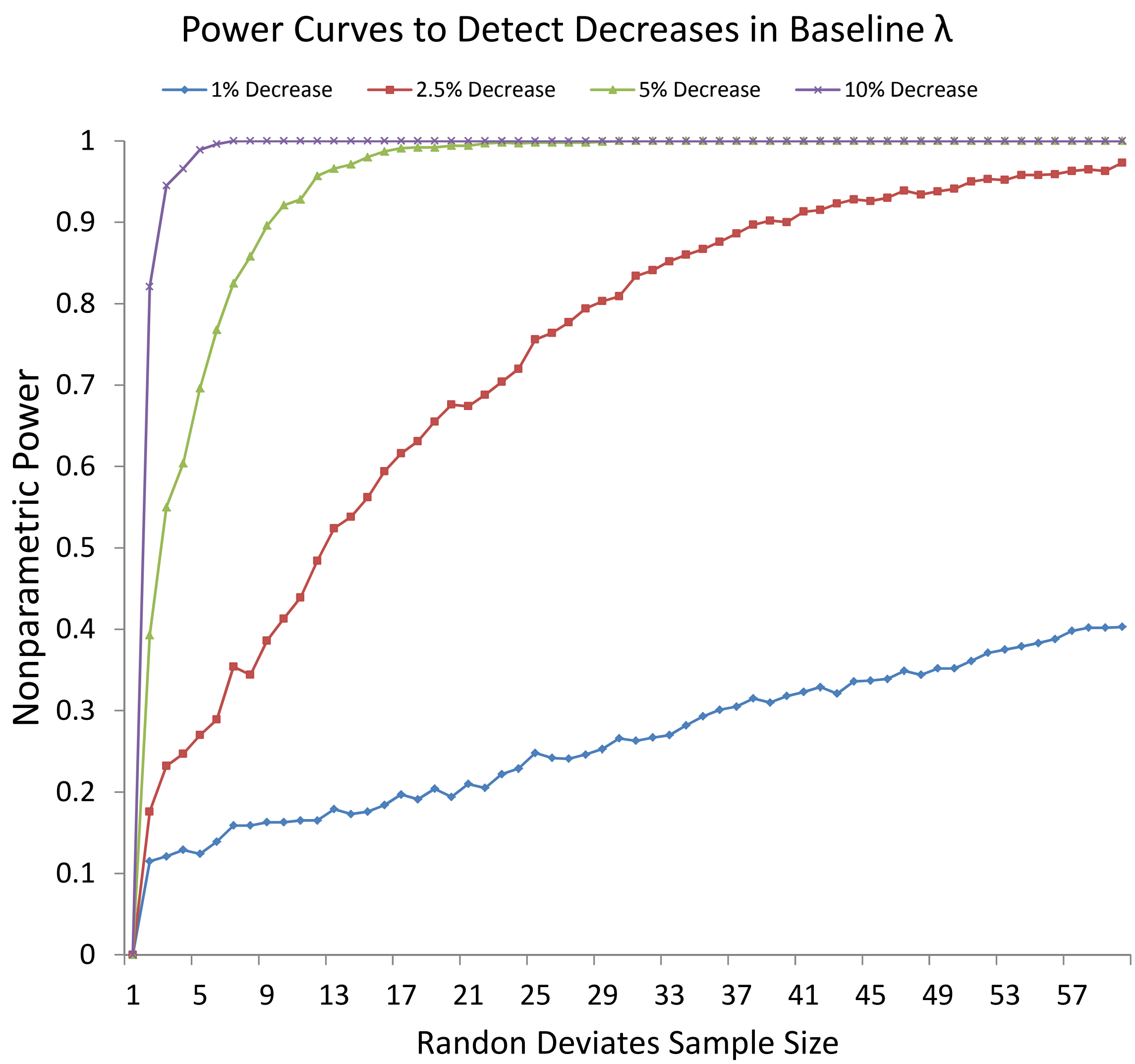


Figure 6-3: Assessment of statistical power of detecting decreases in mean λ (provided in Figure 6-1). Power in this case relates only to the number of random deviates from the baseline λ, and future λ estimate distributions are required to be 'certain' that a difference is 'real'.

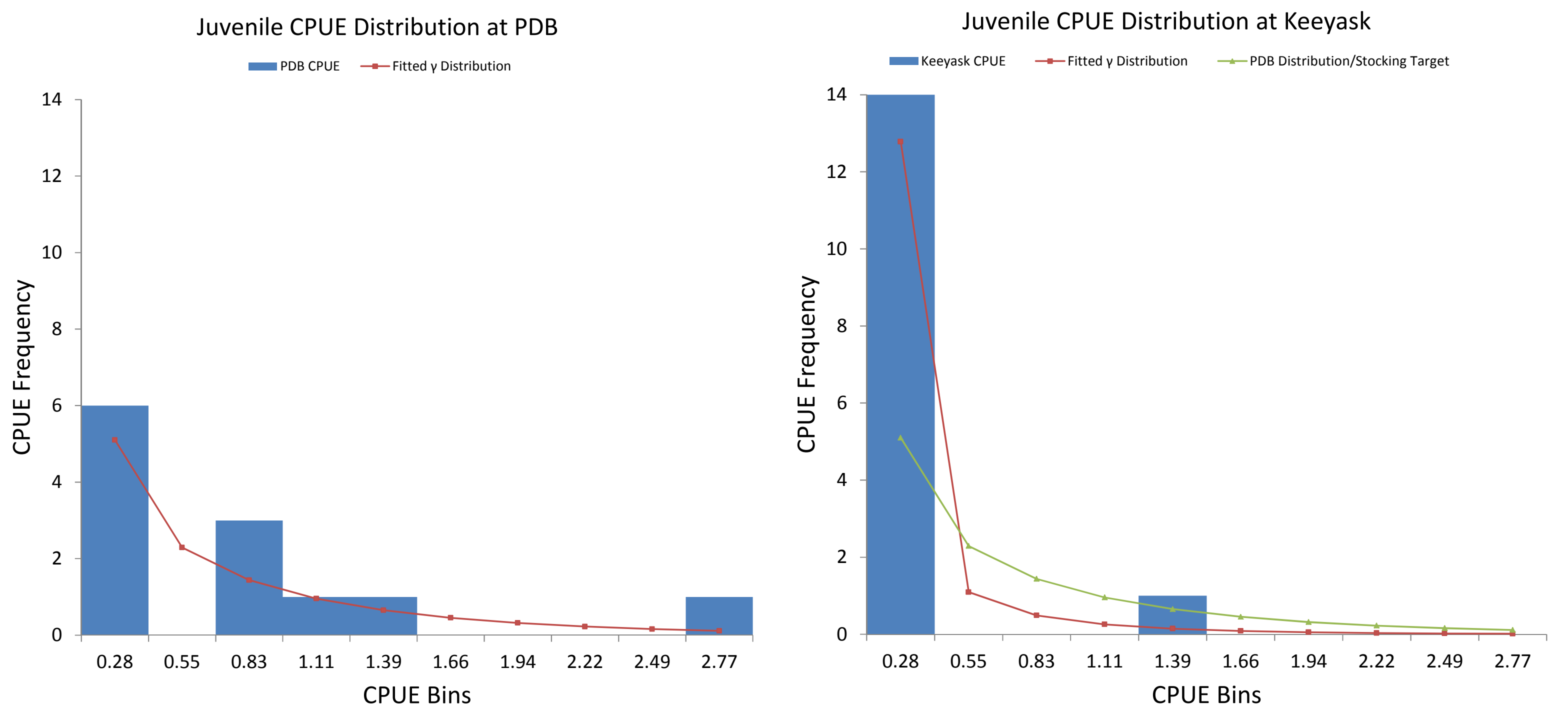


Figure 6-4: Juvenile CPUE distributions in the Slave Falls Reservoir (PDB) and Keeyask. The y axis indicates the CPUE frequency, standardized to a maximum of 14. The x axis indicates the upper end of each CPUE bin used in the analysis. The first bin includes 0.

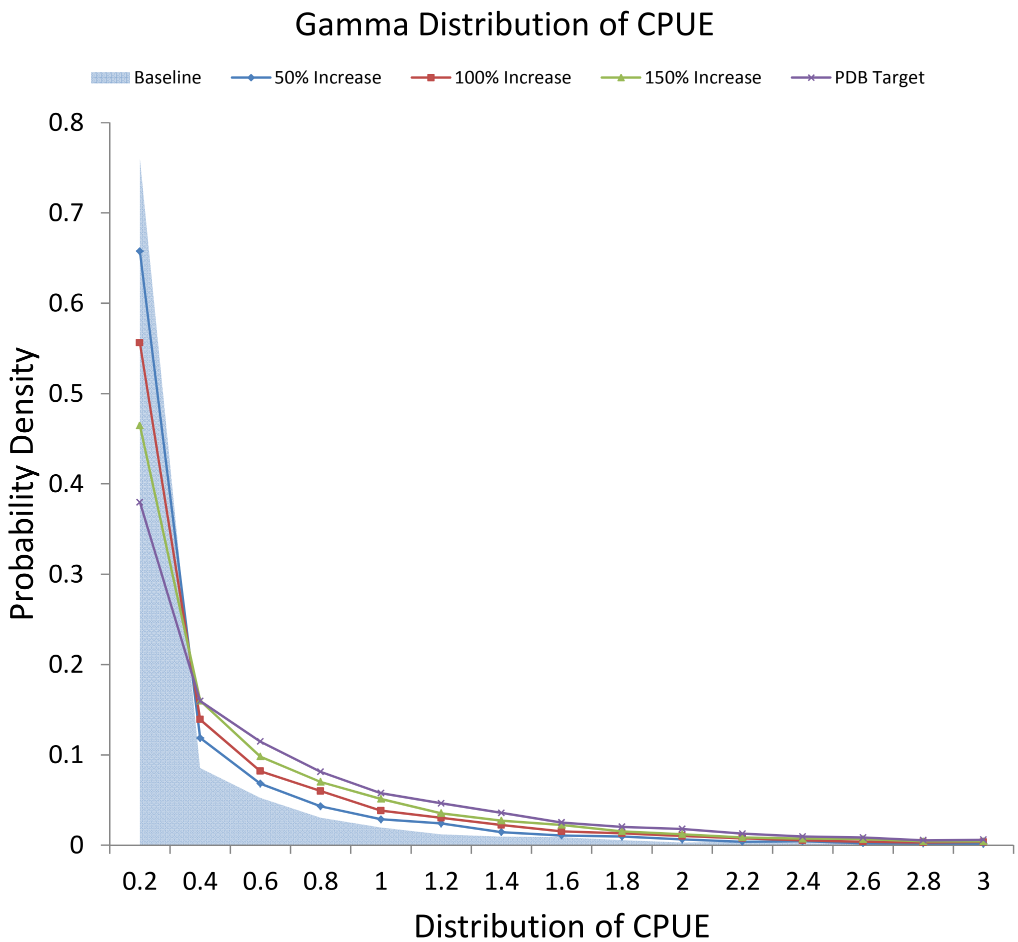


Figure 6-5: Fitted distribution for CPUE of juvenile sturgeon showing baseline (Keeyask) and target (Slave Falls = PDB). Increases of 50%, 100% and 150% of baseline values are shown.

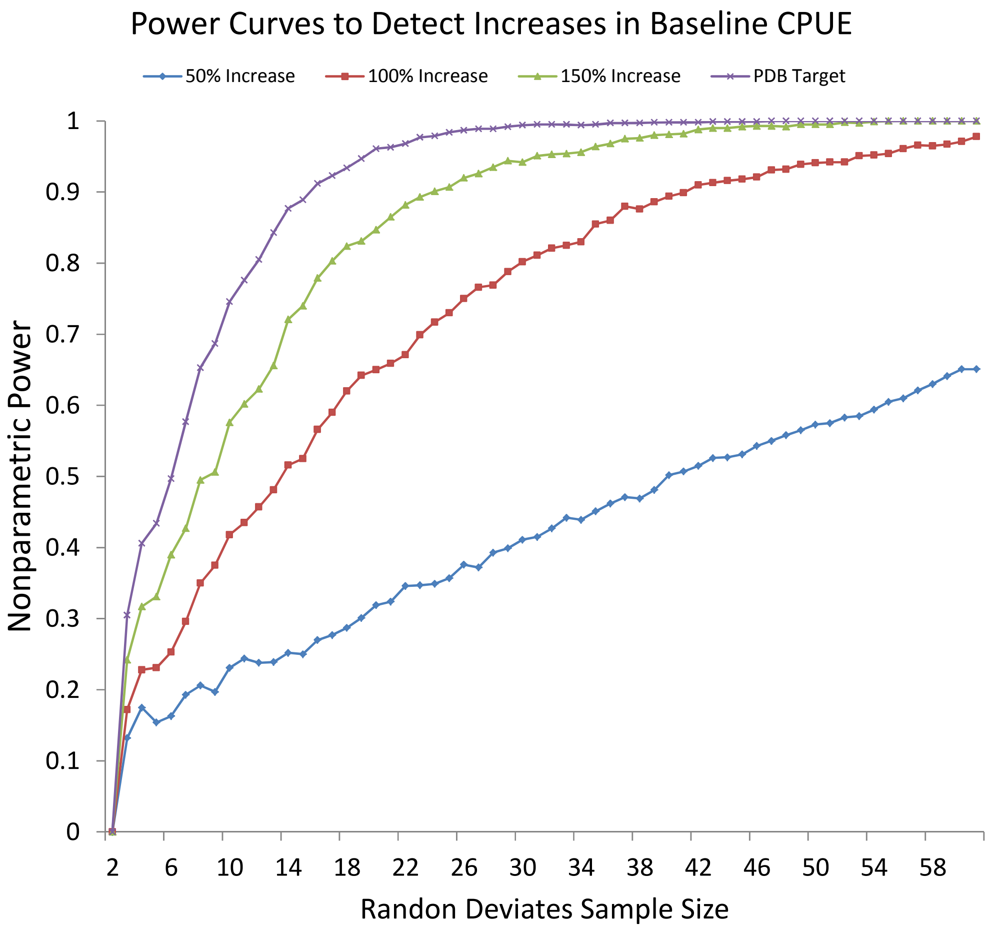


Figure 6-6: Power curves to detect increases in juvenile CPUE based on distributions shown in Figure 6-3.

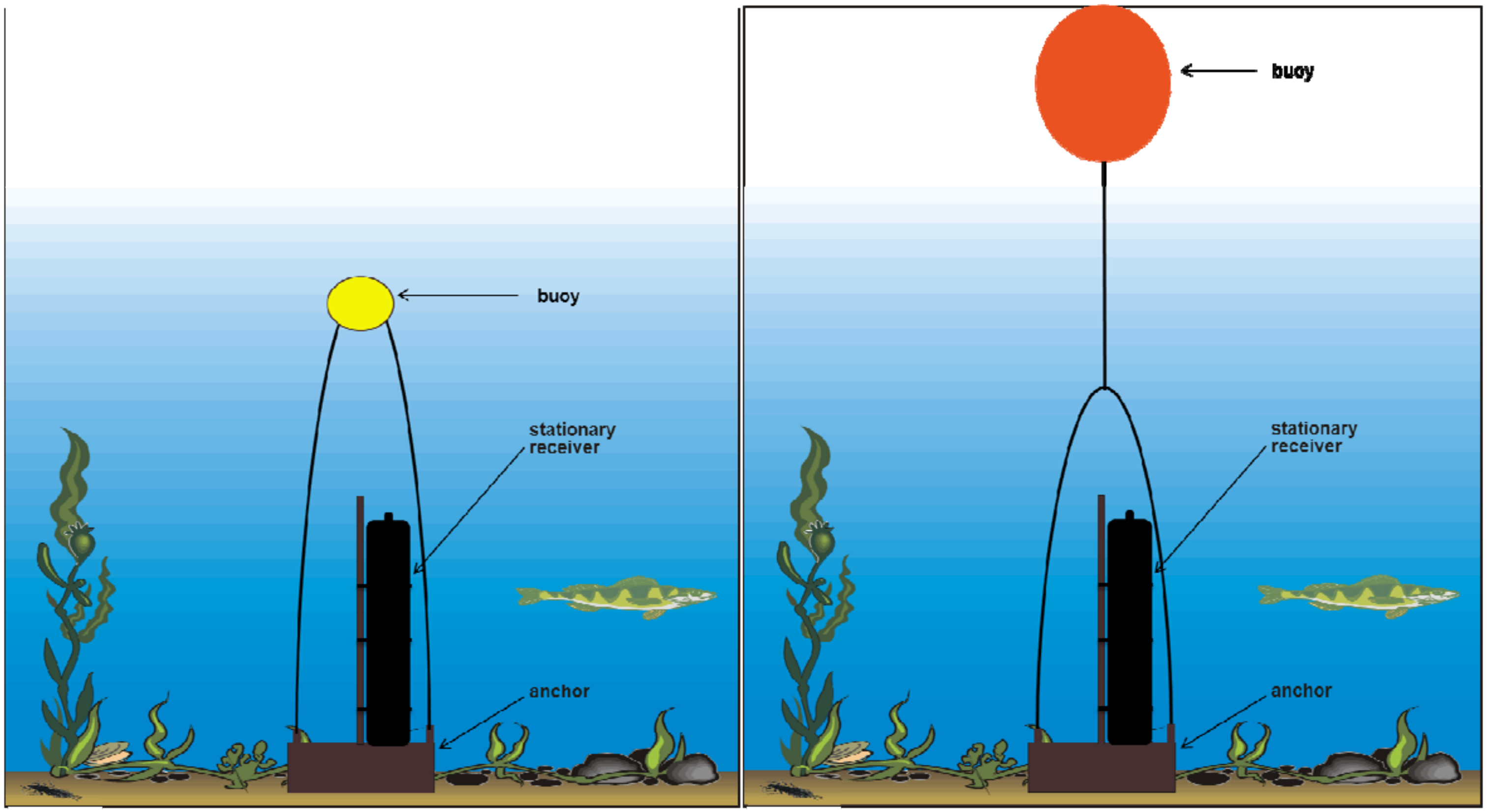


Figure 6-7: Mooring apparatus used for Vemco stationary acoustic receivers set during winter and summer, in the Keeyask study area.

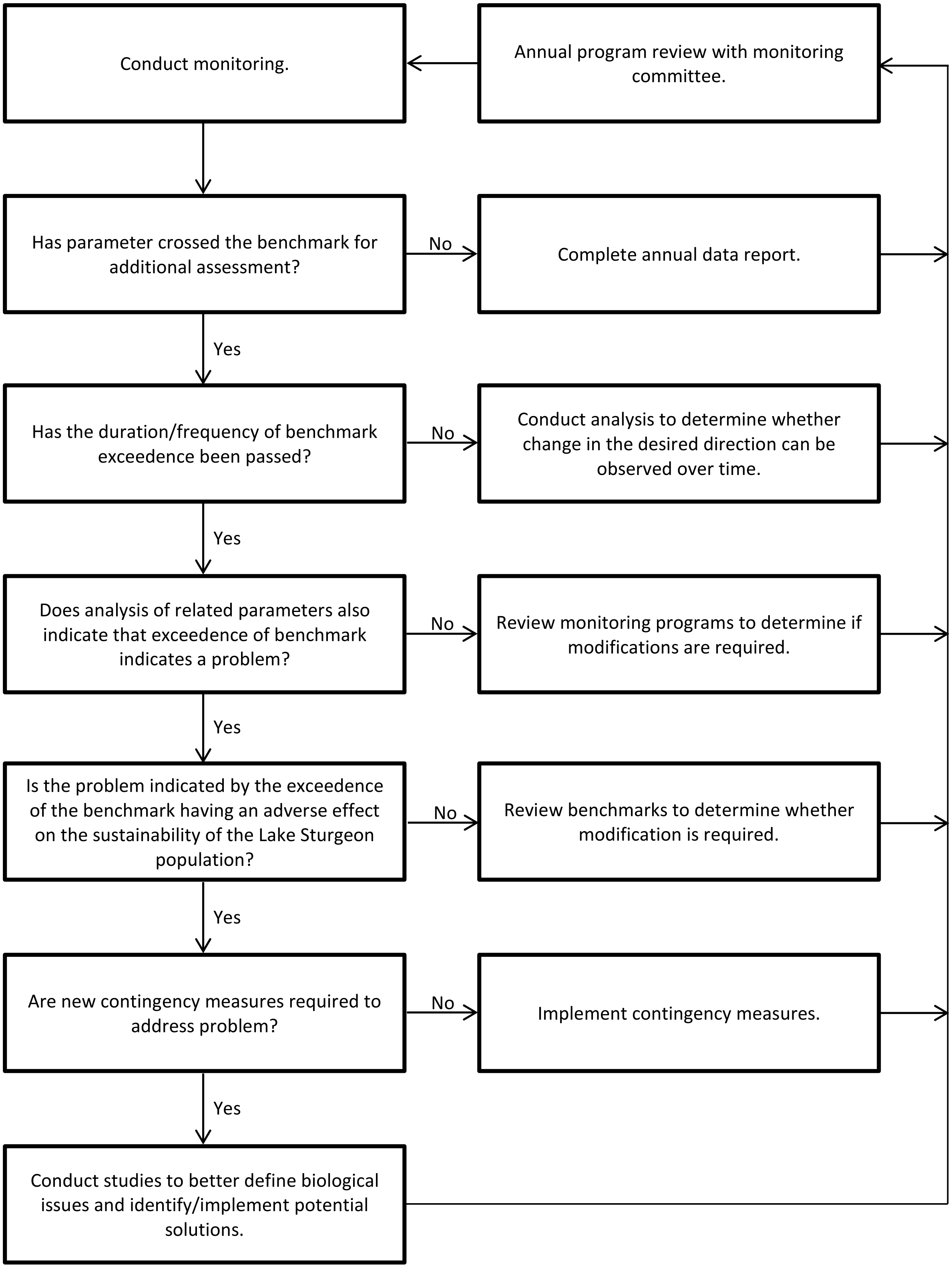


Figure 6-8: Lake Sturgeon adaptive management assessment framework.

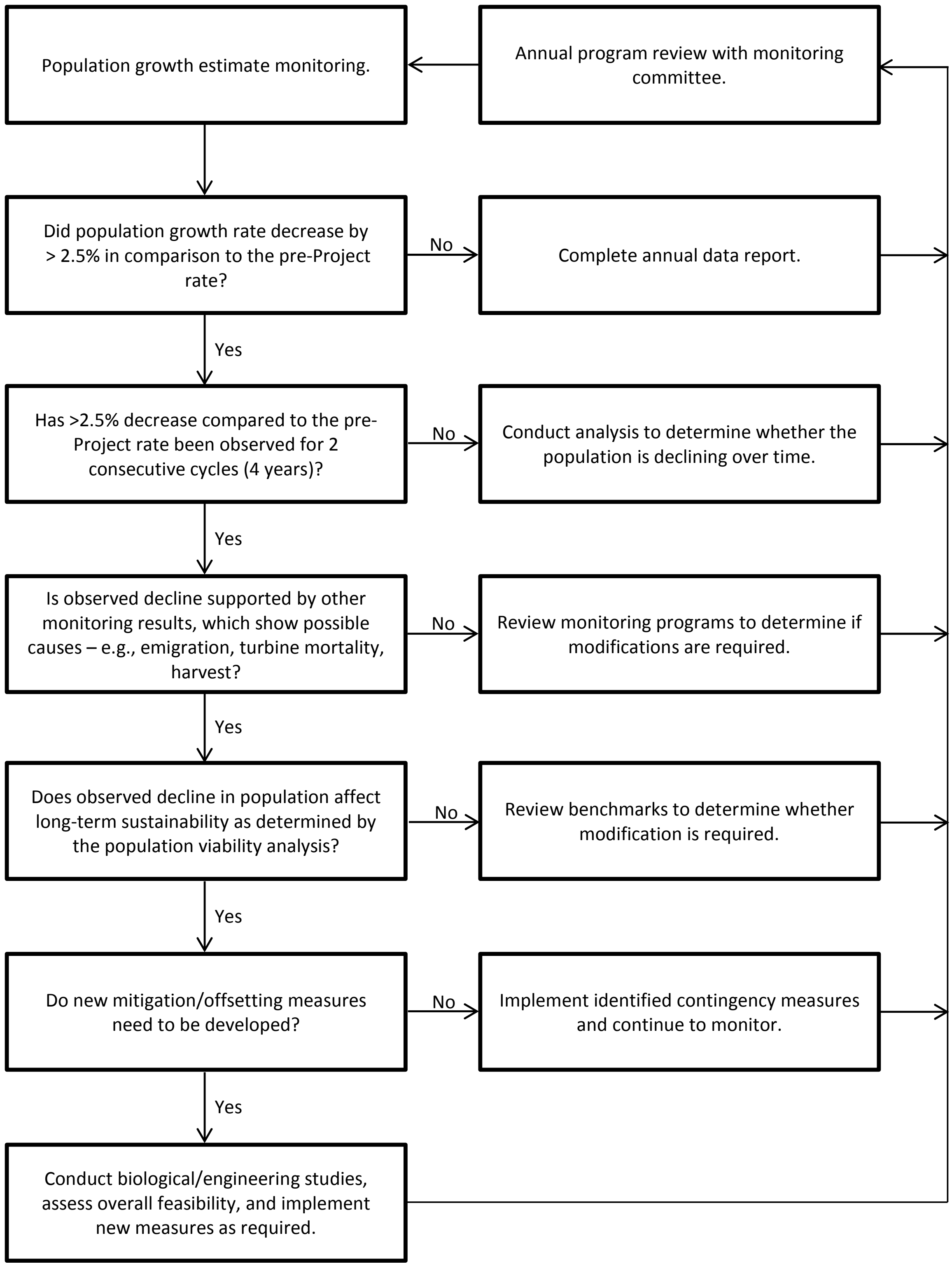


Figure 6-9: Lake Sturgeon adult population assessment.

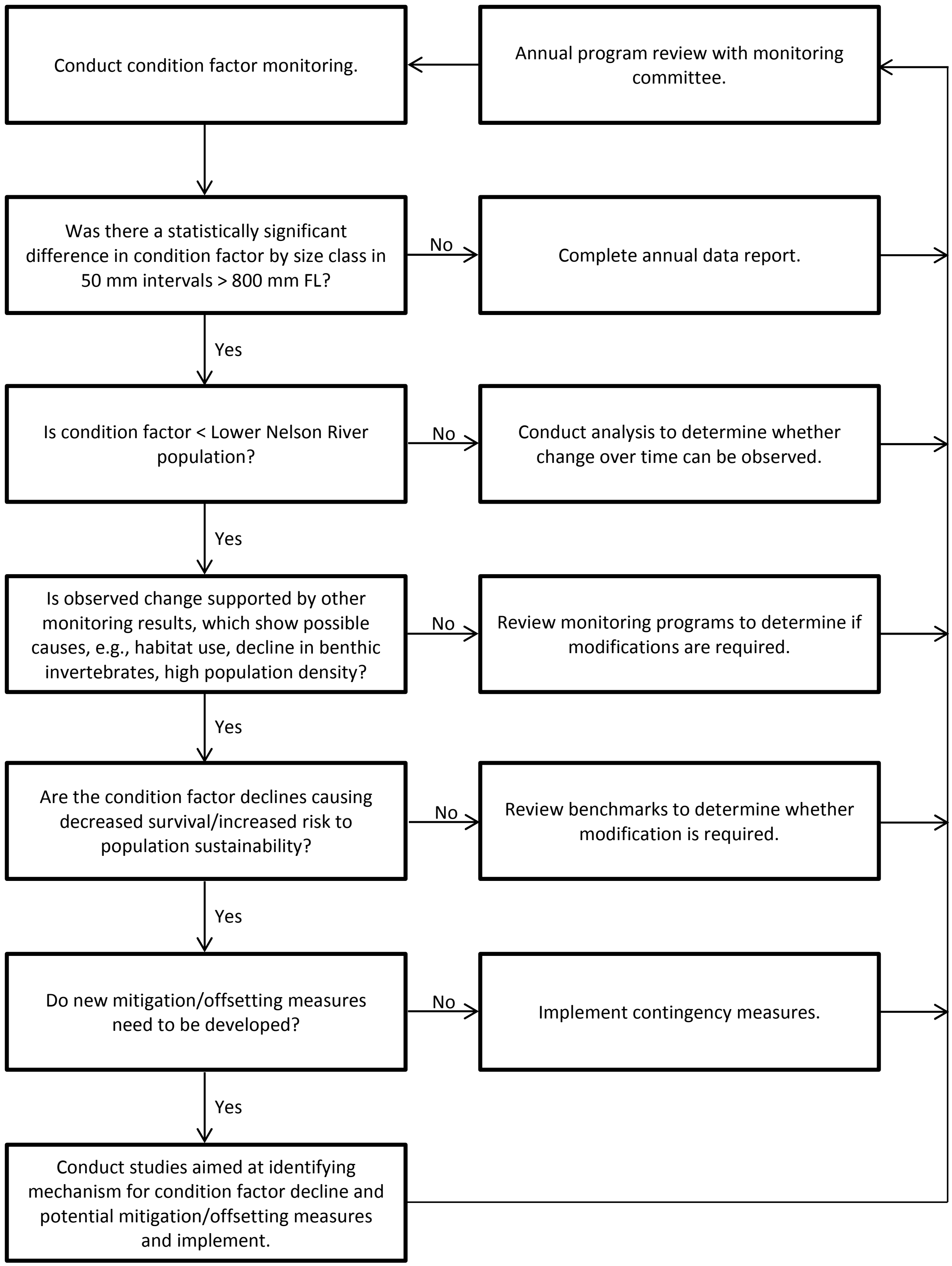


Figure 6-10: Lake Sturgeon adult condition.

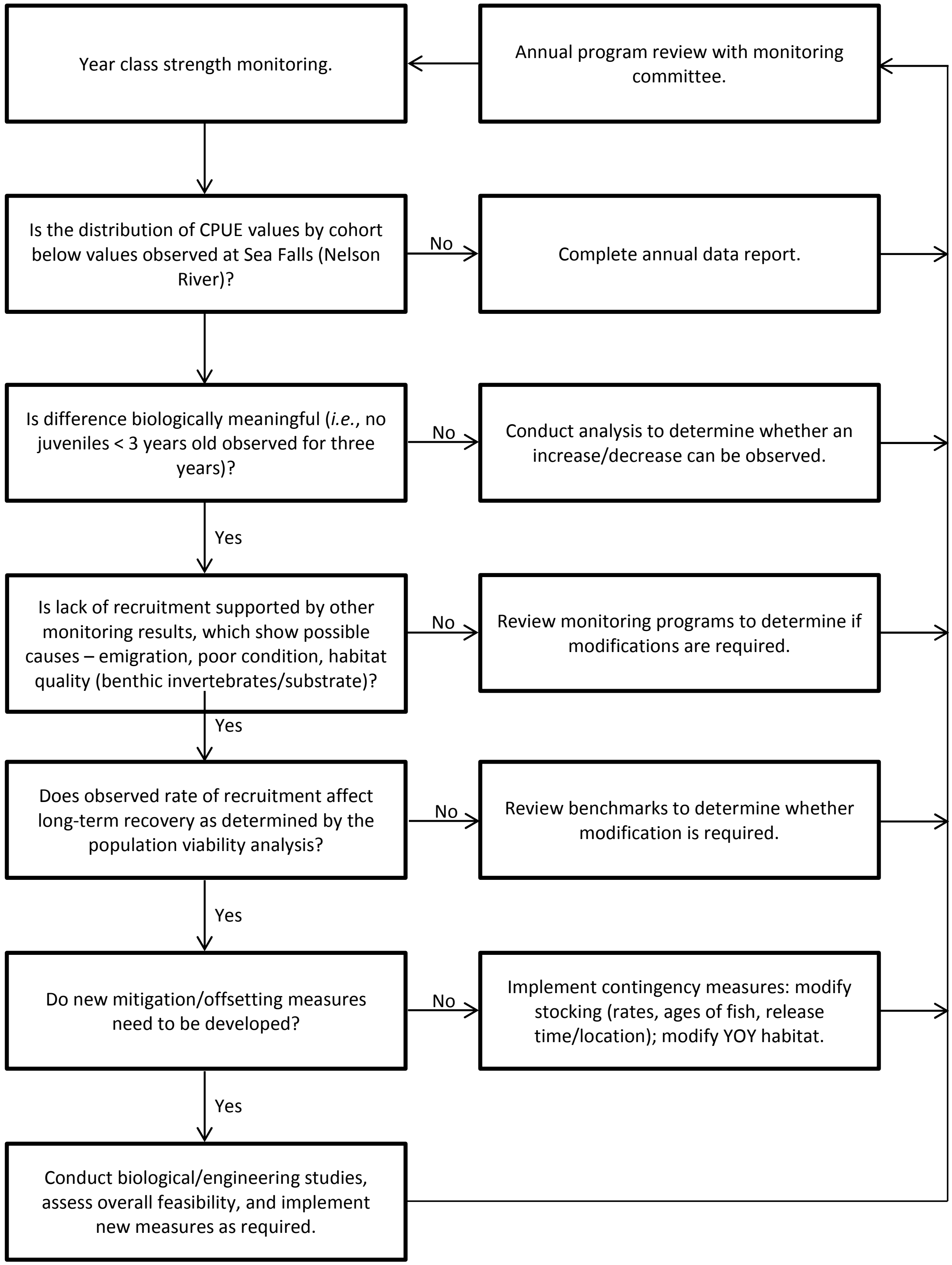


Figure 6-11: Lake Sturgeon recruitment assessment.

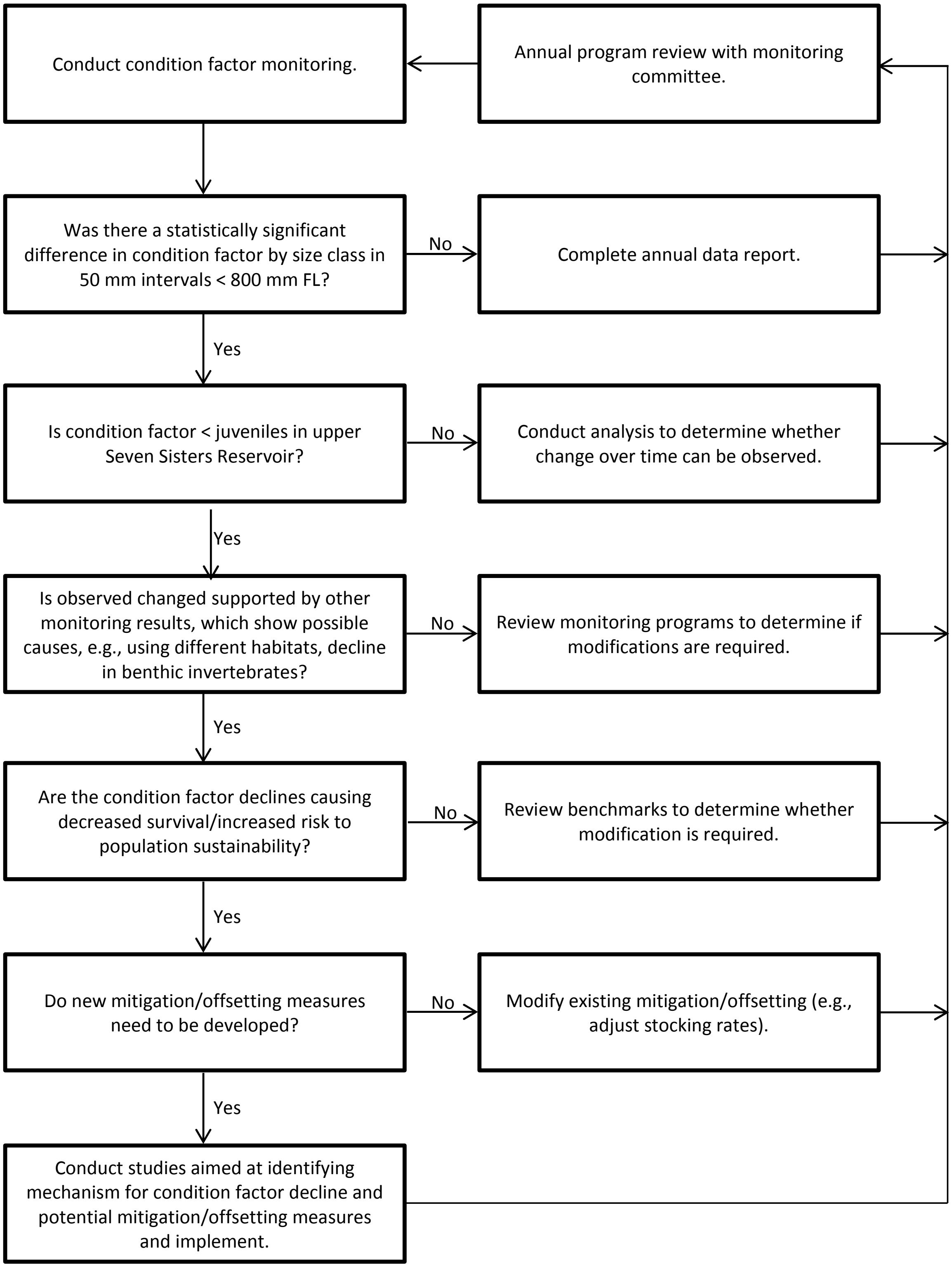


Figure 6-12: Lake Sturgeon juvenile condition factor.

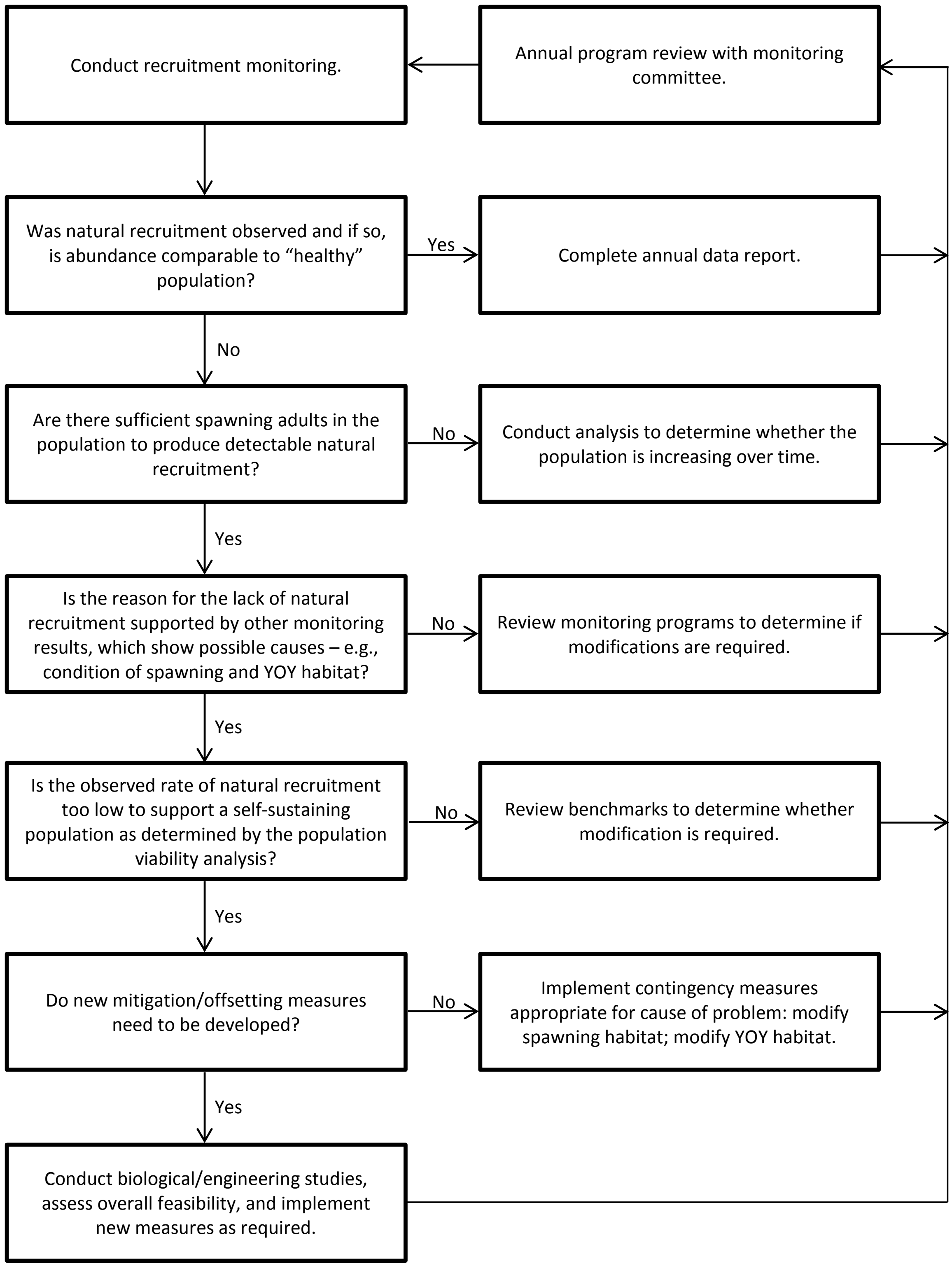


Figure 6-13: Lake Sturgeon natural recruitment.

Year

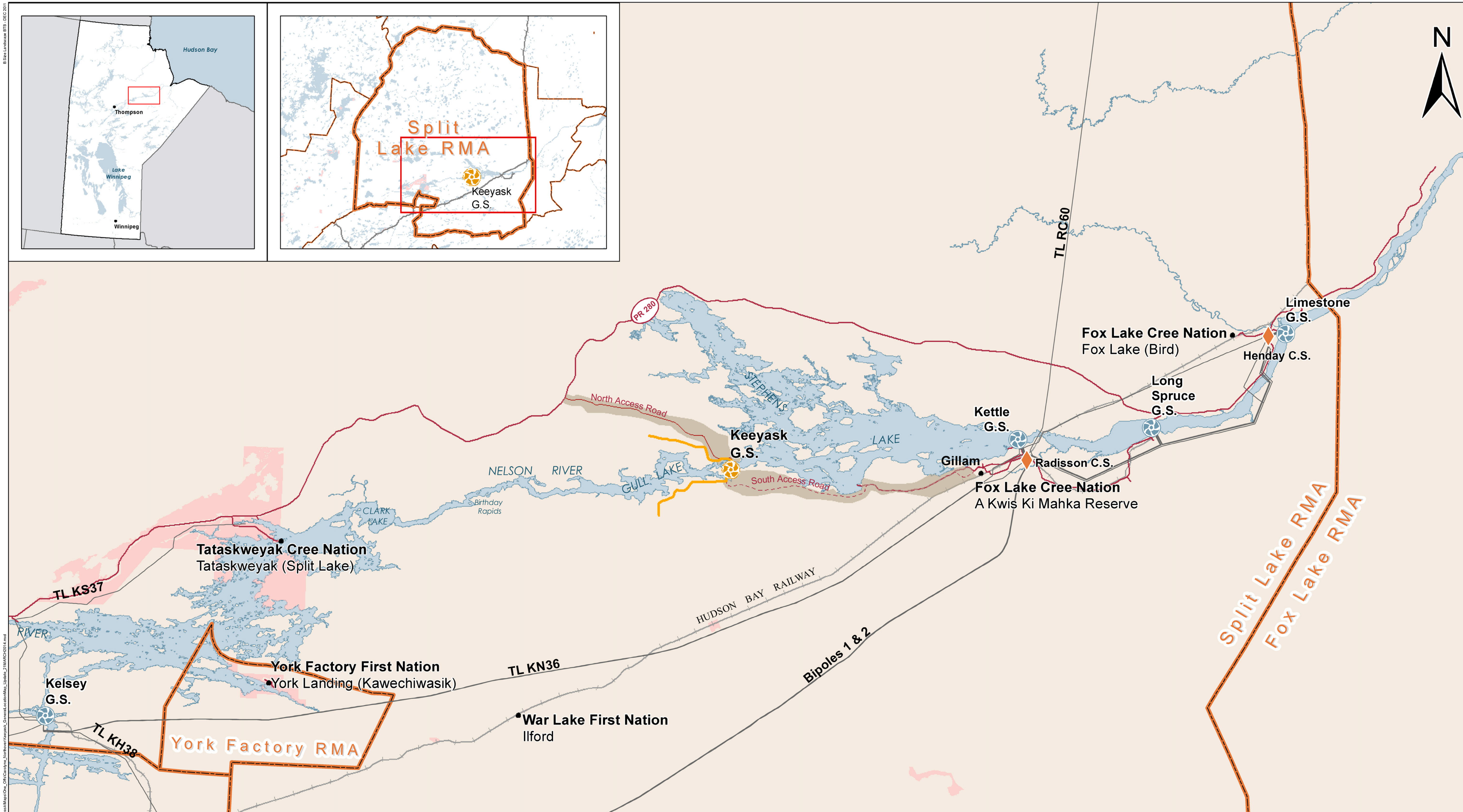
	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Project																			
Offsetting / Mitigation																			
Tree clearing	■	■																	
Monitoring																			
Gull Lake / Keeyask Reservoir							+	+	+	+	+	+[a]			+			+	
Stephens Lake - South		+[1]			+[1]		+	+[1]	+	+	+[1]	+[a]		+[1]			+[1]		
Split Lake			+[1]			+[1]	+[c]	+[c]	+[1]			+[1]			+[1]			+[1]	
Aiken River		+[2]			+[2]			+[2]			+[2]			+[2]			+[2]		
Longspruce Forebay											(+)	(+)	(+)[a]			(+)			(+)

	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Project																		
Offsetting / Mitigation																		
Tree clearing																		
Monitoring																		
Gull Lake / Keeyask Reservoir		+			+			+			+			+			+[b]	
Stephens Lake - South	+[1]			+[1]			+[1]			+[1]			+[1,b]			+[1]		
Split Lake		+[1]			+[1]			+[1]			+[1]			+[1]			+[1]	
Aiken River	+[2]			+[2]			+[2]			+[2]			+[2]			+[2]		
Longspruce Forebay			(+)			(+)			(+)			(+)						

Notes:
Grey shading indicates the year during which Keeyask reservoir will reach full supply level.
a. Assumed attainment of maximum fish mercury concentrations post-Project.
b. Assumed attainment of pre-Project mercury concentrations or concentrations that are stable at post-impoundment background levels.
c. AEMP monitoring because CAMP has no scheduled monitoring during the first two years post-flooding.
1. Ongoing monitoring carried out under CAMP; note that CAMP monitoring sites for fish mercury are all located in the south basin of the Stephens Lake.
2. Ongoing monitoring carried out due to request by War Lake First Nation and York Factory First Nation.
( ) Assumes that maximum predicted mercury concentrations in fish from Stephens Lake have been exceeded by more than 10%.

Figure 7-1: Planned schedule for mercury in fish flesh monitoring during Keeyask Generating Station construction (2014-2019); commissioning (2020); and operation (2021+). Plus = conduct monitoring activity; heavy line = end of AEMP.

10.0 MAPS



KEEYASK
Hydropower Limited Partnership

DATA SOURCE:
Manitoba Hydro; Government of Manitoba; Government of Canada

CREATED BY:
Manitoba Hydro - Hydro Power Planning - GIS & Special Studies

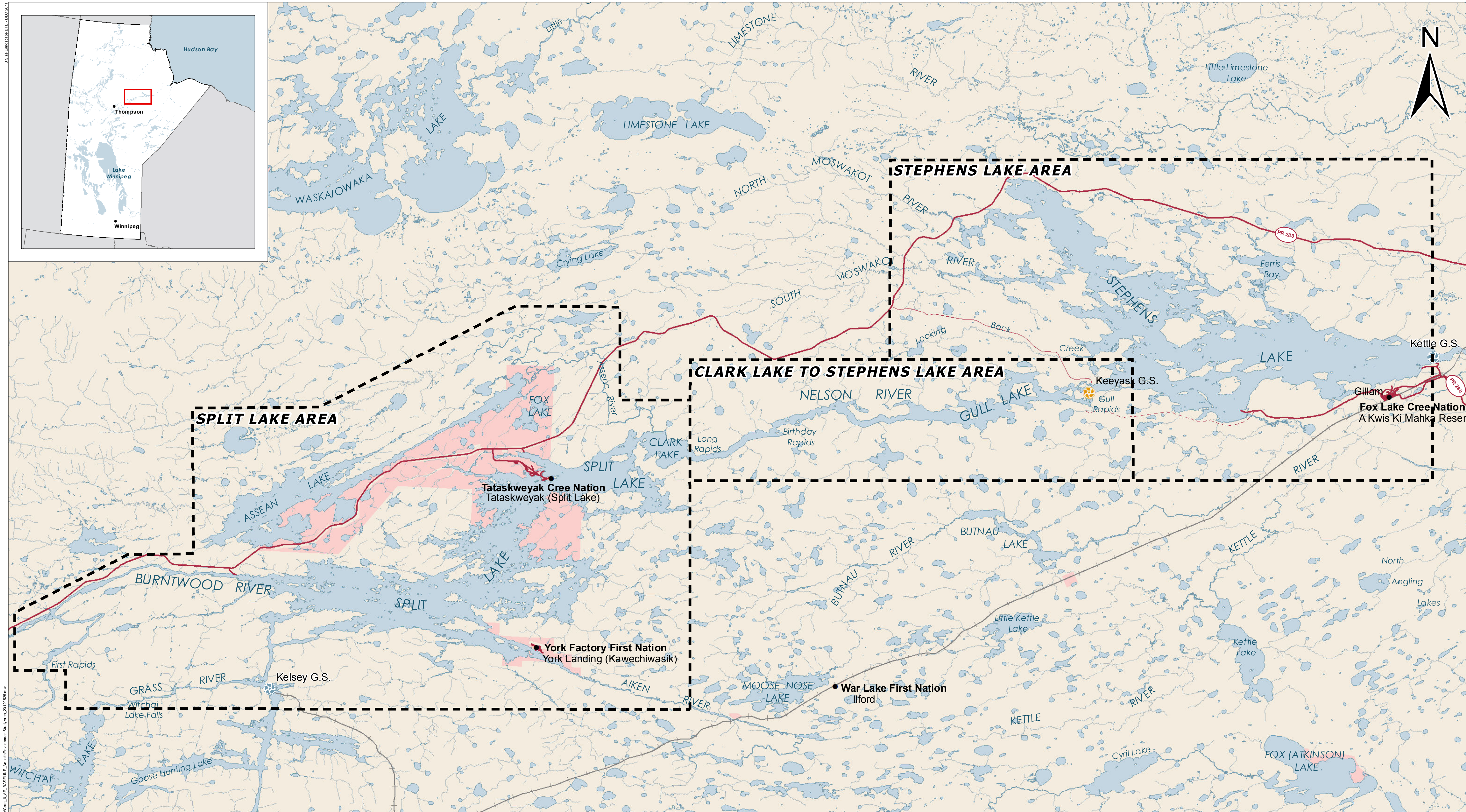
COORDINATE SYSTEM:	DATE CREATED:	REVISION DATE:
UTM NAD 1983 Z15N	03-AUG-11	21-MAR-14
0 5 10 Kilometres / 0 4 8 Miles	VERSION NO: 2.0	QA/QC: JCL/YYY/ZZZ

Legend

- Generating Station (Existing)
- Keeyask Generating Station
- Converter Station
- Keeyask Principal Structures
- Highway
- Access Road
- South Access Road
- Rail
- Transmission Line
- Proposed Road Corridor
- First Nation Reserve
- Resource Management Area

General Project Location

Map 1-1



Legend

- Area Boundary
- Generating Station (Construction)
- Generating Station (Existing)
- First Nation Community
- Highway
- Access Road
- Proposed Access Road
- Rail
- First Nation Reserve
- Waterbody

KEEYASK Hydropower Limited Partnership

DATA SOURCE: Government of Canada, North/South Consultants		
CREATED BY: North/South Consultants		
COORDINATE SYSTEM: UTM NAD 1983 Z15N	DATE CREATED: 26-FEB-10	REVISION DATE: 25-MAY-12
0 4 8 Kilometres / 0 3.5 7 Miles	VERSION NO: 2.0	QA/QC: PMC/FSV/MWZ

Aquatic Environment Study Area

Map 1-2

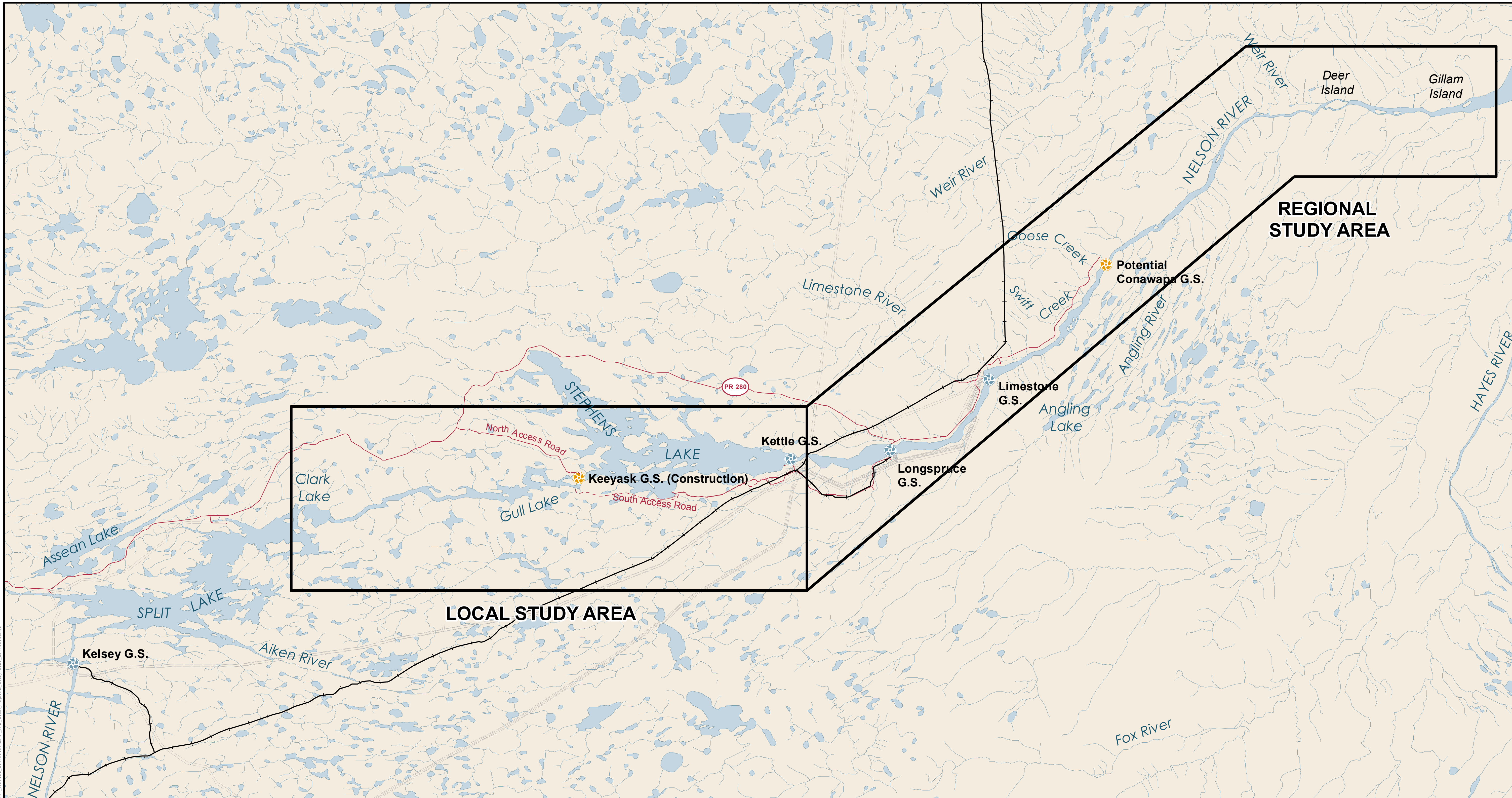
KEEYASK
Hydropower Limited Partnership

0 25 50 Kilometres
0 10 20 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:500 000

Baseline Water Quality Sampling Sites

Map 2-1



KEEYASK Hydropower Limited Partnership

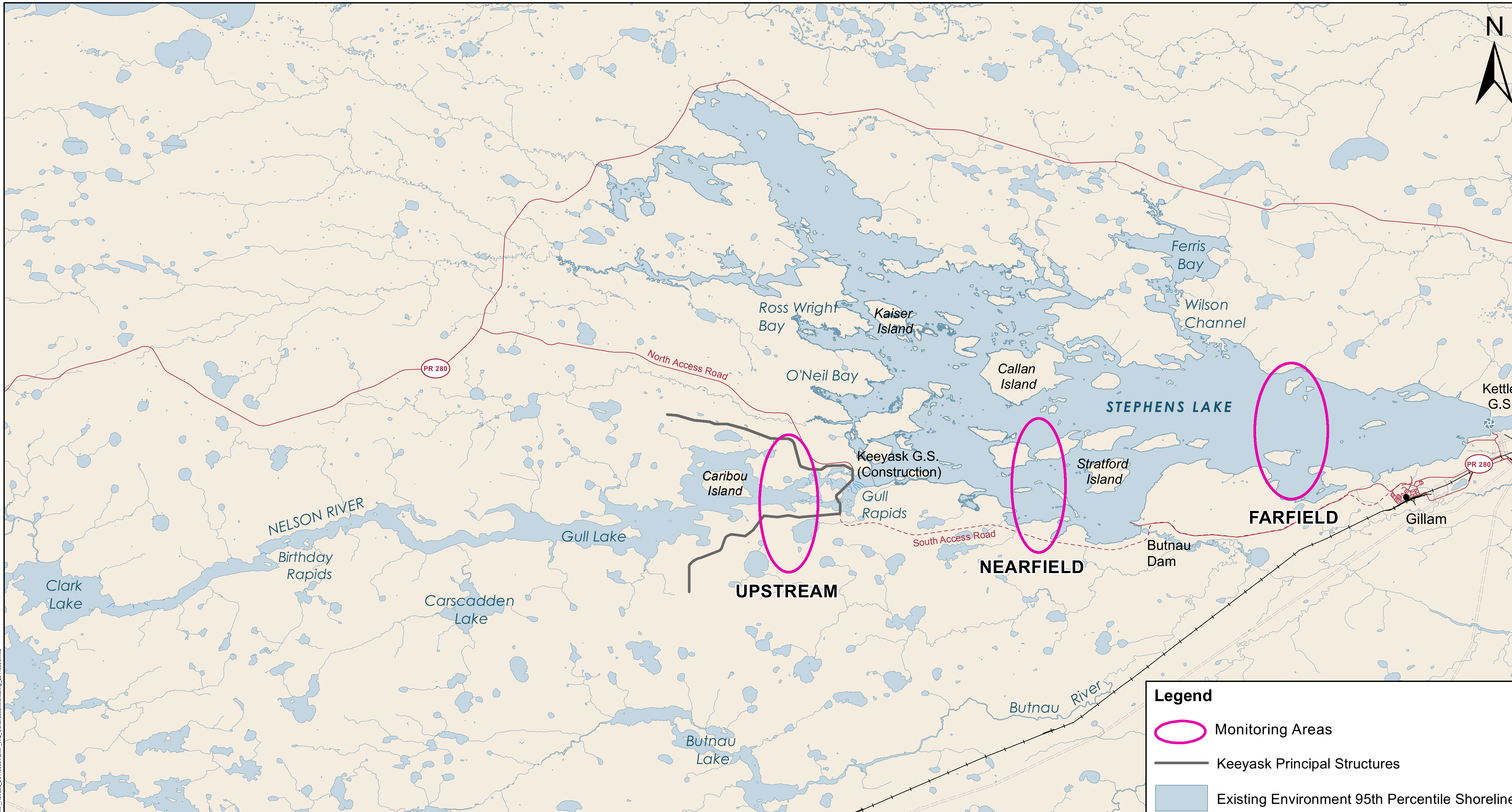
0 25 50 Kilometres

0 10 20 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:500 000

Water Quality
Local and Regional Study Areas

Map 2-2



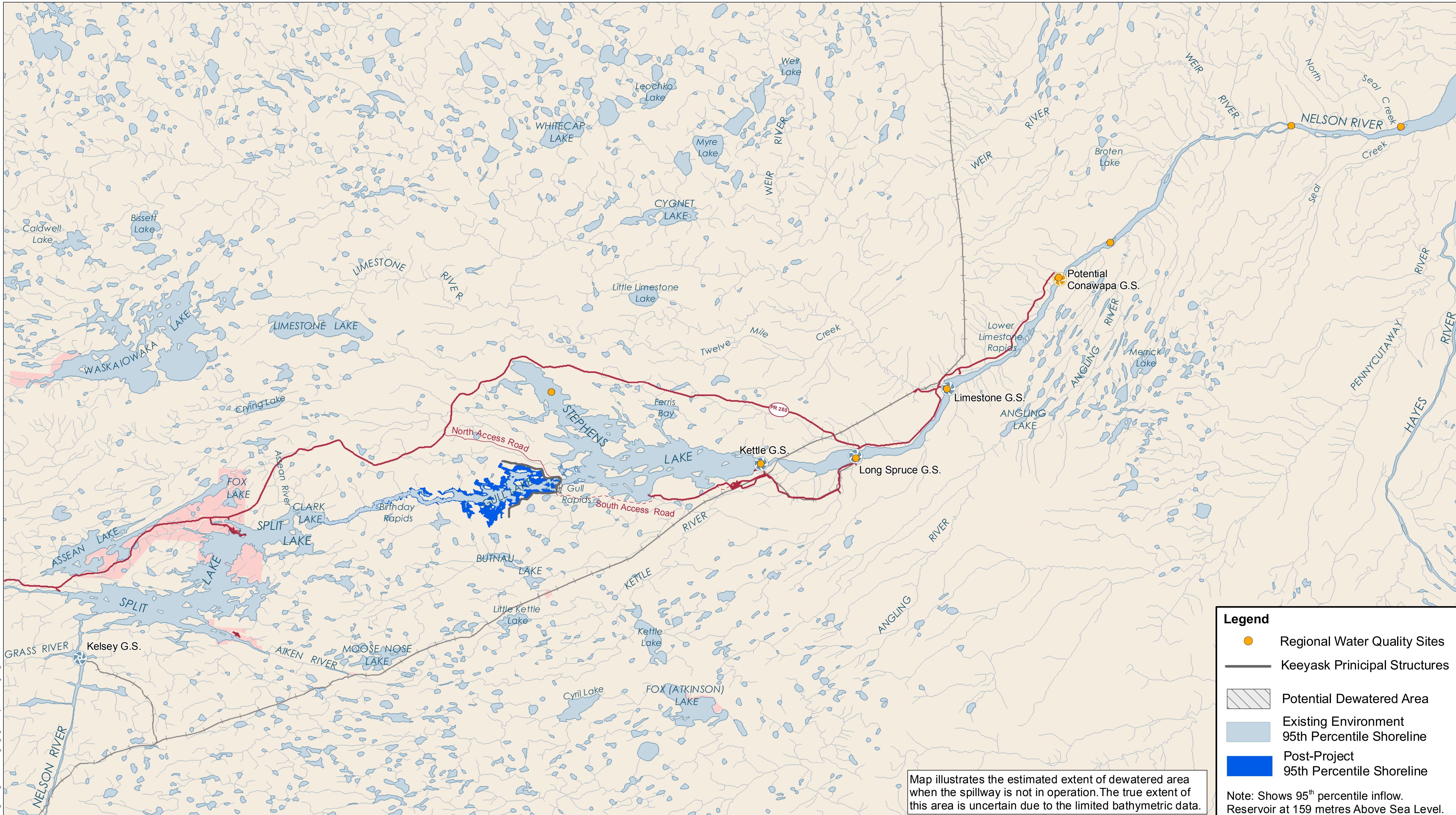
KEEYASK
Hydropower Limited Partnership

0 5 10 15 Kilometres
0 2 4 6 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000,
Stephens Lake Shoreline-Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro

Water Quality Construction Monitoring
Local Study Area

Map 2-3



KEEYASK Hydropower Limited Partnership

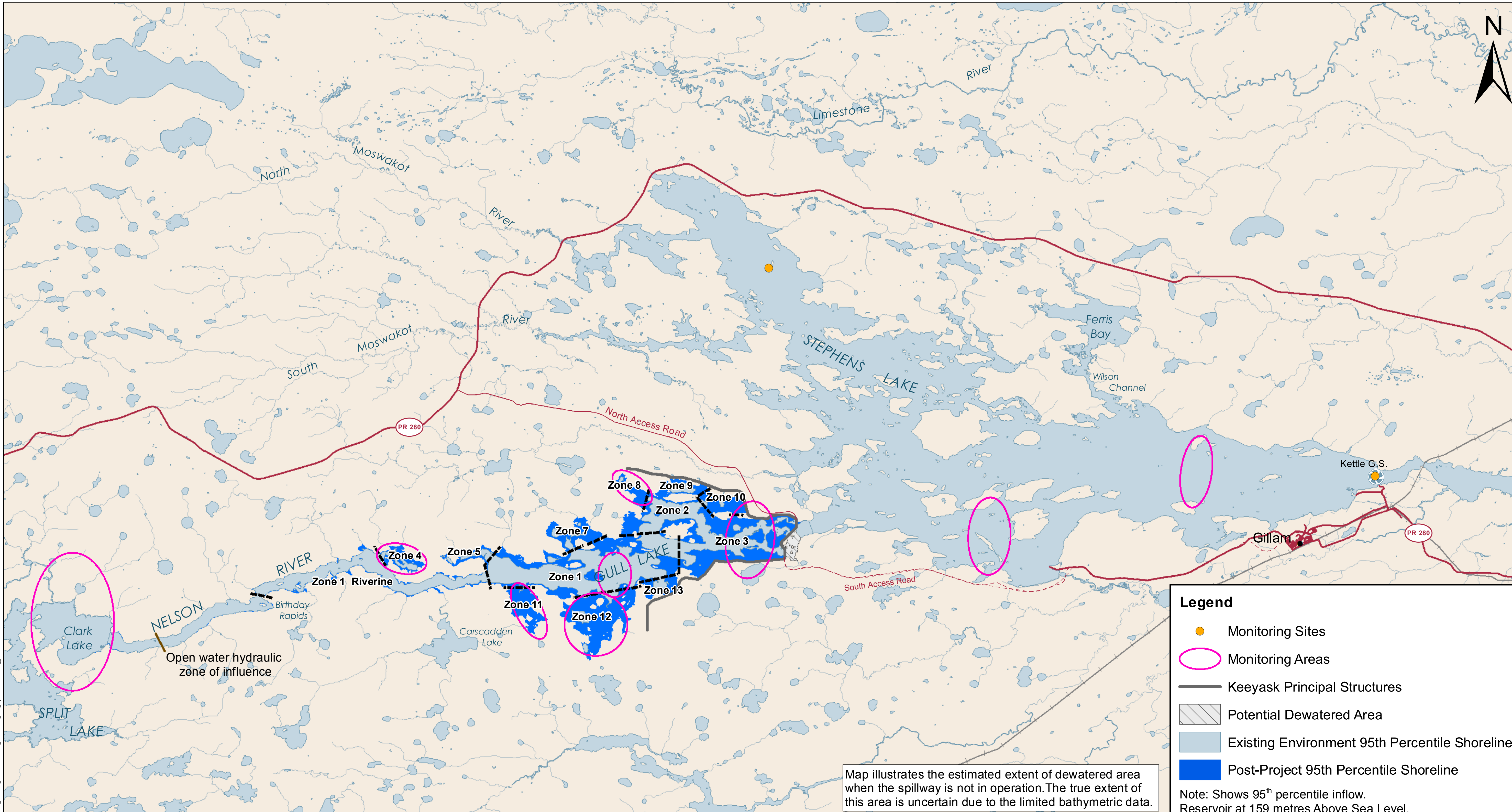
0 10 20 30 40 Kilometres

0 5 10 15 20 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:500 000

Water Quality Regional Study Area Monitoring Sites

Map 2-4



KEEYASK
Hydropower Limited Partnership

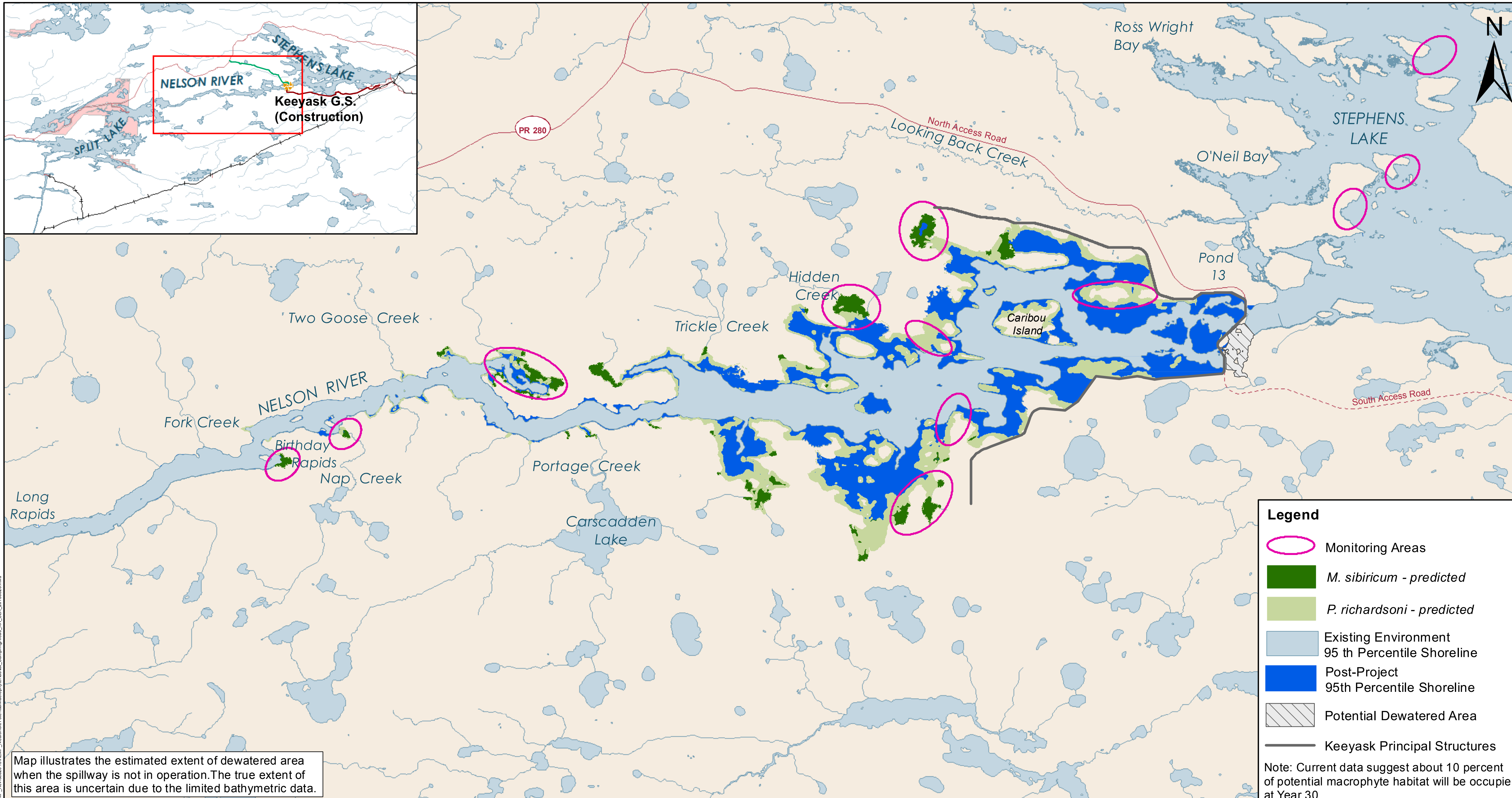
0 25 50 75 100 Kilometres
0 25 50 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Nelson River Shoreline modelled by Manitoba Hydro.
Extents of dewatered area are estimated based on the existing environment 95th percentile flow.

Water Quality Operation Monitoring

Local Study Area

Map 2-5



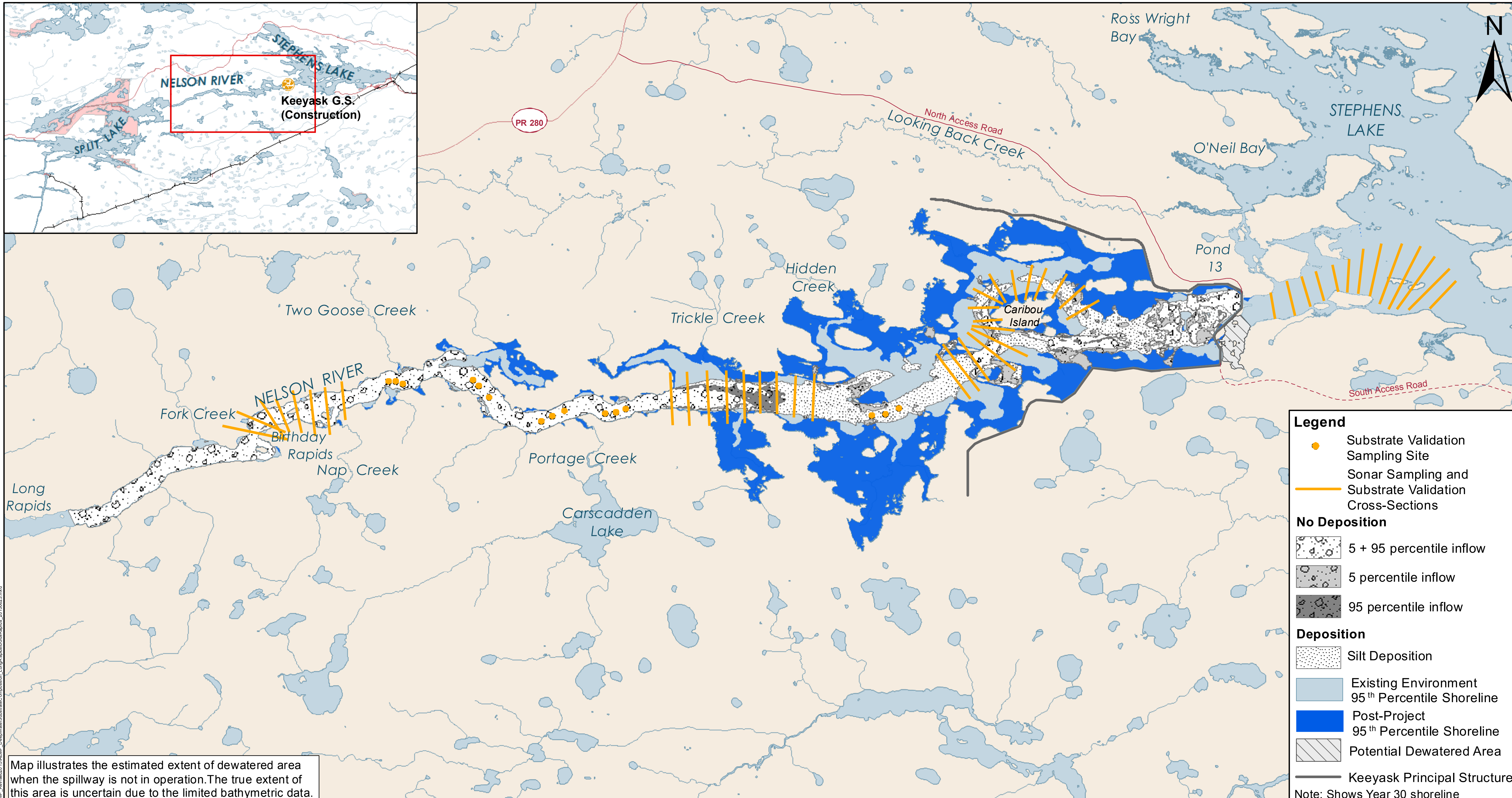
KEEYASK
Hydropower Limited Partnership

0 2.5 5 7.5 10 Kilometres
0 1.25 2.5 3.75 5 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Stephens Lake Shoreline - Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro.
Extents of dewatered area are estimated based on the existing environment 95th percentile flow.

Macrophyte Habitat Monitoring Areas

Map 3-1



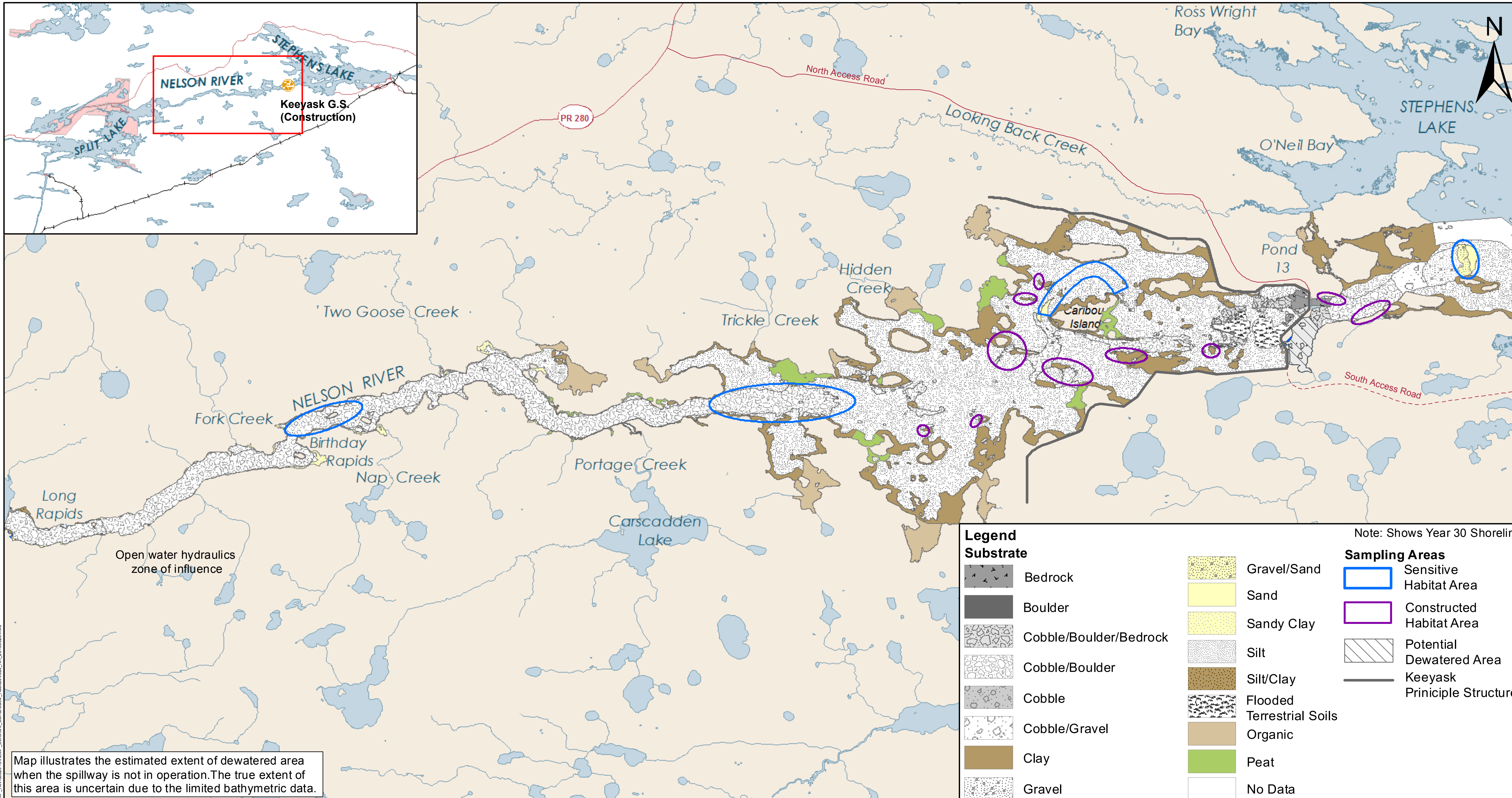
KEEYASK
Hydropower Limited Partnership

0 2.5 5 7.5 10 Kilometres
0 1.25 2.5 3.75 5 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Stephens Lake Shoreline - Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro.
Extents of dewatered area are estimated
based on the existing environment 95th percentile flow.

Deep Water Substrate Composition Monitoring

Map 3-2



KEEYASK Hydropower Limited Partnership

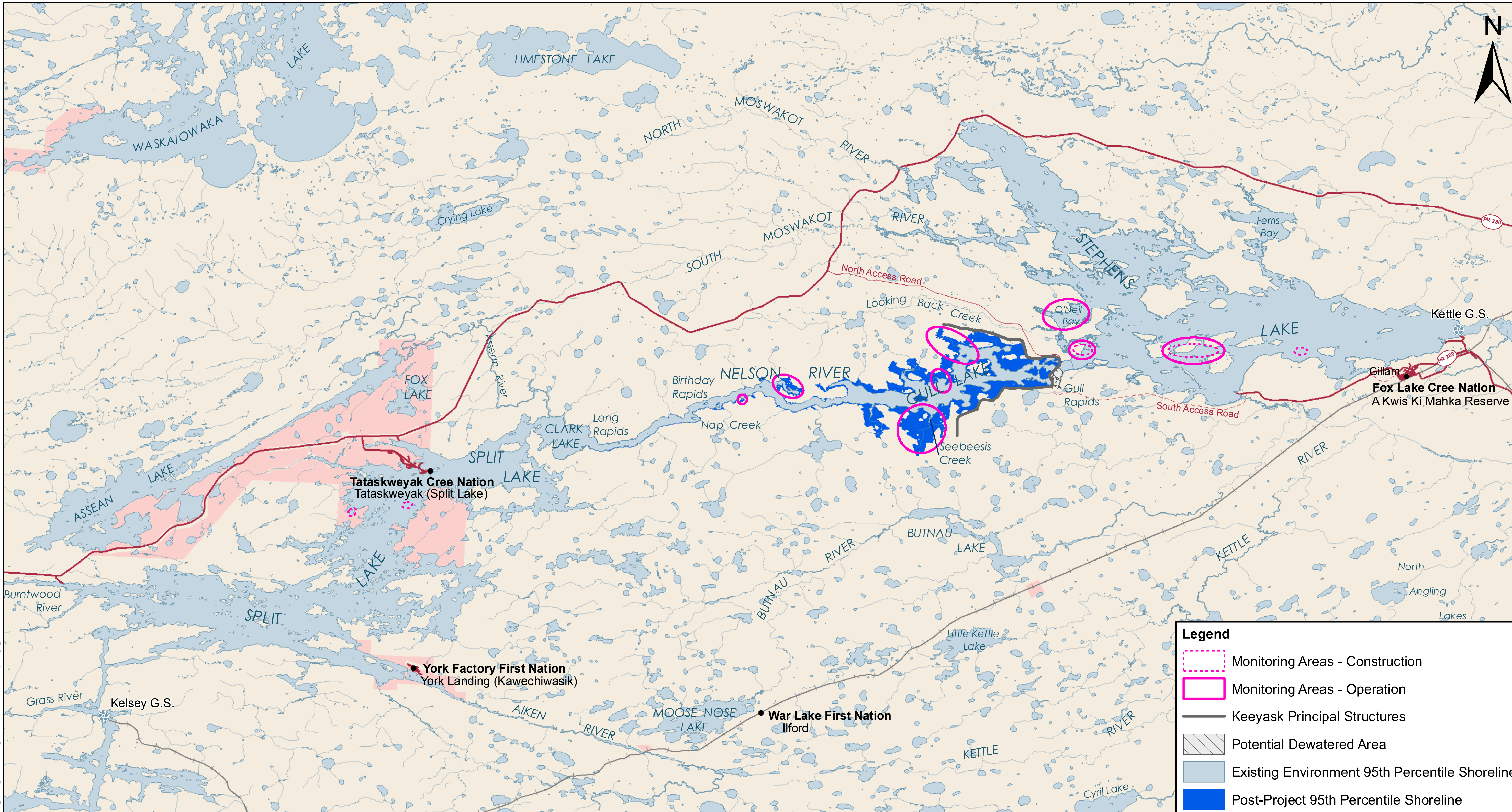
0 2.5 5 7.5 10 Kilometres

0 1.25 2.5 3.75 5 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Stephens Lake Shoreline - Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro.
Extents of dewatered area are estimated based on the existing environment 95th percentile flow.

Sensitive and Constructed Habitat Areas

Map 3-3

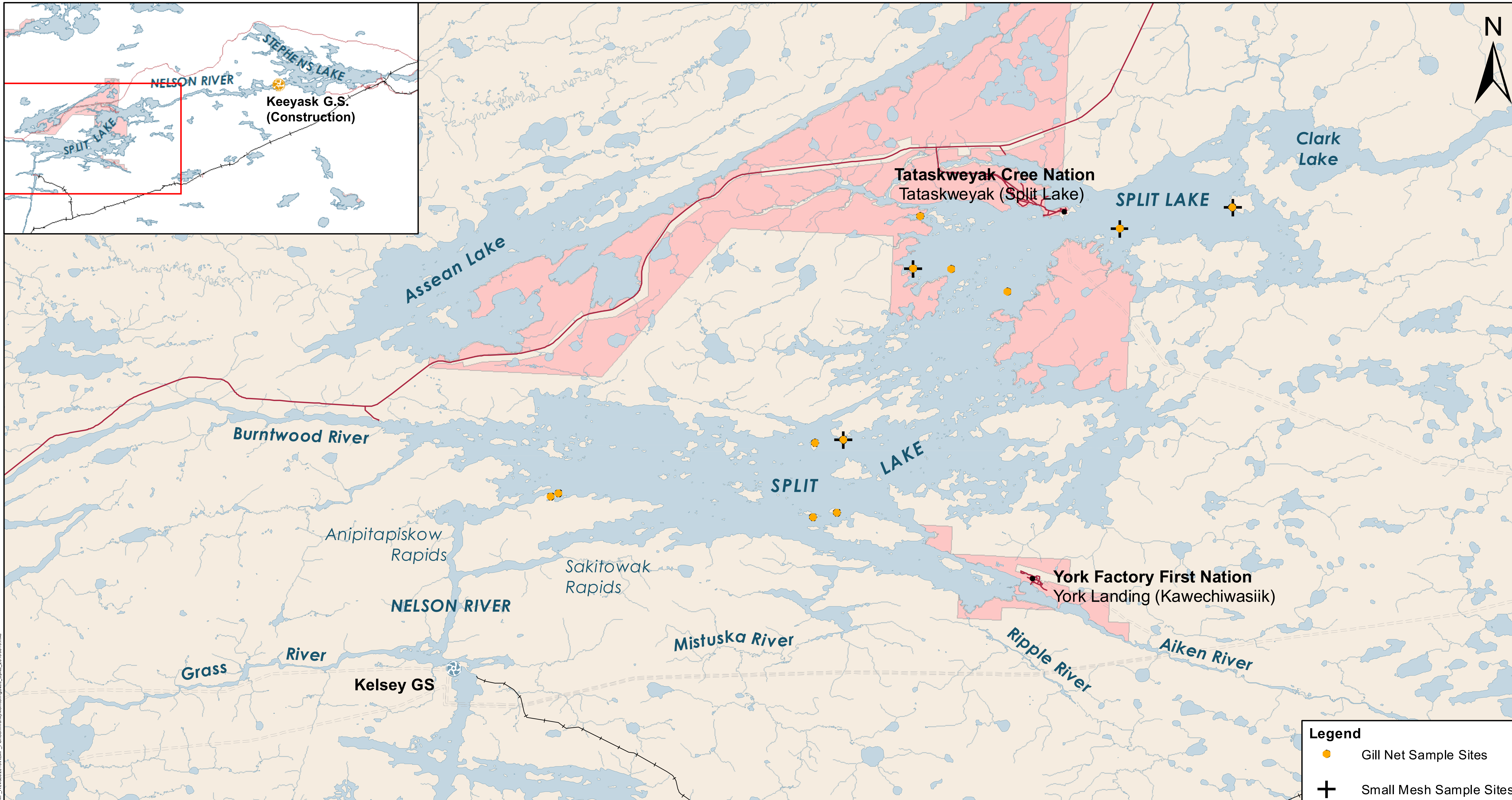


KEEYASK Hydropower Limited Partnership

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Nelson River Shoreline modelled by Manitoba Hydro.
Extents of dewatered area are estimated based on the existing environment 95th percentile flow.

Benthic Macroinvertebrate Monitoring Areas

Map 4-1



KEEYASK
Hydropower Limited Partnership

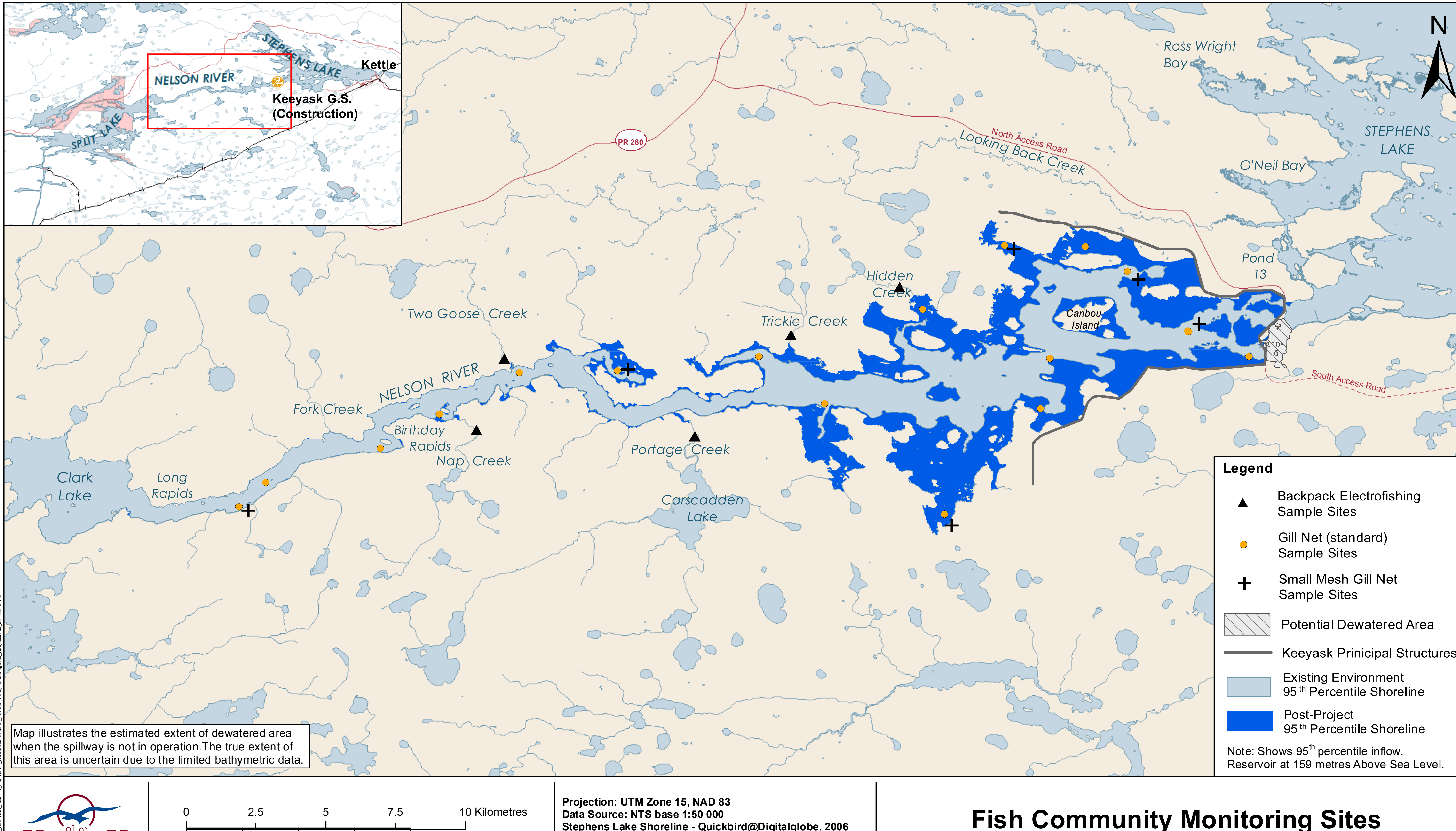
0 3 6 12 Kilometres

0 1.5 3 6 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000

Fish Community Monitoring Sites
Split Lake Area

Map 5-1

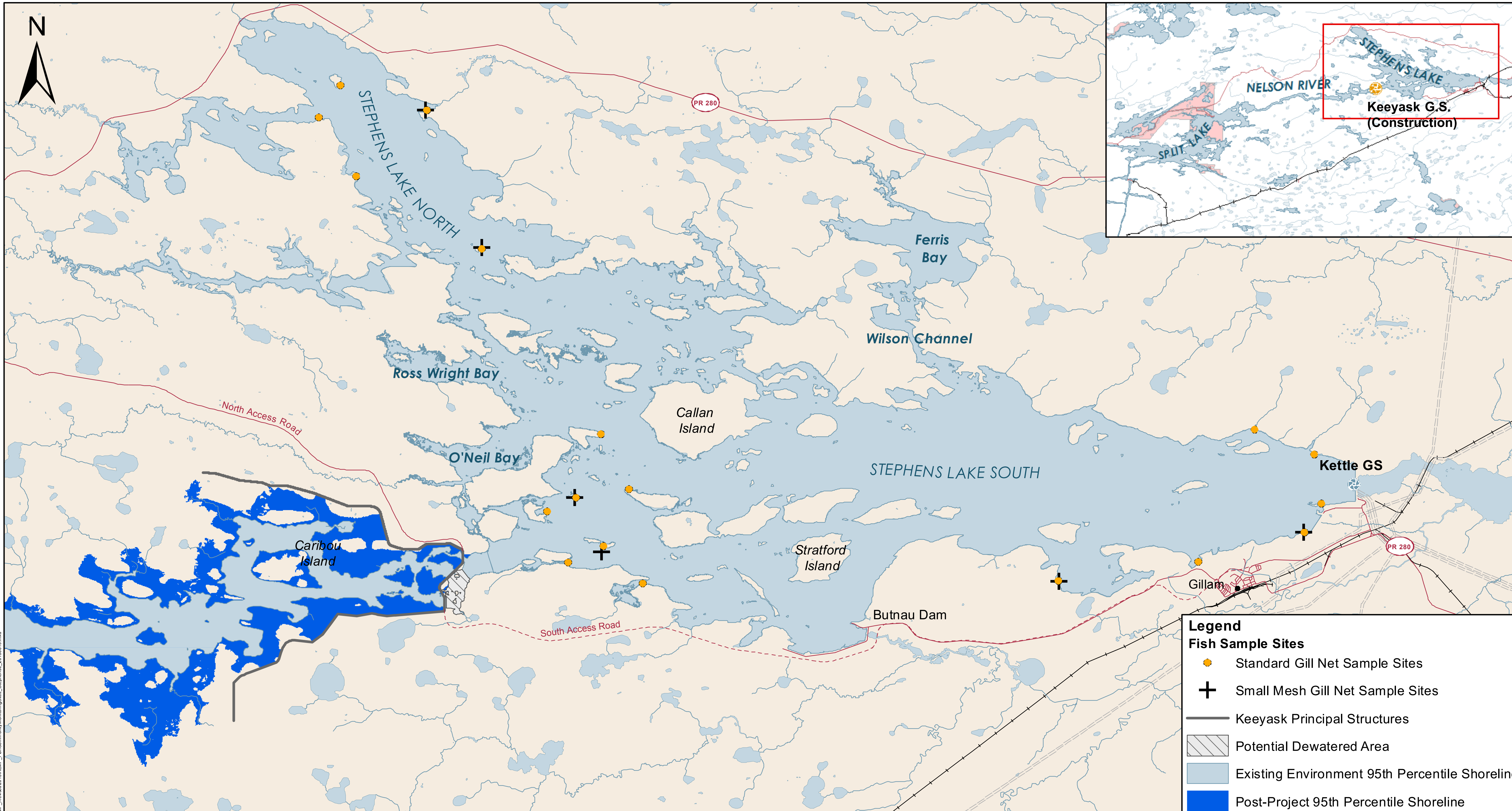


Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Stephens Lake Shoreline - Quickbird@Digitalglobe, 2006
Nelson River Shoreline (95th percentile inflow) modelled by Manitoba Hydro. Extents of dewatered area are estimated based on the existing environment 95th percentile inflow.

Fish Community Monitoring Sites

Keeyask Area

Map 5-2



KEEYASK Hydropower Limited Partnership

0 25 50 75 100 Kilometres

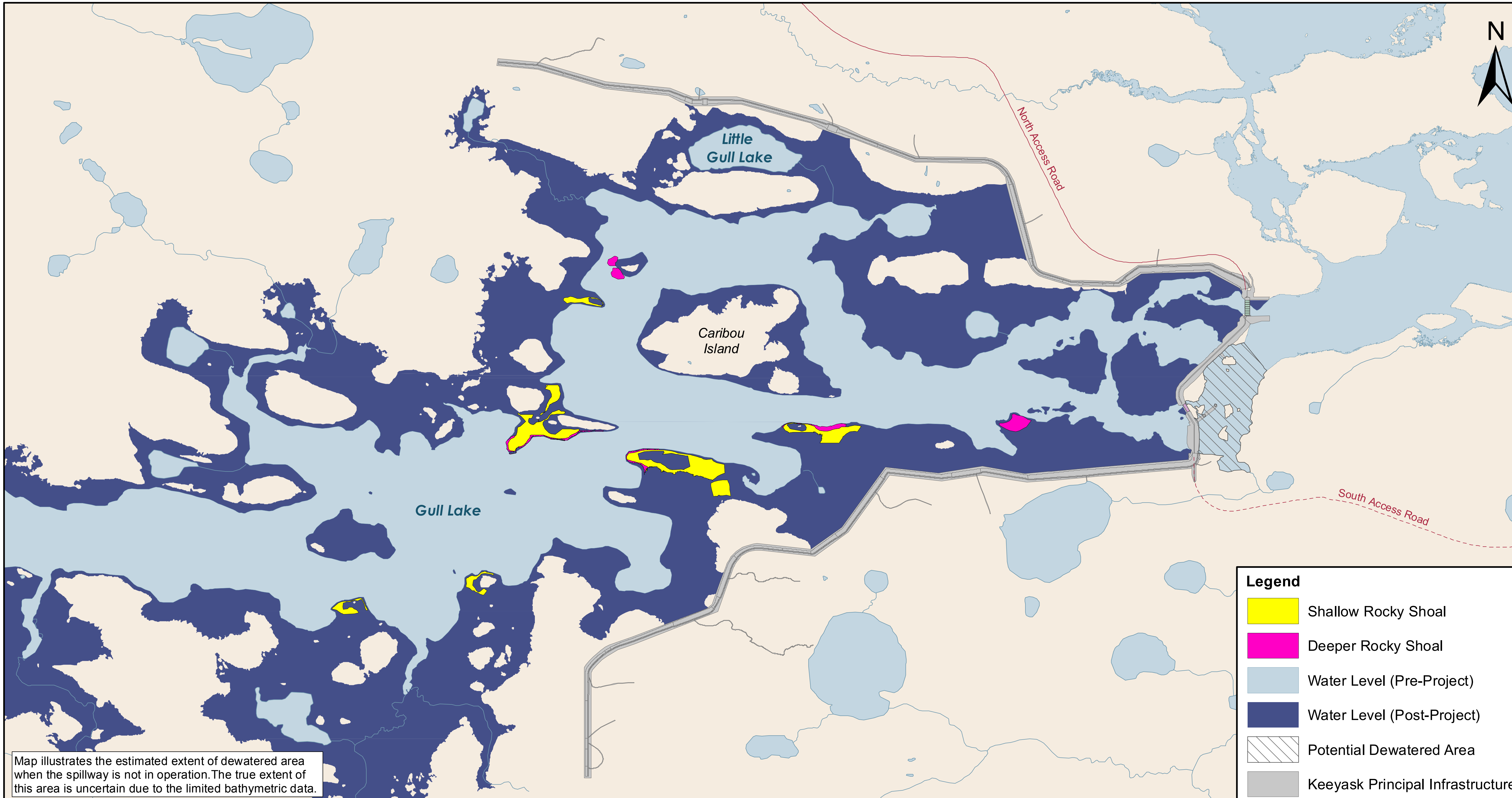
0 25 50 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Nelson River Shoreline modelled by Manitoba Hydro.
Extents of dewatered area are estimated based on the existing environment 95th percentile flow.

Fish Community Monitoring Sites

Stephens Lake Area

Map 5-3



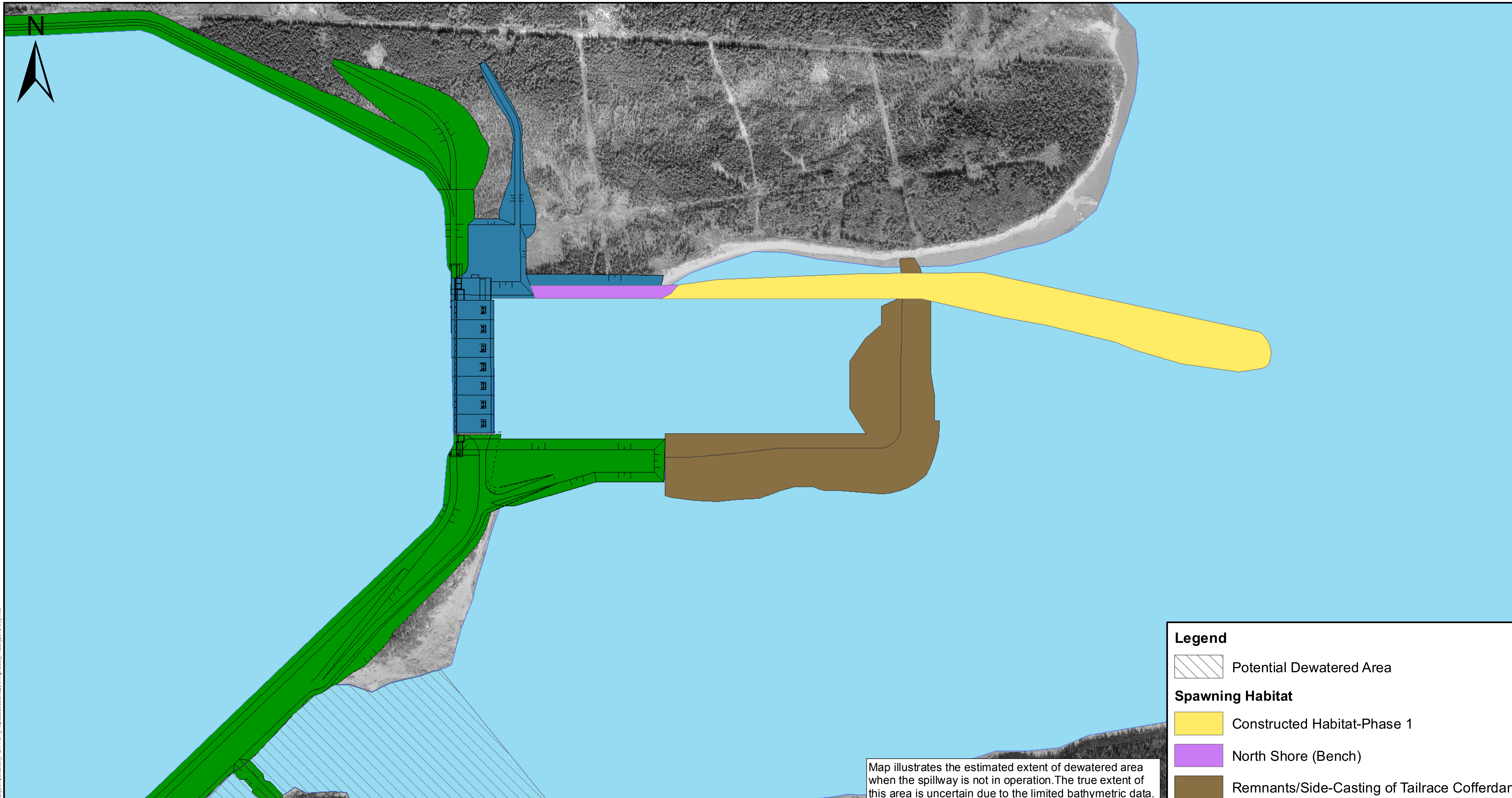
KEEYASK
Hydropower Limited Partnership

0 1 2 3 4 Kilometres
0 0.5 1 1.5 2 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Stephens Lake Shoreline - Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro
Extents of dewaterd area are estimated based on the existing environment 95th percentile flow.

Preferred Spawning Shoal Development Locations in the Keeyask Reservoir

Map 5-4

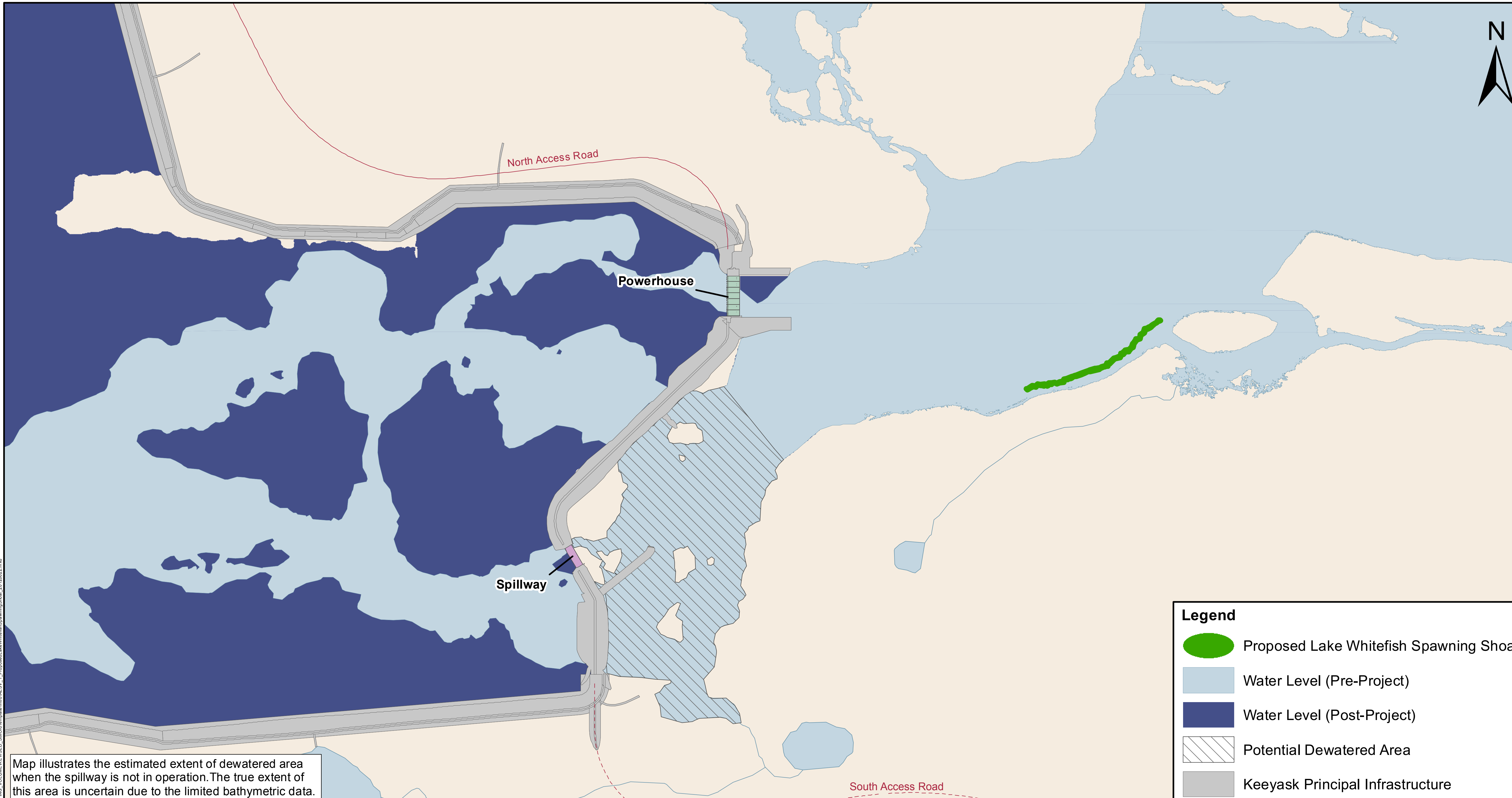


KEEYASK Hydropower Limited Partnership

0 100 200 300 400 Metres
0 250 500 750 1,000 Feet

Projection: UTM Zone 15, NAD 83
Data Source: Memorandum GN-9.8.18 Rev. 0, Figure 26
Extents of dewatered area are estimated based on the existing environment 95th percentile flow.

Proposed Location of Spawning Habitat
Phase 1

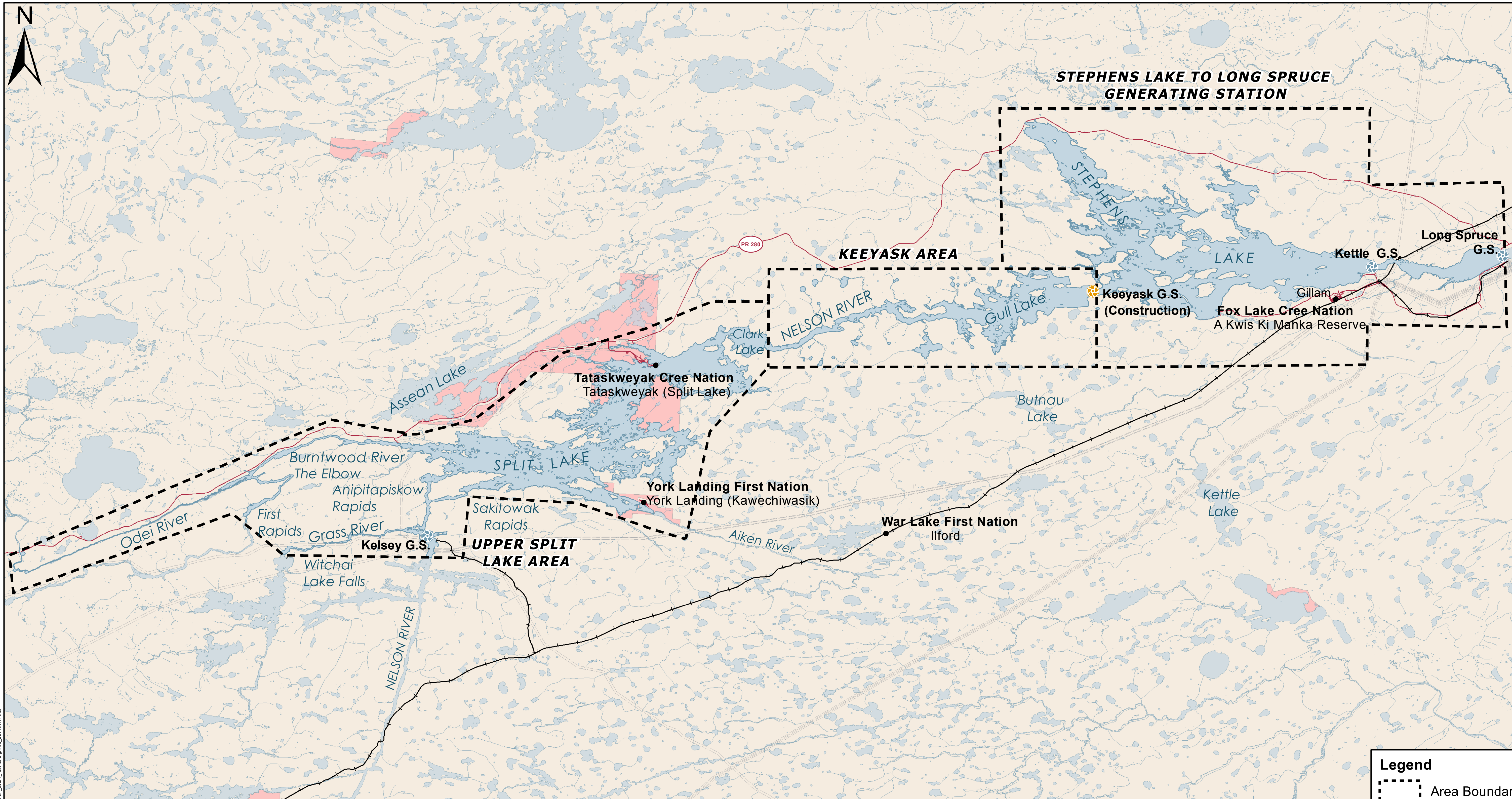


KEEYASK Hydropower Limited Partnership

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Stephens Lake Shoreline - Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro
Extents of dewaterd area are estimated based on the existing environment 95th percentile flow.

Proposed Lake Whitefish Spawning Shoal

Map 5-6



KEEYASK Hydropower Limited Partnership

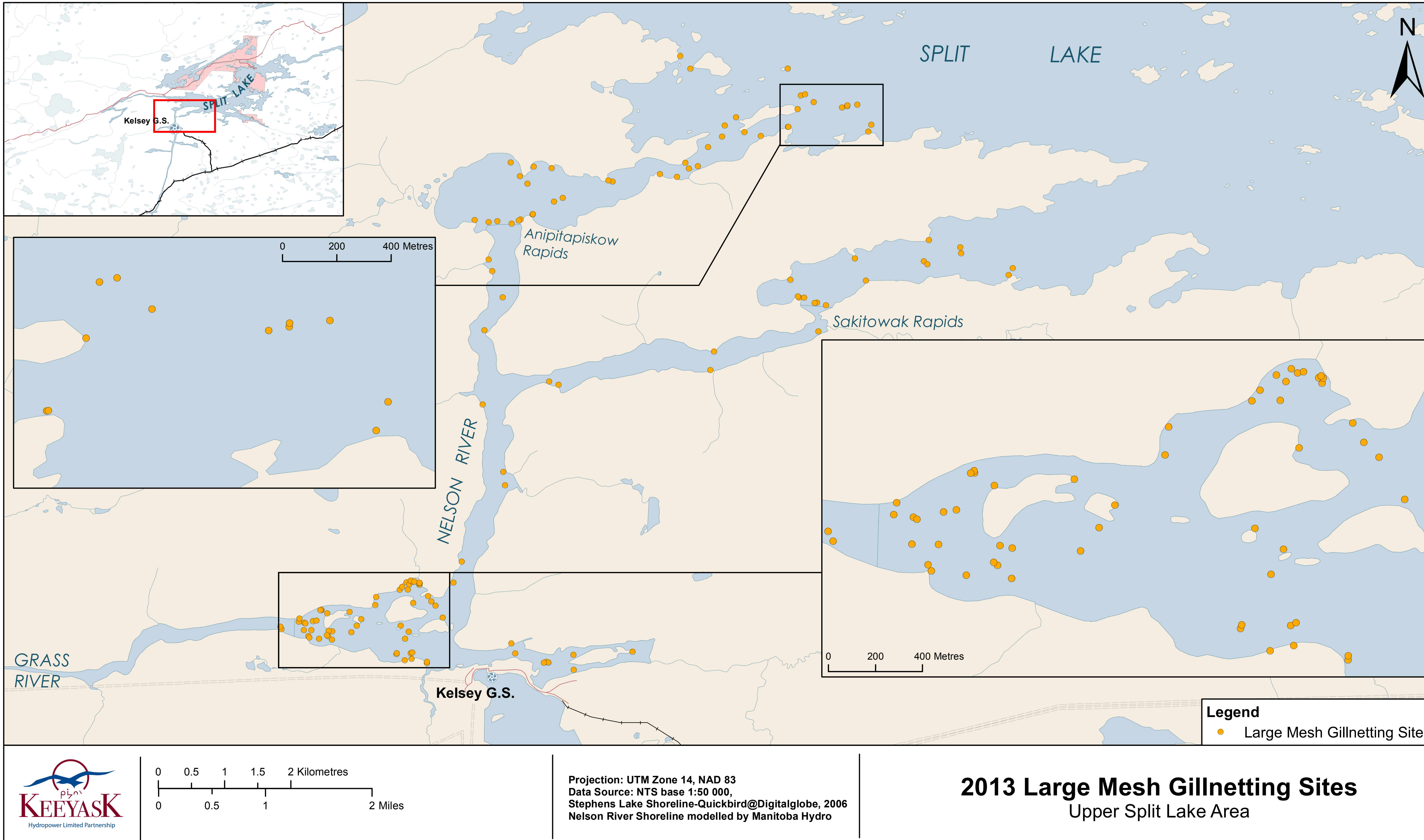
0 10 20 30 Kilometres

0 5 10 15 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000,
Stephens Lake Shoreline-Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro

Lake Sturgeon Monitoring Areas

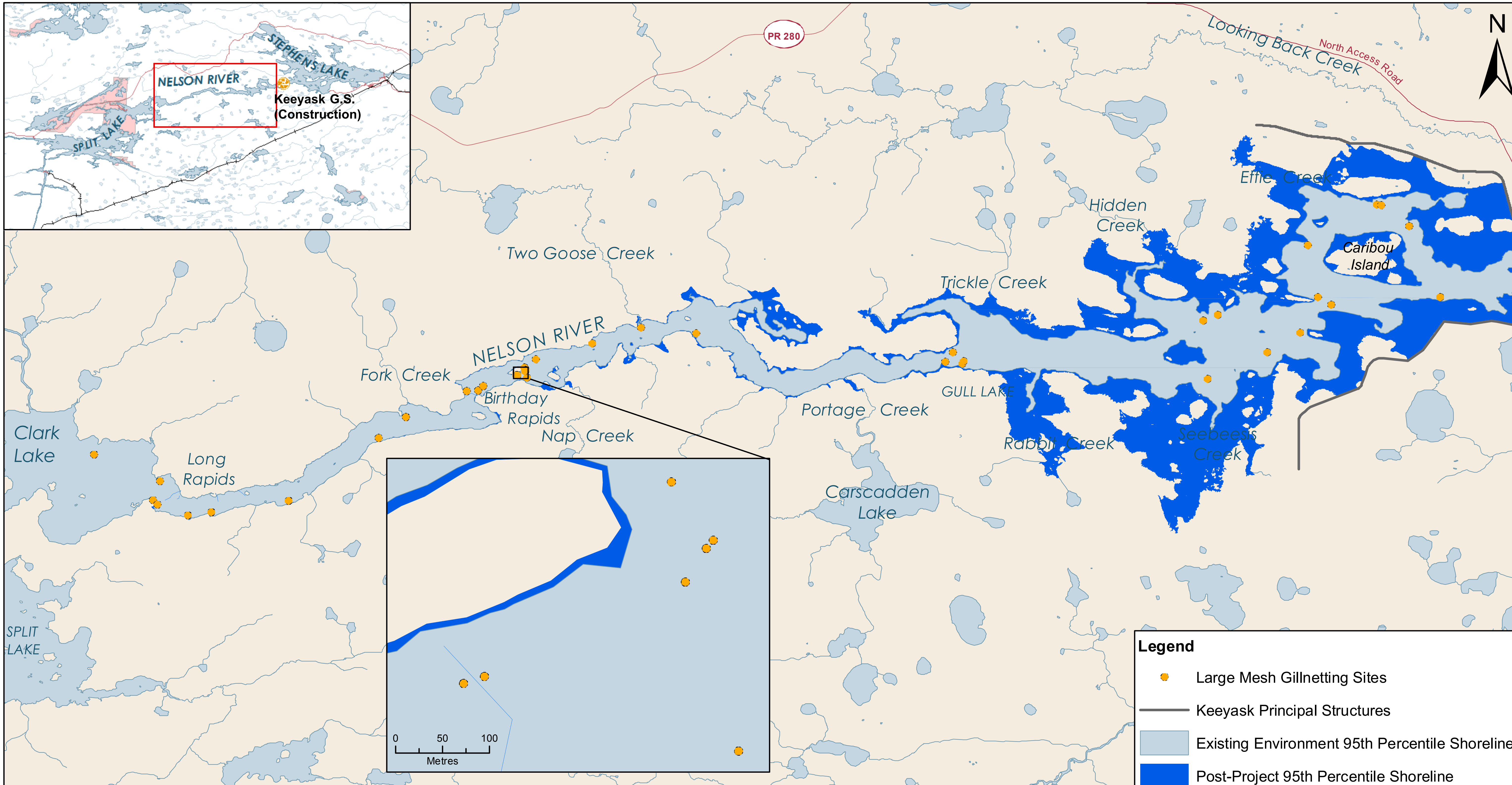
Map 6-1



2013 Large Mesh Gillnetting Sites

Upper Split Lake Area

Map 6-2



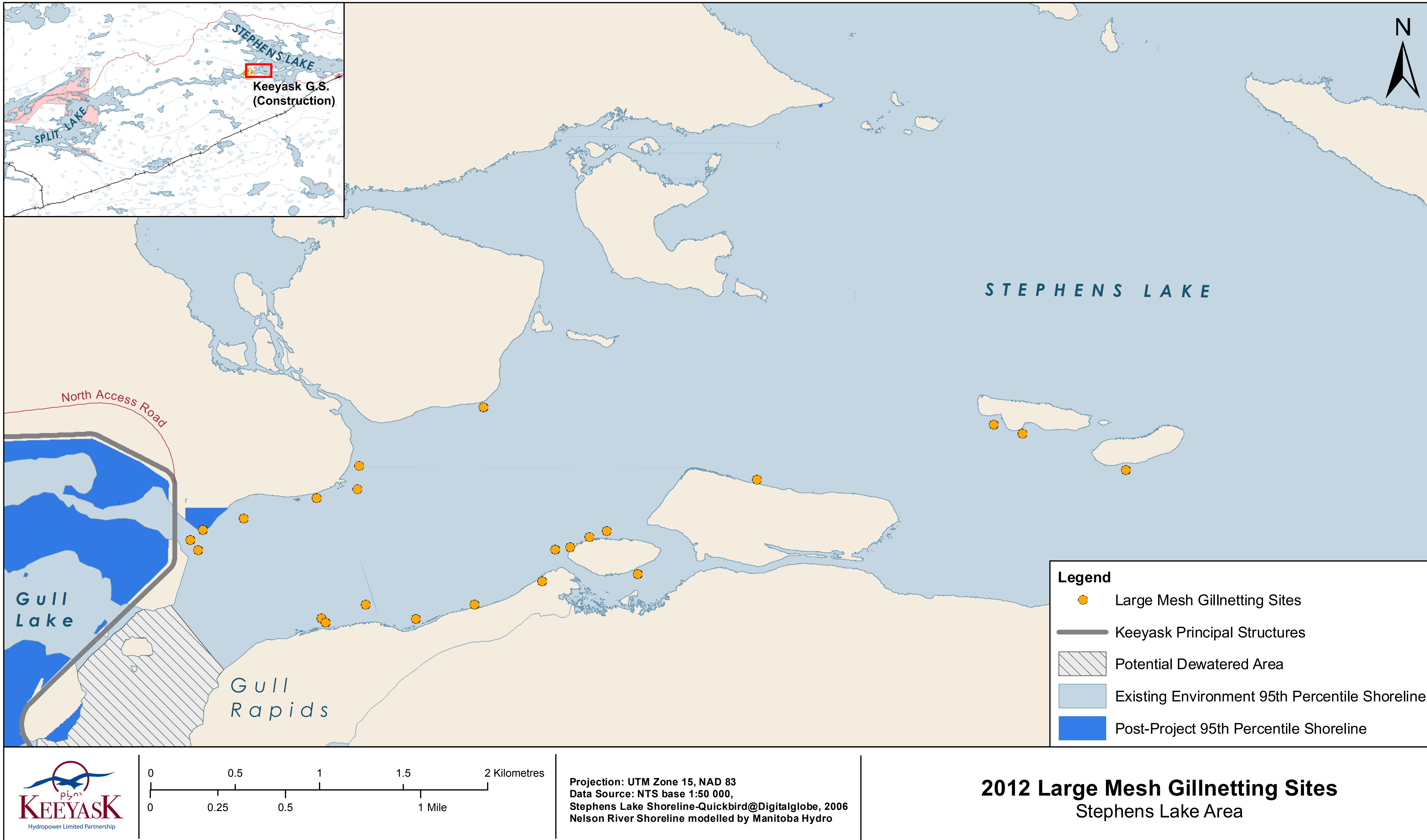
KEEYASK
Hydropower Limited Partnership

0 2 4 6 8 Kilometres
0 1 2 3 4 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000,
Stephens Lake Shoreline-Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro

2012 Large Mesh Gillnetting Sites
Keeyask Area

Map 6-3

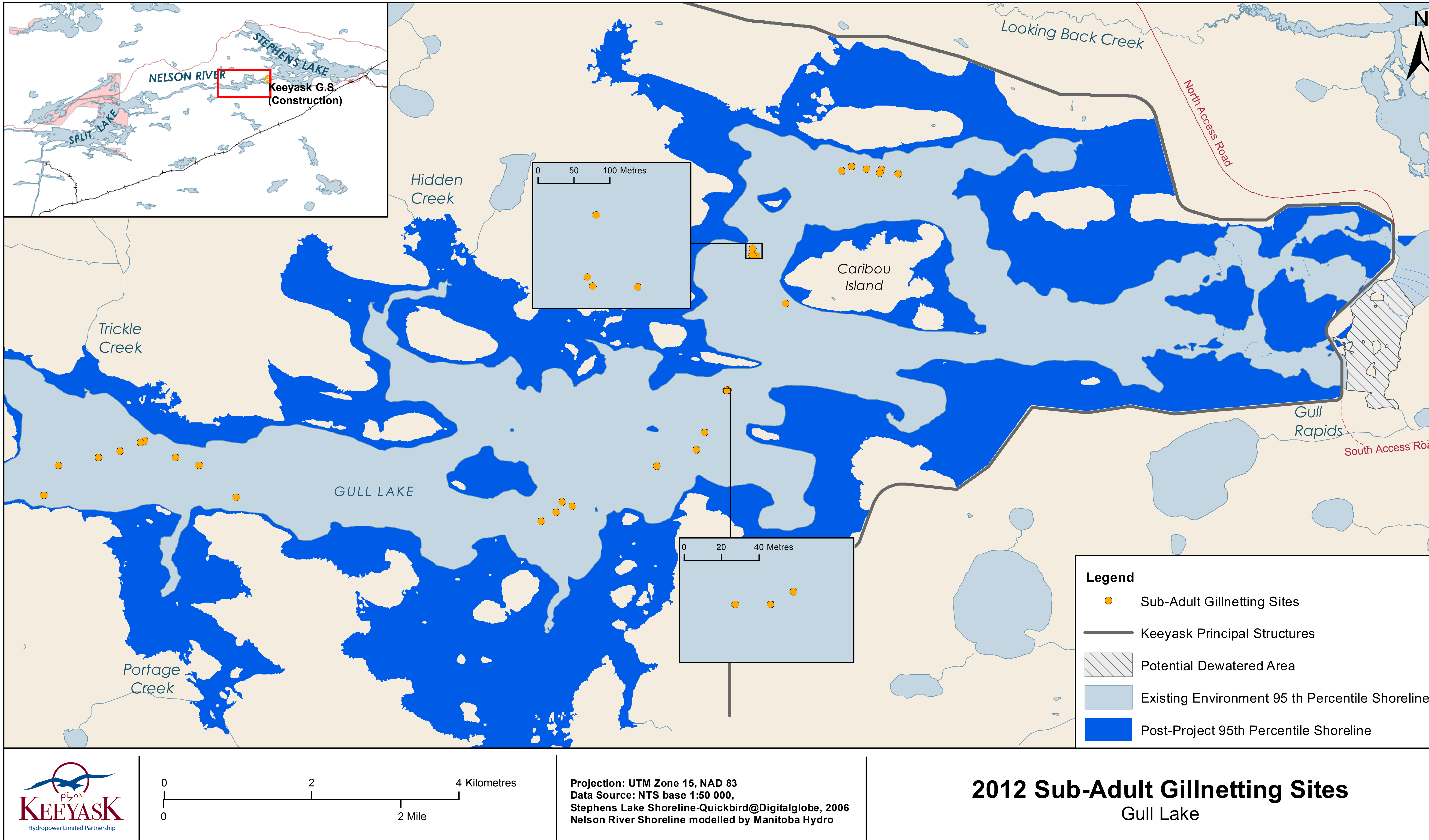


KEEYASK
Hydropower Limited Partnership

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000,
Stephens Lake Shoreline-Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro

2012 Large Mesh Gillnetting Sites
Stephens Lake Area

Map 6-4



Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000,
Stephens Lake Shoreline-Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro

2012 Sub-Adult Gillnetting Sites
Gull Lake

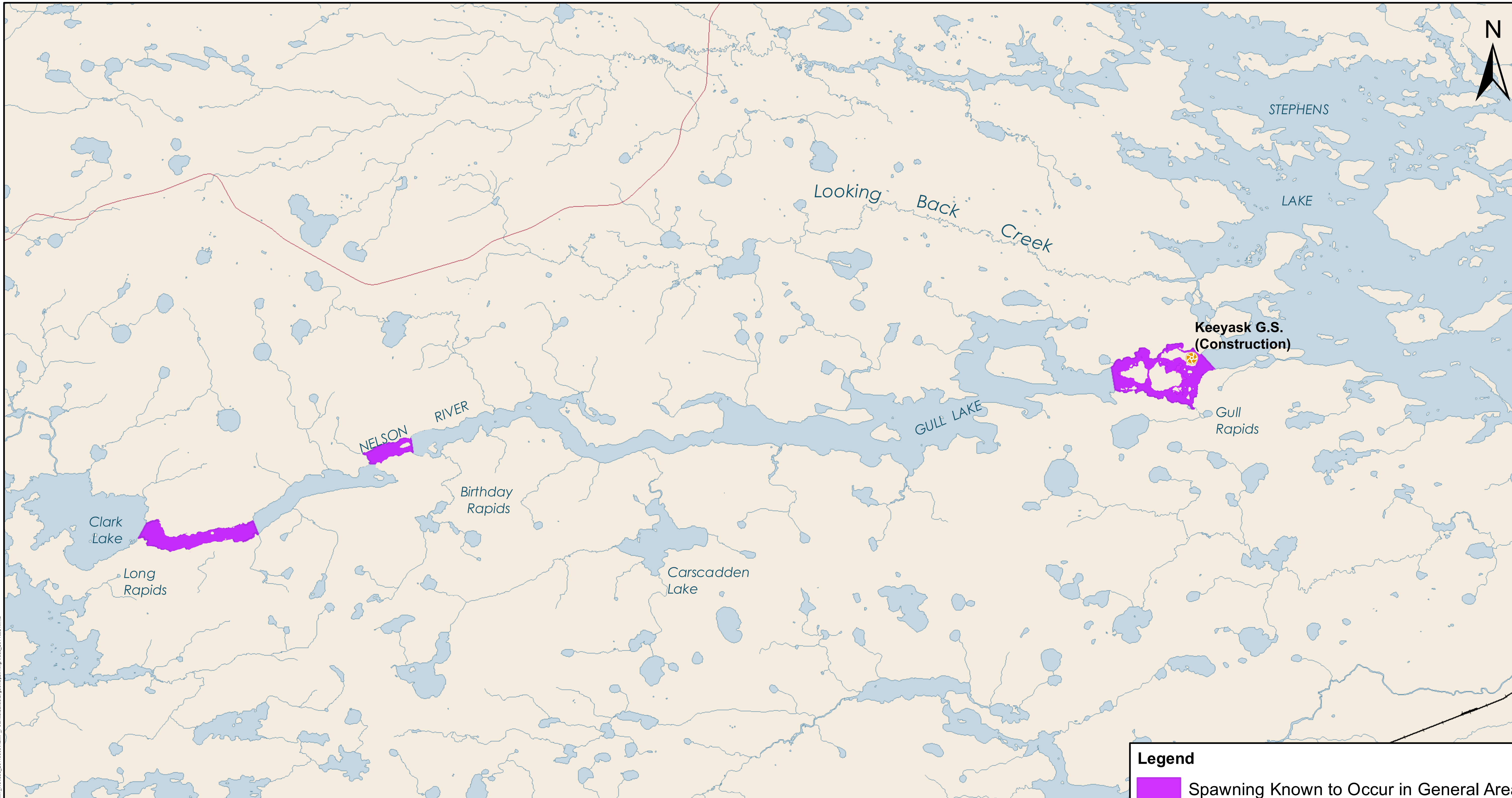
Map 6-5

KEEYASK
Hydropower Limited Partnership

0 250 500 750 1,000 Metres
0 0.125 0.25 0.5 Mile

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000,
Stephens Lake Shoreline-Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro

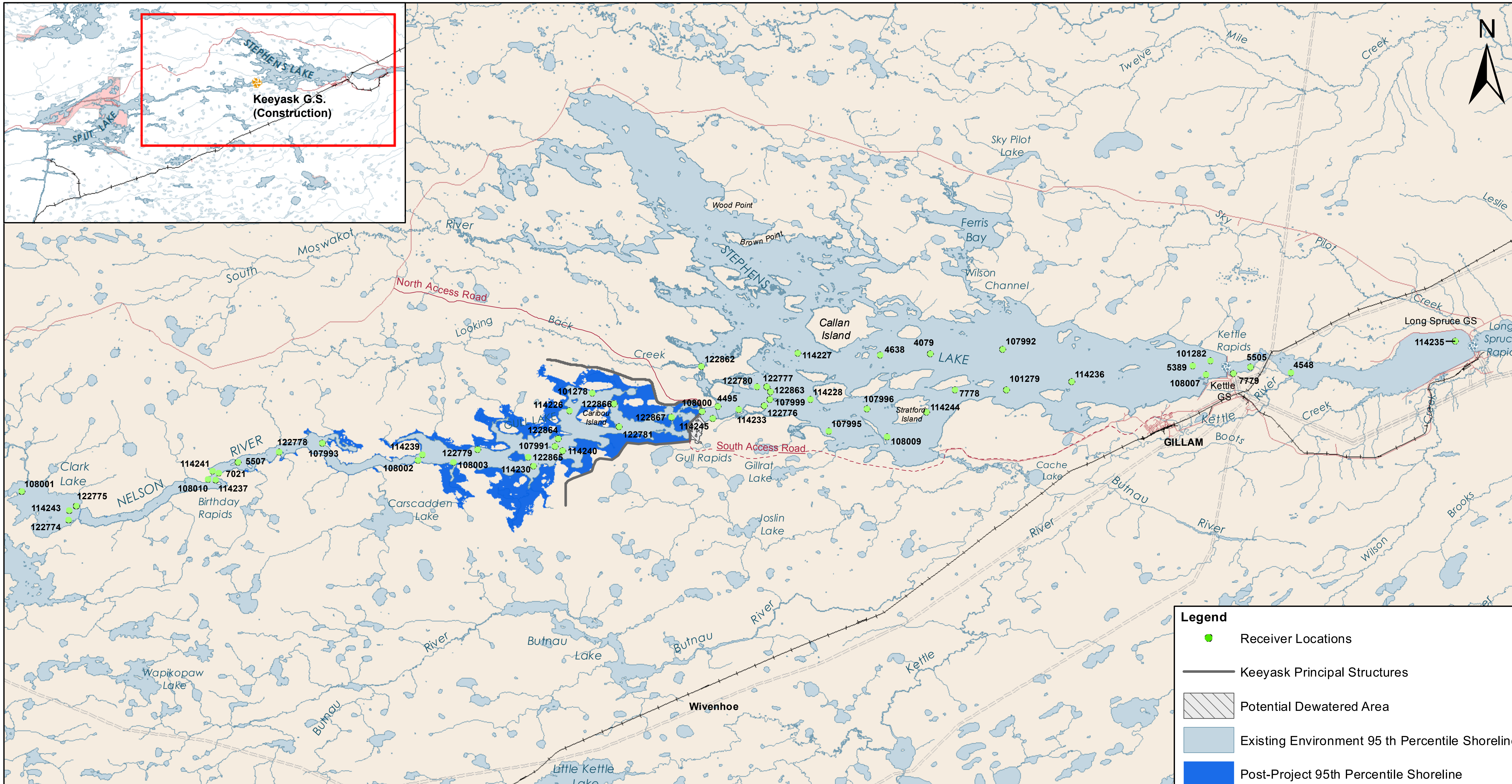
2012 Sub-Adult Gillnetting Sites
Stephens Lake



KEEYASK Hydropower Limited Partnership

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000

Potential Lake Sturgeon Spawning Areas



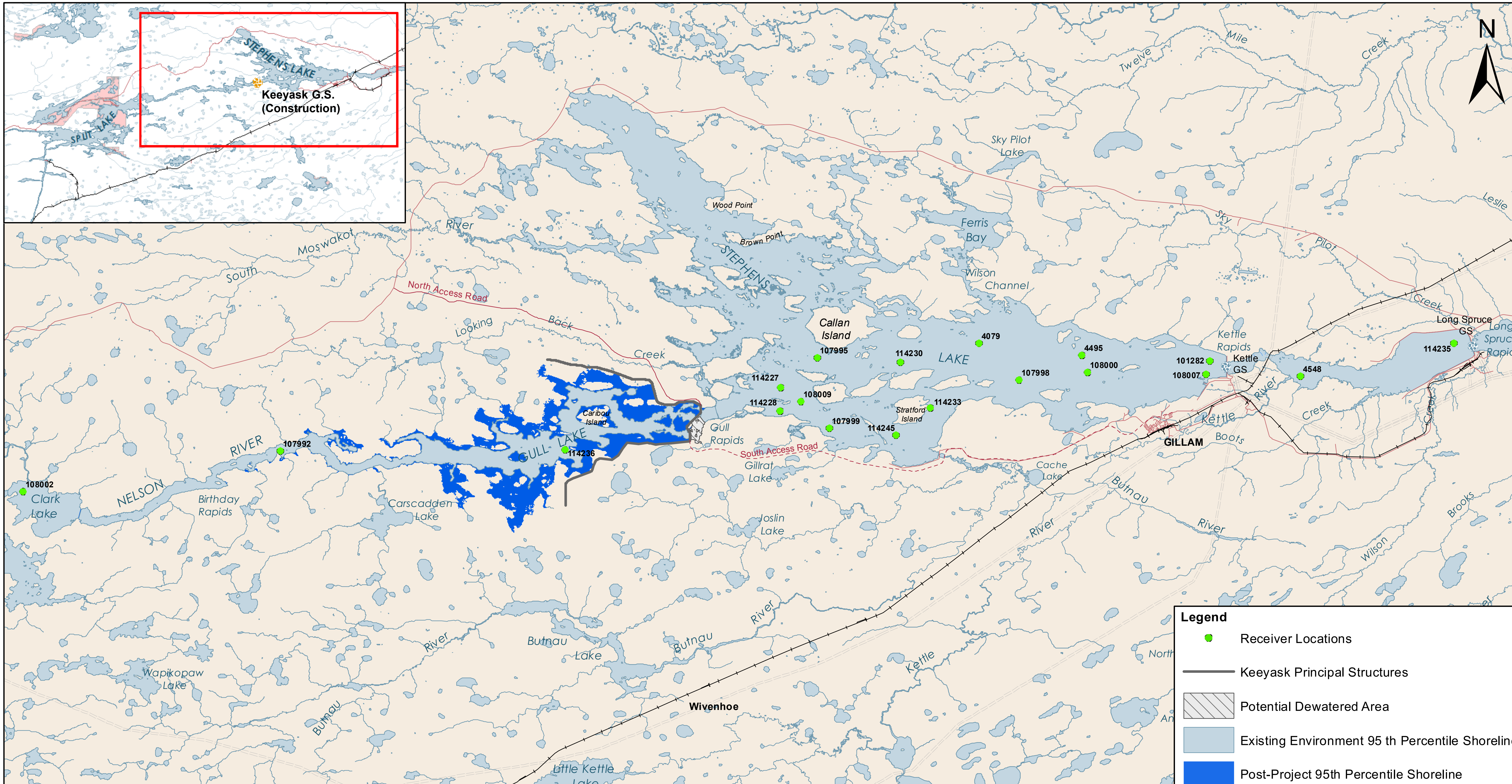
Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000,
Stephens Lake Shoreline-Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro

0 5 10 15 20 Kilometres
0 2.5 5 10 Miles

KEEYASK
Hydropower Limited Partnership

Summer 2013 Receiver Locations

Map 6-8



KEEYASK
Hydropower Limited Partnership

0 5 10 15 20 Kilometres
0 2.5 5 10 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000,
Stephens Lake Shoreline-Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro

Winter 2012/2013 Receiver Locations

Map 6-9

KEEYASK
Hydropower Limited Partnership

0 2 4 Kilometres
0 2 4 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000,
Stephens Lake Shoreline-Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro

Mercury in Fish Flesh Monitoring Sites
Aiken River

Map 7-1

APPENDICES

APPENDIX 1A
TERMS OF REFERENCE FOR THE KEEYASK FISHERIES REGULATORY REVIEW COMMITTEE (KFRRC)

KEEYASK FISHERIES REGULATORY REVIEW COMMITTEE
Committee Terms of Reference

1. PURPOSE

The Keeyask Fisheries Regulatory Review Committee (the Committee) is a committee of representatives from the Keeyask Hydropower Limited Partnership (the Partnership), Manitoba Conservation and Water Stewardship (Fisheries Branch) and Fisheries and Oceans Canada that will review and discuss the results of relevant aspects of the Keeyask Aquatic Effects Monitoring Plan (AEMP) to assist the Partnership in complying with fisheries-specific regulatory requirements outlined in the Keeyask *Fisheries Act* Authorization and in *The Environment Act* (Manitoba) Licence for the Project, and in determining whether adaptive management measures may be required to do so. The Committee will also create a forum for the sharing of expertise and information among the parties.

2. ACTIVITIES & SCOPE OF THE COMMITTEE

It is acknowledged that uncertainty exists with respect to the proposed mitigation and offsetting program for Keeyask and that adaptive management measures may be required at key milestones during Project development and operation. These are specifically outlined in the Keeyask Fisheries Act Authorization and related documentation.

As a result of this uncertainty, and in order for the Committee to achieve its intended purpose, the Committee will review and discuss the results of monitoring plans, including the robustness of monitoring activities and the ability of these programs to detect change. The outcomes of these monitoring programs will provide an indication of the success of fisheries-related mitigation and offsetting measures implemented in accordance with the Manitoba *Environment Act* Licence and *Fisheries Act* Authorization issued for the Keeyask Generation Project.

The Committee will review the results of fisheries aspects of the AEMP and based on regulatory requirements determine whether adaptive management measures may be required. For the purposes of this Committee, adaptive management includes any potential changes to the following aspects of the fisheries specific monitoring, mitigation and offsetting program:

- Fisheries related monitoring outlined in the AEMP. Among other things, this could include changes in the scope of monitoring, the benchmarks used in the monitoring program and methods (including data collection and analysis).
- Fisheries related mitigation and offsetting measures as specified in the Fisheries Protection Program of the Keeyask Application for Fisheries Act Authorization and in the Manitoba *Environment Act* Licence.

Specifically, the Committee's review of monitoring results will focus on the following key questions:

a. Are monitoring measures and related benchmarks robust enough to determine possible effects of the Keeyask Generation Project on the sustainability of fish populations or should modifications or additions to this plan be implemented?
b. Are the actual effects of the Keeyask Generation Project consistent with the benchmarks specified in the fisheries components of the AEMP and, if benchmarks are not met, should adaptive management measures, including alternative, additional or enhanced mitigation and/or offsetting measures should be implemented?
c. Does monitoring of Lake Sturgeon populations show that the objective of developing sustainable populations upstream and downstream of the Keeyask Generating Station is being achieved or should modifications/additions to fisheries mitigation and/or offsetting measures be implemented?
d. Does monitoring of fish populations and movements/behaviour in the Keeyask region demonstrate that upstream fish passage at the Keeyask Generating Station is required and beneficial for the sustainability of fish populations both upstream and downstream of the station?
e. Are the results of fish movement and turbine mortality studies sufficient to conclude that fish mortality is not affecting the sustainability of fish populations upstream or downstream of the Keeyask Generating Station, or should additional studies and/or mitigation measures be implemented?

It is also possible that additional fisheries related questions and concerns may be discussed by the Committee based on what is learned as the Project is constructed and operated.

In general terms, appropriate adaptive management measures will be identified in cases where the outcomes of monitoring programs indicate one or more of the following:

- Potential non-compliance with the terms and conditions of the *Fisheries Act* Authorization or the Manitoba *Environment Act* Licence.
- The methods in the monitoring program are not robust enough to detect change as specified by the benchmarks set out in the AEMP and there are proven more robust methods available, or
- The duration or frequency of a benchmark exceedance specified in the AEMP has been passed, or
- Observed monitoring results indicate a worsening condition, rather than natural variation, and this condition is a result of the Keeyask Generation Project, or
- Analysis of data indicates that the benchmarks in the AEMP are not sufficiently protective, or
- The overall objective of developing/maintaining sustainable fish populations is not being met based on the provincial Fisheries Management Objectives, or
- The outcomes of research in the Keeyask region or elsewhere indicate that there may be more appropriate or effective monitoring or mitigation measures available.

While the focus of the discussions will be on the outcomes of the AEMP, information on fisheries gained through Aboriginal Traditional Knowledge monitoring programs undertaken by the Partner First Nations (Tataskweyak Cree Nation, War Lake First Nation, York Factory First Nation and Fox Lake Cree Nation) will also be shared with the Committee for consideration in its deliberations.

The Partnership will also provide any relevant information it may receive from the public.

3. DECISION MAKING FOR ADAPTIVE MANAGEMENT

Committee members commit that they will use best efforts to reach consensus decisions on all matters. This means that Committee members will review, discuss and modify ideas, as appropriate, until all Committee members are comfortable with the proposed approach.

The following process will be used by the Committee to review monitoring results and to determine the potential need for the implementation of adaptive management, including the implementation of those adaptive management measures already outlined in the Fisheries Protection Program of the Keeyask Fisheries Authorization:

- The Partnership and its consultants will conduct monitoring based on the AEMP, and will prepare an assessment of the findings, including a determination of whether the outcomes are a result of the Keeyask Generation Project. This assessment will also propose appropriate actions to be taken if the assessment determines adaptive management is required to address fisheries-related issues for any of the reasons listed above. Reasonable actions could include further studies to identify appropriate offsetting/mitigation measures if no contingency measures to address a particular issue have been identified to date.
- DFO and Manitoba Conservation & Water Stewardship (Fisheries Branch) will review and provide their perspectives on the Partnership's monitoring results, its assessment of these results and any proposed actions.
- If it is agreed that the outcomes are not a result of constructing and operating the Keeyask Generation Project, then the Partnership will not be responsible for implementing additional measures beyond those already outlined in the Manitoba *Environment Act* Licence and the *Fisheries Act* Authorization issued for the Keeyask Generation Project.
- If, after several rounds of discussion, a technical issue arises that the parties cannot agree upon related to the outcome of monitoring or proposed actions and, if all parties agree it is appropriate, then an external expert will be selected by the Committee to review and provide advice on the issue. The Committee will work together to make a decision based on this advice.
- If, after the provision of expert advice, the Committee can still not reach consensus on a decision, then the matter will be elevated to a senior level within each respective organization and addressed between the organizations at that level for resolution.

All parties recognize the role of the regulatory agencies in determining compliance with the terms and conditions of the *Fisheries Act* Authorization (DFO) or the Manitoba *Environment Act* Licence (Manitoba) through their respective compliance processes.

It is acknowledged that each party on the Committee holds a different scope of responsibility with respect to decision-making on behalf of its organization, and this will be respected by all Committee members. Specifically:

- Fisheries and Oceans Canada representatives on the Committee are mandated to determine compliance with the fisheries protection provisions of the *Fisheries Act* . Aquatics-related issues that go beyond this specific area of responsibility will be deferred to the appropriate federal or provincial regulatory agency.
- Manitoba Conservation and Water Stewardship representative on the Committee are mandated to oversee compliance on matters related to fisheries management and achievement of the Fisheries Management Objectives for the Keeyask Generation Project.
- Manitoba Hydro representatives on the Committee are mandated, on behalf of the Partnership, to maintain compliance with the fisheries-specific regulatory requirements for the Keeyask Generation Project[1]. In accomplishing this task, MH representatives are required to share and discuss the outcomes of Committee meetings with the Partnership's Monitoring Advisory Committee (MAC) and to seek the input of MAC prior to Committee meetings.

4. COMMITTEE MEMBERSHIP

Committee membership will be drawn from the parties and will include:

- Keeyask Hydropower Limited Partnership: Three (3) representatives from Manitoba Hydro involved in aquatic monitoring activities will participate on behalf of the Partnership. It is anticipated that regular attendance will include the Partnership's lead for implementing the Aquatics Effects Monitoring Plan (who will also act as Committee Chair; see section 5 below), the Chair of the MAC, and an additional staff person with fisheries expertise. The lead consultant retained by the Partnership to undertake aquatics monitoring studies for the Keeyask Generation Project will also participate in all Committee meetings.

- Manitoba Conservation & Water Stewardship (Fisheries Branch): Two (2) representatives from Manitoba Conservation & Water Stewardship (Fisheries Branch) responsible for fisheries management and oversight of the Fisheries Management Objectives for the Keeyask Generation Project will participate on behalf of the Province.

- Fisheries and Oceans Canada: Up to two (2) individuals from Fisheries and Oceans Canada (DFO) representing the Fisheries Protection Program will participate on behalf of the regulatory agency. As feasible and warranted, participation by other DFO sectors will be on a case-by-case basis to address specific issues and concerns.

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[1] Under the terms of the Joint Keeyask Development Agreement, Manitoba Hydro is responsible for constructing and operating the Keeyask Generation Project on behalf of the Keeyask Hydropower Limited Partnership. This includes compliance and maintenance with all project-specific licences, authorizations and permits.

To the extent possible, all parties will endeavour to provide consistency in their representation on the Committee. The parties will advise the Partnership (acting as the Committee's Administrative Support) of their Committee members prior to the first meeting of the Committee and, similarly, will be responsible for advising the Partnership (acting as the Committee's Administrative Support), of any changes in its Committee representation.

The parties may request that additional representatives or consultants be able to attend a Committee meeting, depending on the topics to be discussed. This type of request will be made to the Committee Chair and will be sent to other Committee members to ensure there are no objections.

5. CHAIR

The Partnership's lead representative will Chair the Committee and will be responsible for the following activities:

- Chairing Committee meetings
- Scheduling Committee meetings, and
- Distributing meeting materials and meeting notes.

Efforts will be made to distribute relevant documents to be discussed at Committee meetings as early as possible so that ample review time is available and early written comments can be provided. To this end, efforts will be made to distribute relevant documents such that the following can be achieved:

- A 30-day review period of monitoring reports; followed by
- A one-week compilation of comments within each organization; followed by
- The distribution of comments to all Committee members one week prior to the meeting.

Meetings agendas will be distributed at least one week in advance of the meeting date.

Meeting notes will be recorded and distributed to Committee members under direction of the Chair within two weeks of the meeting date.

6. MEETING FREQUENCY & LOCATION

During the course of construction and the first ten years of operation, the Committee will meet at least twice annually; additional meetings of the Committee will be called as needed and as determined by Committee members.

Committee meetings will at least occur on the following two occasions annually:

1. Early in a new year (January/February) to review and discuss the results of aquatics-related monitoring activities undertaken for the Keeyask Generation Project, any related issues and concerns, and preliminary monitoring activities proposed for the upcoming year based on the AEMP. Discussion at this time would include any possible modifications that may be required to the monitoring plan or to mitigation and/or offsetting measures based on monitoring results.

2. Spring (late March/early April) to review and finalize the proposed monitoring activities for the upcoming year.

The number of annual meetings may be reduced to one if Committee members are in agreement that monitoring activities are well established and the final review of proposed monitoring is not required.

Committee meetings will be held in Winnipeg and, on occasion, if appropriate, in Thompson, Gillam or at the Keeyask site, if agreed to by the Committee.

7. COSTS FOR COMMITTEE PARTICIPATION & ACTIVITIES

Each party to the agreement commits to provide the staff resources required to participate in the Committee, and to review the outcomes of monitoring results. Costs for individual representatives to participate in meetings will be covered by their respective organizations, unless otherwise agreed to among the parties.

The Partnership commits to provide ongoing logistical support for the Committee, including the provision of a note-taker, meeting logistics (room, food, etc.), distribution of Committee materials and other logistical matters, including making arrangements for and covering the costs of travel and accommodation for Committee members if meetings take place at locations other than Winnipeg.

The Partnership will cover the costs for reviews of materials by experts agreed to by the Committee (see Section 4 above).

8. REPORTING & PUBLIC ENGAGEMENT

All aquatics-related adaptive management measures, including changes to the monitoring plan or mitigation and/or offsetting measures that may have been determined through the Keeyask Aquatics Regulatory Committee, will be reported on in the Annual Monitoring Overview Report issued by the Partnership and in its more detailed annual monitoring reports provided to regulators. These reports will include, at a minimum, a discussion of the following:

- What was done in the year in terms of aquatics monitoring (both through the AEMP and Aboriginal Traditional Knowledge monitoring) and the implementation of mitigation and offsetting measures.
- Key findings of all aquatics monitoring.
- Any adaptive management measures made to monitoring/mitigation/offsetting.

All of these reports will be provided to each of the Partner First Nations, and to the Split Lake, Fox Lake and York Factory Resource Management Boards. They will also be made publicly available on the Partnership's Website and, where requested or required, notifications of the posting and/or hard copies of the materials will be distributed to interested parties. Through its Website, the Partnership will also maintain opportunities for public input on the outcomes of its Environmental Protection Program; any comments received specific to fisheries-related measures will be shared with the Committee.

It is understood that each regulatory agency may also undertake its own engagement process to provide opportunities for public input into its review of monitoring programs and its own deliberations with respect to adaptive management measures.

9. CONFIDENTIALITY & PUBLIC COMMUNICATION

It is understood and expected that Committee members will communicate within their organizations about matters discussed in the Committee. It is also agreed that information shared at the Committee on a confidential basis will be clearly identified by the Party sharing the information and will treated as such within each organization. It is recognized that DFO is responsible for ensuring its obligations under the *Access to Information Act* and the *Privacy Act* are met. Similarly, MCWS and Manitoba Hydro have obligations under such statutes as *The Freedom of Information and Protection of Privacy Act* in Manitoba that must also be met.

From time to time, Committee members may have an opportunity to speak publicly about the Committee. In these circumstances, the Committee member will seek permission of the Committee in advance.

10. AMENDMENT OF TERMS OF REFERENCE

The Committee may amend the Terms of Reference from time to time provided that all parties are in Agreement.

APPENDIX 1B
MANITOBA FISHERIES BRANCH – FISHERIES MANAGEMENT OBJECTIVES KEEYASK DAM / GULL LAKE AREA 2012

CONTEXT

The proposed Keeyask Hydroelectric Project will separate Stephens Lake (the human-created reservoir for Kettle Generating Station) from the mainstem of the Nelson River, downstream of Split Lake and Clark Lake. The proposed development is expected to back-flood the Nelson River, creating a reservoir that will change hydraulic and hydrologic conditions upstream of the proposed development at least as far as Birthday Rapids – an area understood to be a significant Lake Sturgeon habitat. These changes to the hydrograph are expected to have consequential changes to the responding physical habitat and to the biota currently within the area. These fisheries management objectives have been prepared at the request of the proponent based on the assumption that the proposed Project receives regulatory approval. Therefore, the objectives are based on best-case / desired outcomes under the development scenario and reflect objectives generally for the area bounded by Birthday Rapids to the outflow of Stephens Lake. Provincial fisheries management objectives are neither an endorsement nor a criticism of any project or development, but are a solicited response to proponents who seek to mitigate the effects of their work on fish stocks and habitats and contribute to Fisheries Branch management of those stocks.

FISHERIES MANAGEMENT OBJECTIVES (FMOS)

Objectives

- Target species that support local fisheries (Walleye, Northern Pike, Lake Whitefish) should exist at levels that support a sustainable harvest.
- Maintain self-sustaining stocks (including forage and other non target fish species) in the form they currently exist (*i.e.*, acceptably similar or appropriate ecological structure and function).
- In addition to this, it is noted that a viable whitefish population that is valued for subsistence harvest[1] is found in Gull Lake. This population should continue to exist at levels that support sustainable harvest.
- A viable population of Lake Sturgeon above the proposed Keeyask Generating Station site.
- Conditions that support the development of a viable and self-sustaining population of Lake Sturgeon in Stephens Lake.
- Determination for the need for fish passage (types, timing, mechanisms and species) to support future stocks associated with the new ecosystem should be based on scientifically experimental and defensible assessment in conjunction with provincial management goals and in consultation with provincial fisheries managers.

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[1] The term *subsistence harvest* used here refers only to fish stock capacity and does not reflect either the health or any other measure of fish quality of the fishes within those stocks.

Mechanisms that support FMOs

- Mitigate habitat degradation / destruction both above and below the proposed GS.
- Avoid further decline of the existing Lake Sturgeon population.
- Use stocking to recover stocks and for rehabilitation purposes (particularly in the upstream area) to the point where over the long term a self-sustaining population more capable of meeting the domestic needs of the local communities is established.
- Stocked sturgeon should be recruited to brood stock to increase the contribution of natural reproduction instead of being used to increase the sustainable harvest.
- Since management and conservation efforts for this area are dependent on the support and endorsement of local First Nation harvesters, it is critical that the purpose of any stocking program be suitably communicated to users to ensure that the stocking does not undermine the conservation message.
- Local sturgeon management and conservation efforts to ensure that existing stocks are sustainable.
- Provision for future fish passage should be set aside (*i.e.*, allocated) during Project planning and construction.
- Any sturgeon stocking plan should be presented to local users in a manner that supports the management and conservation messages planned within it, and does not present a false confidence in the robustness of stocks.
- Programs that compensate for lost fishing opportunities in the Project area with increased fishing opportunities in other areas are considered a Project effect and may require additional management or mitigation measures.

APPENDIX 1C
INFORMATION FROM PHYSICAL ENVIRONMENT MONITORING PLAN AND COORDINATED AQUATIC MONITORING PROGRAM

1C.1 SUMMARY OF PHYSICAL ENVIRONMENT MONITORING INFORMATION RELEVANT TO THE AEMP

The PEMP will provide a complete description of the monitoring of the physical environment. Several topics addressed in the PEMP will be required as inputs to the AEMP, as described below:

- Measurement of water depth and velocity during the open-water period under a variety of flow conditions upstream and downstream of the Keeyask GS will be required to validate predictions used as input into post-Project aquatic habitat models;
- Monitoring of sediment parameters (*e.g.*, total suspended solids (TSS), turbidity) upstream and downstream of the Keeyask GS to provide input into the water quality program;
- Monitoring of shoreline erosion and peat breakdown will provide a link between mineral and organic inputs and effects to water quality;
- Measurement of sediment deposition upstream and downstream of the GS will be used as an input to the aquatic habitat (substrate) and benthic invertebrate monitoring programs;
- Monitoring of dissolved oxygen (DO) and water temperature in the reservoir mainstem, flooded backbays, and downstream of the Keeyask GS will provide important information for the water quality, benthic invertebrate, and fish community programs; and
- Monitoring of total dissolved gas pressure upstream and downstream of the Keeyask GS under a variety of flow conditions will provide input into whether biological monitoring is required.

Results of monitoring immediately upstream and downstream of instream construction sites, as described in the SMP, will also be required to interpret results of the water quality and biological monitoring programs.

1C.2 COORDINATED AQUATIC MONITORING PROGRAM (CAMP)

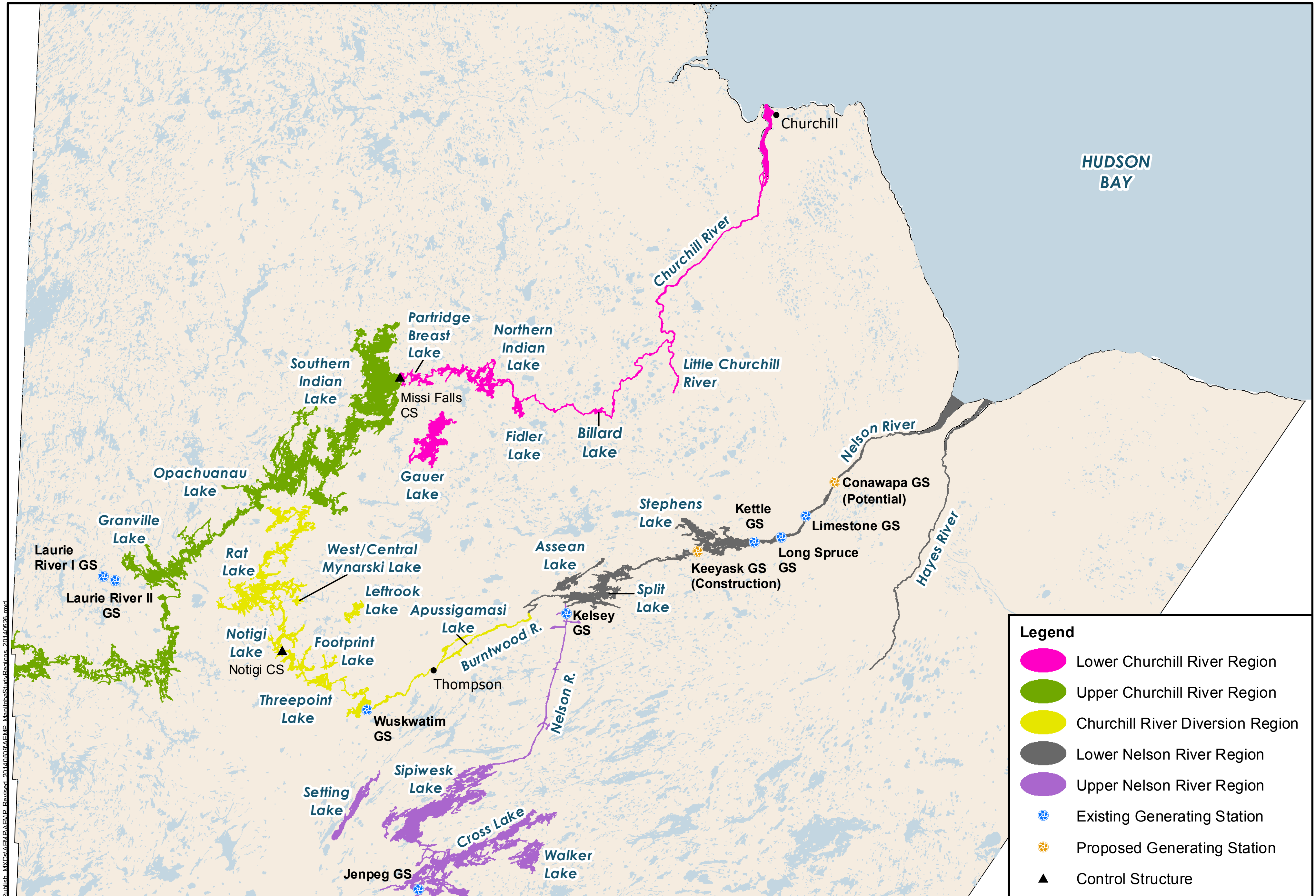
Monitoring of water quality, benthic invertebrates, fish, and mercury in fish flesh is conducted by MCWS and Manitoba Hydro under the Coordinated Aquatic Monitoring Program (CAMP) at several sites in the region. Table 1C-1 lists CAMP waterbodies in the region and indicates the sampling programs and frequencies for each water body. Locations of waterbodies are provided in map 1C-1. CAMP monitoring data will be obtained and considered within the AEMP reporting to: (i) provide additional information on affected areas (*i.e.*, Stephens Lake) and (ii) provide context for changes observed in the study area (*e.g.*, Split and Assean lakes, the Hayes River, the lower Nelson River downstream of the Limestone GS). To the extent feasible, data from CAMP will be used in place of additional sampling under the Keeyask AEMP (for example, sampling in Split Lake for the water quality, benthic invertebrate and fish community components will be done under CAMP).

Table 1C-1: Waterbodies Sampled as a Part of the Coordinated Aquatic Monitoring Program (CAMP).

Region	Waterbody	Sampling Program					
		Water Quality	Sediment Quality	Phytoplankton	Benthic Macroinvertebrates	Fish	Mercury in Fish Flesh
Upper Churchill River	Southern Indian Lake (Area 4)	Annual	Every 6 years	Every 3 years	Annual	Annual	Every 3 years
	Granville Lake	Annual	Every 6 years	Every 3 years	Annual	Annual	Every 3 years
	Southern Indian Lake (Area 1)	Every 3 years	-	Every 3 years	Every 3 years	Every 3 years	-
	Southern Indian Lake (Area 6)	Every 3 years	-	Every 3 years	Every 3 years	Every 3 years	Every 3 years
	Opachuanau Lake	Every 3 years	-	Every 3 years	Every 3 years	Every 3 years	-
Churchill River Diversion (upper)	Notigi Lake	Every 3 years	-	Every 3 years	Every 3 years	Every 3 years	-
	Rat Lake	Every 3 years	-	Every 3 years	Every 3 years	Every 3 years	Every 3 years
	West/Central Mynarski Lake	Every 3 years	-	Every 3 years	Every 3 years	Every 3 years	-
Churchill River Diversion (lower)	Threepoint Lake	Annual	Every 6 years	Every 3 years	Annual	Annual	Annual
	Leftrook Lake	Annual	Every 6 years	Every 3 years	Annual	Annual	Annual
	Apussigamasi Lake	Every 3 years	-	Every 3 years	Every 3 years	Every 3 years	-
	Footprint Lake	Every 3 years	-	Every 3 years	Every 3 years	Every 3 years	-
Lower Churchill River	Northern Indian Lake	Annual	Every 6 years	Every 3 years	Annual	Annual	Every 3 years
	Churchill River at Little Churchill River	Annual	Every 6 years	Every 3 years	Annual	Annual	Every 3 years
	Gauer Lake	Annual	Every 6 years	Every 3 years	Annual	Annual	Every 3 years
	Partridge Breast Lake	Every 3 years	-	Every 3 years	Every 3 years	Every 3 years	-
	Billard Lake	Every 3 years	-	Every 3 years	Every 3 years	Every 3 years	-
	Fidler Lake	Every 3 years	-	Every 3 years	Every 3 years	Every 3 years	-

Table 1C-1: Waterbodies Sampled as a Part of the Coordinated Aquatic Monitoring Program (CAMP).

Region	Waterbody	Sampling Program					
		Water Quality	Sediment Quality	Phytoplankton	Benthic Macroinvertebrates	Fish	Mercury in Fish Flesh
Lower Churchill River	Churchill River at Red Head Rapids	Every 3 years	-	Every 3 years	Every 3 years	Every 3 years	-
Upper Nelson River	Cross Lake - West basin	Annual	Every 6 years	Annual	Annual	Annual	Every 3 years
	Setting Lake	Annual	Every 6 years	Annual	Annual	Annual	Every 3 years
	Playgreen Lake	Every 3 years	-	Every 3 years	Every 3 years	Every 3 years	Every 3 years
	Little Playgreen	Every 3 years	-	Every 3 years	Every 3 years	Every 3 years	-
	Walker Lake	Every 3 years	-	Every 3 years	Every 3 years	Every 3 years	-
	Sipiwesk Lake	Every 3 years	-	Every 3 years	Every 3 years	Every 3 years	Every 3 years
	Nelson River - downstream of Sipiwesk Lake to Kelsey GS	Every 3 years	-	Every 3 years	Every 3 years	Every 3 years	-
Lower Nelson River	Split Lake	Annual	Every 6 years	Annual	Annual	Annual	Every 3 years
	Assean Lake	Annual	Every 6 years	Annual	Annual	Annual	Every 3 years
	Nelson River Mainstem – downstream of Limestone GS	Annual	Every 6 years	Every 3 years	Annual	Annual	Every 3 years
	Hayes River	Annual	Every 6 years	Every 3 years	Annual	Annual	Every 3 years
	Stephens Lake - north arm	Every 3 years	-	Every 3 years	Every 3 years	Every 3 years	-
	Stephens Lake - south	Every 3 years	-	Every 3 years	Every 3 years	Every 3 years	Every 3 years
	Limestone Forebay	Every 3 years	-	Every 3 years	Every 3 years	Every 3 years	Every 3 years
	Burntwood River - First Rapids to Split Lake	Annual	-	Every 3 years	Every 3 years	Every 3 years	-



Co-ordinated Aquatic Monitoring Program (CAMP)

0 50 100 150 200

Kilometres

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Coordinate System: UTM Zone 14, NAD 83
Data Source: Canvec © Her Majesty the Queen in Right of Canada, Department of Natural Resources. All rights reserved.
Created By: North/South Consultants
Date Created: 27/05/2014

Study Regions
Northern Manitoba

Map 1C-1

APPENDIX 2A
ANALYSIS OF BASELINE WATER QUALITY DATA

2A.1 INTRODUCTION

An assessment and analysis of baseline water quality data was undertaken to assist with advising on the study design for the AEMP. This assessment included:

- Screening of data to eliminate data with insufficient analytical detection limits;
- Initial screening of baseline data for the local study area through graphical presentation;
- Statistical evaluation of spatial differences between baseline water quality sites in the local study area;
- Statistical evaluation of seasonal differences in baseline water quality in the local study area; and
- An *a priori* power analysis to provide a preliminary evaluation of the power of the baseline water quality data set and to assist with defining the level of sampling effort (*i.e.*, identify sample sizes) for the water quality monitoring program.

The following provides an overview of the methods and results of this analysis.

2A.2 METHODS AND APPROACH

The water quality monitoring program focuses upon areas upstream and downstream of construction activities and upstream, within, and downstream of the reservoir during operation (*i.e.*, the local study area). Therefore the preliminary exploratory analyses of the existing baseline data set focused upon water quality data collected from Clark Lake through Stephens Lake (*i.e.*, the local study area). For all analyses, values reported as below the measurement detection limit were assigned a value of one half of the detection limit.

2A.2.1 SUMMARY STATISTICS

Summary statistics (mean, median, standard error [SE], standard deviation [SD], minimum, maximum, n, coefficient of variation [COV], and 95th percentile) were derived for selected sites. COV was calculated as SD/mean x 100; COV facilitated rapid comparisons of the variability of datasets to assist with identifying the most robust metrics as well as to assist with advising on sampling design.

2A.2.2 SPATIAL COMPARISONS

Data for selected key indicators were compared spatially (*i.e.*, across sites) to identify which sites could be aggregated for characterizing baseline water quality conditions and to assist with study design. Statistical methods varied in accordance with results of tests for normality of data. For parameters exhibiting a normal distribution, analyses were conducted using an analysis of variance (ANOVA) and a Tukey's test ($\alpha = 0.05$). For parameters not meeting the assumptions of a normal distribution (normality was tested on raw, untransformed data and log-transformed data), analyses were performed using the non-parametric Kruskal-Wallis test followed by the Dunn's multiple pairwise comparisons procedure (two-tailed; $\alpha = 0.05$). Sites included in this analysis were located within the local study area and along the main flow of the lower Nelson River (see Map 2A-1).

2A.2.3 SEASONAL ANALYSIS

Seasonality of the data was also examined for a representative site (NR2) by comparing the four sampling periods for the open-water season using available baseline data. Like spatial comparisons, seasonality was examined with ANOVA and a Tukey's test or the Kruskal-Wallis test with Dunn's multiple pairwise comparisons. Data were tested for normality on raw data and on log10 transformed data. ANOVA was applied to raw or log-transformed data where the assumption of normality was met.

2A.2.4 PRELIMINARY POWER ANALYSES

Selected key water quality indicators were subject to an *a priori* power analysis to identify the power of the existing data and provide a preliminary evaluation of sample sizes for post-Project monitoring.

Power analysis was conducted following general guidance provided in the Environment Canada (EC) Metal Mining Environmental Effects Monitoring Guidance Document (EC 2012). Specifically, values for α (Type I error) and β (Type II error) were set at 0.1 as advised in EC (2012); resulting power is 0.9. Power analyses were run using PopTools version 3.2 (build 5) add-in for Microsoft Excel 2010.

A Priori Power Analyses

Power analysis by simulation was implemented using PopTools (Hood 2010).Two types of power analyses were used one based on a *t*-test (parametric) and one based on the Mann-Whitney (nonparametric) *U*-test. Figure 2A-1, shows the basic analysis flow for power analysis by simulation described below. Power analyses examined the power of existing data to detect predefined levels of change (i.e., effects sizes). Effects sizes were defined as the benchmarks (*i.e.*, water quality objectives or guidelines or 95th percentiles of baseline data) described in Section 2.1.2. Using the *dNormalDev*(mean, SD) function, random data were generated for the observed baseline and hypothetical monitoring scenarios. The Excel formula for a *t*-test was used keeping the first row fixed. This process was iterated 1000 times by Monte Carlo simulation to determine the frequency of a realised *t*-probability greater than α (Type I error), which provided an estimate of β (Type II error) with the power of the test being 1-β.

For nonparametric tests, the same process was used, but baseline data were fit to a distribution and then random deviates were generated using the appropriate functions *e.g.*, *dLogNormalDev*(Mean, SD). The test was iterated 1000 times to estimate β Type II error. In certain scenarios, where datasets contained a significant number of censured values (*i.e.*, values below the detection limit), baseline data were assumed to follow a true distribution below the associated detection limit.

2A.3 RESULTS

2A.3.1 OVERVIEW OF BASELINE DATA

An inventory of baseline water quality sampling conducted from 2001 through 2013 in the Lower Nelson River area, excluding tributaries, is summarized in Table 2A-1 and sites are illustrated in Map 2A-2. As winter data are relatively limited, exploratory data analyses were conducted using data collected in the open-water season. Baseline results for selected water quality parameters for sites located along the mainstem of the lower Nelson River between Clark Lake and the Kettle Generating Station (GS) are presented in Tables 2A-2 and 2A-3. These sites were examined as representative of upstream conditions (upstream for construction monitoring and upstream and reservoir sites for operation) and downstream of the GS (*i.e.*, Stephens Lake) and which fall in the local study area. COVs were variable – typically being highest for trace metals and inorganic nitrogen (*i.e.*, ammonia and nitrate) and lowest for conductivity, hardness, total dissolved solids (TDS), and pH.

2A.3.2 SPATIAL COMPARISONS

With a few exceptions, water quality did not vary significantly among the sites examined for spatial differences based on available baseline data (Table 2A-4). Sites from Clark Lake (CL1) to the site located in southwestern area of Stephens Lake (STL1) were not significantly different. Site STL2, in the southeastern area of Stephens Lake exhibited significantly lower concentrations of aluminum and iron than two upstream sites (NR2 and STL1) using all available baseline data. However, these differences may at least in part be explained by differences in the data sets between the sites; site STL2 was the only site that was sampled in 2012 and sampling was conducted three times in the open-water season in that year (in all other years the sampling frequency was four). Comparing sites using data collected in 2009 indicates that aluminum and iron were not significantly different across these sites. TSS was also lower at site STL2 (located in the eastern portion of Stephens Lake) than three upstream sites (NR1, NR2, and STL1); comparisons between sites using data from 2009 only, also indicated no significant differences.

2A.3.3 SEASONAL ANALYSIS

Due to the relatively few spatial differences in water quality, further exploratory analyses were focused upon the baseline data set collected at a representative site (NR2). Data for this representative sampling site (site NR2) were examined for seasonal differences to assist with identification of sampling frequency and appropriate amalgamation of data. Sampling in the open-water season was conducted four times per year when sampled, roughly monthly from June through early October. Sampling periods were assigned to four discrete periods and examined for statistical differences for selected water quality parameters. Of 23 parameters evaluated, only one (TSS) varied significantly between any of the sampling periods (Table 2A-5). TSS was significantly lower in fall (sampling period 4) than the early summer period (sampling period 2). Due to the general lack of seasonal differences, subsequent exploratory power analyses were conducted using data for the entire open-water season.

2A.3.4 PRELIMINARY POWER ANALYSES

Data for sites CL1, NR2, GL1, GL2, NR2, STL1, and STL2 were combined for exploratory power analysis due to the general lack of significant spatial differences as described in Section 3.2. As noted in Section 3.3, with one exception, analysis of seasonality of the data indicated no significant differences and data for the open-water season were pooled.

Results of preliminary power analyses for selected water quality parameters based on the baseline data set for sites NR1, GL1, GL2, NR2 STL1, and STL2 collectively, are presented in Table 2A-6. For the majority of the water quality parameters evaluated for power, a sample size of 5 was adequate or more than adequate to detect the level of change (*i.e.*, proposed water quality benchmarks) with a power of 0.9 or greater. Based on the existing baseline data, an exceedance of a benchmark for most metals and for pH, nitrate, and ammonia would be detectable with a sample size of 1-2; this is due to the relatively low variability of the baseline data but primarily due to the difference between existing conditions and the benchmarks. The lowest power associated with a sample size of 5 occurred for TSS in relation to comparisons to the low benchmark (*i.e.*, change of 5 mg/L from background). To obtain a power of 0.9 to detect a change in TSS of the magnitude of the low benchmark, a sample size of 12 would be required. Given that TSS and turbidity will be monitored through the SMP and PEMP and that the water quality AEMP is intended to supplement the SMP and PEMP for these parameters, it is proposed to apply a sample size of 5 for the initial monitoring for all parameters, with regular review of the data and the program.

2A.4 REFERENCES

2A.4.1 LITERATURE CITED

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Environment Canada. 2012. Metal mining technical guidance for Environmental Effects Monitoring. ISBN 978-1-100-20496-3.

Hood, G. M. 2010. PopTools version 3.2.5. Available on the internet. URL http://www.poptools.org

Table 2A-1: Overview of baseline water quality sampling completed in the Burntwood and Nelson rivers and off-system sites in the Keeyask area: 2001-2013. Numbers indicate the number of sampling periods completed in the ice-cover (IC) or open-water (OW) seasons by site and year.

Location	Site ID	2000/2001		2001/2002		2002/2003		2003/2004		2004/2005		2005/2006		2008/2009		2009/2010		2010/2011		2011/2012		2012/2013		2013/2014	
		OW	IC	OW	IC	OW	IC	OW	IC	OW	IC	OW	IC	OW	IC	OW	IC	OW	IC	OW	IC	OW	IC	OW	IC
Split Lake Area																									
Burntwood River - near Split Lake	SpL1		1	4	1	4		4	1	4					1	4	1	3	1	3	1	3	1	3	1
Kelsey GS Forebay	SpL9									4															
Kelsey GS Forebay	UFS017																			3	1				
Upper Nelson River downstream of Kelsey GS	SpL2			4		4		4		4						4									
Split Lake	SpL3		1	4	1	4		4								4									
Split Lake	SpL4		1	4	1	4		4								4									
Split Lake	SpL5		1	4	1	4		4	1							4									
Split Lake	SpL6		1	4	1	4		4																	
Split Lake	SpL7		1	4	1	4		4	1	4						4									
Split Lake (near community)	SPL-Tu-5														1										
Split Lake (near community)	UFS011	3		3		3		3		3		3		3		3	1	3	1	3	1	3	1	3	1
Split Lake	SpL8		1	4	1	4		4		4						4									
Split Lake	SPL-Tu-4														1										
York Landing	YL-1					4		4		4						4									
Downstream of Split Lake to Stephens Lake																									
Clark Lake	CL1			4		4		4		4						4									
Nelson River	NR1		1	4		4	1	4		4						4									
Gull Lake	GL1			4		4	1	4							1	4									
Gull Lake	GL2			4	1	4	1	4	1							4									
Nelson River	NR2			4		4	1	4	1	4					1	4									
Stephens Lake																									
Stephens Lake	STL-1		1	4	1	4	1	4	1	4					1	4									
Stephens Lake	STL-2			4	1	4	1	4		4						4	1					3	1		
Stephens Lake	STL-3									4						4	1					3	1		
Stephens Lake	STL-4															4									
Stephens Lake	GT-1					4	1	4		4															
Near Kettle GS and STL-2	K-Tu-4														1										
Downstream of Stephens Lake																									
Long Spruce forebay	NR-3					4	1	4	1	4			1		1	4									
Limestone GS forebay	NR-4					4	1	4	1	4			1		1	4	1	3	1		1			3	1
Conawapa GS site	NR-5					4		4		4						4									
LNR upstream of Angling River	NR-6					4		4		4				3		4		3	3						
LNR between Angling and Weir Rivers	C-Tu-8														1										
LNR at Deer Island	NR-7					4		4		4						4									
LNR at Gillam Island	NR-8					4		4		4						4									
Offsystem Sites																									
Assean Lake	AL1		1	4	1	4		4																	
Assean Lake	AL2		1	4	1	4		4								3	1	3	1	3	1	3	1	3	1
Hayes River	ABS002													3		3	1	3	1	3	1	3	1	3	1

Table 2A-2: Summary statistics for selected routine water quality parameters.

Sample	Site ID		Years	Dissolved Ammonia	Dissolved Nitrate/ nitrite	Total Nitrogen	Total Phosphorus	DOC	Conductivity	TDS	TSS[1]	Laboratory Turbidity	True Color	Laboratory pH	Chlorophyll *a*	Hardness as $CaCO_3$	DO	Specific Conductance	*In situ* Turbidity
				(mg N/L)	(mg N/L)	(mg/L)	(mg/L)	(mg/L)	(µmhos/cm)	(mg/L)	(mg/L)	(NTU)	(TCU)	-	(µg/L)	(mg/L)	(mg/L)	(µS/cm)	(NTU)
Upstream																			
Clark Lake	CL1	Mean	2001-2004, 2009	0.0093	0.0203	0.47	0.040	8.4	290	182	14.3	27.1	25.6	8.17	5.4	117	11.53	271	53
Clark Lake	CL1	Median	2001-2004, 2009	0.0080	0.0179	0.45	0.040	8.2	290	181	14.0	25.0	20.0	8.21	5.0	116	11.16	268	45
Clark Lake	CL1	Min	2001-2004, 2009	<0.0030	<0.005	0.28	0.026	6.0	266	150	9.0	16.0	15.0	7.88	3.0	105	8.70	208	30
Clark Lake	CL1	Max	2001-2004, 2009	0.0330	0.0540	0.62	0.057	11.0	311	210	28.0	45.0	60.0	8.35	12.0	129	15.19	335	130
Clark Lake	CL1	SD	2001-2004, 2009	0.0077	0.0158	0.09	0.008	1.0	16	18	4.3	7.8	14.5	0.13	2.2	8	1.78	34	27
Clark Lake	CL1	SE	2001-2004, 2009	0.0017	0.0035	0.02	0.002	0.2	6	6	1.0	1.9	5.1	0.03	0.5	3	0.41	8	7
Clark Lake	CL1	n	2001-2004, 2009	20	20	20	20	20	8	8	20	16	8	20	20	8	19	19	15
Clark Lake	CL1	95th Percentile	2001-2004, 2009	0.0207	0.0455	0.61	0.050	9.2	310	204	20.4	39.0	49.5	8.33	8.2	128	13.83	323	109
Clark Lake	CL1	COV	2001-2004, 2009	82	78	19	19	12	5	10	30	29	57	2	40	7	15	12	51
Nelson River	NR1	Mean	2001-2004, 2009	0.0113	0.0191	0.47	0.039	8.5	294	191	16.0	26.8	28.8	8.17	5.4	122	11.44	264	53
Nelson River	NR1	Median	2001-2004, 2009	0.0100	0.0125	0.50	0.037	9.0	297	196	15.0	26.0	25.0	8.20	4.8	120	11.22	267	48
Nelson River	NR1	Min	2001-2004, 2009	<0.0030	<0.005	0.10	0.024	6.0	276	168	10.0	10.0	15.0	7.96	3.0	111	8.63	208	20
Nelson River	NR1	Max	2001-2004, 2009	0.0380	0.0680	0.67	0.058	10.0	307	204	23.0	45.0	50.0	8.38	10.0	136	15.16	321	120
Nelson River	NR1	SD	2001-2004, 2009	0.0097	0.0181	0.12	0.009	1.0	14	16	3.8	8.5	15.5	0.14	2.0	10	1.82	34	25
Nelson River	NR1	SE	2001-2004, 2009	0.0022	0.0040	0.03	0.002	0.2	7	8	0.8	2.1	7.7	0.03	0.4	5	0.42	8	6
Nelson River	NR1	n	2001-2004, 2009	20	20	20	20	20	4	4	20	16	4	20	20	4	19	19	17
Nelson River	NR1	95th Percentile	2001-2004, 2009	0.0345	0.0462	0.61	0.053	9.9	306	203	22.1	39.0	47.0	8.35	10.0	134	13.90	319	104
Nelson River	NR1	COV	2001-2004, 2009	86	95	25	22	12	5	8	24	32	54	2	37	9	16	13	48
Gull Lake	GL1	Mean	2001-2003, 2009	0.0134	0.0200	0.50	0.040	8.4	294	191	14.5	28.0	28.8	8.13	5.6	123	11.32	267	53
Gull Lake	GL1	Median	2001-2003, 2009	0.0095	0.0189	0.51	0.038	8.5	296	194	12.9	26.0	25.0	8.13	5.0	126	10.94	263	48
Gull Lake	GL1	Min	2001-2003, 2009	<0.002	<0.005	0.30	0.027	6.0	278	172	8.0	18.0	15.0	7.91	3.0	108	9.03	204	20
Gull Lake	GL1	Max	2001-2003, 2009	0.0400	0.0510	0.75	0.061	10.2	304	202	25.0	44.0	50.0	8.35	10.0	132	15.32	320	98
Gull Lake	GL1	SD	2001-2003, 2009	0.0115	0.0162	0.11	0.009	1.0	12	13	4.8	7.7	15.5	0.15	2.2	10	1.80	33	24
Gull Lake	GL1	SE	2001-2003, 2009	0.0029	0.0040	0.03	0.002	0.2	6	6	1.2	2.2	7.7	0.04	0.5	5	0.46	9	7
Gull Lake	GL1	n	2001-2003, 2009	16	16	16	16	16	4	4	16	12	4	16	16	4	15	15	13
Gull Lake	GL1	95th Percentile	2001-2003, 2009	0.0365	0.0443	0.64	0.054	9.3	304	201	23.5	39.6	47.0	8.33	10.0	131	14.16	317	97
Gull Lake	GL1	COV	2001-2003, 2009	86	81	22	23	11	4	7	33	28	54	2	39	8	16	12	44
Gull Lake	GL2	Mean	2001-2003, 2009	0.0106	0.0223	0.49	0.040	8.2	295	196	15.0	27.8	28.8	8.15	5.7	123	11.08	273	51
Gull Lake	GL2	Median	2001-2003, 2009	0.0090	0.0192	0.50	0.040	8.0	298	196	13.2	25.0	25.0	8.14	5.1	122	11.09	268	54
Gull Lake	GL2	Min	2001-2003, 2009	<0.002	<0.005	0.29	0.022	6.0	279	190	10.0	18.0	15.0	7.96	3.8	112	8.98	209	20
Gull Lake	GL2	Max	2001-2003, 2009	0.0423	0.0640	0.66	0.057	10.1	306	200	24.0	45.0	50.0	8.36	10.0	135	14.84	322	96
Gull Lake	GL2	SD	2001-2003, 2009	0.0097	0.0180	0.10	0.009	1.1	13	4	4.3	8.0	15.5	0.15	2.1	10	1.79	31	21
Gull Lake	GL2	SE	2001-2003, 2009	0.0024	0.0045	0.03	0.002	0.3	6	2	1.1	2.3	7.7	0.04	0.5	5	0.46	8	6
Gull Lake	GL2	n	2001-2003, 2009	16	16	16	16	16	4	4	15	12	4	16	16	4	15	14	13
Gull Lake	GL2	95th Percentile	2001-2003, 2009	0.0256	0.0453	0.62	0.051	10.0	306	200	21.2	41.2	47.0	8.35	10.0	133	14.08	321	83
Gull Lake	GL2	COV	2001-2003, 2009	92	81	21	22	13	4	2	28	29	54	2	36	8	16	11	41

Table 2A-2. Summary statistics for selected routine water quality parameters.

Sample	Site ID		Years	Dissolved Ammonia (mg N/L)	Dissolved Nitrate/ nitrite (mg N/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	DOC (mg/L)	Conductivity (µmhos/cm)	TDS (mg/L)	TSS[1] (mg/L)	Laboratory Turbidity (NTU)	True Color (TCU)	Laboratory pH -	Chlorophyll *a* (µg/L)	Hardness as $CaCO_3$ (mg/L)	DO (mg/L)	Specific Conductance (µS/cm)	*In situ* Turbidity (NTU)
Upstream																			
Nelson River	NR2	Mean	2001-2004, 2009	0.0097	0.0207	0.49	0.039	8.2	284	173	15.3	26.8	26.9	8.15	5.5	114	11.46	268	51
Nelson River	NR2	Median	2001-2004, 2009	0.0072	0.0152	0.51	0.038	8.4	285	170	14.4	25.5	22.5	8.19	5.5	111	11.12	265	48
Nelson River	NR2	Min	2001-2004, 2009	<0.002	<0.005	0.29	0.018	5.3	254	140	10.0	18.0	15.0	7.85	2.0	94	8.53	205	21
Nelson River	NR2	Max	2001-2004, 2009	0.0403	0.0670	0.67	0.057	10.0	311	210	28.0	43.3	60.0	8.36	12.0	136	15.32	322	100
Nelson River	NR2	SD	2001-2004, 2009	0.0093	0.0181	0.08	0.009	1.1	20	23	4.3	6.8	12.0	0.14	2.2	13	1.87	31	22
Nelson River	NR2	SE	2001-2004, 2009	0.0021	0.0040	0.02	0.002	0.2	7	5	1.0	1.7	2.7	0.03	0.5	3	0.43	7	5
Nelson River	NR2	n	2001-2004, 2009	20	20	20	20	20	8	20	20	16	20	20	20	20	19	19	17
Nelson River	NR2	95th Percentile	2001-2004, 2009	0.0210	0.0429	0.61	0.050	9.1	309	210	21.4	37.1	50.5	8.35	8.2	134	14.18	321	98
Nelson River	NR2	COV	2001-2004, 2009	95	87	17	24	13	7	13	28	25	45	2	41	11	16	11	43
Downstream																			
Stephens Lake	STL1	Mean	2001-2004, 2009	0.0095	0.0211	0.49	0.037	8.3	287	182	14.7	26.5	26.2	8.17	5.7	111	11.44	270	50
Stephens Lake	STL1	Median	2001-2004, 2009	0.0086	0.0170	0.51	0.036	8.0	285	175	14.8	24.5	25.0	8.21	5.2	112	11.71	271	44
Stephens Lake	STL1	Min	2001-2004, 2009	<0.003	<0.005	0.34	0.024	5.3	256	130	9.0	17.0	15.0	7.86	2.0	89	8.56	207	23
Stephens Lake	STL1	Max	2001-2004, 2009	0.0300	0.0610	0.66	0.057	11.0	308	300	23.0	41.0	60.0	8.36	12.0	133	16.05	325	95
Stephens Lake	STL1	SD	2001-2004, 2009	0.0073	0.0173	0.09	0.008	1.2	17	37	3.4	7.2	11.0	0.15	2.5	11	2.05	30	21
Stephens Lake	STL1	SE	2001-2004, 2009	0.0016	0.0039	0.02	0.002	0.3	6	8	0.8	1.8	2.5	0.03	0.6	2	0.46	7	5
Stephens Lake	STL1	n	2001-2004, 2009	20	20	20	20	20	8	20	20	16	20	20	20	20	20	20	17
Stephens Lake	STL1	95th Percentile	2001-2004, 2009	0.0205	0.0449	0.62	0.051	10.1	307	228	18.3	39.5	41.0	8.34	10.1	127	13.97	320	90
Stephens Lake	STL1	COV	2001-2004, 2009	77	82	18	22	15	6	20	23	27	42	2	44	10	18	11	42
Stephens Lake	STL2	Mean	2001-2004, 2009, 2012	0.0099	0.0201	0.49	0.037	8.2	275	187	10.8	23.2	33.9	8.16	5.2	120.7	11.15	269	41.2
Stephens Lake	STL2	Median	2001-2004, 2009, 2012	0.0080	0.0100	0.50	0.038	8.0	281	192	10.0	23.0	15.0	8.19	5.3	123.0	11.55	271	39.5
Stephens Lake	STL2	Min	2001-2004, 2009, 2012	<0.003	<0.005	0.31	0.022	6.0	221	150	3.0	12.0	12.9	7.88	2.0	106.0	8.25	204	19.0
Stephens Lake	STL2	Max	2001-2004, 2009, 2012	0.0220	0.0570	0.70	0.065	10.0	305	224	20.0	35.0	94.4	8.41	10.0	134.0	15.52	326	75.0
Stephens Lake	STL2	SD	2001-2004, 2009, 2012	0.0067	0.0184	0.10	0.010	0.9	33	26	3.7	6.4	30.1	0.15	2.0	9.8	2.02	33	16.0
Stephens Lake	STL2	SE	2001-2004, 2009, 2012	0.0014	0.0038	0.02	0.002	0.2	12	10	0.8	1.5	11.4	0.03	0.4	3.7	0.42	7	3.6
Stephens Lake	STL2	n	2001-2004, 2009, 2012	23	23	23	23	23	7	7	23	19	7	23	23	7	23	23	20
Stephens Lake	STL2	95th Percentile	2001-2004, 2009, 2012	0.0200	0.0536	0.65	0.050	9.9	304	220	16.8	31.4	81.1	8.37	7.9	132.2	13.65	318	69.3
Stephens Lake	STL2	COV	2001-2004, 2009, 2012	68	91	21	27	11	12	14	34	27	89	2	39	8	18	12	39

1. One outlier (92 mg/L) from site GL-2 in July 2001 removed from data set.

Table 2A-3: Summary statistics for selected metals.

Sample	Site ID		Years	Total metals (mg/L)														
				Aluminum	Arsenic	Cadmium	Calcium	Chromium	Copper	Iron	Lead	Magnesium	Manganese	Nickel	Potassium	Sodium	Uranium	Zinc
Upstream																		
Clark Lake	CL1	Mean	2001-2004, 2009	1.20	0.00124	<0.00002	28.0	0.0030	0.0028	0.79	<0.0005	11.4	0.0190	0.0045	2.71	15.4	0.0006	0.01
Clark Lake	CL1	Median	2001-2004, 2009	1.32	0.00129	<0.00002	27.8	0.0020	0.0024	0.82	<0.0005	11.4	0.0189	0.0019	2.69	15.5	0.0006	<0.01
Clark Lake	CL1	Min	2001-2004, 2009	0.38	0.00101	<0.00002	25.6	<0.001	<0.001	0.38	<0.0005	9.9	0.0158	<0.002	2.40	12.8	0.0004	<0.01
Clark Lake	CL1	Max	2001-2004, 2009	2.00	0.00140	0.00003	30.5	0.0120	0.0070	1.15	0.0008	12.8	0.0250	0.0220	3.20	19.1	0.0008	0.05
Clark Lake	CL1	SD	2001-2004, 2009	0.50	0.00015	-	1.7	0.0038	0.0019	0.24	-	1.1	0.0030	0.0072	0.26	2.3	0.0001	0.02
Clark Lake	CL1	SE	2001-2004, 2009	0.18	0.00005	-	0.6	0.0013	0.0007	0.08	-	0.4	0.0010	0.0025	0.09	0.8	0.0000	0.01
Clark Lake	CL1	n	2001-2004, 2009	8	8	7	8	8	8	8	8	8	8	8	8	8	8	8
Clark Lake	CL1	95th Percentile	2001-2004, 2009	1.81	0.00139	0.00002	30.3	0.0089	0.0056	1.07	0.0007	12.8	0.0234	0.0157	3.09	18.7	0.0007	0.04
Clark Lake	CL1	COV	2001-2004, 2009	42	12	-	6	127	67	30	-	10	16	160	10	15	20	131
Nelson River	NR1	Mean	2001-2004, 2009	0.99	0.00121	<0.00002	29.6	0.0015	0.0026	0.74	<0.0006	11.7	0.0180	<0.002	2.75	15.9	0.0006	<0.01
Nelson River	NR1	Median	2001-2004, 2009	0.88	0.00120	<0.00002	28.7	0.0014	0.0023	0.75	<0.0006	11.8	0.0194	<0.002	2.77	16.1	0.0006	<0.01
Nelson River	NR1	Min	2001-2004, 2009	0.56	0.00104	<0.00002	27.0	<0.001	0.0021	0.41	<0.0006	10.7	0.0100	<0.002	2.56	14.0	0.0005	<0.01
Nelson River	NR1	Max	2001-2004, 2009	1.65	0.00139	<0.00002	33.9	0.0026	0.0036	1.06	<0.0006	12.5	0.0234	0.0027	2.90	17.4	0.0007	<0.01
Nelson River	NR1	SD	2001-2004, 2009	0.53	0.00017	-	3.0	0.0011	0.0007	0.32	-	0.7	0.0058	0.0009	0.14	1.5	0.0001	-
Nelson River	NR1	SE	2001-2004, 2009	0.26	0.00008	-	1.5	0.0006	0.0004	0.16	-	0.4	0.0029	0.0005	0.07	0.8	0.0000	-
Nelson River	NR1	n	2001-2004, 2009	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Nelson River	NR1	95th Percentile	2001-2004, 2009	1.58	0.00138	<0.00002	33.1	0.0025	0.0034	1.05	<0.0006	12.4	0.0230	0.0027	2.89	17.3	0.0007	<0.01
Nelson River	NR1	COV	2001-2004, 2009	53	14	-	10	76	28	42	-	6	32	-	5	10	10	-
Gull Lake	GL1	Mean	2001-2003, 2009	0.93	0.00120	<0.00002	29.8	0.0016	0.0025	0.76	<0.0006	11.8	0.0200	0.0020	2.86	16.9	0.0006	<0.01
Gull Lake	GL1	Median	2001-2003, 2009	0.89	0.00120	<0.00002	30.4	0.0017	0.0024	0.76	<0.0006	12.1	0.0196	0.0023	2.97	17.5	0.0006	<0.01
Gull Lake	GL1	Min	2001-2003, 2009	0.53	0.00110	<0.00002	26.1	<0.001	0.0020	0.49	<0.0006	10.3	0.0173	<0.002	2.48	14.9	0.0005	<0.01
Gull Lake	GL1	Max	2001-2003, 2009	1.42	0.00130	<0.00002	32.4	0.0026	0.0030	1.01	0.0005	12.6	0.0235	0.0024	3.02	17.8	0.0008	<0.01
Gull Lake	GL1	SD	2001-2003, 2009	0.38	0.00008	-	2.7	0.0009	0.0004	0.24	0.0001	1.0	0.0029	0.0007	0.25	1.3	0.0001	-
Gull Lake	GL1	SE	2001-2003, 2009	0.19	0.00004	-	1.4	0.0005	0.0002	0.12	0.0001	0.5	0.0014	0.0003	0.13	0.7	0.0001	-
Gull Lake	GL1	n	2001-2003, 2009	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Gull Lake	GL1	95th Percentile	2001-2003, 2009	1.36	0.00129	<0.00002	32.2	0.0025	0.0029	0.99	<0.0006	12.5	0.0232	0.0024	3.02	17.8	0.0007	<0.01
Gull Lake	GL1	COV	2001-2003, 2009	41	7	-	9	57	17	32	-	9	14	34	9	8	17	-
Gull Lake	GL2	Mean	2001-2003, 2009	0.70	0.00122	<0.00002	29.9	0.0015	0.0021	0.61	<0.0006	11.8	0.0185	<0.002	2.79	16.9	0.0006	<0.01
Gull Lake	GL2	Median	2001-2003, 2009	0.70	0.00122	<0.00002	29.7	0.0014	0.0021	0.59	<0.0006	11.8	0.0186	<0.002	2.82	16.8	0.0006	<0.01
Gull Lake	GL2	Min	2001-2003, 2009	0.46	0.00104	<0.00002	27.2	<0.001	0.0020	0.44	<0.0006	10.8	0.0166	<0.002	2.58	15.5	0.0005	<0.01
Gull Lake	GL2	Max	2001-2003, 2009	0.95	0.00140	<0.00002	33.0	0.0027	0.0022	0.81	<0.0006	12.8	0.0201	0.0024	2.94	18.4	0.0007	<0.01
Gull Lake	GL2	SD	2001-2003, 2009	0.22	0.00015	-	2.4	0.0009	0.0001	0.16	-	0.8	0.0018	0.0007	0.17	1.3	0.0001	-
Gull Lake	GL2	SE	2001-2003, 2009	0.11	0.00007	-	1.2	0.0005	0.0000	0.08	-	0.4	0.0009	0.0004	0.09	0.7	0.0000	-
Gull Lake	GL2	n	2001-2003, 2009	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Gull Lake	GL2	95th Percentile	2001-2003, 2009	0.92	0.00138	<0.00002	32.6	0.0025	0.0022	0.78	-	12.7	0.0201	0.0022	2.94	18.3	0.0007	<0.01
Gull Lake	GL2	COV	2001-2003, 2009	32	12	-	8	63	4	26	-	7	10	-	6	8	14	-

Table 2A-3: Summary statistics for selected metals.

Sample	Site ID		Years	Total metals (mg/L)														
				Aluminum	Arsenic	Cadmium	Calcium	Chromium	Copper	Iron	Lead	Magnesium	Manganese	Nickel	Potassium	Sodium	Uranium	Zinc
Upstream																		
Nelson River	NR2	Mean	2001-2004, 2009	1.37	0.00130	0.00002	28.0	0.0019	0.0036	1.03	0.0006	10.7	0.0225	0.0026	2.73	14.1	0.0006	0.0108
Nelson River	NR2	Median	2001-2004, 2009	1.35	0.00125	0.00001	27.9	0.0020	0.0027	0.98	0.0006	10.4	0.0209	0.0029	2.69	13.7	0.0005	<0.01
Nelson River	NR2	Min	2001-2004, 2009	0.57	0.00080	<0.00002	23.0	<0.001	<0.001	0.50	<0.0006	8.6	0.0160	<0.002	2.30	10.5	0.0004	<0.01
Nelson River	NR2	Max	2001-2004, 2009	2.53	0.00250	0.00009	32.8	0.0028	0.0193	1.66	0.0014	13.1	0.0314	0.0043	3.16	18.8	0.0008	0.0700
Nelson River	NR2	SD	2001-2004, 2009	0.45	0.00041	0.00002	2.8	0.0008	0.0039	0.29	0.0003	1.3	0.0046	0.0009	0.26	2.7	0.0001	0.0144
Nelson River	NR2	SE	2001-2004, 2009	0.10	0.00009	0.00001	0.6	0.0003	0.0009	0.06	0.0001	0.3	0.0010	0.0002	0.06	0.6	0.0000	0.0032
Nelson River	NR2	n	2001-2004, 2009	20	20	12	20	8	20	20	20	20	20	20	20	20	20	20
Nelson River	NR2	95th Percentile	2001-2004, 2009	2.09	0.00193	0.00006	32.7	0.0028	0.0076	1.48	0.0009	12.6	0.0310	0.0043	3.10	18.1	0.0007	0.0225
Nelson River	NR2	COV	2001-2004, 2009	33	32	135	10	42	109	28	52	13	21	34	9	19	17	134
Downstream																		
Stephens Lake	STL1	Mean	2001-2004, 2009	1.33	0.00121	<0.00002	27.5	0.0015	0.0029	0.95	0.0006	10.6	0.0200	0.0040	2.65	14.2	0.0006	<0.01
Stephens Lake	STL1	Median	2001-2004, 2009	1.25	0.00120	<0.00002	27.7	0.0014	0.0030	0.96	0.0006	10.5	0.0189	0.0027	2.60	14.5	0.0006	0.0100
Stephens Lake	STL1	Min	2001-2004, 2009	0.45	0.00060	<0.00002	23.6	<0.001	0.0020	0.45	<0.0006	8.6	0.0122	<0.002	2.20	10.6	0.0004	<0.01
Stephens Lake	STL1	Max	2001-2004, 2009	2.43	0.00240	0.00003	31.4	0.0027	0.0076	1.59	0.0019	13.3	0.0278	0.0300	3.14	19.6	0.0007	0.0200
Stephens Lake	STL1	SD	2001-2004, 2009	0.52	0.00037	0.00001	2.3	0.0009	0.0013	0.32	0.0004	1.1	0.0042	0.0062	0.22	2.5	0.0001	0.0046
Stephens Lake	STL1	SE	2001-2004, 2009	0.12	0.00008	0.00000	0.5	0.0003	0.0003	0.07	0.0001	0.2	0.0009	0.0014	0.05	0.6	0.0000	0.0010
Stephens Lake	STL1	n	2001-2004, 2009	20	20	12	20	8	20	20	20	20	20	20	20	20	20	20
Stephens Lake	STL1	95th Percentile	2001-2004, 2009	1.96	0.00164	0.00003	31.1	0.0026	0.0042	1.50	0.0016	12.0	0.0263	0.0072	2.91	17.7	0.0007	0.0200
Stephens Lake	STL1	COV	2001-2004, 2009	39	31	-	8	64	43	34	70	10	21	154	8	18	14	-
Stephens Lake	STL2	Mean	2001-2004, 2009, 2012	0.67	0.00121	<0.00002	29.1	0.0010	0.00201	0.54	0.0004	11.6	0.0165	0.0017	2.72	16.8	0.0006	<0.01
Stephens Lake	STL2	Median	2001-2004, 2009, 2012	0.37	0.00120	<0.00002	29.6	0.0005	0.00190	0.43	0.0003	11.7	0.0159	0.0021	2.85	17.4	0.0007	<0.01
Stephens Lake	STL2	Min	2001-2004, 2009, 2012	0.21	0.00086	<0.00002	25.2	<0.001	0.00157	0.21	0.0002	10.4	0.0103	0.0010	2.12	12.9	0.0005	<0.01
Stephens Lake	STL2	Max	2001-2004, 2009, 2012	1.67	0.00158	0.00001	32.9	0.0021	0.00250	1.24	0.0008	12.7	0.0243	0.0024	3.11	18.9	0.0007	0.0055
Stephens Lake	STL2	SD	2001-2004, 2009, 2012	0.53	0.00023	0.00000	2.6	0.0007	0.00033	0.39	0.0002	0.9	0.0050	0.0006	0.35	2.0	0.0001	-
Stephens Lake	STL2	SE	2001-2004, 2009, 2012	0.20	0.00009	0.00000	1.0	0.0002	0.00013	0.15	0.0001	0.3	0.0019	0.0002	0.13	0.8	0.0000	-
Stephens Lake	STL2	n	2001-2004, 2009, 2012	7	7	7	7	7	7	7	7	7.0	7	7	7	7	7	7
Stephens Lake	STL2	95th Percentile	2001-2004, 2009, 2012	1.46	0.00152	<0.00002	32.1	0.0019	0.00246	1.10	0.0007	12.7	0.0234	0.0023	3.08	18.6	0.0007	<0.01
Stephens Lake	STL2	COV	2001-2004, 2009, 2012	79	19	-	9	66	17	72	56	7.9	30	39	13	12	12	-

Table 2A-4: Summary of statistical analyses comparing baseline water quality between sites located between Clark Lake and the Kettle GS on the main flow of the lower Nelson River (*i.e.*, CL1, NR1, GL1, GL2, NR2, STL1, and STL2). Significant differences are denoted in red.

Parameter	Normality	P value		Difference
		ANOVA	Kruskal-Wallis	
Ammonia	N	-	0.943	
Nitrate	N	-	0.999	
TN	N	-	0.966	
TP	Y	0.910	-	
DOC	N	-	0.805	
Lab conductivity	Y	0.607	-	
TDS	N	-	0.357	
TSS	N	-	0.001[1]	STL2 lower than NR1, NR2, and STL1
Lab Turbidity	Y	0.592	-	
True Colour	N	-	0.994	
Lab pH	Y	0.987	-	
Chlorophyll *a*	N	-	0.999	
Hardness	Y	0.132	-	
In situ pH	N	-	0.969	
DO	Y	0.989	-	
Specific Conductance	Y	0.991	-	
In situ Turbidity	N	-	0.721	
Aluminum	Y	0.011[2]	-	STL2 lower than STL1 and NR2
Arsenic	N	-	0.992	
Calcium	Y	0.342	-	
Chromium	N	-	0.574	
Copper	N	-	0.178	
Iron	Y	0.005[3]	-	STL2 lower than STL1 and NR2
Lead	N	-	0.044	No significant difference with a Dunn's test
Magnesium	N	-	0.066	
Manganese	Y	0.056	-	
Molybenum	N	-	0.689	
Nickel	N	-	0.107	
Potassium	N	-	0.709	
Sodium	Y	0.033	-	No significant difference with a Tukey's test
Uranium	N	-	0.77	

1. p value 2009 only: 0.926.
2. p value 2009 only: 0.979.
3. p value 2009 only: 0.980.

Table 2A-5: Summary of results of statistical analyses for seasonal differences in selected water quality parameters for site NR2. Significant differences are denoted in red.

Parameter	P value		Comments
	ANOVA	Kruskal-Wallis	
TP	0.157	-	
TN	0.278	-	
Ammonia	0.752	-	
Nitrate	-	0.643	
Lab conductivity	0.799	-	
Lab pH	0.872	-	
TDS	0.33	-	
True Colour	0.224	-	
Chlorophyll a	0.093	-	
TSS	**0.023**	-	Fall lower than summer 1
Lab Turbidity	0.09	-	
DO	0.079	-	
Aluminum	0.224	-	
Iron	0.276	-	
Hardness	0.592	-	
Calcium	0.545	-	
Magnesium	0.627	-	
Potassium	0.149	-	
Sodium	0.935	-	
DOC	-	0.454	
Manganese	-	0.205	
Lead	-	0.632	
Copper	-	0.300	

Table 2A-6: Summary of power analysis output for key water quality indicators relative to benchmarks and additional supporting water quality parameters relative to 95th percentiles of baseline data.

Parameter:	TP		TN		Ammonia		Nitrate		TSS				Lab turbidity		*In situ* turbidity		*In situ* specific conductance		Lab Conductivity		pH			
Effect Size:	50% increase	0.058 mg/L	95th Percentile	0.63 mg/L	MWQSOG	0.896 mg N/L	MWQSOG	2.93 mg N/L	MWQSOG	25 mg/L increase	MWQSOG	5 mg/L increase	95th Percentile	40.4 NTU	95th Percentile	97 NTU	95th Percentile	321 µS/ cm	95th Percentile	308 µmhos /cm	MWQSOG	6.5	MWQSOG	9
	Power	N	Power	N	Power	N	Power	N	Power	N	Power	N	Power	N	Power	N	Power	N	Power	N	Power	N	Power	N
	-	1	-	1	-	1	-	1	-	1	-	1	-	1	-	1	-	1	-	1	-	1	-	1
	0.468	2	0.308	2	0	2	0	2	0	2	0	2	0	2	0	2	0.286	2	0.227	2	0.999	2	0.975	2
	0.718	3	0.514	3	1	3	1	3	0.997	3	0.327	3	0.551	3	0.688	3	0.493	3	0.323	3	1	3	1	3
	0.87	4	0.669	4	1	4	1	4	1	4	0.435	4	0.717	4	0.837	4	0.649	4	0.433	4	1	4	1	4
	0.95	5	0.769	5	1	5	1	5	1	5	0.488	5	0.782	5	0.884	5	0.776	5	0.51	5	1	5	1	5
	0.98	6	0.837	6	1	6	1	6	1	6	0.542	6	0.864	6	0.938	6	0.848	6	0.629	6	1	6	1	6
	0.992	7	0.881	7	1	7	1	7	1	7	0.607	7	0.911	7	0.96	7	0.898	7	0.689	7	1	7	1	7
	0.996	8	0.918	8	1	8	1	8	1	8	0.683	8	0.946	8	0.988	8	0.93	8	0.736	8	1	8	1	8
	0.998	9	0.953	9	1	9	1	9	1	9	0.702	9	0.963	9	0.99	9	0.956	9	0.785	9	1	9	1	9
	1	10	0.971	10	1	10	1	10	1	10	0.761	10	0.98	10	0.994	10	0.974	10	0.826	10	1	10	1	10
	1	11	0.978	11	1	11	1	11	1	11	0.794	11	0.99	11	0.994	11	0.986	11	0.862	11	1	11	1	11
	1	12	0.988	12	1	12	1	12	1	12	0.832	12	0.995	12	0.996	12	0.992	12	0.886	12	1	12	1	12
	1	13	0.995	13	1	13	1	13	1	13	0.87	13	0.996	13	0.997	13	0.996	13	0.924	13	1	13	1	13
	1	14	0.996	14	1	14	1	14	1	14	0.896	14	0.998	14	0.998	14	0.997	14	0.942	14	1	14	1	14
	1	15	0.996	15	1	15	1	15	1	15	0.909	15	1	15	0.998	15	0.996	15	0.951	15	1	15	1	15
	1	16	0.995	16	1	16	1	16	1	16	0.924	16	1	16	1	16	0.998	16	0.957	16	1	16	1	16
	1	17	0.997	17	1	17	1	17	1	17	0.934	17	1	17	1	17	0.998	17	0.971	17	1	17	1	17
	1	18	0.997	18	1	18	1	18	1	18	0.941	18	1	18	1	18	0.999	18	0.976	18	1	18	1	18
	1	19	0.998	19	1	19	1	19	1	19	0.952	19	1	19	1	19	0.999	19	0.983	19	1	19	1	19
	1	20	0.999	20	1	20	1	20	1	20	0.968	20	1	20	1	20	1	20	0.987	20	1	20	1	20

Table 2A-6. Summary of power analysis output for key water quality indicators relative to benchmarks and additional supporting water quality parameters relative to 95th percentiles of baseline data.

Parameter:	Chlorophyll *a*		DO		Aluminum		Arsenic		Chromium		Copper		Iron		Lead		Nickel		Molybdenum		Uranium	
Effect Size:	95th Percentile	10 µg/L	MWQSOG	6.5 mg/L	95th Percentile	1.98 mg/L	MWQSOG	0.15 mg/L	MWQSOG	0.097 mg/L	MWQSOG	0.0106 mg/L	95th Percentile	1.45 mg/L	MWQSOG	0.00383 mg/L	MWQSOG	0.0596 mg/L	MWQSOG	0.073 mg/L	MWQSOG	0.033 mg/L
	Power	**N**	**Power**	**N**	**Power**	**N**	**Power**	**N**	**Power**	**N**	**Power**	**N**	**Power**	**N**	**Power**	**N**	**Power**	**N**	**Power**	**N**	**Power**	**N**
	-	1	-	1	-	1	-	1	-	1	-	1	-	1	-	1	-	1	-	1	-	1
	0	2	0	2	0.277	2	0	2	0	2	0	2	0.332	2	0	2	0	2	0	2	1	2
	0.699	3	0.817	3	0.46	3	1	3	1	3	0.983	3	0.59	3	0.999	3	1	3	1	3	1	3
	0.806	4	0.914	4	0.606	4	1	4	1	4	0.993	4	0.717	4	0.999	4	1	4	1	4	1	4
	0.881	5	0.955	5	0.717	5	1	5	1	5	0.997	5	0.822	5	1	5	1	5	1	5	1	5
	0.936	6	0.981	6	0.79	6	1	6	1	6	1	6	0.893	6	1	6	1	6	1	6	1	6
	0.977	7	0.997	7	0.851	7	1	7	1	7	1	7	0.923	7	1	7	1	7	1	7	1	7
	0.991	8	0.999	8	0.891	8	1	8	1	8	1	8	0.957	8	1	8	1	8	1	8	1	8
	0.995	9	1	9	0.924	9	1	9	1	9	1	9	0.973	9	1	9	1	9	1	9	1	9
	0.998	10	0.999	10	0.951	10	1	10	1	10	1	10	0.987	10	1	10	1	10	1	10	1	10
	1	11	1	11	0.963	11	1	11	1	11	1	11	0.994	11	1	11	1	11	1	11	1	11
	1	12	1	12	0.976	12	1	12	1	12	1	12	0.997	12	1	12	1	12	1	12	1	12
	1	13	1	13	0.982	13	1	13	1	13	1	13	0.997	13	1	13	1	13	1	13	1	13
	1	14	1	14	0.987	14	1	14	1	14	1	14	0.998	14	1	14	1	14	1	14	1	14
	1	15	1	15	0.992	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15
	1	16	1	16	0.994	16	1	16	1	16	1	16	0.998	16	1	16	1	16	1	16	1	16
	1	17	1	17	0.993	17	1	17	1	17	1	17	1	17	1	17	1	17	1	17	1	17
	1	18	1	18	0.996	18	1	18	1	18	1	18	1	18	1	18	1	18	1	18	1	18
	1	19	1	19	0.998	19	1	19	1	19	1	19	1	19	1	19	1	19	1	19	1	19
	1	20	1	20	0.998	20	1	20	1	20	1	20	1	20	1	20	1	20	1	20	1	20

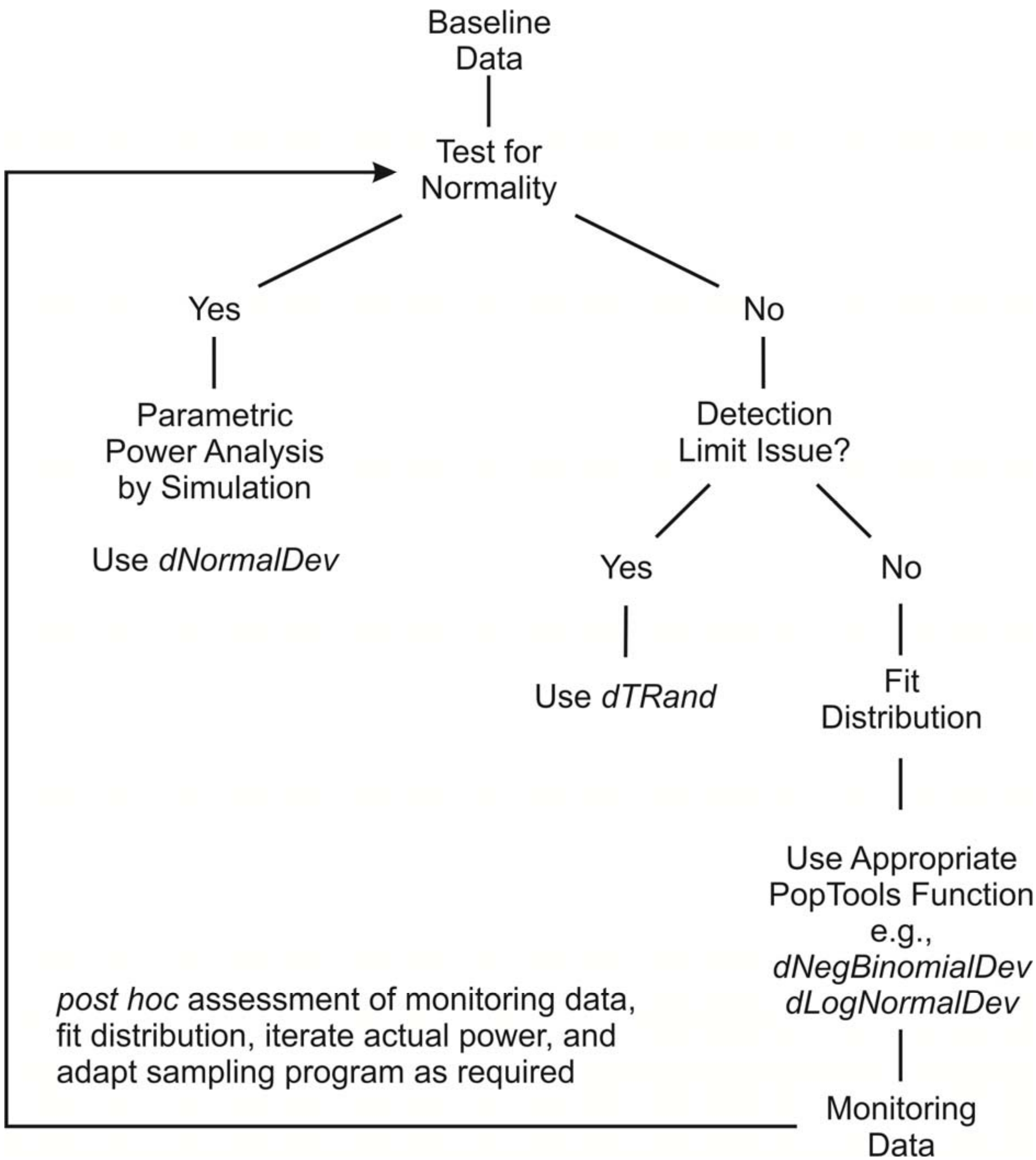

Figure A2-1. Basic treatment of baseline data for power analysis by simulation. The post hoc assessment of monitoring data allows for more precise assessment of power and any adaptive decisions to the sampling program that arise.

Water Quality Sampling Sites - Local Study Area Mainstem

Map 2A-1

KEEYASK Hydropower Limited Partnership

0 25 50 Kilometres

0 10 20 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:500 000

Baseline Water Quality Sampling Sites

Map 2A-2

APPENDIX 4A
RESULTS OF PRELIMINARY POWER ANALYSES FOR BASELINE BENTHIC MACROINVERTEBRATE DATA

4A.1 INTRODUCTION

An analysis of baseline benthic macroinvertebrate data was undertaken to assist with advising on study design for the AEMP. This analysis included:

- Determining summary statistics (including coefficient of variation [COV]) for nearshore and offshore aquatic habitat types by waterbody and sampling year to examine spatial differences;
- Determining the number of field sub-samples (*i.e.*, grabs) per replicate station that would provide an estimate with 20% precision (*i.e.*, an acceptable level of variance) for each metric by waterbody and sampling year;
- Statistical evaluation of inter-annual differences in macroinvertebrate metrics for the nearshore and offshore habitat types by waterbody; and
- An exploratory *a priori* power analysis was conducted to provide an evaluation of the power of recent baseline benthic macroinvertebrate data collected in the study area for post-Project comparisons and to assist with defining the level of sampling effort (*i.e.*, identify sample sizes) for the AEMP.

The following provides an overview of the methods and results of this analysis.

4A.2 EVALUATION OF DATA FOR POST-PROJECT MONITORING

The benthic macroinvertebrate AEMP will focus upon areas upstream and downstream of construction activities, and upstream, within, and downstream of the reservoir during operation. Therefore the analyses of benthic macroinvertebrate data utilized recent baseline data collected as part of the CAMP in Split (2010, 2011, and 2012 for nearshore habitat type; 2009, 2010, 2011, and 2012 for offshore habitat type; Map 4A-1) and Stephens (south; 2009 and 2012 for offshore habitat type only; Map 4A-2) lakes. CAMP data from these two waterbodies are used for this purpose as:

- CAMP provides recent baseline data for study area (2009 and onwards);
- CAMP study design is stratified by major aquatic habitat type and is comparable to the proposed Keeyask AEMP study design; and,
- CAMP level of identification is to Family (Genus for Ephemeroptera), allowing for calculation of meaningful richness metrics, and diversity and evenness indices.

4A.2.1 DESCRIPTION OF EXISTING DATA

4A.2.1.1 Data Analysis Methods

Selected metrics were calculated for each replicate sample and summary statistics (n, mean, median, standard error [SE], standard deviation [SD], minimum, maximum, coefficient of variation [COV], and 95th percentile) were derived for each lake for the nearshore (Split Lake only due to availability of data) and offshore (Split Lake and Stephens [south] lakes) aquatic habitats type to examine spatial differences. Metrics selected to describe the benthic macroinvertebrate community included:

- **Abundance**: total invertebrate abundance [individuals per kicknet (nearshore) or individuals per m^2 (offshore)]; non-Insecta abundance [individuals per kicknet (nearshore) or individuals per m^2 (offshore)]; and Insecta abundance [individuals per kicknet (nearshore) or individuals per m^2 (offshore)]);
- **Composition**: EPT:Chironomidae ratio; Simpson's Diversity Index; and evenness [Simpson's Equitability ED]); and
- **Richness**: total taxonomic richness (family-level); and Hill's Effective [EH'] richness (family level) metrics (Magurran 1988, 2004).

Additionally, the number of field sub-samples (*i.e.*, grabs) per replicate station that would provide an estimate with 20% precision (*i.e.*, an acceptable level of variance) for each metric was determined for each lake by sampling year. The number of field sub-samples was calculated as follows:

$n = s^2/ D^2*X^2$, where

X = the sample mean

n = the number of field sub-samples

s = the sample variance

D = the index of precision (*i.e.*, 0.20)

COV was calculated as SD/mean x 100; COV facilitated comparisons of the variability of various data sets to assist with identifying the most robust metrics as well as to assist with advising on sampling design. The variability of the metrics examined was then described to facilitate identification of those metrics with the lowest natural variation for further consideration and analysis.

4A.2.1.1.1 Statistical Analyses of Inter-Annual Differences

Detailed statistical analyses were conducted on Split and Stephens (south) lakes datasets. The baseline dataset is largest for Split Lake and would conceptually therefore provide the most robust pre-Project database for use in post-Project monitoring. Inter-annual differences in macroinvertebrate metrics were assessed statistically for the nearshore and offshore habitat types.

All data were tested for normality prior to statistical analysis and data that were normally distributed were assessed using parametric statistics while non-normally distributed data were analysed using non-parametric tests. Differences between years were assessed using the t-test (parametric) or Mann-Whitney test (non-parametric) when two years of data were available; ANOVA with Bonferroni pairwise comparison (parametric) or Kruskal-Wallis followed by multiple pairwise comparisons (Dunn's procedure) (non-parametric) were used when three or more years of data were available. All tests were assessed with significance level of 0.05; analyses were performed using XLStat Version 2007.4.

4A.2.1.2 Results

4A.2.1.2.1 Abundance

In the offshore, total macroinvertebrate abundance was variable between Split and Stephens (south) lakes and inter-annually within the same lake, ranging from a mean of 2,981 individuals/m^2 (Split Lake: 2012) to 7,794 individuals/m^2 (Stephens Lake [south]: 2009) (Tables 4A-1 and 4A-2). Within Stephens (south) Lake, total abundance was significantly higher in 2009 in comparison to 2012; no significant differences among years were observed in Split Lake, although total abundance was somewhat lower in 2012 in comparison to preceding years. The data exhibited relatively higher COVs (COVs up to 42%), particularly in 2009 prior to the study design review and modification that took place prior to 2010 and subsequent years sampling, but were normally distributed. In the nearshore of Split Lake, total abundance also varied inter-annually and was significantly lower in 2010 in comparison to 2012; data were not normally distributed in 2010 only. COVs of samples collected in the nearshore were higher than those from the offshore. This may reflect the more variable nature of the shallower areas of the lakes (*i.e.*, strongly affected by water level fluctuations and wave energy, increased substrate heterogeneity, and potentially affected by anthropogenic factors).

Non-Insecta and Insecta abundance in these two lakes generally followed the same patterns observed for total macroinvertebrate abundance (Tables 4A-3, 4A-4, 4A-5, and 4A-6).

4A.2.1.2.2 Composition

The EPT:Chironomidae ratio in the offshore was variable between the two lakes and inter-annually within the same lake, ranging between a low of 0.92 (Stephens Lake [south]: 2012) and a high of 645 (Split Lake: 2009) (Tables 4A-7 and 4A-8). Within Stephens (south) Lake, the ratio was significantly higher in 2009 in comparison to 2012; this was also the case in Split Lake, but the ratio was also significantly higher than the one estimated in 2010. The data exhibited relatively higher COVs (COVs up to 168%), particularly in 2009 prior to the study design review and modification, and were normally distributed with the exception of Split Lake in 2009. In the nearshore of Split Lake, the ratio also varied inter-annually and was significantly lower in 2011 in comparison to 2010 and 2012; data were normally distributed all three years. COVs of samples collected in the nearshore were also quite variable, with COVs ranging between 11% and 93%.

Within the offshore habitat type, Simpson's Diversity Index and evenness tended to be somewhat similar between Split and Stephens (south) lakes, more so than between the nearshore and offshore habitats within Split Lake (Tables 4A-9, 4A-10, 4A-11, and 4A-12). Differences between habitat types in Split Lake were evident for these two indices. With the exception of 2011, diversity was somewhat higher in the nearshore in comparison to the offshore, whereas evenness was consistently higher in the offshore. The increased substrate heterogeneity of the nearshore may lead to an increased number of taxa present, albeit with invertebrates of different species less similar in abundance (*i.e.*, abundance less evenly distributed amongst the taxa present). Data for these two indices were normally distributed, with the exception of diversity in Split Lake, offshore, 2009 and 2010, and evenness in Split Lake, nearshore, 2011. COVs for diversity were less than or equal to 20% in the offshore of both lakes; this was also the case in the nearshore of Split Lake, with the exception of 2011 (COV 35%). In contrast, COVs for evenness were greater than 20% in both lakes and both habitat types in Split Lake, with the exception of Split Lake, offshore, 2010 and 2011, and Split Lake, nearshore, 2010. No significant differences were observed between years in the offshore habitat of Stephens (south) Lake for either diversity or evenness; however, in Split Lake, numerous significant inter-annual differences were observed for both indices in the two habitat types sampled.

4A.2.1.2.3 Richness

Similar to the diversity metric, total taxonomic richness decreased with increasing water depth in Split Lake (Table 4A-13). Effective richness was similar between the habitat types in Split Lake (Table 4A-14), which is likely indicative that the higher total taxonomic richness in the nearshore is due to an increased number of 'rare' taxa in comparison to the offshore. In the offshore, total and effective richness were somewhat higher in Split Lake in comparison to Stephens (south) Lake (Table 4A-13, 4A-14. 4A-15, and 4A-16). Data for these two indices in Split Lake were normally distributed, with the exception of total and effective richness in the nearshore, 2011; in Stephens (south) Lake, only effective richness in 2012 was normally distributed. COVs for these two metrics in Split Lake were typically less than 20%, with the exception of total richness, offshore, 2009 (25%) and 2010 (22%), and effective richness, nearshore, 2011

(54%) and 2012 (41%). In Stephens (south) Lake, COVs for these two metrics were greater than 20%, except for total richness, 2012 (12%). No significant differences were observed between years in the offshore habitat of Stephens (south) Lake for either richness metric; however, in Split Lake, numerous significant inter-annual differences were observed for both metrics in the two major habitats sampled.

4A.2.2 POWER ANALYSES

4A.2.2.1 Data Analysis Methods

The most robust metrics identified through review of the baseline data for further statistical exploration and consideration under the AEMP were also subject to a power analysis to:

- Provide an analysis of the power of the existing data set to be used as the foundation for detecting post-Project change (*i.e.*, Before-After comparisons);
- Explore samples sizes (*i.e.*, number of replicate stations within a waterbody or area of a waterbody) required for detecting pre-defined levels of change. Based on experience with other AEMPS, an effect size of ±50% change in a metric is likely most appropriate to use (*i.e.*, realistically achievable with a well-designed program); however, a CES of ±25% may be achievable for certain metrics with comparatively reduced levels of variability; and
- Identify required modifications to the AEMP sampling program (*i.e.*, number of replicate stations).

Power analysis was conducted following general guidance provided in the Environment Canada Metal Mining EEM Guidance Document (EC 2012). Specifically, values for α (Type I error) and β (Type II error) were set at 0.1 as advised in EC (2012); resulting power is 0.9. Evaluation of power of the existing baseline data for benthic macroinvertebrate community metrics was conducted using data collected from Split Lake (evaluated by habitat type for pooled years of data).

The variability of numerous benthic macroinvertebrate metrics measured during the CAMP were evaluated and described to assist with identifying the most robust metrics for further statistical exploration and consideration under the AEMP. Metrics that were subject to a power analysis included:

- Total macroinvertebrate abundance;
- Simpson's Diversity Index; and
- Total taxonomic Richness.

COVs for the composition and richness metrics were typically less than 20% for each habitat type in Split Lake and were therefore identified for further analysis; exceptions included Simpson's Diversity Index (nearshore: 2011) and taxonomic richness (offshore: 2009, 2010) (Tables 4A-9 and 4A-13). COV for total macroinvertebrate abundance (Table 4A-1) was somewhat higher in comparison, particularly in the nearshore aquatic habitat type, but this metric was retained as it is among the most commonly used indicators for the status of the benthic macroinvertebrate community in lakes.

Effects sizes examined in the power analysis included the mean of a metric ±50% and ±25%. These effects sizes were selected based on the Metal Mining EEM Guidance document, scientific literature, and other recent/current AEMPs (*e.g.*, Azimuth 2012). For metrics with a non-normal distribution (nearshore: total macroinvertebrate abundance and Simpson's Diversity Index), all distributions were fitted to log-normal prior to analyses; for Simpson's Diversity Index, it was truncated at 1. Analyses were run using PopTools version 3.2 (build 5) add-in for Microsoft Excel 2010.

4A.2.2.2 Results

4A.2.2.2.1 Total Macroinvertebrate Abundance

The power of the existing total macroinvertebrate abundance data set from Split Lake for detecting a pre-defined level of change (*i.e.*, mean ± 50%, mean ± 25%) is low for both change scenarios explored in the nearshore aquatic habitat type (Table 4A-17). The offshore habitat type has considerably higher power for detecting change post-Project, with a power of 1.000 for detecting a change in the mean of ±50% and 0.850 for ±25%.

Sample sizes (*i.e.*, the number of replicate stations within an aquatic habitat type) required for detecting pre-defined levels of change in the abundance metric were high for both aquatic habitat types, with the exception of ±50% in the offshore (Table 4A-18). This is likely related to the high variability in the existing data set, particularly in the nearshore (Table 4A-1: COVs up to 88%). A total of 59 and 10 replicate stations will be required in the nearshore and offshore, respectively, to detect a change in the mean of ±50% (power of 0.9).

4A.2.2.2.2 Simpson's Diversity Index

The power of the existing diversity index metric data set to be able to detect change is high for all change scenarios in both major habitat types (Table 4A-17). The power is 1.000 in the offshore to be able to detect a change in the mean of ±50% and ±25%. In the nearshore, power is also 1.000 to be able to detect a change of ±50%, but declines to a power of 0.819 for ±25%.

To detect a ±50% change in the mean, the nearshore and offshore require 7 and 3 replicate stations, respectively (Table 4A-18). The number of replicate stations required to be able to detect smaller changes in the mean increases more notably in the nearshore habitat type (19 replicate stations) in comparison to the offshore (6 replicate stations).

4A.2.2.2.3 Total Taxonomic Richness

The power of the existing total taxonomic richness data set from Split Lake for detecting a pre-defined level of change is also high for all change scenarios and both major types explored (Table 4A-17). The power is 1.000 in both habitats to be able to detect a change in the mean of ±50%., but declines slightly to 0.930 and 0.959 in the nearshore and offshore, respectively, for a change of ±25%.

To detect a ±50% change in the mean, the nearshore and offshore require 4 and 6 replicate stations, respectively (Table 4A-18). The number of replicate stations required to be able to detect smaller changes in the mean increases for both major habitat types, more so in the offshore. The greater relative increase in the number of replicate stations in the offshore is likely related to the higher variability in the existing data set of this major habitat type (Table 4A-13: COVs range between 10 and 25% in the offshore, but only between 7 and 16% in the nearshore).

4A.3 SUMMARY & PRELIMINARY RECOMMENDATIONS FOR AEMP

EC (2012) recommends benthic macroinvertebrate sampling should include at a minimum, five replicate stations, each consisting of a minimum of three sub-samples, for both the potentially affected and reference areas. Replicate stations should be located within the dominant habitat class to reduce variability (where possible). Actual number of samples may vary on a site-specific basis and existing data should be analysed to identify adequate sample size.

The field protocol for baseline sampling as part of the CAMP in Split (2010, 2011, and 2012 for nearshore habitat type; 2009, 2010, 2011, and 2012 for offshore habitat type) and Stephens (south; 2009 and 2012 for offshore habitat type only) lakes differs between nearshore and offshore aquatic habitat types, and between 2009 and subsequent sampling years in the offshore.

In the intermittently exposed nearshore, each replicate station is comprised of a timed 3-minute composite kick/sweep sample, for a total of five composite near-shore samples (*i.e.*, five replicate stations) per nearshore polygon. Within each replicate station, three sub-samples are collected along separate, randomly selected transects. Each transect consists of a 1-minute zigzag travelling kick/sweep sample in a perpendicular direction from the water's edge to about 1 m water depth (width of zigzag is approximately 1 m). The three sub-samples collected within a replicate station are pooled, providing a single descriptor value from each station. For 2009, 15 sites, each consisting of a single grab sample, were collected from the offshore. The offshore study design was refined for 2010 (and subsequent years) in order to minimize the inherent variability within the benthic macroinvertebrate data prior to considerations that involved significantly increasing the amount of sampling effort; these modifications increased the statistical power of the data, but did not increase sampling effort or analytical costs. Beginning in 2010, each replicate station is comprised of five benthic grab sub-samples collected using a random number table and sampled from designated sampling locations around an anchored boat within the 10 x 10m replicate station area. The five grab sub-samples collected from a replicate station are pooled, providing a single descriptor value from each of the five replicate stations in the offshore polygon.

The power of the existing data set in Split Lake to be able to detect a post-Project change in the mean of ±25% is high for the metrics investigated, with the exception of total macroinvertebrate abundance in the nearshore (Table 4A-17). The nearshore only has a power of 0.194 for detecting a ±25% change in the mean of total macroinvertebrate density; the power increases to 0.432 for a ±50%. Sample sizes (*i.e.*, the number of replicate stations within an aquatic habitat type) required for detecting pre-defined levels of change (*i.e.*, mean ± 50%, mean ± 25%; power of 0.9) in total macroinvertebrate density in Split Lake are high in comparison to the other two metrics investigated, particularly for the nearshore (Table 4A-18: minimum of 59 required to detect change in mean of ± 50%). Minimum sample sizes for other metrics required to detect a change in the mean of ± 50% ranged from 3 (Simpson's Diversity Index, offshore) to 7 (Simpson's Diversity Index, nearshore). In the offshore, the sample size required for Simpson's Diversity Index is 6 to be able to detect a change in the mean of ±25%. The most sensitive metric to change in the nearshore was total taxonomic richness, whereas Simpson's Diversity Index was the most sensitive in the offshore.

The number of field sub-samples (*i.e.*, grabs) per replicate station was determined for Split and Stephens (south) lakes by aquatic habitat type and year that would provide an estimate with 20% precision (*i.e.*, an acceptable level of variance) for each metric (Tables 4A-1 to 4A-16). For total macroinvertebrate density, this number ranged between 1 and 4 sub-samples in the offshore and 4 and 20 in the nearshore. The number of field sub-samples was somewhat higher for the metrics non-Insecta abundance, Insecta abundance, and EPT:Chironomidae ratio, particularly in the nearshore for non-Insecta abundance (5-23 sub-samples), and in the offshore for EPT:Chironomidae ratio (1-71 sub-samples); the number of field sub-samples required is reduced when 2009 data for the offshore are not considered. For all other metrics, the number of sub-samples required ranged between 1 and 7 in the nearshore, and 1 and 5 (2, if 2009 data not considered) in the offshore.

4A.4 REFERENCES

4A.4.1 LITERATURE CITED

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Table 4A-1: Summary statistics for total macroinvertebrate abundance: Split Lake.

Metric	Total Macroinvertebrate Abundance						
Habitat Type	Nearshore			Offshore			
Year	2010	2011	2012	2009	2010	2011	2012
n (rep. stn.)	5	5	5	15	5	5	5
Mean [1]	95	314	715	4963	4917	5038	2981
SD	84.00	128.89	392.56	1999.49	903.00	916.54	668.17
SE	38.00	57.64	175.56	516.27	404.00	409.89	298.81
Median	64	307	481	5021	4747	4732	2986
Min	36	121	377	1212	3996	4271	2179
Max	243	444	1256	8137	6420	6593	3968
Sub-samples (20% precision)	20	4	8	4	1	1	1
95th Percentile	210.8	439.3	1206.4	7682.7	6105.6	6287.5	3806.0
COV (%)	88	41	55	40	18	18	22
Mean + 2 x SD	263.00	571.84	1500.06	8961.98	6723.00	6871.17	4317.06
Mean - 2 x SD	-73.00	56.29	-70.19	964.02	3111.00	3205.01	1644.39
Mean +50%	142.50	471.10	1072.40	7444.50	7375.50	7557.13	4471.09
Mean -50%	47.50	157.03	357.47	2481.50	2458.50	2519.04	1490.36
Mean +25%	118.75	392.58	893.67	6203.75	6146.25	6297.61	3725.91
Mean -25%	71.25	235.55	536.20	3722.25	3687.75	3778.57	2235.54
Data Normally Distributed	No	Yes	Yes	Yes	Yes	Yes	Yes
Significant Inter-annual Difference	Yes - 2010 vs 2012[2]			No[3]			

1. individuals per kicknet (nearshore) or individuals per m^2 (offshore)
2. p-value 2010 vs 2011 0.077; 2010 vs 2012 0.001; 2011 vs 2012 0.120
   (Kruskal-Wallis test followed by multiple pairwise comparison [Dunn's procedure])
3. p-value 2009 vs 2010 0.955; 2009 vs 2011 0.927; 2009 vs 2012 0.022;
   2010 vs 2011 0.904; 2010 vs 2012 0.063; 2011 vs 2012 0.049
   (ANOVA with Bonferroni pairwise comparison)

Table 4A-2: Summary statistics for total macroinvertebrate abundance: Stephens Lake.

Metric	Total Macroinvertebrate Abundance	
Habitat Type	Offshore	
Year	2009	2012
n (rep. stn.)	15	5
Mean [1]	7794	3180
SD	3237.21	679.37
SE	835.84	303.82
Median	7098	2929
Min	2900	2597
Max	16015	4112
Sub-samples (20% precision)	4	1
95th Percentile	12378.8	4022.4
COV (%)	42	21
Mean + 2 x SD	14268.42	4538.56
Mean - 2 x SD	1319.58	1821.09
Mean +50%	11691.00	4769.74
Mean -50%	3897.00	1589.91
Data Normally Distributed	Yes	Yes
Significant Inter-annual Difference	Yes[2]	

1. individuals per m^2
2. p-value 0.006 (t-test)

Table 4A-3: Summary statistics for non-Insecta abundance: Split Lake.

Metric	Non-Insecta Abundance						
Habitat Type	Nearshore			Offshore			
Year	2010	2011	2012	2009	2010	2011	2012
n (rep. stn.)	5	5	5	15	5	5	5
Mean [1]	50	246	360	3365	3402	3719	1985
SD	47.00	113.45	343.78	1405.04	1206.00	787.02	605.84
SE	21.00	50.73	153.74	362.78	539.00	351.97	270.94
Median	29	267	250	3722	3419	3419	1731
Min	15	68	75	866	2063	3073	1399
Max	132	350	906	5497	5252	5078	2972
Sub-samples (20% precision)	22	5	23	4	3	1	2
95th Percentile	115.0	346.5	818.8	5345.4	4925.8	4792.8	2798.9
COV (%)	94	46	96	42	35	21	31
Mean + 2 x SD	144.00	473.16	1047.35	6174.58	5814.00	5293.46	3196.90
Mean - 2 x SD	-44.00	19.37	-327.75	554.42	990.00	2145.37	773.56
Mean +50%	75.00	369.40	539.70	5046.75	5103.00	5579.12	2977.84
Mean -50%	25.00	123.13	179.90	1682.25	1701.00	1859.71	992.61
Mean +25%	62.50	307.83	449.75	4205.63	4252.50	4649.27	2481.53
Mean -25%	37.50	184.70	269.85	2523.38	2551.50	2789.56	1488.92
Data Normally Distributed	No	Yes	Yes	Yes	Yes	Yes	Yes
Significant Inter-annual Difference	Yes - 2010 vs 2012[2]			No[3]			

1. individuals per kicknet (nearshore) or individuals per m^2 (offshore)
2. p-value 2010 vs 2011 0.024; 2010 vs 2012 0.016; 2011 vs 2012 0.888
   (Kruskal-Wallis test followed by multiple pairwise comparison [Dunn's procedure])
3. p-value 2009 vs 2010 0.952; 2009 vs 2011 0.572; 2009 vs 2012 0.035;
   2010 vs 2011 0.679; 2010 vs 2012 0.073; 2011 vs 2012 0.031
   (ANOVA with Bonferroni pairwise comparison)

Table 4A-4: Summary statistics for non-Insecta abundance: Stephens Lake.

Metric	**Non-Insecta Abundance**	
Habitat Type	**Offshore**	
Year	**2009**	**2012**
n (rep. stn.)	15	5
Mean [1]	4943	1798
SD	2428.85	780.59
SE	627.13	349.09
Median	4415	1731
Min	1558	967
Max	11080	2958
Sub-samples (20% precision)	6	5
95th Percentile	8777.7	2784.5
COV (%)	49	43
Mean + 2 x SD	9800.57	3358.86
Mean - 2 x SD	85.17	236.48
Mean +50%	7414.31	2696.50
Mean -50%	2471.44	898.83
Data Normally Distributed	Yes	Yes
Significant Inter-annual Difference	Yes[2]	

1. individuals per m^2
2. p-value 0.012 (t-test)

Table 4A-5: Summary statistics for Insecta abundance: Split Lake.

Metric	Insecta Abundance						
Habitat Type	Nearshore			Offshore			
Year	2010	2011	2012	2009	2010	2011	2012
n (rep. stn.)	5	5	5	15	5	5	5
Mean [1]	45	68	355	1599	1515	1319	995
SD	37.00	22.43	148.25	993.95	380.00	246.24	178.75
SE	17.00	10.03	66.30	256.64	170.00	110.12	79.94
Median	34	64	356	1558	1327	1197	995
Min	21	41	126	260	1169	1082	779
Max	111	94	537	2857	1933	1645	1255
Sub-samples (20% precision)	17	3	4	10	2	1	1
95th Percentile	96.0	92.8	510.5	2796.1	1930.2	1618.8	1214.8
COV (%)	82	33	42	62	25	19	18
Mean + 2 x SD	119.00	112.67	651.64	3586.47	2275.00	1811.16	1353.00
Mean - 2 x SD	-29.00	22.93	58.63	-389.33	755.00	826.19	638.00
Mean +50%	67.50	101.70	532.70	2397.86	2272.50	1978.01	1493.25
Mean -50%	22.50	33.90	177.57	799.29	757.50	659.34	497.75
Mean +25%	56.25	84.75	443.92	1998.21	1893.75	1648.34	1244.37
Mean -25%	33.75	50.85	266.35	1198.93	1136.25	989.01	746.62
Data Normally Distributed	No	Yes	Yes	Yes	Yes	Yes	Yes
Significant Inter-annual Difference	Yes - 2010 vs 2012[2]			No[3]			

1. individuals per kicknet (nearshore) or individuals per m^2 (offshore)
2. p-value 2010 vs 2011 0.289; 2010 vs 2012 0.001; 2011 vs 2012 0.034
   (Kruskal-Wallis test followed by multiple pairwise comparison [Dunn's procedure])
3. p-value 2009 vs 2010 0.831; 2009 vs 2011 0.479; 2009 vs 2012 0.133;
   2010 vs 2011 0.684; 2010 vs 2012 0.286; 2011 vs 2012 0.504
   (ANOVA with Bonferroni pairwise comparison)

Table 4A-6: Summary statistics for Insecta abundance: Stephens Lake.

Metric	Insecta Abundance	
Habitat Type	Offshore	
Year	2009	2012
n (rep. stn.)	15	5
Mean [1]	2851	1382
SD	1190.28	214.82
SE	307.33	96.07
Median	2770	1356
Min	909	1154
Max	4934	1630
Sub-samples (20% precision)	4	1
95th Percentile	4510.0	1618.8
COV (%)	42	16
Mean + 2 x SD	5231.44	1811.80
Mean - 2 x SD	470.32	952.52
Mean +50%	4276.32	2073.23
Mean -50%	1425.44	691.08
Data Normally Distributed	Yes	Yes
Significant Inter-annual Difference	Yes[2]	

1. individuals per m^2
2. p-value 0.015 (t-test)

Table 4A-7: Summary statistics for EPT:Chironomidae ratio: Split Lake.

Metric	EPT:Chironomidae Ratio						
Habitat Type	Nearshore			Offshore			
Year	2010	2011	2012	2009	2010	2011	2012
n (rep. stn.)	5	5	5	15	5	5	5
Mean	1.37	0.27	1.84	645.03	2.76	10.20	1.79
SD	0.15	0.25	0.89	1086.82	1.34	3.02	0.18
SE	0.07	0.11	0.40	280.62	0.60	1.35	0.08
Median	1.38	0.22	2.23	32.00	2.12	9.40	1.77
Min	1.19	0.09	0.58	4.86	1.59	7.22	1.64
Max	1.58	0.70	2.64	2813.37	4.86	14.80	2.09
Sub-samples (20% precision)	0.3	21	6	71	6	2	0.3
95th Percentile	1.55	0.61	2.61	2752.77	4.55	14.13	2.03
COV (%)	11	93	48	168	49	30	10
Mean + 2 x SD	1.67	0.77	3.62	2818.67	5.44	16.24	2.15
Mean - 2 x SD	1.07	-0.23	0.07	-1528.61	0.08	4.15	1.42
Mean +50%	2.06	0.41	2.77	967.55	4.14	15.29	2.68
Mean -50%	0.69	0.14	0.92	322.52	1.38	5.10	0.89
Mean +25%	1.71	0.34	2.31	806.29	3.45	12.74	2.23
Mean -25%	1.03	0.20	1.38	483.77	2.07	7.65	1.34
Data Normally Distributed	Yes	Yes	Yes	No	Yes	Yes	Yes
Significant Inter-annual Difference	Yes - 2011 vs 2010 and 2012[1]			Yes - 2009 vs 2010 and 2012[2]			

1. p-value 2010 vs 2011 0.008; 2010 vs 2012 0.187; 2011 vs 2012 0.001
   (ANOVA with Bonferroni pairwise comparison)
2. p-value 2009 vs 2010 0.001; 2009 vs 2011 0.192; 2009 vs 2012 <0.0001;
   2010 vs 2011 0.106; 2010 vs 2012 0.615; 2011 vs 2012 0.034
   (Kruskal-Wallis test followed by multiple pairwise comparison [Dunn's procedure])

Table 4A-8: Summary statistics for EPT:Chironomidae ratio: Stephens Lake.

Metric	**EPT:Chironomidae Ratio**	
Habitat Type	**Offshore**	
Year	**2009**	**2012**
n (rep. stn.)	15	5
Mean	2.08	0.92
SD	0.86	0.28
SE	0.22	0.13
Median	2.00	0.86
Min	0.86	0.65
Max	4.20	1.35
Sub-samples (20% precision)	4	2
95th Percentile	3.26	1.29
COV (%)	41	31
Mean + 2 x SD	3.80	1.49
Mean - 2 x SD	0.36	0.35
Mean +50%	3.12	1.38
Mean -50%	1.04	0.46
Data Normally Distributed	Yes	Yes
Significant Inter-annual Difference	Yes[1]	

1. p-value 0.009 (t-test)

Table 4A-9: Summary statistics for Simpson's Diversity Index: Split Lake.

Metric	Simpson's Diversity Index						
Habitat Type	Nearshore			Offshore			
Year	2010	2011	2012	2009	2010	2011	2012
n (rep. stn.)	5	5	5	15	5	5	5
Mean	0.82	0.49	0.76	0.61	0.75	0.73	0.73
SD	0.07	0.17	0.12	0.08	0.05	0.04	0.05
SE	0.03	0.08	0.05	0.02	0.02	0.02	0.02
Median	0.84	0.47	0.83	0.63	0.77	0.75	0.75
Min	0.74	0.30	0.60	0.40	0.67	0.68	0.65
Max	0.89	0.78	0.85	0.70	0.78	0.77	0.80
Sub-samples (20% precision)	0.2	3	1	0.4	0.1	0.1	0.1
95th Percentile	0.89	0.72	0.85	0.70	0.78	0.77	0.79
COV (%)	9	35	15	13	7	5	7
Mean + 2 x SD	0.96	0.84	0.99	0.77	0.85	0.81	0.84
Mean - 2 x SD	0.68	0.15	0.53	0.45	0.65	0.65	0.63
Mean +50%	1.23	0.74	1.14	0.92	1.13	1.10	1.10
Mean -50%	0.41	0.25	0.38	0.31	0.38	0.37	0.37
Mean +25%	1.03	0.62	0.95	0.76	0.94	0.92	0.92
Mean -25%	0.62	0.37	0.57	0.46	0.56	0.55	0.55
Data Normally Distributed	Yes	Yes	Yes	No	No	Yes	Yes
Significant Inter-annual Difference	Yes - 2011 vs 2010 and 2012[1]			Yes - 2009 vs 2010, 2011, and 2012[2]			

1. p-value 2010 vs 2011 0.002; 2010 vs 2012 0.470; 2011 vs 2012 0.007
   (ANOVA with Bonferroni pairwise comparison)
2. p-value 2009 vs 2010 0.001; 2009 vs 2011 0.004; 2009 vs 2012 0.006;
   2010 vs 2011 0.746; 2010 vs 2012 0.666; 2011 vs 2012 0.914
   (Kruskal-Wallis test followed by multiple pairwise comparison [Dunn's procedure])

Table 4A-10: Summary statistics for evenness: Split Lake.

Metric	Evenness (Simpson's Equitability)						
Habitat Type	Nearshore			Offshore			
Year	2010	2011	2012	2009	2010	2011	2012
n (rep. stn.)	5	5	5	15	5	5	5
Mean	0.10	0.17	0.28	0.31	0.15	0.41	0.52
SD	0.01	0.09	0.14	0.11	0.02	0.06	0.12
SE	0.01	0.04	0.06	0.03	0.01	0.03	0.06
Median	0.10	0.14	0.33	0.30	0.15	0.42	0.45
Min	0.08	0.10	0.14	0.18	0.11	0.32	0.41
Max	0.11	0.32	0.45	0.50	0.17	0.46	0.70
Sub-samples (20% precision)	0.3	7	6	3	0.4	0.5	1
95th Percentile	0.11	0.29	0.43	0.50	0.17	0.46	0.68
COV (%)	10	52	49	35	13	14	24
Mean + 2 x SD	0.12	0.35	0.56	0.53	0.19	0.52	0.77
Mean - 2 x SD	0.08	-0.01	0.01	0.09	0.11	0.30	0.27
Mean +50%	0.15	0.25	0.42	0.47	0.23	0.61	0.78
Mean -50%	0.05	0.08	0.14	0.16	0.08	0.20	0.26
Mean +25%	0.13	0.21	0.35	0.39	0.19	0.51	0.65
Mean -25%	0.08	0.13	0.21	0.23	0.11	0.31	0.39
Data Normally Distributed	Yes	No	Yes	Yes	Yes	Yes	Yes
Significant Inter-annual Difference	Yes - 2010 vs 2012[1]			Yes - 2009 vs 2010 and 2012; 2010 vs 2009, 2011, and 2012[2]			

1. p-value 2010 vs 2011 0.056; 2010 vs 2012 0.001; 2011 vs 2012 0.203
   (Kruskal-Wallis test followed by multiple pairwise comparison [Dunn's procedure])
2. p-value 2009 vs 2010 0.004; 2009 vs 2011 0.046; 2009 vs 2012 0.000;
   2010 vs 2011 0.000; 2010 vs 2012 <0.0001; 2011 vs 2012 0.083
   (ANOVA with Bonferroni pairwise comparison)

Table 4A-11: Summary statistics for Simpson's Diversity Index: Stephens Lake.

Metric	**Simpson's Diversity Index**	
Habitat Type	**Offshore**	
Year	**2009**	**2012**
n (rep. stn.)	15	5
Mean	0.55	0.61
SD	0.11	0.10
SE	0.03	0.04
Median	0.54	0.61
Min	0.35	0.46
Max	0.74	0.73
Sub-samples (20% precision)	1	1
95th Percentile	0.72	0.72
COV (%)	20	16
Mean + 2 x SD	0.77	0.81
Mean - 2 x SD	0.33	0.41
Mean +50%	0.83	0.92
Mean -50%	0.28	0.31
Data Normally Distributed	Yes	Yes
Significant Inter-annual Difference	No[1]	

1. p-value 0.299 (t-test)

Table 4A-12: Summary statistics for evenness: Stephens Lake.

Metric	Evenness (Simpson's Equitability)	
Habitat Type	Offshore	
Year	2009	2012
n (rep. stn.)	15	5
Mean	0.44	0.61
SD	0.20	0.13
SE	0.05	0.06
Median	0.45	0.61
Min	0.19	0.46
Max	0.95	0.75
Sub-samples (20% precision)	5	1
95th Percentile	0.74	0.74
COV (%)	45	21
Mean + 2 x SD	0.84	0.87
Mean - 2 x SD	0.04	0.36
Mean +50%	0.66	0.92
Mean -50%	0.22	0.31
Data Normally Distributed	Yes	Yes
Significant Inter-annual Difference	No[1]	

1. p-value 0.091 (t-test)

Table 4A-13: Summary statistics for total taxonomic richness (family-level): Split Lake.

Metric	Taxonomic Richness (Family-Level)						
Habitat Type	Nearshore			Offshore			
Year	2010	2011	2012	2009	2010	2011	2012
n (rep. stn.)	5	5	5	15	5	5	5
Mean	13	14	18	6	9	9	8
SD	2.00	0.89	2.86	1.46	2.00	0.89	0.89
SE	1.00	0.40	1.28	0.38	1.00	0.40	0.40
Median	12	14	18	6	9	10	7
Min	11	12	15	4	8	8	7
Max	17	14	22	8	12	10	9
Sub-samples (20% precision)	1	0.1	1	2	1	0.2	0.3
95th Percentile	16.2	14.0	21.6	8.0	11.6	10.0	8.8
COV (%)	15	7	16	25	22	10	12
Mean + 2 x SD	17.00	15.39	23.93	8.79	13.00	11.19	9.39
Mean - 2 x SD	9.00	11.81	12.47	2.95	5.00	7.61	5.81
Mean +50%	19.50	20.40	27.30	8.81	13.50	14.10	11.40
Mean -50%	6.50	6.80	9.10	2.94	4.50	4.70	3.80
Mean +25%	16.25	17.00	22.75	7.34	11.25	11.75	9.50
Mean -25%	9.75	10.20	13.65	4.40	6.75	7.05	5.70
Data Normally Distributed	Yes	No	Yes	Yes	Yes	Yes	Yes
Significant Inter-annual Difference	Yes - 2010 vs 2012[1]			Yes - 2009 vs 2010 and 2011[2]			

1. p-value 2010 vs 2011 0.475; 2010 vs 2012 0.005; 2011 vs 2012 0.035
   (Kruskal-Wallis test followed by multiple pairwise comparison [Dunn's procedure])
2. p-value 2009 vs 2010 <0.0001; 2009 vs 2011 <0.0001; 2009 vs 2012 0.020;
   2010 vs 2011 1.000; 2010 vs 2012 0.045; 2011 vs 2012 0.045
   (ANOVA with Bonferroni pairwise comparison)

Table 4A-14: Summary statistics for Hill's effective richness (family-level): Split Lake.

Metric	Hill's Effective Richness						
Habitat Type	Nearshore			Offshore			
Year	2010	2011	2012	2009	2010	2011	2012
n (rep. stn.)	5	5	5	15	5	5	5
Mean	7.97	2.31	4.93	3.25	5.26	3.83	3.89
SD	1.50	1.26	2.00	0.60	0.68	0.54	0.75
SE	0.67	0.56	0.89	0.15	0.30	0.24	0.34
Median	8.06	1.90	5.88	3.17	5.31	4.08	3.94
Min	6.21	1.43	2.49	2.10	4.35	3.15	2.87
Max	9.62	4.54	6.68	4.04	6.23	4.40	4.92
Sub-samples (20% precision)	1	7	4	1	0.4	1	1
95th Percentile	9.5	4.0	6.6	4.0	6.1	4.4	4.8
COV (%)	19	54	41	18	13	14	19
Mean + 2 x SD	10.97	4.83	8.92	4.45	6.62	4.92	5.39
Mean - 2 x SD	4.97	-0.20	0.93	2.05	3.90	2.74	2.39
Mean +50%	11.96	3.47	7.39	4.88	7.89	5.74	5.83
Mean -50%	3.99	1.16	2.46	1.63	2.63	1.91	1.94
Mean +25%	9.96	2.89	6.16	4.06	6.58	4.78	4.86
Mean -25%	5.98	1.74	3.69	2.44	3.95	2.87	2.92
Data Normally Distributed	Yes	No	Yes	Yes	Yes	Yes	Yes
Significant Inter-annual Difference	Yes - 2010 vs 2011[1]			Yes - 2010 vs 2009, 2011, and 2012[2]			

1. p-value 2010 vs 2011 0.001; 2010 vs 2012 0.104; 2011 vs 2012 0.104
   (Kruskal-Wallis test followed by multiple pairwise comparison [Dunn's procedure])
2. p-value 2009 vs 2010 <0.0001; 2009 vs 2011 0.087; 2009 vs 2012 0.060;
   2010 vs 2011 0.001; 2010 vs 2012 0.002; 2011 vs 2012 0.880
   (ANOVA with Bonferroni pairwise comparison)

Table 4A-15: Summary statistics for total taxonomic richness (family-level): Stephens Lake.

Metric	Total Taxonomic Richness	
Habitat Type	Offshore	
Year	2009	2012
n (rep. stn.)	15	5
Mean	5	4
SD	1.42	0.55
SE	0.37	0.24
Median	4	4
Min	3	4
Max	7	5
Sub-samples (20% precision)	2	0.4
95th Percentile	7.0	5.0
COV (%)	30	12
Mean + 2 x SD	7.64	5.50
Mean - 2 x SD	1.96	3.30
Mean +50%	7.20	6.60
Mean -50%	2.40	2.20
Data Normally Distributed	No	No
Significant Inter-annual Difference	No[1]	

1. p-value 0.838 (Mann-Whitney test)

Table 4A-16: Summary statistics for Hill's effective richness (family-level): Stephens Lake.

Metric	Hill's Effective Richness	
Habitat Type	Offshore	
Year	2009	2012
n (rep. stn.)	15	5
Mean	3.01	2.71
SD	0.83	0.69
SE	0.21	0.31
Median	2.61	2.59
Min	1.93	1.86
Max	4.72	3.74
Sub-samples (20% precision)	2	2
95th Percentile	4.5	3.6
COV (%)	28	26
Mean + 2 x SD	4.67	4.10
Mean - 2 x SD	1.35	1.33
Mean +50%	4.52	4.07
Mean -50%	1.51	1.36
Data Normally Distributed	No	Yes
Significant Inter-annual Difference	No[1]	

1. p-value 0.497 (Mann-Whitney test)

Table 4A-17: Power of existing benthic macroinvertebrate data to detect pre-defined levels of change in Split Lake.

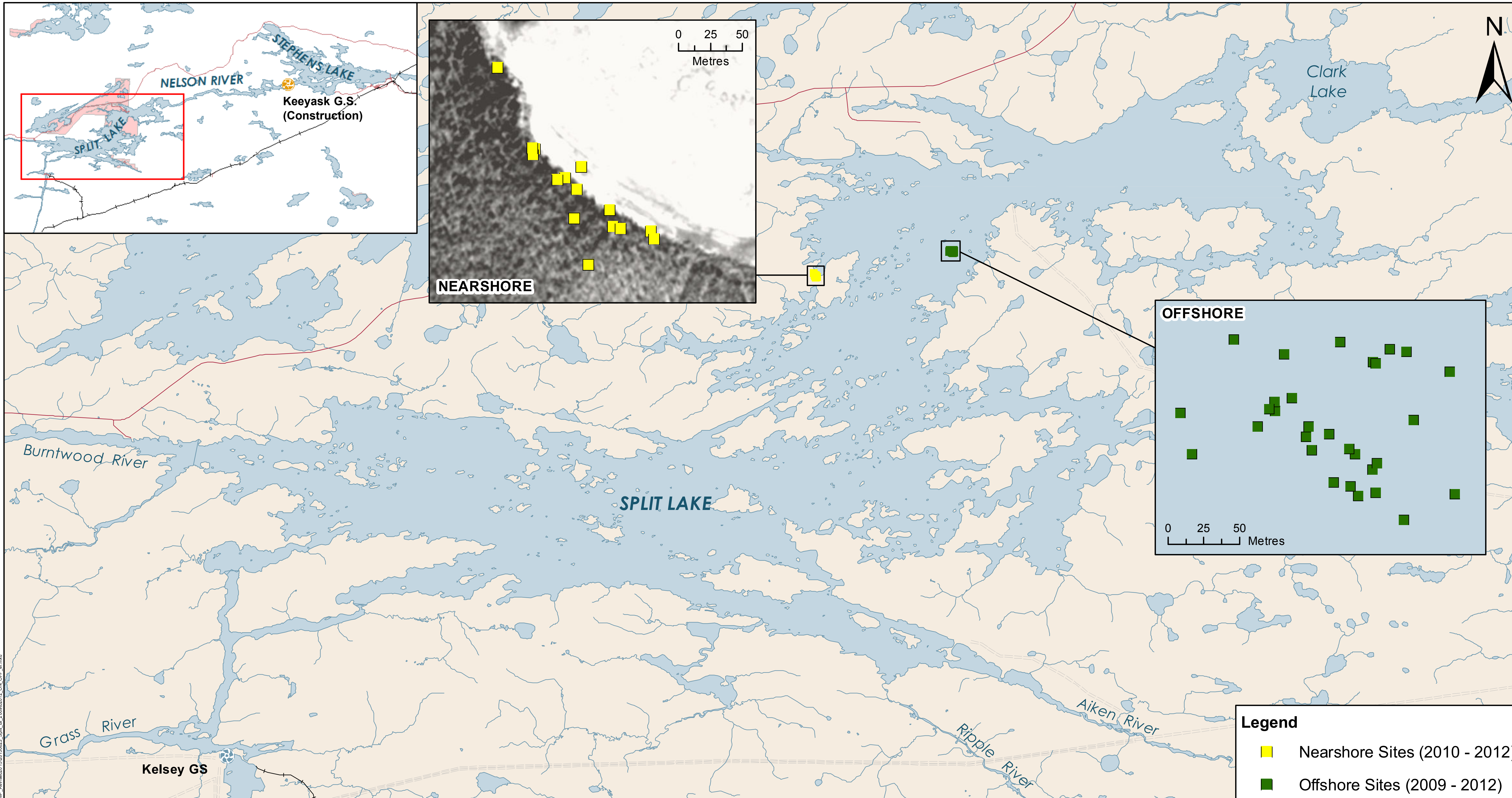
Metric	Nearshore (2010, 2011, 2012; n = 15)	
	Mean +/-50%	Mean +/-25%
Total macroinvertebrate abundance	0.432	0.194
Non-Insecta abundance	0.607	0.297
Insecta abundance	0.607	0.287
EPT:Chironomidae ratio	0.581	0.242
Simpson's Diversity Index	1.000	0.819
Evenness	0.799	0.384
Taxonomic richness	1.000	0.930
Hill's effective richness	0.761	0.352

Metric	Offshore (2009-2012; n = 30)	
	Mean +/-50%	Mean +/-25%
Total macroinvertebrate abundance	1.000	0.850
Non-Insecta abundance	0.999	0.782
Insecta abundance	0.972	0.595
EPT:Chironomidae ratio	0.760	0.376
Simpson's Diversity Index	1.000	1.000
Evenness	0.997	0.714
Taxonomic richness	1.000	0.959
Hill's effective richness	1.000	0.983

Table 4A-18: Sample sizes (*i.e.*, number of replicate stations) required for detecting pre-defined levels of change in Split Lake.

Metric	Nearshore (2010, 2011, 2012; n = 15)	
	Mean +/-50%	Mean +/-25%
Total macroinvertebrate abundance	59 (0.899)	>>61
Non-Insecta abundance	33 (0.892)	>>61
Insecta abundance	32 (0.899)	>>61
EPT:Chironomidae ratio	36 (0.902)	142 (0.899)
Simpson's Diversity Index	7 (0.919)	19 (0.890)
Evenness	20 (0.901)	61 (0.870)
Taxonomic richness	4 (0.891)	14 (0.905)
Hill's effective richness	22 (0.896)	84 (0.898)

Metric	Offshore (2009-2012; n = 30)	
	Mean +/-50%	Mean +/-25%
Total macroinvertebrate abundance	10 (0.904)	37 (0.900)
Non-Insecta abundance	12 (0.894)	43 (0.900)
Insecta abundance	20 (0.906)	70 (0.897)
EPT:Chironomidae ratio	44 (0.895)	>>61
Simpson's Diversity Index	3 (0.972)	6 (0.914)
Evenness	14 (0.902)	54 (0.899)
Taxonomic richness	6 (0.890)	22 (0.897)
Hill's effective richness	5 (0.890)	18 (0.902)

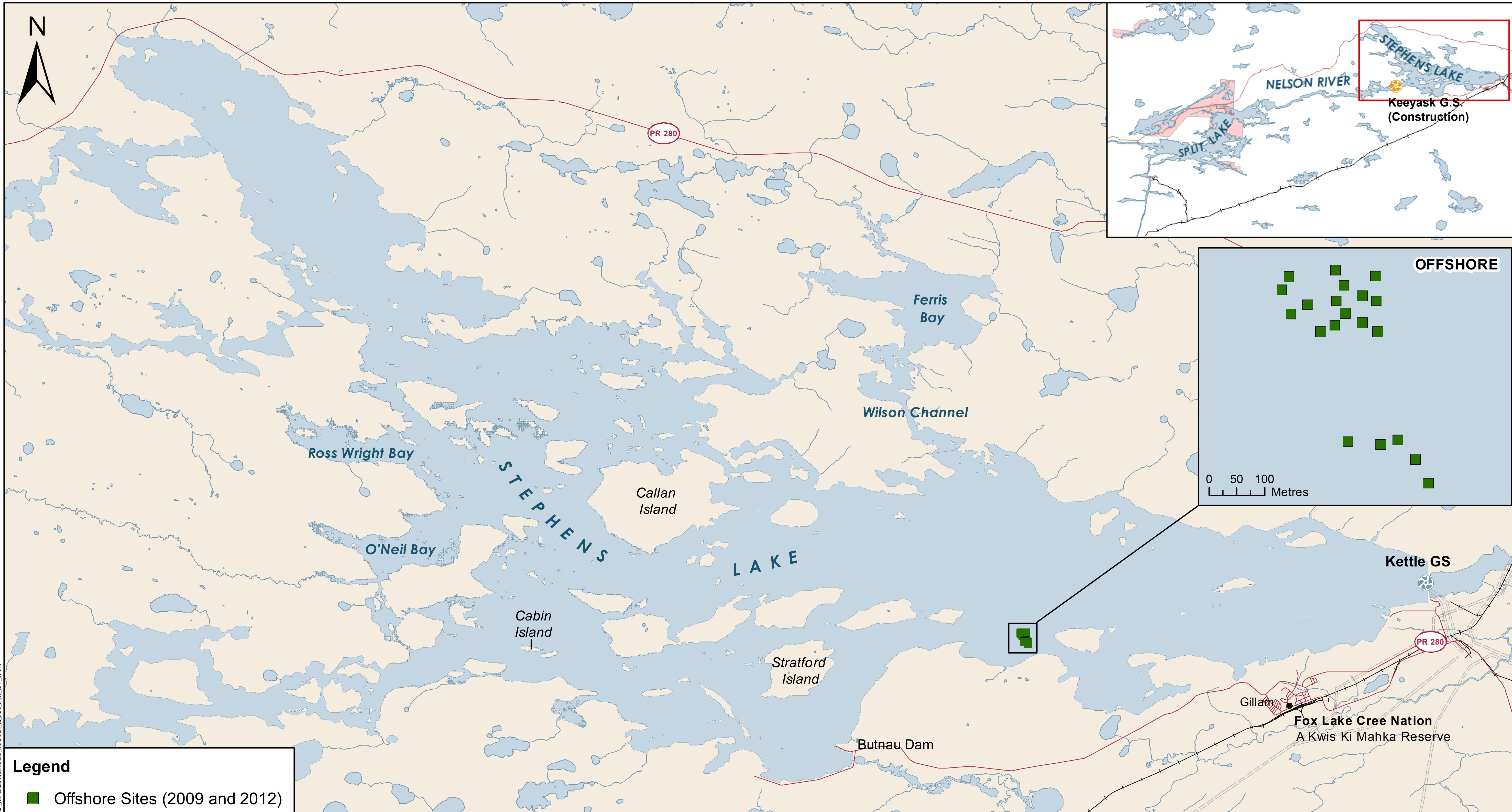


KEEYASK
Hydropower Limited Partnership

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000

Benthic Invertebrate Sites
Split Lake

Map 4A-1



KEEYASK
Hydropower Limited Partnership

0 5 10 Kilometres
0 2 4 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000,
Stephens Lake Shoreline-Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro

Benthic Invertebrate Sites
Stephens Lake

APPENDIX 6A
STATISTICAL TERMS USED IN THE DISCUSSION OF THE LAKE STURGEON POPULATION ANALYSIS

6A.1 TERMS

Akaike's Information Criterion (AIC): A measure of the explanatory power of a statistical model, accounting for the number of model parameters. AIC weights models based on fit with the average model and selects the best model based on information theory.

Alpha (α): The probability of committing a Type I error (falsely rejecting a true null hypothesis) in statistical testing.

Burnham Lambda Variant: A version of the Jolly-Seber population model (a classic open population model) which adds new individuals to the population indirectly by modelling the rate of population growth (Lambda λ) between time intervals. The Lambda parameter provides a measure of population growth since the first year, with values less than 1 indicating population decline, a value of 1 indicating equilibrium and values greater than 1 indicating population growth. The Burnham (1991) method to assess Lambda is not conditional on individuals being seen, and therefore includes an estimate for population size at the first time-period.

CloseTest Application: A statistical software package that tests the assumption of closure in mark-recapture data (Stanley and Burnham 1999). The program uses the Chi-squared statistic to test the Jolly-Seber model against no mortality (NM) and no recruitment (NR), both of which indicate a violation of the closure assumption. The test of closure is necessary when using the Robust Design population model, as the population is assumed to be closed between primary and secondary sampling periods.

Coefficient of Variation: The value obtained by dividing the sample standard deviation by the sample mean. It is used to compare variability among different populations because it has been standardized by the sample mean.

Effect Size: The expected difference in means of groups that have experienced different treatments.

Hybrid Model: A population model that combines components of both open population models (which assume that births, deaths, immigration and emigration occur between sample periods) and closed population models (which assume that no births, deaths, immigration or emigration occur between sample periods).

Markovian Immigration/ Emigration: The probability of moving between availability states between primary occasions i and i+1 is conditional on the state of the individual at time i-1 (Kendall 2001).

Random Deviate: A particular outcome of a random variable.

Random Immigration/ Emigration: The probability of moving between availability states between primary occasions i and i+1 is independent of the previous state of the system (Kendall 2001).

Robust Design: A hybrid population model that combines elements of closed and open population models and accounts for immigration and emigration of individuals. In contrast to the Jolly-Seber model, there are multiple recapture events (instead of one recapture event) between survival intervals. The recapture events are so close in time that it is assumed the populations are closed during sampling (no mortality or emigration is occurring) (Kendall 2001).

Significance Testing: The process of using statistical tests to support or reject claims about a population using sample data

Statistical Power: The probability of correctly rejecting a false null hypothesis in a statistical test. It is equal to 1 – β, where β is the probability of committing a Type II error (incorrectly accepting a false null hypothesis).

Trend Analysis: A statistical technique to determine patterns that arise in data. Patterns over time are usually of interest, however spatial and directional patterns may also be examined. Trends may be analyzed using parametric methods (*e.g.*, linear regression), non-parametric methods (*e.g.*, Mann-Kendall test), or a mix of the two (Helsel and Hirsch 2002).

Type I Error: Incorrectly rejecting a true statistical null hypothesis, also known as a "false positive." The probability of committing a Type I error is denoted by α.

Type II Error: Incorrectly accepting a false statistical null hypothesis, also known as a "false negative." The probability of committing a Type II error is denote by β.

6A.2 REFERENCES

6A.2.1 LITERATURE CITED

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