SECTION 3
AQUATIC HABITAT

Hydropower Limited Partnership

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF MAPS

LIST OF APPENDICES

3.0 AQUATIC HABITAT

3.1 INTRODUCTION

Fish habitat is defined in the *Fisheries Act* as "Spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes".

Because fish habitat is defined by its capability to support fish life processes (including food production), the term aquatic habitat is used in this section to describe the structure of the environment within which fish, and the aquatic biota on which they feed, live. Aquatic habitat is typically classified on the basis of water depth, water velocity, substrate type, and cover (including large rooted plants, terrestrial debris, riparian vegetation, and other large structures). These characteristics determine whether individuals, communities, and populations of fish and other aquatic biota can find the biophysical features they need for life, such as suitable areas for reproduction, feeding sites, resting sites, cover from predators and adverse environmental conditions, movement corridors, and overwintering. The biophysical characteristics of the habitat play a large role in determining the species composition and biomass of the biotic community that can be sustained.

When physical attributes of the aquatic environment change, the existing quantity and quality of aquatic habitat will likely be altered, resulting in effects on aquatic biota. To predict the potential effects on fish and other aquatic biota that result from changes in the water level and flow regime, it is necessary to know how those changes will affect the biophysical variables (water depth, water velocity, bottom substrate, and cover) that determine habitat structure and use. Potential effects of hydroelectric development on aquatic habitat include changes in: water depth (including flooding and/or dewatering); the extent and frequency of water level fluctuations; water velocity; substrate; and the abundance and type of cover. These potential changes to the physical environment are discussed in the Physical Environment Supporting Volume (PE SV). The effects of these changes to the aquatic ecosystem are discussed in Section 2 (water quality), this section (aquatic habitat), Section 4 (lower trophic levels), Section 5 and Section 6 (the fish community), and Section 7 (fish quality).

A brief description of the study area, information sources, and methods for the aquatic habitat assessment are provided in Section 3.2. The historic and current aquatic habitat conditions for the study area are described in Section 3.3. Project effects, including construction, operation, residual, and cumulative effects, and mitigation are described in Section 3.4, along with environmental monitoring and follow-up programs.

3.2 APPROACH AND METHODS

The following sections provide a description of the general approach to the aquatic habitat assessment (Section 3.2.1), a brief description of the study area (Section 3.2.2), information sources used to describe and characterize the environmental setting (Section 3.2.3), and a description of the approach for the effects assessment (Section 3.2.4).

3.2.1 Overview to Approach

The approach taken for the aquatic habitat effects assessment was similar to the general approach taken for other aquatic environment components and was comprised of two major steps:

- A description of the existing aquatic habitat conditions to provide the basis for assessing the potential effects of the Project on these components; and
- An effects assessment in which the predicted post-Project environment was described and changes from existing environment quantified.

The water regime (PE SV, Section 4), physiography of the shoreline (PE SV, Section 5), and erosion and sedimentation (PE SV, Section 6 and Section 7) interact to form the basis of the aquatic habitat in an area, which is further modified by biological processes (*e.g.*, growth of shoreline and instream vegetation). Therefore, the temporal scope of the aquatic habitat assessment as it relates to the physical variables is defined by the information provided by these disciplines: the existing environment was developed based on the period 1977 to 2006 and the post-Project conditions are based on a long-term simulated flow record (PE SV, Section 4.2.5.1).

Biological components of the aquatic habitat were based on the period during which field studies were conducted in the area, generally between 1997 and 2006. This period included both high and low flows, and therefore would indicate interannual variability related to flows.

No analysis of trends in aquatic habitat was conducted, since the current water regime was established in 1977 and has been operated within set bounds since that time (PE SV, Section 4.3.1) and analyses of shoreline erosion processes indicate that overall average rates within the study period were relatively constant, though there was considerable interannual variability (PE SV, Section 6.3.1). Likewise, analyses of future conditions for water regime (PE SV, Section 4.3.2), shoreline erosion processes (PE SV, Section 6.3.1) and sedimentation (PE SV, Section 7.3.2) indicate that no major changes are expected in the absence of the Project.

The effects assessment was based on relationships identified between changes to the physical environment (as discussed in the PE SV) and resulting effects on aquatic habitat. Post-Project aquatic habitat conditions were predicted using water regime models developed for post-Project conditions (PE SV, Section 4) in conjunction with models developed from other reservoir environments (in particular reservoirs of the lower Nelson River).

Post-Project aquatic habitat conditions were predicted using the results of the water regime models (PE SV, Section 4), and mineral and peatland erosion and sediment deposition studies (PE SV, Section 5 and Section 6, respectively). The physical environment studies provided key information to understand change (*i.e.*, magnitude and rate), and the spatial and temporal characteristics of the variables of change that ultimately drive the form and maintenance of aquatic habitat as the reservoir evolves. The Aquatic Environment Supporting Volume studies of aquatic habitat addressed specific questions related to the long-term quality and form of habitat at local scales by empirical observation and modelling derived from reservoirs of the lower Nelson River.

3.2.2 Study Area

The study area for aquatic habitat studies extends along the Nelson River from Split Lake downstream to Stephens Lake in the east (Map 1-2). The magnitude of physical change (*e.g.*, changes in water levels and flows) as a result of the Project differs substantially among areas (PE SV, Section 4.4) and, consequently, the aquatic habitat study area was divided into three areas on the Nelson River as follows:

- Split Lake area (Split Lake and adjoining waterbodies, including Assean Lake and Clark Lake). This area is upstream of any direct hydraulic influence of the Project. Habitat in this area was described to provide supporting information for studies of aquatic biota (Section 4, Section 5, and Section 6);
- Keeyask area (Nelson River and tributary streams extending from the outlet of Clark Lake to approximately 6 kilometres [km] downstream of Gull Rapids). Project-related changes to the water regime and direct losses of habitat due to the presence of the GS will occur within this reach (PE SV, Section 4.4). This area was subdivided at Gull Rapids, as the rapids form a boundary for the aquatic biota under existing conditions, and mark a boundary between the reservoir and downstream environment in the post-Project environment.; and
- Stephens Lake area (Stephens Lake and adjoining waterbodies). This area is immediately downstream of the Keeyask area and the Project will not affect the water regime. Habitat in this area was described to provide the basis for assessment of effects to aquatic biota, as the fish community inhabiting this area also uses habitat in the directly affected riverine section up to and including Gull Rapids. Stephens Lake, as the reservoir of the Kettle GS formed in the early 1970s, also provides a useful proxy to assist in predicting effects of the Project (Section 1).

The majority of aquatic habitat investigations were conducted in the Keeyask area, as this area will be directly affected by the Project and quantitative estimates of pre and post-Project habitat were required.

Aquatic habitat was also described as part of the assessment of the north and south access roads stream crossings.

3.2.3 Data and Information Sources

Section 1.5 summarizes the overall sources of information used for the Project, including technical studies, scientific publications and local knowledge. Specific sources of information used to characterize the environmental setting for aquatic habitat are detailed in this section.

3.2.3.1 Existing Published Information

Aquatic habitat studies have previously been conducted in the study area. Programs focused on the effects of hydroelectric generating stations (GS) (*e.g.*, construction and operation of the Kettle GS) or on the effects of the Churchill River Diversion (CRD)/Lake Winnipeg Regulation (LWR) projects, and also focused on Split and Stephens lakes.

Prior to CRD/LWR, a bathymetric survey was conducted on Split Lake by the province of Manitoba in 1966 (Schlick 1968). A limnological survey was conducted on the Kettle reservoir (*i.e.*, Stephens Lake) as part of the Lake Winnipeg Churchill and Nelson River Study Board (LWCNRSB) program (Crowe 1973). In the late 1980s, bathymetric data were collected from Split and Stephens lakes as part of Manitoba's Ecological Monitoring Program (Cherepak 1990). The effects of previous hydroelectric development in northern Manitoba on the Split Lake Resource Management Area were assessed as part of the Split Lake Cree Post-Project Environmental Review (PPER, Split Lake Cree - Manitoba Hydro Joint Study Group 1996a, b, c). The effects of hydroelectric development on water levels and flows in the study area are specifically discussed in Split Lake Cree - Manitoba Hydro Joint Study Group (1996b).

During the late 1990s, bathymetry and habitat characterization studies were conducted by the Tataskweyak Environmental Monitoring Agency (TEMA) for Tataskweyak Cree Nation (TCN) and Manitoba Hydro (Kroeker 1999; Lawrence *et al.* 1999).

3.2.3.2 Keeyask Environmental Studies

Methods related to water regime, erosion and sedimentation, which form key inputs to aquatic habitat, are provided in Section 4, Section 5 and Section 6 of the PE SV, respectively. Detailed information on data collection methods related to other aquatic habitat variables is provided in Appendix 3A. A brief summary is provided here.

The substrate composition in the Clark Lake to Gull Rapids reach was determined through a combination of transects using acoustic sonar with validation using a probe and Ponar dredge. Substrate composition was also mapped in the 6 km reach below Gull Rapids. Substrate composition could not be determined immediately upstream, within, or downstream of rapid sections due to safety concerns. Substrate composition in these areas was estimated based on known physical conditions.

The presence of aquatic macrophytes in the Clark Lake to Gull Rapids reach was determined by helicopter (using global positioning system-linked [GPS-linked] video), and boat-based GPS surveys where the presence of macrophytes visible from the water surface was recorded. Macrophyte sampling to determine species composition was conducted at selected locations (Section 4).

Stream habitat in the Clark Lake to Gull Rapids reach was assessed using low-level helicopter survey and was recorded using GPS-linked digital video.

Aquatic macrophyte presence and absence was assessed using aerial surveys, and macrophyte species composition, substrate, depth, and slope information was collected in the Stephens Lake area using boat-based surveys.

3.2.4 Assessment Approach

The approach to habitat assessment varied depending on requirements to support the environmental impact assessment, as follows:

Split Lake area – The approach to habitat description in the Split Lake area was similar to that of the more intensively studied areas, but was at a more general level of detail sufficient to provide an overall description of the habitat available to the biota and determine habitat types at benthic invertebrate and fish community sampling locations.

Keeyask area – The approach to habitat assessment in the Keeyask area was detailed as quantitative information was required to assess predicted change due to the Project, and to provide information on changes in aquatic habitat required to support assessments of the lower trophic levels and fish community.

Stephens Lake area – The approach to habitat assessment in Stephens Lake was to define the basic types of habitat in the reservoir. Detailed studies also were undertaken within the western, central, and east areas of the reservoir where information was needed to develop predictive models to characterize the aquatic habitat in the Keeyask reservoir, at about 30 years after flooding.

One model required data as far downriver as the Limestone GS.

The habitat assessment considered habitat conditions under a range of flow conditions: low (5th percentile flows); intermediate (50th percentile flows) and high (95th percentile flows). Information on water depth and velocity was based on the water regime (PE SV, Section 4).

For the purposes of predicting habitat conditions in the post-Project environment and quantifying areal changes in habitat area between the pre and post-Project environments, conditions at 95th percentile flows (pre-Project) and full supply level (FSL) in the reservoir post-Project were used. This approach was adopted as the water elevation at the 95th percentile provides the upper boundary on habitat generally considered to be aquatic. Consequently, area calculations for the pre-Project environments provide measures of maximum potential habitat.

Post-Project habitat areas to support plant, invertebrate and fish production could be affected by frequent cycling of elevations in the reservoir between 159 metres above sea level (m ASL) (full supply level, FSL) and 158 m ASL (minimum operating level, MOL). Habitat in this **intermittently-exposed zone** (IEZ) was quantified (Appendix 3D, Table 3D-1) and used in fish and invertebrate community assessments (Section 4 and Section 5). However, for the existing environment only habitat areas available at 95th percentile flow elevation were used for comparison of potential gains or losses in area.

3.2.4.1 The Existing Environment - Habitat Classification and Availability

This section describes habitat classification applied to the Keeyask area, with rationale for selection of habitat categories.

3.2.4.1.1 Habitat Availability and Suitability

Habitat availability varies in space and time in response to environmental variation. The maximum habitat availability (*i.e.*, potential habitat) is determined by the range of habitat variables during the long-term. The habitat that is able to sustain aquatic life (*i.e.*, suitable habitat) tends to be formed from the more recent water regime, which occupies a portion of the longer-term range. Suitable habitat, therefore, will tend to be smaller than the potential habitat given that it is more closely linked to the recent water regime. The area of suitable habitat that is actually occupied by biota depends on the interaction between the recent environmental variation and the ability of a species to adapt to that variation.

3.2.4.1.2 Habitat Classification

A hierarchical classification system was developed to describe the mainstem aquatic habitat. Lacustrine and riverine habitats were classified according to the habitat variables shown in Figure 3-1 and Table 3-1, except for stream habitat, which is described below. Lacustrine and riverine habitats were classified at a near "bank full" condition, referred to as the 95th percentile (PE SV, Section 4.3.1; described in definition below) in order to account for the availability of all potential aquatic habitats. The classified habitat information was used in the lower trophic (Section 4) and fish community assessments (Section 5). Habitat classes as defined in Table 3-1 were modified as depicted in Appendix 3D (Table 3D-1), with respect to substrate category for purposes of invertebrate and fish community assessments (Section 4 and Section 5).

Stream habitat was classified into riffle/pool/glide/run classes according to BCMOE and DFO (1989). While the majority of stream habitat could be classified using this system, additional classes were created for stream habitat that fell outside these categories. Peatland Drainage was used to describe a low-velocity low gradient stream with indeterminate channel margins that were predominantly organic substrates and were bounded by peat. Peatland Pools were similar to Peatland Drainage but were larger, deeper, composed of standing water and organic substrates, and often associated with beaver dams.

Each of the habitat variables used to classify riverine and lacustrine areas of the Nelson River is described below.

Reach Type

The overall Keeyask area was classified as either "riverine" or "lacustrine". "Lacustrine" reaches may contain both standing (lentic) and flowing (lotic) habitat.

Water Movements – Lentic and Lotic Water Masses

Water movements exert a strong influence on the distribution of habitat and biota and the use of habitats by fish. The fluvial channel of the Nelson River passes through lake and reservoir basins. As a result, water masses in the study area within the fluvial channel are usually flowing (lotic), or are standing (lentic) where the river widens into a wetted basin, bay, or tributary confluence. The boundary between lotic and lentic habitat was defined as 0.2 metres per second (m/s). Lentic habitat describes nearly 3/4 of the areas of fine silt/clay deposition observed in the Keeyask area. Lentic habitats (velocity less than 0.2 m/s) support organisms that typically avoid flowing waters and are adapted to live in standing waters, including many species of aquatic plants. Lotic habitats support organisms that depend on flowing waters to carry out their life processes. Many organisms are also adapted to carry out part of their life processes (*e.g.*, reproduction) in flowing waters, and other functions (*e.g.*, overwintering) in standing waters. Lotic environments were further classified into low (0.2−0.5 m/s), moderate (greater than 0.5 to less than or equal to 1.5 m/s) and high (greater than1.5 m/s) water velocity. The low, moderate, and high velocity categories were based on swimming efficiencies of fish species occurring in the study area (Appendix 5E).

Habitat Depth Zones

The structure of habitat changes with water depth. Habitats were classified according to Habitat Depth Zone that distinguishes the differences in shallow and deep habitat.

Lakes, rivers, and reservoirs frequently exhibit distinctive zones related to water depth. These zones can be differentiated on the basis of the bottom characteristics, the maximum depth of light penetration, and rooted plant distribution. Studies within the Nelson River have shown that most rooted vascular plant species are found above approximately 3 m in depth. The shallow edge of a river, lake, or reservoir often has bottom materials that differ when compared to those found in swift flowing mid-river areas, or deeper areas in a lake or reservoir, in response to waves or currents. The shallow and deep classification accommodates these differences by defining the boundary between these zones at a water depth of 3 m. Habitat differences between the shallow and deep zones noted above, exert a strong influence on the fish species and life stages that use those habitats as well as on the invertebrate community composition and biomass.

Water depth was standardized relative to the 95th water level percentile, unless otherwise noted.

Water Surface Level Zones

Habitats were classified according to water level zones, which describe variation in water surface level. Variation in water surface elevation over time influences aquatic habitat availability and suitability. Water levels in the study area are irregular and largely controlled by flows arising from the Nelson River drainage, the Churchill River Diversion, and regulation of Stephens Lake by the Kettle GS (PE SV, Section 4).

Water level zones are used to distinguish the aquatic habitats that experience a range of water level variations from habitats that are usually wetted. Water level ranges were the criteria used to separate the IEZ from the predominantly-wetted zone due to the irregular pattern of dewatering over time. The ranges used were defined by seasonal (1 May to 31 October) water level percentiles that account for 90% of the variation for the period of the existing environment (1977–2006) (PE SV, Section 4.3.1). The IEZ is defined by the range between the 95th and 5th water level percentiles and describes most (90%) of the water level variation.

The IEZ occupies the shallowest part of the Shallow Zone. The Shallow Zone, therefore, occupies the range between the 95th open water season water level percentile to 3 m water depth. An additional zone, Backwater Inlet, was defined within the small tributary inlets where these fall within the zone of water level fluctuation from the Nelson River (*i.e.*, the IEZ).

For the fish community assessments (Section 5), habitat areas in the existing environment were standardized to 95th percentile water elevation, thereby providing the area of potential habitats available to fish.

Substrate

Substrates in river, lake, or reservoir habitats were classified based on a simplified interpretation of the Wentworth particle size classification (Wentworth 1922) for granular materials (Table 3-2). Methods for collecting the data included visual classification, sonar interpretation, benthic grab sampling, probing with an aluminum rod, and dropping or dragging rebar tied to string to the bottom. Detailed methods are found in Appendix 3A.

At its simplest level, bottom substrate is divided into soft versus hard composition/compaction categories. Aquatic macrophytes grow primarily on soft, mineral substrates and do not grow on hard substrates. Additionally, the invertebrate community found in and on soft substrates is typically very different from those found associated with hard substrates. Fish community assemblages will frequently differ between soft and hard substrates, primarily due to either a preference for aquatic macrophytes or because of availability/preferences in invertebrate prey items. The additional delineation of substrate into composition classes (*e.g.*, boulder/cobble, gravel, sand, fines) can be used to further refine the identification of invertebrate habitat preferences, and to a lesser extent, fish habitat preferences. The delineation of gravel and sand has proven particularly useful in defining the distribution of young-of-the-year lake sturgeon (*Acipenser fulvescens*; Section 6).

Vegetation

Aquatic macrophyte beds are delineated as an aquatic habitat variable that provides a wide range of functions for aquatic biota. Aquatic macrophytes support a rich variety of invertebrates and fish as they provide a growing platform for some invertebrates, cover from predators for invertebrate and small-bodied fish species, ambush cover for certain predatory fish species, and shelter from adverse weather conditions.

Plant distribution information from surveys was mapped as polygons. Detailed methods for rooted aquatic macrophyte surveys are provided in Section 4.

3.2.4.1.3 Data Integration

Data describing substrate and aquatic plants were combined with depth and velocity information to create maps showing the existing environment under 95^{th} percentile inflows. Data were categorized into habitat types using the classification system described above. Both spatial distribution of habitat types and quantitative estimates were used as inputs to the lower trophic level and fish community assessments. Additional analyse for selected parameters were conducted under 5^{th} percentile flows, to describe variation in these parameters.

3.2.4.1.4 Linking Aquatic Habitat to Higher Trophic Levels

The aquatic habitat classification system described above was linked to the biological communities through two approaches based on differing levels of spatial resolution:

- Habitat classification was based on categories of water depth, velocity, substrate and presence/absence of macrophytes defining patches of habitat. This classification system generalized substrate into: (i) quality (mineral vs. organic, including detritus, peat and fine organic matter); and (ii) compaction (hard vs. soft, in which silt, clay and sandy bottom types were soft). Rationale and areas of different habitat classes are provided in Appendix 3D; and

- General habitat types were classified based on larger sections of a given waterbody that might comprise several habitat classifications but formed a unit, or ecotype, that was used by larger, mobile fish species. For the reach of the Nelson River between the outlet of Clark Lake and Gull Rapids, ecotypes in the existing environment consisted of nearshore lacustrine, offshore lacustrine, riverine, and backbay. In the post-Project environment, the ecotypes for this reach consisted of backbay reservoir, riverine reservoir, nearshore lentic reservoir, offshore lentic reservoir, nearshore lotic reservoir, and offshore lotic reservoir.

3.2.4.2 The Post-Project – Predicting Habitat Change Over Time

Water depths, shorelines, and water surface information (PE SV, Section 4.2.5.4) was used to develop base maps of the post-Project environment. The post-Project IEZ describes the range of water levels as defined by the combination of inflows and reservoir stage. The post-Project IEZ was assessed by combining a low inflow with the Minimum Operating Level (MOL: *i.e.*, 5th percentile and 158 m ASL reservoir) and the high inflow with the Full Supply Level (FSL, *i.e.*, 95th percentile and 159 m ASL reservoir).

The open water season hydraulic zone of influence (HZI) of the project is defined by the 95th percentile inflow and 159 m ASL reservoir. The upstream extent of the HZI ends at Long Rapids, approximately 3 km below the outlet of Clark Lake (PE SV Map 4.4-6). However, assessments included riverine habitats upstream of the HZI to include Long Rapids, as these habitats are expected to be used by the Keeyask area fish community in the post-Project setting. Operation of the GS will also affect the open water regime in 3–4 km of the riverine reach below the GS (PE SV Map 4.4-9). Habitat assessment also included the riverine reach down to and including Stephens Lake, as these areas will be used by fish downstream of the GS in the post Project environment.

3.2.4.2.1 Long-Term Aquatic Habitat Prediction (Year 30)

The Physical Environment studies suggest that the change and rates of change arising from the physical processes in the reservoir will have largely stabilized or slowed appreciably prior to Year 30 (PE SV); therefore, Year 30 is considered a reasonable model for the long-term condition of the reservoir.

The spatial extent of the aquatic habitat assessment includes all of the Project HZI. In addition, the assessment includes areas immediately up river and down river of the HZI to describe the habitat adjacent to the areas where change is expected.

Four empirical models were used to estimate substrate and rooted habitat distributions for Year 30 (Appendix 3B). These models were based in large part on observed conditions in Stephens Lake, which forms a model of reservoir developed in similar conditions to the proposed Keeyask reservoir 30 years after impoundment.

The composition of the substrate in the longer-term (30 years) was estimated for the reservoir using three empirical models derived either from the local area or from the published scientific literature. The Year 30 substrate map was derived from three models used in sequence:

- An empirical model was developed to estimate the pattern of deposition of material in lotic habitat. The model was based on substrate type, depth, bottom slope, and depth averaged velocity. All variables were taken from sites in the Nelson River in the vicinity of Gull Lake, Stephens Lake, and the Limestone Reservoir;
- An empirical model developed by Rowan *et al.* (1992), and validated by Cooley and Franzin (2008), was used to estimate areas of deposition in lentic habitat. The model was based on depth, bottom slope, and maximum fetch (wave energy); and
- An empirical model was developed to estimate the organic/mineral boundary that marks the transition from organic deposition to silt deposition, as observed in bays on Stephens Lake. The model was based on depth, bottom slope, and exposure to wave energy.

The presence of potential macrophyte habitat was then estimated using an empirical model based on distributions observed in Stephens Lake (Appendix 3C). The predictive macrophyte model included variables describing pre-flood soil type, distance to pre-flood mineral soils, water depth, bottom slope, and exposure (a type of fetch measurement).

The aquatic habitat predictive models are described in appendices 3B and 3C. Model results were used to estimate the areas of each habitat type in the upstream Keeyask area (outlet of Clark Lake to the Keeyask GS) that would be available to fish and lower trophic organisms at 159 m and 158 m ASL reservoir elevation (Appendix 3D). Areal distributions of habitat types were subsequently used to predict effects of reservoir creation and operation on lower trophic organisms and on the fish community (Section 4 and Section 5).

3.2.4.2.2 Predictions of Habitat Changes Over Time (Years 1, 5, and 15)

The temporal approach for the aquatic effects assessment is based on the initial full supply level, a long-term 30-year time step, and intervening time steps at Years 1, 5, and 15. The initial full supply level condition represents the first time the reservoir will attain full supply level at the start of the operating phase of the Project. The initial full supply level, hereby referred to as Initial FSL, describes the shape, size, and water velocity characteristics of the reservoir based pre-flood information, such as topography, but before the effects of erosion and sedimentation occur. The surface of some peatlands will also rise with the water surface. This would reduce the water surface area one could observe on the reservoir one day after initial FSL, but not the area of inundation as water will be underneath the peat. The initial FSL, therefore, serves to provide an aquatic baseline from which to track future changes in the reservoir. The Year 30 time step was selected based on aquatic studies at Stephens Lake. Assessments made for time steps other than initial FSL or Year 30 were undertaken based on modelling results of the PE SV (Section 4, Section 6, and Section 7), and Keeyask environmental studies. The interpretation of the character of the reservoir from Year 1 to Year 15 was facilitated by shoreline erosion and sedimentation modelling that estimated the incremental set-back of the shoreline over time. The types and quantities of sediments that were predicted to be released to the aquatic environment, and where these might be deposited (with emphasis in the first 15 years after impoundment when the physical processes are most active), also were inputs to characterizing reservoir habitats over time. Based on that interpretation, a model (Appendix

3D) was developed to estimate the availability of aquatic habitat types to fish and lower trophic levels at the 1, 5, and 15-year time steps after impoundment. The model inputs included:

- Year 30 habitat area and distribution predictions based on the Stephens Lake model outcomes (appendices 3B and 3C);
- Existing environment habitat conditions in the reach between Clark Lake outlet and Gull Rapids; and
- Predictions of reservoir area expansion, peat resurfacing and transport, sedimentation, plant bed destruction/development, and mode of operation effects on habitat availability.

3.3 ENVIRONMENTAL SETTING

3.3.1 Pre-1997 Conditions

3.3.1.1 Split Lake Area

The Kelsey GS (completed in 1961) did not significantly affect Split Lake because the station is operated as a run-of-the-river GS and did not alter flows from the upper Nelson River (Split Lake Cree - Manitoba Hydro Joint Study Group 1996b). Schlick (1968) calculated the total lake area of Split Lake to be 283.9 square kilometres (km^2) and described the lake as relatively shallow, with an average depth of 7.0 m and a maximum depth of 29.9 m. After 1976, LWR resulted in a seasonal reversal of flows and levels on the lake and CRD increased flows entering from the Burntwood River. CRD resulted in an eight-fold increase in average annual flows on the Burntwood River upstream of First Rapids (Split Lake Cree - Manitoba Hydro Joint Study Group 1996b). Water levels on Split Lake prior to CRD/LWR were higher in summer, while in the post-project, they average 0.7 m higher (at the community of Split Lake) in winter. During the post-project period, water levels on Split Lake decreased by an average of 0.2 m during the summer and increased by 0.8 m during winter; however the range of water levels did not change noticeably. Annual flows in Split Lake increased by about 167 cubic metres per second (m^3/s). In 1989, Cherepak (1990) reported that the post-CRD/LWR water area of Split Lake was 269.8 km^2 and the mean and maximum depths of the lake were 4.5 and 23 m, respectively.

3.3.1.2 Keeyask Area

Impoundment of the Kettle GS reservoir in 1970 resulted in a backwater effect at Gull Rapids that typically ranges from 141.1 m ASL in winter to 139.2 m ASL in summer (Split Lake Cree - Manitoba Hydro Joint Study Group 1996b). CRD increased the average flow through the reach by 246 m^3/s, an increase of approximately 8%, and water levels increased marginally. LWR reversed the seasonal pattern of flow such that average flows are more similar during the summer and winter, with winter flows averaging about 194 m^3/s more than summer flows. Prior to regulation, average summer flows had been 892 m^3/s higher than winter flows. In the post-project period, there is now a greater range in water fluctuations.

3.3.1.3 Stephens Lake Area

Crowe (1973) estimated the surface area of the Nelson River between lower Gull Rapids and the Kettle dam prior to construction of the Kettle GS at 101.5 km^2. The impoundment of the Kettle GS reservoir resulted in the formation of Stephens Lake by flooding the existing river and lakes. Stephens Lake attained the full supply water level of the reservoir for the first time in 1971 when the water level immediately upstream of the GS increased by approximately 31.5 m (Split Lake Cree - Manitoba Hydro Joint Study Group 1996b). The reservoir surface area increased by about 263 km^2, or about 3.6 times that of surface area found within the extent of the reservoir before flooding (Cherepak 1990). In 1989, Cherepak (1990) reported that the post-CRD/LWR water surface area of Stephens Lake was 364.7 km^2 and the mean and maximum depths of the lake were 7.6 and 35 m, respectively. Changes in the shape of the shoreline in Stephens Lake during the period 1971–1997 are apparent from topographic mapping or aerial photography due to erosion of mineral soils and/or degradation or movement of organic soils within the reservoir. The changes in the shape, extent, and number of islands apparent in topographic maps are most notable in shallow bays.

Operation of the Kettle GS can noticeably affect short-term water levels on Stephens Lake. It is typically drawn down over a week, and has been drawn down by as much as 2.4 m in a one-month period (Split Lake Cree - Manitoba Hydro Joint Study Group 1996b). Although LWR resulted in a reversal of seasonal flows and water levels, these effects are not discernable due to the operation of the Kettle GS. Prior to regulation, average water levels were typically 0.9 m higher in summer compared to winter, whereas the reservoir is now operated such that winter levels are approximately 0.4 m higher than summer levels. CRD resulted in an increase of flows such that the average flow out of Stephens Lake has increased by 227 m^3/s.

3.3.2 Current Conditions (Post-1996)

3.3.2.1 Overview and Regional Context

The Nelson River originates at the outlet of Lake Winnipeg and flows in a north-northeast direction for approximately 680 km where it empties into Hudson Bay (PE SV, Section 4). The Aquatic Environment Study Area extends from the Kelsey GS to the Kettle GS (Map 1-2). The study area is characterized by three large lakes, Split Lake, Gull Lake, and Stephens Lake, the latter of which is the reservoir for the Kettle GS, and various sections of the Nelson River mainstem. The mainstem river is often characterized by one swiftly flowing channel, although islands and off-current bays are present along portions of the river. There are five major rapids within the study area: Anipitapiskow and Sakitowak rapids located between the Kelsey GS and Split Lake; Long Rapids and Birthday Rapids located between Clark Lake and Gull Lake; and Gull Rapids at the outlet of Gull Lake. The three lakes all contain numerous islands.

The reach of the Nelson River between the Kelsey GS and the Kettle GS can be described as a series of inter-connected riverine and lacustrine reaches that each contain both lotic (water flowing at 0.2 metres per second [m/s] or greater) and lentic (standing water with a velocity of less than 0.2 m/s) aquatic habitats. The total area of large river and lake habitat in this reach is 65,322 ha; the upstream boundaries occur at barriers resulting from First Rapids on the Burntwood River and the Kelsey GS on the Nelson

River, and the downstream boundary is the Kettle GS at the outlet of Stephens Lake. Three large lakes, including Split, Clark, Gull and the Stephens Lake reservoir are located in this reach. Water depths in the area of the reservoir immediately upstream of the Kettle dam exceed water depths in the mentioned lake and river environments. The reaches of river upstream of direct effects of water level regulation in the Nelson River offer a wide diversity of water depth, velocity, substrate, and potential plant habitat.

The majority of the inflow to Split Lake is contributed from the Nelson River (including flows from the Grass River located below the Kelsey GS) and the Burntwood River (including flows from the Odei River) (PE SV, Section 4.3.1). The area from downstream of Clark Lake to the inlet at Stephens Lake, which is within the hydraulic zone of influence of the Project, is characterized by numerous small creeks and two small streams, but major tributaries are absent. The physiography of the Aquatic Environment Study Area is described in the PE SV, Section 5.3.

Upstream of the Aquatic Environment Study Area, the Nelson River is also characterized by a series of river reaches and lakes, culminating in the reservoir for the Kelsey GS. Downstream of the Aquatic Environment Study Area (below the Kettle GS), the Nelson River leaves confines of the Precambrian Shield and has formed an incised river valley within the **glaciomarine** sediments of the Hudson Bay lowlands; in this area streams are a prominent feature of the landscape. There are two additional major rapids on the Lower Nelson River between the Kettle GS and Hudson Bay (Map 3-1).

3.3.2.2 Split Lake Area

The Split Lake area is comprised of Split and Clark lakes, the lower sections of the major inflowing rivers, the Nelson and Burntwood, and other adjoining waterbodies. The surrounding landscape has poor drainage, and is dominated by black spruce forest in upland areas and black spruce bogs, peatlands and fens in lowland areas. The shoreline of Split Lake is stable and is often bedrock controlled and interspersed with bog and marsh areas.

3.3.2.2.1 Nelson and Burntwood Rivers above Split Lake

Most of the water entering Split Lake originates from the Nelson River (including the Grass River) and the Burntwood River (including the Odei River) (PE SV, Section 4.3.1). The Grass River flows into the Nelson River immediately upstream of Split Lake.

Downstream of the Kelsey GS, there is an approximately 5 km long reach of the Nelson River, characterized by predominantly fast moving water, with rocky shoreline and substrate, after which the Nelson River splits into two channels around a large island. Each channel contains a set of rapids: Anipitapiskow Rapids (~7.0 km north of the GS on the north channel) and Sakitowak Rapids (~10.0 km northeast of the GS on the south channel). Both channels empty into Split Lake at the base of the rapids. The Grass River enters the Nelson River from the west immediately downstream of the Kelsey GS. Between Witchai Lake Falls (approximately 5.0 km upstream of the mouth) and the mouth of the Grass River, the shorelines are gradual in slope and water velocities are generally lower than in the Nelson River. Witchai Lake Falls appears to be a natural fish barrier.

The Burntwood River flows swiftly in a north-easterly direction from First (Unetoianumayo) Rapids for approximately 35 km prior to emptying into the western arm of Split Lake. Under high flow conditions, these rapids appear to be a natural barrier to upstream fish passage. Shorelines in this stretch are dominated by moderately sloping bedrock, which is often overlain by fine sediments near First Rapids and becomes increasingly exposed towards Split Lake. Hard substrates predominate in the main channel, while loose fine sediments and associated macrophyte growth occur in many off-current areas. The Odei River enters the Burntwood River from the west. The river meanders in a north-easterly direction before falling several times near the crossing of PR 280 approximately 30 km upstream of its confluence with the Burntwood River. These falls appear to be a natural barrier to fish passage. From here, the Odei River flows as a deep and narrow single channel before becoming braided 5 km from its confluence with the Burntwood River. Shorelines in the Odei River downstream of the falls are moderately sloped, and composed of thick sediments that support abundant riparian vegetation. Where it meets the Burntwood River, the Odei River widens and macrophytes are abundant. Hard substrates predominate in the main channel.

3.3.2.2.2 Split and Clark Lakes

Split Lake is the largest lake on the lower Nelson River. The surface area of Split Lake is 261.0 km^2, with a mean depth of 4.0 m and a maximum depth of 28 m, at a water surface elevation of 167 m (Kroeker 1999). The 5th and 95th seasonal open water percentile lake level elevations are approximately 166 m ASL and 168 m ASL, resulting in an IEZ of approximately 2 m. Water levels on Split Lake are a function of the amount of water flowing into the lake and the narrow constriction at the outlet (PE SV, Section 4.3). Clark Lake is approximately 11 km^2 and is characterized by a central **thalweg** with depths more than 12.0 m and off-current areas that are generally less than 4 m deep, with velocities generally less than 0.5 m/s (PE SV, Section 4.3.1.1).

Split Lake has defined channels that extend from the inlet of the lake through the central basin north and east to Clark Lake (Map 3-2). These channels occur where flows appear to pass through narrows, or where flows diverge when passing groups of islands, which may be distant from the main channel. Split Lake has a complex shoreline and abundant shallow water habitat in areas away from the main basin of deep water, which includes the riverine channel (Map 3-3). Most of the offshore area of the lake is deep water. The lake has complex bottom topography, as is shown by many areas of shallow water surrounded by deep water.

Water velocities are typically low (less than 0.5 m/s) throughout Split Lake, but increase to over 1.5 m/s at the outlet (PE SV, Section 4.3.1.1).

Lake substrates are primarily composed of fine mineral sediments (clay and silt) with small amounts of organic material. Macrophyte distributions in the lake are complex. Some of the main areas where plants are found (Map 3-4) are in shallow, standing water areas in large bays, or in relatively small areas among tightly grouped islands where exposure to wave action is low. A more detailed description of rooted macrophytes species is presented in Section 4.

3.3.2.3 Keeyask Area

The Keeyask area is an approximately 45 km long section of the Nelson River, characterized by swiftly flowing reaches of the river and Gull Lake which is essentially a widening of the river channel (Map 1-3).

The Keeyask area was divided into reaches based on similar characteristics in the riverine or lacustrine habitat (Map 3-5). Note that Reach 12 is located in the Stephens Lake area, but is often included with discussion of the Keeyask area given the close proximity and similarity in habitat.

The majority of inflow to the Keeyask area is contributed from the upper Nelson River system (68%) or the Burntwood River (29%), with local inflows contributing 3% (PE SV, Section 4.3.1). Small tributaries, such as Two Goose Creek, Portage Creek, Broken Boat Creek, and Seebeesis Creek, contribute additional flow into the Keeyask area (PE SV, Section 4.3.1.1.6). Tributaries entering into the Keeyask area are discussed in more detail below.

The land adjacent to the river in the upper section of the reach is well drained and dominated by black spruce, while peatlands become more common in the lower section of the reach (Gull Lake vicinity). Shorelines of the riverine sections consist of bedrock and boulder/cobble with some areas of finer materials. The north shore has more frequent deposits of peat than the south shore, which is predominantly thin peat over mineral soils, except in the presence of small tributaries. A detailed description of the physiography of the Keeyask area is provided in PE SV, Section 5.

3.3.2.3.1 Description of the Mainstem

Immediately below Clark Lake, is Long Rapids which is about 3 km long, and is relatively shallow, fast flowing and turbulent, with some areas of white water habitat. Between Clark Lake and Birthday Rapids there is an approximate 4 m drop in water level, velocities are typically more than 1.5 m/s within this reach, and standing waves are common (PE SV, Section 4.3.1). Depths range from less than 4 m in the Long Rapids area to more than 15 m just upstream of Birthday Rapids. The substrate and shoreline features of this section of the river are largely bedrock and boulder/cobble. Downstream of Long Rapids the river widens to about 600 m, deepens, and velocity decreases.

Birthday Rapids, situated approximately 10 km downstream of Clark Lake, is a 300 m wide constriction in the Nelson River that is characterized by a fairly steep gradient (drop of approximately 1.8–2.0 m) with high velocities (greater than 1.5 m/s), (PE SV, Section 4.3.1) white water habitat, and boulder/cobble/bedrock substrate. Below Birthday Rapids the next 15 km of the Nelson River is a relatively uniform approximately 600 m wide channel with medium to high water velocities and relatively consistent depths of less than 8.0 m (PE SV, Section 4.3.1). River substrates here are primarily bedrock in shallow water, boulder and cobble in the thalweg, with some fine sediment in areas with reduced velocity in shallow water. There are a few large bays with reduced water velocity, which in some years will support aquatic macrophytes.

Gull Lake features a diversity of aquatic habitats, including **lotic** and **lentic** environments. Gull Lake is generally a very wide channel with several islands and bays (PE SV, Section 4.3.1). Depths along the main body of the lake are more than 7 m, with some areas approaching 20 m in depth. Depths around the islands and in the bays are substantially shallower (less than 3 m). Due to the width and depth of Gull Lake, velocities are typically less than 0.5 m/s. Under 50th and 95th percentile flows, velocities in the 0.5–1.5 m/s range become increasingly more abundant in Gull Lake, particularly in the main river channel(s) (PE SV, Map 4.3-5). At the downstream end of Gull Lake, the Nelson River splits around Caribou Island. The north channel is generally wider, shallower, and longer than the south channel. As a result, approximately 75% of the river discharge is conveyed by the south channel (PE SV, Section 4.3.1). Both channels are characterized by moderate velocities (0.5–1.5 m/s). Lake substrates are predominantly cobble and boulder in on-current areas, with soft substrates in off-current areas. Aquatic vegetation is primarily restricted to lower velocity areas that are off the major river channel. The presence of macrophytes and their location may vary from year to year depending on water levels.

Gull Rapids is the largest set of rapids in the Keeyask area with a drop of approximately 11 m across its approximately 2 km length (PE SV, Section 4.3.1). There are several islands and channels located in Gull Rapids. Gull Rapids is a dynamic environment, with new channels being cut periodically due to the erosive forces of the existing ice and water processes occurring in the area (PE SV, Section 4.3.1). Most of the flow (75% to 85%) passes through the south channel of Gull Rapids, with little to no flow being conveyed by the north channel during low Nelson River discharge (PE SV, Section 4.3.1). All channels include rapid and turbulent flows featuring the highest velocities (greater than 1.5 m/s) found within the Keeyask area. The substrate and shoreline of Gull Rapids are composed of bedrock and boulders.

Just below Gull Rapids, the Nelson River enters Stephens Lake. Stephens Lake was formed in 1971 by the creation of the Kettle GS. Between Gull Rapids and Stephens Lake, there is an approximately 6.0 km-long reach of the Nelson River that, although affected by the Kettle reservoir, remains a lotic environment with moderate water velocity. A breach in the north and south bank of the Nelson River below Gull Rapids occurred during winter 2000/2001, when the ice dam that forms each year in the area was particularly massive (PE SV, Appendix 4A). The north breach has since developed into a well-formed channel that connects via "Pond 13" to O'Neil Bay in Stephens Lake.

A detailed description of habitat in the Keeyask area based on specific variables is provided below.

Habitat Variables

Habitat variables discussed in the following sections are characterized under 95th percentile flow open water conditions. Effects under variable flows and ice conditions are discussed under "Environmental Variation".

Water depth in the Keeyask area is deepest in the primary thalweg and tends to become deeper in the downstream direction. Depths as shallow as 2.5 m occur between Clark Lake and Birthday Rapids. Depth attains a maximum of 16 m in Gull Lake (Map 3-6). Most of the main channel of the river has depths in the range of 8–12 m.

Most of the Nelson River habitat within the Keeyask area is deep (*i.e.*, more than 3 m), with shallow habitat in the main channel being limited to two areas: 1) the reach of river between Clark Lake and Birthday Rapids; and 2) Gull Rapids (Map 3-7). Shallow habitat is abundant in bays in the Gull Lake area. Areas that are backwatered during high flow events are limited to inlets or the upper extent of shallow bays fed by tributaries. The IEZ of the Nelson River is described later in this section.

Lotic water masses are defined as having a depth average velocity of 0.2 m/s or greater. A lotic water mass is continuous throughout the thalweg of the Keeyask area, despite having apparent riverine and lacustrine sections. Lentic water masses are limited to narrow bays or areas where the river is notably wider than the thalweg.

Velocities in the riverine portion upstream of Gull Lake are predominantly moderate or high (Map 3-8). Velocities are lower in Gull Lake but moderate velocity habitat (0.5−1.5 m/s) is found throughout the lake (Map 3-8).

White water habitat exists in several riverine locations upstream of Gull Lake. White water habitat is formed in a rapid, when a river's gradient increases enough to disturb its laminar flow and create turbulence. Sites with white water may have sudden drops in riverbed level and may be associated with eddies where reverse flows occur. The presence of white water suggests the diversity of hydraulic habitat over a small area is relatively high and so provides important fish habitat during spawning or for refugia or feeding.

The location of rapids with white water habitat does not change with different inflows, although at some locations white water occurs only under lower flow conditions. Under an inflow of 3,102 m^3/s (just above the 50^{th} percentile condition), white water was observed at various locations in the Keeyask area (Map 3-9 to Map 3-13). White water habitat is well developed mainly in two localized areas occupying part of the river channel between Clark Lake and Birthday Rapids. This area is known as Long Rapids (Map 3-9). Within Reach 4, white water at Birthday Rapids spans the full width of the Nelson River (about 275 m) (Map 3-10). White water is present on both sides of the island downstream of Birthday Rapids, but is better developed under lower flows. In the north channel, white water habitat is localized in two areas: 1) the north side of the island; and 2) just downstream along the north bank of the Nelson River. The white water on the south side of the island spans most of the width of the south channel (~200 m wide). Water movements in reaches 5–8 are turbulent in several areas but no white water is developed. White water in Reach 9A and 9B, Gull Rapids, is frequent in the north channel (Map 3-11), middle channel (Map 3-12), and south channel (Map 3-13).

The substrate distribution upstream of Gull Rapids corresponds closely to the pattern of flows and water depth. This is most notable when lentic and lotic areas are compared; habitats along the edge of the river in lentic habitat typically are depositional (*i.e.*, soft bottomed; silt/clay), whereas the areas of lotic habitat are erosion or transport environments (*i.e.*, hard bottomed; boulder to gravel).

Areas that are deep and lotic are found within the thalweg and are dominated by hard bottomed materials (*i.e.*, mainly boulder/cobble/gravel) (Map 3-14). Generally, the largest materials line the riverbed in reaches 2A–5. In Reach 6, the flows disperse enough to enable cobble to form a stable bottom. Some lotic habitat in this reach has a stable bottom formed of gravel, as shown downstream of Seebeesis Creek along the south shore (Map 3-14), providing evidence of dampened velocity gradient in the lower part of Reach 6. Decreases in thalweg velocity are evident again farther downstream where the secondary channel that flows around the north side of Caribou Island allows sand to form a stable bottom. Sand is not abundant in Deep habitat, and has only been located in this channel. Velocity in this area is not fast enough to create a net movement of sand away from the area but is sufficient to transport silt/clay downstream. Observations of near bottom velocity in these two areas averaged 0.26 m/s, with a corresponding depth averaged velocity of 0.48 m/s with water depths in the range of 8–11 m (Appendix 3A).

Areas of shallow and lentic habitat are present along the edge of the river in the form of depositional bays (*i.e.*, mostly silt/clay). Organic materials are found mostly in the lower reaches of the tributaries where backwater effects from the Nelson River occur during times of higher flows (Map 3-14).

Below Gull Rapids, the riverbed shows that a size gradient of materials occurs in the first 6 km as velocity drops. Flows are sufficient to maintain the bed processes of erosion and transport for more than 5 km, as evident by substrates of sand or greater material size (Map 3-15). A small eroded channel exists about 2 km downstream of Gull Rapids on the south bank. The substrate of the channel was mainly clay but it should be noted that changes in flow among seasons over time may create changing hydraulic conditions and the long term character of the substrate may change. About 3.5 km downstream of Gull Rapids, gravel starts to dominate the flooded thalweg which then grades to gravel/sand and then to sand over the next two kilometres. The zone of homogenous silt deposition in the flooded thalweg starts about 5.5 km below Gull Rapids at depths of about 17–20 m.

The position of the silt boundary in the flooded thalweg of the river as it enters Stephens Lake appears to be formed by relatively high magnitude flows. Low inflows, *i.e.*, 5th or 50th percentile, form lentic habitat about 1.2–2.2 km up river of the depositional boundary and this standing water overlies erosion and transport substrate habitat. In comparison, flows above the 50th percentile maintain lotic habitat over the gravel and sand substrates that extend to depths of 17–20 m, where the onset of silt deposition begins. Homogeneous silt deposition dominates the bottom of the flooded thalweg down river of the silt boundary even in lotic habitat during relatively high inflows, due to increased water depth/lack of channel confinement.

The lentic habitat in the river channel downstream of Gull Rapids on the north bank of Reach 11 is not depositional as was observed consistently in lentic habitat up river of Gull Rapids. This is an apparent response to the winter hydrodynamics resulting from the hanging ice dams (PE SV 4.3.2.5), which may create a seasonal shift in the position of the lentic/lotic boundary.

The distribution of macrophytes (Map 3-16) above Gull Rapids corresponds closely with the distribution of standing or low water velocity, shallow water, and silt/clay substrate. Most of these habitat variables co-occur in low slope areas, including the relatively large bays in the Gull Lake area, but small plant beds are also found in portions of the Nelson River mainstem. In the first 4 km below Gull Rapids, the availability of potential habitat is limited and macrophytes are sparse.

Environmental Variation

Variation in flows, within and among years, determines the amount and type of aquatic habitat available to biota. A comparison of annual and seasonal flows is provided in the PE SV, Section 4.3.1.

Open water season inflows during the period when the majority of environmental assessment studies were conducted (2000−2006) varied to near the full range expected in the Nelson River (Figure 3-2, further described in PE SV, Section 4). The maximum hourly discharge during this period was observed in the fall of 2005, when flow was about 6,590 m^3/s, or about 1.2 times the 95th percentile flow of 5,266 m^3/s. The lowest discharge occurred in the fall of 2003 when flow was 1,372 m^3/s, or about 0.73 times lower than the 5th percentile of 1,882 m^3/s. Most years had flows for extended periods in the range of 3,000–4,000 m^3/s; *i.e.*, higher than the 50th percentile (2,866 m^3/s). The following discussion compares aquatic habitat at 95th and 5th percentile inflows, and also describes other changes that have occurred as a result of variation in open water flows.

Upstream of Gull Rapids, difference in average water depth for the reaches ranged from 0.6 to 1.7 m at 5th and 95th percentile flows. The average depth of the IEZ in reaches 2–8 (upstream of Gull Rapids) ranges from 1.2–2.1 m. Water depth in many areas of Gull Rapids is uncertain (PE SV, Appendix 4A) preventing calculation of the IEZ. Water level variation in reaches downstream of Gull Rapids is primarily controlled by operation of the Kettle GS.

During the open water season, changes in depth over short time periods are small: for example, the typical 1-day water level variation on Gull Lake is 0.01 m, while the 7-day variation was 0.07 m (PE SV, Section 4.3.1).

Variations in flow result in changes in velocity magnitude and pattern in the river. Differences in velocity between the 5th (Map 3-17) and 95th percentile inflows above Gull Rapids are smallest in the riverine reaches, in particular at rapids, and are largest in the lacustrine reaches (Map 3-18). Maximum velocities within each reach are typically found in rapids or narrows; the 5th percentile maxima are 87% (4.4 m/s) of the 95th percentile flows (5.1 m/s), and are very similar. Away from the rapids, the average riverine velocity also remains similar between low and high flows; the average 5th percentile flow rate is 1.0 m/s, and this is 75% of the 1.36 m/s average of the 95th percentile. In the lacustrine reaches, the average 5th percentile velocity is 0.21 m/s; this is 65% of the 0.33 m/s modelled for the 95th percentile flow. These data show that the riverine sections do not slow notably over a wide range in flows, but the area of faster water near each narrows does decrease. In the lacustrine reaches, the decrease in velocity between the 95th and the 5th percentile inflows is largest suggesting that changes of flow are more likely to have an effect on the type and distribution of substrate in Gull Lake, for example.

The discussion of aquatic habitat above was based on open water conditions, which is an important period to determine the distribution of aquatic biota and includes most biologically significant periods, such as spawning. However, ice scour in shallow areas can disrupt littoral biota and formation of ice dams or thick ice cover can make areas unsuitable for overwintering fish. As described in PE SV, Section 4.3.1.4, the formation of ice is complex and varies considerably between years. Constrictions in the river due to formation of ice results in higher overall water elevation in some sections than during the open water season and the distribution of velocity may be substantially different from the open water season. In particular, nearshore velocity can be high in riverine reaches.

Macrophytes

The presence or absence of rooted macrophytes depends on the availability of suitable wetted habitat, and the ability of plants to occupy that habitat. Changes in water level for a prolonged period during the growing season result in shifts in the location of macrophyte beds as plants respond to the changes in the availability of suitable habitat. When river levels remain low, some of the potential habitat higher on the bank is not wetted (*i.e.*, not suitable) and the elevation to which light can penetrate will also be lower (Figure 3-3). In the Nelson River, the zone of suitable habitat fluctuates up and down the bank within the zone of potential habitat as water levels change; as such, the suitable habitat will always be smaller than the potential habitat, and more closely linked to the recent water regime.

Constraint criteria were used to define the area of habitat with potential for macrophyte growth, and calculate the proportion of occupied habitat. The constraint criteria were limited to observations made during 2001, 2003, and 2006 in reaches 5–8. The constraint criteria were: 1) 95th percentile inflow water surface; 2) silt/clay substrata; 3) standing or low water velocity (depth averaged) (*i.e.*, less than0.5 m/s); and 4) water depths less than 3 m at a 5th percentile inflow (to account for light penetration at low water). The constraint criteria accounted for 94–99.7% of the macrophyte data observed each year.

Macrophyte stands observed in any one year tended to occupy the same general areas in the other years (Map 3-16), but notable differences in the depth of plant beds, their size, and number was evident between years. Water levels varied within and among years but in general they were high in 2001 and 2006 and were low in 2003 (Figure 3-2). The average depth of the plant beds in 2003 (1.9 m), when compared using depths relative to the 95th percentile, was notably greater than that of 2001 and 2006 (1.2 m, 0.72 m) (Figure 3-4A). After the 2003 depths were adjusted to account for low water using the 5th percentile inflow instead, the average depth (0.95 m) appears similar to the other years (Figure 3-4B) with a grand mean depth of 1.09 m and a standard deviation of 0.68 m. These data show that plants in the Keeyask area have adapted to considerable interannual variation of water levels.

Low water years appear to have fewer but larger macrophyte stands when compared to high water years (Table 3-3). Although 2001 and 2006 were both years of high water and both had relatively small average stand sizes, the total area occupied by plants in 2001 was about 2.5 times that observed in 2006 (Table 3-3). In 2005, water levels in the Keeyask area were also high for most of the open water season (Figure 3-2) and this may have also contributed to the distribution observed at higher elevations in 2006. Review of the water regime data for the early part of the growing season suggests that the relatively lower water levels in 2001, *i.e.*, nearer to the 50th percentile inflow, may have provided better conditions (*i.e.*, somewhat similar to 2003) than in 2006 when water levels remained relatively high throughout the growing season.

The total area that macrophytes occupied in reaches 5–8 during the three years of study was 788 hectares (ha) (164 ha of overlapping plants was surveyed among years). Therefore, over the years of study, rooted macrophytes occupied 624 ha of the 1,168 ha (*i.e.*, 53.4%) of the total potential habitat available (Table 3-4). In any one year, plants occupied 13.6–37.7% of the suitable habitat, or 12.5% to 30.7% of the potential habitat, that was available over the years. On average, the area of plants found in reaches 2B-9A is 208 ha.

In summary, low water levels provide better overall conditions for plant growth in the Keeyask area as the soft textured substrate in the extensive flats of the bays becomes sufficiently shallow to be suitable; this appears to result in fewer but much larger macrophyte beds. At high water, many of these areas do not to support plant growth. Instead, the plant beds are visible at higher elevations (which correspond with sloped parts of the channel) as relatively narrow bands that are oriented parallel to shore. The effect of intra and inter-annual variation of the water regime on macrophyte distribution is large. The ability of plants to occupy suitable habitat ranged from 13.6–37.7%; the range was slightly smaller when potential habitat was considered.

3.3.2.3.2 Description of Creek Habitat

Twenty-three small creeks drain into the Keeyask area. With the exception of Portage Creek and Two Goose Creek, the creeks in the Keeyask area drain small basins in low-lying peatland topography (Map 3-18). Low-level aerial surveys (Appendix 3A) show the predominant character of the creeks is peatland pool habitat and low velocity sections often have indeterminate channels that are bounded by peatlands. Most of the creek channels descend gradually to the Nelson River and the substrate is mainly organic. The size and habitat characteristics of these tributaries suggest that most are ephemeral.

Of the 86 km of stream present in the Keeyask area only about 1.5 km (1.7%) of well-developed hydraulic habitat exists, characterized by riffle/pool/run/glide habitat sequences, which is found primarily in Portage Creek and Two Goose Creek (Map 3-20). These two tributaries arise from headwater lakes and sections of each creek cascade down relatively steep reaches of the watershed where a meandering channel has developed and riffle/pool/glide habitat sequences are found. Below Carscadden Lake, Portage Creek alternates between riffle/pool/glide sequences and predominantly glide habitat as the stream descends over a stepped plateau. Two Goose Creek has riffle/pool/glide sequence habitat immediately below the headwater lake, and also near the confluence of the Nelson River. Gull Rapids Creek has a small amount of boulder habitat near the confluence with the Nelson River.

The location of the confluence of the Nelson River and each creek mouth varies with discharge of the Nelson River. The confluence often is found within the channel of the Nelson River when the river discharge is low. When river discharge is high, the lower reaches of the creek become inundated and a lentic backwater habitat forms. The range in the IEZ at Portage Creek and Two Goose Creek is shown for the open water season for the lower reaches of each creek in Map 3-20. At Portage Creek, the range of the IEZ during the open water season is 2.8 m; this creates a backwater inlet about 60 m in length. At Two Goose Creek, the backwater effect from the IEZ is relatively narrow as it is confined within the creek channel, which extends up the creek about 240 m. The substrate type in both backwater inlets is silt/clay.

Well-developed hydraulic habitat, as evident by riffle/run/pool/glide sequences, is found in Portage Creek and Two Goose Creek at elevations above the IEZ. Portage Creek has about 1,500 m of glide habitat below Carscadden Lake followed by 250 m of riffle/pool/glide habitat dominated by cobble and boulder substrates. Approximately 500 m of additional glide habitat then gives way to 1 km of riffle/pool/glide sequences that terminate at the onset of the backwater inlet. Two Goose Creek has 200 m of riffle/pool/glide habitat immediately below a headwater lake, and about 75 m more near the confluence with the Nelson River. Under conditions of low Nelson River discharge, and low flows in the tributaries, access up into these two tributaries by fish may be difficult due to the presence of the riffles in the lower reaches.

At Gull Rapids Creek, about 50 m of boulder habitat is found within the IEZ of the Nelson River. Reliable estimates of stage variation are lacking for monthly, weekly, or daily time steps due to the hazardous nature of the river in this area. Mapping of the open water season 95^{th} percentile suggests that this stretch of boulder habitat is fully inundated at high water. However, at lower Nelson River and Gull Rapids Creek discharges, the area of boulders may form an impediment to fish passage.

3.3.2.4 Stephens Lake Area

Stephens Lake was impounded by the Kettle GS in 1970, but did not attain full supply level until 1971. The reservoir flooded about 96 km² of waterbodies including about 48 km² of the Nelson River and Moose Nose Lake, the latter of which now lies within the north arm of Stephens Lake (Map 3-21). Today, Stephens Lake is surrounded by seven watersheds that drain the local topography. The North and South Moswakot rivers and Looking Back Creek, all of which drain into the north arm, are three of the lake's largest tributaries. The southern part of Stephens Lake, beginning approximately 5 km downstream of Gull Rapids, consists of the original Nelson River channel flowing eastward between several islands created by flooding and into the Kettle GS reservoir. The normal operational range of Stephens Lake is 2 m, with 5th and 95th percentile elevations of 139.2 m and 141.1 m, respectively (PE SV, Section 4.3.1.2), resulting in an IEZ of 1.9 m.

Most of Stephens Lake is lentic, including the north arm and the eastern half of the reservoir where it is wide and relatively deep. Spot measurement of water movements in the north arm are less than 0.05 m/s (Map 3-22). Most water movement observations at sites in the eastern half of Stephens Lake are about 0.1 m/s, except immediately upstream of the Kettle GS where velocities range from 0.3–0.4 m/s.

Lotic water masses occur under higher inflow conditions, primarily in the western half of the reservoir where currents tend to follow the original thalweg of the Nelson River (Map 3-22). Depth averaged velocity models for the Keeyask area (Section 3.3.2.3) suggest that lotic habitat ceases in Reach 11 (of the Keeyask area) and/or 12 when inflows are equal to or less than the 50th percentile suggesting that, under low to moderate flows, nearly all the reservoir is lentic habitat.

Substrates in Stephens Lake are either mineral or organic-based. The western half of the lake, including the north arm, contains a large amount of flooded terrestrial habitat and shallow bays that have flooded shorelines and predominantly silt or fine organic material substrates. However, some of the north arm is relatively deep (8−14 m) and along its eastern side retains much of the original, rocky shoreline and mineral-based substrates. Flooded islands along the original Nelson River channel in the southern part of the lake have mixed shorelines of submerged trees and a combination of clay, sand, and gravel substrates.

The eastern portion of Stephens Lake (*i.e.*, the Kettle GS reservoir) is relatively deep compared to the rest of the lake (mean depth = 24.7 m). The deepest area of the reservoir occurs in the original pre-flood Nelson River thalweg adjacent to the dam intake channel. Substrates in the reservoir are composed primarily of fine silt depositional materials; however, granular (sand/gravel) materials are found in clay along both the north and south shorelines.

Studies of rooted macrophyte distribution in the western end of Stephens Lake were undertaken to support development of a model to predict macrophyte abundance in the Keeyask reservoir (Map 3-23). Aquatic plants were found frequently in standing water areas, and showed a strong affinity for clay or organic based substrata. No plants were observed on inundated peat. Details of survey results and the macrophyte model are provided in Appendix 3C. Two of the nine species of macrophytes identified were observed frequently in standing water areas of Stephens Lake and each of the two species exhibited different habitat preferences. *Potamogeton richardsonii*, the most frequently observed species, showed a strong affinity for clay substrata and was found at depths mainly below the IEZ, while *Myriophyllum* *sibiricum* showed a preference for areas with fine organic deposits that are commonly found at the ends of flooded bays (Figure 3-5; Table 3-5).

As described in Section 3.2.4.2, Stephens Lake was used as a proxy to develop models to assist in predicting the future aquatic habitat conditions in the Keeyask reservoir (Appendix 3B).

3.3.2.5 Access Road Stream Crossings

The north and south access roads will cross five streams. The construction of the north access road was assessed in the Keeyask Infrastructure Project Environmental Assessment Report (KIP EA). The current assessment considers the operation of the north access road stream crossings and the construction and operation of the south access road. A map of the stream crossing locations is provided in Map 1-4. Detailed aquatic habitat assessments are provided in Appendix 3E. Information on stream hydrology is provided in PE SV, Section 4.

3.3.2.5.1 North Access Road

The north access road crosses two streams: an unnamed tributary of the South Moswakot River and Looking Back Creek, which flows in to Stephens Lake.

The unnamed tributary is a small intermittent stream with morphology and habitat ranging from boreal wetland with a braided channel and beaver dams to a well-defined narrow channel in upland forest. Although the unnamed tributary is a small second-order stream, the road crossing is in the headwaters where it is a first-order stream. Pool habitat, with a moderate level of cover composed primarily of over-stream vegetation and woody debris, is present at the crossing site. As described in the KIP EA, this stream will be crossed by a culvert, with riprap to stabilize the banks on either side. No habitat alterations outside of the crossing location are expected.

Looking Back Creek is a medium-sized seasonal to perennial stream with a well-defined meandering channel lying within a narrow well-drained floodplain. Fish habitat at the Looking Back Creek crossing site consists of run/glide habitat (laminar flow) with a small amount but high diversity of cover, including over-stream vegetation, woody debris, cut bank, instream vegetation, and boulder. Stream substrate was moderately compacted fine sediments with sporadically occurring boulders.

The crossing location is in close proximity to Stephens Lake, with no barriers to fish passage downstream.

As described in the KIP EA, this stream will be crossed by a clear span bridge with no effect on aquatic habitat.

3.3.2.5.2 South Access Road

The south access road will cross three small streams: Gull Rapids Creek; an unnamed tributary of Stephens Lake; and Gillrat Lake Creek.

Although Gull Rapids Creek is a small second-order stream, the road crossing is located where the tributary is a first-order stream. Gull Rapids Creek is an ephemeral stream that drains bogs, fens, and a large headwater pond located upstream of the crossing site. At the proposed crossing location, the stream consists entirely of pool habitat with little or no velocity, fine substrate, and a high level of cover composed of over-stream vegetation (10%) and instream vegetation (90%).

Unnamed tributary of Stephens Lake is a very small first-order stream, with the majority of the watershed (90%) located upstream of the crossing location. It drains a small unnamed lake (approximately 750 m upstream of the crossing) and flows into Stephens Lake approximately 400 m downstream of the crossing. This stream drains bogs, fens, and a small lake upstream of the crossing location. At the proposed crossing site, there are two stream channels both lying within a relatively broad, saturated floodplain. Both channels consisted entirely of pool habitat with little or no velocity, fine substrate, and a moderate level of cover composed of over-stream vegetation, instream vegetation, and cut bank.

Gillrat Lake Creek is a relatively small first-order stream, with virtually the entire watershed located upstream of the crossing location. The stream drains Gillrat Lake and flows into Stephens Lake. Numerous beaver dams restrict upstream fish passage to Gillrat Lake; downstream of the crossing location the creek was not impacted by beaver dams or other impasses to fish. Gillrat Lake Creek drains bogs, fens, and Gillrat Lake. At the proposed crossing location, the channel is well-defined and has stable bank, with habitat consisting of a variety of pool, run, and riffle habitats, a mixture of fine, cobble, and boulder substrates, and a moderate level of cover composed of over-stream vegetation, large organic debris, cut bank, boulder, and instream vegetation.

3.3.3 Current Trends/Future Conditions

Apart from the effect of inter-annual variations in flow, aquatic habitat has been relatively stable over the recent past, given that analyses of the water regime and sedimentation (Section 6.2.3.2.6 and Section 6.2.3.2.8) do not identify any pronounced trends. However, the formation of large ice dams at Gull Rapids has created and would continue to create new channels, due to water level staging and redirection of flows, and may cause changes to the river bottom such as the movement of substrate (*e.g.,* boulders) (Section 6.2.3.2.8). The potential effects of climate change were considered separately as described in Section 6.4.9.

3.4 PROJECT EFFECTS, MITIGATION AND MONITORING

3.4.1 Construction Period

The following section considers potential effects related to the construction of the GS and south access road during the construction period. Construction of the north access road was addressed under the EIS for the Keeyask Infrastructure Project (Keeyask Hydropower Partnership Ltd. 2009).

This section considers those effects to aquatic habitat that are restricted to the construction period (*e.g.*, habitat affected by the construction of infrastructure, such as cofferdams). The effects of water levels that attain FSL for the first time, which occurs later in Stage II of the Construction period, are discussed in the section on Operation.

Potential construction-related effects considered in this assessment include:

- Loss of aquatic habitat due to construction of project infrastructure(*e.g.*, cofferdams, spillway features) ;
- Changes in water levels and velocity immediately upstream and downstream of the construction site due to river management;
- Construction of a two temporary causeways between Pond 13 and the Nelson River to allow vehicle access to deposits N-5 and G-3;
- Changes in substrate downstream of the GS due to the deposition of construction-related sediments; and
- Loss/alteration of habitat at the south access road crossings.

A detailed description of the sequence of water level staging and changes in velocity during construction, including winter, is found in the PE SV, Section 4.4.1 and Section 4.4.1.6, which includes maps of the general arrangement and names of the principal structures. A detailed summary of water level changes is also provided in PE SV, Table 4.4-1. These two sections are summarized below to capture the main sequence of in-water activities, to identify temporary and permanent changes to habitat, and potential overlaps of work in periods of time that are important for spawning and larval incubation of fish (*i.e.,* 15 May to 15 July and 15 September to 15 October), as discussed further in Section 5 and Section 6. In general, the spring spawning period, which includes the spawning and larval emergence of lake sturgeon, was considered most sensitive and was provided greater priority.

3.4.1.1 Overview

Instream activity during Stage I of the construction period (June 2014 to September 2017) dewaters habitat in the north and central channels of Gull Rapids (reaches 8 and 9), and diverts most river flows to the south channel (Map 3-24). Stage I of construction avoids the spring period, but overlaps with the fall period at two cofferdam sites, as described below. The main effects on habitat availability are losses due to dewatering, and **disruption** to available lotic habitat due to diversion. Substrate quality also will be disrupted due to erosion, transport, and deposition of bank and cofferdam materials into the downstream area primarily due to river staging in the Gull Rapids area. The area of habitat loss within the footprint of the Project infrastructure is about 30% of the dewatered area in Stage I. In Stage II, which begins in fourth open water season of construction (September 2017 to December 2019), the spillway cofferdam is partially removed which increases wetted area, and the south dam is built in two stages (Map 3-24). As a result, lotic habitat will be disrupted near the spillway where flows are concentrated and increase in velocity. New lentic habitat will be created below the south dam, but will vary in area due to inflows and construction activity, until the spillway construction is complete. Cofferdams will be removed from the powerhouse and tailrace area in year 6 (2019). Substrate quality will be disrupted in Stage II temporarily due to the erosion, transport, and deposition of mobilized materials from river staging in Gull Rapids and to a lesser extent, the Gull Lake area, into the downstream area.

A summary of the temporary and permanent changes to aquatic habitat for each of the two phases of construction is provided in Table 3-6.

3.4.1.2 Stage I Changes to Aquatic Habitat

The total area dewatered during Stage I of construction is estimated to be 131.5 ha, inclusive of the Project infrastructure that accounts for about 30.6 ha (Table 3-6, Map 3-24).

Changes to aquatic habitat in Stage I result initially from construction of the North Channel rock groin, which is scheduled to begin after spawning and larval emergence of lake sturgeon has occurred in mid-July, during the first open water period of construction. The north channel rock groin will be permeable but will divert most of the flow to the south channel, effectively dewatering much of the north and central channels (see Table 3-6, above). Instream work in this year will be completed in late October, during the fall spawning period, after about three months of work when the Stage I island cofferdam, the impermeable quarry cofferdam, and the powerhouse cofferdam at the downstream extent of the north channel are in place.

In year 2, the second open water period of construction, instream works begin again in mid-July to avoid effects to the spring/early summer period. Wetted habitat losses in the second year of Stage I occur in the dewatered area within the spillway cofferdam and the central dam Stage I cofferdam. Construction of the spillway cofferdam will take will take about three months to complete (mid-October). The cofferdam for the central dam will be built from mid-August to early October, which partially coincides with the fall spawning period. Construction at the central dam starts a week or more after the spillway cofferdam construction begins. Water level increases above existing levels are expected due to the combined effects of diversion and encroachment in the south channel by the spillway cofferdam, which is expected to increase the amount of eroded materials (PE SV, Section 6.4.1.1) and suspended materials (PE SV, Section 7.4.1.1). Increases in water levels, assuming a 1:20 year construction design flood (PE SV, Section 4.4.1.2), will be about 0.9 m at the upstream extent of the spillway cofferdam, and about 0.8 m upstream of Gull Rapids (PE SV Map 4.4-1). Increases in average velocity in the area of the spillway are about 0.3 m/s or less (PE SV Figure 4.4-3), and in the context of this rapids habitat, are considered small.

No instream activities are planned in year 3 (2016), during blasting and excavation at the powerhouse and spillway. Partial removal of the spillway cofferdam is planned in mid-summer 2017, and does not overlap with the spawning/incubation periods in spring or fall.

3.4.1.3 Stage II Changes to Aquatic Habitat

The total area dewatered during Stage II of construction is estimated to be 123.9 ha, of which the Project infrastructure accounts for about 29.2 ha (Table 3-6, Map 3-24). Note that in Map 3-24, the infrastructure that is permanently flooded in Stage II of construction (*i.e.*, a substrate alteration), is shown within the dewatered areas for Stage I.

Instream activity during Stage II occurs in years 4–6 of the construction period (August 2017-December 2019) involves the partial removal of the spillway cofferdam and construction of the upstream and downstream south dam rockfill cofferdams, which over about a two-week period, direct flows to the spillway. The main effects on habitat availability during Stage II construction are:

- Permanent habitat losses due to the construction of upstream and downstream south rockfill cofferdams and central cofferdam;
- Disruption to available lotic habitat due to temporary creation of lentic habitat downstream of the south rockfill dam and concentration of flow towards the spillway;
- Increases in water levels as far upstream as Gull Lake due to staging; and
- Disruption of substrate quality due to initial use of the spillway and temporary changes in the processes of erosion, transport, and deposition of flooded bank and cofferdam materials into the downstream area (see Table 3-6, above).

Stage II Construction activities start in year 4 (August 2017) with partial removal of spillway cofferdam. This work will be completed primarily in August, but may extend a few days into the fall spawning period. The South Dam upstream rockfill cofferdam will be completed mostly in the fall period in order to avoid instream activity during the spring/early summer period the following year. Unregulated flows will first pass through the partially completed spillway in September (2017) and thereafter while the north, central, and south dams are constructed. The downstream side of the south rockfill dam will be built during spring spawning period (mid-May to mid-July). Although this activity cannot be completed before the spring period (withstanding an early thaw), this is not expected to occur on a spawning area given it will be lentic habitat (PE SV, Map 4.4-9). In the area of the spillway, velocities will be about 10 m/s, or about 2 m/s faster than Stage I, under a 1:20 year construction design flow scenario, which in both cases will prevent upstream movements of fish (Section 5). Flooding during Stage II of construction, according to this scenario, could be up to 1.5 m higher than occurs under present conditions but would be limited to the Gull Rapids area, and is not expected to exceed water levels experienced during Stage I (PE SV, Section 4.4.1.4 and Map 4.4-3).

Final construction works on the spillway will occur from July of year 4 (2017) to November of year 5 (2018). Water levels upstream of the structure will increase due planned closure of spillway bays, but levels will vary depending on inflow and the number of spillway bays used during this time (PE SV, Section 4.4.1.4).

The powerhouse and tailrace cofferdams will each be removed in year 6 (2019) within a one month period. The powerhouse cofferdam removal will overlap with the latter part of the spring spawning period, whereas the tailrace cofferdam removal occurs during most of the fall spawning period. The tailrace cofferdam removal will wet the tailrace area more than one month before first power generation.

Reservoir impoundment is planned for about one month during November of year 6 (2019) at a rate of about 0.5–1.0 m/day, which would store a relatively small amount in the reservoir (*i.e.*, about 3–10% of the November monthly discharge), leaving sufficient instantaneous flows available for the downstream area.

Lotic habitat will be created below the powerhouse for the first time when the first turbine becomes operational in December of year 6 (2019). As discussed in the section on Operation, this is expected to erode materials from the areas where construction occurred and transport and deposit materials in Reaches 11 and 12. Incremental movement and deposition of materials could be expected until the time all turbines are operational.

At initial FSL, the Project infrastructure will create a permanent loss of 10.4 ha (Reach 9B), and all dewatered habitat upstream of the Keeyask GS will be flooded (Reach 9A). The area of dewatered habitat below the Keeyask GS is not known well but is estimated to be about 101.4 ha. The total loss of rapids habitat over bedrock and boulder substrate habitat in Reach 9B, which includes the Project infrastructure below the reservoir and dewatered area, is about 111.8 hectares. Further changes to aquatic habitat are discussed in the section on Operation.

3.4.1.4 Construction of Causeways for Temporary Haul Roads to N-5 and G-3 Borrow Areas

The construction of two temporary causeways will be built to access the N-5 and G-3 borrow areas (see Project Description Supporting Volume [PD SV]) for about seven years during the construction period. Access to N-5 will require crossing the Pond 13 south channel (Photo 3-1). Culverts will be placed to allow fish passage through the crossing under the full range of Stephens Lake water levels. The channel between N-5 and G-3 presently does not connect Pond 13 with the Nelson River. To ensure that no entrapment of fish occurs, a channel will be excavated on the west side of the G-3 causeway. Each crossing site is not unique in terms of the substrate, depth, or water movements, and is small relative to adjacent similar habitat. The effects to aquatic habitat at the crossing locations are considered small in magnitude, local in area, temporary in duration, and continuous in frequency.

Source: P. Cooley, North/South Consultants Inc., 2006.

Photo 3-1: Pond 13 area looking north towards Looking Back Creek

3.4.1.5 Downstream Sedimentation

During each of the Stage I and Stage II instream construction activities, which are expected to last in the order of four years, approximately 50% of the additional suspended sediment concentrations will likely be deposited in the Nelson River as it enters Stephens Lake (PE SV, Section 7.4.1.2). This sediment will form a layer estimated to be up to approximately 0.6 centimetres (cm) thick near the inflow of the river to Stephens Lake, and then diminish to approximately 0.1 cm in the southern half of the reservoir towards Kettle GS. Deposited material is expected to include silt, sand and coarser material. This material is expected to remain on the lake bottom into the operation period.

3.4.1.6 Loss/Alteration of Habitat at South Access Road Stream Crossings

Three of the stream crossings along the south access road are described in Section 3.3.5 of the PD SV, and are shown in Map 4.2-1 of that volume, or Map 1-4 in this volume. At each of the three first order stream crossings (Gull Rapids Creek, an unnamed tributary of Stephens Lake, and Gillrat Lake Creek), the footprint of the road, combined with the installation of single or double corrugated pipe culvert(s), may result in several changes in aquatic habitat including the following:

- In-filling of stream channel from placement of culvert and roadbed material;
- Physical disturbance or damage to instream and riparian habitat;
- Depending on the size and method of installation, some changes in water depth for the length of the culvert at some sites, and an increase in depth immediately upstream and downstream of the culvert at most sites;
- Introduction of riprap at the upstream and downstream ends of the culvert to reduce erosion;
- Introduction of runoff and sediment into watercourses during construction resulting in sedimentation of downstream habitats;
- Loss of rooted submergent aquatic plant habitat in the immediate footprint of the road; and
- Depending on the size and method of installation, some increase in average water velocity for the length of the culvert, and a short-length immediately upstream and downstream at all sites.

Impacts related to construction will be minimized due to control measures outlined in the PD SV and practices described in the Environmental Protection Plan.

3.4.2 Operation Period

As discussed in Section 6.2.3.3.2, the total area of large river and lake habitat in the Kelsey GS to Kettle GS regional study area is approximately 65,000 ha (160,618 acres). Construction of the Keeyask GS will divide this area into an upstream area of approximately 40,000 ha (98,842 acres) (including flooded area of the reservoir) and a downstream area of approximately 30,000 ha (74,132 acres).

Effects to aquatic habitat are described for the following areas:

- Split Lake area, including Split and Clark lakes;
- The outlet of Clark Lake to the GS; this area comprises the portion of the Keeyask area described in the existing environment that will be upstream of the GS;
- Downstream of the GS; this area comprises the portion of the Keeyask area that will be within and downstream of the GS, including a portion of Gull Rapids, the riverine reach below Gull Rapids and Stephens Lake; and
- North and south access road crossings.

3.4.2.1 Split Lake Area

For open water conditions, there is no effect on the water levels and the fluctuations on Clark and Split Lakes due to the Keeyask project for either of the modes of operation (PE SV, Table 4.4-7). Under low flow conditions which occur on average once every 20 years, there may be a possibility that, due to the Project, peak winter water levels on Split Lake could be increased by up to 0.2 m above those which would occur without the Project in place. Even with the increased water level due to Project, the level on Split Lake would remain within the same range of winter levels that has been experienced historically (PE SV, Table 4.4-7). Given that these changes will remain within the range of existing water levels, no effect to aquatic habitat in the Split Lake area is expected.

3.4.2.2 Outlet of Clark Lake to the Keeyask Generating Station

The reach of the Nelson River from downstream of the outlet of Clark Lake to the Keeyask GS, which will form the future Keeyask reservoir, will undergo substantial changes to aquatic habitat following impoundment. A linkage diagram illustrating the pathways of potential effect to aquatic habitat is presented in Figure 3-6. The principal sources of change will be the footprint of the Keeyask GS Project itself (PE SV) and water level regulation (PE SV). Water level regulation will result in changes to the ice regime and the water regime. Changes to the water regime will affect aquatic habitat. Changes in the water regime include different water levels and flows during the open water and ice cover seasons (PE SV, Section 4.4), flooding of land (PE SV, Section 4.4.2.2), shoreline erosion processes (PE SV, Section 6.4), and sedimentation (PE SV, Section 7.4). Effects to aquatic habitat were predicted based on a synthesis of changes to the physical environment in conjunction with additional analyses based on observed conditions in other reservoirs (described in Appendix 3B). Potential changes to aquatic biota resulting from changes to aquatic habitat are discussed in Section 3, Section 4, Section 5 and Section 6.

This section addresses the assessment of operation-related effects for the conditions expected in the short-term (*i.e.*, at the time of initial FSL), in the first years as the conditions in the reservoir evolve, (represented by projections for Year 1, Year 5, and Year 15) and the long-term (represented by conditions in Year 30 after impoundment, which is expected to be similar to conditions in subsequent decades).

The section begins with an overview of changes to the reach, followed by a quantitative description of habitat at initial FSL, the predicted long-term habitat in terms of areas and types (based on modelled conditions at Year 30 post impoundment), and a description of evolution of habitats in the reservoir at Years 1, 5, and 15. Both the initial FSL and Year 30 assessments have relatively strong certainty from observation of the Keeyask area and Stephens Lake, an adjacent reservoir roughly 30 years after impoundment. The evolution of habitat conditions at the intermediate time steps is a less certain process, based on interpretation of the effects of physical factors (PE SV, Section 4, Section 6, and Section 7) on habitat development over an intervening time period (Years 1, 5, and 15).

Changes in habitat between existing and post-Project conditions are described based on 95th percentile flows, which represent the maximum extent of aquatic habitat and thus form a useful basis for comparison. Post-Project water levels will be maintained in the range of 158–159 m ASL by operation of the GS, and effects on water surface elevation due to inflows are only experienced in the upper riverine section.

3.4.2.2.1 Overview

At the time of initial FSL the main effects of the Keeyask GS upstream of the station will be:

- A loss of rapids (*i.e.*, white water habitat);

- An alteration of riverine habitat (at the upper end of the reservoir);
- A conversion of riverine aquatic habitat to reservoir habitat (at the lower end of the reservoir); and
- Creation of flooded terrestrial habitat.

As the reservoir ages, the altered habitat is predicted to change in both area and composition. For example, the flooded terrestrial habitat that will be widely abundant at the initial FSL will change to several types of reservoir habitat over time. Substrate distribution within the reservoir will be determined mainly by the distribution and magnitude of water movements, available bed materials, and pre-flood land cover. The long term patterns of habitat in the reservoir will not be readily distinguished until peatland and mineral erosion processes slow to near background levels (PE SV, Section 6; described below). The lower reservoir is expected to become mainly a depositional environment, given that this area has the greatest increase in depth and decrease in velocity, with a resulting relatively large proportion of lentic habitat.

Overall, the reservoir will approximately double the volume of water that is currently within the existing river and lake. The decrease in velocity will increase the travel time for water flowing in the mainstem from 10 to 20 hours in the existing environment to approximately 15 to 30 hours post-Project (PE SV, Section 4.4.2.2). Water residence times in newly formed bays of the reservoir will vary and be up to one month, though times would be longer in the shallowest areas furthest from the mainstem (PE SV, Section 4.4.2.2).

3.4.2.2.2 Aquatic Habitat at Initial Full Supply Level

The open water area of the reservoir at initial FSL will increase by approximately 45 km^2 (Map 3-25), as defined by the HZI of the Project, resulting in a reservoir surface area of 93 km^2 (under a 50^{th} percentile inflow; PE SV, Section 4.4.2.2). The resulting amount of flooded area does not include any lakes or rivers that will be flooded and incorporated within the reservoir (PE SV, Section 4.4.2.2). The HZI above the GS extends to the upstream end of Reach 2B and is controlled by dykes, local topography, backwater effects from the principal structures, and inflows (Map 3-26).

At the time of initial FSL, the reservoir will contain flooded aquatic habitat and flooded terrestrial habitat. The amount of aquatic habitat that is altered or flooded at initial FSL is summarized in Table 3-7. The main changes at this time will be increases in depth, establishment of a new IEZ based on daily and weekly rather than seasonal water level variation, decrease in velocity, loss of white water habitat, and the formation of different lentic and lotic habitats within the reservoir.

Increases in water depth resulting from flooding (Map 3-27) range, on average, from 0.28 m in reach 2B to 10.1 m in Reach 9A (Table 3-8). In general, within the existing channel, most of the reservoir will increase in depth by less than 6 m and most flooded areas will be less than 4 m deep. Changes in the depth of flooding in the downriver direction are most notable at Birthday Rapids and Gull Rapids. The average depth of increase immediately above Birthday Rapids in Reach 3 is 0.46 m, which is relatively small compared to that farther downstream in Reach 4 where water depths will increase about 2.3 m. Most of the main thalweg in Reach 6 will be about 20 m deep (Map 3-28). Depths in the main thalweg north of Caribou Island will range from 16−17 m. Downriver in Reach 9A, Gull Rapids, the average depth of flooding is about 10 m, or about 4 m greater than Reach 8. Reach 9A, however, has a diverse topography. Increase in water depth can be as little as 3 m where islands today rise above Gull Rapids, or 31 m where the intake channels to the turbines would be excavated (Map 3-27). A detailed description of changes to water depths, water levels, and water level fluctuations as a result of the Project is provided in PE SV, Section 4.4.

The range in the IEZ before the Project (IEZ_{ee}) and after the Project (IEZ_{pp}) for the study reaches are found in Table 3-8. The depth of the IEZ_{pp} will be slightly larger than the IEZ_{ee} above Birthday Rapids, but will be smaller below. The range of the IEZ_{pp} will continue to have a pattern similar to that of the IEZ_{ee}, where stage variation in the riverine section (Reaches 2B–5) exceeds that of the more open reaches downriver likely due to the confines of the river channel. The IEZ_{pp}, and Deep/Shallow zones (*i.e.*, IEZ and Predominantly Wetted zones) are shown in Map 3-29.

The frequency of water level changes will be altered under the Project (PE SV, Section 4.4.2.2). Under the base loaded scenario, the one day and seven day water level variation during open water will remain at 0. However, under the Peaking mode of operation, one day water level variations could be as large as 0.8–1.0 m at Gull Lake, diminishing to 0.4 m upstream of Birthday Rapids. Over seven days, water levels in Gull Lake would vary up to 1 m, reducing slightly to a variation of 0.9 m downstream of Birthday Rapids.

A detailed description of changes to water velocities as a result of the Project is provided in PE SV, Section 4.4, the maps of which have been reproduced, in part, here. Post-Project decreases in velocity are greatest in the riverine reaches 2B to 5 and 9A, and least in 6, 7, and 8 (*i.e.*, lacustrine reaches in Gull Lake) (Map 3-30). Depth average model results show that most of the flooded area will be lentic habitat. Post-Project differences in water velocity modelled between high and low flows appear relatively small between Birthday Rapids and the upstream extent of hydraulic influence, but farther downriver the velocities in reaches 5 and 6 decrease notably under low flows (Map 3-31and Map 3-32). Under 5^{th} percentile inflows and a 158 m reservoir stage, models suggest that low velocity habitat will be found farther upstream in the main channel, near the upstream boundary of Reach 5 (Map 3-32). In the lower reservoir, the currents of the thalweg, which follow the original river channel closely, decrease more and alternate between low velocity and standing water habitat. Under 95^{th} percentile flows and a 159 m reservoir stage, the riverine reach consistently maintains a moderate velocity, and low velocity flows are maintained throughout the original river channel, except for north of Caribou Island (Map 3-31). White water habitat will remain in Long Rapids.

During the winter, the reservoir is expected to form a thermal ice cover, and the large effects of ice dams on water velocity currently observed are not expected to occur (PE SV, Section 4.4.2.4).

Changes in substrate composition and pattern in flooded aquatic habitat at initial FSL will be limited given erosion and sedimentation processes will have had insufficient time to erode and transport materials into the river. Substrate composition, therefore, will be similar to the pre-flood condition, with the exception that flooded terrestrial bottom type would also be present.

Virtually all existing potential macrophyte habitat above the GS will be lost due to increases in water depth, although some small patches of potential habitat may persist in small bays in Reach 2B or 3.

Above the GS, flooding will create backwater inlet habitat in the lower reaches of Portage Creek and Two Goose Creek (Map 3-33) thereby inundating 0.91 ha of creek habitat. Flooding will result in a loss of about 15.5% (0.8 ha) of Portage Creek and 31% (0.92 ha) of Two Goose Creek (Table 3-9).

3.4.2.2.3 Aquatic Habitat at Year 30

At Year 30, reservoir expansion will have increased the reservoir area to about 99.8 km^2, an increase of 7–8 km^2 due to mineral bank erosion and shore peat breakdown (PE SV, Section 6.4.2.1, see Map 6.4-6 and Map 6.4-7). Shoreline erosion, peatland resurfacing and transport, and sedimentation processes will remain active in some areas, but are at rates that are much slower than in the first 15 years of the reservoirs history (PE SV, Section 6.4.2.1). The physical environment modelling studies and the aquatic environment observations on Stephens Lake collectively suggest that the exposed nearshore areas of a reservoir in the study area at Year 30 will be mostly mineral, whereas sheltered bays retain more of their pre-flood peatland characteristics. Less wave energy is available in flooded bays, and when compared to the main basin of the reservoir, the slope of bays is minimal and the peat deposits tend to be larger and deeper. The inherent character of peatland bays infers that they are less able to shift to a mineral nearshore area over time. For the Keeyask reservoir, the physical environment studies estimate that mineral-based shorelines are expected to increase from 28% to 69% of the total shoreline length over 30 years. This transition from mainly peat-based substrates, which do not support rooted plants, to nearshore slopes that develop from mineral soils due to erosion and resurfacing of peat is important as it helps develop potential macrophyte habitat over time. Water velocities and water depths at Year 30 will essentially be the same as following the initial FSL, with the exception of changes in very shallow water due to shoreline recession, peatland resurfacing, and development of nearshore slopes that will slightly increase the amount of lentic habitat around the perimeter of the reservoir.

The results of substrate modelling for the Keeyask reservoir at Year 30 are provided in Appendix 3B. The pattern of substrate deposition in the reservoir is similar when 95th and 5th percentile inflow scenarios are compared, although some differences are apparent. The 95th percentile inflow model results suggest that the silt sediment boundary would occur up to about 1 km farther downstream in Reach 6, at the entrance to present day Gull Lake, when compared to the 5th percentile inflows. A few small areas that are depositional under 95th percentile inflows will not be under 5th percentile flows. These non-depositional sites under low flows tend to be shallow where flows would be constrained, such as near the boundary of reaches 6 and 7 at narrows found between islands, and in shallow areas within present day Gull Rapids.

Soil erosion studies indicate the river banks will erode (PE SV, Section 6.3.1.2.2), including the riverine reaches 4 and 5 below Birthday Rapids. The altered state of the banks is expected to be sandy/clay given the deposits are mainly glacial till, with local occurrences of **glaciofluvial** or glaciolacustrine sediments. Nearshore sedimentation studies suggest however that the mineral sediments eroded from these banks will not be transported downriver, so deposition of gravel and sand at the entrance to Gull Lake is not expected (PE SV, Section 7). The PE studies of the existing environment demonstrated limited bed load movement from upstream (PE SV 7.3.1.2); this is expected to continue in the future with the Project;

The combined results of the terrestrial soil studies (TE SV, Section 2.3.4.2), peatland and mineral erosion studies (PE SV, Section 5 and Section 6), sedimentation studies (PE SV, Section 7) and the reservoir habitat models (Map 3-34 and Appendices 3B and 3C) suggest:

- The bottom of the thalweg in the riverine section (reaches 2B–5) of the reservoir is expected to remain free of silt. The thalweg of reaches 2B–5 expected to maintain a bed composition similar to that of the existing environment;
- Most of the lower reservoir (reaches 6–9A) will become depositional with silt sediments, except for some of the main thalweg areas where velocity, depth, exposure, and slope are sufficient to keep the substrate silt-free with a substrate composition similar to today;
- Shallow water substrate type depends strongly on the pre-flood soils (Appendix 3C). In open areas of the reservoir, clay substrata forms from pre-flood mineral soils or from thin peat veneers overlying mineral deposits, often in glaciolacustrine deposits. The substrate in other shallow habitat is inundated fibrous or humic peat where pre-flood peatlands are large and relatively deep;
- Deposits of fine organic material will accumulate in lentic habitat at the ends of bays fed by local peatland streams in reaches 5–7(Appendix 3C); and
- Potential macrophyte habitat may develop in many nearshore areas of the reservoir. Areas of thin peat, which is a common soil type within the bounds of the future reservoir (PE SV 5.3.3.2), will resurface or erode and expose mineral-based soils (Appendix 3C). Once relatively stable, nearshore processes (*i.e.*, waves and water level variation) will wash the clay and aggregate lag and keep some or the entire photic zone on the nearshore slope silt free. Potential macrophyte habitat may even develop at the ends of sheltered bays where peat accumulation was relatively thick, after peat has floated away and local water masses prevent silt from the main reservoir to deposit (Appendix 3C).

The availability of potential and suitable macrophyte habitat in the proposed reservoir (reaches 2B–9A) varies by mode of operation. Under a base loaded mode of operation scenario, when the Keeyask GS operates at 159 m ASL continuously, the amount of habitat that is suitable is equal to the potential (*i.e.*, all potential habitat is permanently wetted). Conversely, under a peaking mode of operation, the area of suitable habitat is expected to be less than the potential due to dewatering from daily and weekly draw down.

For the Base loaded mode of operation at the 95th percentile and 159 m ASL reservoir stage, the area of potential macrophyte habitat in the reservoir is estimated to be 1,878.1 ha (Map 3-35), or 1.6 times more than the 1,197 ha of potential macrophyte habitat present in reaches 2A–9A in the existing environment. For the peaking mode of operation, the area of suitable macrophyte habitat (*i.e.*, assuming half of the post-Project IEZ is suitable), is 1,396 ha or about 26% less than the Base loaded mode of operation. The suitable macrophyte habitat of the peaking mode of operation is about 1.2 times more than exists in the same area under present day conditions.

The actual area occupied by plants in the reservoir may range widely in space and time, given that Keeyask environmental studies have shown the area of potential habitat actually occupied varied from a low of 11.5% at Stephens Lake (regulated reservoir) to a maximum of 31% in the unregulated river/lake environment of the Keeyask area (Table 3-4). At present, it remains uncertain if the range of habitat occupied by macrophytes arises from intrinsic differences between habitats in a reservoir and large river, or if the area occupied by macrophytes is attributable to incomplete colonization of the potential habitat available in Stephens Lake. In addition, the Stephens Lake reservoir experienced high water conditions during the Keeyask environmental studies, which may suggest plants could have been depth (*i.e.*, light) limited and so had lower areas of occupation. Consequently, as a highly conservative approach, it was assumed that 10% of the potential habitat at Year 30 would be occupied by rooted macrophytes. Estimates suggest that the area occupied by rooted macrophytes at Year 30 is 187.8 ha under Base loaded mode of operation or 139.6 ha for peaking. When compared to the average area occupied in reaches 2B–9A (*i.e.*, 208 ha) in the existing environment, this equates to a loss of 10.7% under a Base loaded scenario or 48.9% under peaking.

3.4.2.2.4 Evolution of the Reservoir - Year 1 to Year 15

The physical processes responsible for the development and maintenance of aquatic habitat in the Keeyask area after the Project are expected to slow to levels at or near those expected without the Project before or by Year 15 (PE SV, Section 6.4.2, Section 6.4.4, and Section 7.4.2). These studies suggest: 1) that rates of shoreline erosion are expected to stabilize at rates similar to those of the existing environment by about Year 15; 2) like the rate of shoreline erosion, the rates of mineral deposition will be greatest at Year 1 and generally decrease thereafter; and 3) the peatland disintegration models suggest that most of the flooded peatland dynamics, which are unique to the post-Project, have occurred by Year 15.

When compared to the Peaking Mode of operation, the Base loaded scenario generates a slightly higher rate of mineral erosion, and rate of mineral deposition (PE SV, Section 6.4.2.1 and Section 7.4.2.1). The mode of operation is not expected to change the amount of peat resurfacing or rate of disintegration, or movement of floating peat (PE SV, Section 6.4.2.1).

The results of total suspended solids, dissolved oxygen, and organic sediment models by the physical environment studies are described in Section 2 of this volume and in the PE SV, Section 7 and Section 9. A detailed examination of the differences between Base loaded and Peaking operations is provided in the PE SV, Section 4.4.2.2.

3.4.2.2.5 Development of Reservoir Habitat

The Keeyask environmental studies suggest that the reservoir habitat may begin to approach a more stable state by Year 15 given that the physical processes that force the composition and distribution of habitat (including water depth and velocity regimes established at initial FSL) have slowed appreciably. Accordingly, the main habitat patterns that are well established at Year 30 are expected to be evident by Year 15. Although erosion, transport, and deposition are expected to continue in the reservoir after Year 15, the rates of change within the habitats established are expected to be relatively low and/or episodic over smaller areas. In all but the highly exposed areas such small increments of change are not expected to alter the type of reservoir habitat developed by Year 15 but more heterogeneity would be evident (*i.e.*, arising from remnants of flooded terrestrial and shore erosion) than in Year 30. Further, the ability of the reservoir to form habitat boundaries (*i.e.*, those that define the edges of habitat types like rock, sand, or silt) is in part dependent on the available hydraulic energy. As such, substrate habitat boundaries that form in Deep Water due to the pattern of lentic/lotic habitat are more likely to be evident earlier in the reservoir than shallow habitat, which, due to erosion, is relatively unstable for longer periods of time. Deep Water habitat boundaries, such as the superimposition of silt on the existing riverbed, could probably be observed by Year 5. In Shallow and Lentic habitat, the habitat boundaries that form in back bays would be at a slower rate than those that form in the main body of the reservoir where wave energy is higher, but could stabilize earlier than highly exposed sites.

Year 1

As described in detail in the PE SV, the physical changes from the state at initial FSL are mainly: 1) the ongoing peat resurfacing and transport, 2) mineral and peat erosion, 3) mineral sediment deposition in shallow water and silt sediment begins to deposit in many areas of the lower reservoir.

One year after flooding the reservoir substrate is expected to be heterogeneous and composed of flooded terrestrial habitat, flooded aquatic habitat, and early signs of newly formed substrate that will eventually be predominant at Year 30. The area of flooded terrestrial habitat (*i.e.*, where substrate is still the same as at initial FSL) is expected to decrease relative to initial FSL; many areas of the lower reservoir will be heterogeneous and composed of pre-flood and post-flood materials. The distribution of post-flood materials is expected to be discontinuous and under-developed due to the limited time the reservoir has had to segregate water masses, move materials that have been mobilized since flooding, and the available bottom types. Floating peat islands will be readily apparent and mobile on the surface of the reservoir (PE SV, Appendix 6D). Differences in the rate of peatland and mineral shore erosion around the perimeter of the reservoir (PE SV, Section 6.4.2.1) suggest differences in the rate of reservoir habitat evolution may be apparent. The shallow flooded terrestrial areas in the south Shallow Water area of Reach 6 are expected to have the highest rates of shore erosion and deposition at Year 1 (PE SV, Section 7.4.2.1).

The post-Project distribution of aquatic habitat types within each water elevation zone (MOL=158 m ASL, FSL=159 m ASL, and the IEZ) that are expected to develop by Year 1 are shown in Appendix 3D (Table 3D-1). These predicted habitat distributions were used in the lower trophic level and fish community assessments (Section 4 to Section 6).

Local tributaries that enter at the ends of bays will have pooled tea-colour peatland water at the end of the bays; the visible contrast to that of the turbid water of the main reservoir will remain a long-term characteristic of the reservoir (Appendix 3B). The location where the peatland water mass meets the more turbid water of the reservoir will influence the long-term position of organic and silt habitat boundaries evident at Year 30 (Appendix 3B). The flooded terrestrial bays will have markedly different water quality characteristics and are expected to show large seasonal changes in oxygen (Section 2).

Year 5

At Year 5, the area of substrate comprised of post-flood materials is expected to increase while the area of flooded terrestrial habitat will decrease. Sedimentation analyses indicate erosion and sedimentation processes in the reservoir remain active at five years post-flooding (PE SV, Section 6.4.2.1 and Section 7.4.2.1). Sedimentation analysis indicates rates of sediment deposition of 0−1 cm/year in offshore areas (PE SV, Section 7.4.4). Mineral sediment, primarily in the form of silt, is expected to cover much of the flooded aquatic habitat and flooded terrestrial habitat, except where water velocity, surface wave energy, or slope of the substrate is sufficient to prevent deposition (Appendix 3B).

Erosion of thin peatlands in exposed areas of shallow water of the lower reservoir is expected to expose the underlying mineral soils (PE SV, Section 6.4.2.1). Aquatic studies of Stephens Lake also show that, over time, a clay-based substrate will form from pre-flood topography that is mineral or thin peat from which potential macrophyte habitat will begin to develop (Appendix 3B). Occupation of the potential plant habitat by rooted macrophytes could occur but would probably be infrequent and, in general, not a widely visible aspect of the reservoir. According to the results of erosion and sedimentation studies (PE SV, Section 6.4.2.1), the habitat adjacent to the southern shoreline area of Reach 7 and in Reach 9 would likely be the most unstable Shallow habitat in the reservoir.

Ends of back bays fed by peatland streams will lack silt sediment originating from the turbid waters of the main reservoir (Appendix 3B) and will resemble flooded terrestrial habitat. Peat resurfacing and transport away from the bays appears to be slower when compared to the main body of the reservoir (Larter 2010). At Year 5 peat is likely to be a readily visible characteristic of back bays in the reservoir; floating and mobile peat is estimated to be greatest at Year 5 (PE SV, Appendix 6D). The greatest accumulation of floating peat is expected in the southern bays of the lower reservoir (PE SV, Section 7.4.4). Some of this mobile peat could anchor on shores and superimpose existing reservoir habitat. This would constitute a small and short-term loss of habitat that is not expected to influence biota.

The boundaries of post-flood substrate materials in deep water, (*i.e.*, substrates of silt and other harder bottom types) could evident by Year 5 in lentic habitat given that silt sedimentation is the dominant open-water process but, as described in later time steps, is discontinuous in the Lotic areas of the lower reservoir.

The post-Project distribution of aquatic habitat types within each water elevation zone (MOL=158 m ASL, FSL=159 m ASL, and the IEZ) that are expected to develop by Year 5 are shown in Appendix 3D (Table 3D-1). These predicted habitat distributions were used in the lower trophic level and fish community assessments (Section 4 to Section 6).

Year 15

The main habitat patterns that are evident and well established at Year 30 (described in previous section) are expected to be present at Year 15. When compared to the reservoir habitat at Years 1 and 5, relatively stable shallow water habitats will have developed given that peatland disintegration, mineral erosion and mineral sedimentation processes are expected to have slowed markedly (PE SV, Section 6.4.2.1 and Section 7.4.2.1). It is anticipated that the areas of post-flood substrate materials at Year 15 would be somewhat less than at Year 30 as some heterogeneity would persist given that some remnant flooded terrestrial habitat would remain but the segregation of distinct reservoir habitats (Appendix 3B) would be recognizable.

Some of the potential macrophyte habitat available at Year 30 would be present at Year 15 but heterogeneity would be expected due to remnants of flooded terrestrial habitat and occasional changes in quality of some of that habitat due to ongoing erosion. A predominantly clay-based substrate with some aggregate lag will begin to be widely available in the lower reservoir in Shallow Water within the zone of wave action (Appendix 3B); this is expected to form the primary habitat for the rooted macrophyte *Potamogeton richardsonii*. Some of the potential macrophyte habitat found at the ends of back bays also will have developed. By Year 15, much of the fibrous surface layers of the resurfaced peat will have resurfaced and transported away (PE SV, Section 7) which creates and enables fine organic deposition to form (Appendix 3B). The ends of sheltered bays with fine organic deposition are expected to form some of the habitat for the rooted macrophyte *Myriophyllum sibiricum*.

The Deep Water habitat patterns of silt deposition are expected to be quite similar to modelled estimates of Year 30 (described in previous section). Unlike the development of Shallow Habitat, which in most areas of the reservoir responds mainly to the intermittent effects wave action and water level cycling, the Deep Water habitat will arise from water depth and velocity regimes that will have acted continuously since initial FSL. Silt deposits, which will sediment at rates from 0–1 cm/year (PE SV 7.4.2.1) will form a continuous surface where deposition is expected at Year 30 (described in previous section), but at Year 15 the deposits will be thinner (PE SV 7.4.2.1). In reaches 2A–5 the velocity of the thalweg will be sufficient to maintain the bottom type observed in the studies of the existing environment. A substrate material size gradient is not expected where riverine flows leave Reach 5 and enter Reach 6 upstream of the zone of deep water silt deposition based on sediment transport analysis that suggest negligible amounts of sand and gravel material will be transported from the flooded banks upstream in the flooded riverine reaches (PE SV, Section 7). This is unlike the material size gradient that appears to have formed 4–5 km below Gull Rapids after Kettle GS was built (see Map 3-14). The area of the confluence of reaches 5 and 6 will be monitored after the Project to determine if sand and gravel transport and deposit in this area.

The post-Project distribution of aquatic habitat types within each water elevation zone (MOL=158 m ASL, FSL=159 m ASL, and the IEZ) that are expected to develop by Year 15 are shown in Appendix 3D (Table 3D-1). These predicted habitat distributions were used in the lower trophic level and fish community assessments (Section 4 to Section 6).

3.4.2.3 Downstream of the Keeyask Generating Station

3.4.2.3.1 Aquatic Habitat at Impoundment

Mainstem Habitat

Construction of the Keeyask GS will change or eliminate all aquatic habitat in Gull Rapids as it exists today. The upstream section of the rapids will become a part of the reservoir, while the middle and lower sections of the rapids will be covered with the structures of the GS, modified into the intake and tailrace channels, or dewatered. Under existing environment conditions, the majority of the flow passes through the south channel of Gull Rapids (PE SV, Section 4.4.2.3). Following construction of the Keeyask GS, the flow will be directed through the powerhouse on the northern part of the channel. When the spillway operates (approximately 12% of the time based on historical flow conditions) (PE SV, Section 4.4.2.2) the surface water levels are expected to be below existing conditions (PE SV, Section 4.4.2.3). When the spillway is not operational portions of the south channel of Gull Rapids will be dewatered (PE SV, Section 4.4.2.3, see Map 4.4-11). The area of the spillway that will be dewatered when the spillway is closed is not well known, but a preliminary estimate is about 104 ha. As the spillway dewaters, some pools may form that remain isolated from the main flow of the Nelson River (Table 3-7) and may not provide overwintering habitat for fish (described in Section 5).

Effects to the water regime downstream of the Keeyask GS are described in the PE SV, Section 4.4.2.3 and Section 4.4.2.5. The water level downstream of the GS tailrace will be determined mainly by the level of Stephens Lake. There will be a drop in water level ranging from 0.1 to 0.2 m over a 3 km long reach between the powerhouse tailrace and Stephens Lake, depending on the magnitude of the GS discharge and the level of Stephens Lake. The magnitude of water level fluctuations within this 3 km long reach will depend on plant discharge, the amount of cycling at the Keeyask GS, and Stephens Lake water level fluctuations. Stephens Lake water levels will not be affected by operation of the Keeyask GS. The maximum water level changes in this reach due to cycling at the station are expected to be less than 0.1 m (PE SV, Table 4.4-3). However, during the open water season, in addition to the effect of cycling, this reach will continue to experience changes in water levels related to differences in inflow and regulation on Stephens Lake. This will result in an overall range in the order of 2 m, with daily and weekly water level fluctuations in the order of 0.3 m and 1 m, respectively. During winter, changes in water level due to lack of formation of an ice dam, and the formation of new channels will no longer occur (e.g. the channel that connects the Nelson River to Pond 13).

The downstream HZI of the project in the open water season is within 3 km of the GS, where changes in the path and magnitude of flows are expected (PE SV Section 4.4.2.3). It can be shown that differences in modelled velocity before and after the Project downstream of the HZI but upstream of the silt boundary in the flooded channel (*i.e.*, 3–5 km below the GS) is within the range of the existing environment. Below the GS, under 95th percentile inflows to the reservoir, spill occurs and the velocities are high for the first 1 km below the tailrace, which then decrease to moderate for the next 2 km and then are low out into Stephens Lake (Map 3-31). Under 5th percentile inflows to the reservoir, the tailrace velocities are moderate for about the first 1.5 km and decrease from low to standing about 3 km downriver (Map 3-32). Differences in modelled water velocity between the existing environment and post-Project at 95th percentile inflows (Map 3-30) show that water velocities after the Project will increase in the powerhouse tailrace area and then route along the south bank, which is a pattern that is the reverse of the existing environment (See Map 3-8). The pattern of water movements is similar for the 5th percentile inflows (Map 3-32), although spill does not occur. The shift of flows to the south half of the channel after the Project increases the area of lentic habitat along the north bank (compare Map 3-8 and Map 3-31). The ice cover that forms below the GS will resemble a thermal ice cover similar to what currently occurs on Stephens Lake downriver of the Keeyask area (PE SV, Section 4.4.2.5), although small ice free areas will form immediately downstream of the tailrace. Ice dams will no longer form 3–5 km below the GS, and the thermal ice cover will greatly reduce winter erosion in this area (PE SV, Section 6.4.2.2).

As discussed in Section 3.4.1.5, construction activities are expected to result in the deposition of a layer of sediment estimated to be up to 0.6 cm thick near the inflow of the river to Stephens Lake, and then diminish to 0.1 cm towards the Kettle GS.

Gull Rapids Creek

In the existing environment, Gull Rapids Creek flows into the south bank of the Nelson River, approximately 1 km upstream of the base of Gull Rapids. Gull Rapids Creek has a limited amount of well-developed hydraulic habitat. The lotic creek habitat that is available (0.01 ha) is found within the IEZ of the mainstem of the Nelson River in the existing environment. Riffle habitat (3 m^2) was observed only at one location in the IEZ. These riffles may be inundated, flowing, or exposed depending on changes in water surface level of the Nelson River and flows from the creek.

Following construction of the GS, Gull Rapids Creek will flow into the portion of the South Channel of Gull Rapids that will be dewatered. After the Project, the lower reaches of the creek will no longer experience intermittent flooding. Although Gull Rapids Creek itself will experience little effect, habitat within Gull Rapids Creek will become isolated from that of the Nelson River.

3.4.2.3.2 Aquatic Habitat at Year 30

The substrate in lentic habitat along the north bank may become depositional within 2 km of the Keeyask GS over time, based on the availability of lentic habitat (Map 3-31), and the loss of the hanging ice dam (PE SV, Section 4.4.2.4). This lentic habitat will be slightly larger after the Project due to a shift in the path of current, but will be found in the same general area as before the Project (Map 3-32). In the existing environment, this lentic habitat did not have a depositional substrate; this was unlike the other lentic habitat observed upstream of Gull Rapids (compare Map 3-8 and Map 3-14). It is currently thought that the hydraulic diversity created by the ice dam in winter, may have prevented this lentic area from being a site of net deposition. Consequently, the decrease of hydraulic diversity under a thermal ice cover after the Project could enable the lentic habitat to be more like that observed above Gull Rapids in the existing environment, and become depositional. Although the available data suggest this lentic habitat will develop a silt substrate over time, which has been the assumed state for all fish habitat analyses later in the EIS (Section 4 to Section 6), the rate of deposition or the resultant area of the persistent silt deposit is not certain. This area will be monitored after the project.

As noted above, construction is expected to result in the deposition of a thin layer of sediment in the mainstem portion of Stephens Lake; this will persist in the operation period. These sediments, however, are expected to be re-distributed according to particle size after high flow events (*i.e.*, sand and gravel will sort by size similar to the pattern observed in the existing environment).

3.4.2.4 North and South Access Roads Area

Loss of habitat due to the placement of the culvert and alteration due to the placement of riprap in the smaller streams will continue through the operating period. No incremental effects related to sediment inputs from erosion are expected due to the application of erosion control measures. No effects to habitat in Looking Back Creek are expected.

3.4.3 Residual Effects

3.4.3.1 Construction Period

Residual effects of construction of the Project on aquatic habitat are summarized in Table 3-10.

Key residual effects of construction are:

- Installation of instream structures such as cofferdams will change water levels and flows within and upstream of Gull Rapids, resulting in the loss of habitat in the north and middle channels of Gull Rapids in Stage I of construction and loss of remaining habitat in the south channel in Stage II; and
- A thin layer of sediment will deposit in the river and Stephens Lake, but no change in substrate composition will occur.

3.4.3.2 Operation Period

Residual effects of operation of the Project on aquatic habitat are summarized in Table 3-11.

Key residual effects of operation are:

- Conversion of river/lake environment to reservoir in an approximately 40 km (25 mile) long reach between the outlet of Clark Lake and Gull Rapids, with associated changes in depth, velocity and substrate;
- Loss of white water habitat in Birthday Rapids;
- Loss of existing littoral habitat, including areas of macrophyte beds;
- Loss of tributary habitat;
- Deposition of silt over existing sand and hard substrates in deep areas of Gull Lake;
- Creation of new aquatic habitat through the flooding of terrestrial areas;
- A reduction in the range of water level changes in the reservoir but an increase in the frequency;
- At the GS, Gull Rapids will be eliminated and approximately 111.8 ha of riverbed will be dewatered or included in the footprint of the GS structures;
- Changes in water levels and flows and minor changes to substrate will occur in the river reach downstream of the GS; and
- A reduction in ice scour and disturbance of aquatic habitat by ice upstream and downstream of the GS.

3.4.3.3 Summary of Residual Effects

Considering construction and operation, effects to aquatic habitat will be large and long-term, over a medium geographic extent. These residual effects to aquatic habitat will be continuous and irreversible during the lifespan of the Project, and are found in Table 3-10 and Table 3-11.

The technical aquatic habitat assessment is based on models, scientific literature, and information collected from a proxy reservoir (*i.e.*, Stephens Lake) and the overall certainty associated with the predictions is moderate to high depending on the habitat characteristic.

3.4.4 Environmental Monitoring and Follow-up

As described in Chapter 8 of the Keeyask Generation Project: Response to EIS Guidelines, Environmental Monitoring Plans are being developed as part of the Environmental Protection Program for the Project. The intent of the monitoring plans is to determine whether effects of the Project are as predicted and mitigation measures are functioning as intended. The monitoring plans will also provide for follow-up actions if effects are greater than predicted; the actions that would be taken depend on the nature and magnitude of the effect. The design of the monitoring plans will also consider uncertainties identified during the analysis and/or raised by the KCNs or during the regulatory review process. For example, the technical analysis predicts that effects to water quality will occur within the reservoir and downstream but that no effects will occur upstream in Split Lake; based on local knowledge, the KCNs have identified effects to Split Lake and therefore, Split Lake is being included in the monitoring program.

An outline of monitoring planned for the aquatic habitat component of the aquatic environment is provided below. A detailed monitoring plan will be provided in the Aquatic Effects Monitoring Plan. This document will provide a detailed description of the rationale, schedule, sampling locations and sampling methods for the technical monitoring that is proposed for the Project. This plan will be implemented in consultation with regulators, in particular Fisheries and Oceans Canada and Manitoba Conservation and Water Stewardship, and it is expected that it will change based on regulatory review and on-going review of monitoring results. This monitoring plan will be implemented during the construction phase of the Project, and will continue into the operation phase. Reports detailing the outcomes of monitoring programs will be prepared and submitted to regulators, to meet conditions of the Environment Act licence and other authorizations for the Project.

Aquatic habitat monitoring will be conducted to verify modelled predictions for post-Project habitat, which includes development of nearshore and rooted macrophyte habitat in shallow water, as well as the patterns of substrate in deep water that include key habitat for fish VEC species. Conditions at areas of constructed habitat, such as velocity, depth and substrate, will also be monitored in association with the PEMP to confirm the design characteristics are maintained over time. Monitoring will occur annually for the first three years after initial FSL, a three year interval from Year 5–15, and a three to five year interval from Year 15–30, depending on results. A detailed description of the aquatic habitat monitoring is provided in the AEMP.

3.5 REFERENCES

3.5.1 Literature Cited

Cooley, P.M., and Franzin, W.G. 2008. Predicting the spatial mud energy and mud deposition boundary depth in a small boreal reservoir before and after draw down. Lake and Reservoir Management 24(3): 261−272 pp.

Cherepak, B.C. 1990. The post-flood morphometry and bathymetry of Split and Stephens lakes, 1989. MS Report No. 90–08, Manitoba Department of Natural Resources, Winnipeg, MB.

Crowe, J.M.E. 1973. Limnological investigations of Kettle Reservoir and the Nelson River above Kelsey. MS Rep. No. 73-06. Manitoba Department of Mines, Resources and Environment Management, Winnipeg, MB. 34 pp.

BCMOE (British Columbia Ministry of the Environment) and DFO (Department of Fisheries and Oceans). 1989. Fish Habitat Inventory and Information Program, Stream Survey Guide. 33 pp.

Kroeker, K. 1999. Split Lake depth map. TEMA Data Report #99-02. A report prepared for the Tataskweyak Environmental Monitoring Agency by North/South Consultants Inc., Winnipeg, MB. 4 pp.

Larter, J. 2010. Remote sensing of a dynamic sub-arctic peatland reservoir using optical and synthetic aperture radar data. Master's thesis. University of Manitoba, Winnipeg, Manitoba. 212 pp.

Lawrence, M.J., Fazakas, C.R, Zrum, L., Bezte, C., and Bernhardt, W.J. 1999. The Split Lake aquatic ecosystem: a synthesis of Split Lake biological and environmental data, January 1997 to October 1998. A report prepared for the Tataskweyak Environmental Monitoring Agency by North/South Consultants Inc., Winnipeg, MB. 87 pp.

Rowan, D.J., Kalff, J., and Rasmussen, J.B. 1992. Estimating the mud deposition boundary depth in lakes from wave theory. Canadian Journal of Fisheries and Aquatic Sciences 49: 2490−2497 pp.

Schlick, R.O. 1968. A survey of Split Lake in 1966. MS Report No. 68–8, Manitoba Department of Mines and Natural Resources, Winnipeg, MB.

Split Lake Cree - Manitoba Hydro Joint Study Group. 1996a. Analysis of change: Split Lake Cree Post Project Environmental Review. Split Lake Cree - Manitoba Hydro Joint Study Group; vol. 1 of 5.

Split Lake Cree - Manitoba Hydro Joint Study Group. 1996b. History and first order effects: Manitoba Hydro projects - Split Lake Cree Post Project Environmental Review. Split Lake Cree - Manitoba Hydro Joint Study Group; vol. 2 of 5.

Split Lake Cree - Manitoba Hydro Joint Study Group. 1996c. Environmental matrices: Summary of Manitoba Hydro impacts - Split Lake Cree Post Project Environmental Review. Support from William Kennedy Consultants Ltd. & InterGroup Consultants Ltd. Split Lake Cree - Manitoba Hydro Joint Study Group; vol. 3 of 5.

Wentworth, C.K. 1922. A scale of grade and class terms for clastic sediments. Journal of Geology 30: 377-392 pp.

TABLES, FIGURES, MAPS

Table 3-1A: Aquatic habitat classification of lentic water masses. A "lake" or "river" reach describes the predominant characteristic in an area

Classification of Lentic Habitat					
Reach Type	**Water Movement**	**Habitat Zone**	**Water Level Zone**	**Substratum/Vegetation**	
"Lake" or "River"	Lentic	Backwater Inlet	Intermittently Exposed	Cobble/boulder	
				Cobble/boulder/bedrock	
				Cobble/boulder/gravel	
				Gravel	
				Sand	
				Peat	
				Silt/clay	No plants
					Rooted vascular
				Silt	No plants
					Rooted vascular
		Shallow	Intermittently Exposed	Cobble/boulder	
				Cobble/boulder/bedrock	
				Cobble/boulder/gravel	
				Gravel	
				Sand	
				Peat	
				Silt/clay	No plants
					Rooted vascular
				Silt	No plants
					Rooted vascular
			Predominantly Wetted	Cobble/boulder	
				Cobble/boulder/bedrock	
				Cobble/boulder/gravel	
				Gravel	
				Sand	
				Peat	
				Silt/clay	No plants
					Rooted vascular
				Silt	No plants
					Rooted vascular
		Deep	Predominantly Wetted	Cobble/boulder	
				Cobble/boulder/bedrock	
				Cobble/boulder/gravel	
				Gravel	
				Sand	
				Peat	
				Silt/clay	No plants
					Rooted vascular
				Silt	No plants
					Rooted vascular

Table 3-1B: Aquatic habitat classification of lotic water masses. A "lake" or "river" reach describes the predominant characteristic in an area

Classification of Lotic Habitats						
Reach Type	**Water Movement**	**Habitat Zone**	**Water Level Zone**	**Substratum/Vegetation/Water Velocity**		
"Lake" or "River"	Lotic	Shallow	Intermittently Exposed	Cobble/boulder		High, Moderate, Low
				Cobble/boulder/bedrock		High, Moderate, Low
				Cobble/boulder/gravel		High, Moderate, Low
				Gravel		High, Moderate, Low
				Sand		Moderate, Low
				Silt/clay	No plants	High, Moderate, Low
					Rooted vascular	High, Moderate, Low
				Silt	No plants	Low
					Rooted vascular	Low
			Predominantly Wetted	Cobble/boulder		High, Moderate, Low
				Cobble/boulder/bedrock		High, Moderate, Low
				Cobble/boulder/gravel		High, Moderate, Low
				Gravel		High, Moderate, Low
				Sand		Moderate, Low
				Silt/clay	No plants	Low
					Rooted vascular	Low
		Deep	Predominantly Wetted	Cobble/boulder		High, Moderate, Low
				Cobble/boulder/bedrock		High, Moderate, Low
				Cobble/boulder/gravel		High, Moderate, Low
				Gravel		High, Moderate, Low
				Sand		Moderate, Low
				Silt/clay	No plants	High, Moderate, Low
					Rooted vascular	High, Moderate, Low

Table 3-2: Wentworth aggregate material size classification showing the simplified classification of aggregate materials derived for the Keeyask EIS. Note that the substrate is often mixed and habitat classes may contain more than one substrate type (*e.g.,* silt/clay)

Size range (metric)	Wentworth Aggregate Class Name	Keeyask Aggregate Class Name
> 256 mm	Boulder	Boulder
64–256 mm	Cobble	Cobble
32–64 mm	Very coarse gravel	
16–32 mm	Coarse gravel	
8–16 mm	Medium gravel	Gravel
4–8 mm	Fine gravel	
2–4 mm	Very fine gravel	
1–2 mm	Very coarse sand	
0.5–1 mm	Coarse sand	
0.25–0.5 mm	Medium sand	Sand
125–250 µm	Fine sand	
62.5–125 µm	Very fine sand	
3.90625–62.5 µm	Silt	Silt
< 3.90625 µm	Clay	Clay
< 1 µm	Colloid	

Table 3-3: Average area, total area, and count of the macrophyte stands observed in reaches 5–8 during sampling in 2001, 2003, and 2006

Macrophyte Sample Year	Average Area (Ha)	Total Area (Ha)	Count
2001	3.4	359.0	105
2003	11.3	282.7	25
2006	1.8	146.4	83

Table 3-4: Area and percent statistics for each year of study that show the area occupied by macrophytes, the area of suitable habitat for macrophyte growth (in the same year), and the potential area of suitable habitat (among years) for reaches 5–8

Year	Area Occupied (Ha)	Area of Suitable Habitat (Ha)	Suitable Habitat Occupied (%)	Potential Habitat (Ha)	Potential Habitat Occupied (%)
2001	359.0	1075.0	33.4	1168.4	30.7
2003	282.7	749.4	37.7	1168.4	24.2
2006	146.4	1075.0	13.6	1168.4	12.5

Table 3-5: Frequency of substratum types sampled at each location where macrophytes were either present or absent in Stephens Lake during 2005 and 2006

Species	Substrate									
	Detritus	Gravel	O_f[1]	O_h	O_m	Organic Deposition	Silt-based[2]	Clay-based[3]	Sand-based[4]	Total
Absent	51	1	47	3	11	9	11	38	14	185
Myriophyllum sibiricum	0	0	0	0	0	68	0	14	0	82
Potamogeton richardsonii	2	0	0	0	0	27	2	161	11	203
Other	1	0	0	0	0	20	1	24	8	54
Total	**54**	**1**	**47**	**3**	**11**	**124**	**14**	**237**	**33**	**524**

1. O_f, O_m, and O_h are organic material derived from pre-flood peatlands in a fibric, mesic, or humic state, respectively.
2. Silt-based substrates are silt or primarily silt with a fraction of sand.
3. Clay-based substrates are clay or primarily clay with a fraction of silt or sand.
4. Sand-based substrates are sand or primarily sand with a fraction of silt.

Table 3-6: Area of aquatic habitat alteration, temporary disruption, and loss for Stage I and Stage II of the construction period. Note that areas within each stage do not overlap. Units are hectares

Stage	Type	Dewatered	Infrastructure				Total
			Altered (permanently flooded)	Temporary Disruption	Loss	Total	Dewatered
Stage 1	Infrastructure		12.3	13.3	5.0	30.6	
	Dewatered Area	100.9					131.5
Stage 2	Infrastructure		11.2	11.4	6.6	29.2	
	Dewatered Area	94.7					123.9

Table 3-7: Area (hectares) of habitat altered, flooded, lost, and dewatered habitat for initial flooding time step according to the hydraulic zone of influence, as defined by 95th percentile inflows and 159 m ASL reservoir stage for the post-Project. The area that is dewatered in Reach 9B is not well known. Flooded area includes pre-flood water bodies

Reach	2B	3	4	5	6	7	8	9	9B	10	11	12	Grand Total
Altered habitat	198.1	268.5	307	750.4	1832.0	709.3	466.8	290.1	86.5	-	122.0	-	5030.7
Flooded habitat	1.4	5.5	21.1	222.3	2308.6	675.6	752.4	462.9	-	-	-	-	4449.8
Loss of habitat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.4	-	-	-	10.4
Dewatered habitat	-	-	-	-	-	-	-	-	101.4	-	-	-	101.4
Total	**199.5**	**274.0**	**328.1**	**972.7**	**4140.6**	**1384.9**	**1219.2**	**753.0**	**198.3**	**-**	**599.6**	**-**	**9592.3**

Table 3-8: Average depth (m) of the intermittently exposed zone (IEZ) for the existing environment (EE) and post-Project (PP) and average depth of flooding (m) for Reaches 2B–12 in the Keeyask area, as defined by 95th percentile inflows and 159 m above sea level reservoir stage for the post-Project. The IEZ in Reach 9B is not known. The water level variation in reaches 11 and 12 is described in the PE SV, Section 4

Reach	2B	3	4	5	6	7	8	9A
IEZ EE	1.76	1.90	2.09	1.97	1.62	1.41	1.43	0.99
IEZ Post-Project	1.84	1.92	1.57	1.25	1.07	1.04	1.04	1.01
Depth of Flooding	0.28	0.46	2.32	3.96	5.49	5.89	5.84	10.08

Table 3-9: Affected area of Gull Rapids Creek, Portage Creek, and Two Goose Creek in the Keeyask area for the Post-Project. Note that the Backwater Inlet Habitat Type is the area of creek that was backwatered during a low water period in the Nelson River at time of survey. When the Nelson River is at high water, the Backwater Inlet occupies all of the Intermittently Exposed Zone (IEZ). EE = existing environment. PP = post project

Stream	Habitat Zone	Habitat Type	Affected Area (m^2)	% of Affected Creek
Gull Rapids Creek	EE IEZ	Backwater Inlet	109.4	48.7
		Riffle	2.9	1.3
		Run	112.5	50.1
		Total	**224.8**	**100.0**
Portage Creek	EE IEZ	Backwater Inlet	1,808.7	20.7
		Run	120.4	1.4
	EE IEZ - PP IEZ	Pool	2,029.4	23.2
		Riffle	470.3	5.4
		Run	3,650.3	41.8
	PP IEZ	Riffle	86.1	1.0
		Run	569.9	6.5
		Total	**8,735.1**	**100.0**
Two Goose Creek	EE IEZ	Backwater Inlet	8,872.1	95.7
		Pool	139.4	1.5
	EE IEZ - PP IEZ	Pool	114.7	1.2
		Riffle	25.7	0.3
		Run	98.7	1.1
	PP IEZ	Run	22.9	0.2
		Total	**9,273.4**	**100.0**
		Total Affected Area	**18,233.4**	

Table 3-10: Residual effects on aquatic habitat: construction period

Environmental Effect	Mitigation/Enhancement	Residual Effect
Keeyask Area (including Reach 12 of Stephens Lake).		
Installation of instream structures such as cofferdams will change water levels and flows within and upstream of Gull Rapids, resulting in the loss of habitat in the north and middle channels of Gull Rapids in Stage I of construction and loss of remaining habitat in the south channel in Stage II. A thin layer of sediment will deposit in the river and Stephens Lake, but change in substrate composition is not expected to occur.	Footprint of infrastructure and dewatering cannot be mitigated for habitat loss.	Large magnitude, small extent, and medium-term for sediments. Long-term for permanent instream structures.

Table 3-11: Residual effects on aquatic habitat: operation period

Environmental Effect	Mitigation/Enhancement	Residual Effect
Split Lake Area		
No effect	Project design to avoid water level effects to Split Lake.	None
Keeyask Area		
The riverine habitat from downstream of the outlet of Clark Lake to upstream of Birthday Rapids (reaches 2B–3) will be slightly altered due to a relatively small increase in depth, decrease in velocity, and localized areas of bank changes. The area from Birthday Rapids to Gull Lake (reaches 2B–5) will remain as riverine habitat but would be altered due to a notable increase in depth, decrease in velocity, a change from white water to turbulent habitat in the Birthday Rapids area, and changes in river bank composition. Lower reaches of creek habitat will be inundated. Flooding in the area of Gull Lake to Keeyask GS (Reaches 6–9A) incurs a loss of existing shallow habitats, creation of flooded terrestrial habitat, partial or complete flooding of creeks, flooding of most of Gull Rapids, and destruction of habitat at Gull Rapids located under principal GS structures. Over time, discontinuous deposits of silt will form on existing cobble/gravel/sand substrates in main river channel areas of Gull Lake. Continuous deposits of silt will settle and cover most flooded terrestrial areas; new littoral habitats will evolve in shallow water < 3 m water depth. Over time, rooted aquatic vegetation will establish in some shallow areas.	Selection of 159 m reservoir elevation reduced proportion of newly flooded area in reservoir. Selection of a 1 m draw down range reduced the area of the IEZ. Habitat creation for fish, including lake sturgeon, is discussed in Section 5.0 and Section 6.0.	Large, medium extent, and long-term effects for the reach as a whole, though effects are small above Birthday Rapids.

Table 3-11: Residual effects on aquatic habitat: operation period

Environmental Effect	Mitigation/Enhancement	Residual Effect
Within the reservoir, the total range of water level variation will be reduced to 1 m, reducing the depth range within the intermittently exposed zone (IEZ). However, under a peaking scenario, the IEZ will be dewatered on a daily or weekly basis, in contrast to the existing environment, where changes in water level occur much more slowly. A more stable ice cover is expected to form which would decrease winter ice scour in shallow areas.		
Downstream of GS/Stephens Lake Area Gull Rapids downstream of the GS will be dewatered (south channel) or converted into a tailrace channel, eliminating these areas as productive fish habitat. Dewatering of Gull Rapids also removes a defined channel for Gull Rapids Creek to flow in, disconnecting the creek from the Nelson River. A portion of the south channel will be wetted during operation of the spillway, but this area is not expected to provide productive fish habitat. The distribution of water velocity within the 4 km of the river downstream of the station will be changed. Further downstream into Stephens Lake, a thin layer of sediment deposited during the construction period will overlie some of the existing similar substrate.	Habitat creation for fish, including lake sturgeon, is discussed in Section 5.0 and Section 6.0.	Large, medium extent, and long-term effects.

Table 3-11: Residual effects on aquatic habitat: operation period

Environmental Effect	Mitigation/Enhancement	Residual Effect
An ice dam will no longer form at the inlet of Stephens Lake and the more stable ice cover is expected to reduce ice scour in shallow areas. In the absence of an ice dam, the distribution of water velocity under ice is expected to change. In the long term, the change in water velocity during winter may result in changes from predominantly coarser to finer substrates in some areas, including sections along the south and north river banks. Sediments deposited during construction are expected to be redistributed according to particle size after high flow events.		
North and south access road stream crossings There will be a loss of aquatic habitat within the footprint of the culvert(s) at the four streams where culvert crossings are installed.	Use of clear span bridge on Looking Back Creek avoids effects to instream habitat; placement of culverts as per Manitoba Stream Crossing Guidelines to avoid changes to upstream and downstream stream channels.	Large, small extent, long-term site specific at culverts. Negligible effect to habitat in stream as a whole.

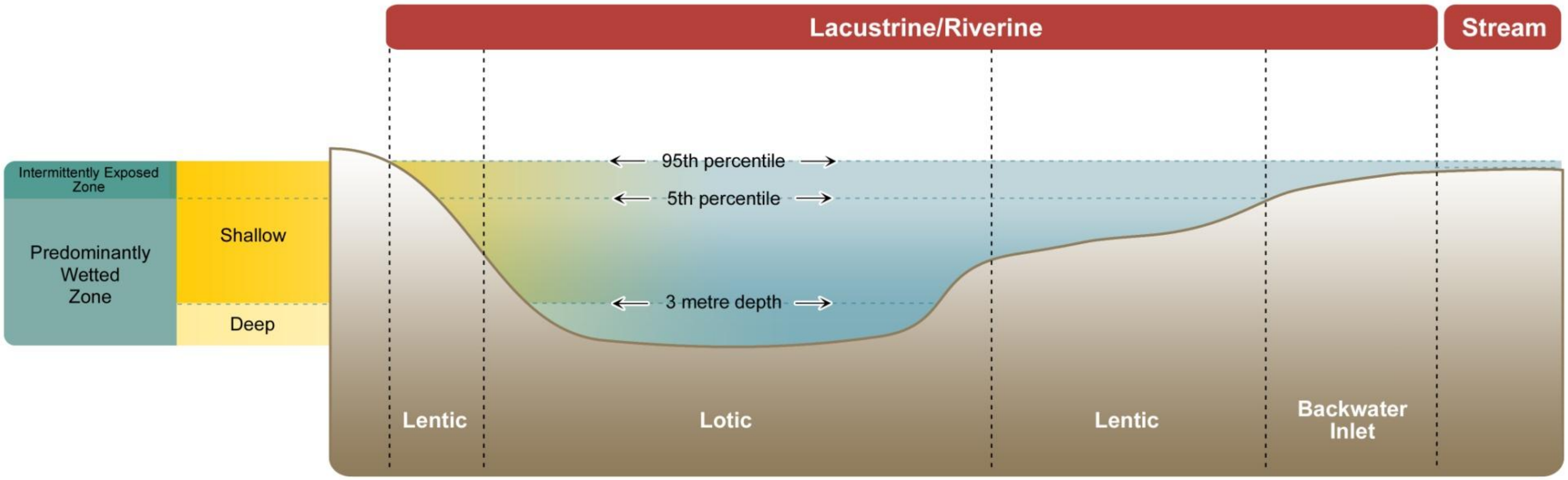


Figure 3-1: Schematic diagram showing the breakdown of aquatic habitat into a series of habitat variables

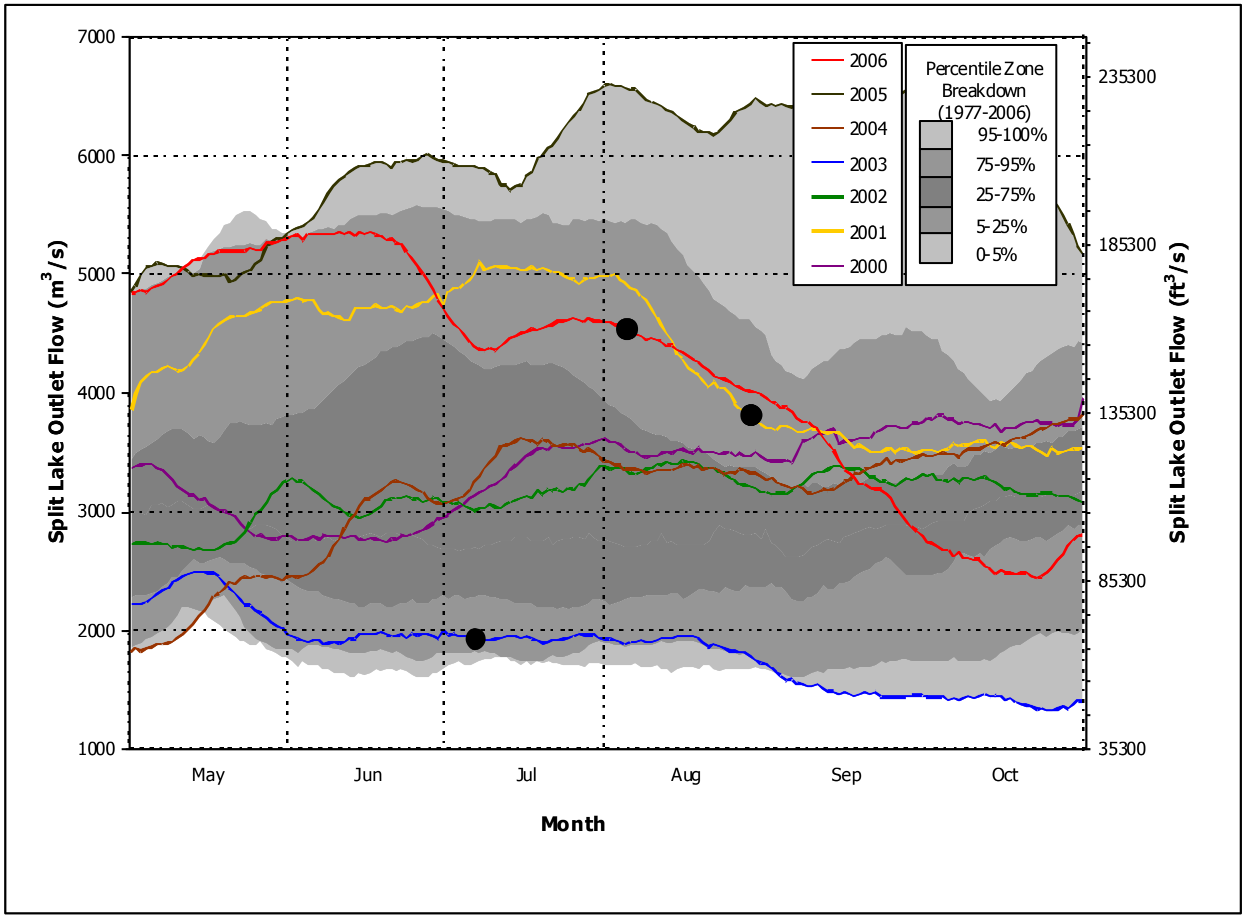


Figure 3-2: Split Lake outlet discharge from 2000–2006. The black circles indicate the time of the macrophyte surveys in the Keeyask area. Discharge data are adapted from PE SV, Section 4

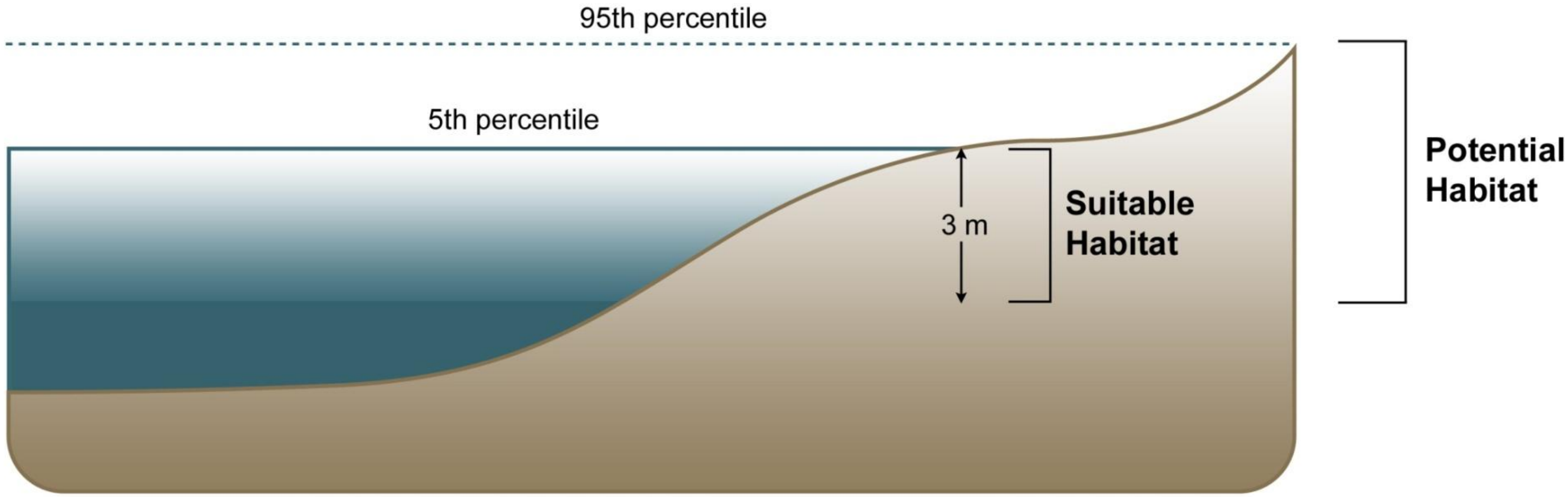


Figure 3-3: The relationship of inflow, water surface elevation and macrophyte habitat. This 5th percentile (low flow) scenario shows that suitable habitat extends from the 5th percentile water surface elevation to 3 m depth (which is the approximate maximum penetration of light) in the permanently wetted zone

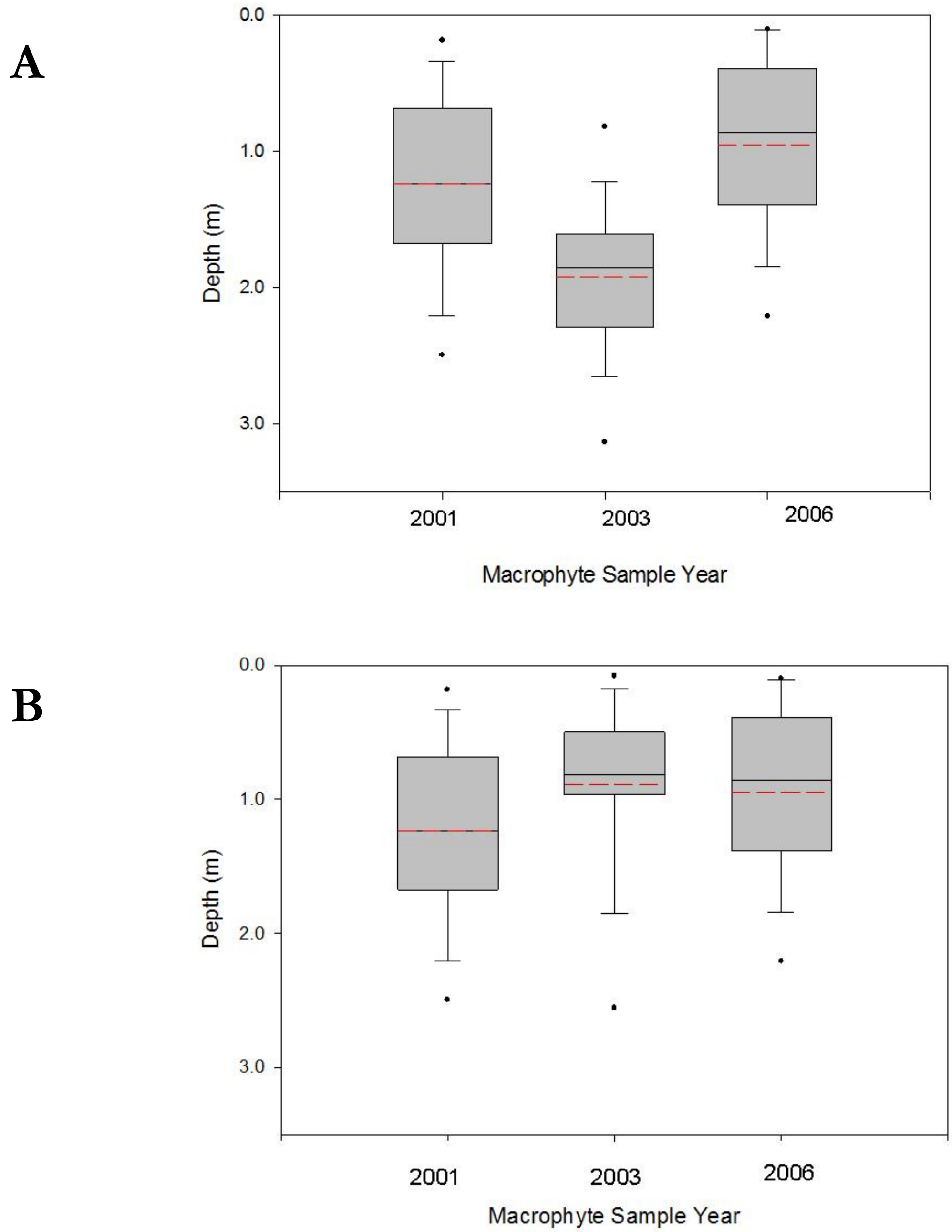


Figure 3-4: Depths of macrophyte beds observed in 2001, 2003, and 2006 when compared to depths relative to the 95th percentile (A), and when the 2003 depths were adjusted to the 5th percentile (B)

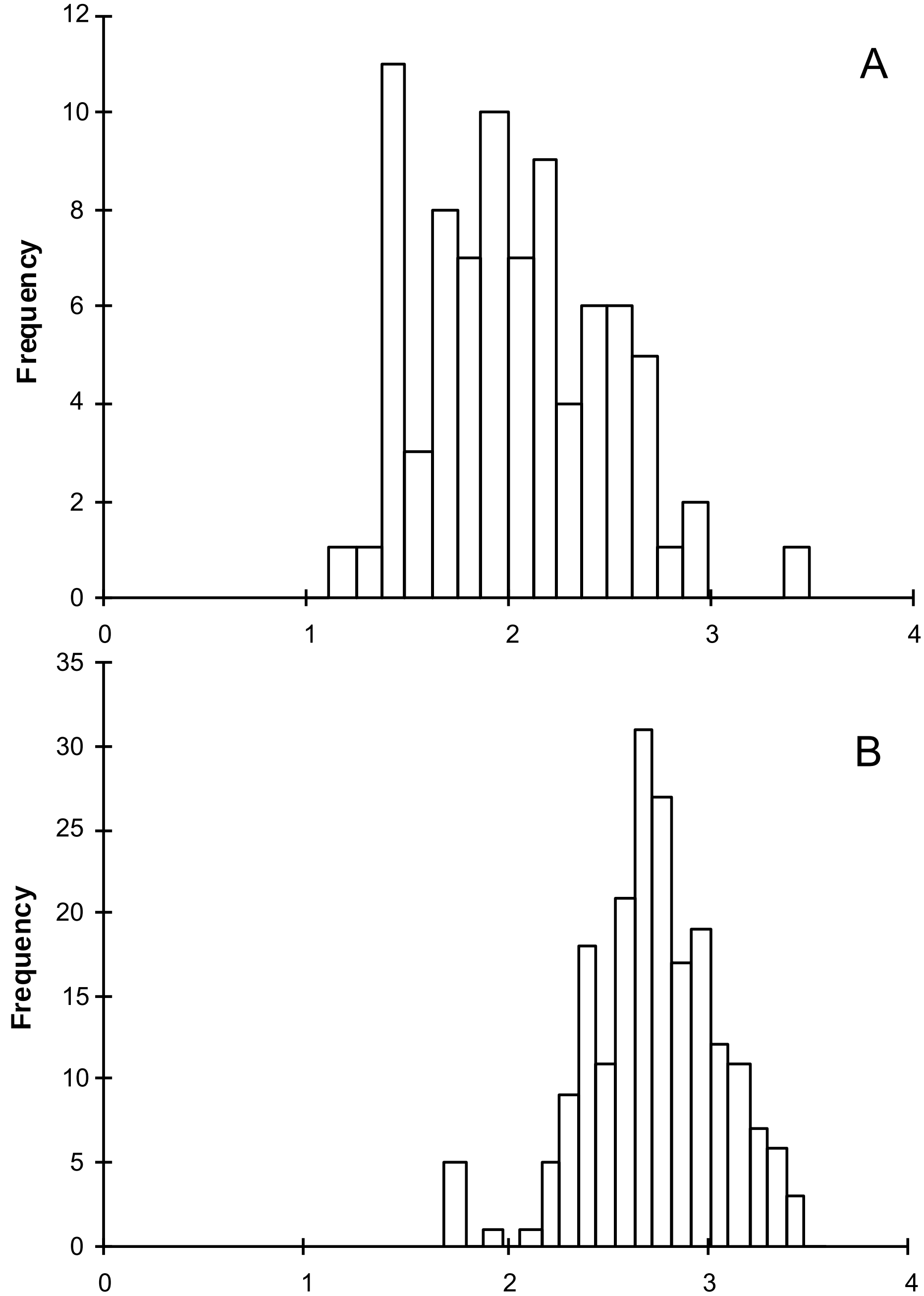


Figure 3-5: Frequency vs. water depth histogram of *Myriophyllum sibiricum* (A), *Potamogeton richardsonii* (B) in Stephens Lake. Water depth has been standardized to the 95th water level percentile

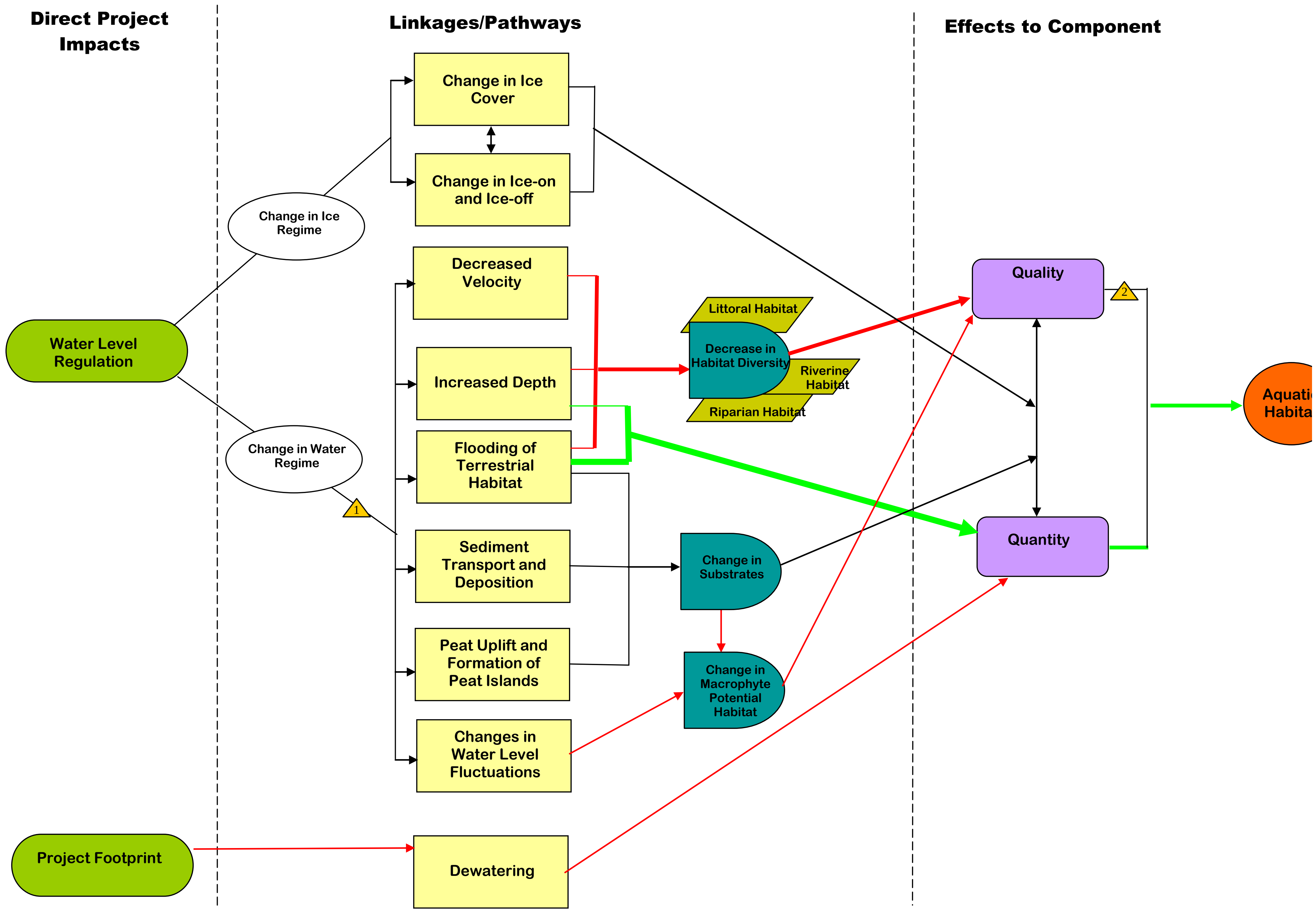
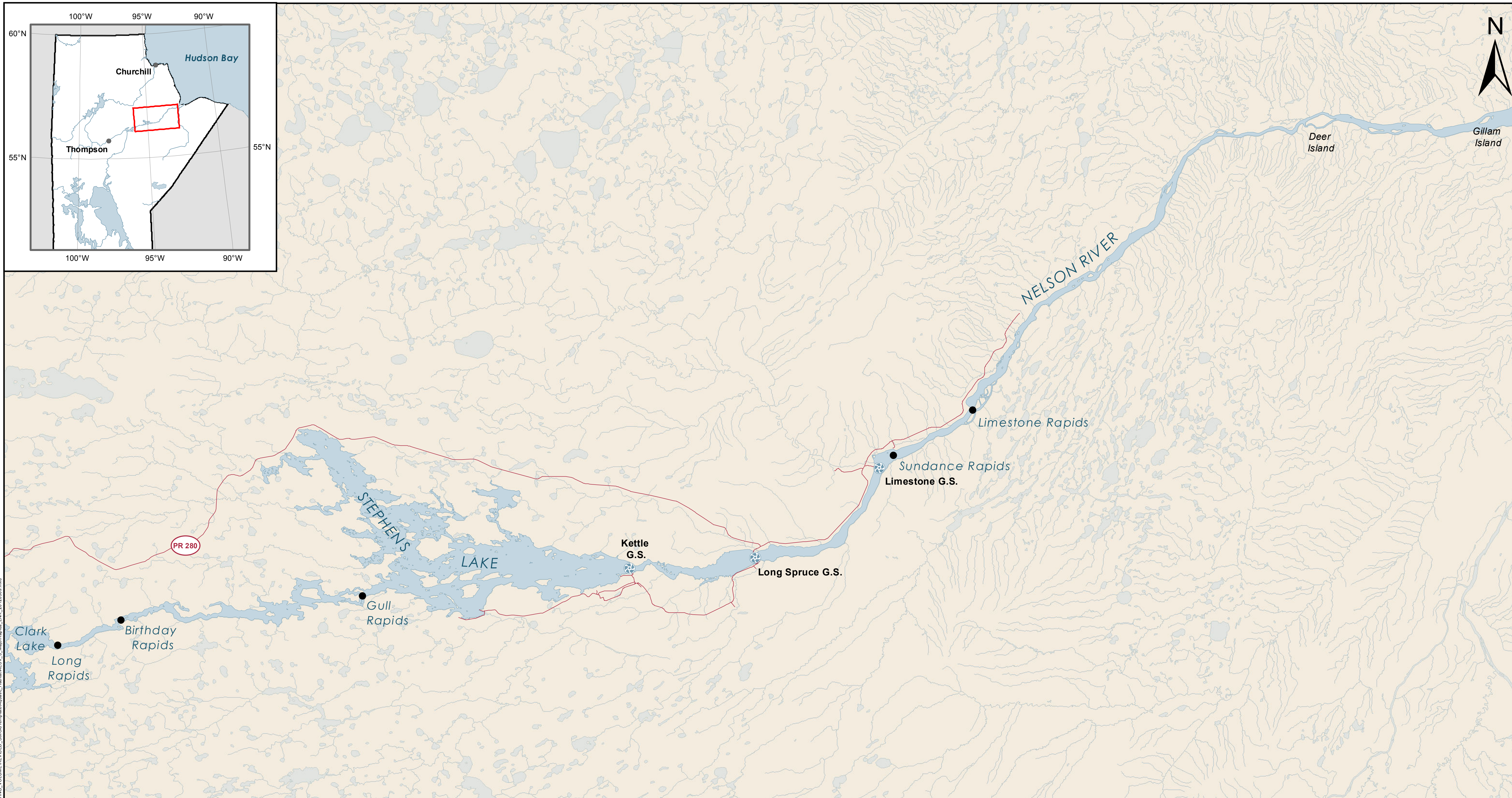


Figure 3-6: Pathways of change to aquatic habitat (arrows: green = positive effect; red = negative effect; black = neutral effect; thicker lines indicate greater magnitude of effect; triangles represent mitigation: 1 = selection of 159 m reservoir elevation and 1 m operating regime; 2 = habitat structure in reservoir and downstream)

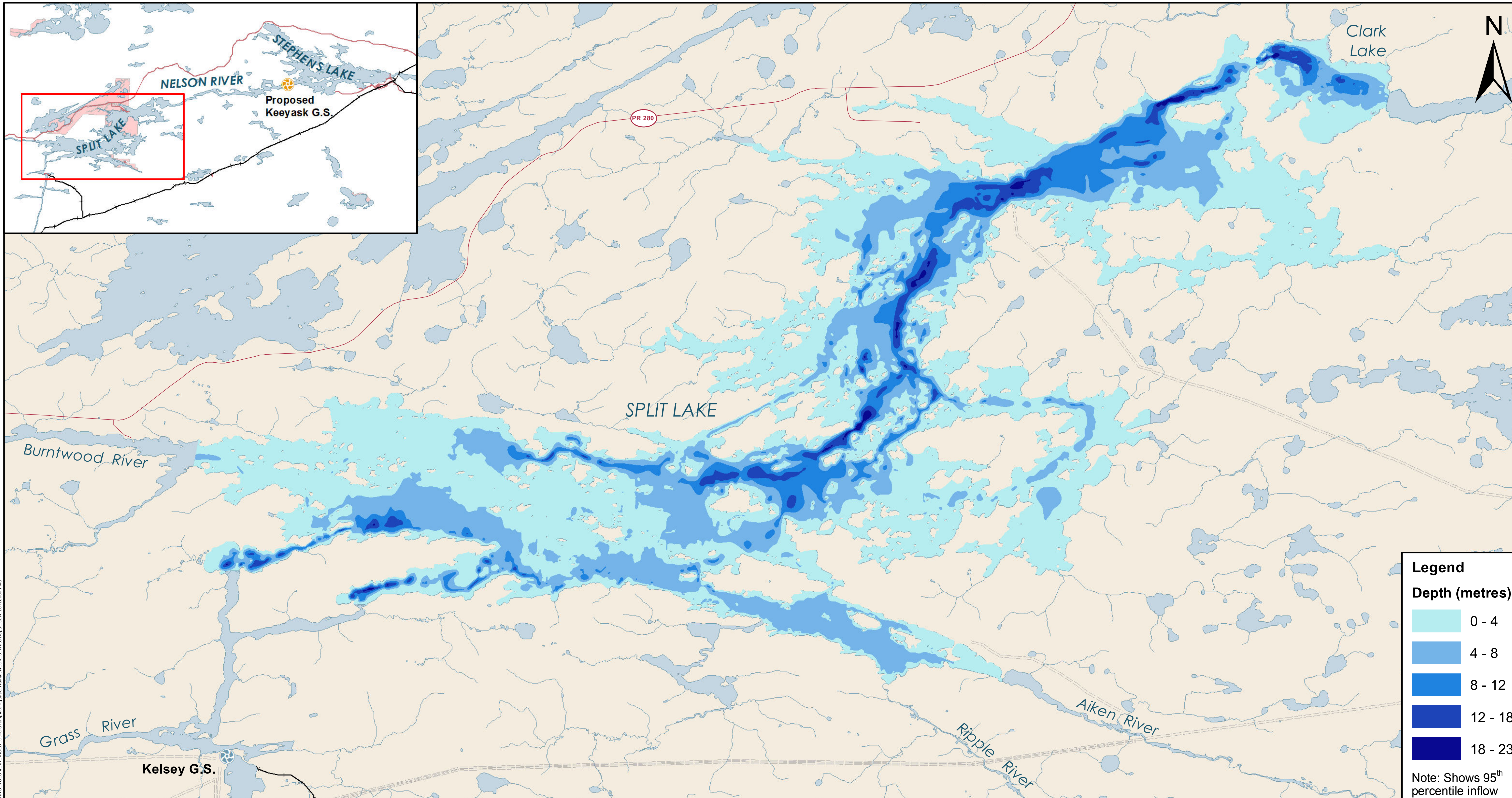


KEEYASK
Hydropower Limited Partnership

0 10 20 30 Kilometres
0 5 10 15 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:250 000

Major Rapids
Lower Nelson River

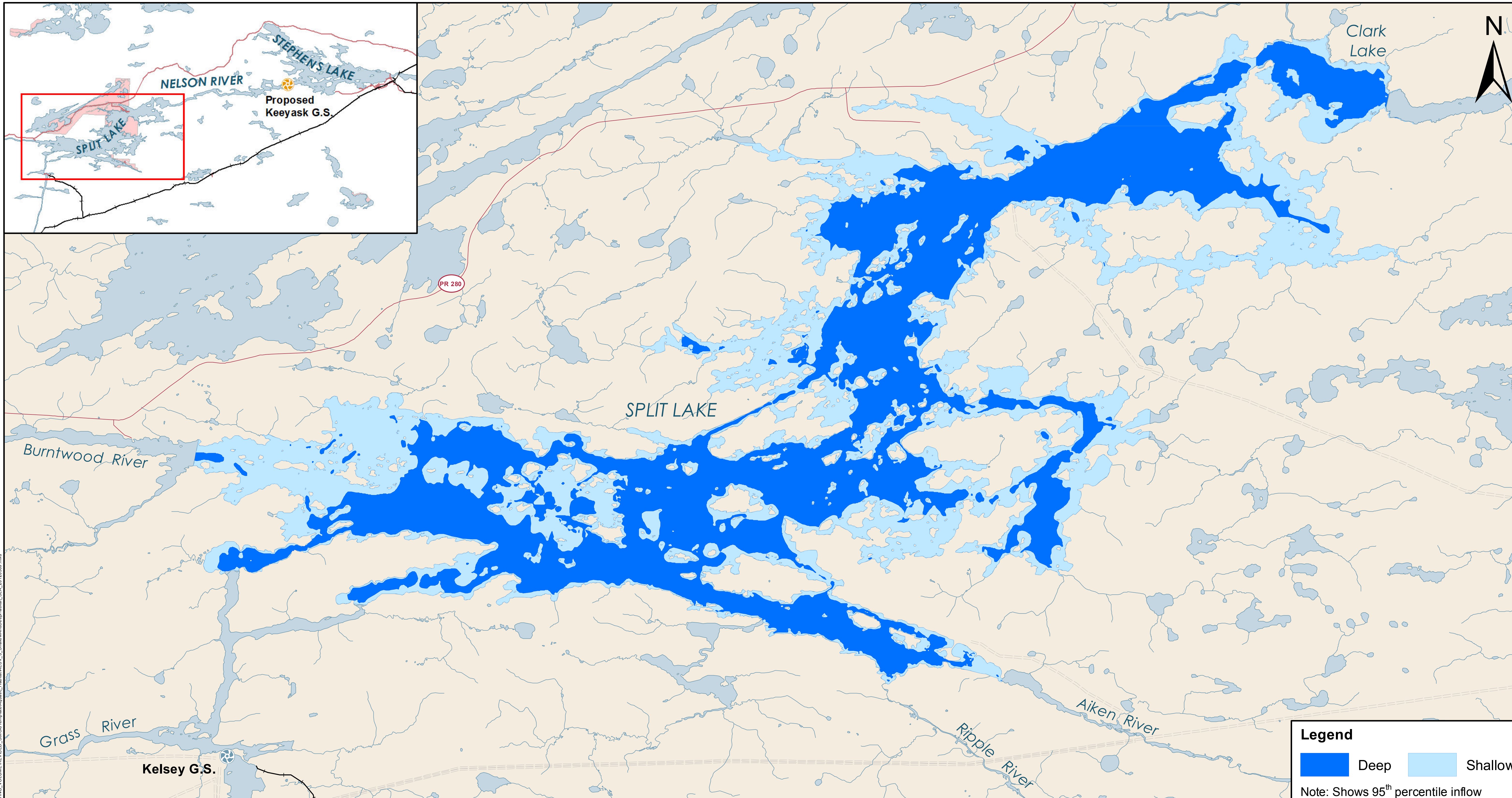


KEEYASK
Hydropower Limited Partnership

0 5 10 Kilometres
0 2.5 5 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000

Water Depth
Split Lake Area

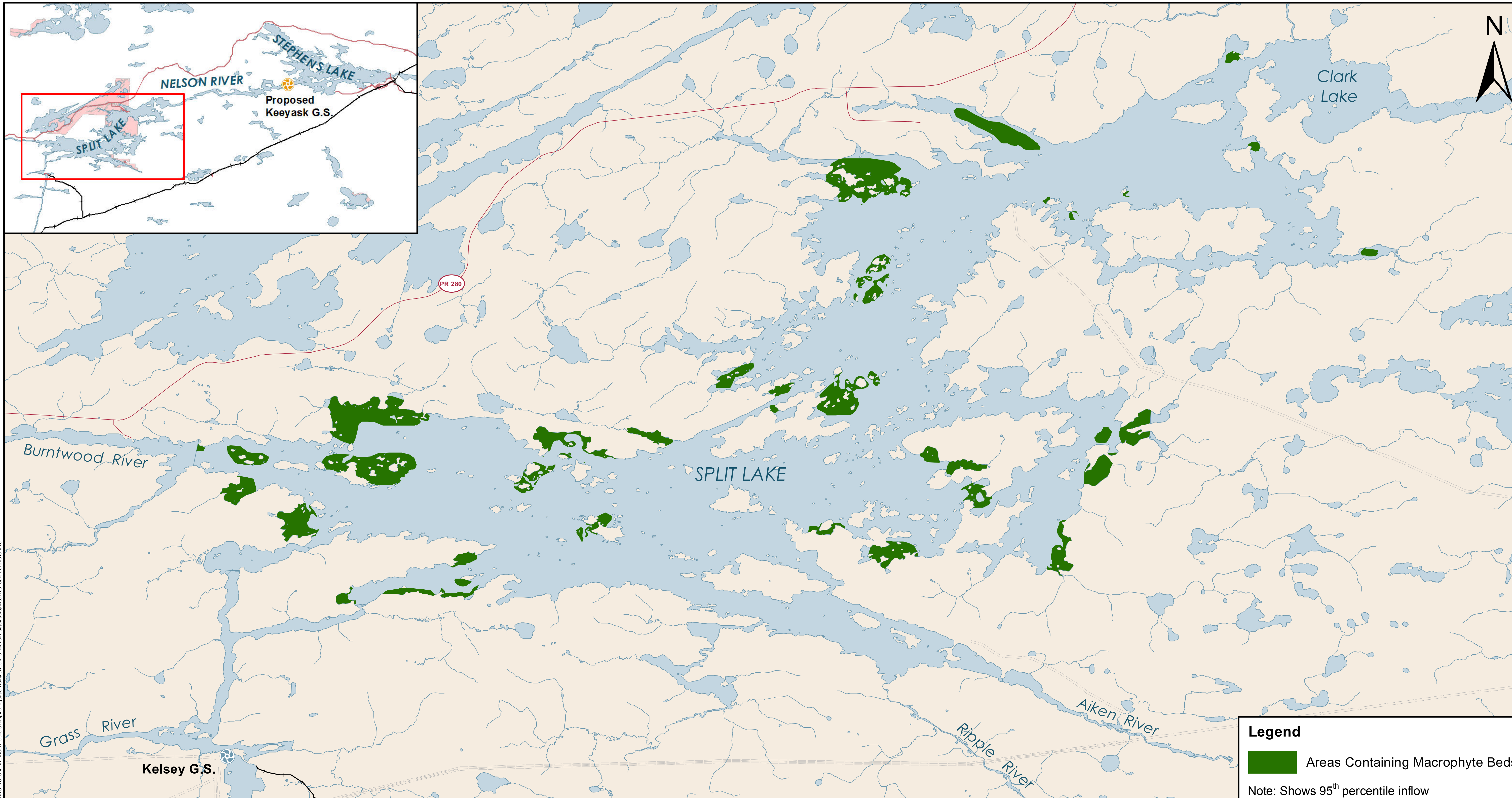


KEEYASK
Hydropower Limited Partnership

0 5 10 Kilometres
0 2.5 5 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000

Shallow and Deep Habitat
Split Lake Area

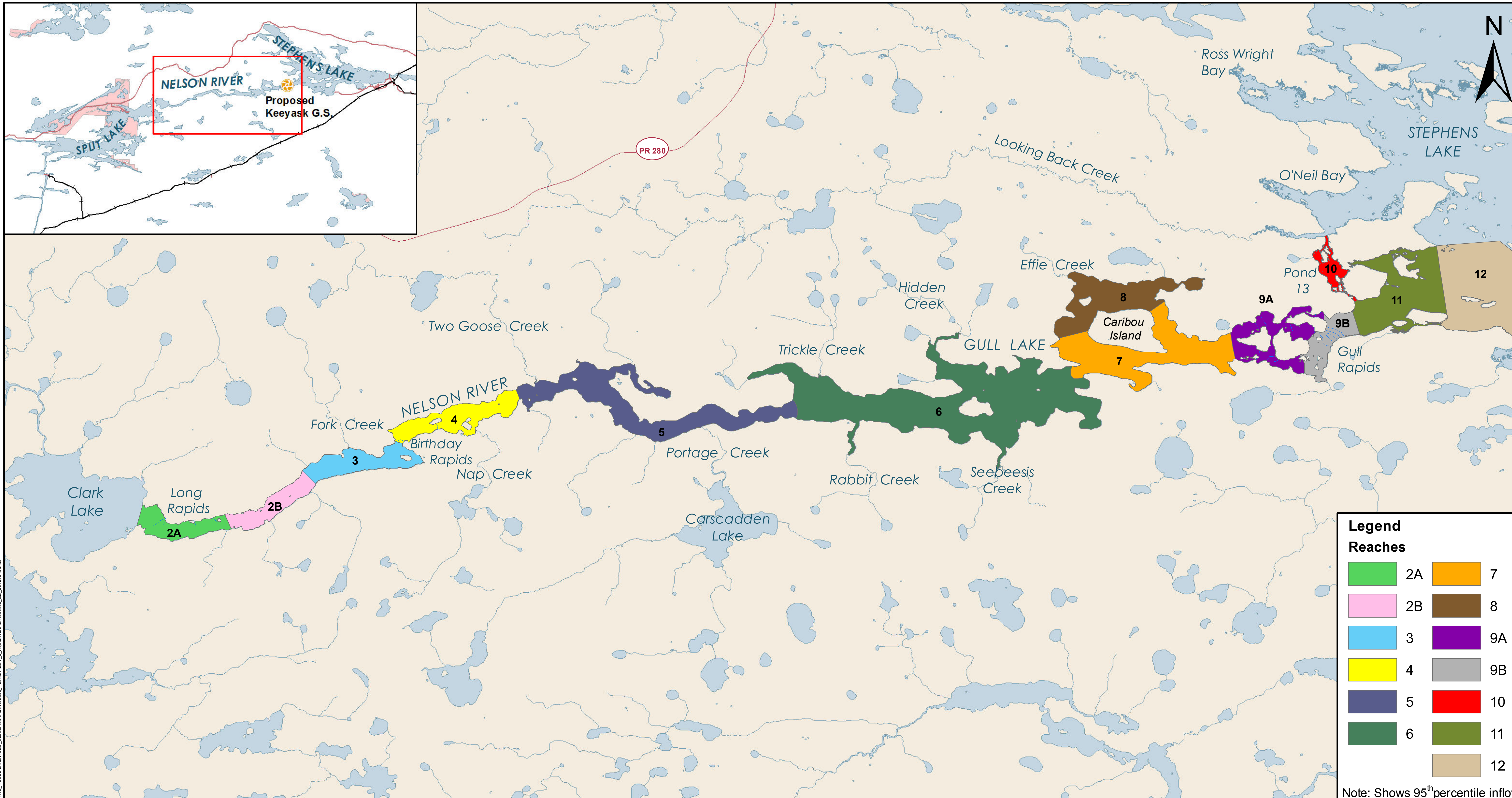


KEEYASK Hydropower Limited Partnership

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000

Areas of Large Macrophyte Beds

Split Lake Area



KEEYASK Hydropower Limited Partnership

0 2.5 5 7.5 10 Kilometres

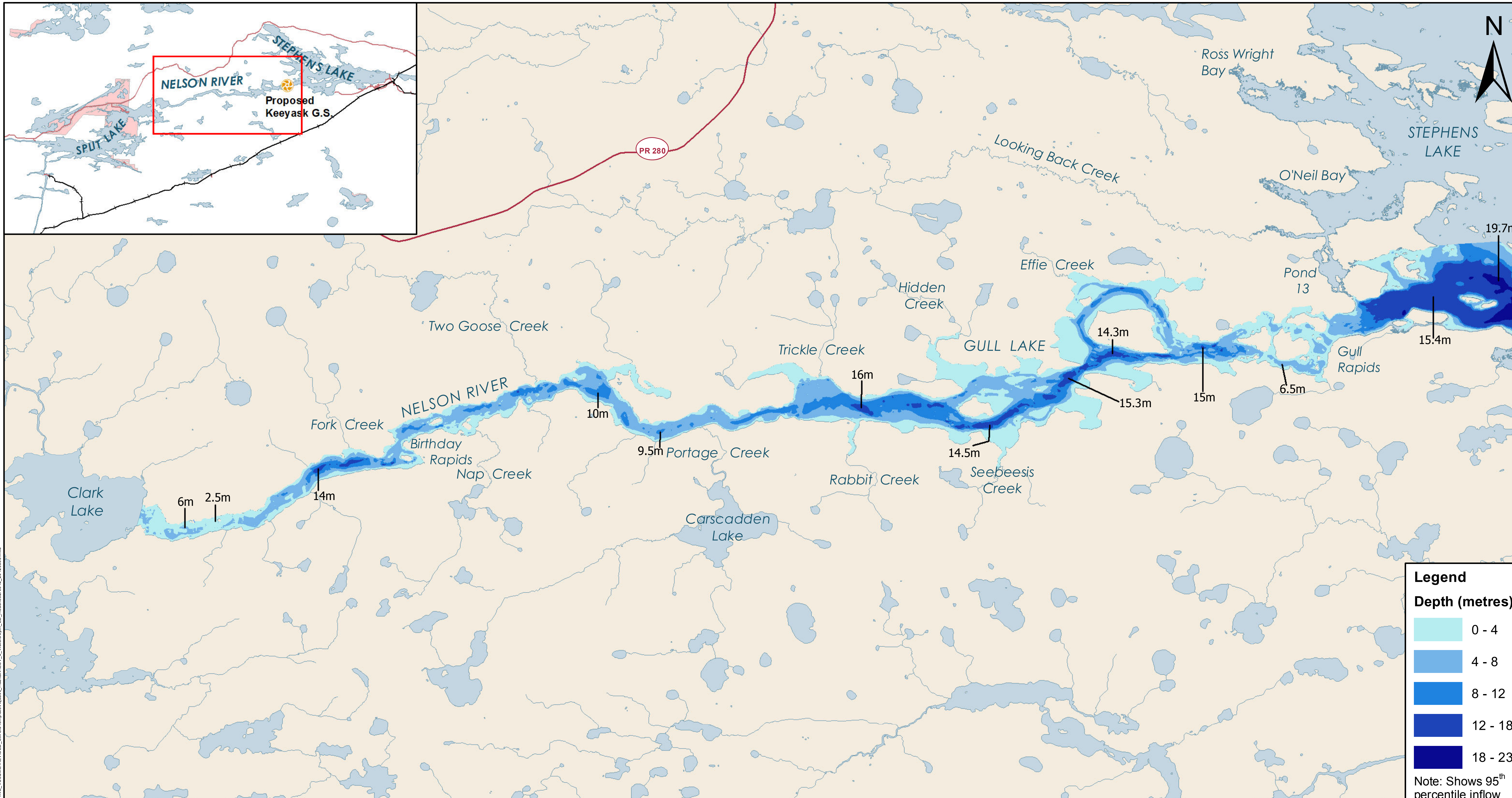
0 1.25 2.5 3.75 5 Miles

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

Aquatic Habitat Reaches

Existing Environment

Map 3-5

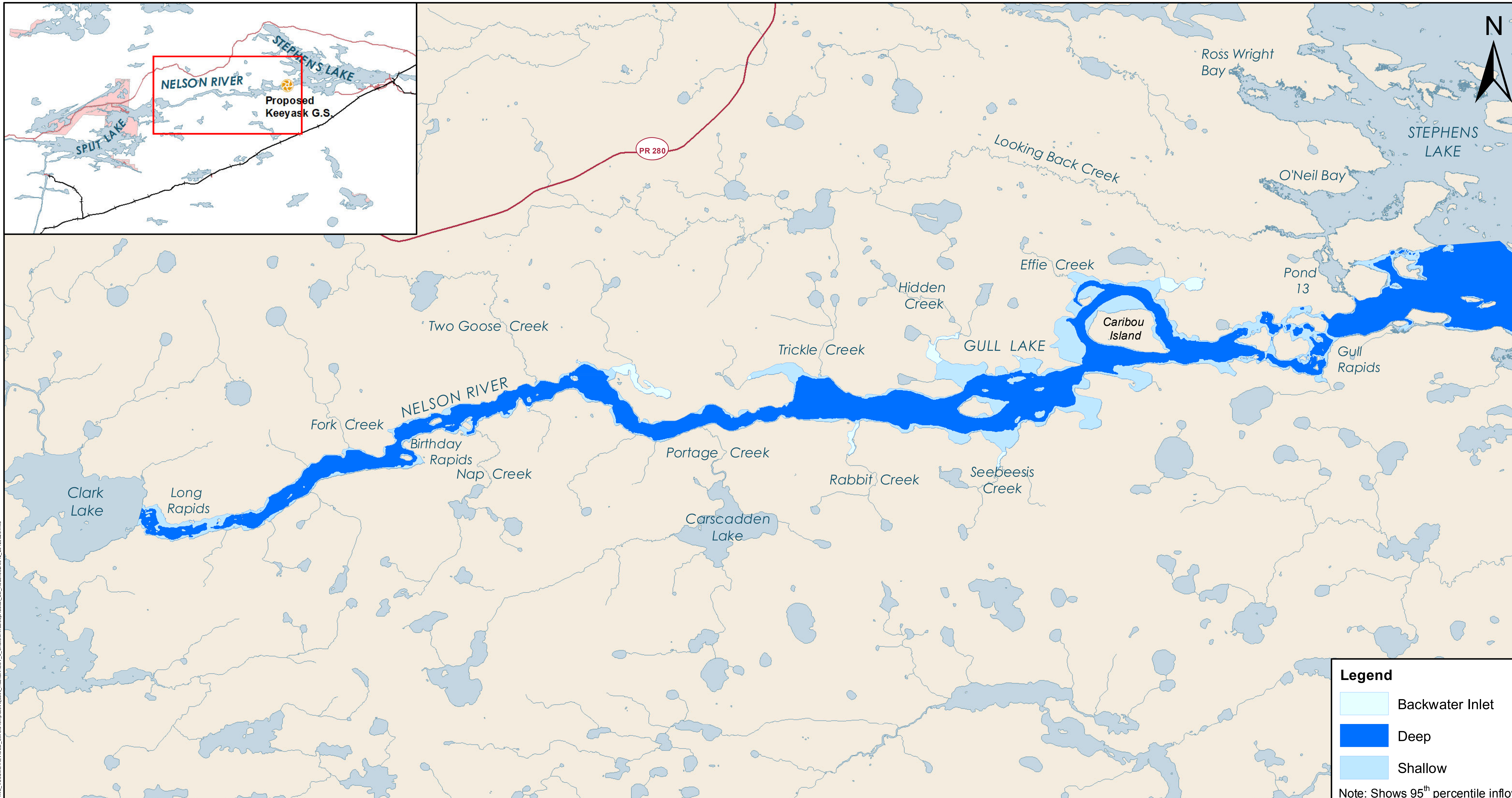


0 2.5 5 7.5 10 Kilometres
0 1.25 2.5 3.75 5 Miles

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

Water Depth

Existing Environment - Reaches 2A to 12



KEEYASK Hydropower Limited Partnership

0 2.5 5 7.5 10 Kilometres

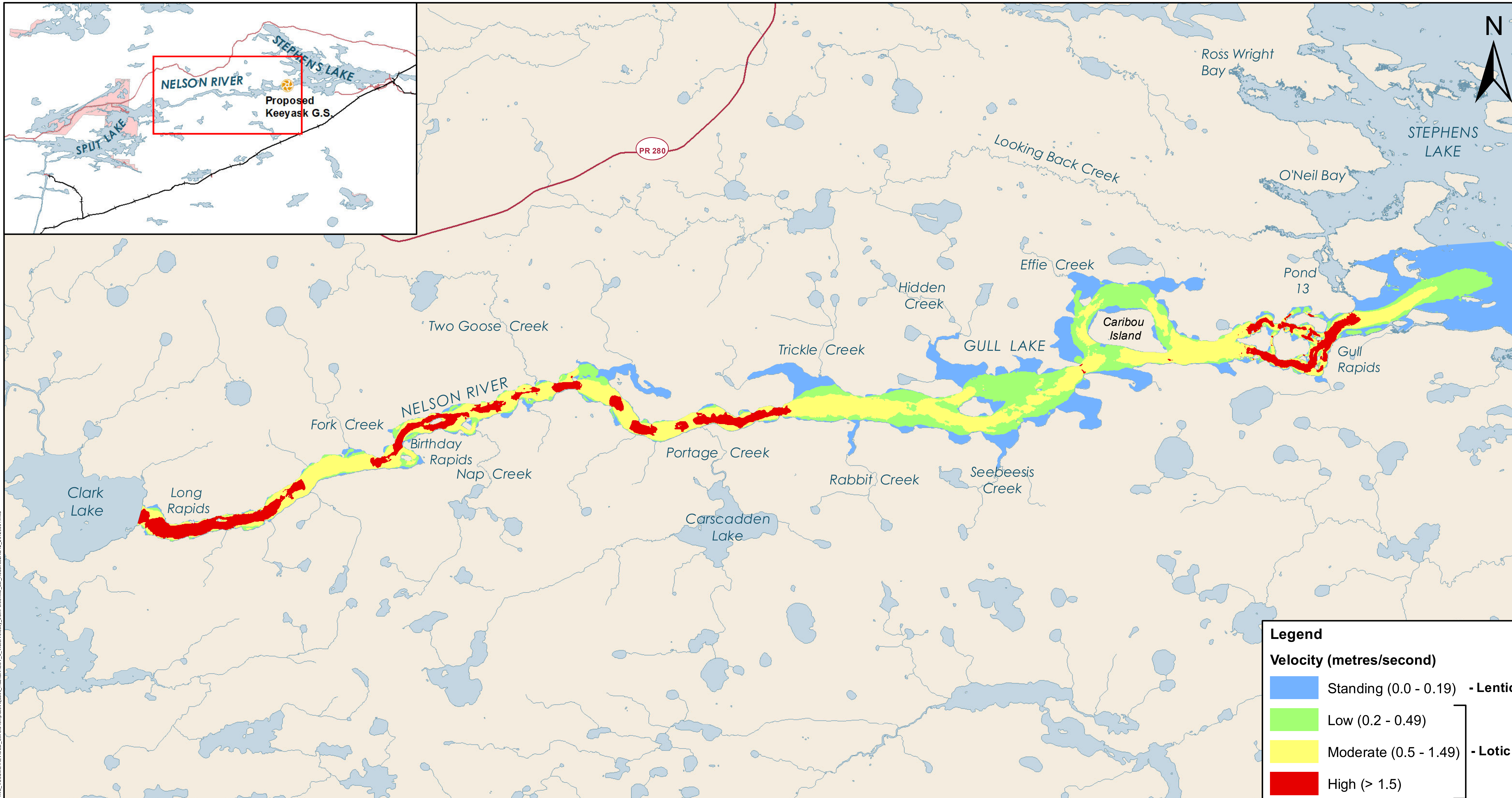
0 1.25 2.5 3.75 5 Miles

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

Shallow and Deep Habitat

Existing Environment - Reaches 2A to 12

Map 3-7



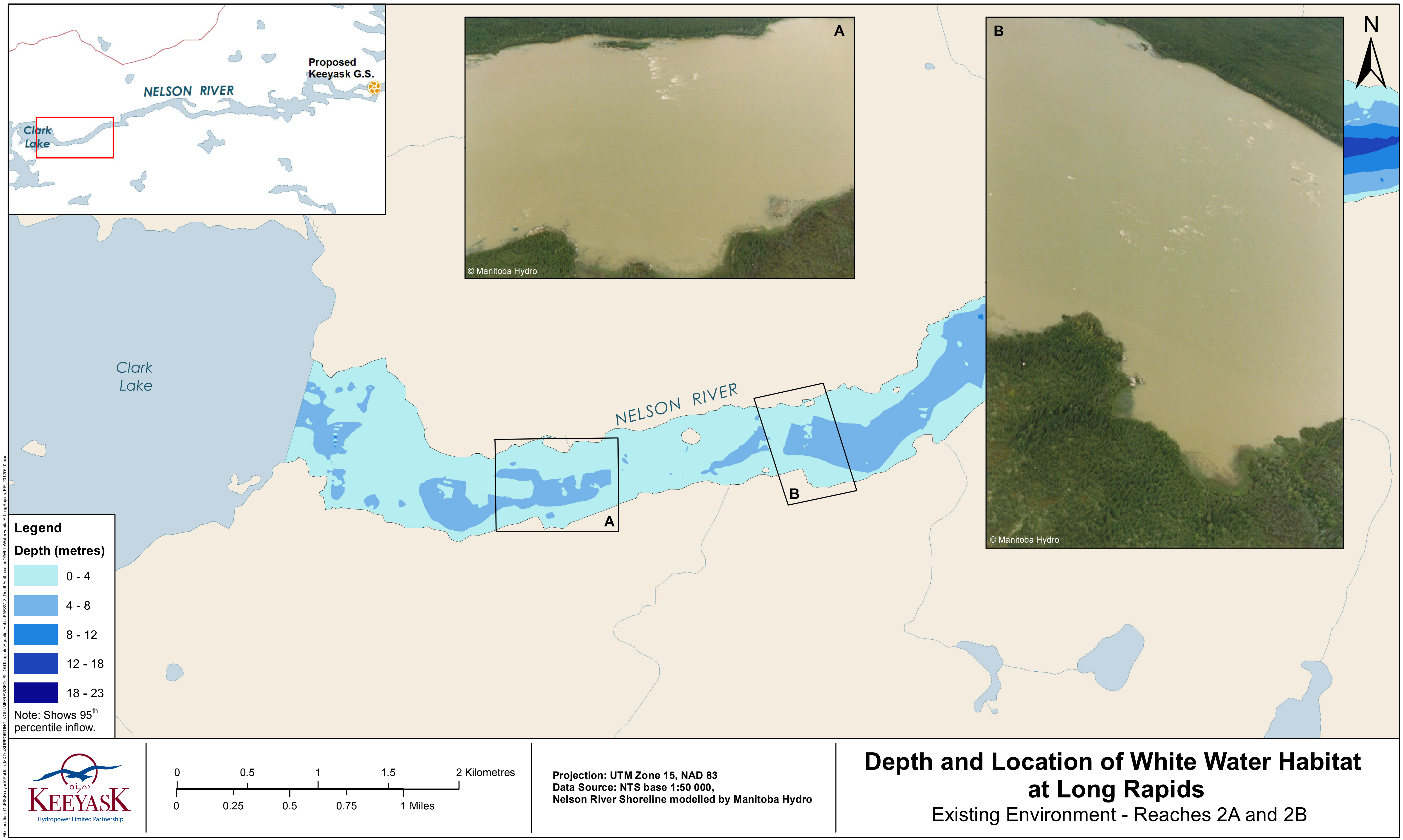
KEEYASK
Hydropower Limited Partnership

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

Water Velocity at 95th Percentile Inflow

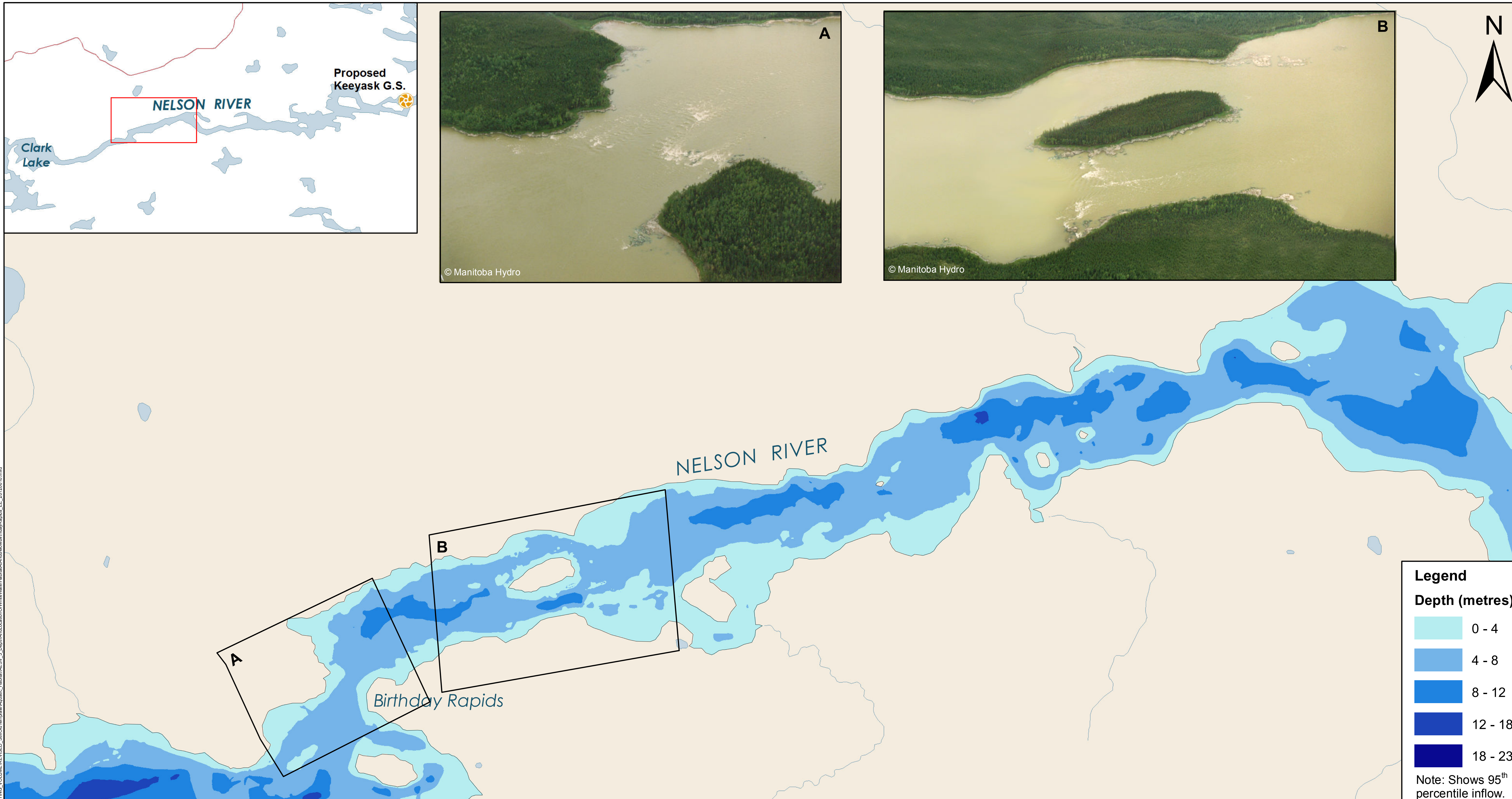
Existing Environment - Reaches 2A to 12



Depth and Location of White Water Habitat at Long Rapids

Existing Environment - Reaches 2A and 2B

Map 3-9



Keeyask Hydropower Limited Partnership

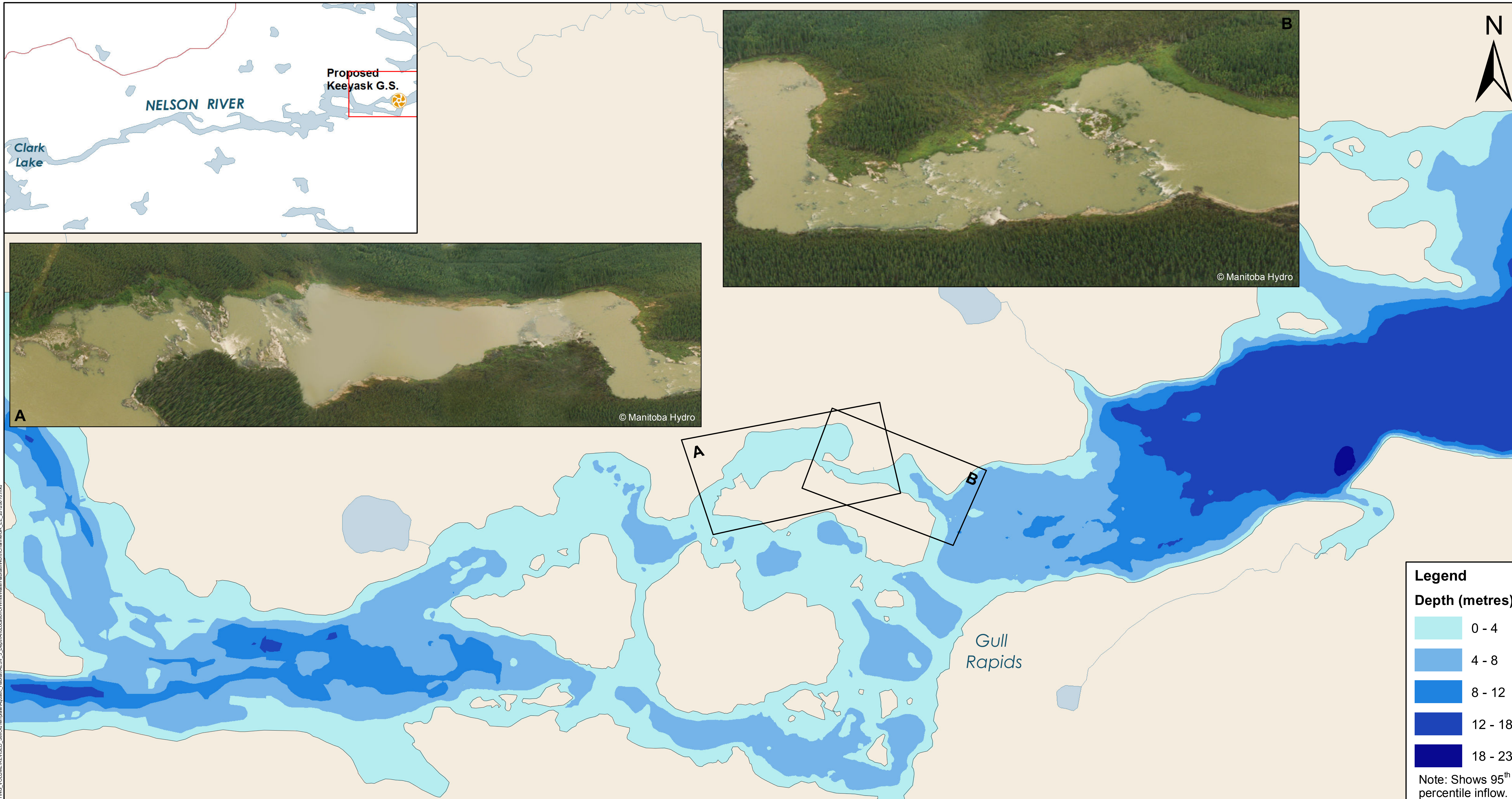
0 1 2 Kilometres
0 0.5 1 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000,
Nelson River Shoreline modelled by Manitoba Hydro

Depth and Location of White Water Habitat at and Below Birthday Rapids

Existing Environment - Reaches 3 and 4

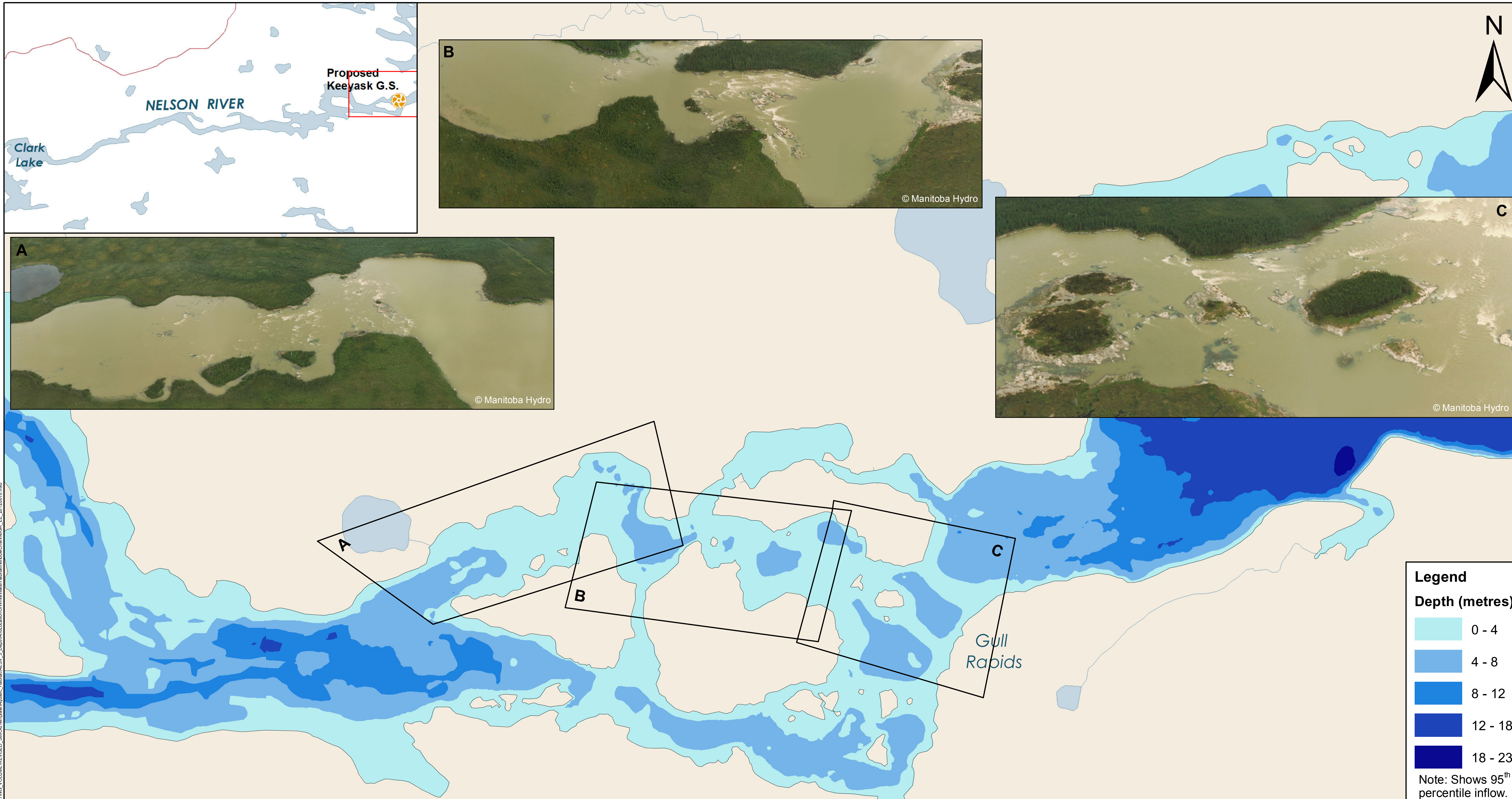
Map 3-10



Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000,
Nelson River Shoreline modelled by Manitoba Hydro

Depth and Location of White Water Habitat in the North Channel of Gull Rapids

Existing Environment - Reaches 9A and 9B



KEEYASK
Hydropower Limited Partnership

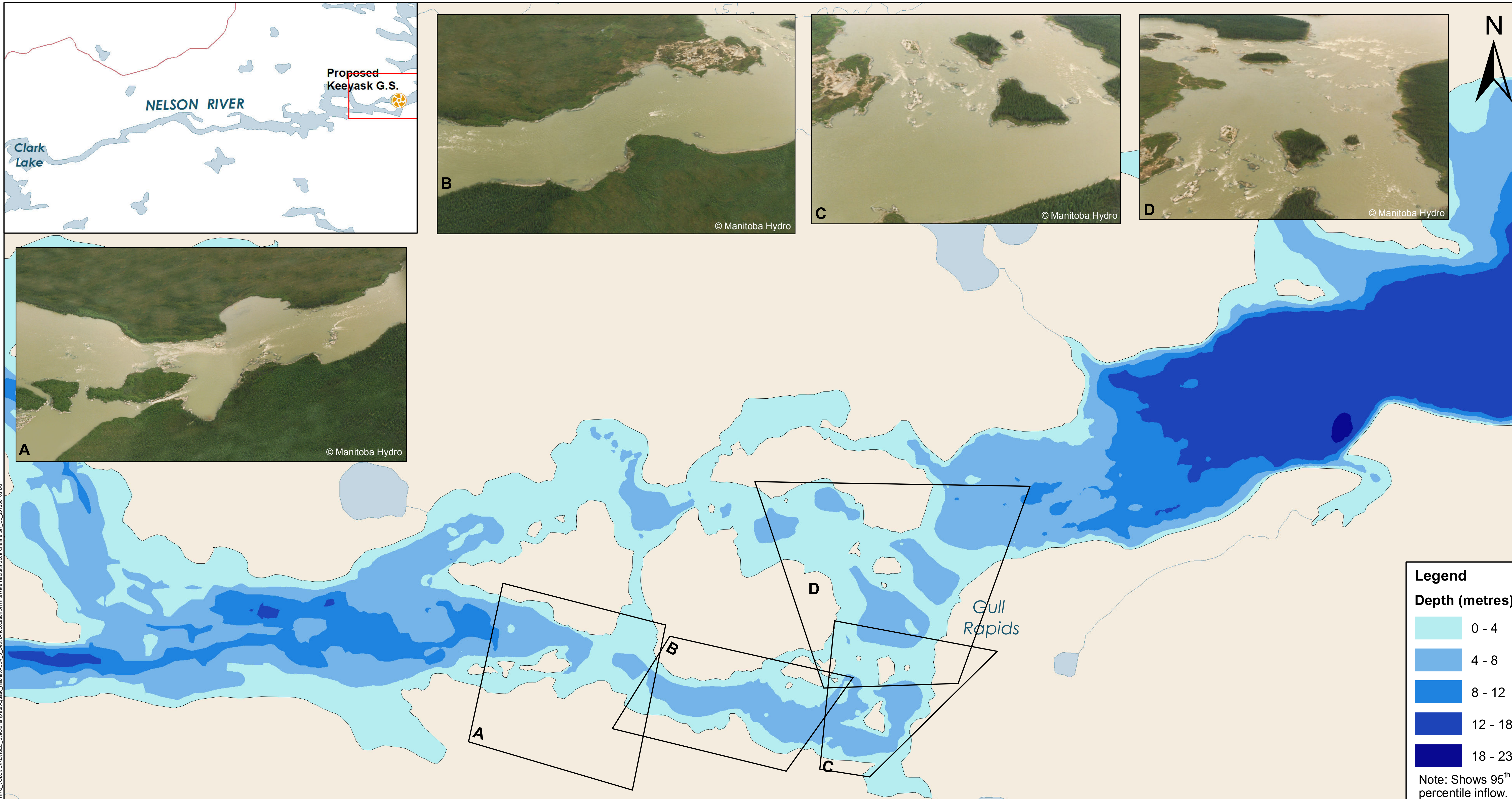
0 1 2 Kilometres
0 0.5 1 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000,
Nelson River Shoreline modelled by Manitoba Hydro

Depth and Location of White Water Habitat in the Middle Channel of Gull Rapids

Existing Environment - Reaches 9A and 9B

Map 3-12



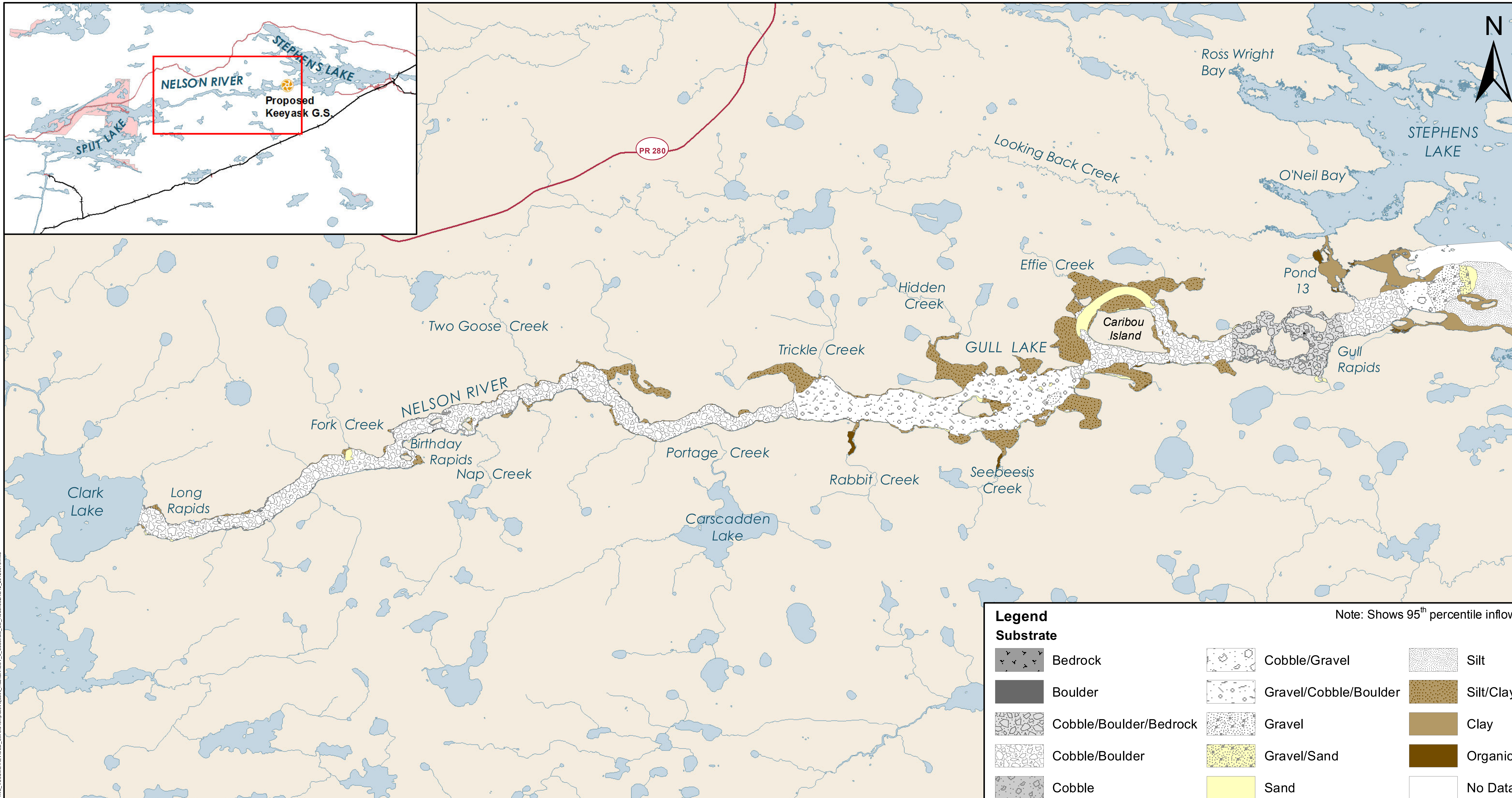
KEEYASK
Hydropower Limited Partnership

0 1 2 Kilometres
0 0.5 1 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000,
Nelson River Shoreline modelled by Manitoba Hydro

Depth and Location of White Water Habitat in the South Channel of Gull Rapids

Existing Environment - Reaches 9A and 9B



Keeyask Hydropower Limited Partnership

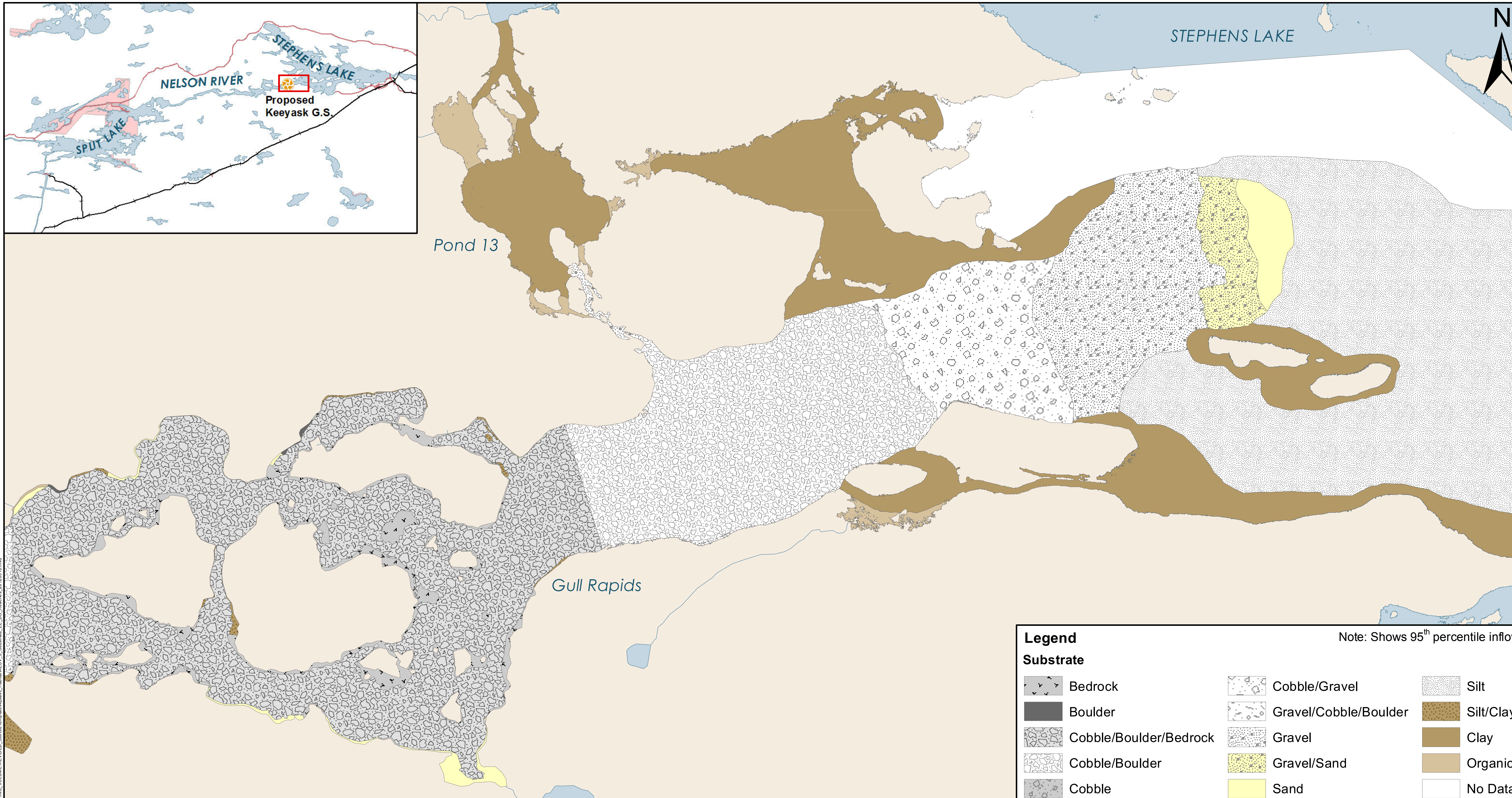
0 2.5 5 7.5 10 Kilometres

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

Substrate

Existing Environment - Reaches 2A to 12



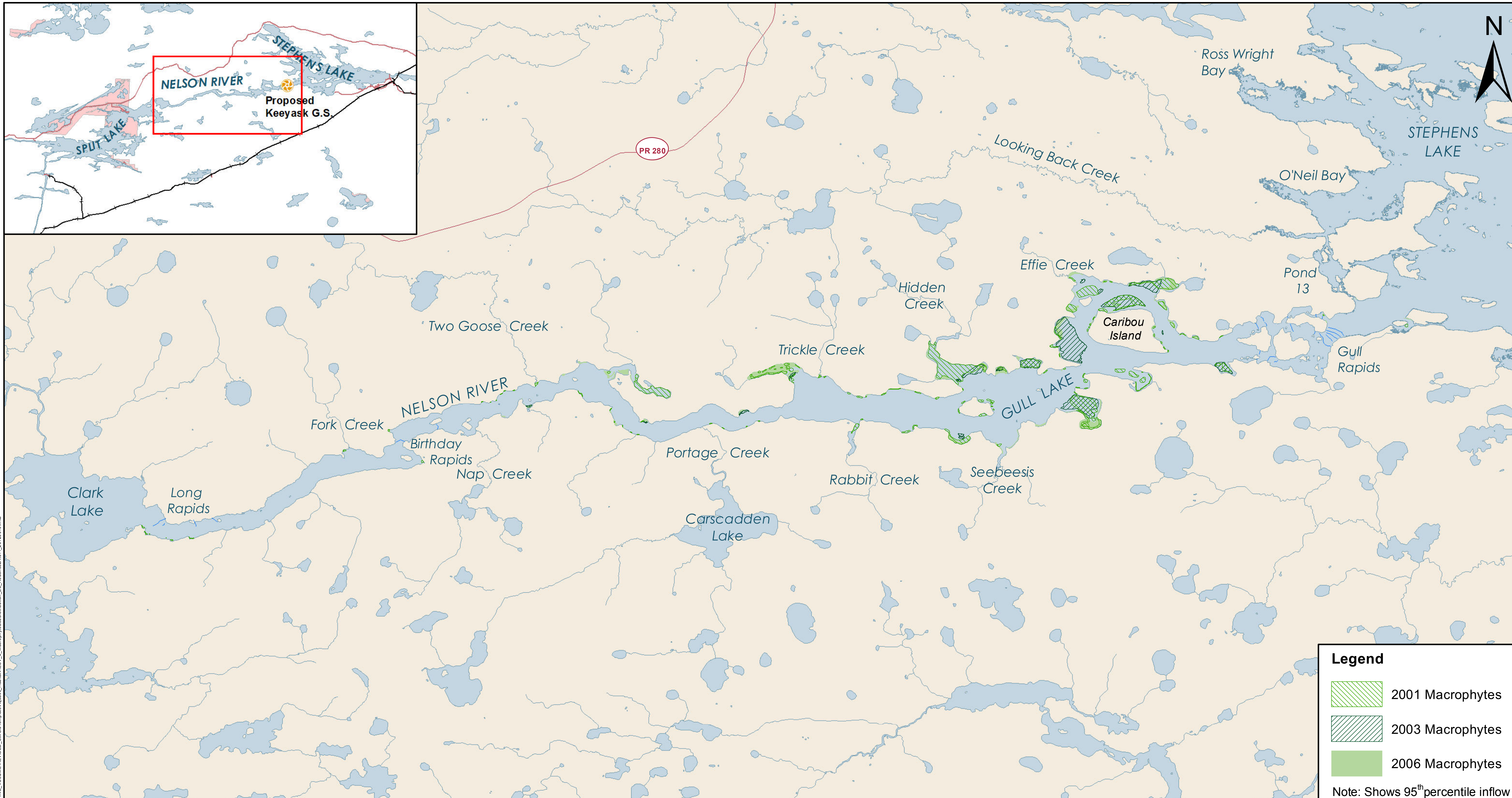
KEEYASK Hydropower Limited Partnership

0 1 2 Kilometres
0 0.5 1 Miles

Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000,
Stephens Lake-Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro

Substrate

Existing Environment - Reaches 9B,10,11 and 12



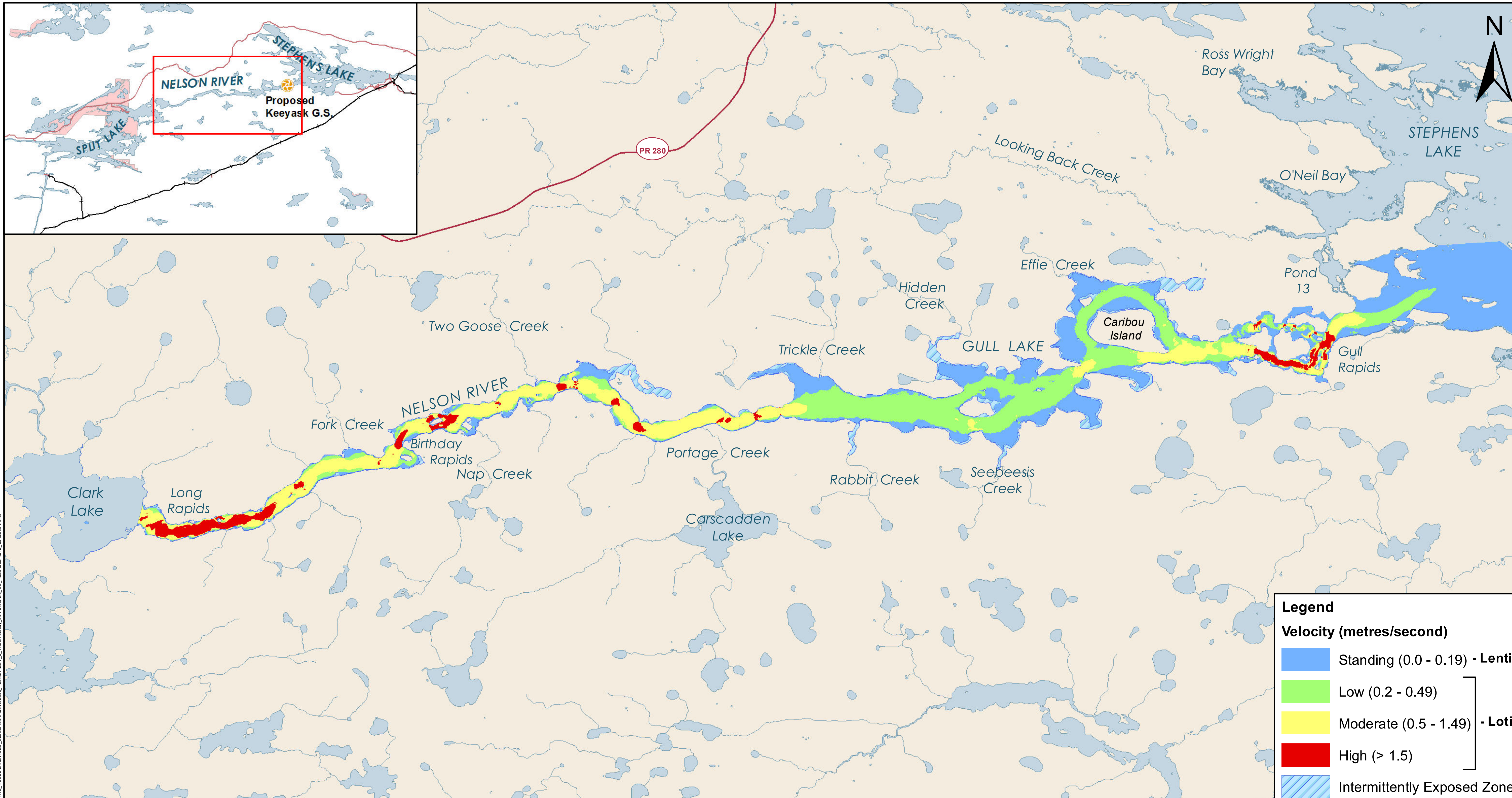
Keeyask Hydropower Limited Partnership

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

Macrophyte Bed Distribution
Existing Environment - Reaches 2A to 11

Map 3-16



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

Water Velocity at 5th Percentile Inflow

Existing Environment - Reaches 2A to 12

Map 3-17

KEEYASK Hydropower Limited Partnership

0 2.5 5 7.5 10 Kilometres

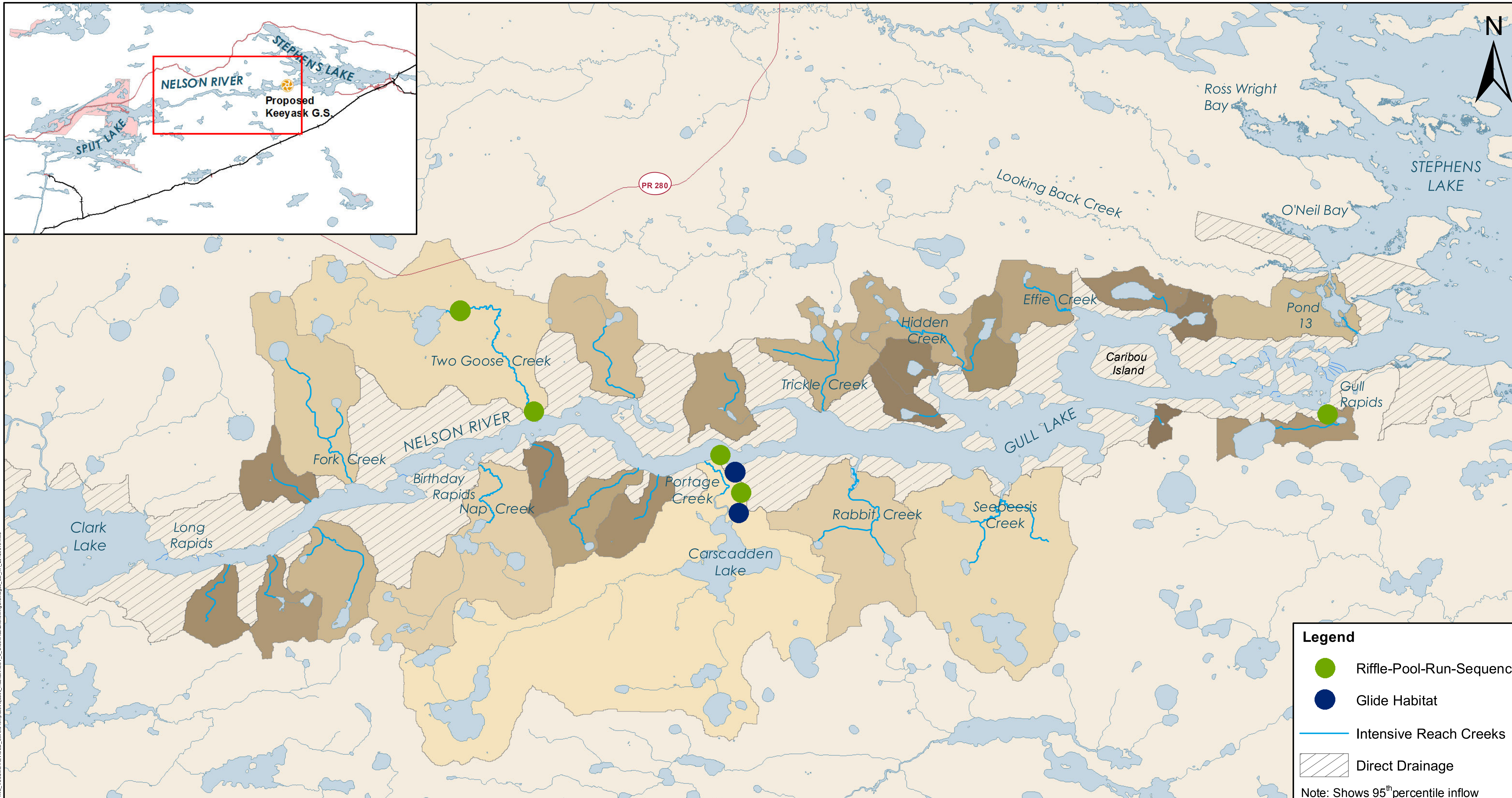
0 1.25 2.5 3.75 5 Miles

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

Water Velocity Comparison - 95th Percentile Inflow Subtracted from 5th Percentile Inflow

Existing Environment - Reaches 2A to 12

Map 3-18



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

Creek Habitat Showing Drainages

Existing Environment - Reaches 2A to 12

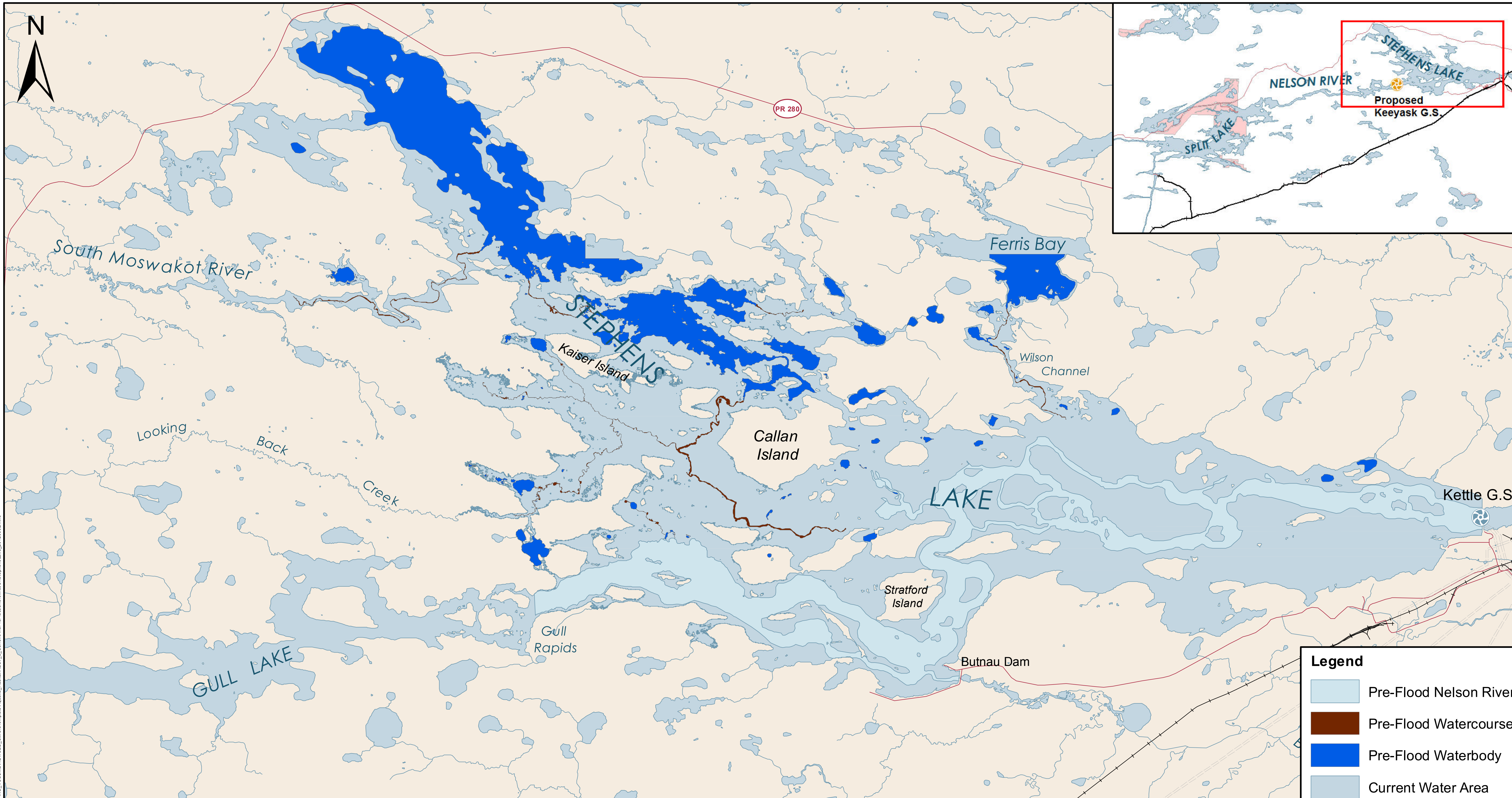
Map 3-19

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

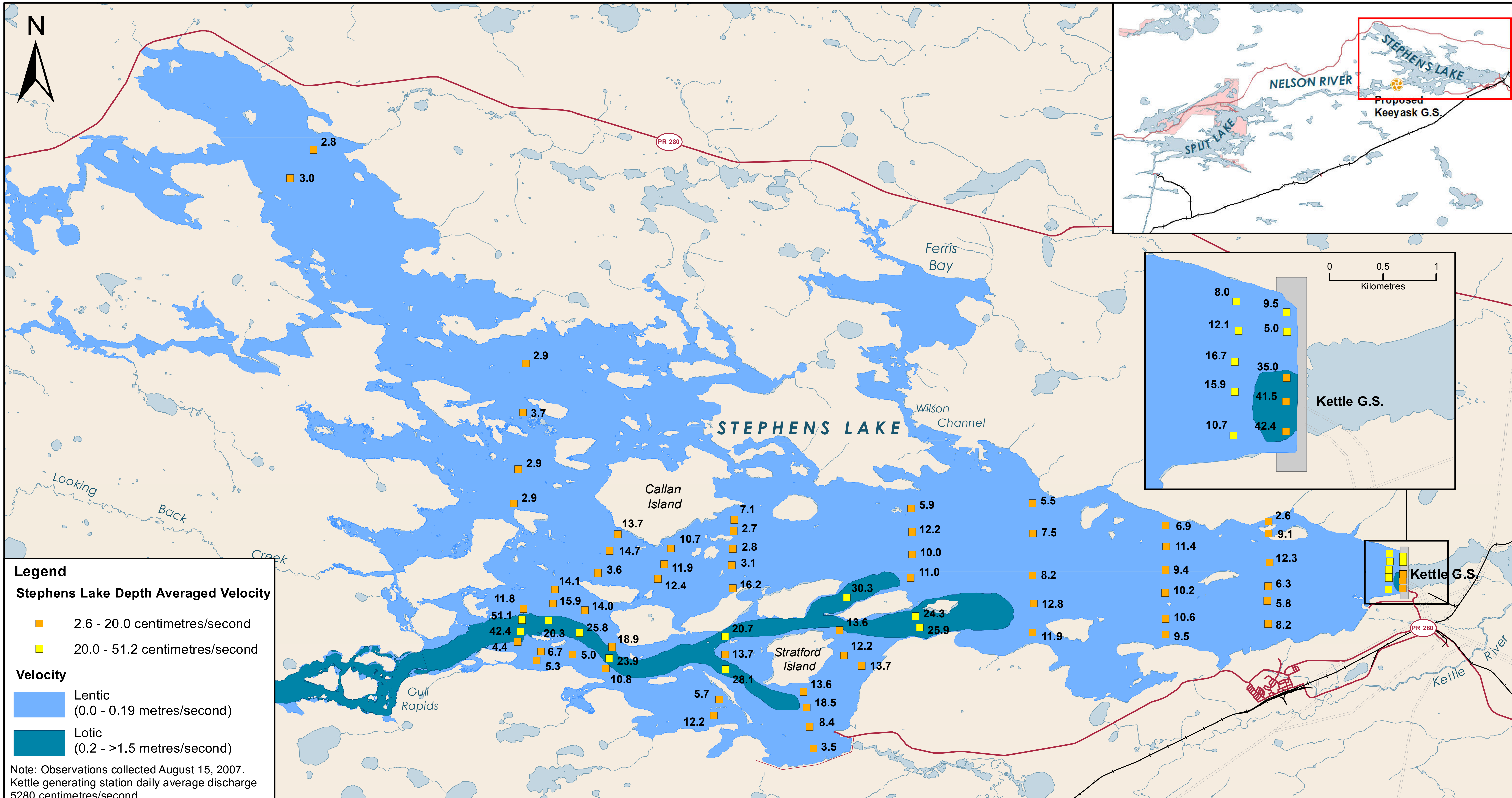
Creek Habitat
Existing Environment - Reaches 3 to 9B



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
Pre-Flood hydrography from terrestrial volume

Current and Pre-Flood Shorelines on Stephens Lake



KEEYASK
Hydropower Limited Partnership

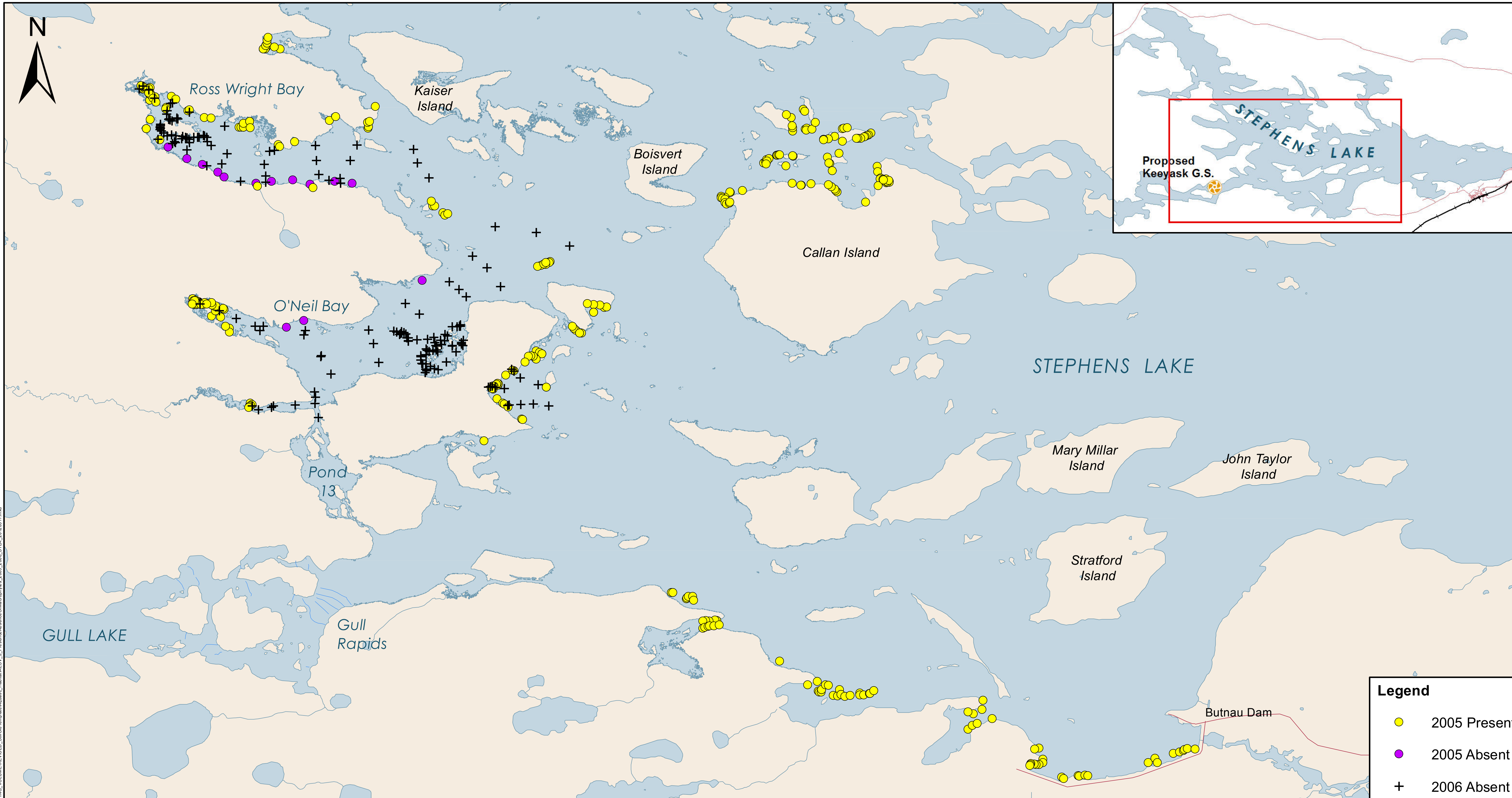
0 5 10 Kilometres

0 2.5 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

Lentic and Lotic Habitat

Stephens Lake Area



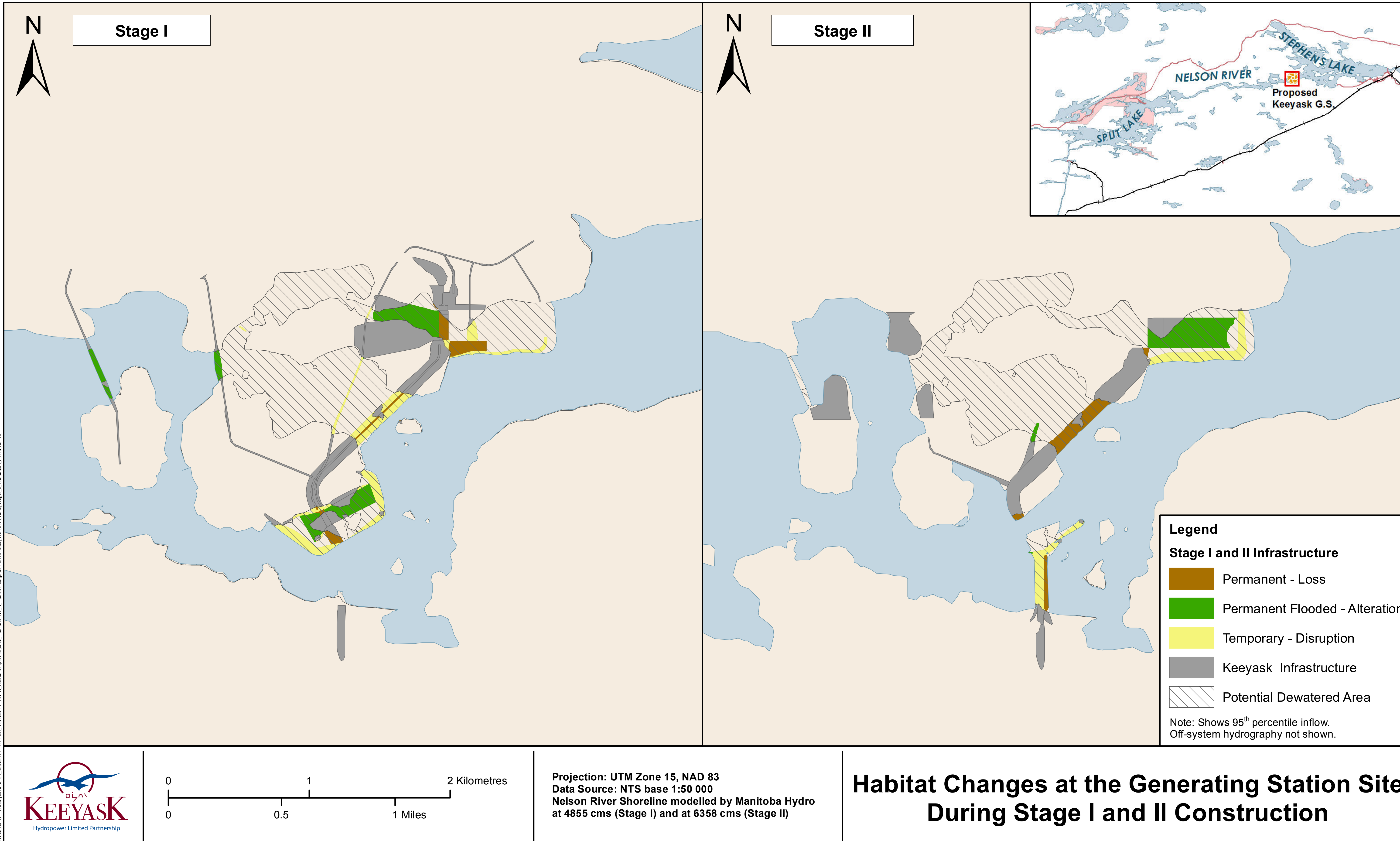
KEEYASK Hydropower Limited Partnership

0 2.5 5 Kilometres
0 1.25 2.5 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

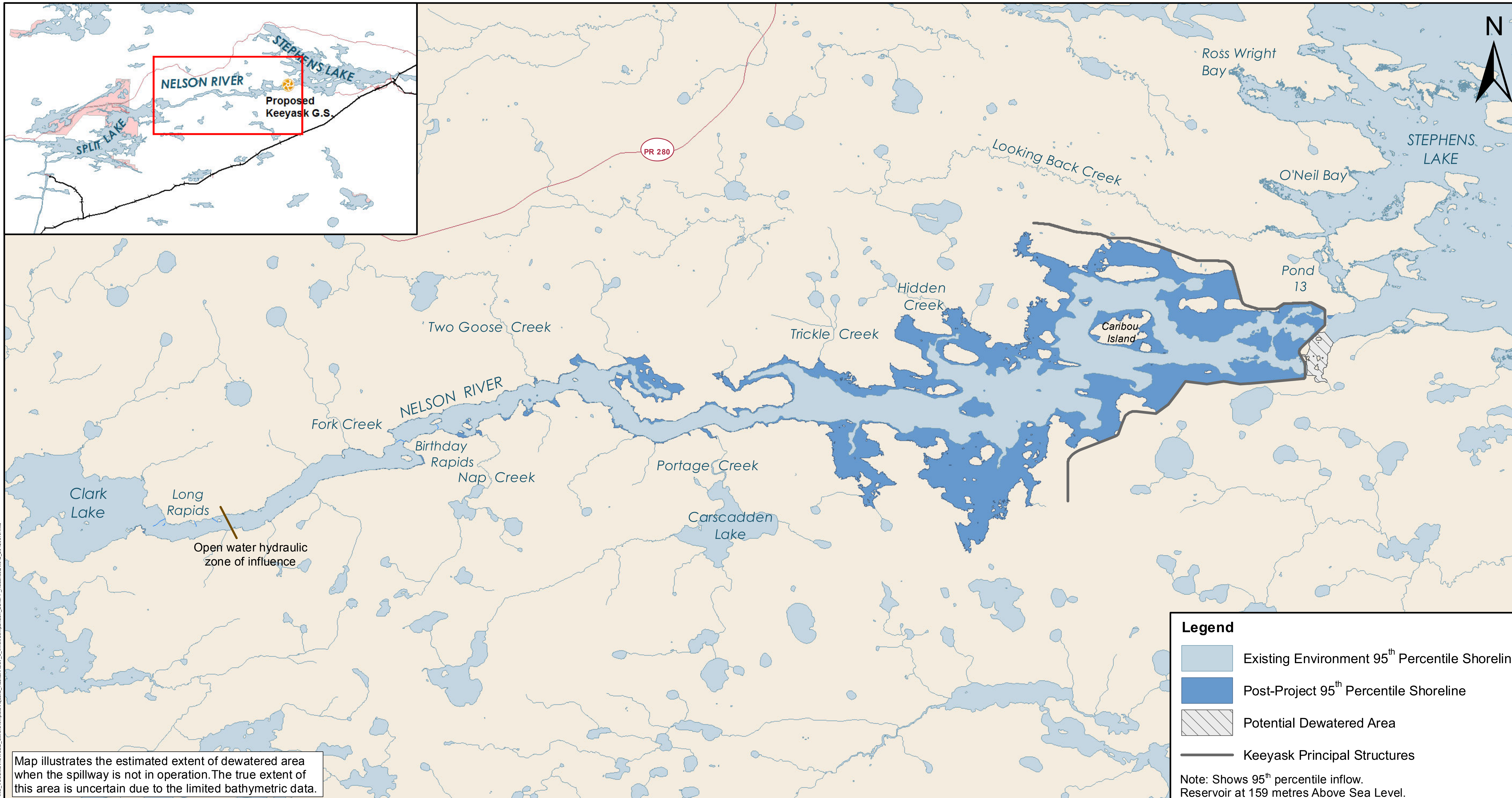
Presence/Absence of Macrophytes 2005 - 2006

Stephens Lake Area



Habitat Changes at the Generating Station Site During Stage I and II Construction

Map 3-24



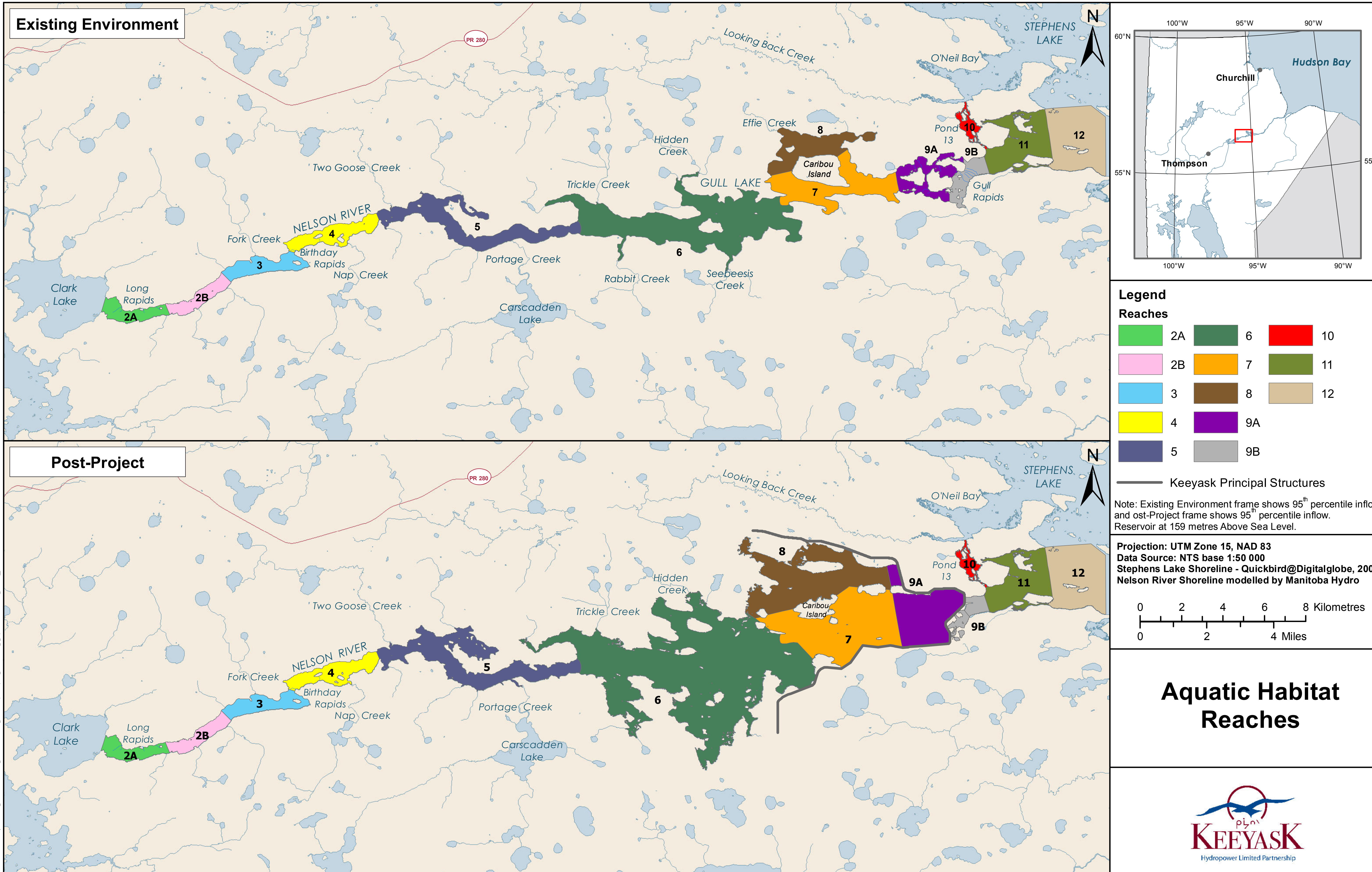
KEEYASK Hydropower Limited Partnership

0 2.5 5 7.5 10 Kilometres
0 1.25 2.5 3.75 5 Miles

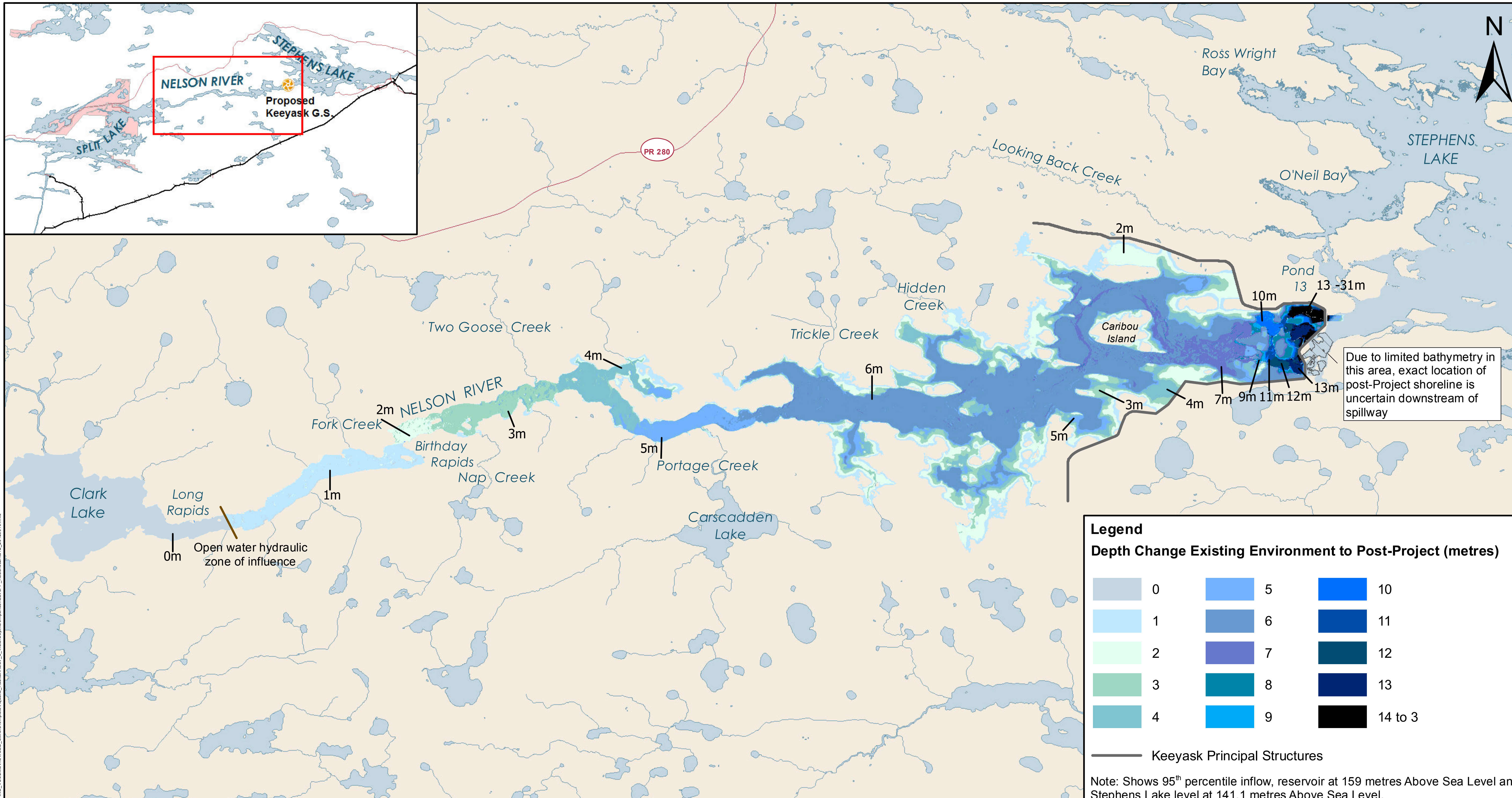
Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Stephens Lake Shoreline - Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro.
Extents of dewatered area are estimated based on the existing environment 95th percentile flow.

Inflow Comparison
Existing Environment versus Post-Project
Reaches 2A to 12

Map 3-25


Existing Environment
Post-Project
PR 280
STEPHENS LAKE
Looking Back Creek
O'Neil Bay
Effie Creek
Hidden Creek
Two Goose Creek
Trickle Creek
GULL LAKE
Caribou Island
Pond 13
Gull Rapids
NELSON RIVER
Fork Creek
Birthday Rapids
Nap Creek
Portage Creek
Rabbit Creek
Seebeesis Creek
Carscadden Lake
Clark Lake
Long Rapids
2A
2B
3
4
5
6
7
8
9A
9B
10
11
12
N
100°W
95°W
90°W
60°N
55°N
Hudson Bay
Churchill
Thompson
Legend
Reaches
2A
2B
3
4
5
6
7
8
9A
9B
10
11
12
Keeyask Principal Structures
Note: Existing Environment frame shows 95th percentile inflow and ost-Project frame shows 95th percentile inflow. Reservoir at 159 metres Above Sea Level.
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 2 4 6 8 Kilometres
0 2 4 Miles
Aquatic Habitat Reaches
KEEYASK
Hydropower Limited Partnership

Map 3-26

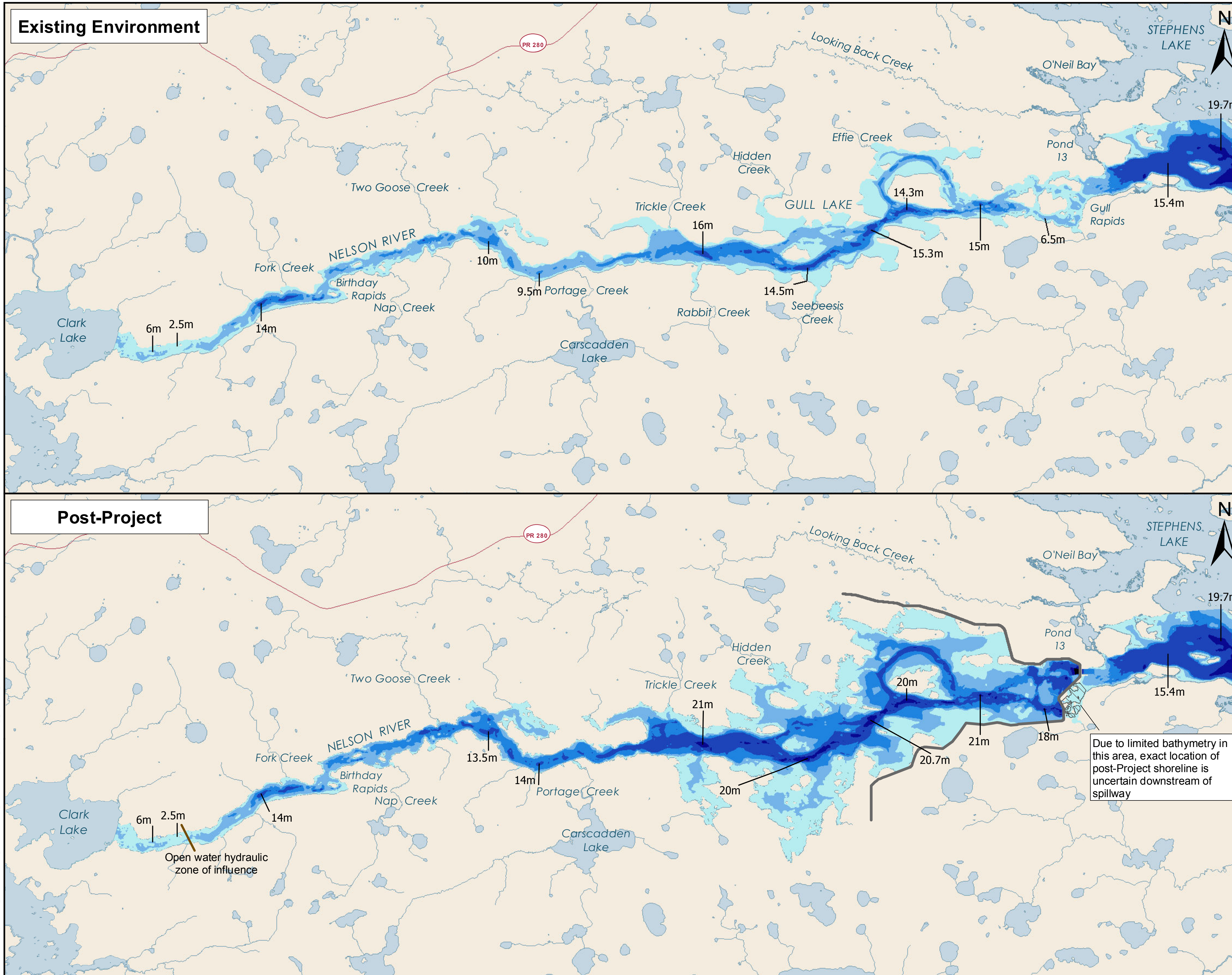


KEEYASK
Hydropower Limited Partnership

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.

Water Depth Comparison
Existing Environment versus Post-Project
Reaches 2A to 12



Legend

Depth (metres)

- 0 - 4
- 4 - 8
- 8 - 12
- 12 - 18
- 18 - 23
- 23 - 31
- Keeyask Principal Structures

Note: Existing environment frame shows 95th percentile inflow and post-Project frame shows 95th percentile inflow, reservoir at 159 metres Above Sea Level and Stephens Lake level at 141.1 metres Above Sea Level.

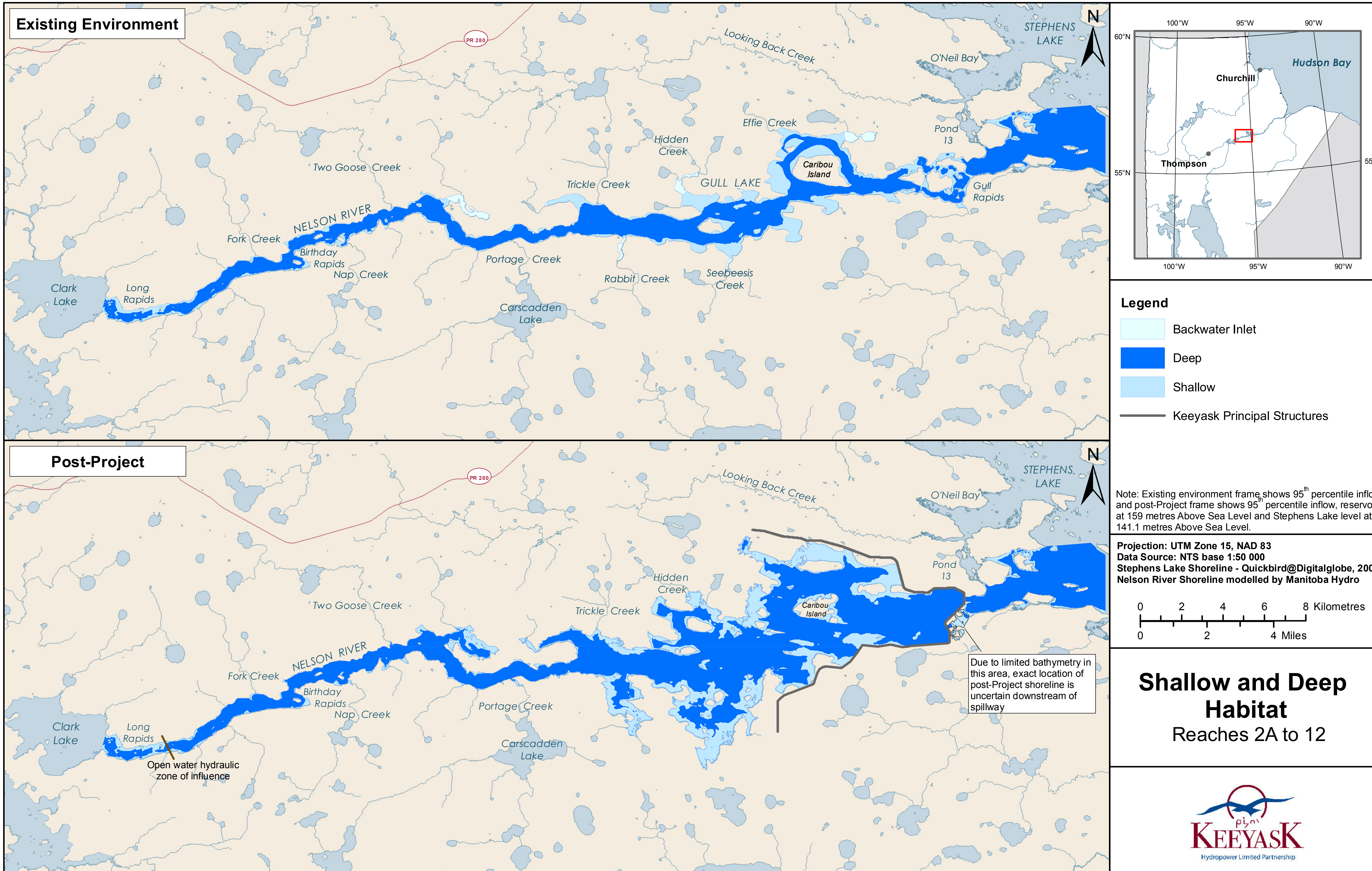
Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Stephens Lake Shoreline - Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro

0 2 4 6 8 Kilometres
0 2 4 Miles

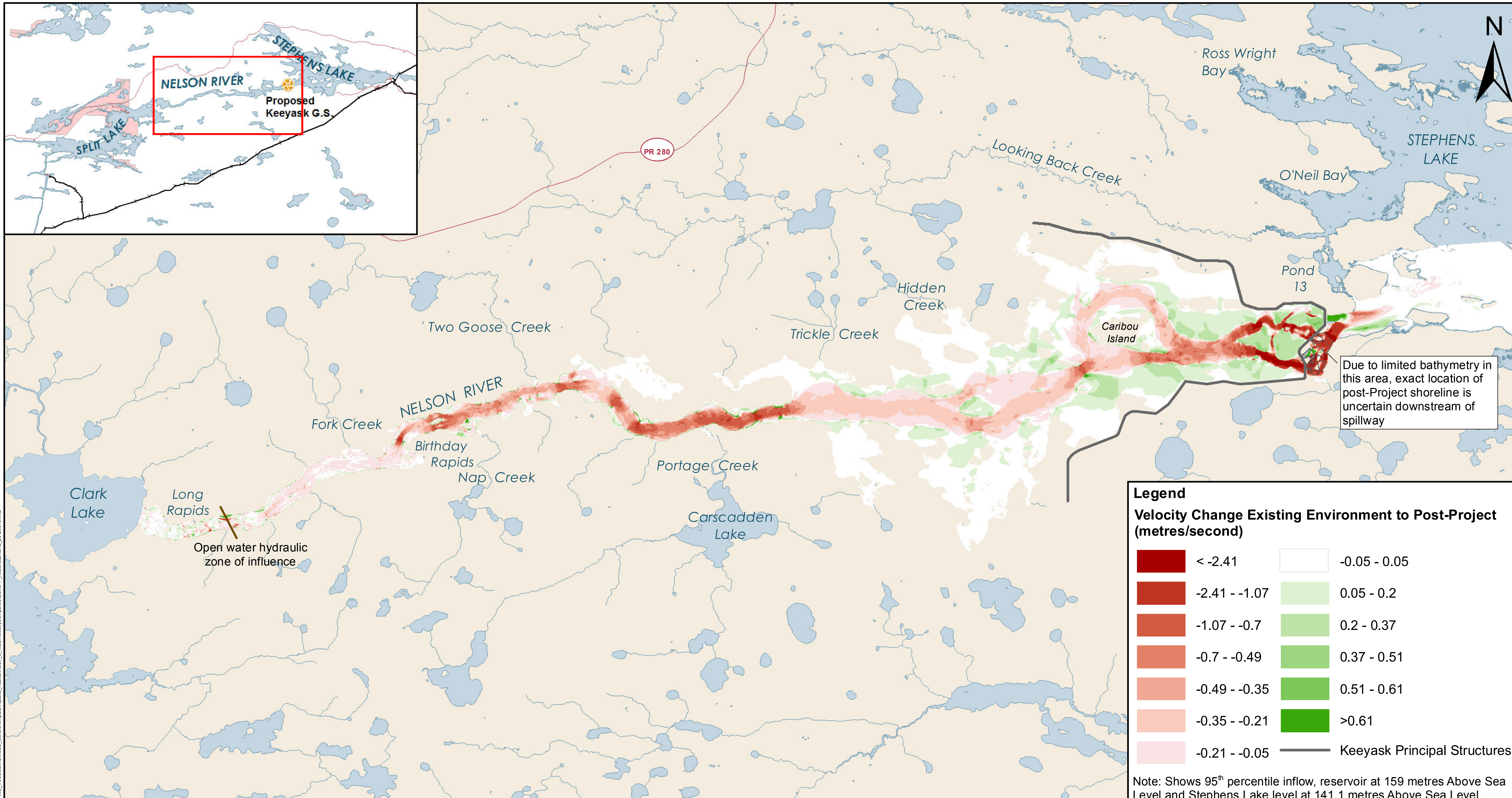
Water Depth
Reaches 2A to 12

KEEYASK
Hydropower Limited Partnership

Map 3-28


Existing Environment
Post-Project
STEPHENS LAKE
Looking Back Creek
O'Neil Bay
PR 280
Effie Creek
Hidden Creek
Pond 13
Caribou Island
GULL LAKE
Gull Rapids
Two Goose Creek
Trickle Creek
NELSON RIVER
Fork Creek
Birthday Rapids
Nap Creek
Portage Creek
Rabbit Creek
Seebeesis Creek
Clark Lake
Long Rapids
Carscadden Lake
Open water hydraulic zone of influence
Due to limited bathymetry in this area, exact location of post-Project shoreline is uncertain downstream of spillway
N
Hudson Bay
Churchill
Thompson
100°W
95°W
90°W
60°N
55°N
Legend
Backwater Inlet
Deep
Shallow
Keeyask Principal Structures
Note: Existing environment frame shows 95th percentile inflow and post-Project frame shows 95th percentile inflow, reservoir at 159 metres Above Sea Level and Stephens Lake level at 141.1 metres Above Sea Level.
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 2 4 6 8 Kilometres
0 2 4 Miles
Shallow and Deep Habitat
Reaches 2A to 12
KEEYASK
Hydropower Limited Partnership

Map 3-29



KEEYASK Hydropower Limited Partnership

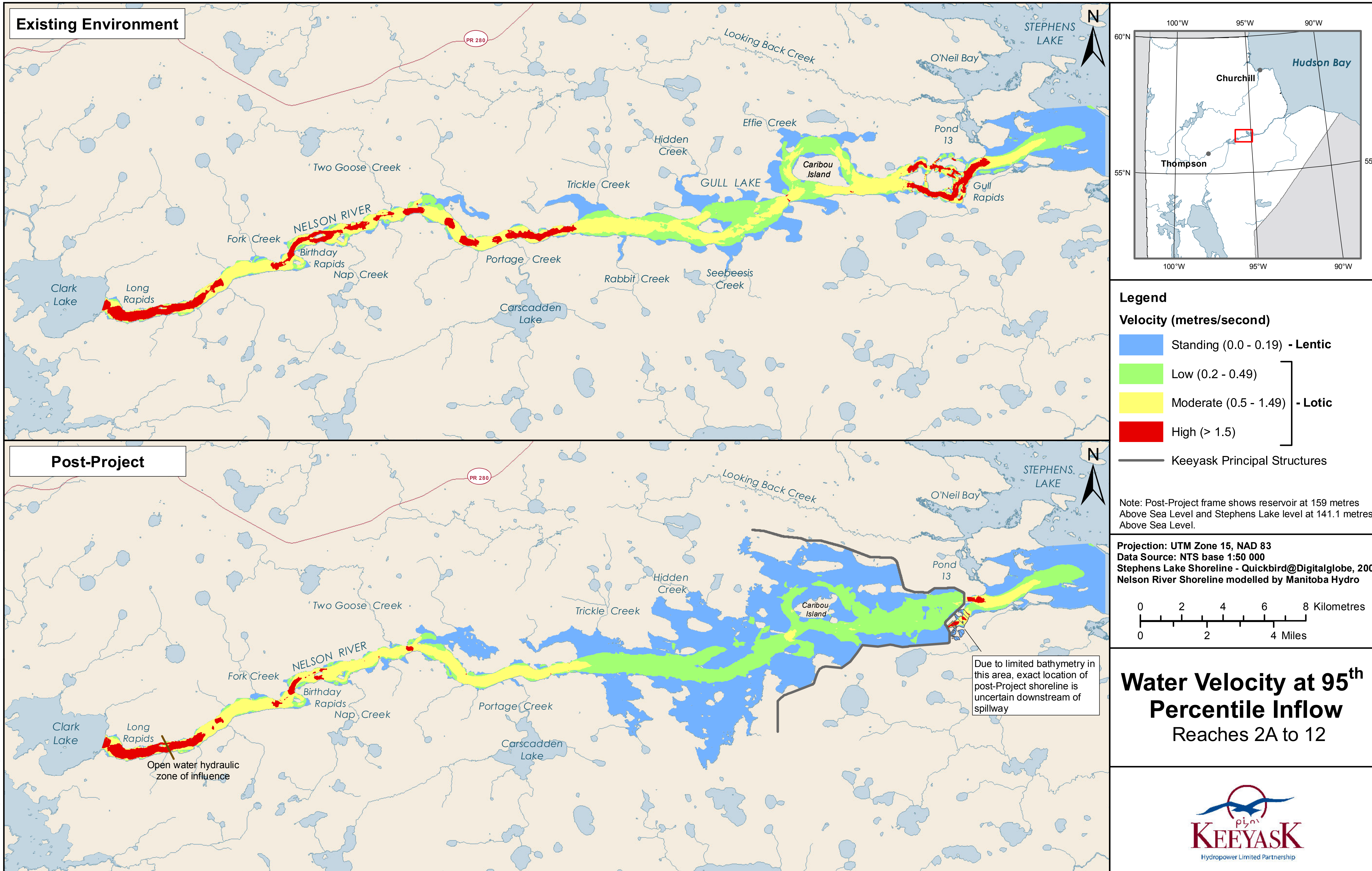
0 2.5 5 7.5 10 Kilometres
0 1.25 2.5 3.75 5 Miles

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.

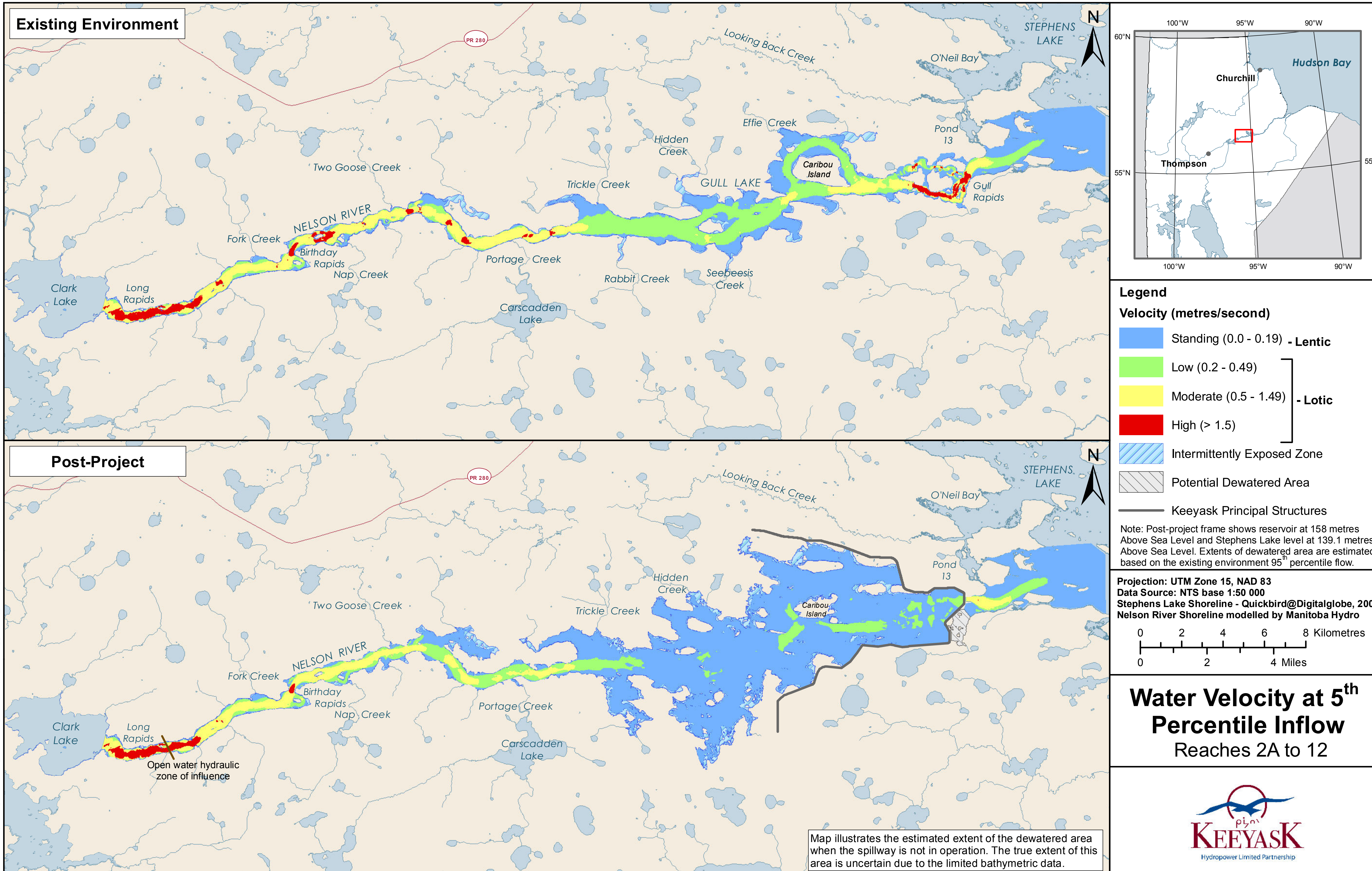
Water Velocity Comparison Existing Environment versus Post-Project

Reaches 2A to 12

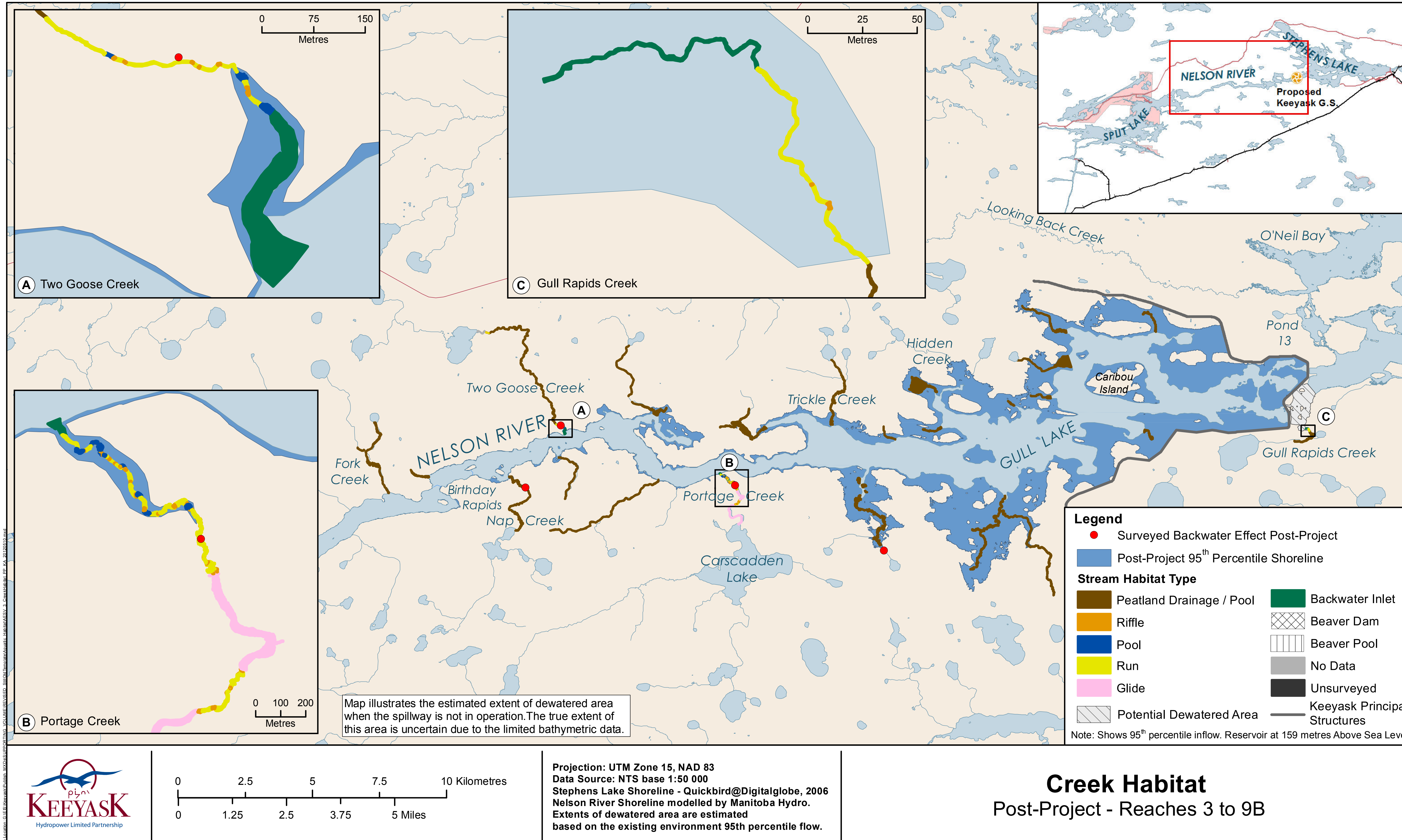
Map 3-30


Existing Environment
Post-Project
PR 280
Looking Back Creek
STEPHENS LAKE
O'Neil Bay
Effie Creek
Hidden Creek
Pond 13
Caribou Island
Gull Rapids
GULL LAKE
Trickle Creek
Two Goose Creek
NELSON RIVER
Fork Creek
Birthday Rapids
Nap Creek
Portage Creek
Rabbit Creek
Seebeesis Creek
Carscadden Lake
Clark Lake
Long Rapids
Open water hydraulic zone of influence
Due to limited bathymetry in this area, exact location of post-Project shoreline is uncertain downstream of spillway
N
100°W
95°W
90°W
60°N
55°N
Hudson Bay
Churchill
Thompson
Legend
Velocity (metres/second)
Standing (0.0 - 0.19) - Lentic
Low (0.2 - 0.49)
Moderate (0.5 - 1.49)
High (> 1.5)
- Lotic
Keeyask Principal Structures
Note: Post-Project frame shows reservoir at 159 metres Above Sea Level and Stephens Lake level at 141.1 metres Above Sea Level.
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 2 4 6 8 Kilometres
0 2 4 Miles
Water Velocity at 95th Percentile Inflow
Reaches 2A to 12
KEEYASK
Hydropower Limited Partnership

Map 3-31


Existing Environment
Post-Project
PR 280
STEPHENS LAKE
Looking Back Creek
O'Neil Bay
Effie Creek
Pond 13
Hidden Creek
Caribou Island
GULL LAKE
Gull Rapids
Two Goose Creek
Trickle Creek
NELSON RIVER
Fork Creek
Birthday Rapids
Nap Creek
Portage Creek
Rabbit Creek
Seebeesis Creek
Carscadden Lake
Clark Lake
Long Rapids
Open water hydraulic zone of influence
Map illustrates the estimated extent of the dewatered area when the spillway is not in operation. The true extent of this area is uncertain due to the limited bathymetric data.
100°W
95°W
90°W
60°N
55°N
Hudson Bay
Churchill
Thompson
Legend
Velocity (metres/second)
Standing (0.0 - 0.19) - Lentic
Low (0.2 - 0.49)
Moderate (0.5 - 1.49) - Lotic
High (> 1.5)
Intermittently Exposed Zone
Potential Dewatered Area
Keeyask Principal Structures
Note: Post-project frame shows reservoir at 158 metres Above Sea Level and Stephens Lake level at 139.1 metres Above Sea Level. Extents of dewatered area are estimated based on the existing environment 95th percentile flow.
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 2 4 6 8 Kilometres
0 2 4 Miles
Water Velocity at 5th Percentile Inflow
Reaches 2A to 12
KEEYASK
Hydropower Limited Partnership

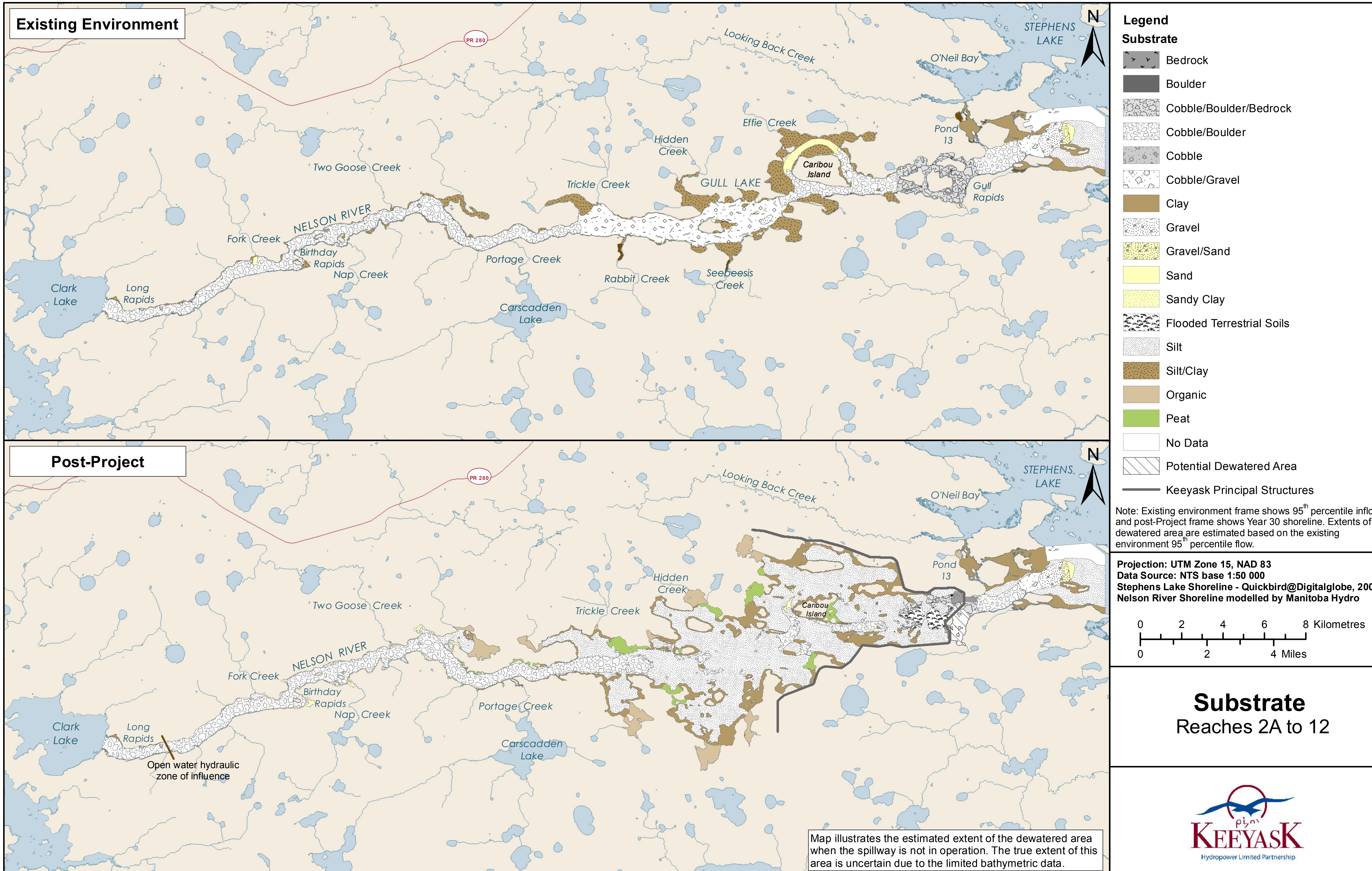
Map 3-32



Creek Habitat

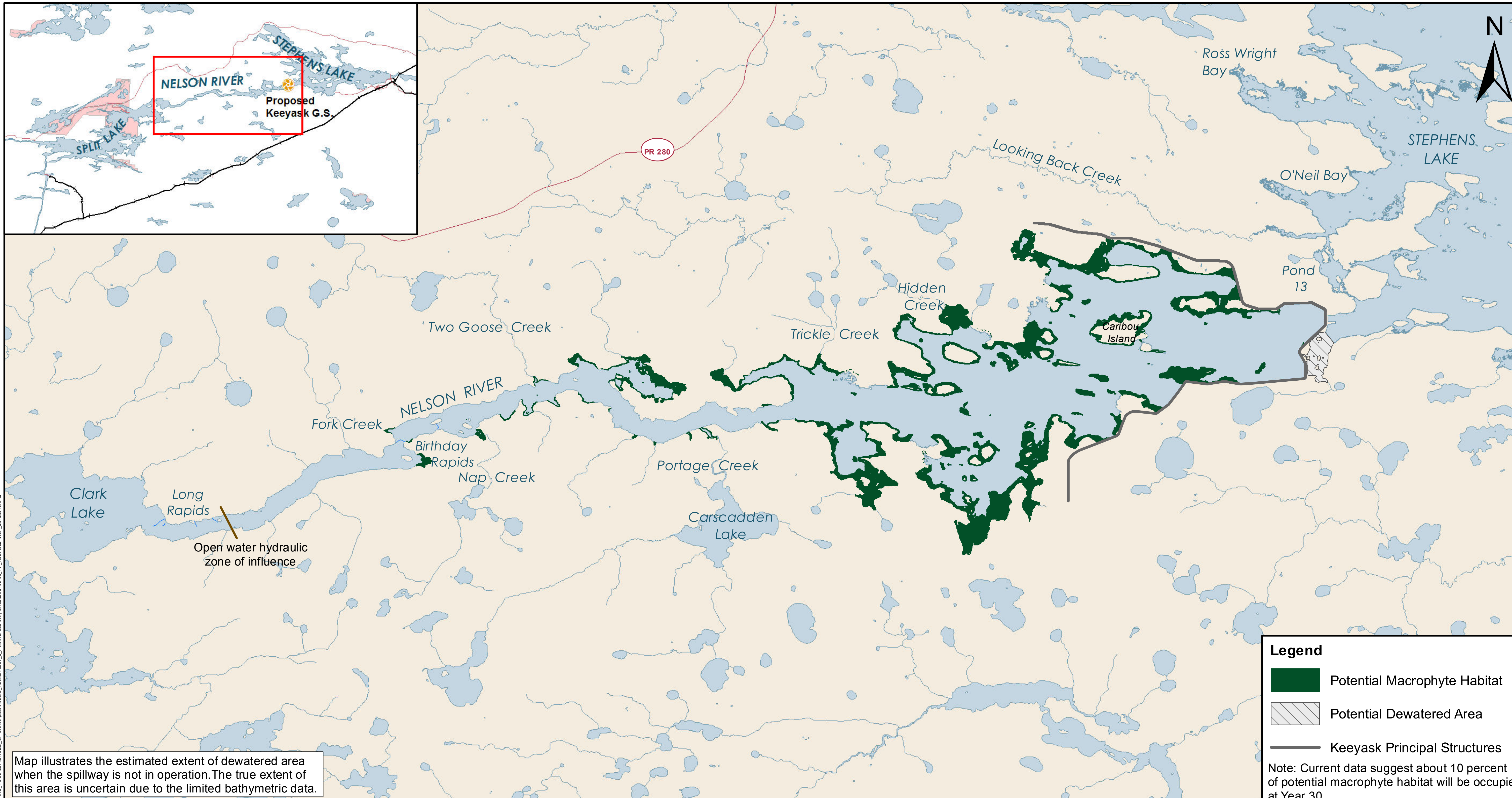
Post-Project - Reaches 3 to 9B

Map 3-33



Existing Environment
Post-Project
PR 280
Looking Back Creek
STEPHENS LAKE
O'Neil Bay
Effie Creek
Pond 13
Caribou Island
Gull Rapids
Hidden Creek
GULL LAKE
Trickle Creek
Two Goose Creek
NELSON RIVER
Fork Creek
Birthday Rapids
Nap Creek
Portage Creek
Rabbit Creek
Seebeesis Creek
Carscadden Lake
Clark Lake
Long Rapids
Open water hydraulic zone of influence
Map illustrates the estimated extent of the dewatered area when the spillway is not in operation. The true extent of this area is uncertain due to the limited bathymetric data.
Legend
Substrate
Bedrock
Boulder
Cobble/Boulder/Bedrock
Cobble/Boulder
Cobble
Cobble/Gravel
Clay
Gravel
Gravel/Sand
Sand
Sandy Clay
Flooded Terrestrial Soils
Silt
Silt/Clay
Organic
Peat
No Data
Potential Dewatered Area
Keeyask Principal Structures
Note: Existing environment frame shows 95th percentile inflow and post-Project frame shows Year 30 shoreline. Extents of dewatered area are estimated based on the existing environment 95th percentile flow.
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 2 4 6 8 Kilometres
0 2 4 Miles
Substrate
Reaches 2A to 12
KEEYASK
Hydropower Limited Partnership

Map 3-34



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.

Potential Macrophyte Habitat at Year 30

Post-Project - Reaches 2A to 9A

APPENDICES

APPENDIX 3A
AQUATIC HABITAT METHODS

3A.1 INTRODUCTION

This appendix describes field surveys conducted to acquire habitat data related to substrate type and macrophyte distribution required to:

i) Provide information on the existing environment in the Keeyask area; and

ii) Provide the field data necessary for the development of models to predict future conditions in the Keeyask reservoir based on conditions in Stephens Lake (described in Appendix 3B and Appendix 3C).

This appendix also describes field surveys and data analysis conducted to describe habitat of the tributary streams in the Keeyask area.

3A.2 KEEYASK AREA

3A.2.1 SUBSTRATE

The following data collection and mapping methods outline the approach taken to create the existing environment surface substrate map used to describe the bottom type habitat of the Keeyask area (Section 3.3.2.3, Map 3-14).

3A.2.1.1 Field Surveys

Data collection for substrate mapping consisted of both sonar and bottom-type validation surveys conducted during a number of field programs between 2001 and 2009.

The majority of the data collection was completed in August 2001. The 2001 boat-based survey used a Meridata MD100 digital depth sounder linked to a mapping grade GPS (Trimble ProXL). A river bottom profile generated in real-time on the unit's graphic display was used to interpret the bottom type, bottom compaction, and presence of aquatic vegetation. Bottom validation using a probe and Ponar dredge was conducted at irregular intervals along the survey transects. The survey covered the area from Clark Lake up to the safely navigable area above Gull Rapids and the base of Gull Rapids to 2.5 km downstream. The survey covered the north and south shorelines of the Nelson River, latitudinal transects spaced approximately 500 m apart were used to cover the river (Map 3A-1, Map 3A-2, Map 3A-3, and Map 3A-4).

In order to further validate the acoustic data collected in 2001, boat-based Ponar and rebar drag surveys were conducted in the area of Gull Lake and upstream of Gull Rapids in 2006. Boat-based Ponar and rebar drag surveys were conducted in 2007 downstream of Gull Rapids in order to determine the general areas of substrate changes along the transition boundary to Stephens Lake. An additional survey was conducted in 2008 in the downstream portion of Gull Lake in areas identified as important lake sturgeon habitat to collect substrate, depth and velocity information.

From 12–27 September 2008 a Price Type "AA" Current Meter (Model 1210) and a Ponar grab sampler were used in the vicinity of Caribou Island in Gull Lake in order to determine sturgeon habitat in the area. Discharges (outflow at Split Lake) at the time of sampling ranged from 4225–4845 m^3/s. The results of these velocity and bottom type samples were incorporated into the final substrate map.

In July 2009, an additional sonar survey was conducted approximately 2.5 km downstream of Gull Rapids in order to fill in data gaps not previously acquired. The survey was conducted with a Quester Tangent Corporation (QTC) Series V scientific grade echo sounder coupled to a Trimble Pro XRS sub-metre grade GPS. The transducer was positioned approximately 40 cm below the surface of the water adjacent to the hull of the boat. The echo sounder had a frequency of 50 kilohertz (kHz) and was set to collect at 5-second intervals. The survey consisted of six longitudinal transects filled in by multiple latitudinal tracks spaced approximately 250 m apart (Map 3A-3).

Additional validation data were compiled from a number of fish community and lower trophic level field programs conducted between 2001 and 2009 in which habitat data were recorded. These validation datasets consisted of GPS point observations describing surface and, in some cases, sub-surface substrate types.

3A.2.1.2 Mapping

The 2001 Meridata MD100 track data were classified according to substrate changes verified in the field and on the bottom profile read-out. Validation substrates were classified based on a simplified interpretation of the Wentworth particle size classification for granular materials (Table 3-2). A simple coding structure was used to create aggregate substrate classes where they occurred:

- Composition: 1 = Boulder Cobble; 2 = Gravel; 3 = Sand; 4 = Fines (25 original classes);
- Compaction: 1 = Hard; 2 = Moderate; 3 = Soft; and
- Vegetation Density: 1 = low; 2 = medium; 3 = high.

Data were post-processed in a Microsoft Excel worksheet, complete with ID, easting, northing, depth, compaction, composition, and vegetation density, for a total of 309,023 classified data points. Data were then imported into ArcGIS (ESRI 2009) geographic information systems (GIS) mapping software and plotted along with available base mapping.

A series of Thiessen polygon analyses were conducted in order to interpolate the discrete data point classifications to the areas of the river between the survey transects. A buffer was applied such that the classified polygons would extend outside of the shoreline area. A Thiessen polygon interpolation is an exact method of interpolation that assumes that the values of the unsampled locations are equal to the value of the nearest sampled point. The method is known as a local interpolator because the other data points in the dataset do not influence the interpolation process (Heywood *et al.* 1998). The Thiessen polygons were smoothed in order to remove relics of the interpolation process. Like classes of the original 25 were aggregated to reduce the number of substrate classes.

The QTC acoustic data collected in 2009 were analyzed separately from the 2001 Meridata MD100 acoustic bottom type data. The QTC echo sounder data were analyzed using QTC Impact (QTC 2009). An unsupervised classification approach was used to identify the acoustic classes identifying the boundary between soft (depositional) and hard bottom types. The Ponar and rebar drag validation sites collected during the survey and classified according to a simplified Wentworth particle size classification (Table 3-2), were used to label the unsupervised classification classes representing soft and hard substrates. The classification allowed for the identification of the boundary between lake sedimentation and clean riverine hard substrates.

3A.2.2 ROOTED MACROPHYTES

The following data collection, mapping, and analysis methods were used to quantify and describe rooted macrophyte occupancy within the Keeyask area (Section 3.3.2.3, Table 3-5, Map 3-16).

3A.2.2.1 Surveys – 2001, 2003, and 2006

Information on aquatic plant abundance, species composition, and distribution was recorded during the boat-based bathymetric and aquatic habitat mapping survey conducted from late July to late August 2001 from Clark Lake to downstream of Gull Rapids (Map 3A-2, Map 3A-3, and Map 3A-4). For detailed survey methods for abundance and composition refer to Appendix 4A. The location of areas supporting rooted plants visible from the surface was transcribed directly onto field maps. Plants were identified on-site and species composition and relative densities were recorded. GPS transect data collected during the survey were coded as having low, medium, or high plant density (Section 3A.2.1.2).

Fifteen aquatic macrophyte beds were identified and mapped at seventeen locations in the Nelson River between Birthday and Gull rapids (including Gull Lake) during late August 2003. The average depths of these macrophyte beds ranged from 0.26 to 1.36 m. Aquatic macrophyte beds were mapped based on the abundance of macrophytes within a bed; individual plants or small groupings of plants were not mapped. A Trimble ProXR with a TSC1 datalogger for sub-metre accuracy was used to record data. Because 2003 was a low water year, the perimeters of macrophyte beds were walked and depths were taken manually (with a metre stick) and recorded in metres. The data collected in the field were then downloaded into Pathfinder Office v2.90 (Trimble 2009). Trimble Pathfinder point files were exported as shapefiles (environmental systems research institute) and imported into ArcGIS 9.3 (ESRI 2009). Polygons were digitized and presented as maps displaying the location of the macrophyte beds.

An aerial survey was conducted between Birthday and Gull rapids in August 2006, and aquatic macrophyte bed locations were recorded on maps. Based on these observations, the edges of the plant beds were delineated and these polygons were digitized into the GIS.

3A.2.2.2 Macrophyte Occupancy

A GIS-based analysis was used to determine the area of macrophyte habitat occupied relative to the total potential habitat available and the use of water depths among years of study. A series of spatial queries were executed in order to identify areas of potential plant habitat based on substrate, water movement and depth criteria generally associated with macrophyte cover. The following criteria were identified:

- Keeyask area reaches 5–8;
- Substrate identified as being silt/clay;
- Water movement identified as being standing or low velocity; and
- Depth being shallow (less than 3 m) or backwater habitat.

The query result areas were summed to give a total habitat occupied at the 95th percentile water level. The same procedure was replicated for the 5th percentile water level shoreline and depth inputs. The total area of habitat occupied, and total percent of suitable and potential habitat occupied for all three survey years were then summarized (Table 3-5).

Twenty random sample points were created for each macrophyte stand for each of the three years macrophyte beds were observed in the field (2001, 2003 and 2006). Point generation was constrained by a rule specifying that each point was spaced a minimum of 5 m from another to ensure that a discrete depth value was extracted from a depth grid. Smaller macrophyte stands therefore had fewer than 20 random points. The 95th percentile depth grid was used to extract values for 2001 and 2006 and the 5th percentile depth grid was used for 2003 points.

The number of random sample points generated for 2001 was 2,045 in 105 beds, 176 for 2003, and 1,592 for 2006 in 83 macrophyte beds; 2003 had fewer sample points because of a lower count of total beds (25). Descriptive statistics, including mean, minimum, maximum, and standard deviation, were generated from the depth points and are presented in Section 3.2.3.3. A box plot chart was generated to present a relative comparison of the depths and distribution of macrophyte stands over the three years.

3A.2.3 CREEK HABITAT

The following data collection and mapping methods were used to describe creek habitat and watershed area within the Keeyask area (Map 3-20).

3A.2.3.1 Aerial Survey of Tributaries

An aerial survey was conducted on 25 May 2005 along selected tributaries of the Nelson River between Birthday Gull rapids (Map 3A-5). Aerial video was captured along the tributaries using a GPS linked aerial video system (Red Hen Systems Inc., Fort Collins, Colorado) mounted on the nose of a Bell Jet Ranger helicopter. Aerial frame surveys were conducted at about 100 m above the tributaries.

3A.2.3.2 Creek Habitat Mapping

Where creek channels were well defined and visible, left and right banks were digitized from the 1999 and 2006 Manitoba Hydro digital orthographic photos. A scale of 1:5,000 was used to produce a vector representation of all perennial and a limited number of intermittent creeks in the Keeyask area. Digitizing was terminated at either upstream waterbodies (*i.e.*, Carscadden Lake) or where creek boundaries were no longer distinguishable on the photography. Where left and right creek banks were generally indistinguishable (*i.e.*, ill-defined channels due to the presence of peat), the centerline was digitized and buffered to a 3 m width to produce a more generalized representation of these creeks.

The Red Hen Systems geo-located aerial video was then used to locate and delineate habitat types, these included: riffle-run-pool sequences; glides; peatland pools; and peatland channels. Polygons were built to represent each habitat type cartographically and to determine the area of each habitat type.

3A.2.3.3 Creek Watershed Analysis

A spatial watershed database for selected tributaries in the study area was developed for the impact assessment. Existing federal hydrography and digital elevation datasets were identified for use in a GIS-based watershed mapping analysis.

The National Hydro Network (NHN 2009) was identified as the best available geographic information system (GIS) vector water features data set for the Keeyask area. An important feature of the dataset is the inclusion of a linear drainage network, in addition to the basic cartographic features. The network features are intended for water flow analysis, water and watershed management, environmental and hydrographical applications.

The Canadian Digital Elevation Data (CDED) (NHN 2009) digital elevation model was identified as the best available elevation data for the watershed analysis. The CDED consists of an ordered array of ground elevations at regularly spaced intervals. Elevation units are in metres above sea level relative to mean seal level. The appropriate CDED distribution tiles, managed by national topographic database 1:50,000 map sheet code, were downloaded for the study area. The tiles were then merged together prior to analysis.

Prior to beginning the watershed delineation analysis, a total of 188 study area tributary outlets were identified (Kelsey GS to Limestone GS). This was completed by spatially intersecting the 05UF000 NHN stream network with all major waterbodies in the study area. The NHN stream network, CDED digital elevation model, and tributary outlets were the three primary data inputs required for the analysis (Map 3A-6). The extension Arc Hydro (Maidment 2002) for ArcGIS ® was implemented for the drainage analysis. The three primary data inputs were used in the Arc Hydro model to delineate approximately 188 watersheds for the overall study area. The watersheds pertaining to the Keeyask area were selected out for further analysis and tabulation of areas.

3A.3 STEPHENS LAKE AREA

3A.3.1 SUBSTRATE

The following data collection and mapping methods were used to create substrate maps to describe the existing environment bottom type habitat of Stephens Lake (Section 3.3.2.4).

3A.3.1.1 Field Surveys

Substrate surveys were conducted in 2006 in selected study areas on Stephens Lake (Map 3A-7). The survey was conducted with a QTC Series V scientific grade echo sounder coupled to a Trimble Pro XRS sub-metre grade GPS. The transducer was positioned approximately 40 cm below the surface of the water adjacent to the hull of the boat. The echo sounder has a frequency of 50 kHz and was set to collect at 5-second intervals. Sonar data were processed using QTC Impact® acoustic waveform processing software. Data from 12–13 August, which included the four bays on the west side of Stephens Lake, were pooled together for multivariate analysis and classification. Acoustic data collected in the Kettle reservoir on 15 August was treated separately.

Substrate validation data were acquired during the acoustic sonar surveys carried out on 12–15 August 2006. At pre-selected points along planned transects, detailed bottom information was collected using a Ponar bottom sampler and aluminum probe. A total of 310 substrate validation sample sites complete with GPS co-ordinates, substrate type and composition were documented in Ross Wright Bay (n=123), O'Neil Bay (n=131), the North Open Bay (n=11), and the South Open Bay (n=45). This is a subset of the 524 total validation samples collected in 2005 and 2006 in support of the macrophyte study on Stephens Lake. Validation substrates were classified based on a simplified interpretation of the Wentworth particle size classification for granular materials (Table 3-2).

3A.3.1.2 Mapping

QTC Impact® uses principal component analysis to reduce the 166 acoustic elements or variables recorded in the field to three principal component variables (Q1, Q2, Q3) that contain greater than 90% of the variability found within the dataset. QTC Impact uses an unsupervised cluster analysis to group like samples together to form clusters of samples with similar bottom type acoustic response. The unsupervised classification approach requires user-supplied labelling of classes using validation data collected in the field after clustering. The unsupervised classification of the merged Ross Wright Bay, O'Neil Bay, and North and South Open Bay dataset resulted in six optimal acoustic bottom type classes. The distributions of classified QTC tracks for each of Ross Wright Bay, O'Neil Bay, and North and South Open Bays were mapped for further interpretation purposes. The Kettle reservoir dataset was classified separately and resulted in four acoustic bottom type classes. Classified QTC tracks were exported from QTC Impact (QTC 2009) and imported into ArcGIS 9.3 (ESRI 2009) GIS software for mapping. Classified acoustic sonar tracks were labelled with acoustic bottom type classes, according to their coincidence with the accompanying classified bottom type validation sites. The two datasets were then used to generate surface substrate maps for each of the four study areas by digitizing polygon boundaries around interpreted changes in substrate type.

3A.3.2 ROOTED MACROPHYTES

The following data collection, mapping, and analysis methods were used to describe existing environment rooted macrophyte habitat within Stephens Lake (Section 3.3.2.4) and to develop a predictive macrophyte model for the future Keeyask GS reservoir (Appendix 3C).

3A.3.2.1 Surveys

Areas of Stephens Lake that were historically inundated by impoundment by the Kettle GS in 1971 were surveyed in 2005 and 2006 to describe the existing aquatic habitat in previously flooded areas and assist in the development of a predictive aquatic macrophyte model. Species composition, abundance and distribution of vascular macrophytes and the variables that influence habitat preference (*i.e.*, water depth, slope, and substrate) were documented to support model development.

An aerial survey was conducted in late July, 2005, along the western shoreline of Stephens Lake to determine macrophyte bed locations and to direct the subsequent boat-based sampling program. Aerial video was captured along 72 km of shoreline using a GPS linked system (Red Hen Systems Inc., Fort Collins, Colorado) mounted on a Bell Jet Ranger helicopter. Aerial frame surveys were conducted at about 100 m above the lake surface. The locations of the macrophyte beds were recorded on maps.

From late July to early August 2005, 524 sites were visited by boat in the vicinity of Ross Wright and O'Neil bays in Stephens Lake and presence/absence macrophyte data and aquatic habitat information were collected. Macrophyte species were identified and at each location, water depth, bottom slope, and substrate type were recorded. Water depth (± 5 cm) was measured at the center of each plant stand using an incremented 5 m aluminium probe. Slope of the substrate was determined using the change in depth over a known distance using the aluminium probe, or a scientific-grade vertical echosounder operating at 50 kHz (QTC), coupled with Trimble Pro XR differential (sub-meter) GPS. Substrate type at the location of the macrophyte bed was classified based on texture or compaction with the probe, and/or with a 'Petit' Ponar dredge (bottom dredge sampler).

In early August 2006, sampling was directed to areas where plants were recorded as absent in 2005. Information from the first field survey was used to locate areas where plants were absent and boat-based sampling was used to collect depth, slope, and substrate information. Effort was stratified within the preferred water depth range observed in 2005, as well as above and below this depth range.

3A.3.2.2 Mapping and Data Analysis

Data collected in Stephens Lake were used to develop a predictive macrophyte model. Model development is described in Appendix 3C.

3A.4 REFERENCES

3A.4.1 LITERATURE CITED

Canadian Digital Elevation Data [Computer File]. 2009. Sherbrooke, Quebec: Centre for Topographic Information, Earth Sciences Sector, Department of Natural Resources Canada (Geobase) http://www.geobase.ca/geobase/en/find.do?produit=cded. [Accessed December, 2009].

ESRI 2009. ArcGIS Desktop: Release 9.3. Environmental Systems Research Institute. Redlands, California.

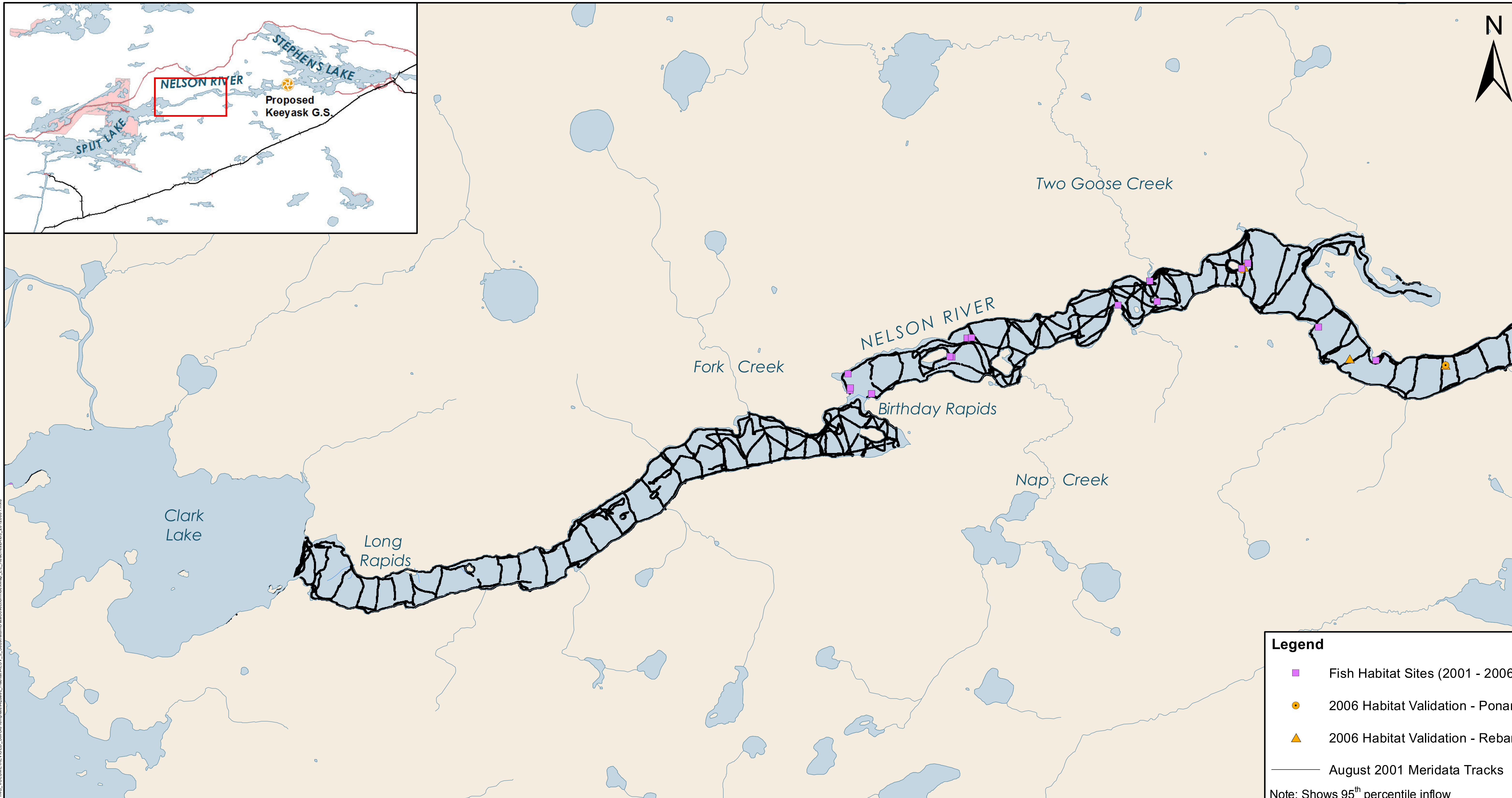
Heywood, I., Ceornelius, S., and Carver, S. 1998. An Introduction to Geographical Information Systems. Pearson Education Limited, New York, NY.

Maidment, D.R. 2002. Arc Hydro: GIS for water resources. ESRI Press. Redlands, California.

National Hydro Network (NHN) [Computer File]. 2009. Sherbrooke, Quebec: Centre for Topographic Information, Earth Sciences Sector, Department of Natural Resources Canada (Geobase) http://www.geobase.ca/geobase/en/find.do? produit=csc2000v&language=en. [Accessed December, 2009].

QTC 2010. QTC Impact Release 3.4. Quester Tangent Corporation. Sannichton, British Columbia.

Trimble 2009. GPS Pathfinder Office: Release 2.9. Trimble Navigation Limited. Sunnyvale, California.



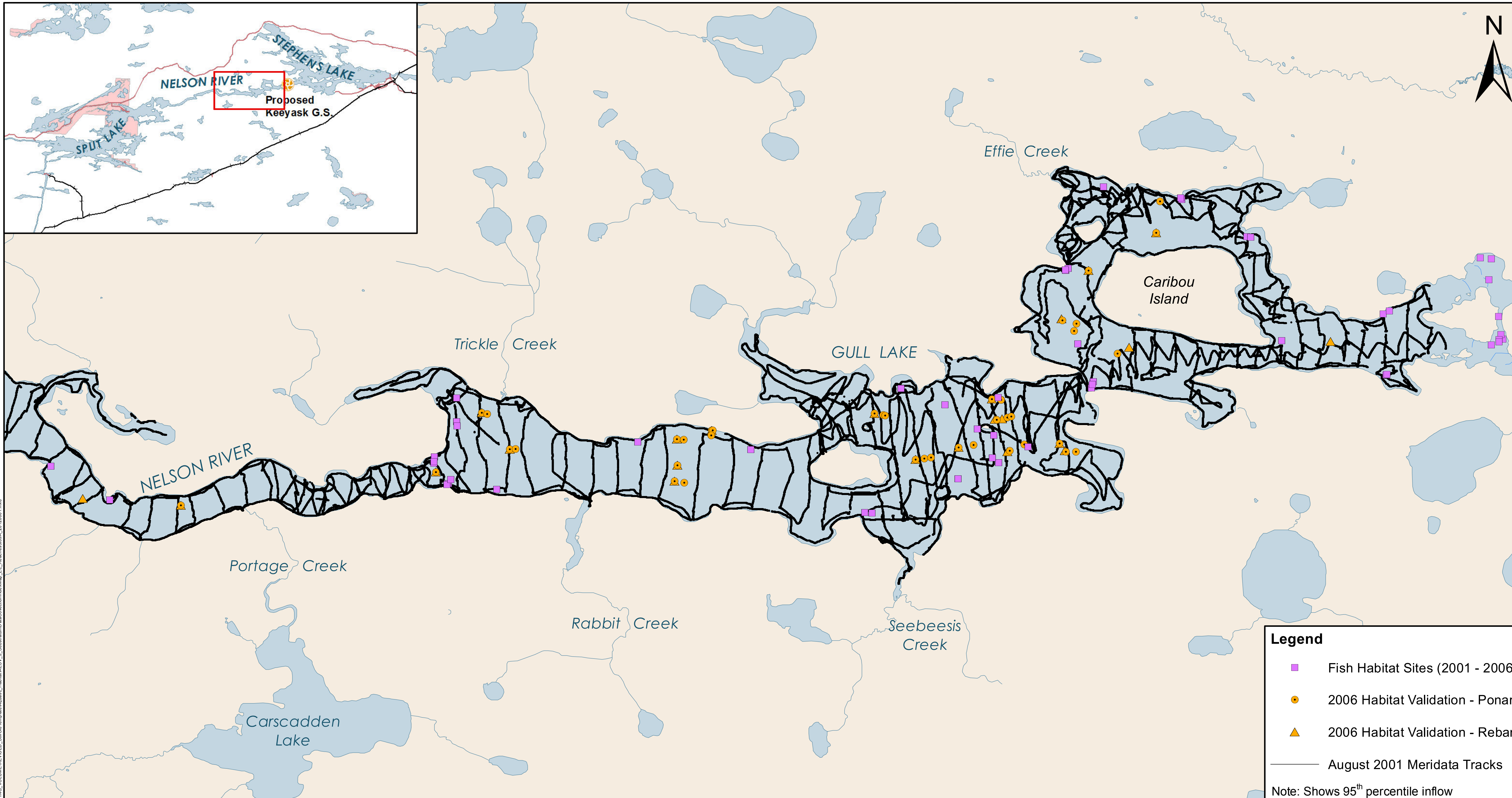
KEEYASK Hydropower Limited Partnership

0 2.5 5 Kilometres
0 1 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

Substratum Data Collection Index Map

Existing Environment - Reaches 2A - 5

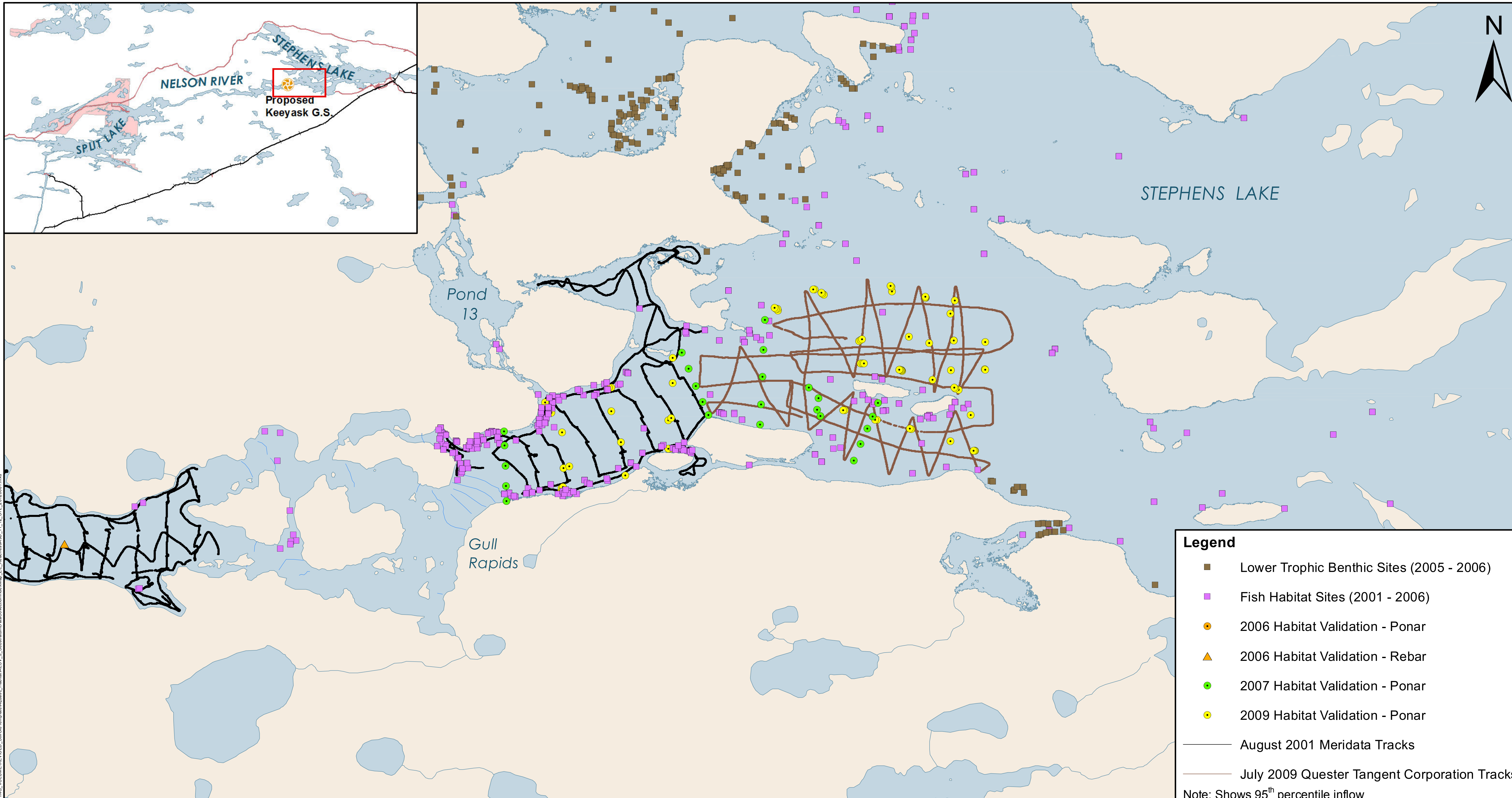


Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000,
Stephens Lake Shoreline-Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro

Substratum Data Collection Index Map

Existing Environment - Reaches 5 - 9A

Map 3A-2



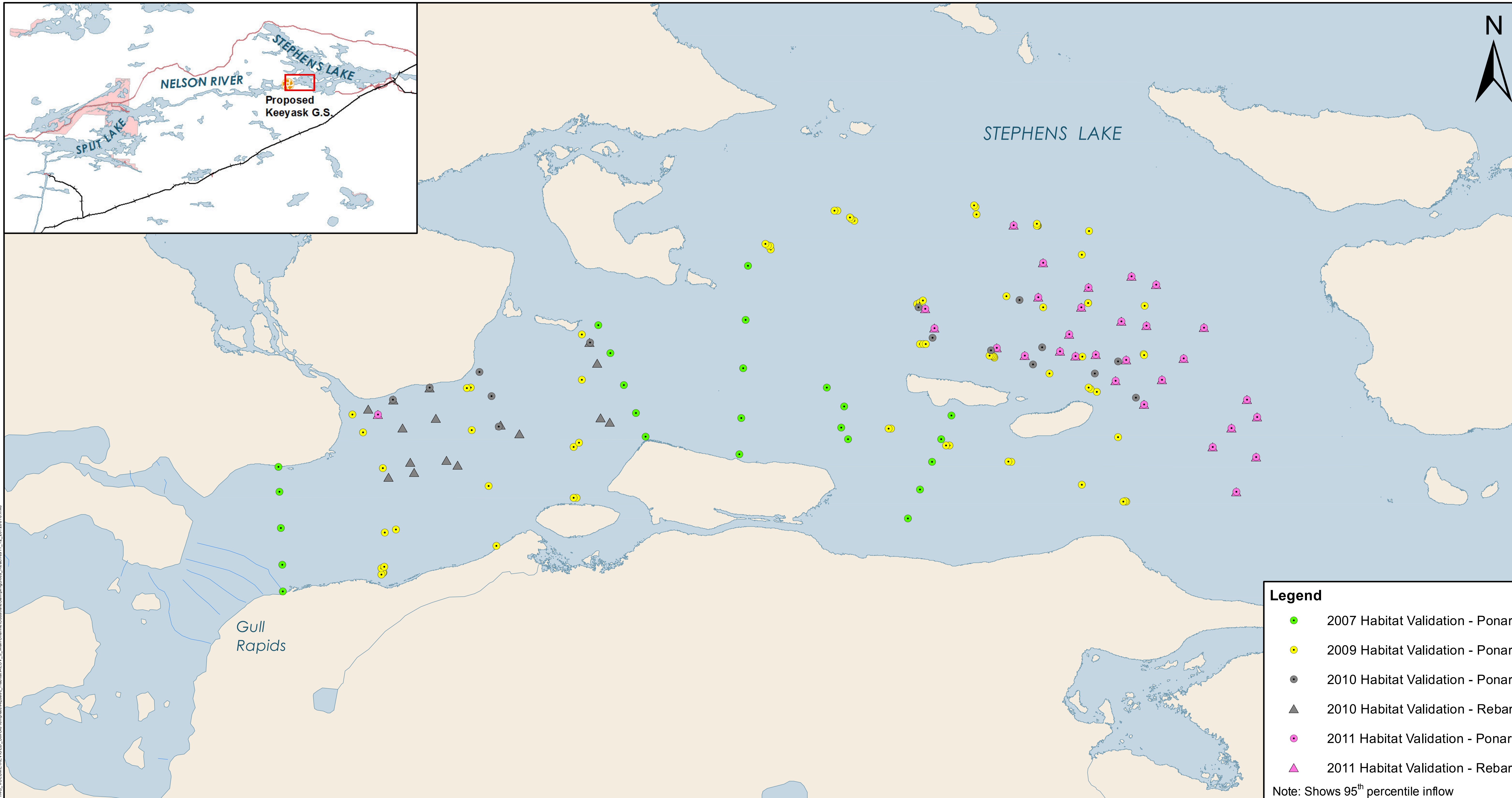
KEEYASK
Hydropower Limited Partnership

0 1 2 3 Kilometres
0 0.5 1 1.5 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

Substratum Data Collection Index Map

Existing Environment - Reaches 9A, 9B, 11,12
and Stephens Lake



KEEYASK Hydropower Limited Partnership

0 1 2 Kilometres
0 0.5 1 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

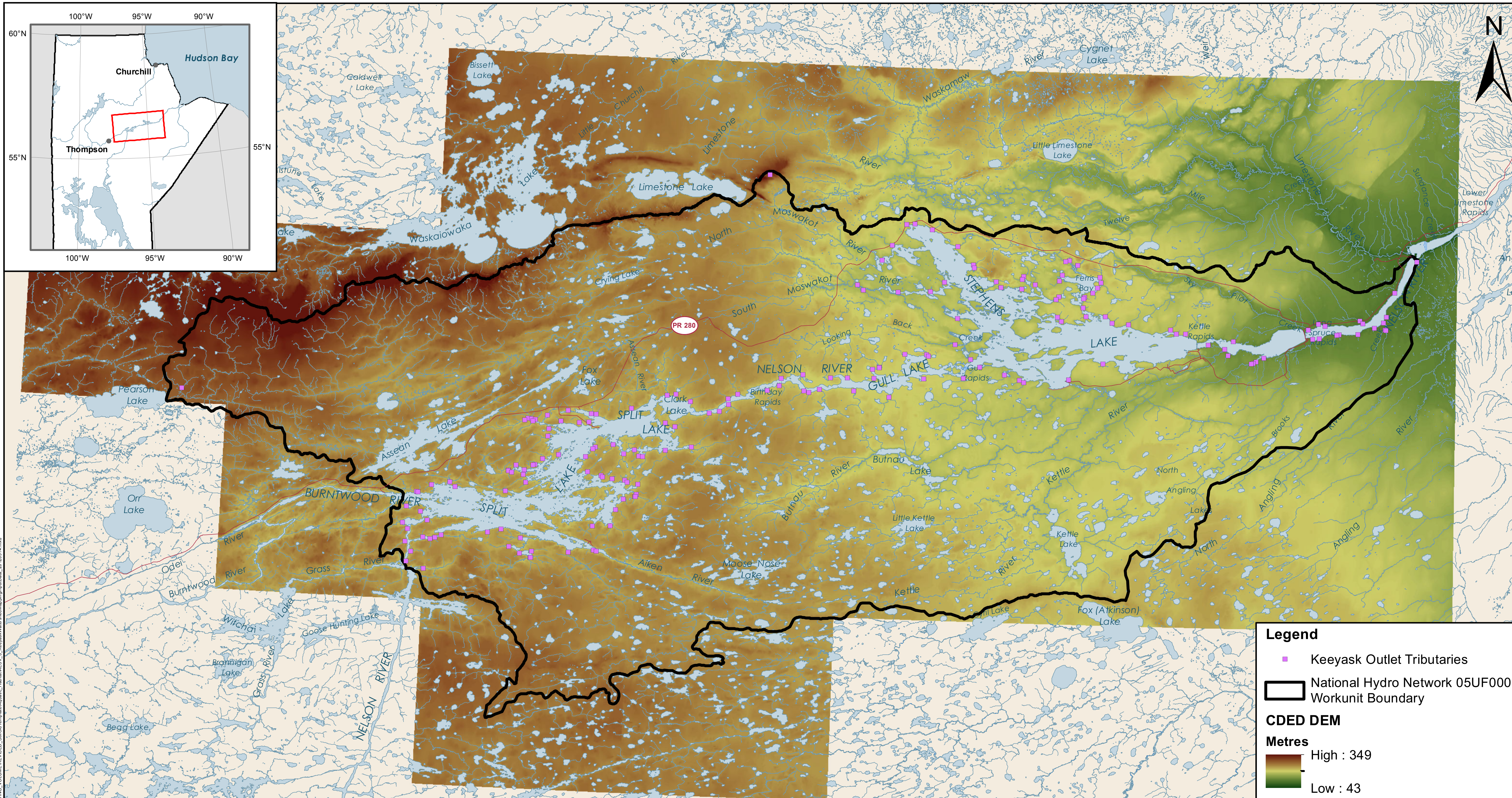
Main Channel Substrate Sampling Sites

Existing Environment - Reaches 11 and 12

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

Redhen Data Collection Helicopter Survey Tracks for Stream Habitat Assessments

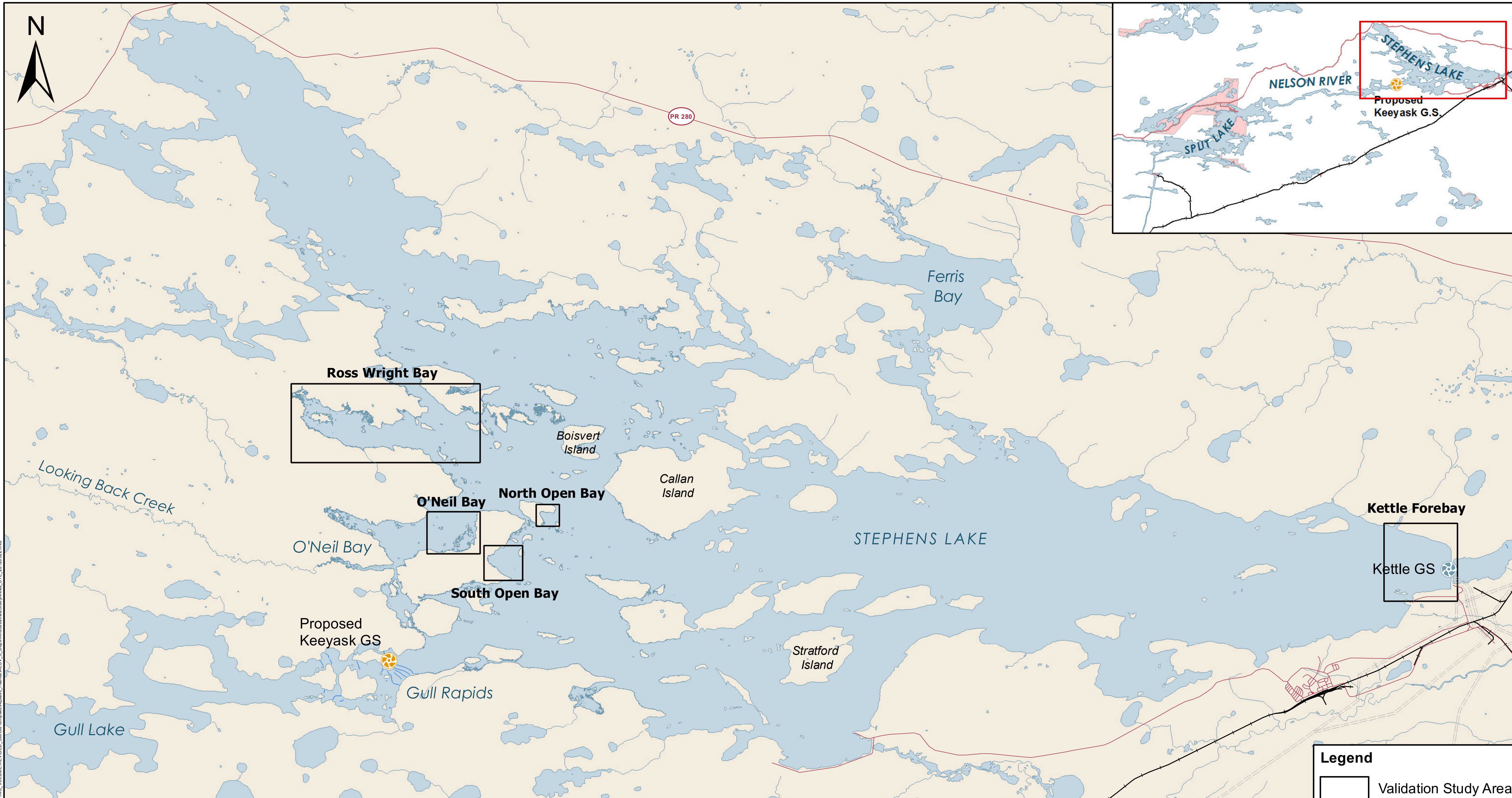


0 10 20 30 40 Kilometres

0 5 10 15 20 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

Keeyask Watershed Mapping Input Data



KEEYASK Hydropower Limited Partnership

0 5 10 Kilometres
0 2.5 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

Depth and Substrate Study Areas
Stephens Lake

APPENDIX 3B
DEVELOPMENT OF RESERVOIR HABITAT AND MODELS TO ESTIMATE AQUATIC HABITAT AVAILABILITY IN THE KEEYASK RESERVOIR 30 YEARS AFTER FLOODING

3B.1 INTRODUCTION

This appendix presents a summary description of the development of aquatic habitat in riverine and lacustrine sections of reservoirs in the lower Nelson River at Year 30, and provides a summary of four spatial models used to estimate aquatic habitat availability in the Keeyask reservoir at this time step. The modelling work has built upon the results of physical environment studies that estimated post-Project shoreline, water depth, and depth averaged velocity for initial full supply level (initial FSL) conditions, and the estimated size and shape of the reservoir for Year 30 derived from models of peatland disintegration and shore erosion (PE SV, Section 4, Section 6, and Section 7).

Three models were used to estimate substrate distributions in the proposed reservoir and the fourth was used to estimate potential macrophyte habitat. For the substrate predictions, two lentic and one lotic model were used. For standing water habitat, a published deposition model was used for the offshore zone of the reservoir, and a second model was developed from flooded areas of Stephens Lake to estimate the areas where fine organic deposition would occur in bays. For lotic reservoir habitat, a deposition model was developed using data from the lower Nelson River, including the Keeyask area, Stephens Lake, and the Nelson River between the Limestone GS and the Long Spruce GS. The lotic deposition model was run twice to estimate the pattern of deposition at 95th and 5th percentile inflows. All model results were integrated to estimate the state of habitat for Year 30 post-Project. The fourth model, the predictive macrophyte model, is summarized here in brief. The full text describing the model development and validation is found in Appendix 3C.

Certainty in model predictions was assessed by means of Cross Validation and the Relative Operating Characteristic.

3B.2 DEVELOPMENT OF YEAR 30 RESERVOIR HABITAT

The evolution of reservoir habitat from flooded terrestrial and flooded aquatic habitat is complex and depends in part on the design of project-specific infrastructure, and how this intersects with the local topography. The elevation of the proposed water level on the pre-flood topography determines the shape (*i.e.*, size, depth, and geometry) of the reservoir (PE SV, Section 4), and the distribution of inundated soil types (Terrestrial Environment Supporting Volume [TE SV], Section 2.3.4.2 and Map 2.3-4. The shape of the reservoir, in turn, controls the expression of hydraulic energy (PE SV, Section 4 and Section 5), in the form of waves and currents and the relative position of water masses within the reservoir.

Over time, habitat in the reservoir develops through the interaction of these physical processes in areas of relatively high magnitude change. Habitat in reservoirs changes from flooded terrestrial or flooded aquatic habitat via the processes of erosion, transport, and sedimentation (PE SV, Section 6 and Section 7). Areas where effects are relatively small at Year 30 (*i.e.*, the habitat is altered but not markedly changed) remain similar to the initial FSL aquatic habitat and still resemble their basic pre-flood characteristics.

In the Keeyask area, the study of pre-flood soils and land cover (TE SV, Section 2.3.4.2) show that a generalized land cover sequence is apparent in the ecosite data that consists of three land cover types. The topographic sequence of mineral, thin peat, and deep peat is common in the study area (Figure 3B-1). This landcover sequence determines most of the locally available surficial and parent materials for redistribution in the reservoir.

Section 3B.2.1, Section 3B.2.2 and Section 3B.2.3 provide a basic description of the development of Shallow and Deep habitat for the Keeyask reservoir at Year 30 as understood from studies of Stephens Lake and, to a lesser extent, the Limestone reservoir. Each section below describes a major habitat type and provides a link to a model found in Section 3B.4. that predicts that type of habitat distribution.

3B.2.1 DEVELOPMENT OF SHALLOW WATER HABITAT IN FLOODED TERRESTRIAL AREAS

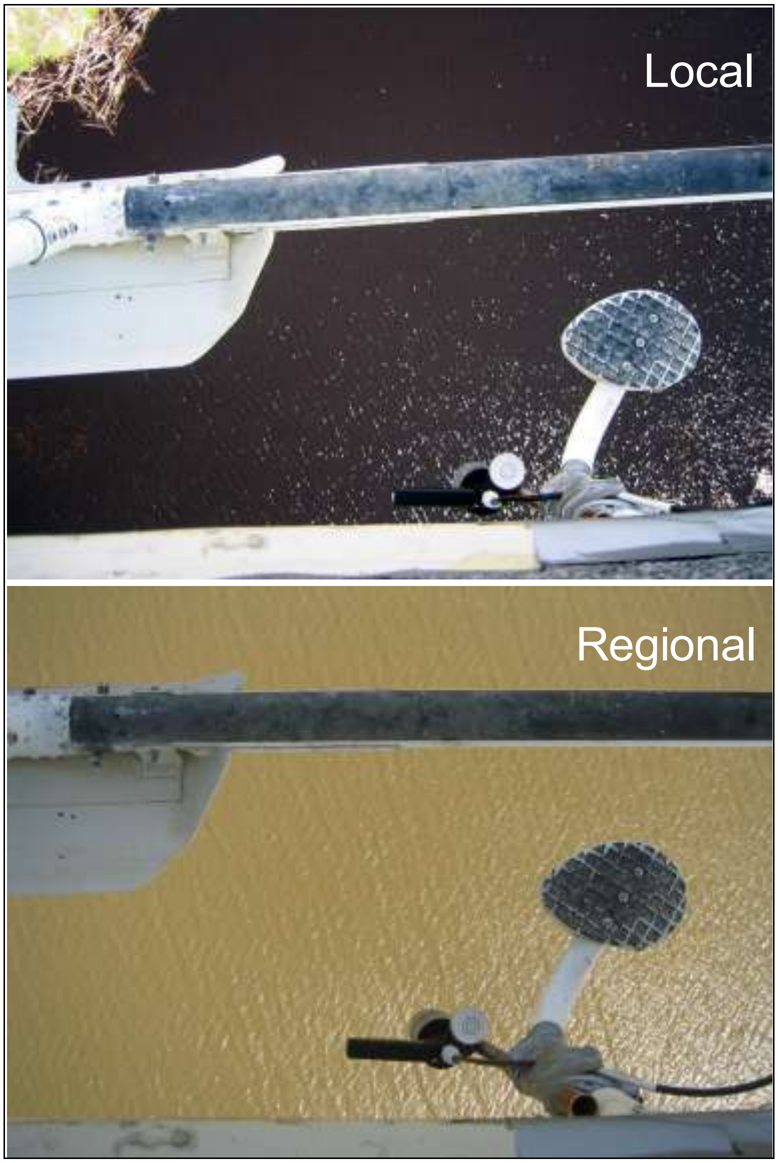
The water masses in the flooded thalweg of the Nelson River in Stephens Lake are markedly different than those of the surrounding peatland watersheds (Section 2). The water masses can be divided into local, mixed, and regional water masses (Map 3B-1) based on multivariate analysis of the water quality and light attenuation characteristics (Figure 3B-2). Local water masses appear tea-stained, are derived from peatland watersheds, and are adjacent to the Nelson River, which enters the Stephens Lake area with higher turbidity (Photo 3B-1).

Persistent deposition of fine organic material (FOM) in Stephens Lake typically occurs when a tributary of sufficient drainage area pools Local peatland water in the terminal end of a bay. The pool of Local water prevents the sediment-rich water of the main reservoir from fully diffusing through the entire bay. The ends of flooded bays in the reservoir tend to be peatlands before flooding (TE SV, Section 2.3.4.2 and Map 2.3-4). The persistent accumulation of FOM at the ends of flooded bays results from the exclusion of water with higher suspended sediment concentration from an area that has abundant sources of organic material (from local peatlands and via stream inflows).

The area where the Local and Mixed water masses meet determines the boundary between the fine organic deposition and the zone of silt deposition. The zone of silt deposition in deep water is the dominant bottom type in the Stephens Lake reservoir.

Mixed water masses tend to be more dilute than Regional water masses (Section 2) and so rates of silt deposition from mixed water masses appear to be lower than most of the main basin. Near surface Ponar grab samples in areas with Mixed water masses show a layered sample where silt has superimposed the pre-flood inundated peatland soil. The deposits of silt are relatively deep and homogenous farther offshore in areas of Regional water masses. The changes in bottom type of the flooded terrestrial bay forms a sequence where organic deposition changes to silt deposition. Silt deposition appears to cover the entire Lentic flooded terrestrial habitat that is not influenced by waves and/or slope (Photo 3B-2).

The model that predicts the depositional boundary between fine organic material and silt is described in Section 3B.4.3.



Source: North/South Consultants Inc. (P. Cooley), 2006

Photo 3B-1: Aerial view of Local and Regional water masses observed in the western end of Stephens Lake

Source: North/South Consultants Inc. (P. Cooley), 2006

Photo 3B-2: Ponar samples taken from Shallow Lentic habitat within a flooded terrestrial bay showing (A) fine organic deposition from the end of a bay in a peatland water mass, (B) layer of silt covering pre-flood peat in a mixed water mass, and c) homogenous silt deposit in Deep habitat near the main reservoir

3B.2.2 DEVELOPMENT OF NON-DEPOSITIONAL HABITAT IN SHALLOW LENTIC AREAS

Studies of the shallow water habitat in flooded areas of the west end of Stephens Lake about 30 years after flooding show that pre-flood thin peat soils or mineral soils, inundated in shallow water in moderate to high exposure, erode through the thin peat (if present) down to the mineral parent material (Figure 3B-3). The reworking of peat veneer or deep mineral soils by wave action over time forms a nearshore slope that is a mainly cohesive clay matrix with a smaller amount of sand to cobble surface lag found in the swash zone (Photo 3B-3). About 79% (109/137) of all samples taken in Stephens Lake from areas that were either deep mineral or peat veneer before flooding evolved into clay-based samples by 2005 or 2006. Other nearshore slopes formed from glaciofluvial deposits tend to have more sand/gravel, or infrequently, cobble in the study area. The clay substrate that forms in shallow water receives enough wave energy and is of sufficient slope to remain free of silt; further, much of this shallow water habitat is located within the IEZ of water level variation that may also move materials down slope. The clay-based bottom that forms from mineral soils, with or without a thin mantle of peat, provides a nutrient rich and cohesive fine-grained substrate that is potential macrophyte habitat. Studies of Stephens Lake showed that silt was found in Lentic habitat below the clay nearshore areas, which was deeper than the effects of waves. The shallow depth bound of the 95% confidence interval of the mean depth of sediment is 3.4 m (n = 100). This near minimum depth of silt is the same as the maximum depth observed for rooted macrophytes.

A model from the published literature with extensive validation was used to estimate the water depth at which silt deposition would occur in standing water areas of the Keeyask reservoir below the effects of waves (Section 3B.4.2).

3B.2.3 DEVELOPMENT OF DEEP WATER HABITAT IN FLOODED TERRESTRIAL AND FLOODED AQUATIC HABITAT

Studies were undertaken to understand the character of deep-water habitat in the lower Nelson River. The studies from Stephens Lake and Limestone reservoir contrast two different types of reservoirs. The Limestone reservoir represents a riverine reservoir contained mainly within the original river valley (*i.e.*, a large increase in depth relative to area) whereas Stephens Lake is mainly lacustrine as it was formed over a wide area of low relief (large increase in area relative to depth). While both reservoirs have similar maximum depths (*i.e.*, about 32 m) they have notably different thalweg habitats after flooding. The shape of the flooded topography appears to determine if the thalweg substrate will be changed (*e.g.*, cobble to silt) or altered (generally similar bottom composition but with areas of change like bank materials).

Source: Lynden Penner, J.D. Mollard and Associates, 2005

Photo 3B-3: Clay nearshore substrate with granular surface lag, formed in Stephens Lake

Information on depth, substrate, velocity, and exposure (see Appendix 3C 2.1.1) in the central thalweg of the Limestone reservoir showed that the substrate remained hard (*i.e.*, rock) with some finer infill materials. In the Limestone reservoir it appears the thalweg habitat was altered mainly by an increase depth and decrease in velocity given that river currents remained confined to a U-shaped channel; this appears to have maintained the dominant composition of the pre-flood thalweg character except in the area immediately upstream of the dam. In contrast, the habitat type of most of the flooded thalweg within Stephens Lake changed to silt deposition (Section 3.3.2.4) even in areas that were observed as lotic habitat during acoustic Doppler surveys (Appendix 3A) due to the increase in depth and loss of channel confinement. Substrate in some areas of the thalweg below Gull Rapids did not become depositional given currents remained in a riverine channel and depth changes due to the Kettle GS were relatively small.

A lotic deposition model was developed from these studies to estimate the distribution of deposition in the thalweg of the proposed Keeyask reservoir, which is expected to have both riverine and lacustrine-like reaches (Section 3B.4.1). This model extends the results that describe the rate of mineral sedimentation studies (PE SV, Section 7) by being spatially explicit for Year 30.

3B.3 MODELLING APPROACH

3B.3.1 MODELS TO ESTIMATE AQUATIC HABITAT AVAILABILITY IN THE KEEYASK RESERVOIR 30 YEARS AFTER FLOODING

Four spatial aquatic habitat models were developed to estimate habitat availability in the Keeyask reservoir (Table 3B-1) at about 30 years after flooding. Three models were derived to predict the presence or absence of deposition that underlies either lentic (standing) or lotic (flowing) water masses. Two of the depositional models estimated the distribution of mineral deposition (*i.e.*, silt) and the third estimated the distribution of fine organic material. The fourth model predicted the presence of absence of suitable habitat for *Potamogeton richardsonii* and *Myriophyllum sibiricum*, the two dominant species of macrophyte found in flooded habitat of Stephens Lake. The development of a predictive macrophyte model designed for application on the proposed Keeyask reservoir is described here in brief, and in detail in Appendix 3C.

3B.3.1.1 Data Sources and Uncertainty

Initial FSL datasets representing depth, maximum fetch, exposure, and slope were used to estimate the aquatic habitat distributions. The initial FSL data represents the existing environment topography with the only ecological change being the addition of the full supply water level. This approach was adopted when the results of the physical environment studies suggested that changes in the shape of the reservoir over time are relatively small when compared to changes due to initial FSL. Changes in bottom topography in the nearshore zone are expected to occur between initial FSL and Year 30 and are due mainly to peat resurfacing, mineral shore erosion, and mineral sedimentation. A summary follows that describes these changes in order explain the applicability of the initial FSL topography as a proxy for Year 30.

3B.3.1.1.1 Peat Resurfacing

Any effect of peat resurfacing on the bottom topography of the Keeyask reservoir between Initial FSL and Year 30 would be most marked in shallow water where hydrostatic pressure does not keep the peat on the bottom (PE SV, Section 6).

Laboratory analysis of peat resurfacing potential after flooding reveals that the fibrous surface layer (O_f) has the lowest specific gravity and is typically the only layer that floats to the surface after separating from the mesic or humic layers below(PE SV, Section 6). The composition of the dominant peatlands within the predicted flooded area would be 40% veneer bog, 26% blanket bog, and 23% peat plateau bog. These peatland types have O_f thicknesses that average 0.22 m, 0.37 m, and 0.25 m, respectively (PE SV, Section 6). These O_f thicknesses are less than half the 1 m contour interval and therefore are within the error of the post-Project initial FSL depth map. Therefore, the effect of peat resurfacing on bottom topography is small given that almost 90% of the flooded area has layers of peat that have some potential to uplift, which are thinner than the error inherent in the Initial FSL elevation model.

3B.3.1.1.2 Mineral Soil Erosion

Bank recession distances projected over the 30-year modelling period for the Keeyask Project average 4.8 m/year (y), with a maximum of 40.8 m at highly exposed sites (PE SV, Section 6). Maximum bank recession distances without the Project were estimated at 0.4 m/y, or a maximum total recession of about 12 m over the 30-year period. A maximum incremental bank recession of 29 m can be attributed to the Project after 30 years. The changes in the shape of the reservoir over time are therefore relatively small when compared to changes incurred from initial FSL. For example, when the depth of fine mud deposition is estimated (Model # 2 in Table 3B-1) for a 7 km fetch common to the lower reservoir with a 4% slope and then again with the additional 29 m attributed to the Project, the estimated water depth where deposition begins changes from 1.59 m to 1.60 m.

3B.3.1.1.3 Mineral Deposition in Lentic and Lotic Habitat

Sediment coring and ground penetrating radar were used to study sedimentation processes in the lower Nelson River in 2006 for studies in support of PE SV, Section 6. In Stephens Lake, sampling was undertaken at eight sites along transects from the shoreline to about 200 m in the offshore direction. Sampling was directed to study nearshore processes, and did not target the main depositional basins of the reservoir or the pre-flood thalweg of the river. Results demonstrated a general fining of grain sizes with increasing water depth and distance from shore, except where slope was sufficiently high to refocus materials downward. Sediment thickness above pre-flood strata was lower in lotic sites than lentic sites, and the proportion of organic material deposited with the mineral sediment was greater in lentic sites. Glacial deposits that lack either mineral or organic deposition from Stephens Lake were observed on the upper beach slope at some sites, indicating that the upper beach slope is primarily an erosive environment with little fine-grained sediment deposition occurring above the wave base depth. Average sedimentation rates in Stephens Lake since impoundment and below the effect of waves were often 1 cm/y, but can be as high as 2.4 cm/y.

An average nearshore depositional rate of 1 cm/y multiplied by 35 years (1971–2006) equates to an average deposit thickness of 35 cm. In deep water, this change in depth is small relative to the depth in the Initial FSL map and would therefore not have a measurable effect on the results of any model applied. In lentic habitat, silt deposition would be expected below the effects of waves, water levels, or where slope also increases the depth of the depositional boundary. This, however, would not change the location of the silt boundary and only marginally decreases the depth. If peat uplift at a site below the effects of waves occurred shortly after flooding then the silt deposition would likely result in filling the "crater" to an elevation similar to that of the surface of the substrate at initial FSL.

3B.3.1.2 Analysis Methods

Logistic regression and Linear Discriminant Analysis (LDA) are multivariate methods that are suited to the multi-variable data required to estimate reservoir habitat based on conditions before and/or after flooding. Each method has different data requirements and employs a different analytical method, but both result in a predicted outcome that is classified (*i.e.*, nominal) based on a probability value. Classification of objects into groups enables an assessment of the performance of the model by comparison of the agreement between observed and predicted classes, referred to as cross-validation. Both methods also support "block entry" or "stepwise" methods of analysis that describe how the variables are analyzed. Block entry methods analyze all variables together as a group, whereas stepwise methods evaluate the contribution of each variable to the model, and conditionally, drop the variables that do not improve the model significantly.

3B.3.1.2.1 Logistic Regression

Logistic regression is used for predicting the probability of an event by fitting data to a logistic curve, which is sigmoid in shape. Logistic regression is a generalized linear model used for binomial regression. It makes use of several predictor variables that may either be numerical or categorical to predict a binary response variable (0 or 1, presence or absence). Classification of each observation into one of two binary response variables typically is undertaken at a probability of 0.5 "cut" threshold. This type of regression is often used in ecological studies to determine what factors are responsible for the presence or absence of a species.

3B.3.1.2.2 Linear Discriminant Analysis

Linear discriminant analysis (Manley 1994) considers a division of objects into groups by reducing the number of dimensions in the data, develops a predictive model, and supports cross validation to assess the agreement between observed and predicted classes. A predictive model is constructed for known groups (k) that are known *a priori* based on the linear combinations of the available environmental variables (p) that best discriminate among the groups. The number of discriminant axes is the smaller of k – 1 or p. Like the one way Analysis of Variance (ANOVA), the LDA maximizes the F ratio by forming linear composites that maximize the inter- to intra-class variation over k. Each observation in the LDA results with a probability of being assigned to each of the groups; the class with the highest probability is assigned to the observation. The relative contribution of each variable to the LDA can be examined by review of standardized discriminant function coefficients (Legendre and Legendre 2004). The equations of the LDA analysis are provided by the Fishers Discriminant Function coefficients. LDA may be preferred over logistic regression when the number of groups required of the predictive model is greater than two (Pohar *et al.* 2004).

3B.3.1.2.3 Cross-Validation and the Relative Operating Characteristic

Cross-validation is a technique for assessing how the results of a statistical analysis will generalize to an independent dataset. This method is generally used when the goal of the analysis is prediction, and an estimate is needed that shows how well predictive model will perform in practice. Cross-validation involves partitioning a sample of data into complementary subsets, performing the analysis on one subset used to develop the model (*i.e.*, the model set), and validating the analysis on the other subset (*i.e.*, the test set). In this manner, predicted classifications generated from the model subset are compared against the test subset for which the group association is already known. The overall agreement, in percent, is used to suggest how well the model would run under similar conditions on a different dataset.

Selection of observations into model and test groups for each of the models was undertaken by selecting one in every three or four records (depending on the size of each dataset) in the database, which was considered the test validation group and was not used in model building. This systematic sampling was undertaken to ensure all ecotypes were represented in the test group.

The relative operating characteristic (ROC) is a comparison of true positive responses and false positive responses of a classification (Egan 1975; Swets 1988). The ROC may be may be reduced to a single value to facilitate comparison of expected classification performance. A common measure of ROC is that of the area under the curve where the values range from 0.5 to 1.0. Relative operating characteristic values of 0.5 infer the model classifies only about as well as a random model and ROC values approaching 1.0 indicate a perfect fit (*i.e.*, only true positive classification results).

3B.4 PREDICTIVE HABITAT MODELS FOR THE KEEYASK RESERVOIR 30 YEARS AFTER FLOODING

3B.4.1 ESTIMATING THE DISTRIBUTION OF DEPOSITION WITHIN LOTIC HABITAT

An empirical model to estimate the presence or absence of deposition in lotic areas of the proposed Keeyask reservoir was derived from depth, velocity, and exposure data (n = 171) (Table 3B-2) from data collected during habitat survey (Appendix 3A). The depth averaged velocity data were those introduced in Section 4 of the PE SV.

The range in model estimates was assessed under low and high flows by substituting either the 95th FSL or 5th minimum operating level depth-averaged velocity and exposure percentile conditions for these data (n=60; Table 3B-2). Samples finer than sand (*i.e.*, mostly clay and silt) were considered depositional.

A binary logistic regression model was fitted to the lotic deposition/no deposition data. The logistic model was derived from 75% (n = 130) of the available data, referred to as the Model group, by entering the data in a forward stepwise procedure using the variables: 1) site depth (m), 2) exposure (m), and 3) depth-averaged velocity (m/s). Likelihood-ratio tests were used to determine the statistical significance of explanatory variables. Classification agreement and performance was assessed using cross-validation and by means of the ROC.

Cross-validation was undertaken by running the lotic deposition logistic model on the remaining 25% (n = 41) of the data for which class membership was known, but was excluded during model building. These validation samples are referred to as the Test group.

Logistic regression equations to estimate deposition in lotic habitat:

i) 5th percentile inflow

Lotic deposition $_5$ = 0.7336 + 0.182479 *depth* + 0.000836 *exposure* - 22.429063 *velocity*

ii) 95th percentile inflow

Lotic deposition $_{95}$ = 1.6099 + 0.052980 *depth* + 0.001530 *exposure* - 17.42653 *velocity*

Forward stepwise logistic regression results show that velocity, depth, and exposure together provided the best model for the 5th and 95th percentile model runs (Table 3B-3). As expected, depth-averaged velocity was a highly significant variable (Table 3B-4) for describing the presence or absence of deposition in both models. For the 5th percentile model, the contribution of depth was also significant; whereas, in the 95th percentile run, the role of exposure was important (*i.e.*, nearly significant).

Logistic regression results do not lend well to graphical presentation so trends in the data are shown using principal component analysis (PCA). The PCA results are visually similar for the 5th and 95th percentile inflows and the first two component axes in each trial explained about 85% of the variance in the data. For the 95th percentile PCA (Figure 3B-1), the first principal component represented contributions from both exposure and depth, which combined explained most of the variance along that axis (85%); whereas, the second component was dominated by depth averaged velocity (83%). Figure 3B-1 shows that depositional sites tend to be those that had relatively high exposure and water depth at moderate velocity (*e.g.*, Kettle reservoir), or low velocity at moderate exposures and depth (*e.g.*, Stephens Lake thalweg). Sites without deposition tended to occur where velocity is relatively high and where depth and exposure is moderate or low (*e.g.*, central thalweg of Limestone reservoir or the lotic areas of the Keeyask Study Area). In particular, sites upstream of Gull Lake (where the Nelson River flows are fast, the channel is narrow and relatively shallow) are readily apparent in the upper left corner of the biplot.

Cross-validation results employed in the logistic regression analysis showed that classification agreement for the 5th and 95th percentile inflow scenarios was excellent, ranging between 82% to 91% (Table 3B-5). The Test group was not included in model building and provided agreement slightly lower than the

Model group (5–6% lower), as could be expected from a relatively small sample size when compared to the Model group. The deposition class in the Test group achieved 73% agreement. Cross-validation results suggest that the lotic deposition model can correctly classify depositional sites 73% of the time, but can be as high as 83%.

The area under the ROC curve for these according to the 95th percentile inflow and 5th percentile inflow is: $ROC_{95} = 0.967$, $ROC_{5} = 0.948$

where ROC = 1 indicates a perfect fit; and ROC = 0.5 indicates a random fit.

According to the ROC assessment approach, the lotic deposition model has a probability of assigning a true positive result about 95–97% of the time.

The cross-validation and ROC methods of assessment both suggest a strong predictive capacity is achieved in the lotic deposition model. This is evident in Map 3B-2, which compares the predicted bottom type (deposition/no deposition) to the data observed in the field. Map 3B-3 shows the modelled distribution within the lotic habitat area.

3B.4.2 ESTIMATING THE MUD DEPOSITION BOUNDARY DEPTH

Equation 25 of Rowan *et al.* (1992) predicts the presence or absence of deposition in standing water. The boundary between depositional and non-depositional areas is referred to as the mud depositional boundary depth (Mud DBD) that results due to waves and/or from slope due to the tractive force of gravity creating sheer stress. The presence or absence of deposition is estimated using the variables: site depth (m), maximum fetch (km), and slope (%). Equation 25 was derived from empirical data gathered from 54 lakes over a wide range in size in temperate Canada and the northern United States. In a reservoir drawdown study, Cooley and Franzin (2008) conducted a detailed validation of this equation in a drawdown experiment and found remarkable agreement between the observed and modelled deposition distributions.

Deposition is defined as particles that are smaller than 23 um or 5.5 phi, or greater than 60% water content.

Logistic regression equation to estimate the mud DBD:

$$\text{Mud DBD} = -0.107 + 0.742 \log \textit{Maximum Fetch} + 0.0653 \textit{ slope}$$

Rowan *et al.* (1992) show that this equation correctly classifies 683 out of 783 (87%) of fine grained sites and 344 out of 477 (70%) of coarse grained sites from which the model was built.

The extent of silt deposition below the effects of waves was estimated for lentic areas of the lower reservoir using Equation 25 (Rowan *et al.* 1992), the initial FSL depth map, a slope map (%), and a map of maximum fetch distance. This model predicts a zone of no deposition that often appears as a band that follows the perimeter of the reservoir and islands due to wave energy or slope. The lower extent of this zone is delineated as the Mud DBD, below which deposition was predicted for all of the remaining lentic areas.

To assess the validity of the results modelled by Equation 25 for the Keeyask reservoir, the extent of the wave-washed zone mapped according to Equation 25 was scrutinized further by comparison to empirical data from Stephens Lake. Keeyask aquatic studies show that both of the two dominant species of rooted macrophyte are found in shallow water areas above the silt boundary. The upper extent to the distribution of deposition estimated by Equation 25 appears as a band along the shoreline. The width of this band was compared visually to empirical data describing the distance from each plant stand to the shoreline (Figure 3B-4).

The width of the zone between the shoreline and the silt boundary estimated by Equation 25 was 60–75 m wide for most of the lower reservoir, but was as wide as 300 m in a few areas. These distances are in good agreement with measured distances between each plant stand and the shoreline at Stephens Lake. The average distance between the shoreline and stands of *Potamogeton richardsonii*, the most abundant species, was 60 m but ranged as far as 352 m.

The mapped results of this model are provided with those of the next model, described below.

3B.4.3 ESTIMATING THE DISTRIBUTION OF DEPOSITION BY FINE ORGANIC MATERIAL

A binary logistic regression model was fitted to FOM and silt substrate data (n = 238) obtained from flooded areas of Stephens Lake collected during the Keeyask aquatic studies to predict the boundary between FOM and silt substrata in peatland bays. The logistic model was derived from 75% (n = 179) of the available data, referred to as the Model group, by entering the data using a forward stepwise procedure using the variables: site depth (m), exposure (m), and slope (%). Likelihood-ratio tests were used to determine the statistical significance of explanatory variables. Classification agreement and performance was assessed using cross-validation and by means of the ROC.

Cross-validation was undertaken by running the FOM logistic model on the remaining 25% (n = 59) of the data for which class membership was known, but was excluded during model building. These validation samples are referred to as the Test group.

Logistic regression equation for estimating the distribution of FOM:

$$FOM = 5.008 - 0.710\,Depth - 0.003\,Exposure - 0.438\,slope$$

3B.4.3.1 Logistic regression statistics

The explanatory variables bring significant information to the model when compared to the model using only a constant (Table 3B-6). Stepwise results demonstrated three variables provided the best model fit, with each step forming a significant improvement to the model (Table 3B-7). The contribution each variable to the model (in the form of standardized coefficients) is shown in Table 3B-8. Exposure contributed most to the model with a highly significant effect on model form. The effect of depth and slope was also significant, but the role of slope was only about half as important as that of exposure.

3B.4.3.2 Classification agreement and ROC performance

Cross-validation results (Table 3B-9) show that overall classification agreement of the Model group and Test group is 79.9% and 79.7%, respectively. Similarity in percent agreement suggests that the sample size of the Model group was sufficiently large and likely represents all of the data found in the Test group. Results suggest that the FOM model will correctly classify FOM sites about 83% of the time.

The area under the ROC curve for these data is: ROC = 0.908

where ROC = 1 indicates a perfect fit; and ROC = 0.5 indicates a random fit.

According to the ROC assessment approach, the FOM model has a probability of assigning a true positive result about 91% of the time.

The cross-validation and ROC methods of assessment both suggest a strong predictive capacity is achieved in the FOM logistic regression model. This is evident in Map 3B-4, which compares the predicted bottom type (FOM or silt) to the data observed in Stephens Lake. The model results show that most of the error in classification agreement arose due to prediction of FOM in areas lacking inflows from peatland streams.

Application of the FOM logistic model in the Keeyask reservoir (Map 3B-5) was restricted to areas where peatland tributaries drain into flooded bays. Consequently, the results presented here are considered conservative (*i.e.*, the model results, in terms of true positives, would be expected to be higher than documented). The uncertainty of this model is relatively easy to assess given that FOM deposition occurs in bays that co-occur with tributaries, which are readily identified in maps. The precise position of the boundary between silt and FOM in a bay is less certain, but would be considered moderate due to the strong control of bay shape (*i.e.*, exposure) on model results.

Map 3B-6 shows the integration of all models described above to estimate the distribution of deposition in the Year 30 post-Project reservoir.

3B.4.4 MODEL 4 – ESTIMATING THE POTENTIAL DISTRIBUTION OF *POTAMOGETON RICHARDSONII* AND *MYRIOPHYLLUM SIBIRICUM*

This section provides an overview of the main results found in Appendix 3C that details: 1) the development of a predictive reservoir (PR) model to estimate the distribution of potential habitat for *Potamogeton richardsonii* and *Myriophyllum sibiricum* in the proposed Keeyask reservoir; 2) analyses to indicate which of the select environmental variables best accounts for the observed distribution of each species; and 3) documents the use of potential habitat by macrophytes.

The predictive macrophyte model was derived from field data collected from Stephens Lake in mid-summer 2005 and 2006 that described species, location, depth, slope, exposure, and substrate (n = 471) from the existing environment (EE) and the pre-flood (PF) landcover variables distance to mineral soil and peat depth (described in Appendix 3C). The pre-flood variables are key inputs to the model as this allows the presence or absence of aquatic plants in Stephens Lake today to be associated also with pre-flood conditions. Pre-flood soils information also provides an option for the model to work without the need for detailed substrate information, which may not be known *a priori*, when the model is applied in a future scenario.

3B.4.4.1 Assessing the Relative Importance of Existing Environment and Pre-flood Variables

The objectives supporting the development of the predictive macrophyte model was to compare and contrast the EE variables with the PF variables to determine the strengths and weaknesses of the available data to better critique the model.

The first of three LDA analyses included all EE and PF variables and explained 79% of the variance in the data. Substrate type from the EE was the dominant variable discriminating between both species from areas where they were absent. The second LDA analysis was constrained to EE variables only. As expected, the amount of variance increased relative to the first trial (87% explained) and showed that substrate grain size and water depth primarily determined macrophyte distribution in the EE. The third LDA trial, the PR model, aimed to learn which EE and PF variables would be most important when the PF surrogate variables (*i.e.*, distance to mineral soils and peat depth) were used in place of the EE substrate, which was assumed to be unavailable. The third trial aimed to determine if removal of the most important variable in the first two trials resulted in a decrease of model performance. Results of the PR model (Table 3B-10) confirmed that, like the two previous trials, information on bottom type (*i.e.*, either EE substrate or PF soils) was most important to discriminate between the presence of each species from absence. As shown in Figure 3B-6, the PF soil variables dominated discrimination and so comprise most of the weight along the axis of function 1, whereas the EE variables dominated function 2. On function 1, the minimum distance to mineral soil variable weighted the axis nearly twice that of peat depth. The second function was weighted most by slope and exposure, which were weighted similarly, and to a lesser extent by depth.

The PR model classification results explained 67% of the variance in the PF and EE data, which is a decrease of 20% relative to the EE model. This may suggest that the classification performance of the PR model might have dropped drop notably. The cross-validation results, however, showed clearly that this was not the case (Table 3B-11). Both trials on the Test group, not used to build the model, achieved high and equal classification agreement (81%).

The LDA analysis, unlike the logistic models above, supports the discrimination of more than two groups; this enables the two main species of macrophytes in Stephens Lake to be discriminated and the performance of the predictive model for each species to be assessed. Cross-validation results by species or absent show that *M. sibiricum* and *P. richardsonii* can be predicted with about equal confidence about

84 to 86% of the time; whereas, sites where these species are absent is slightly lower, about 74 to 76%. The results also show the Test and Model group each had a classification agreement that was about equal, and that estimates of agreement by species or absent were within 2%. This reveals that the PR model can be used with a high degree of confidence that is equal to that of the EE model (which operated with the benefit of contemporary field data) The PR model results are shown in Map 3B-7. Analyses of habitat preferences by each species are provided in Appendix 3C.

3B.4.4.2 Accounting for Deep Peat in Exposed Areas

The Keeyask reservoir has a few relatively large areas of deep peat in exposed locations, which was a site condition not observed in the macrophyte study area of Stephens Lake. This suggests that the LDA macrophyte model results could be improved if constrained by deep peatland type. Year 30 potential habitat in the lower reservoir was inspected visually to exclude relatively large areas of deeper peatlands, which included peatland plateau bogs and blanket bogs. These peatland types often have surface organic layers than can be up to 2 m thick (PE SV, Section 6). Soil profile information from the areas along the future Year 30 shoreline was reviewed to confirm relatively thick peat (PE SV, Section 6). Based on studies of more than 500 sites in Stephens Lake, these areas would not be suitable for macrophyte growth given peat is abundant on the bottom (intact or inundated peat), detritus, and other small woody debris, and/or water depths in areas of peat uplift that exceed the photic zone. It was therefore assumed that all of the relatively large peatland areas found above the silt boundary (modelled by Equation 25 in Rowan *et al*. 1992) were not potential macrophyte habitat.

3B.5 REFERENCES

3B.5.1 LITERATURE CITED

Cooley, P.M., and Franzin, W.G. 2008. Predicting the spatial mud energy and mud deposition boundary depth in a small boreal reservoir before and after draw down. Lake and Reservoir Management 24(3): 261–272 pp.

Egan, J.P. 1975. Signal detection theory and ROC analysis. Academic Press, New York, N.Y.

Legendre, P., and Legendre, L. 2004. Numerical ecology: developments in environmental modelling. Second English Ed. Elsevier Scientific Publishing Company, Amsterdam.

Manly, B.F.J. 1994. Multivariate statistical methods: a primer. Second Ed. Chapman and Hall, London.

Pohar, M., Blas, M., and Turk, S. 2004. Comparison of logistic regression and linear discriminant analysis: a simulation study. Metodološki Zvezki 1(1): 143–161 pp.

Rowan, D.J., Kalff, J., and Rasmussen, J.B. 1992. Estimating the mud deposition boundary depth in lakes from wave theory. Canadian Journal of Fisheries and Aquatic Sciences 49: 2490–2497 pp.

Swets, J.A. 1988. Measuring the accuracy of diagnostic systems. Science. 240: 1285–1293 pp.

Table 3B-1: List of approaches used to estimate aquatic habitat availability at Year 30 according to: model application, type of water mass (lentic/lotic), modelling method, area of data source

Model #	Application	Water Mass	Model	Method	Area
1	Substrate	Lotic	Presence/absence of deposition	Logistic regression	Nelson River between Birthday Rapids to Limestone GS
2	Substrate	Lentic	Presence/absence of mineral deposition - Equation 25 in Rowan *et al*. (1992)	Logistic regression	Ontario/Quebec
3	Substrate	Lentic	Presence/absence of fine organic material	Logistic regression	Stephens Lake
4	Macrophyte	Lentic	Presence/absence of two dominant macrophyte species from absent	Linear discriminant analysis	Stephens Lake

Table 3B-2: Areas on the Nelson River where substrate or velocity samples were obtained according to time period, daily average discharge (Q) was measured in cubic meters per second in the lower Nelson River, and the presence or absence of deposition of materials finer than sand

Area	Substrate		Velocity		Deposition	
	Date	Q	Date	Q	Yes	No
Limestone reservoir	19 Jun 2006	6305	12 Jul 2007	4285	17	23
Kettle reservoir	21 Jun 2006	6305	19 Sep 2007	3520	15	0
Stephens Lake thalweg	15 Sep 2007	4285	17 Sep 2007	3520	15	13
Stephens Lake	02 Jul 2006	4561	02 Jul 2006	4561	2	0
Keeyask	13 Sep 2006	3423	-	Modelled	14	46
Keeyask 2008	28 Sep 2008	4090	28 Sep 2008	4090	1	25
Total					64	107

Table 3B-3: Forward stepwise logistic regression results for 5th and 95th percentile inflows using 2 or 3 explanatory variables. Decreasing values for the -2Log (likelihood) and Akaike's Information Criterion (AIC) as the number of variables increases indicates an improvement to the model. Values in bold show the best model

Percentile Inflow	No. of Variables	Variables	-2 Log (Likelihood)	Pr > Wald	AIC
5	2	Velocity/depth	72.319	0.000	80.319
	3	Velocity/exposure/depth	**71.463**	0.000	81.463
95	2	Velocity/exposure	60.915	0.000	68.915
	3	Velocity/exposure/depth	**57.971**	0.000	67.971

Table 3B-4: Standardized coefficients for 5th and 95th percentile inflows from a three variable logistic regression model for predicting deposition/no deposition in lotic areas of the lower Nelson River

Percentile Inflow	Source	Value	Standard Error	Wald Chi-Square	Pr > Chi²
5	Velocity	-4.946	0.812	37.145	<0.0001
	Exposure	0.225	0.330	0.467	0.494
	Depth	1.637	0.427	14.727	0.000
95	Velocity	-6.315	1.147	30.293	<0.0001
	Exposure	0.721	0.374	3.719	0.054
	Depth	0.596	0.363	2.700	0.100

Table 3B-5: Cross-validation results for 5th and 95th percentile inflow simulation showing classification agreement (%) of the Model and Test groups for predicting depositional and non-depositional substrata in lotic water masses. Model group n = 130; Test group n = 41

	5th Percentile Inflow		95th Percentile Inflow	
	Model Group	Test Group	Model Group	Test Group
No deposition	88.8	88.4	93.8	88.5
Deposition	87.7	73.3	87.8	80.0
Overall	88.4	82.9	91.5	85.4

Table 3B-6: Likelihood-ratio test demonstrating the effect of the explanatory variables against that of a model using only a constant

Statistic	DF	Chi-square	Pr > Chi²
-2 Log(Likelihood)	3	107.453	<0.0001

Table 3B-7: Forward stepwise logistic regression results using 1, 2, or 3 explanatory variables. Decreasing values for the -2Log (likelihood) and Akaike's Information Criterion (AIC) as the number of variables increases indicates an improvement to the model

No. of Variables	Variables	-2 Log (Likelihood)	Pr > Wald	AIC
1	Exposure	156.970	0.000	166.970
2	Depth/ Exposure	143.989	0.000	153.989
3	Depth/ Exposure/Slope	135.974	0.000	145.974

Table 3B-8: Standardized coefficients for a three variable logistic regression model for predicting the boundary between fine organic material and silt in flooded peatland bays

Source	Value	Standard Error	Wald Chi-Square	Pr > Chi²
Depth	-1.088	0.392	7.705	0.006
Slope	-0.727	0.274	7.036	0.008
Exposure	-1.511	0.306	24.315	< 0.0001

Table 3B-9: Cross-validation results showing classification agreement (%) of the Model and Test groups for predicting the boundary between fine organic material (FOM) and silt in flooded peatland bays. Model group n = 179; Test group n = 59

	Model Group	Test Group
Silt	74.7	76.0
FOM	83.7	82.4
Overall	79.9	79.7

Table 3B-10: Fishers discriminant function coefficients derived for the predictive reservoir model to estimate potential macrophyte habitat derived using linear discriminant analysis (LDA) representing the existing environment (EE) and pre-flood (PF) data. Model number is consistent with Appendix 3C. Model 3 assumes the EE substrate variable phi is unavailable in this future scenario. Adapted from Appendix 3C

Model #	LDA Model	Number of Variables	Class	Constant	EE				PF	
					Slope	Exposure	Depth	Phi	Mineral $Soil_{dist}$	Peat Depth
3	Predictive Reservoir	5	*M. sibiricum*	-13.3283	0.0622	0.0034	1.4159	-	0.0035	0.0923
			P. richardsonii	-11.5641	0.4847	0.0057	1.5413	-	-0.0022	0.0796
			Absent	-17.1007	0.7616	0.0053	1.9736	-	0.0054	0.0949

Table 3B-11: Classification agreement (%) for the predictive reservoir model (PR) to estimate potential macrophyte habitat using linear discriminant analysis (LDA). The Model group represents 75% of the available data (n = 471) and was cross-validated using the remaining Test data not used to build the model. Model number is consistent with the numbering of Appendix 3C

Model #	LDA Model	Number of Variables	Model Agreement (%)	Test Agreement (%)	Test (%)		
					M. sibiricum	***P. richardsonii***	**Absent**
2	EE	4	80.0	81.0	86.0	84.0	76.0
3	PR	5	78.0	81.0	86.0	86.0	74.0

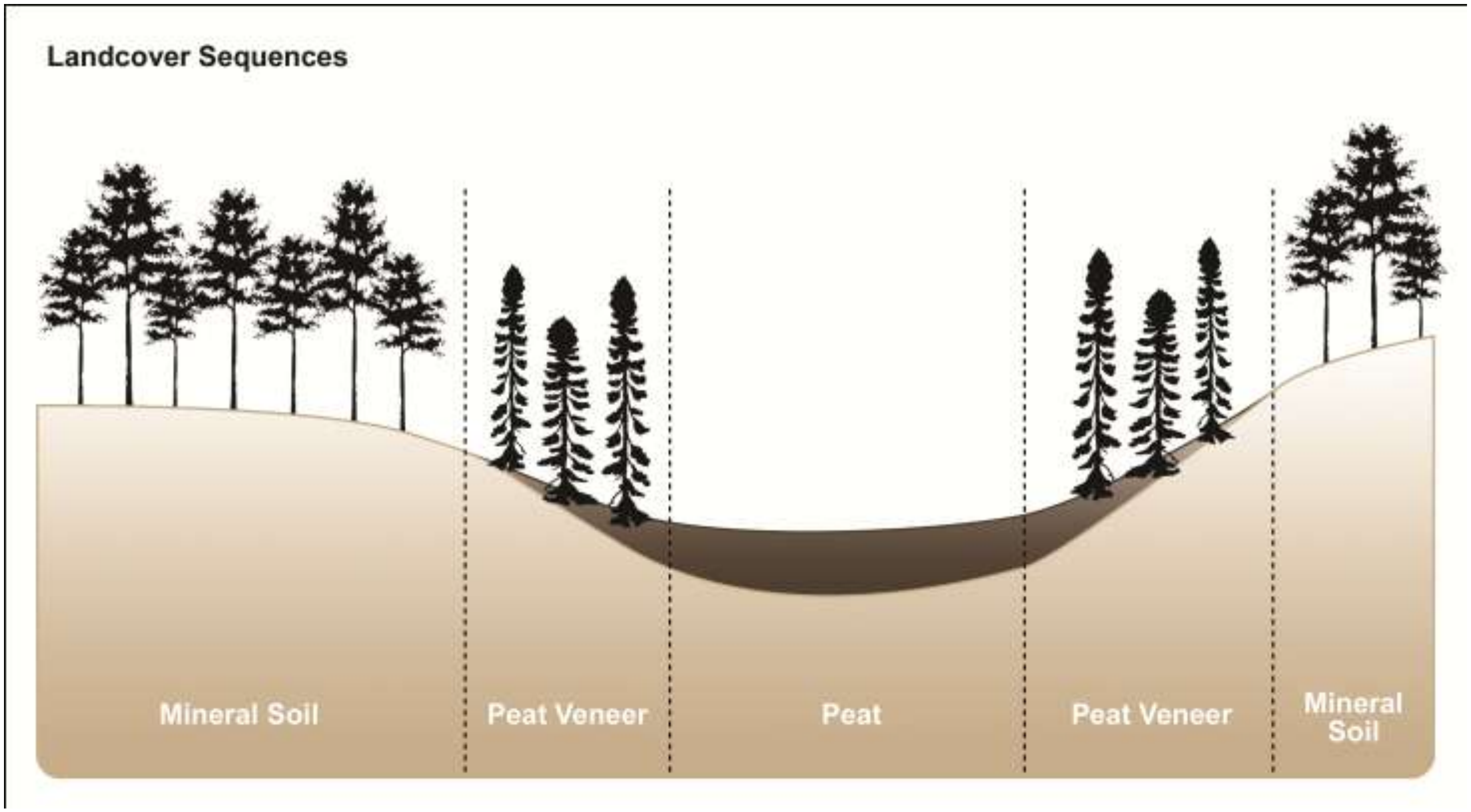


Figure 3B-1: Schematic diagram of topographic sequences of forest and soil types present in the study area where a low relief and gently undulating topography is present. Peat veneer is also regarded as thin peat. Not to scale

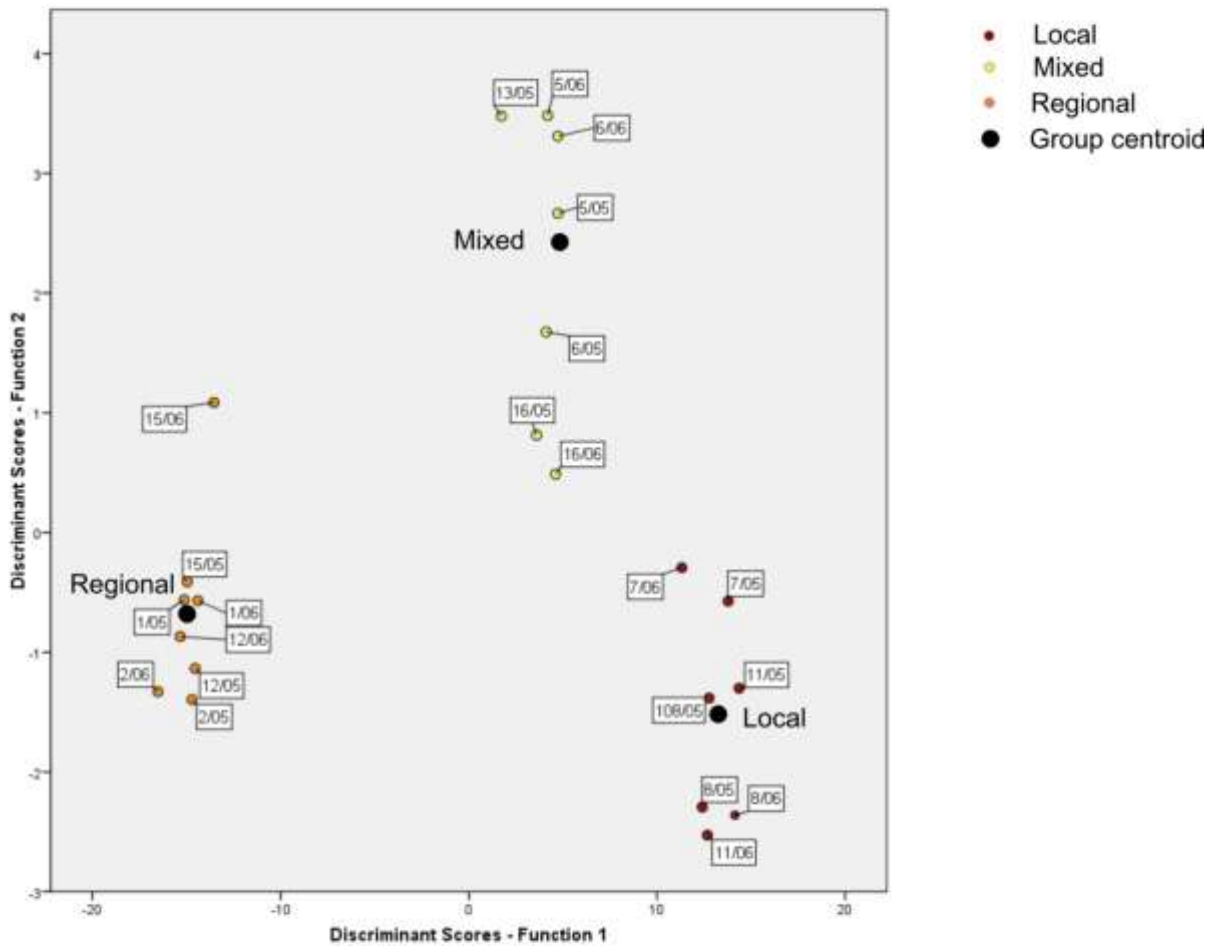


Figure 3B-2: Discriminant Analysis grouping of water quality and light attenuation sites shown in Map 3B-1. Sites are shown (1–15) by year (05/06) by water mass type

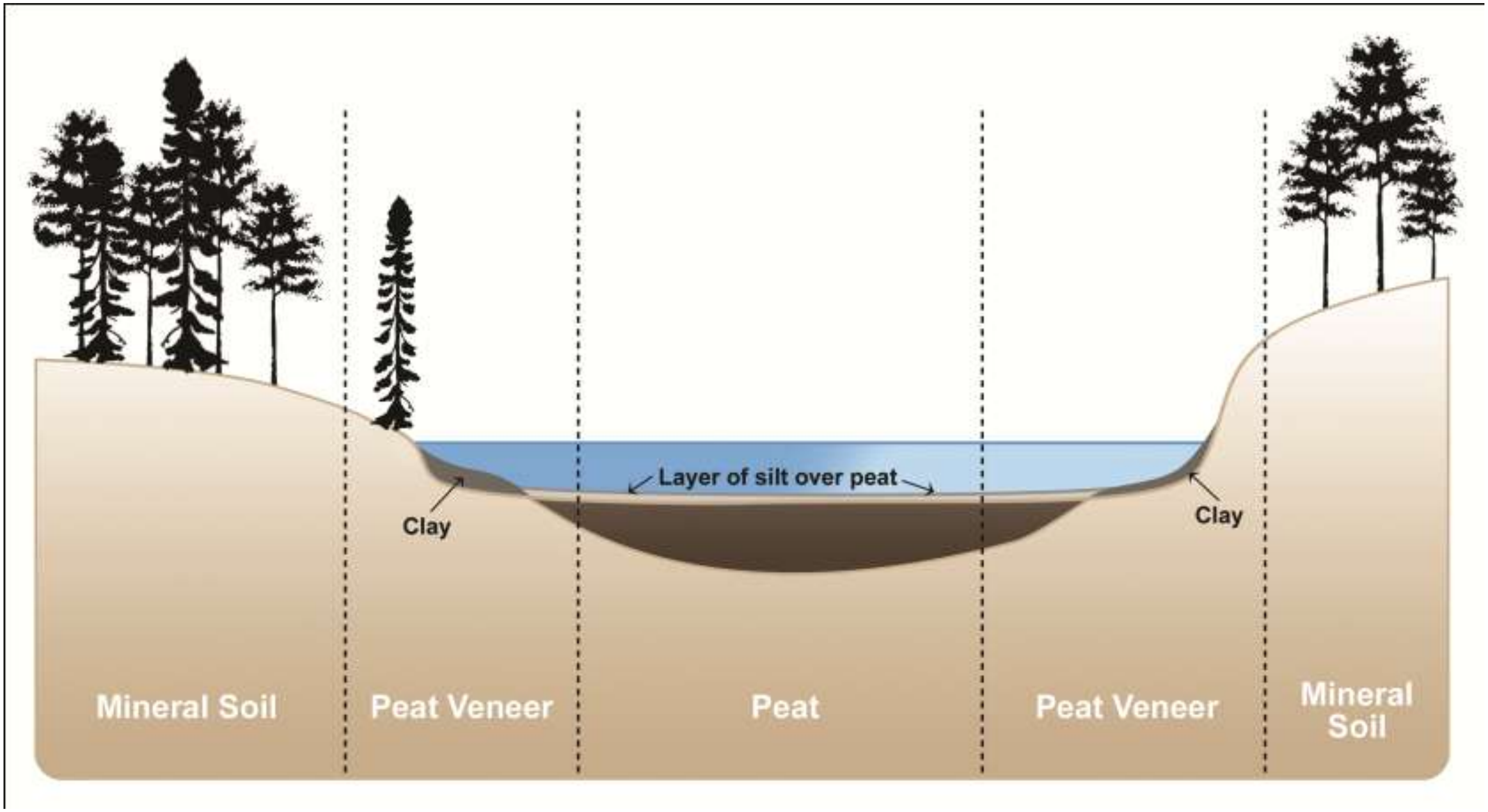


Figure 3B-3: Schematic illustration of post-Project flooded terrestrial habitat showing the development of a clay–aggregate nearshore matrix from a pre-flood peat veneer, and superimposition of silt over the pre-flood peat in deeper areas. Peat veneer is also regarded as thin peat

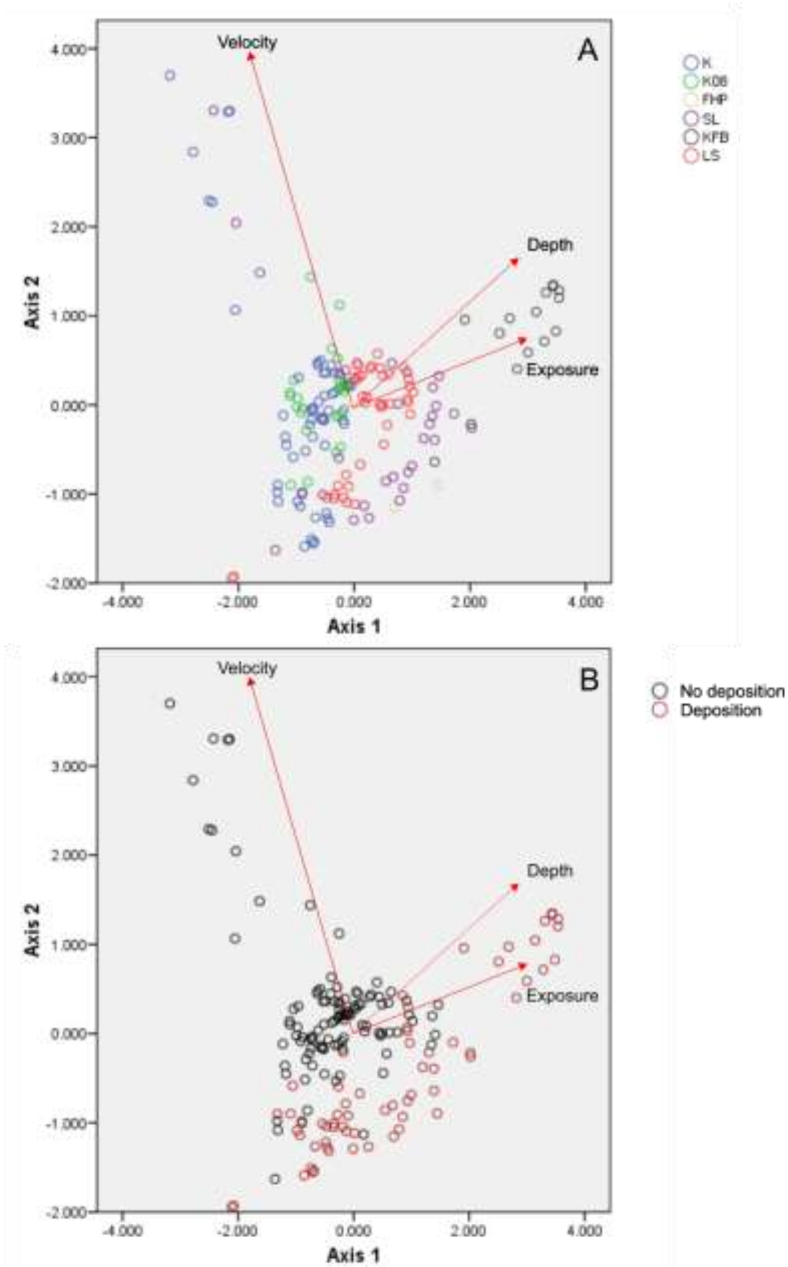


Figure 3B-4: Principal component analysis correlation biplot for 95th percentile inflow scenario of the lotic deposition model showing: (A) scatter of data used to build the model by study area (K = Keeyask 2006, K08 = Keeyask 2008, FHP = Fish Habitat Preferences in Stephens Lake 2006, Stephens Lake thalweg studies 2007, KFB = Kettle reservoir 2006, LS = Limestone reservoir 2006) with arrows indicating correlation amongst variables and each PCA axis, and (B) the same data but classified according to deposition or no deposition as observed in the field

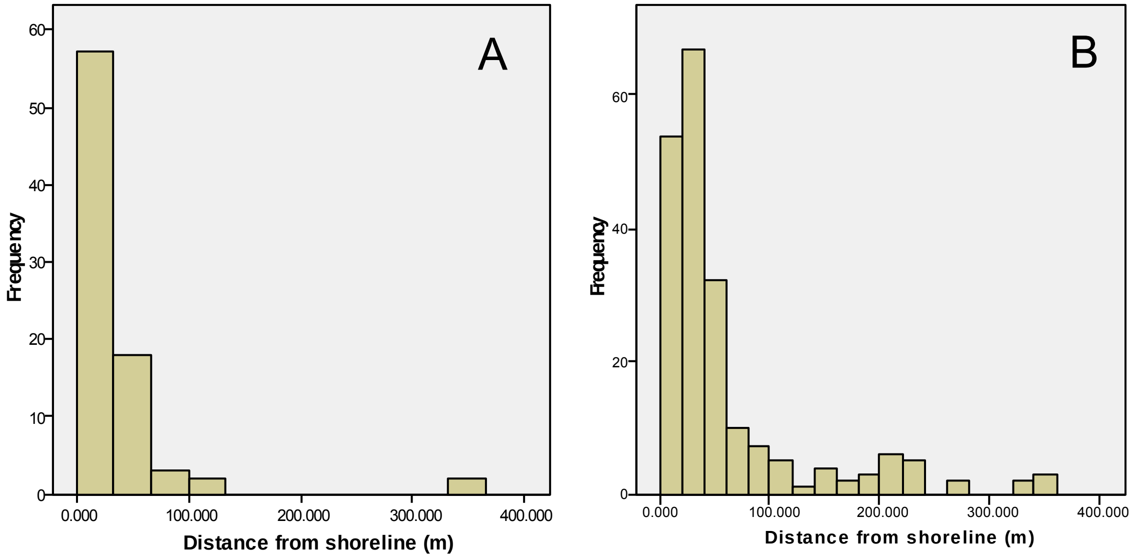


Figure 3B-5: Frequency histograms of the minimum distance of *M. sibiricum* (A) and *P. richardsonii* (B) to the shoreline of Stephens Lake at about the 95th percentile water level

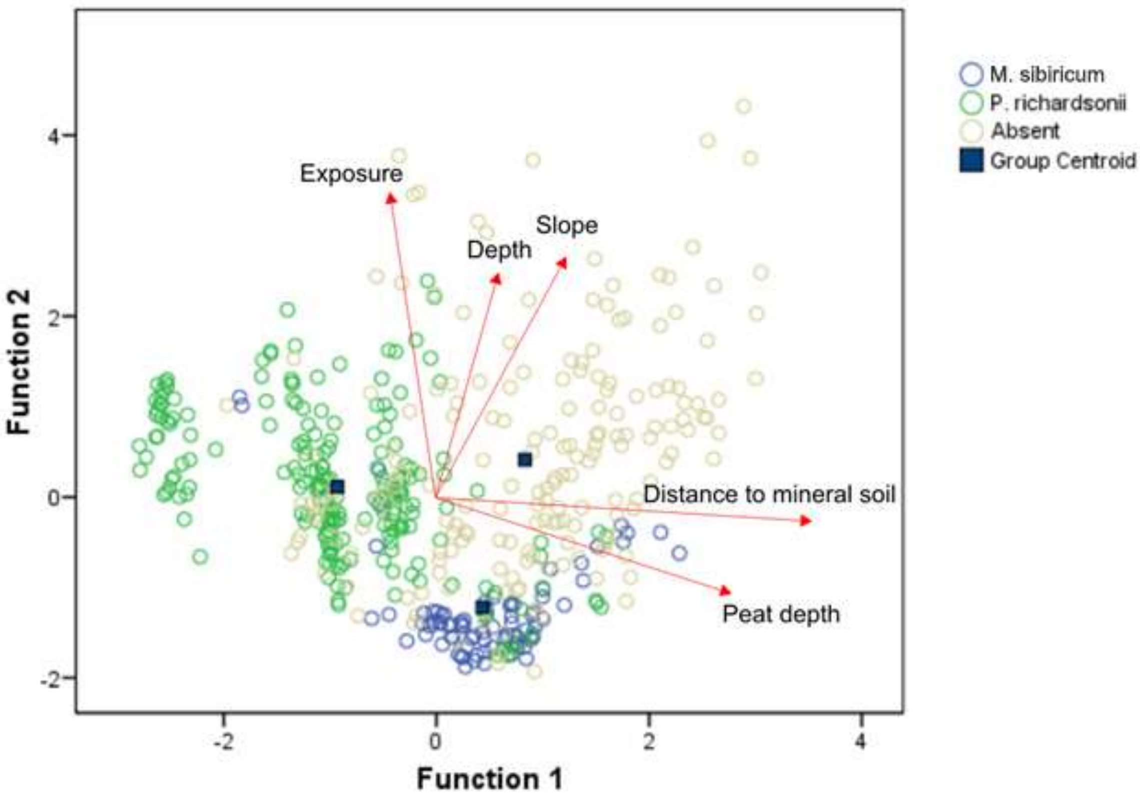


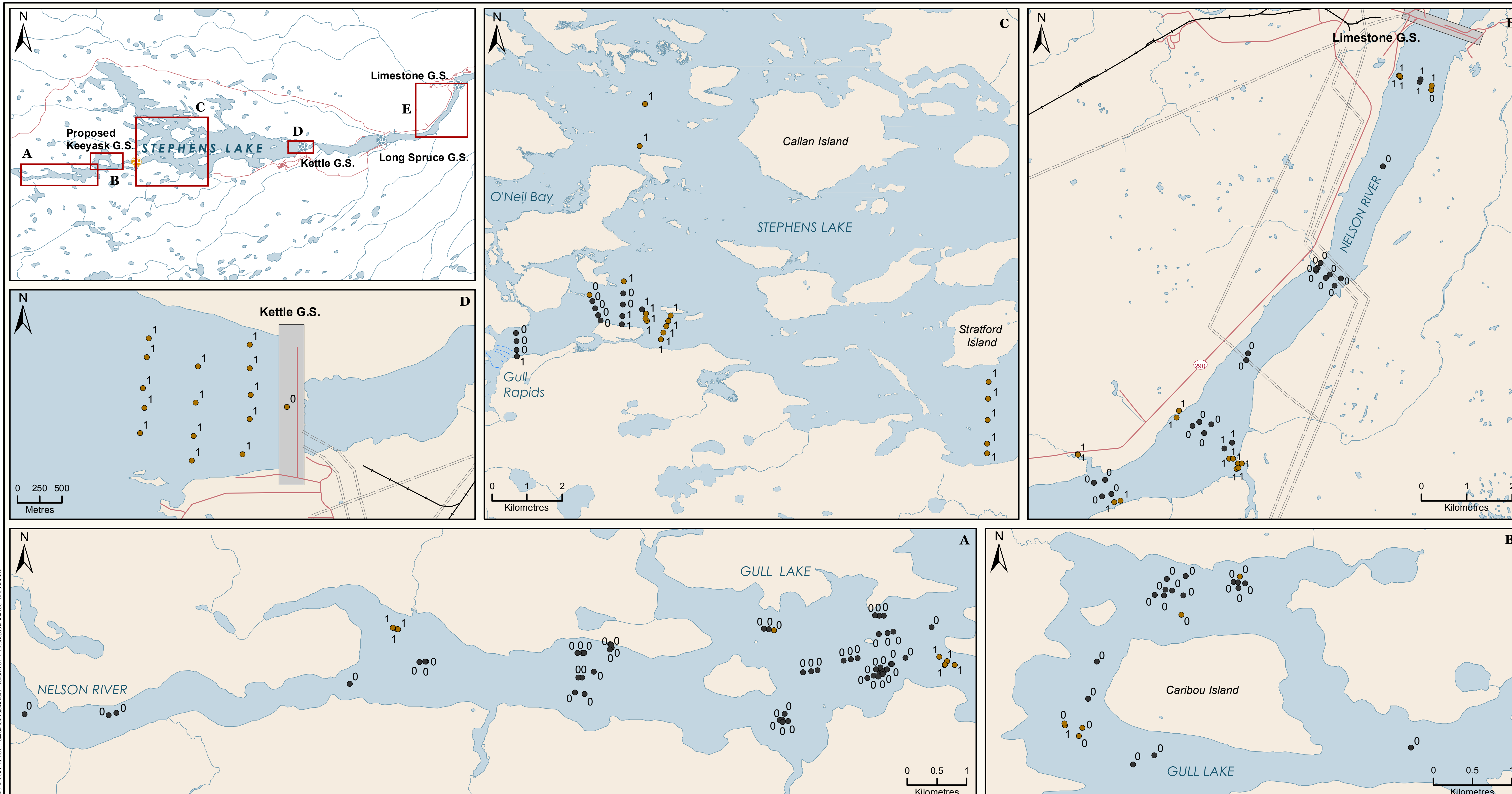
Figure 3B-6: Discriminant analysis scatter plot showing the predictive macrophyte model built from Stephens Lake and applied to the proposed Keeyask reservoir at FSL. The predictive reservoir model contained three existing environment variables (exposure, depth, slope) and two pre-flood variables (distance to mineral soil, peat depth) that are surrogate variables used when the substrate grain size is unknown in this future scenario

Projection: UTM Zone 15, NAD 83
Data Source: © DigitalGlobe, Quickbird Imagery true color composite, September 2, 2006

Water Quality Sites and LOCAL, MIXED and REGIONAL Water Masses

Stephens Lake

KEEYASK Hydropower Limited Partnership



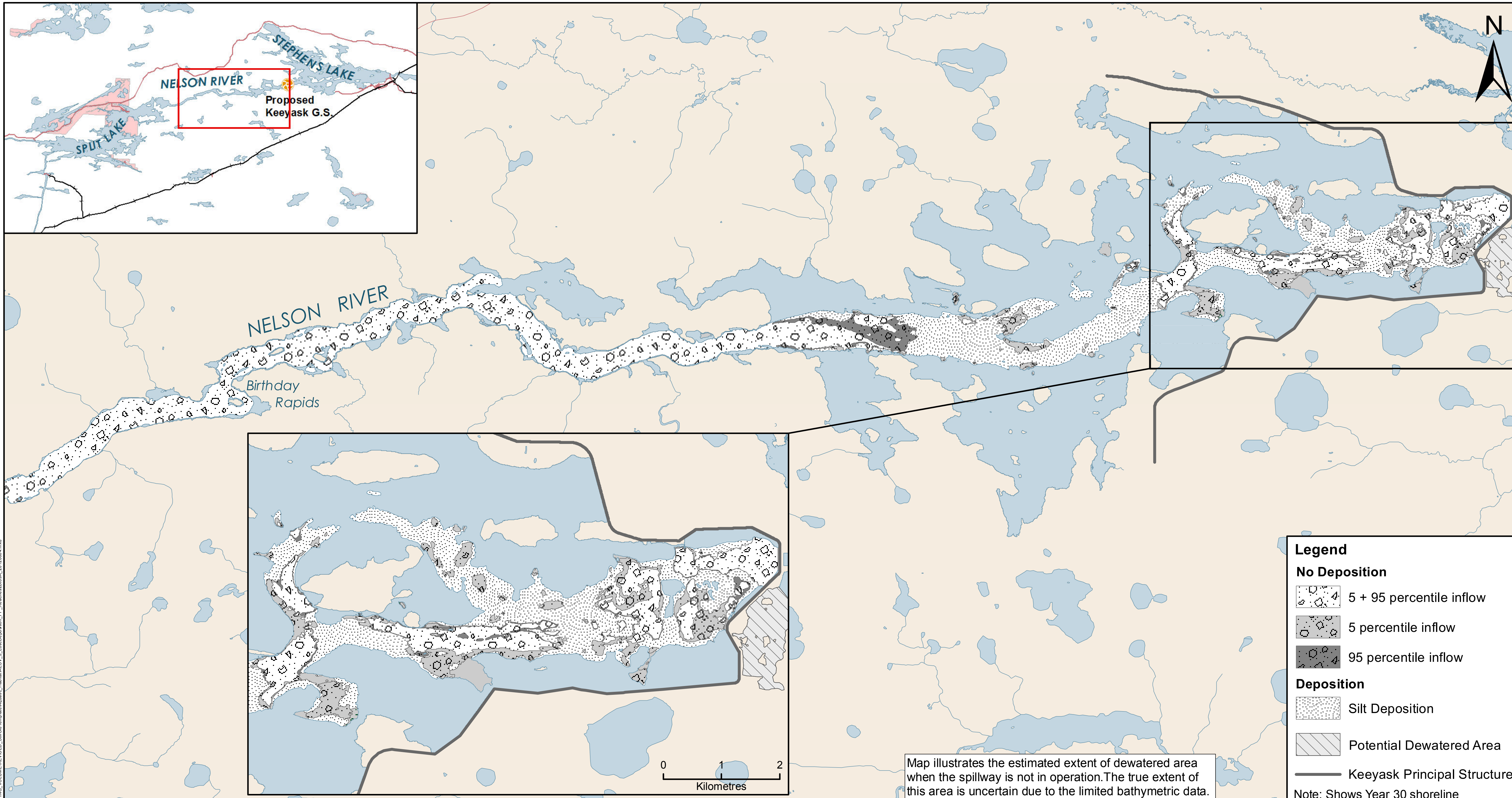
Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Stephens Lake Shoreline - Quickbird@Digitalglobe, 2006
Nelson River Shoreline modelled by Manitoba Hydro

Legend

Observed	Predicted
● = No deposition	0 = No deposition
● = Deposition	1 = Deposition

Note: Cross-validation of observed and predicted classes derived from logistic regression under 95th percentile inflow conditions.

Lotic Depositional Model

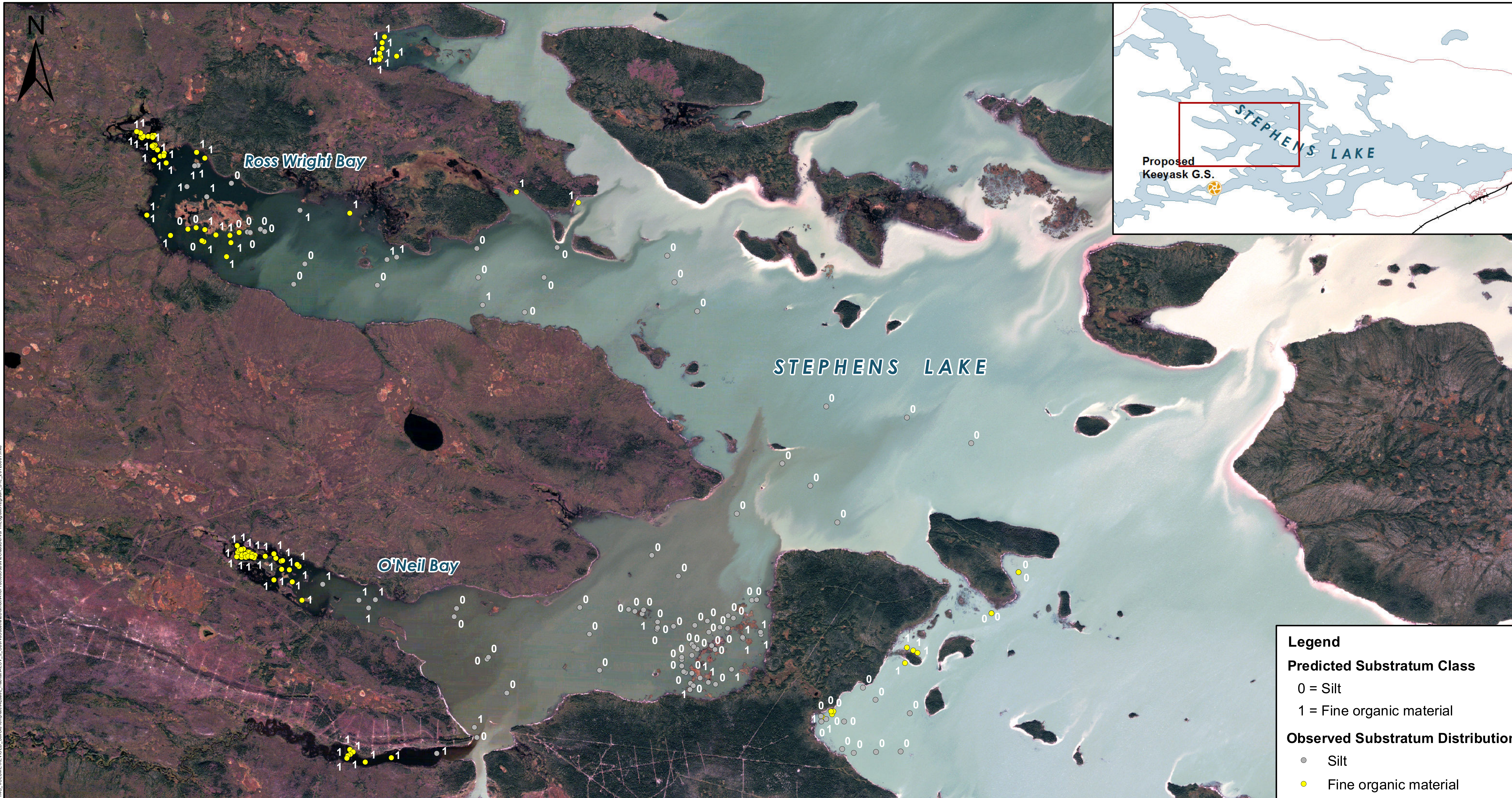


KEEYASK Hydropower Limited Partnership

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 dewatered area are estimated based on the existing environment 95th percentile flow.

Lotic Deposition

Post-Project - Reaches 2B to 9A

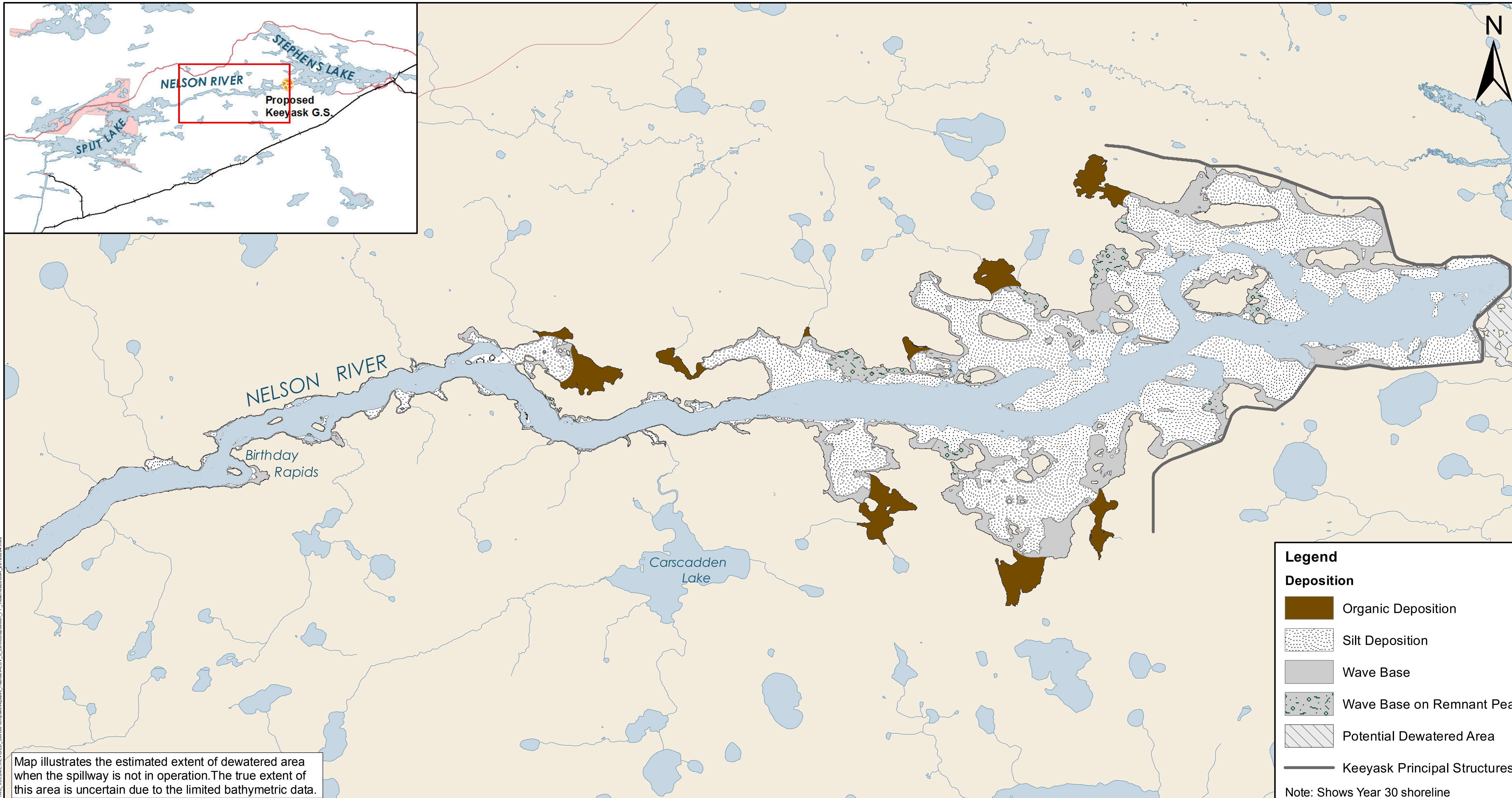


KEEYASK
Hydropower Limited Partnership

Projection: UTM Zone 15, NAD 83
Data Source: © Digitalglobe Quickbird image-Sept 2, 2006

Observed Substratum Distribution and Predicted Substratum Class Derived from Logistic Regression

Stephens Lake

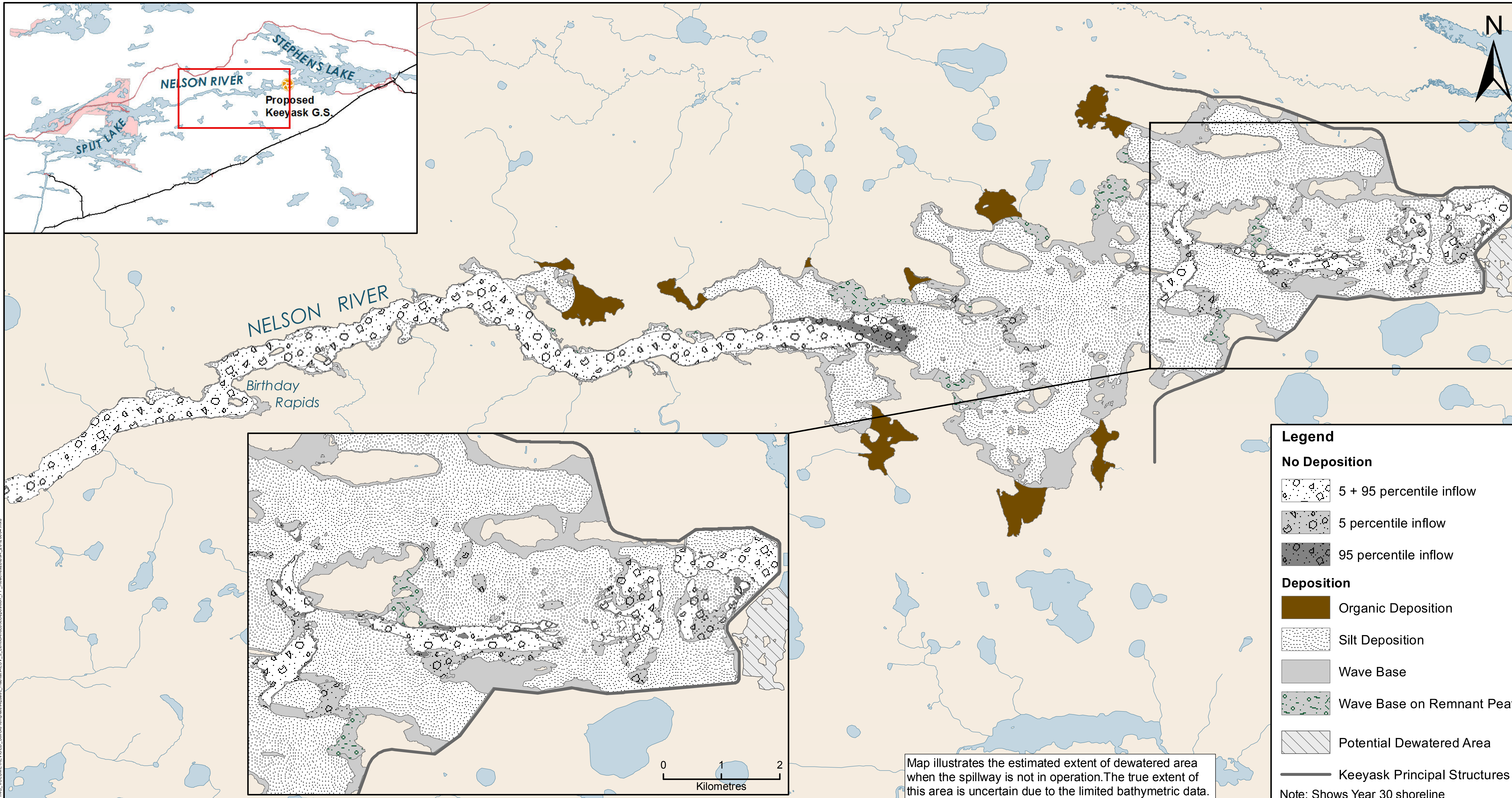


KEEYASK
Hydropower Limited Partnership

0 2.5 5 7.5 Kilometres
0 1.25 2.5 3.75 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.

Lentic Deposition
Post-Project - Reaches 2B to 9A



KEEYASK Hydropower Limited Partnership

0 2.5 5 7.5 Kilometres

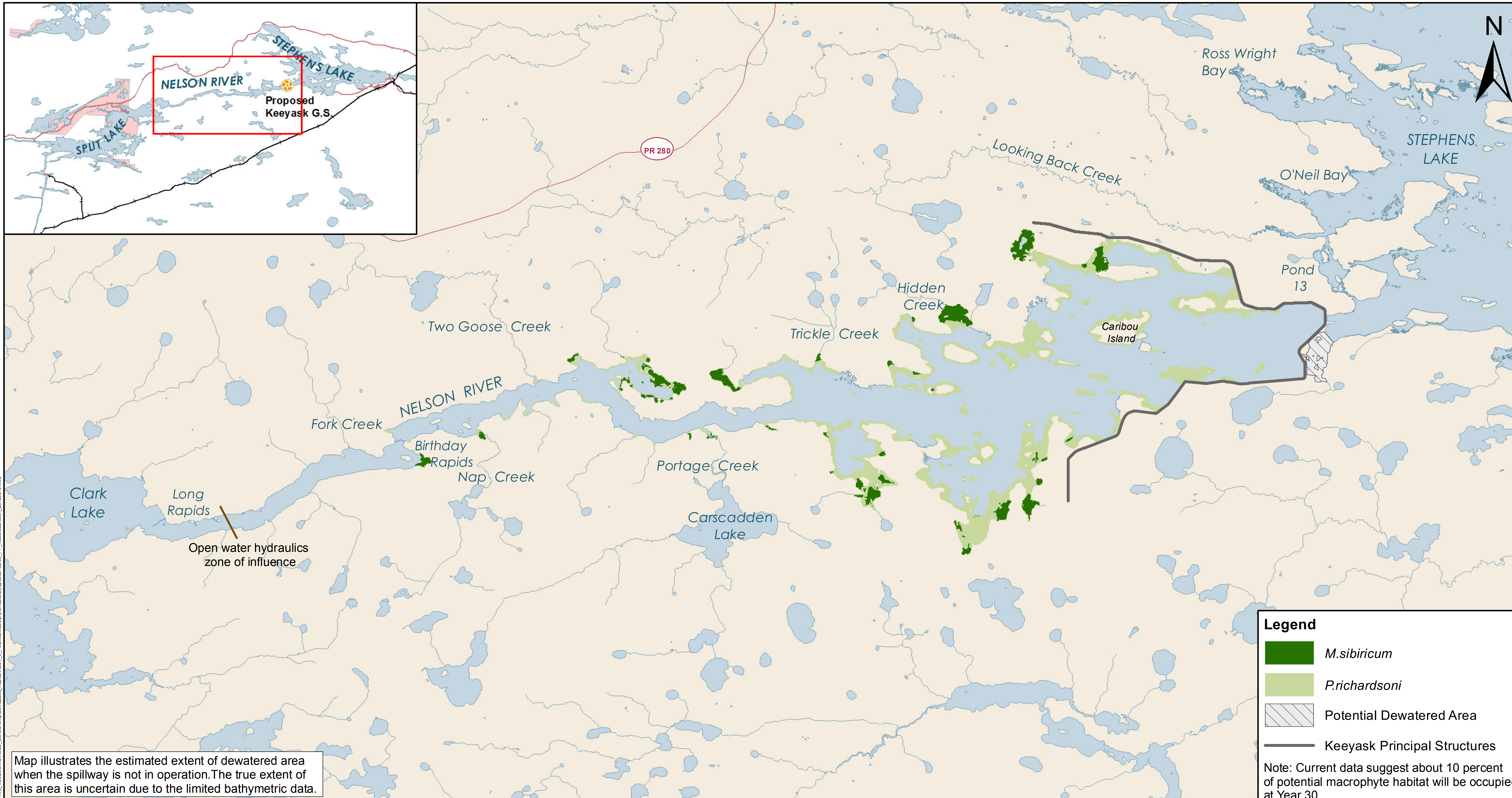
0 1.25 2.5 3.75 Miles

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.

Lentic and Lotic Deposition

Post-Project - Reaches 2B to 9A

Map 3B-6



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.

Potential Macrophyte Habitat by Species at Year 30

Post-Project - Reaches 2A to 9A

APPENDIX 3C
A PREDICTIVE MODEL TO ESTIMATE THE POTENTIAL DISTRIBUTION OF *POTAMOGETON RICHARDSONII* AND *MYRIOPHYLLUM SIBIRICUM* IN THE KEEYASK RESERVOIR

3C.1 INTRODUCTION

This appendix presents the development of a model to predict where Richardson's pondweed (*Potamogeton richardsonii*) and northern water milfoil (*Myriophyllum sibiricum*), the two dominant species found in Stephens Lake, could potentially live in the proposed Keeyask reservoir when it is 30 years old, and to learn how much of that habitat could be used by these species. The development of the model benefited by addressing four main questions: 1) what environmental variables best describe the presence or absence of these two species?; 2) how well can we predict the presence or absence of these species in Stephens Lake today?; 3) how well can we make the same predictions for the proposed Keeyask reservoir?; and 4) how much of the area in Stephens Lake that has a potential for plant growth is actually used by plants?

These two objectives enable an estimate of the potential area of macrophyte habitat occupied by plants in the proposed Keeyask reservoir to be determined for when the reservoir will be about 30 years old, and to provide a preliminary understanding of how much of the potential habitat will be occupied. The actual estimates of potential rooted plant habitat in the Keeyask reservoir are found in Section 3 of the AESV.

Stephens Lake is considered a proxy for the proposed Keeyask reservoir at about year 30. Therefore, the distribution of rooted macrophytes in Stephens Lake was studied to develop a predictive model to estimate the extent of potential habitat in the proposed Keeyask reservoir at Year 30. Application of the model in the Keeyask reservoir first required an understanding of the habitat requirements by rooted macrophytes in Stephens Lake to demonstrate plant and habitat relationships observed in the reservoir. Transfer of the model from Stephens Lake to the Keeyask reservoir involved the substitution of existing environment variables (*e.g.*, substrate) for pre-flood variables (pre-flood soil type) given that the specific composition of substrate in future predictions may not be well known.

The objectives of the model development were as follows:

Objective 1:

To develop a predictive model to estimate the presence or absence of potential habitat for *P. richardsonii* or *M. sibiricum* in the proposed Keeyask reservoir at year 30. In order to do this, three corollary objectives were identified:

1) To determine the relative importance of select environmental variables that influence the distribution of potentially suitable plant habitat in the existing environment of Stephens Lake;

2) To assess how well the distribution of these species can be predicted in the existing environment of Stephens Lake; and

3) To assess any potential decrease in certainty (*i.e.*, model performance) in the model intended for application in the proposed Keeyask reservoir when pre-flood surrogate variables were substituted for existing environment variables.

Seven LDA models were derived from data collected in Stephens Lake during the Keeyask aquatic studies. The models formed a series of sensitivity trials to understand which measured environmental variables were important in determining the distribution of each species at Year 30. LDA was also used to classify the presence or absence of each species, and to evaluate the performance of the classification models.

Objective 2:

Two study areas were selected in Stephens Lake to validate the area of potential habitat actually occupied by plants. In areas of pre-flood mineral soils bathymetric, elevation, slope, and substrate distributions were mapped. The areal extent of aquatic plants was mapped using high resolution satellite data and aerial polygon sketches.

3C.2 METHODS

This section describes the methods used to: 1) develop a predictive model to classify the presence or absence of potential habitat for *P. richardsonii* or *M. sibiricum* in the proposed Keeyask reservoir at Year 30 and 2) to determine the area of macrophyte habitat occupied relative to the total suitable habitat available.

3C.2.1 PREDICTIVE MACROPHYTE MODEL

The predictive macrophyte model was derived from field data collected from Stephens Lake in mid-summer 2005 and 2006 that described species, location, depth, slope, and substrate (n = 471) (Map 3C-1). Each of the two sites selected for validation of the use of suitable habitat (*i.e.*, the amount used relative to available) was a reasonable size for complete survey, found in areas of mineral soils prior to flooding (*i.e.*, potential habitat), and was bounded by unsuitable habitat along the shore and at depth. These field data were associated with pre-flood landcover classification or existing environment variables available in digital maps, as described below.

3C.2.1.1 Wave Energy

Exposure is a form of fetch distance measurement that describes the "openness" of a site (P. Cooley, unpublished computer program) and was estimated to gain an appreciation of the role wave energy has in influencing the distribution of rooted aquatic plants.

As described by Cooley (1999), for each lake or reservoir location in a raster map exposure was estimated in metres, as:

$$\text{Exposure}_{ij} = (\textstyle\sum_{a}\text{=1-360}V_{ija})/360$$

Where, V_{ija} is the fetch distance from the point i, j, to the shore at a specific angle, a, which ranges from 0 to 360º. The interval of fetch measurement on the Cartesian grid, *i.e.*, the unit distance for measurement, was 5 m.

3C.2.1.2 Landcover

Pre-flood landcover classification is a key input to the model as this allows the aquatic plants present in Stephens Lake today to be associated with pre-flood conditions. Pre-flood landcover is a required input to this model as the substrate distribution may not be known in a future reservoir.

Pre-flood landcover classifications that described soils and the thickness of soil strata were used for Stephens Lake (pre-flood) (TE SV, Section 2.3.4.2). Three landcover classes were used to describe the pattern of soils: 1) peatland, 2) peat veneer (*i.e.*, thin peat over mineral), and 3) dry mineral. Peatland and veneer bog are distinguished by the depth of peat being greater or less than 1 m, respectively. Pre-flood soils maps in the area of the proposed Keeyask reservoir were generalized from 12 classes to three to be consistent with the data available for the pre-flood Stephens Lake area. Table 3C-1 lists the aggregation of classes applied in the Keeyask reservoir.

3C.2.1.3 Distance to Mineral Soil and Peat Depth

Distance to mineral soil and peat depth are pre-flood variables derived from digital maps. These variables, like landcover, serve as proxies for reservoir substrate information but provide better descriptors of the relationship of a site to the pre-flood parent material when the pre-flood peat layer was thin (*i.e.*, later removed by reservoir processes) or thick. Sites of peat soil that have short distances to mineral soil typically are thin peat found on sloped sites on the edge of a low hill. Peat sites that are relatively distant from mineral soil topography are typically thick. The minimum distance from each study site in Stephens Lake to the nearest location in a polygon depicting mineral soil (pre-flood) was estimated by measurement of the distance from each location of interest (a macrophyte study site) to the closest part of all mineral soil polygons in the map and outputs the minimum distance measured.

The mineral soil class was defined as either peat veneer or dry mineral soil.

3C.2.1.4 Shoreline Delineation, Bathymetry, and Slope

A shoreline was extracted from high-resolution QuickBird optical image data at an elevation of 140.80 m ASL, which is near the 95th water level percentile of the existing environment. A land and water mask was created by reclassifying the panchromatic band (0.6 m resolution).

Water depth data were standardized to the 95th water level percentile using the reservoir surface water level (Butnau gauging station) during the survey. Acoustic bottom typing and validation was employed to map the depth and bottom types, as described in Appendix 3A.

3C.2.1.5 Data Attribution and Extraction

The attribute fields in the modelling database were as follows: 1) easting and northing map coordinates, 2) presence or absence of either species; 3) water depth standardized to 95th percentile (m); 4) phi substrate grain size (dimensionless numbers ranging – 4 to – 10); 5) slope (%); 6) exposure (m); 7) distance to mineral soils (m); 8) peat depth (m). An additional field was coded to 0 and 1 in order to create a selection variable for building and testing the classification using cross-validation.

3C.2.1.6 Macrophyte Model Building Using Discriminant Analysis

The presence or absence of each species of macrophyte in relation to the existing environment and pre-flood environmental variables was investigated using LDA (Manly 1994) using a forward step-wise variable selection method (SPSS version 15). The LDA technique can be used to create and assess the classification performance of a predictive classification model and to understand the relative importance of the variables included in the classification. The LDA method forms two linear axes, referred to as discriminant functions, to maximally separate each species from each other and from the class 'absent' based on the selected existing environment and pre-flood variables. At each step of the forward step-wise variable selection procedure the variable that minimized the overall Wilks' lambda was entered into the equation until probability was not significant ($\alpha = 0.05$).

Two sets of LDA trials were employed. The first set (n = 471) contained three LDA trials to demonstrate the relative importance of EE and PF variables in controlling plant distribution, and to map the presence or absence of potential habitat for each species in the proposed reservoir: i) model 1 included all variables to demonstrate the overall trends between the EE and PF attributes, ii) model 2 operated upon the existing environment data only, and iii) model 3, the PR model, was intended for application in the proposed Keeyask reservoir. Model 3 recognizes that substrate grain size data (*i.e.*, phi) may not be available in this future scenario and has been removed from forward stepwise variable selection. In particular, the comparison of models 2 and 3 serves to demonstrate the relative importance of the EE substrate to that of the PF proxy variables, distance to mineral soil and peat depth, and to understand how the change of input variables influences the results of the PR model. The second set of LDA trials (*i.e.*, *M. sibiricum*: models 4 and 5; n = 201, *P. richardsonii*: models 6 and 7; n = 293) investigated the relative importance of the environmental variables to each species by removing the other species of macrophyte from the analysis.

Classification performance was assessed using cross validation. Each LDA model was developed using 75% of the data to predict class membership (*i.e.*, *M. sibiricum*, *P. richardsonii*, absent) for 25% of the remaining data for which membership is known. These are referred to as the model and test groups, respectively. The model group was populated using every three of four sequential observations in the database, ensuring representation from all parts of the area studied.

3C.2.2 USE OF POTENTIAL HABITAT BY MACROPHYTES

Two validation areas were selected to determine the amount of macrophyte habitat used relative to the total suitable habitat available (Map 3C-2). In these areas, data were collected to map in detail the area occupied by rooted plants at the water surface and the total area of suitable habitat.

The area occupied by rooted plants, including *P. richardsonii* and *M. sibiricum*, was captured using Red Hen aerial video on-board a Bell Jet Ranger helicopter during field studies in mid-summer in 2005 and 2006 during the Keeyask studies, and with QuickBird high resolution optical satellite imagery on 2 September 2006. At each validation area, data were collected to document: 1) a bathymetric map, 2) a slope map, and 3) a substrate map (field methods are described in Appendix 3A).

All elevation/bathymetric data were standardized to the 95th water level percentile.

3C.2.2.1 Classification of Macrophytes Using Satellite Data

QuickBird high-resolution optical satellite data were used to classify the extent of macrophyte stands in each of the two validation areas, referred to a "North" and "South". Classification of the multispectral data (2.4 m) was undertaken on each area using a clustering routine (Eastman 2000), after which the data were sharpened to improve spatial and spectral resolution using a 0.6 m panchromatic band and a color space transformation. A color space transformation converts true color images between the RGB (red, green, blue) and HLS (hue, lightness, saturation) color space. The classified images were compared to the raw image data, which showed plant stands clearly, and field diagrams of plant distributions collected by low level helicopter survey with aerial video. The class representing macrophytes was extracted from the image data and converted to vector format.

3C.2.2.2 Constraint Criteria Used to Define Potential Habitat

Water depth, slope, and substrate criteria were used to define the area of suitable habitat in the North and South validation study areas. The maximum depth constraint used was 3 m; this was based on the studies of maximum plant depth observation in Stephens Lake that showed the maximum depth of macrophyte growth was 3.4 m (Section 3.3.2.4); few observations were present deeper than 3.2 m. The slope constraint criteria of 6% was also taken from the Stephens Lake studies which showed the maximum slope observed for these two species was 6.5%. A 6% slope threshold was used and is comparable to published aquatic macrophyte biomass information from temperate Canada that showed maximum biomass was on slopes less than 5.33% (Duart and Kalff 1986). The Keeyask aquatic studies demonstrated that silt, peat, detritus, and gravel or larger materials are unsuitable substrata for plants in Stephens Lake (described in Section 3.3.2.4); as a result, clay, and sandy clay were considered potential substrata for the presence of plants in the North and South validation study areas (the substrata classes observed in each study area are shown in Figure 3C-2 and Figure 3C-3).

3C.3 RESULTS

3C.3.1 PREDICTIVE MACROPHYTE MODEL

3C.3.1.1 Relative Importance of Variables from the Existing and Pre-flood Environments

The relative importance of measured environmental variables on the presence or absence of *M. sibiricum* and *P. richardsonii* are presented using a sensitivity analysis for seven trials with LDA. Models 1–3 incorporate the full dataset and models 4–7 partition the data to investigate the effects of environmental variables on the presence or absence of each species separately.

LDA provided good separation of each species of macrophyte from 'absent' in models 1–3 (Figure 3C-1). An understanding of the relative importance of the variables in discrimination of each trial can be gained by examining the standardized canonical discriminant function coefficients (Table 3C-2). The absolute values of the coefficients indicate the relative contribution of a particular variable to the discriminant function. Each discriminant function is the linear combination of the variables that best discriminates among the presence or absence of *M. sibiricum* and *P. richardsonii*.

Models 1–3 show that some overlap in the scatter of points between each species and absent occurs. This would be expected when a species has not fully utilized the entire potential habitat available (some suitable habitats are unoccupied and are recorded as absent). Overlap in the scatter among both species of macrophyte is limited but infers the predicted distributions are, in the strict sense, not mutually exclusive. The use of suitable habitat is discussed in Section 3C3.2.

The results of each LDA sensitivity trial are described below.

3C.3.1.2 Model 1: The Full Model Derived from All Existing Environment and Pre-flood Variables

The first discriminant function explained most of the variance in the full dataset containing the EE + PF data (79%) and was weighted most by substrate grain size (phi) (Table 3C-2; model 1). The substrate type in Stephens Lake was the most important variable in determining the presence or absence of either species of macrophyte. Water depth contributed most to the discrimination along function 1. The second discriminant function was explained mostly by both PF soil variables, most notably minimum distance to mineral soil, and exposure.

The effect of these variables on the discrimination of each species of plant from absent is evident in Figure 3C-1A as a separation of both species of macrophyte from absent on function 1, and a separation of each species from one another on function 2.

3C.3.1.3 Model 2: The Existing Environment Model

The first discriminant function explained most of the variance in the EE data (87%) and was weighted most by phi (Table 3C-2; model 2). Like model 1, the substrate grain size was the single most important variable in determining the presence or absence of either species of macrophyte. The first discriminant function was weighted also by slope and depth. The contribution of exposure to function 2 was about 10x that of any other variable, and so this variable dominates any interpretation of pattern along this axis.

The effect of these variables on the discrimination of each species of plant from absent is evident in Figure 3C-1B as a separation of both species of macrophyte from absent on function 1, and a tight group of *M. sibiricum* located at low exposures on function 2.

3C.3.1.4 Model 3: The Predictive Reservoir Model

The removal of phi as an explanatory variable in the PR model (model 3), decreased the variance accounted for in function 1 to 67% (Table 3C-2; model 3) when compared to models 1 and 2, although the discrimination remained strong. The PF soil variables dominated discrimination along the axis of function 1, whereas the EE variables dominated function 2. On function 1, the minimum distance to mineral soil variable weighted the axis nearly 2x that of peat depth. The second function was weighted most by slope and exposure, which were weighted similarly, and to a lesser extent by depth.

Figure 3C-1C demonstrates a good separation of each species from absent. Function 1 separates *M. sibiricum* and absent from *P. richardsonii*. Function 2 separates *M. sibiricum* from *P. richardsonii* and absent.

3C.3.1.5 Models 4 and 5: Environmental Variables Influencing *M. sibiricum*

Two sensitivity trials were undertaken to better understand the relative importance of the EE + PF variables in explaining the presence or absence of *M. sibiricum*.

Stepwise LDA results for model 4 show that phi, slope, and exposure comprise function 1 and explained 80% of the variance; the stepwise method has removed the depth and both PF soil variables which have not significantly improved the model (Table 3C-3). Phi, like that found for models 1 and 3, was again the dominant variable determining the presence or absence of *M. sibiricum*. Model 5, which removed phi from the dataset, accounted for 56% of the variance. Both PF soil variables and water depth were dropped from this stepwise model. This was not expected given the PF soil variables were the best proxy for phi in Model 3. Instead, exposure and slope were the only significant contributors to predict the potential habitat of *M. sibiricum* in model 5.

3C.3.1.6 Models 6 and 7: Environmental Variables Influencing *P. richardsonii*

Two sensitivity trials were undertaken to better understand the relative importance of the EE + PF variables in explaining the presence or absence of *P. richardsonii*.

Stepwise LDA results for model 6 show that, like all previous models with phi as a candidate variable, the substrate type (*i.e.*, grain size) was the primary explanatory variable and explained 80% of the variance. Both PF soil variables were the next largest contributing variables to model 6. In model 7, where phi was removed, the variance explained decreased to 65%. Both PF soil variables became the dominant explanatory variables for *P. richardsonii*. This was not the case of model 4 for *M. sibiricum*, but was observed earlier in the results of model 3 which included both species. Depth and slope contributed significantly to model 7. Although exposure was shown to be important in model 5 for *M. sibiricum*, it was not a significant variable to determine the potential habitat of *P. richardsonii*.

3C.3.1.7 Discriminant Model Equations

The equations resulting from LDA models 1–7 are listed in Table 3C-4. Model 3 was applied to the proposed Keeyask reservoir. These equations provide one of several steps required to map the potential habitat available for each species of rooted macrophyte.

3C.3.1.8 Classification Agreement

Classification agreement for the Model and Test groups was assessed for models 1–3 (Table 3C-5). Cross validation results for the Model group represent 75% of the data and provided classification agreement of 78–85%. The classification agreement of each Test group was similar to the corresponding model group (less than 3 % difference). This suggests the sample size for the Model groups was sufficiently large and likely represents the full range of multivariate data.

The overall agreement in classification for models 1–3 of the Test group is good, at 86% for the EE + PF model and 81% for the EE and PR models. Agreement was highest for *M. sibiricum* among all Test trials (EE + PF: 95%, EE: 86%; PR 86%) with decreases evident for *P. richardsonii* (EE + PF: 82%, EE: 84%; PR 86%), and absent (EE + PF: 85%, EE: 76%; PR 74%). The decrease in overall classification of the Test group from model 1 to models 2 and 3 is small (5%) and the results for the latter two models are similar. Results for models 4–7 was to explore the effects of environmental variables; these models are unsuitable for classification given they are limited to a binary (present/absence) result of a single species, and so cannot account for two species, which is the focus here.

3C.3.2 USE OF POTENTIAL HABITAT BY MACROPHYTES

In 2005 and 2006 water levels were near the 95th percentile which means all of the potential macrophyte habitat available was wetted, and therefore is also suitable. The substrate and depth distributions of the validation sites are shown in Figure 3C-2 and Figure 3C-3. In brief, the south validation area is near the terminal end of an esker and so has greater availability of aggregate materials, mainly in the form of sandy-clay and localised areas of gravel/cobble in comparison to the north validation location which is mainly a clay bottom in shallow water. Two methods of area assessment were employed: 1) high resolution optical remote sensing to identify clumps of plants, 2) aerial sketches of macrophyte bed boundaries based on observations of closely-spaced clumps of plants using hand-drawn polygons from low level helicopter survey. The remote sensing approach is most conservative given it senses individual plants or those that are tightly spaced. The aerial sketch method is less conservative given that some space within a plant polygon may not be occupied, or it may be occupied but not evident at the water's surface. The total substrate area occupied by plants is probably underestimated by both methods given observation is made at the water's surface. Comparison of the area of potential habitat occupied would be consistent between Stephens Lake and the Keeyask area using the aerial sketch method.

The use of potential habitat by rooted macrophytes in the two validation study areas show that the areas occupied are small relative to the total area suitable (Table 3C-6; Figure 3C-4 and Figure 3C-5). The use of suitable habitat in the two study areas differed by method of assessment and ranged from 2.5–3.5% when high resolution remote sensing methods were employed (Figure 3C-4 and Figure 3C-5) to 11-12.2% for aerial sketches (Figure 3C-6). In both cases, the substrate distribution was the primary constraint on delimiting suitable habitat although the depth limit and upper limit to silt are often in a similar position. Both study areas had unsuitable substrate areas due to peat soils and/or abundant detritus along the shore and silt at water depths mostly greater than 3 m. A few locations in the south validation study area had depths of water that exceeded the suitable range despite having a suitable substrate.

3C.4 SUMMARY AND CONCLUSIONS

This Appendix described two main objectives: 1) to develop a predictive macrophyte model; 2) to understand the difference in area occupied by rooted macrophytes to the total potential habitat available.

Seven LDA models were derived from data collected in Stephens Lake. The models form a series of sensitivity trials to understand which environmental variables are important in determining the distribution of each species when the reservoir is about 30 years old. LDA was also used to classify the presence or absence of each species, and also to evaluate the performance of the classification models.

LDA analyses demonstrated that the distributions of *P. richardsonii* and *M. sibiricum* can be predicted by a single model with 81% confidence. Models derived from data of the EE performed similarly to a model intended for application in the proposed Keeyask reservoir (PR). This suggests there is no apparent decrease in confidence of prediction when pre-flood surrogate variables, such as distance to mineral soils and depth of peat, are used as surrogate variables when substrate type in the future reservoir at 30 years post-flood is unknown.

EE Models showed that substrate grain size and depth primarily determined macrophyte distribution in the existing environment. Analyses of each species separately, however, reveal that the environmental variables influencing the distribution of each species of macrophyte were notably different. The distribution of *M. sibiricum* was determined by substrate type, exposure, and slope. While the distribution of *P. richardsonii* was strongly related to substrate type, depth, and slope, this species was not limited by exposure.

The PR model developed uses pre-flood soil variables as a surrogate for substrate grain size, which is assumed to be unknown in this future scenario. PR LDA analyses by species showed that the pre-flood soil variables were not important predictors for *M. sibiricum* but were the most important for *P. richardsonii*, particularly the variable distance to mineral soils. The analyses suggest the potential distribution of *M. sibiricum* would be limited to sites with a combination of low exposure and slope. Conversely, the potential distribution of *P. richardsonii* was not limited by exposure and may be similar to that of pre-flood mineral soils found in shallow water of the reservoir.

The area occupied by aquatic macrophytes was assessed at two study areas on Stephens Lake in areas of pre-flood mineral soils. Bathymetric, elevation, slope, and substrate distributions were mapped. Substrate type appeared to be the greatest constraint influencing the area of habitat that is suitable for plant growth. Areas that are unsuitable for plant growth are typically peat or detrital materials found in shallow water, cobble/boulder shorelines, or widespread accumulations of silt in a few meters of water. Water depth also appeared to be a constraining variable on plant distribution, but was not as important as bottom type. Approximately 11.5% of the potential area was occupied by rooted plants as gleaned using the aerial polygon sketch method; this approach is expected to better delineate entire plant beds when compared to high resolution satellite data.

Within acceptable depths the substrate type appeared to be the greatest constraint influencing the area of habitat that is suitable. Peat or detrital materials found in shallow water, or widespread accumulations of silt in a few meters of water, typically were found outside of a band in shallow water that is suitable for plants. The high resolution satellite data suggested about 3% of the habitat that was suitable is actually used by rooted macrophytes, but probably is an underestimate given individual clumps of plants in a bed can be sensed. The area of potential plant habitat occupied by plants taken from sketches of plant beds from helicopter, that include the spaces between plants in a bed, is 11.5% of the potential habitat occupied. A conservative estimate of the area occupied for the Keeyask reservoir is 10%.

3C.5 REFERENCES

3C.5.1 LITERATURE CITED

Cooley, P. M. 1999. A manual for analysis and display of lake habitat and fish position information using GIS: physical and hydraulic habitat, draw down, and acoustic telemetry. Canadian Technical Report of Fisheries and Aquatic Sciences 2276: 49 pp.

Cooley, P. M. 2012. Fetch Distance, unpublished computer program.

Duart, C.M. and Kalff, J. 1986. Littoral Slope as a Predictor of the Maximum Biomass of Submerged Macrophyte Communities. Limnology and Oceanography: 31 (5): 1072–1080 pp.

Eastman, R. 2000. Guide to image processing: Idrisi Kilimanjaro GIS. Clark Labs, Worcester, MA.

Manly, B.F.J. 1994. Multivariate statistical methods: a primer. 2nd Edition. Chapman and Hall, London.

Table 3C-1: Generalization of Keeyask area soil classes to three soil groups present in the Stephens Lake pre-flood soil mapping. The Keeyask Soil Classes are defined in detail in Section 2 of the Terrestrial Environment Supporting Volume

Keeyask Soil Class	Macrophyte Model Soil Group
Shallow/Thin Mineral	Mineral
Deep Dry Mineral	
Wet Organic Veneer or Blanket	Veneer Bog
Veneer Bog	
Wet, Deep Peat	Peatland
Blanket Bog	
Peat Plateau Bog (PPB)	
Peat Plateau Bog/Collapse Scar Mosaic	
Horizontal Peatland	
Aquatic Peatland	
PPB: Disintegrating/Forming	
Collapse Scar	

Table 3C-2: Standardized discriminant function coefficients and percent variance explained for three Linear Discriminant Analysis trials using data for both species of macrophyte and absent from the existing environment (EE), and pre-flood (PF) data. Model 1 used all EE and PF variables. Model 2 used EE data only. Model 3 is the Predictive Reservoir model (PR) where substrate grain size data may not be available and has been removed from variable selection in this trial

Discriminant Function	Model 1: EE + PF		Model 2: EE		Model 3: PR	
	1	2	1	2	1	2
Depth	0.266	-0.066	-0.305	-0.101	0.218	0.330
Exposure	0.002	-0.493	0.049	1.026	-0.184	0.590
Slope	0.241	-0.291	-0.353	0.090	0.129	0.604
Phi	-0.853	0.215	0.920	0.166	-	-
Mineral $soil_{dist}$	0.343	0.519	-	-	0.719	0.023
Peat depth	0.258	0.317	-	-	0.426	-0.026
% variance	79.4	20.6	87.5	12.5	67.5	32.5

Table 3C-3: Standardized discriminant function coefficients and percent variance explained on discriminant function 1 for four LDA trials for *M. sibiricum* (models 4 and 5) and *P. richardsonii* (models 6 and 7) using data from the existing environment (EE), and pre-flood (PF). Models 5 and 7 assume substrate grain size data may not be available and has been replaced with the PF surrogate variables: 1) minimum distance to mineral soils, and 2) peat depth

	Model 4: *M. sibiricum* EE + PF	**Model 5: *M. sibiricum* PF**	**Model 6: *P. richardsonii* EE + PF**	**Model 7: *P. richardsonii* PF**
Depth	-	-	0.215	0.249
Exposure	-0.399	0.768	-	-
Slope	-0.435	0.665	0.154	0.199
Phi	0.867	-	-0.766	-
Mineral $soil_{dist}$	-	-	0.487	0.748
Peat depth	-	-	0.338	0.404
% variance	0.80	0.56	0.80	0.65

Table 3C-4: Fishers discriminant function coefficients derived for seven models using Linear Discriminant Analysis (LDA) on data from Stephens Lake representing the existing environment (EE) and Pre-Flood (PF) environments. Models 1–3 contain presence and absence of both species of macrophyte. Models 4–7 include data from one species and absent. Models 3, 5, and 7 assume the substrate variable phi is unavailable

Model Number	LDA Model	Number of Variables	Class	Constant	EE				PF	
					Slope	Exposure	Depth	Phi	Mineral $Soil_{dist}$	Peat Depth
1	Full Model (EE,PF)	6	*M. sibiricum*	-21.3088	-0.0064	0.0041	1.0857	1.8488	0.0034	0.0858
			P. richardsonii	-17.1923	0.4271	0.0063	1.2640	1.5526	-0.0023	0.0741
			Absent	-17.8007	0.7412	0.0056	1.8758	0.5475	0.0054	0.0930
2	EE variables	4	*M. sibiricum*	-12.8270	0.1980	0.0010	1.2580	1.9922	-	-
			P. richardsonii	-11.5431	0.5145	0.0038	1.4138	1.6689	-	-
			Absent	-7.3679	0.9921	0.0021	2.0623	0.7055	-	-
3	Predictive Reservoir	5	*M. sibiricum*	-13.3283	0.0622	0.0034	1.4159	-	0.0035	0.0923
			P. richardsonii	-11.5641	0.4847	0.0057	1.5413	-	-0.0022	0.0796
			Absent	-17.1007	0.7616	0.0053	1.9736	-	0.0054	0.0949
4	*M. sibiricum*	3	*M. sibiricum*	-8.4928	-0.0249	0.0015	-	1.4721	-	-
			Absent	-3.6763	0.6892	0.0041	-	0.4904	-	-
5	*M. sibiricum* predictive	2	*M. sibiricum*	-1.5131	0.2162	0.0016	-	-	-	-
			Absent	-2.9018	0.7695	0.0041	-	-	-	-
6	*P. richardsonii*	5	*P. richardsonii*	-11.8299	0.4233	-	1.8511	1.2436	-0.0024	0.0492
			Absent	-12.9900	0.6732	-	2.3138	0.3977	0.0050	0.0657
7	*P. richardsonii* predictive	4	*P. richardsonii*	-7.5573	0.4829	-	2.0199	-	-0.0024	0.0546
			Absent	-12.5530	0.6922	-	2.3678	-	0.0050	0.0674

Table 3C-5: Classification agreement (%) for existing environment (EE), pre-flood (PF), predictive reservoir models (PR) for Linear Discriminant Analysis trials with: 1) both species of macrophyte included (models 1–3) or 2) where one species has been removed (models 4–7) to evaluate the variables important to each species. The Model group represents 75% of the available data and was cross-validated using the remaining Test data not used to build the model

Model Number	LDA Variables	Number of Variables	Model Agreement (%)	Test Agreement (%)	Test		
					M. sibiricum	***P. richardsonii***	**Absent**
1	EE + PF	6	85.0	86.0	95.0	82.0	85.0
2	EE	4	80.0	81.0	86.0	84.0	76.0
3	PR	5	78.0	81.0	86.0	86.0	74.0
4	EE + PF	3	90.5	95.5	100.0	-	93.0
5	PF	2	85.6	91.0	85.7	-	93.0
6	EE + PF	5	88.7	86.5	-	88.0	84.8
7	PF	4	79.9	84.4	-	90.0	78.3

Table 3C-6: The use of suitable habitat by presence of rooted macrophytes in two study areas on Stephens Lake, in mid-summer 2005 and 2006 using two methods of aerial assessment

Habitat area occupied or suitable	Method	Area (m^2)	% Occupied	% Occupied
Area occupied - north validation area	remote sensing	1627.9	2.5	-
Area occupied - south validation area	remote sensing	5000.1	3.5	-
Area occupied - north validation area	aerial sketch	7222.7	-	10.9
Area occupied - south validation area	aerial sketch	17331.9	-	12.2
Area suitable - north validation area		66336.8		
Area suitable - south validation area		142577.3		
Average (%)			3.0	11.5

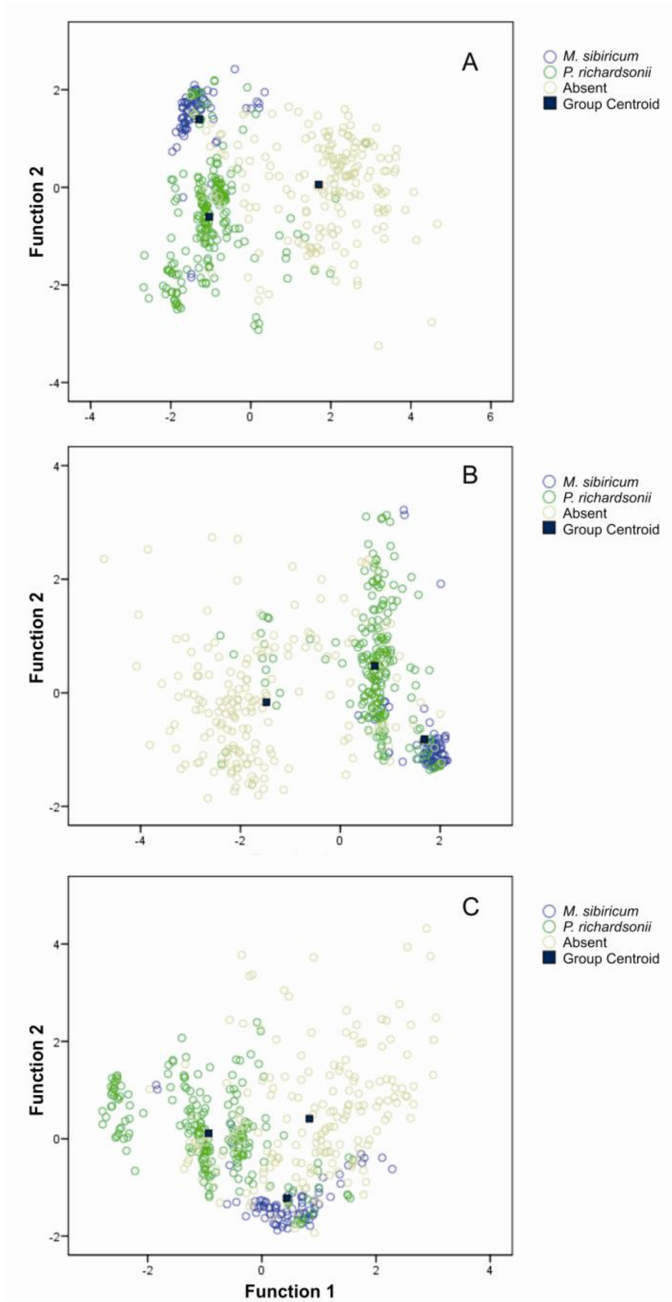


Figure 3C-1: Discriminant analysis scatter plots showing three variants of the predictive aquatic macrophyte model using data from the existing environment (EE) and/or pre-flood (PF) within Stephens Lake. (A) Model 1: full model comprised of all six variables; 4 from the EE and 2 from PF data; (B) Model 2: EE model comprised of all 4 EE variables; (C) Model 3: predictive reservoir model comprised of all EE variables except for phi, which is accounted for by the PF surrogate variables: i) peat depth and ii) distance to mineral soil

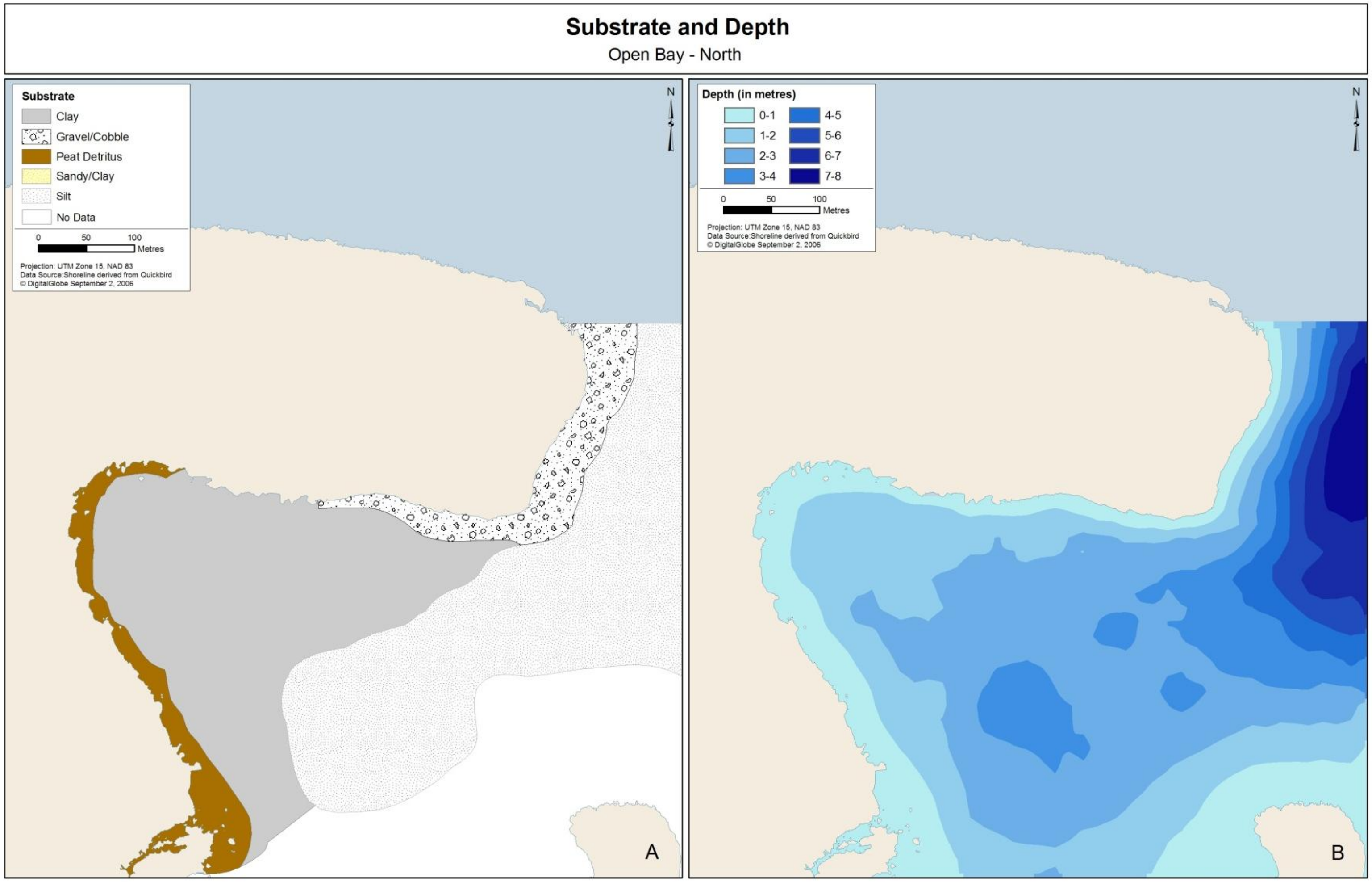


Figure 3C-2: Substrate (A) and water depth (B) distributions for the North validation study areas in Stephens Lake representing a 95th percentile water elevation

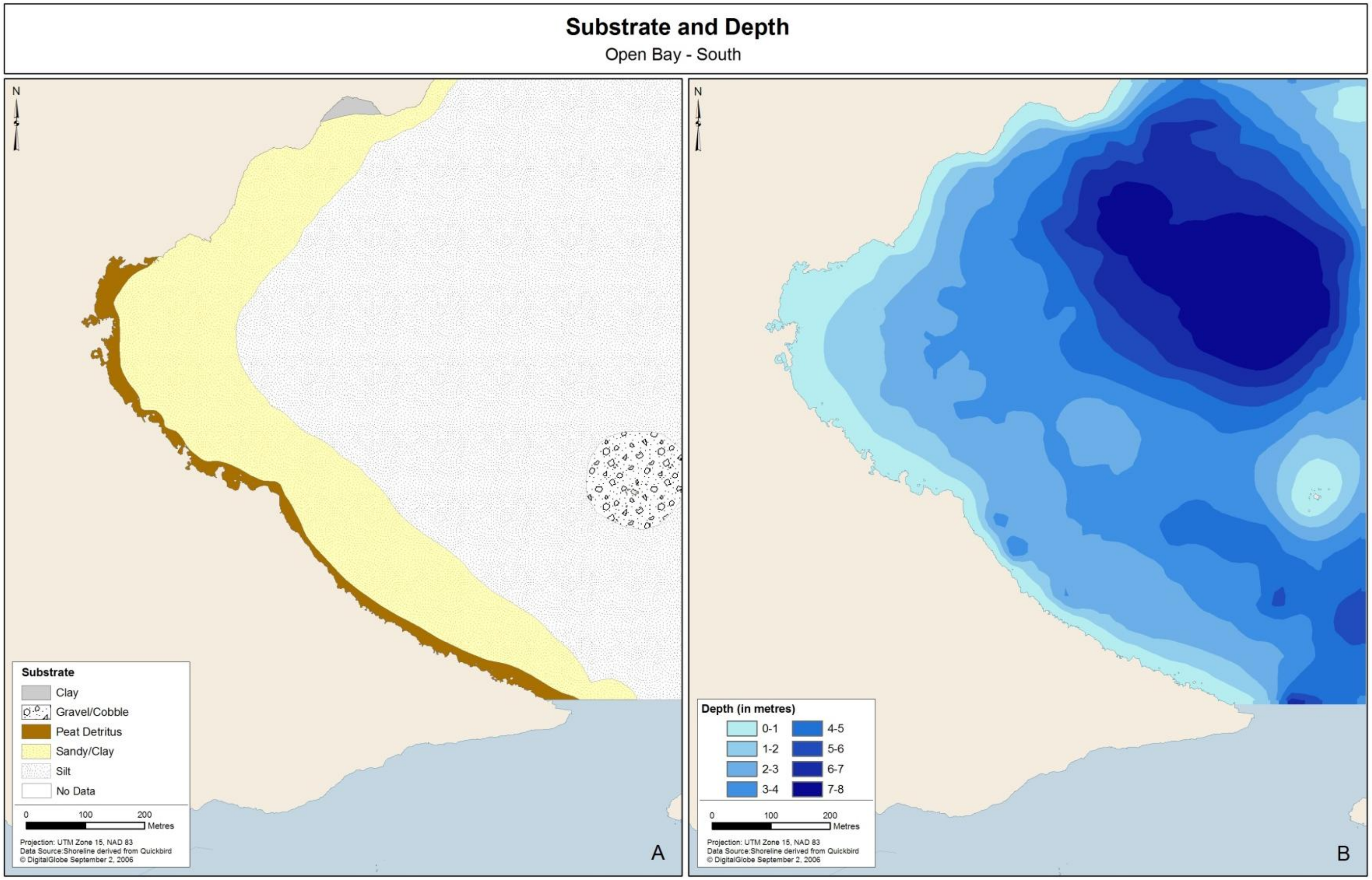


Figure 3C-3: Substrate (A) and water depth (B) distributions for the South validation study areas in Stephens Lake representing a 95th percentile water elevation

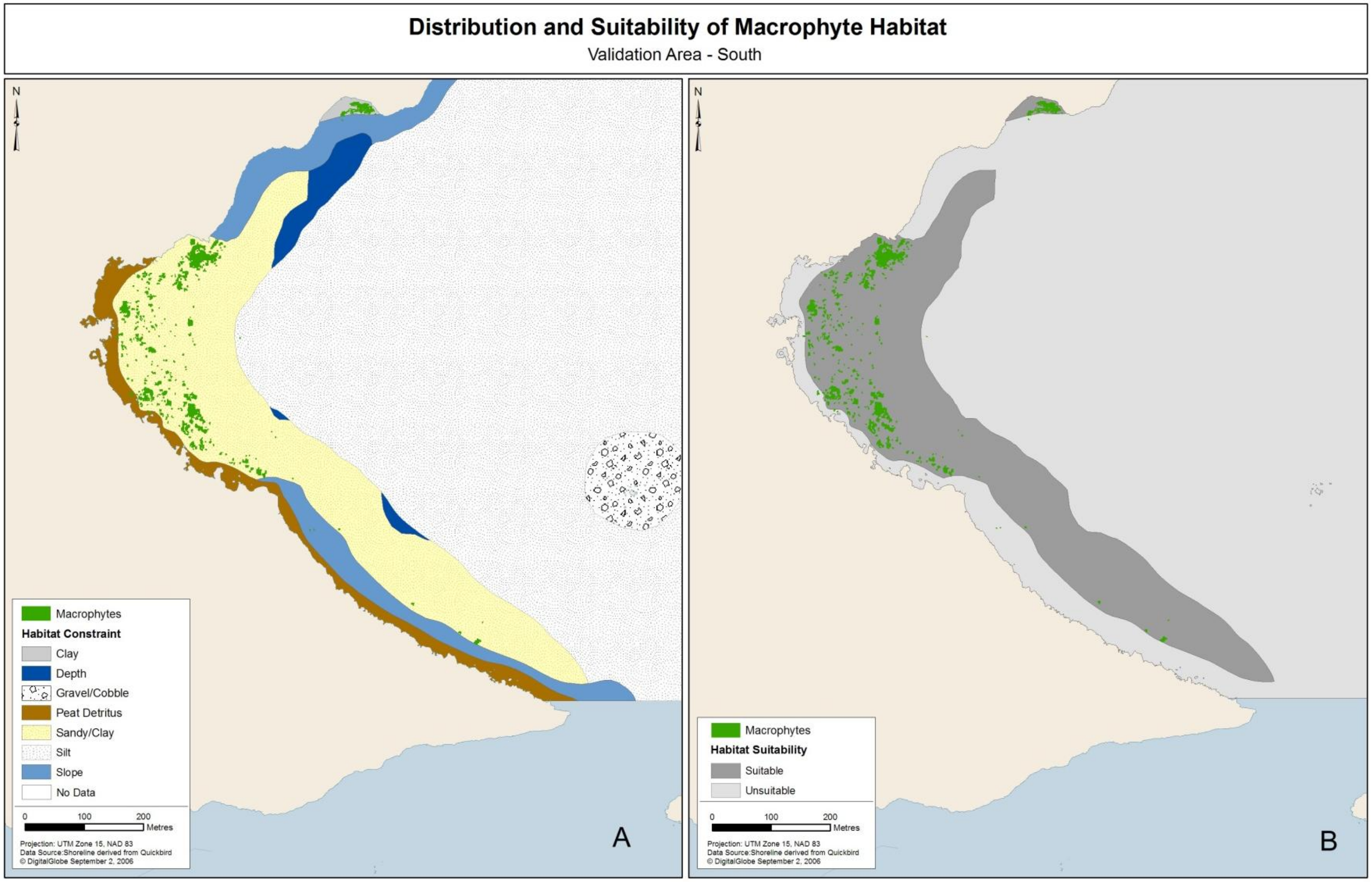


Figure 3C-4: Distribution of habitat constraints on aquatic macrophyte presence (including slopes more than 6 %) (A), and suitability of macrophyte habitat also showing the area occupied by plants relative to that available (B) in the South validation study area in Stephens Lake

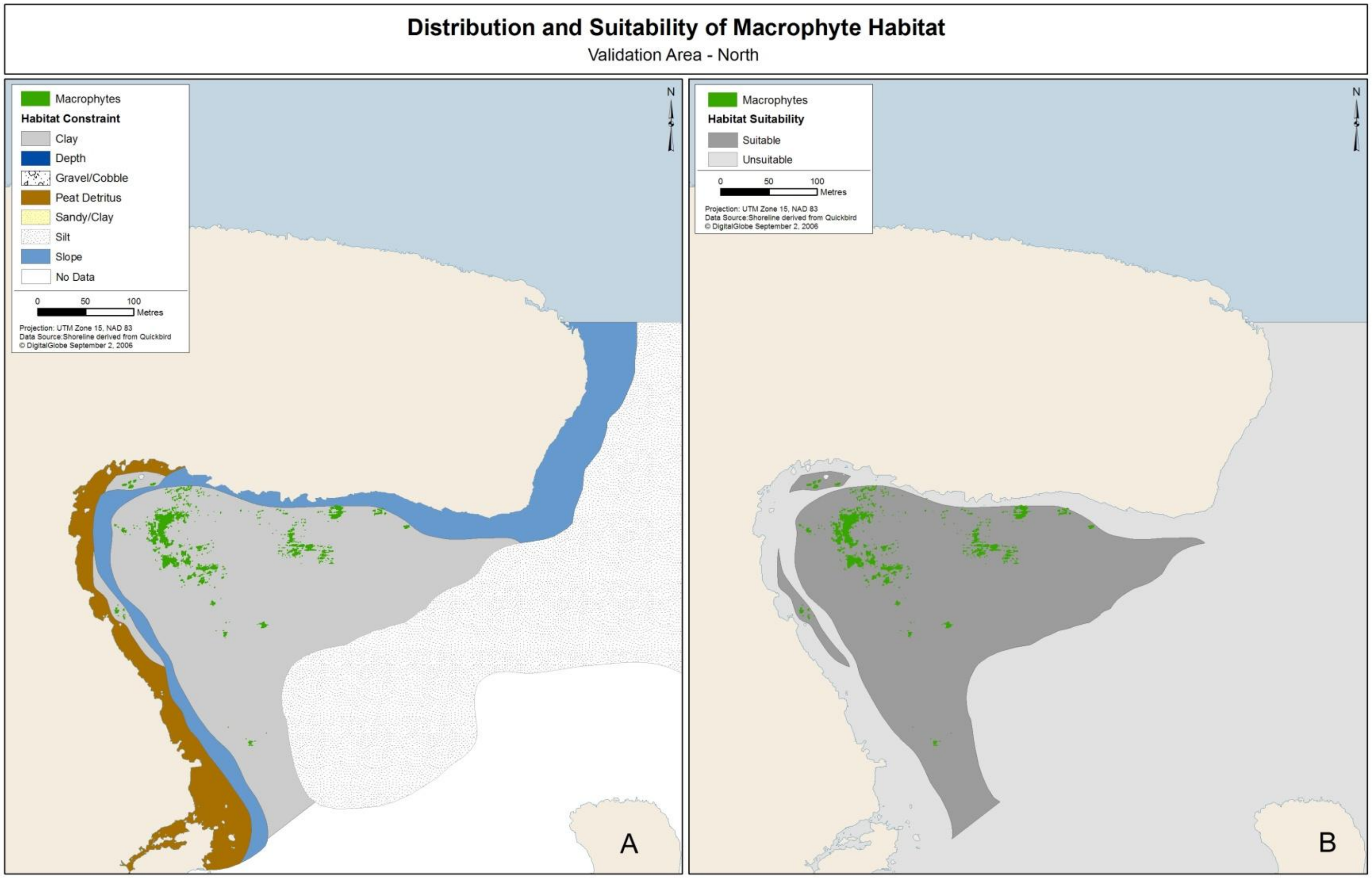


Figure 3C-5: Distribution of habitat constraints on aquatic macrophyte presence (including slopes more than 6 %) (A), and suitability of macrophyte habitat also showing the area occupied by plants relative to that available (B) in the North validation study area in Stephens Lake

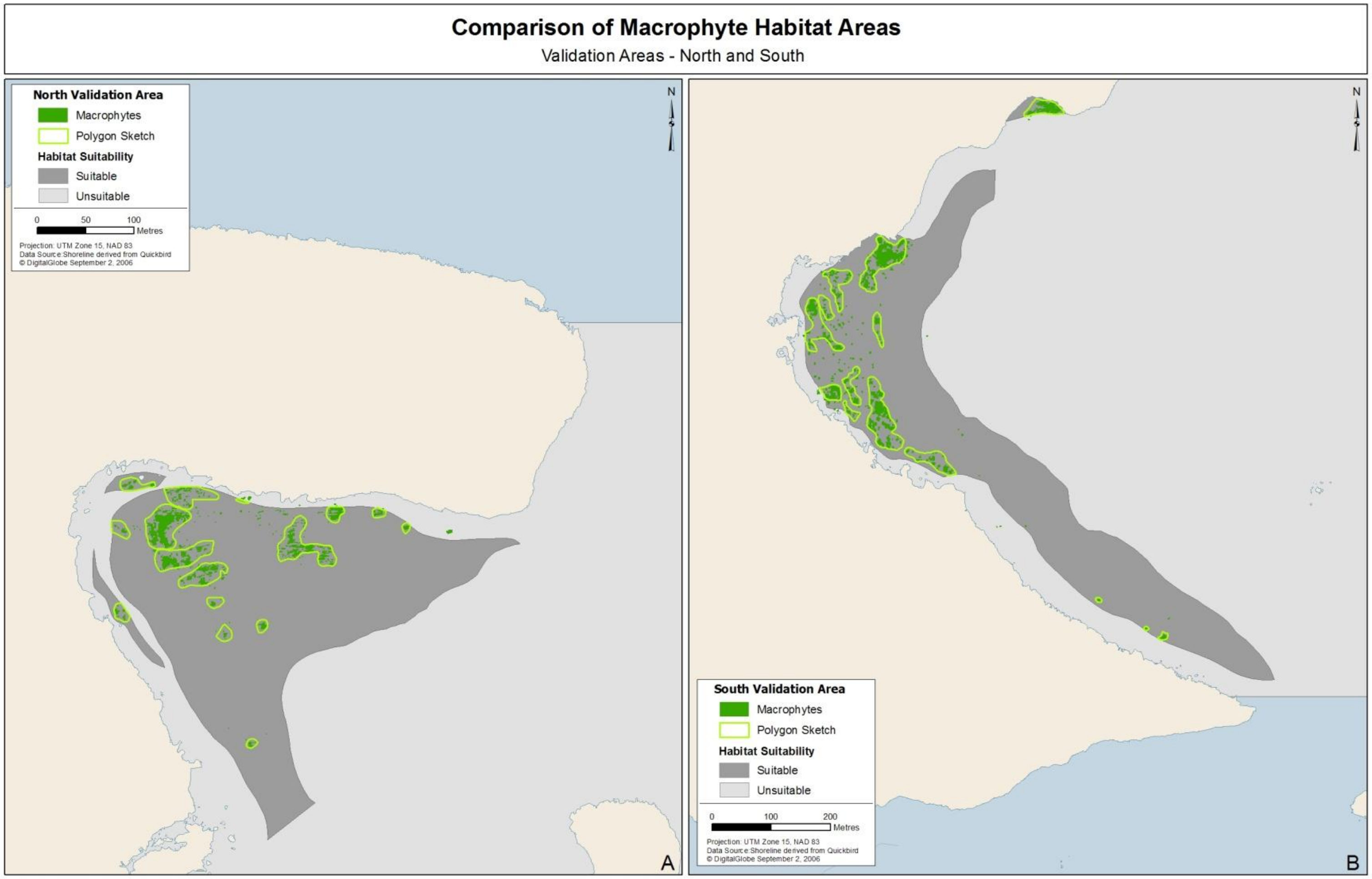
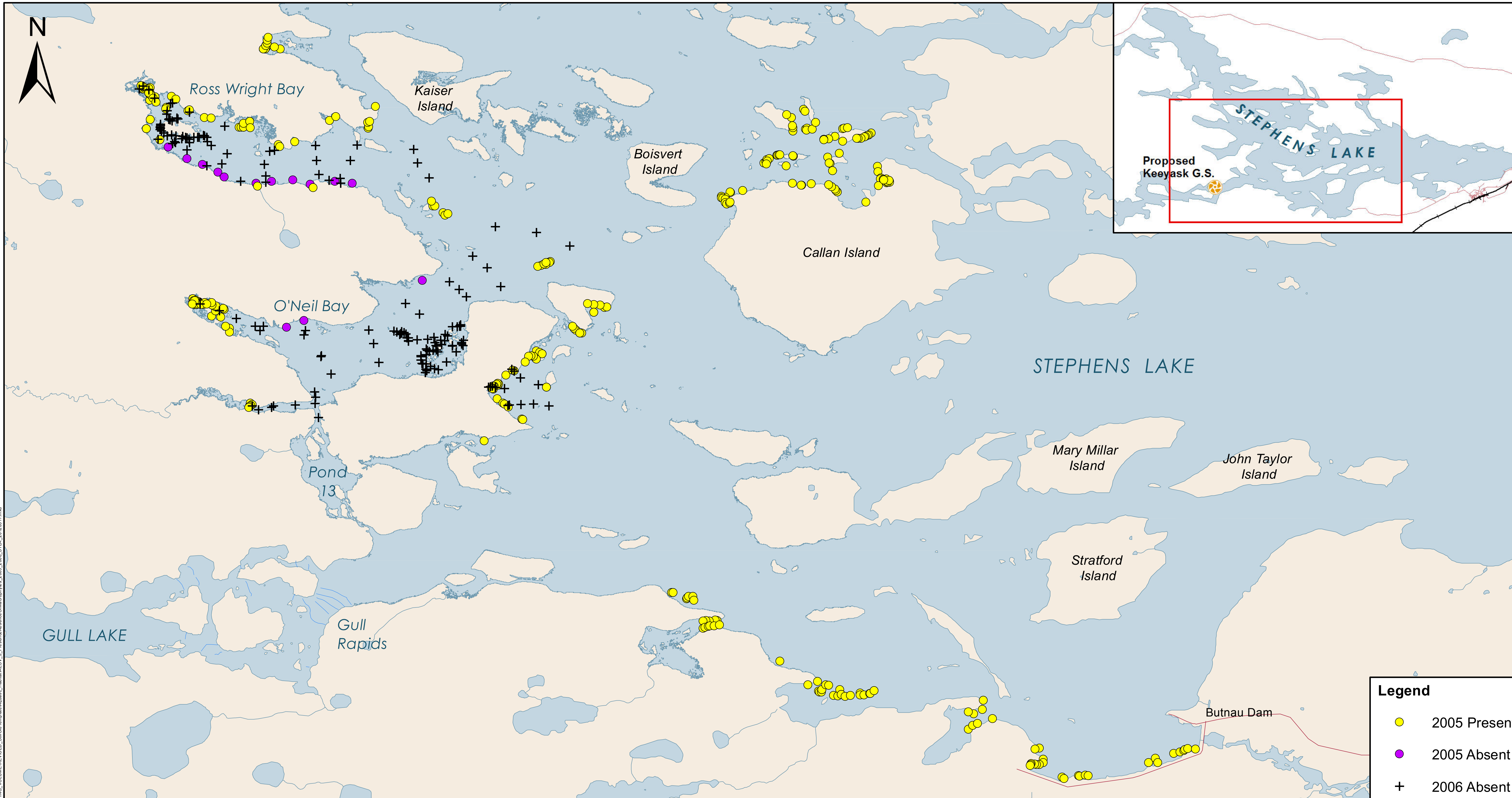


Figure 3C-6: Comparison of the distribution macrophyte beds captured using high resolution optical satellite imagery (described in preceding figure) and aerial polygon sketches for the north and south validation study areas in Stephens Lake



KEEYASK Hydropower Limited Partnership

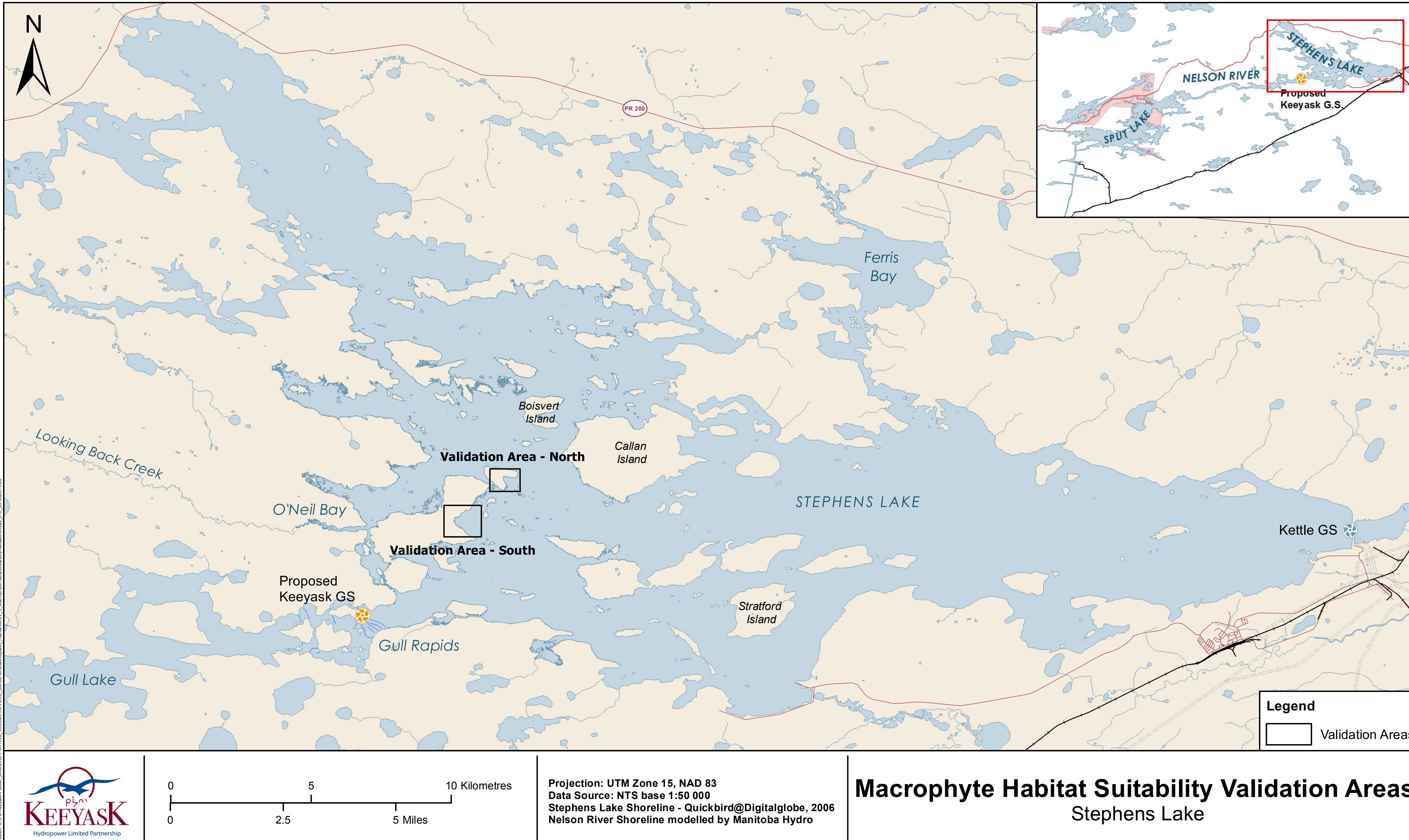
0 2.5 5 Kilometres
0 1.25 2.5 Miles

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

Presence/Absence of Macrophytes 2005 - 2006

Stephens Lake Area

Map 3C-1



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

Macrophyte Habitat Suitability Validation Areas

Stephens Lake

Map 3C-2

APPENDIX 3D
FISH HABITAT AREA MODEL FOR THE "UPSTREAM KEEYASK AREA"

3D.1 INTRODUCTION

A model was developed to estimate the availability of aquatic habitat types to fish and lower trophic levels at various time steps after impoundment. Habitat types were defined based on site-specific characteristics of aquatic habitat that described each location where fish and lower trophic level samples were collected, *i.e.*, water depth, velocity, substrate (compaction and composition) and the presence/absence of macrophytes. The model inputs included: existing environment habitat conditions in the reach between Clark Lake outlet and Gull Rapids; Year 30 habitat area and distribution predictions based on model outputs as described in Section 3.4; predictions of reservoir area expansion peat transport rates; plant bed destruction/development; and mode of operation effects on habitat availability. The main components of the model were developed in sequence as follows:

1. Perform area calculations of each habitat type in the existing environment;
2. Develop area estimates of the habitat types in Year 30 post-Project;
3. Modify the Year 30 habitat areas in the downstream, more lacustrine portion of the reservoir for intermediate time steps (Years 1, 5, and 15) to account for reservoir expansion over time, peat disintegration and transport, and loss and subsequent establishment of plant beds; and
4. Estimate useable habitat areas in the IEZ.

3D.2 HABITAT ANALYSES

The habitat analyses were conducted in four steps, as listed above.

3D.2.1 AREA CALCULATIONS OF HABITAT TYPES IN THE UPSTREAM PROJECT REACH EXISTING ENVIRONMENT

Aquatic habitat in the Nelson River reaches between the outflow of Clark Lake and the Keeyask GS (Upstream Keeyask Area) EE was classified into habitat types based on depth, water velocity, substrate compaction and composition, and presence or absence of vegetation. Area calculations of each habitat type were performed using GIS analysis methods. As described in Section 3.2 the spatial extent of habitat types in this reach was modelled at 95th percentile flow conditions. The area of each habitat type at the 95th percentile flow condition in the EE is shown in Table 3D-1. Areas of shallow water habitat occupied by plants were calculated based on a reach-by-reach and year-by-year analysis of plant bed surveys conducted in 2001, 2003, and 2006.

3D.2 2 AREA ESTIMATES OF HABITAT TYPES IN THE UPSTREAM PROJECT REACH IN YEAR 30 POST-PROJECT

Predictions of the types and areas of aquatic habitats that would occur in the Year 30 post-Project Upstream Keeyask Area (Keeyask reservoir) were based on predictive habitat models developed in large part from studies at Stephens Lake. The area of each Year 30 post-Project habitat type was estimated at FSL using the predicted shoreline at 159 metres above sea level (m ASL) under 95th percentile flow conditions (PE SV) and at 158 m ASL for the MOL of the reservoir (Table 3D-1).

3D.2.3. MODIFICATION OF YEAR 30 HABITAT AREAS FOR INTERMEDIATE TIME STEPS (YEARS 1, 5, AND 15)

The predicted Year 30 habitat areas were modified to characterize reservoir evolution and associated changes to the proportional distribution of each habitat type (Table 3D-1) during the intermediate time steps (Years 1, 5, and 15) to account for:

- Expansion of the Keeyask reservoir over the time series due to shoreline erosion and peatland disintegration;
- Reduction in the area of organic substrates (*i.e.*, peat) in shallow areas over time due to peatland disintegration and transport; and
- Loss and subsequent establishment of aquatic plants beds.

3D.2.3.1 Habitat Area Modifications Attributed to Shoreline Recession/Reservoir Expansion

Shallow water habitat (depth less than or equal to 3 m) areas were modified (back-calculated) at each of the Year 1, 5, and 15 time steps based on an assumption that all of the predicted reservoir expansion in the Year 1–30 period (623.7 ha; Section 3) would occur over terrain that would only increase the areas of shallow water habitat at FSL. The increase in areas of each habitat type was allocated in proportion to the modelled habitat area distributions at Year 30. This was done by multiplying the area of recession in each time step (Year 1 = 623.7; Year 5 = 438.9; and Year 15 = 182.0 ha) by the proportional area of each shallow water habitat in Year 30 (the area of the shallow water habitat type divided by the total shallow water habitat). This recession value was subtracted from each of the Year 30 areas to generate the area of each shallow water habitat at each time step. This calculation was only done for the reservoir at FSL as it was assumed that the MOL area of the reservoir was the same 30 years after impoundment as it was at Year 1 based on the assumption that habitat created by shoreline erosion would be less than 1 m deep.

3D.2.3.2 Habitat Area Modifications Attributed to Peat Disintegration and Transport

Estimates of the effect of peat disintegration and transport on the amount of mineral versus organic substrate habitats in shallow water environments were based on information that the majority of peat disintegration (PE SV Section 6) and transport (PE SV Section 7), and hence mineral exposure, would occur in shallow water habitat in the first five years post-impoundment. To back-calculate the amount of organic/peat substrates from the Year 30 modelled habitat areas for the interim time steps, it was assumed that peat disintegration and transport would be more advanced in later time steps such that 90% of the peat disintegration predicted for Year 30 would have occurred by the end of Year 15, 70% by the end of Year 5, and 50% by the end of Year 1. Further to this premise, it was assumed that the transport of resurfaced and disintegrating peat material (PE SV Section 6) from shallow water habitats would be hastened in areas where water velocity was higher as follows:

Velocity	Year 1	Year 5	Year 15	Year 30
High	100%	100%	100%	100%
Medium	70%	100%	100%	100%
Low	60%	80%	90%	100%
Standing	20%	70%	80%	100%

The above proportions were subtracted from the Year 30 area of habitat types with mineral substrates at each time step and summed to calculate the area of organic habitats. This conversion resulted in the creation of a habitat type that only existed in the reservoir in Year 1 (*i.e.*, Shallow, Medium Velocity, Soft Organic substrate, No Plants – S-M-s-O-N).

3D.2.3.3 Habitat Area Modifications Attributed to Aquatic Plant Bed Development

Ten percent of the potential plant habitat area (as defined in Section 3) was estimated to be occupied by aquatic plants in Year 30. To account for differences in the area occupied by aquatic plants at both FSL and MOL in the intermediate time steps, the proportional area of shallow aquatic habitat types was altered assuming that aquatic plant beds would be lost immediately after flooding and would not re-establish in flooded terrestrial habitat until beyond Year 5. Consequently, in the calculating Year 1 and 5 habitat areas, all those habitat areas that in Year 30 were predicted to support plant beds were assigned to the corresponding habitat category with no plants (*e.g.*, Year 1 and Year 5 Shallow-Low Velocity-Soft-Mineral-Plants habitat area was added to Shallow-Low Velocity-Soft-Mineral-No plants area). The areas occupied by plant beds at Year 15 were estimated to be 25% of the corresponding area of plant establishment by Year 30.

3D.2.4 ESTIMATES OF USEABLE HABITAT AREAS IN THE INTERMITTENTLY EXPOSED ZONE

The effect of two possible modes of operation (peaking and Base loaded modes) on potential fish and lower trophic organism use of habitats and habitat productivity was examined.

3D.2.4.1 Peaking Mode of Operation

A peaking mode of operation involving weekly cycling of flows as described in PE SV, Section 4.4.2.2 was used to examine the effects of this mode of operation on potential fish use and the availability of fish habitats in Upstream Keeyask Area at Years 1, 5, 15, and 30 post-impoundment. This mode of operation indicates that under 50th percentile flow conditions habitats that lie between the FSL and the MOL under the same flow conditions could be dewatered on average 50% of the time in any one week period, and would therefore not be available to fish.

Note: for these estimations of effects of the peaking mode of operation on useable habitat areas, the post-Project habitat areas at FSL under 95th percentile flows were used as a reasonable approximation of habitat areas that would exist under 50th percentile flows. It was assumed that for the most part any differences between habitat exposure at 50th percentile flows and 95th percentile flows would occur in the upstream, riverine portions of the reservoir (PE Volume) and that those differences would not be sufficiently large to meaningfully affect the outcome of the habitat exposure analysis.

This area of periodic exposure or IEZ was calculated as the difference between the size of the reservoir operating at FSL (159 m) and MOL (158 m) at each of the Year 1, 5, 15, and 30 time steps. Because the reservoir expands over time at FSL (described in previous section) due to shoreline erosion and peat disintegration processes, but was assumed to maintain a relatively constant area over time at the MOL, all predicted increases in reservoir area at each time step were attributed to an increase in area of the IEZ.

For the peaking mode of operation, shallow water habitat areas that would be available to fish were calculated for each Year 1, 5, 15, and 30 time step by adding 50% of a habitat's area within the IEZ to that habitat's area at MOL. IEZ area calculations at each of the Year 1-30 time steps are shown in Table 3D-1.

3D.2.4.2 Base Loaded Mode of Operation

The Keeyask GS could be expected to operate in a Base loaded mode of operation 12% of the time or more (PE SV Section 4.4.2.2). Except in emergencies, the Base loaded mode of operation would only occur when the reservoir elevation exceeded the MOL.

Base loaded operations at FSL were examined for potential effects on the availability and quality of fish habitat. The following conditions were examined:

- For short duration base loaded operation (*i.e.*, any continuous duration less than several months), it was considered that fish habitat areas between FSL and MOL would be degraded and therefore would be discounted the same as for the peaking mode of operation (*i.e.*, the IEZ would be discounted by 50%).

- Base loaded operations that continuously persist in excess of several months at FSL may be expected to benefit the forage base for fish in shallow water habitat areas within the IEZ. In this case, there would be no discounting of the IEZ area of shallow water habitats.

Base loaded operation of the GS at the MOL (158 m ASL) would result in the loss of the IEZ as fish habitat. For this operating scenario, habitat area calculations omitted all habitat areas within the IEZ.

Table 3D-1: Habitat-specific area in the existing environment (EE) and four post-Project time steps at 158 m ASL (minimum operating level) and 159 m ASL (full supply level)

Classification[1]	Area (ha)												
	EE	Year 1 Post-Project			Year 5 Post-Project			Year 15 Post-Project			Year 30 Post-Project		
		158	159	IEZ[2]	158	159	IEZ	158	159	IEZ	158	159	IEZ
S-H-h-M-N	146.1	74.7	78.0	3.3	74.7	78.0	3.4	74.7	78.1	3.4	74.7	78.1	3.4
S-L-h-M-N	168.0	27.4	42.6	15.2	31.0	48.3	17.3	32.8	52.6	19.8	34.6	56.7	22.1
S-L-s-M-N	184.1	72.4	92.5	20.2	95.2	125.0	29.8	109.8	154.9	45.1	118.0	173.0	55.0
S-L-s-M-P	32.1	0.1	0.1	0.0	0.1	0.1	0.0	1.2	1.9	0.7	4.8	8.5	3.7
S-L-s-O-N	0.0	62.0	74.0	12.0	35.6	47.1	11.4	18.2	26.7	8.5	4.5	8.9	4.5
S-M-h-M-N	181.2	46.3	60.4	14.2	48.3	63.8	15.5	48.3	64.7	16.4	48.3	65.3	17.0
S-M-s-M-N	27.5	1.1	10.0	8.9	1.1	11.7	10.6	1.1	12.1	11.0	1.1	12.4	11.3
S-M-s-O-N	0.0	2.0	4.1	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S-St-h-M-N	112.7	2.6	4.1	1.5	2.9	4.4	1.5	3.0	4.5	1.5	3.1	4.7	1.6
S-St-s-M-N	773.4	265.2	415.7	150.5	896.1	1385.5	489.4	1041.3	1780.7	739.5	1274.6	2240.9	966.3
S-St-s-M-P	175.2	0.0	2.2	2.2	0.0	2.2	2.2	6.4	26.0	19.6	31.8	127.9	96.1
S-St-s-O-N	0.0	1213.1	2163.8	950.7	582.0	1366.3	784.4	427.9	1177.4	749.5	159.3	743.5	584.3
St-S-s-O-P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	9.7	7.3	12.3	51.4	39.1
D-St-s-M-N	62.1	3014.2	3014.6	0.5	3014.2	3014.6	0.5	3014.2	3014.6	0.5	3014.2	3014.6	0.5
D-St-h-M-N	64.9	36.4	36.4	0.0	36.4	36.4	0.0	36.4	36.4	0.0	36.4	36.4	0.0
D-L-s-M-N	133.4	1472.5	1472.5	0.0	1472.5	1472.5	0.0	1472.5	1472.5	0.0	1472.5	1472.5	0.0
D-L-h-M-N	711.9	792.5	793.2	0.6	792.5	793.2	0.6	792.5	793.2	0.6	792.5	793.2	0.6
D-M-h-M-N	1608.8	1018.8	1019.5	0.7	1018.8	1019.5	0.7	1018.8	1019.5	0.7	1018.8	1019.5	0.7
D-M-s-M-N	50.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D-H-h-M-N	547.4	207.8	207.8	0.0	207.8	207.8	0.0	207.8	207.8	0.0	207.8	207.8	0.0
D-St-s-O-N	0.0	32.7	40.3	7.6	32.7	40.3	7.6	32.7	40.3	7.6	32.7	40.3	7.6
Total	**4979.3**	**8341.8**	**9532.0**	**1190.2**	**8341.8**	**9716.7**	**1374.9**	**8341.8**	**9973.7**	**1631.9**	**8341.8**	**10155.7**	**1813.9**

1. Classification Codes:
   Depth: S = shallow; D = deep.
   Compaction: h = hard; s = soft.
   Velocity: H = high; M = medium; L = low; St = standing.
   Composition: M = mineral; O = organic.
   Vegetation: N = no plants; P = plants.
2. IEZ = intermittently exposed zone.

APPENDIX 3E
NORTH AND SOUTH ACCESS ROAD STREAM CROSSINGS SUMMARY SHEETS

Access Road Watercourse Crossing Description

Figure 1: Aerial view of Looking Back Creek with the crossing location indicated by the red line and the direction of flow by the white arrow.

Figures 2 and 3: Upstream view (left photo) and downstream view of Looking Back Creek, with the crossing location indicated by the red line and the direction of flow by the white arrow.

Keeyask Access Road
Stream Crossing Assessment

Location

UTM:	0360595 / 6250077–NAD 83	**Watercourse Name:**	Looking Back Creek
Date:	7 October, 2004	**Site:**	SC – 1

Site Description

Stream Order:	3
Watershed Size:	124.7 km^2
Upstream of Crossing:	119.8 km^2
Regulated:	No
Channelized:	No
Channel Width:	7.4 m
Wetted Width:	7.4 m
Floodplain Width:	Right: 17 m, Left: 14 m
Maximum Depth:	0.8 m
Stage:	Moderate
Sign of flood above surveyed stage:	0.3 m
Valley Slope Gradient:	Left – 5% Right – 6%
Stream Gradient:	1%
Velocity:	0.31 m/sec
Discharge:	1.32 m^3/sec
Cover Type and Composition:	Total – 80% Over Veg. – 10% LOD – 30% Cutbank – 10% Boulder – 10% In. Veg. – 40%
Habitat Type:	Run – 100%
Bottom Contour:	Uniform
Substrate Type:	Fines – 90% Boulder – 10%
Substrate Compaction:	Moderate
Bank Unstable:	0%
Water Temperature:	3 °C
Turbidity:	7.1 NTU

Riparian Vegetation:	The creek lies within a relatively narrow, well-drained floodplain containing grasses and willows. The valley forest is composed of black spruce and jack pine with an understory of moss, shrubs, and forbs.
Aquatic Vegetation:	Yes
Unique Features:	n/a
Summary:	This crossing is located in the lower portion of the creek, approximately 4 km from Stephens Lake. Habitat in the creek consists primarily of run habitat less than 1 m deep, with some side channel pools. Small areas of gravel/cobble riffle occur further upstream from the crossing. The creek substrates are primarily fines with some boulder and cobble/gravel. The presence of beaver dams began 2 km upstream of the crossing, continuing upstream to the headwaters.

Fisheries Assessment

Capture Method:	Fall 2004–Backpack Electrofishing, 1.5" and 3.5" gill net. Spring 2005 – Hoop net, kick net.
Species Present:	Fall 2004–None. Spring 2005 – walleye, northern pike.
Life History Stage:	Fall 2004–n/a Spring 2005 – pre-spawn and post-spawn adults. One northern pike egg.

[1] For example: walleye, northern pike, suckers

[2] For example: sticklebacks, minnows

Fisheries Assessment

Large-bodied Species[1]

Spawning:	Yes
Migration:	Yes
Rearing:	Yes
Overwintering:	Possibly

Small-bodied Species[2]

Open-water Presence:	Yes
Overwintering:	Possibly

Fish Use and Fish Habitat Summary

This creek provides good habitat for spring and summer spawning, foraging, and rearing for small- and large-bodied species. Spawning habitat for walleye or suckers was not present at the crossing site. Vegetated areas of run habitat along the shorelines may be used by northern pike for spawning. Overwintering habitat may be present at the crossing site in some years but not in others. Habitats in the crossing area were common elsewhere in Looking Back Creek and no rare habitats were present (*i.e.*, gravel riffles, deep off-current pools). Access to the creek from Stephens Lake was unimpeded by beaver dams.

North/South Consultants Inc.
AQUATIC ENVIRONMENT SPECIALISTS

Access Road Watercourse Crossing Description

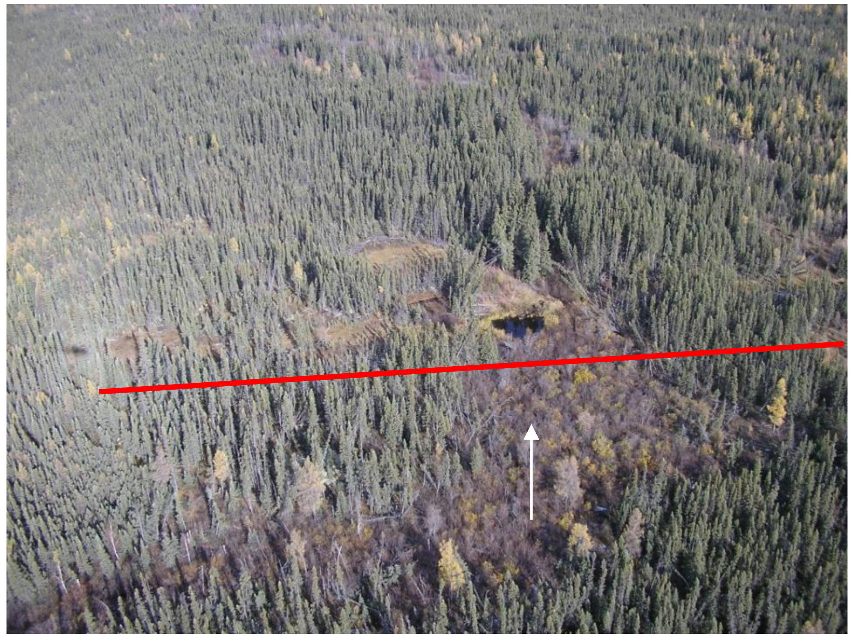


Figure 1: Aerial view of Unnamed Creek with the crossing location indicated by the red line and the direction of flow by the white arrow.

Figures 2 and 3: Upstream view (left photo) and downstream view of Unnamed Creek at the crossing location.

Keeyask Access Road
Stream Crossing Assessment

Location

UTM:	0345689 / 6254940–NAD 83
Date:	6 October, 2004
Watercourse Name:	Unnamed Tributary of the South Moswakot River
Site:	SC– 2

Site Description

Stream Order:	1
Watershed Size:	35.5 km^2
Upstream of Crossing:	4.0 km^2
Regulated:	No
Channelized:	No
Channel Width:	2.5 m
Wetted Width:	2.2 m
Floodplain Width:	Right: 8 m, Left: 8 m
Maximum Depth:	0.6 m
Stage:	Moderate
Sign of flood above surveyed stage:	n/a
Valley Slope Gradient:	Left – 12% Right – 10%
Stream Gradient:	1%
Velocity:	0.02 m/sec
Discharge:	0.02 m^3/sec
Cover Type and Composition:	Total – 60% Over Veg. – 50% LOD – 30% Cutbank – 10% In. Veg. – 10% Canopy Clos. – 80%
Habitat Type:	Pool – 100%
Bottom Contour:	Uniform
Substrate Type:	Fines – 100%
Substrate Compaction:	Low
Bank Unstable:	0%
Water Temperature:	1 °C
Turbidity:	1.5 NTU

Riparian Vegetation:	The creek lies within a relatively narrow, floodplain containing dense willow growth, sedges, grasses, and forbs. The valley forest is composed of black spruce with a moss understory. Further upstream and downstream of the crossing, the creek flows through a broad poorly drained floodplain.
Aquatic Vegetation:	Yes
Unique Features:	Approximately 50 m downstream of the crossing, a log ramp has been constructed to permit crossing the creek along a cut line.
Summary:	This small creek drains two small lakes prior to entering the South Moswakot River (approximately 10 km downstream of the crossing). The crossing is located approximately 1 km from the headwater of the creek. A small beaver dam immediately downstream of the crossing creates a small pool at the crossing site. Several side channels occur within the floodplain.

Fisheries Assessment

Capture Method:	Fall 2004 and Spring 2005 – Backpack Electrofishing
Survey Length:	50 m
Species Present:	None
Life History Stage:	n/a

[1] For example: walleye, northern pike, suckers

[2] For example: sticklebacks, minnows

Fisheries Assessment

Large-bodied Species[1]

Spawning:	No
Migration:	No
Rearing:	No
Overwintering:	No

Small-bodied Species[2]

Open-water Presence:	Possibly
Overwintering:	No

Fish Use and Fish Habitat Summary

If fish make use of this site it is likely restricted to spawning, foraging, and rearing during summer by small-bodied species such as brook stickleback and fathead minnow. Low DO levels or absence of water indicate that this habitat does not support fish in winter. The distance from overwintering habitat and large number of beaver dams reduces the quality of habitat and the likelihood of fish use. Habitat in this creek at the crossing site is typical for this creek and others in the area.

North/South Consultants Inc.
AQUATIC ENVIRONMENT SPECIALISTS

Access Road Watercourse Crossing Assessment

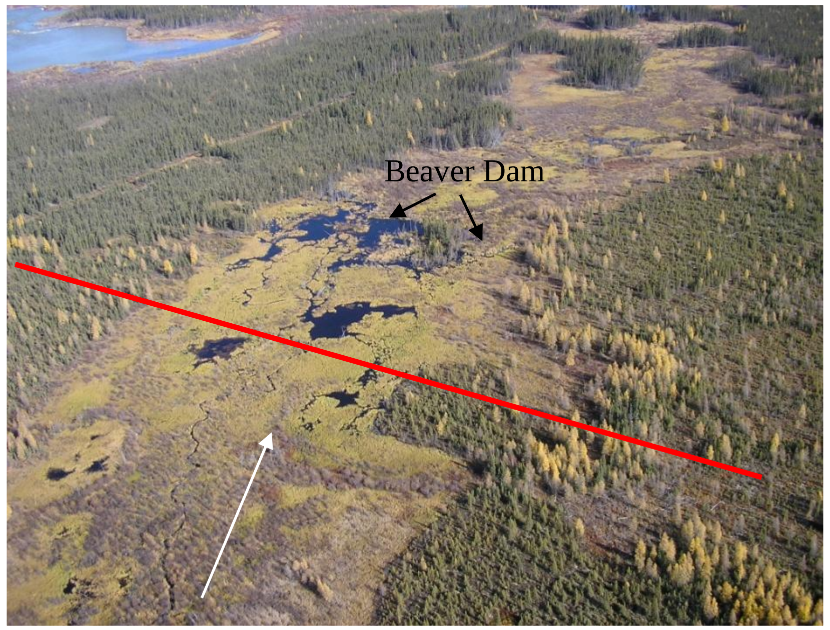


Figure 1: Aerial view of Gull Rapids Creek with the crossing location indicated by the red line and the direction of flow by the white arrow.

Figures 2 and 3: Upstream (left photo) and downstream views of Gull Rapids Creek at the crossing location.

Keeyask Access Road
Stream Crossing Assessment

Location

UTM:	0363277 / 6244594– NAD 83	**Watercourse Name:**	Gull Rapids Creek
Date:	6 October, 2004	**Site:**	SC - 3

Site Description

Stream Order:	1
Watershed Size:	5.1 km^2
Upstream of Crossing:	3.4 km^2
Regulated:	No
Channelized:	No
Channel Width:	2.0 m
Wetted Width:	Standing water within floodplain for 100 m
Floodplain Width:	Right:106 m, Left: 15 m
Maximum Depth:	1.2 m
Stage:	Flood
Sign of flood above surveyed stage:	n/a
Valley Slope Gradient:	Left – 6% Right - 5%
Stream Gradient:	<1%
Velocity Characteristics:	slow - not measurable
Cover Type and Composition:	Total – 100% Over Veg. – 10% In. Veg. – 90%
Habitat Type:	Pool – 100%
Bottom Contour:	Uniform
Substrate Type:	Fines – 100%
Substrate Compaction:	Low
Bank Unstable:	0%
Water Temperature:	5°C
Turbidity:	2.2 NTU

Riparian Vegetation:	The creek lies within a broad floodplain vegetated with sedges and willows at the margin. The low sloping valley contains black spruce and tamarack trees with an understory of moss and shrubs such as Labrador tea.
Aquatic Vegetation:	Yes
Unique Features:	Beaver dams located 150 m downstream and approximately 1 km upstream of crossing.
Summary:	The small creek drains a small lake (approximately 1 km upstream of the crossing) into the Nelson River at Gull Rapids, approximately 1 km downstream of the crossing site. Beaver dams affect aquatic habitat in the creek and the area of the crossing was at flood stage due to a beaver dam. Creek substrate is composed of fines overlain by organic material.

Fisheries Assessment

Capture Method:	Backpack Electrofishing
Survey Length:	50 m
Species Present:	White sucker
Life History Stage:	Adult
Abundance (#fish/min.):	0.25

[1] For example: walleye, northern pike, suckers
[2] For example: sticklebacks, minnows

Fisheries Assessment

Large-bodied Species[1]

Spawning:	Possibly
Migration:	Unlikely
Rearing:	Possibly
Overwintering:	No

Small-bodied Species[2]

Open-water Presence:	Yes
Overwintering:	Possibly
Habitat Quality:	Poor

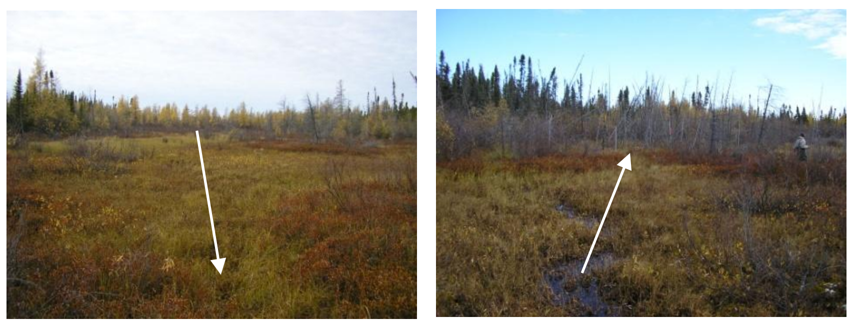
Fish Use and Fish Habitat Summary

Fish use is likely restricted to spring spawning and foraging, and rearing during summer by primarily small-bodied species. Low fall and winter water levels likely restrict overwintering by fish, while beaver dams present a periodic barrier to fish passage both up- and downstream. No rare habitats were present (*i.e.*, gravel riffles, deep off-current pools).

North/South Consultants Inc.
AQUATIC ENVIRONMENT SPECIALISTS

Access Road Watercourse Crossing Assessment

Figure 1: Aerial view of Unnamed Creek with the crossing location indicated by the red line and the direction of flow by the white arrow.



Figures 2 and 3: Upstream view (left photo) and downstream view of Unnamed Creek at the crossing location.

Figure 4: Downstream view 200 m downstream of the crossing site.

Keeyask Access Road
Stream Crossing Assessment

Location

UTM:	0371930 / 6244437–NAD 83
Date:	5 October, 2004
Watercourse Name:	Unnamed Tributary of Stephens Lake
Site:	SC– 4

Site Description

Stream Order:	1
Watershed Size: Upstream of Crossing:	1.7 km^2 1.53 km^2
Regulated:	No
Channelized:	No
Channel Width:	Two channels with water and standing water in floodplain.
Wetted Width:	1.5 m and 0.9 m
Floodplain Width:	Total: 30 m
Maximum Depth:	0.32 m
Stage:	Moderate
Sign of flood above surveyed stage:	n/a
Valley Slope Gradient:	Left – 1% Right - 2%
Stream Gradient:	<1%
Velocity:	slow - not measurable
Cover Type and Composition:	Total – 70% Over Veg. – 80% In Veg. - 10% Cutbank – 10%
Habitat Type:	Pool – 100%
Bottom Contour:	Uniform
Substrate Type:	Fines – 100%
Substrate Compaction:	Low
Bank Unstable:	0%
Water Temperature:	1 °C
Turbidity:	n/a

Riparian Vegetation:	The creek lies within a relatively broad, saturated floodplain dominated by sedges and willows. The valley forest is composed of black spruce and tamarack with an understory of willow, Labrador tea, and moss.
Aquatic Vegetation:	Yes
Unique Features:	Approximately 100 m downstream of the crossing, the creek enters a forested area with a narrow floodplain and thick willow growth, where the channel is well defined containing some areas with boulder.
Summary:	The small creek drains a small-unnamed lake (approximately 750 m upstream of the crossing) into Stephens Lake approximately 400 m downstream of the crossing. The creek channel is braided, shallow and not well defined at the crossing. Beaver dams occur upstream of the crossing, but not downstream.

Fisheries Assessment

Capture Method:	Backpack Electrofishing
Survey Length:	20 m
Species Present:	None
Life History Stage:	n/a

[1] For example: walleye, northern pike, suckers

[2] For example: sticklebacks, minnows

Fisheries Assessment

Large-bodied Species[1]

Spawning:	Unlikely
Migration:	Unlikely
Rearing:	Unlikely
Overwintering:	No.

Small-bodied Species[2]

Open-water Presence:	Yes
Overwintering:	No.
Habitat Quality:	Moderate.

Fish Use and Fish Habitat Summary

Fish use is likely restricted to spring spawning, and foraging and rearing during summer by small-bodied species. Low fall and winter water levels limit overwintering by fish. Higher quality habitat is available 100 m downstream of the crossing and beaver dams restrict fish passage upstream of the crossing.

North/South Consultants Inc.
AQUATIC ENVIRONMENT SPECIALISTS

Access Road Watercourse Crossing Assessment

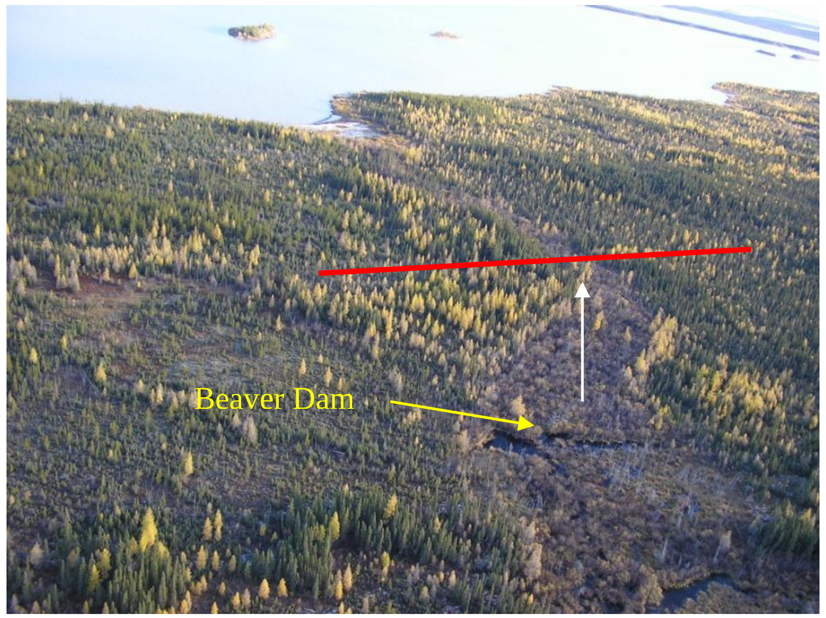


Figure 1: Aerial view of Gillrat Lake Creek with the crossing location indicated by the red line and the direction of flow by the white arrow.

Figures 2 and 3: Downstream view (left photo) and right bank of Gillrat Lake Creek at the crossing location.

Keeyask Access Road
Stream Crossing Assessment

Location

UTM: 0372880 / 6244078–NAD 83
Date: 4 October, 2004

Watercourse Name: Gillrat Lake Creek
Site: SC – 5

Site Description

Stream Order:	1
Watershed Size:	11.0 km^2
Upstream of Crossing:	10.9 km^2
Regulated:	No
Channelized:	No
Channel Width:	3.0 m
Wetted Width:	1.2 m
Floodplain Width:	n/a
Maximum Depth:	0.2 m
Stage:	Moderate
Sign of flood above surveyed stage:	n/a
Valley Slope Gradient:	Left – 2% Right – 4%
Stream Gradient:	2%
Velocity:	0.06 m/sec
Discharge:	0.02 m^3/sec
Cover Type and Composition:	Total – 40% Over Veg. – 20% LOD – 30% Cutbank – 30% Boulder – 10% In. Veg. – 10% Canopy Clos. – 100%
Habitat Type:	Pool – 20% Run – 70% Riffle – 10%
Bottom Contour:	Uniform
Substrate Type:	Fines – 40% Cobble – 30% Boulder – 30%
Substrate Compaction:	Moderate
Bank Unstable:	0%
Water Temperature:	1 °C
Turbidity:	n/a

Riparian Vegetation: The creek lies within a relatively narrow, well-drained floodplain containing dense willow growth, grasses, forbs, and sedges. The valley forest is composed of black spruce, tamarack, willow, and alder. Further upstream the creek flows through a broad poorly drained floodplain.

Aquatic Vegetation: Yes

Unique Features: The creek contains several cobble/boulder riffles and small waterfalls. Two beaver dams occur upstream of the crossing.

Summary: This small creek drains Gillrat Lake, a small lake (approx. 2 km upstream of the crossing) into Stephens Lake approximately 250 m downstream of the crossing. The creek channel is well defined with abundant cover. Starting 200 m upstream of the crossing and continuing to Gillrat Lake, the creek enters a broad floodplain with a number of beaver dams.

Fisheries Assessment

Capture Method: Backpack Electrofishing

Survey Length: 20 m

Species Present: Northern pike

Life History Stage: Juvenile

Abundance (#fish/min.): 0.25

[1] For example: walleye, northern pike, suckers
[2] For example: sticklebacks, minnows

Fisheries Assessment

Large-bodied Species[1]

Spawning: Yes

Migration: Unlikely

Rearing: Yes

Overwintering: No

Small-bodied Species[2]

Open-water Presence: Yes

Overwintering: No

Habitat Quality: Good

Fish Use and Fish Habitat Summary

Fish use is likely restricted to spring spawning, and foraging and rearing during summer. Low fall and winter water levels limit overwintering by fish. Fish overwintering in Stephens Lake are able to use the lower portion of this creek. Beaver dams likely restrict fish passage upstream to Gillrat Lake.

North/South Consultants Inc.
AQUATIC ENVIRONMENT SPECIALISTS