Keeyask Generation Project

Environmental Impact Statement

Supporting Volume

Aquatic Environment

KEEYASK
Hydropower Limited Partnership

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SECTION 3
AQUATIC HABITAT

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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 95th 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 5th 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 50th 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 95th 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 50th 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 5th 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 95th 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 km², an increase of 7–8 km² 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.

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TABLES, FIGURES, AND 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	Gravel
16–32 mm	Coarse gravel	
8–16 mm	Medium gravel	
4–8 mm	Fine gravel	
2–4 mm	Very fine gravel	
1–2 mm	Very coarse sand	Sand
0.5–1 mm	Coarse sand	
0.25–0.5 mm	Medium 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.

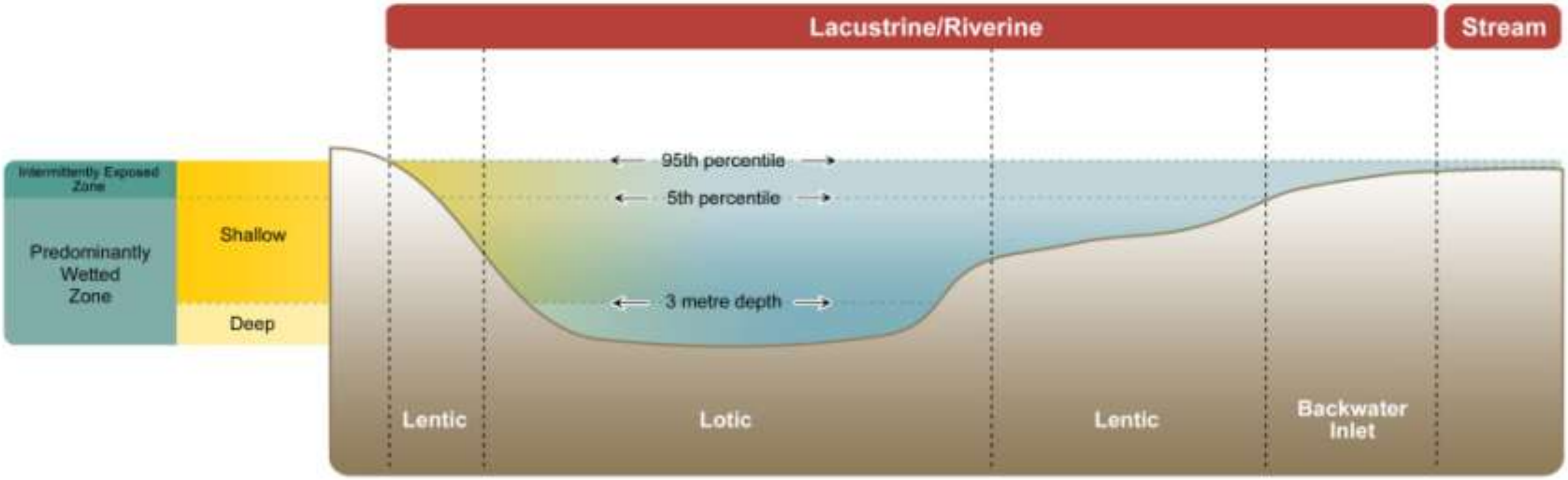

Figure 3-1: Schematic diagram showing the breakdown of aquatic habitat into a series of habitat variables

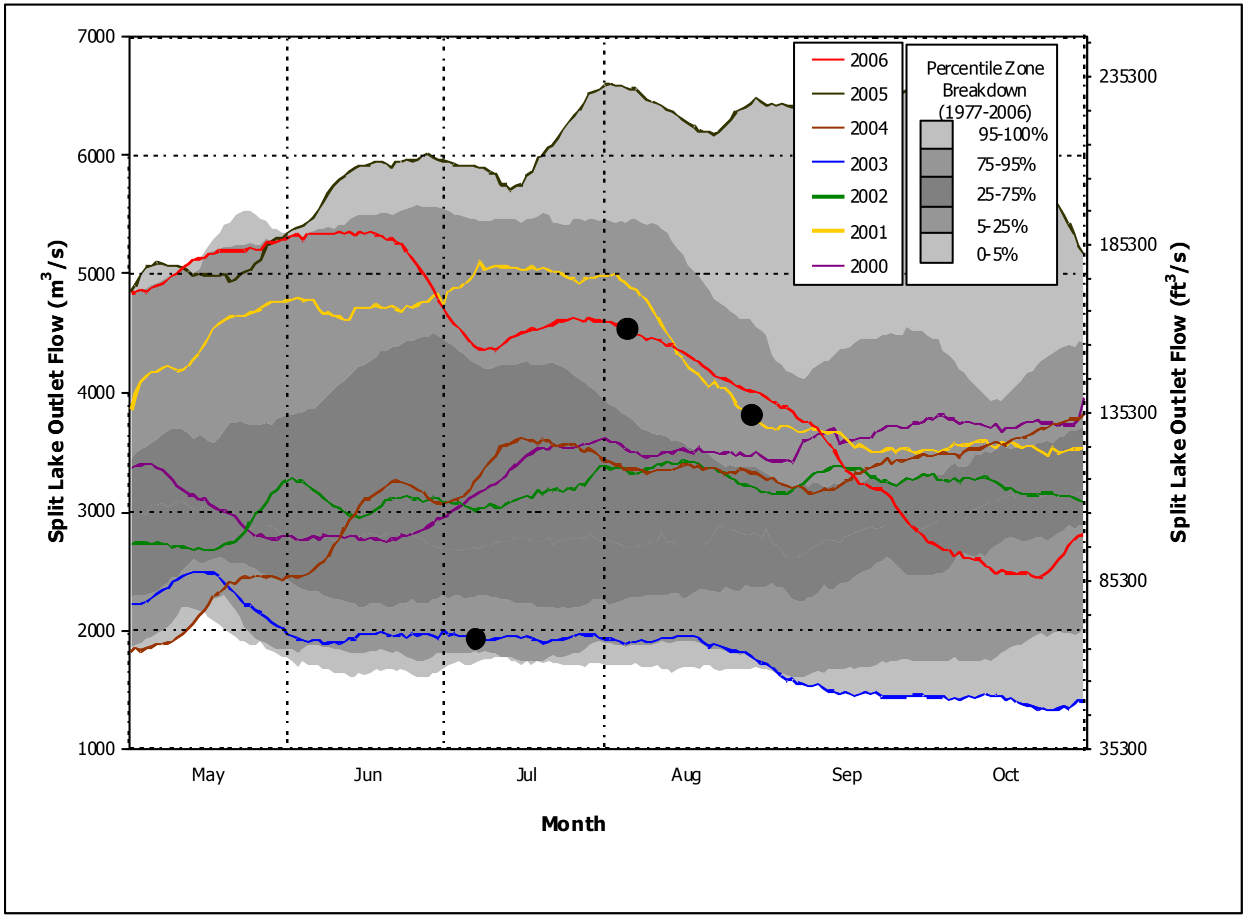

Figure 3-2: **Split Lake outlet discharge from 2000–2006. The black circles indicate the time of the macrophyte surveys in the Keeyask area. Discharge data are adapted from PE SV, Section 4**

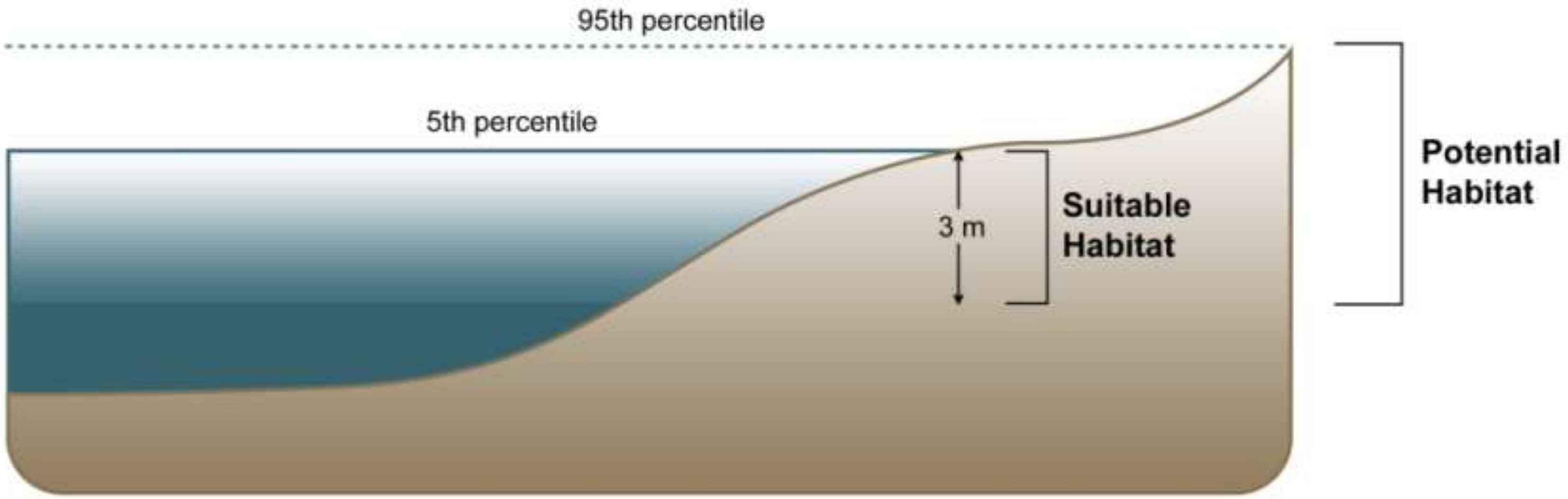

Figure 3-3: The relationship of inflow, water surface elevation and macrophyte habitat. This 5th percentile (low flow) scenario shows that suitable habitat extends from the 5th percentile water surface elevation to 3 m depth (which is the approximate maximum penetration of light) in the permanently wetted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

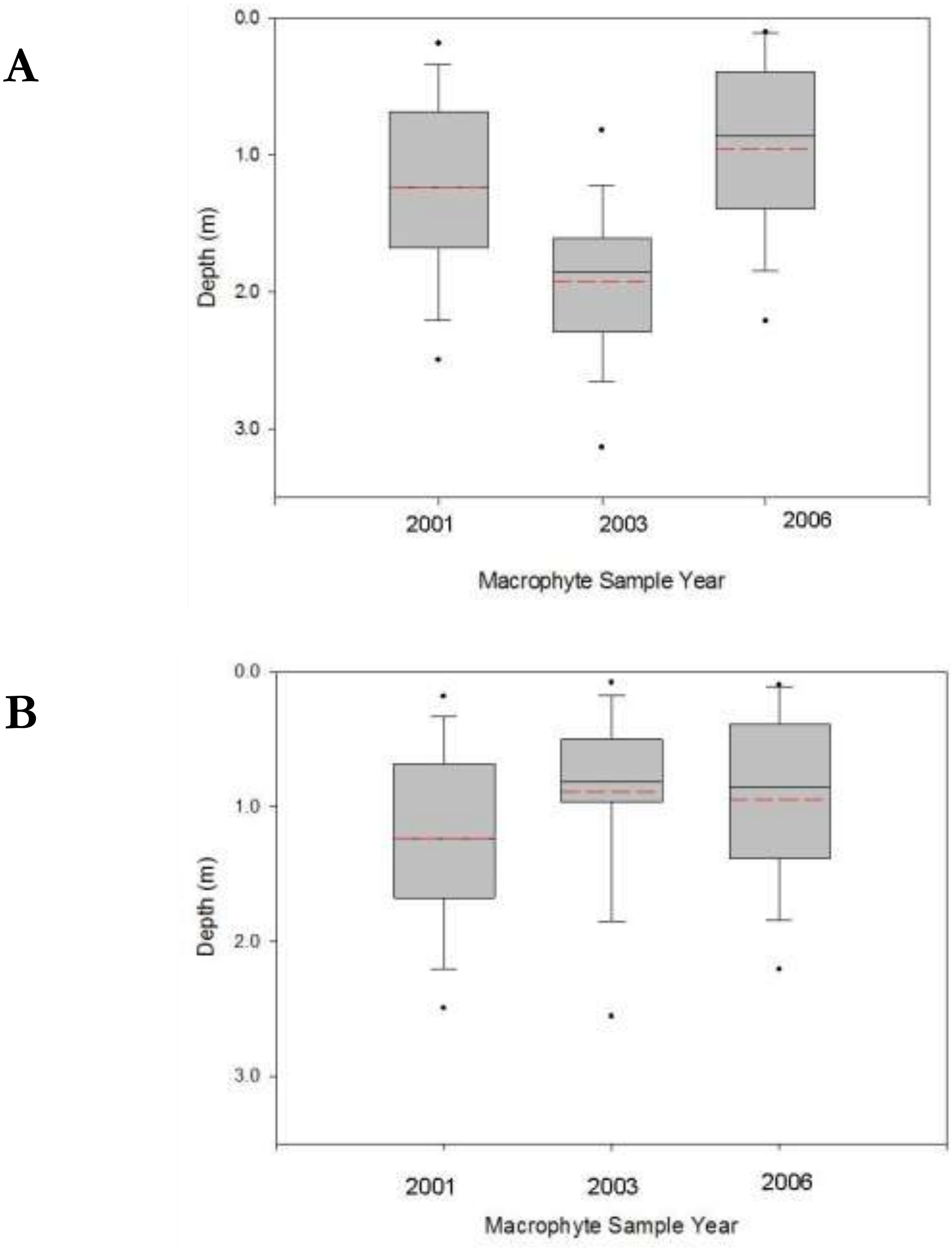

Figure 3-4: **Depths of macrophyte beds observed in 2001, 2003, and 2006 when compared to depths relative to the 95th percentile (A), and when the 2003 depths were adjusted to the 5th percentile (B)**

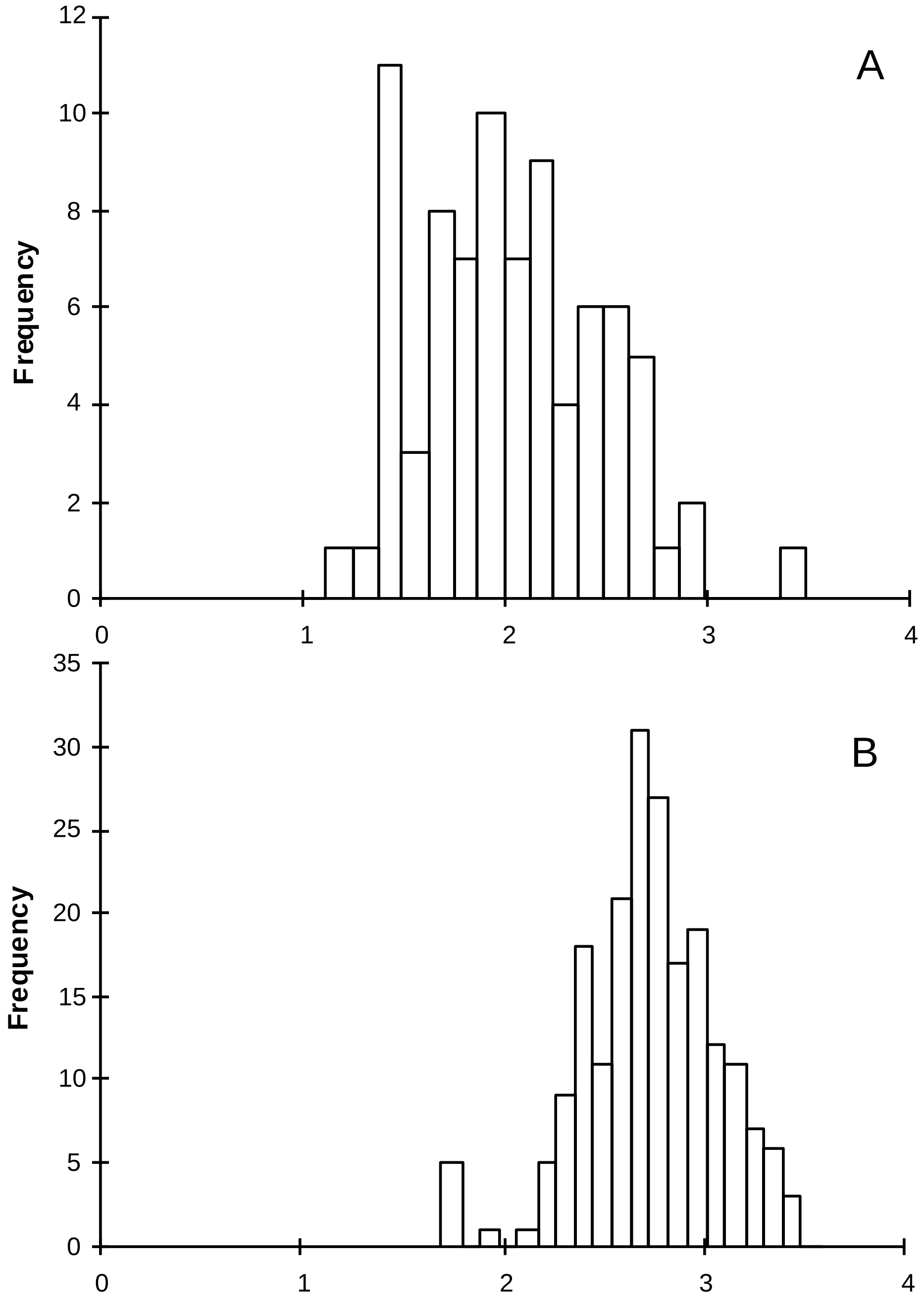

Figure 3-5: Frequency vs. water depth histogram of *Myriophyllum sibiricum* (A), *Potamogeton richardsonii* (B) in Stephens Lake. Water depth has been standardized to the 95th water level percentile

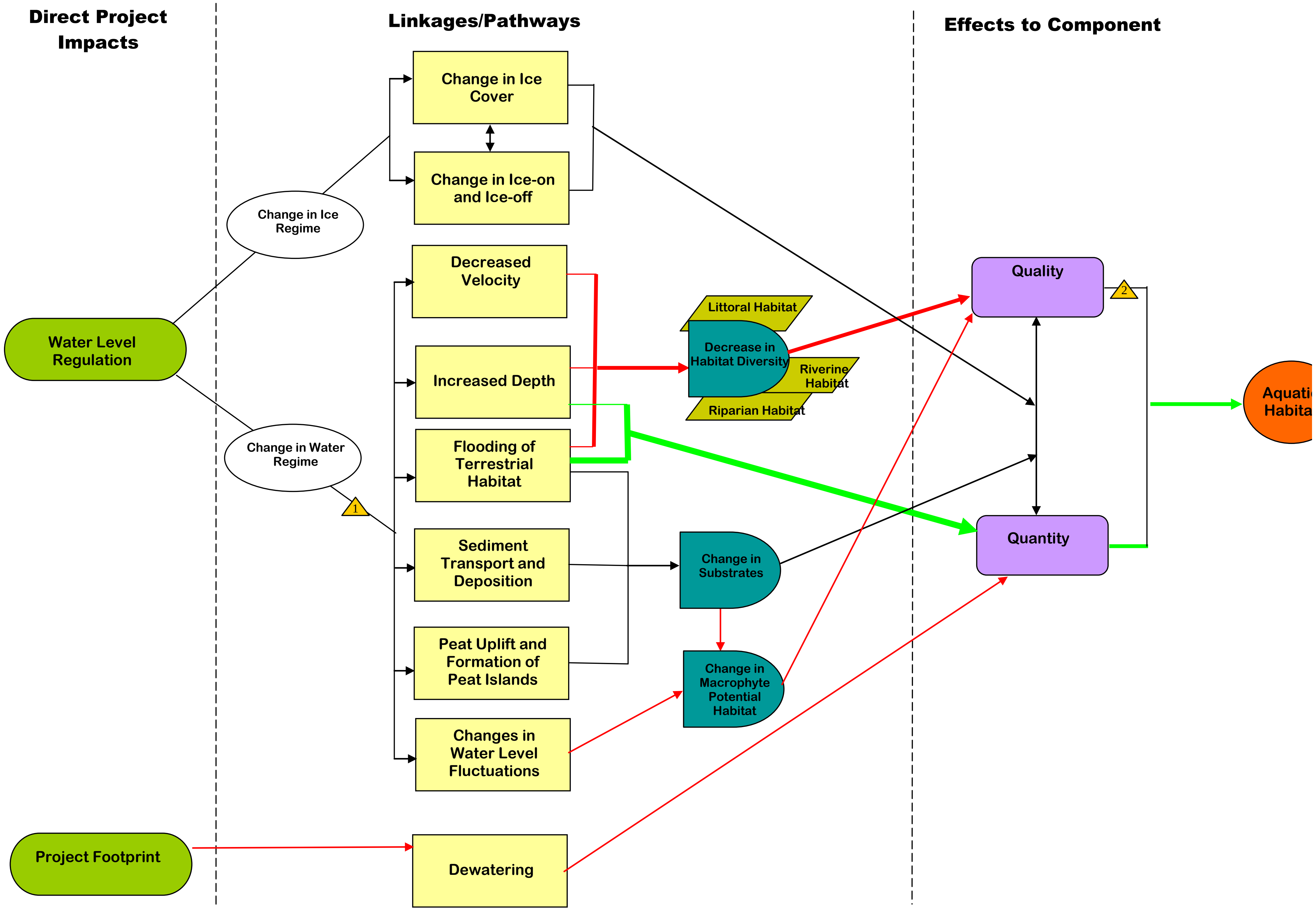

Figure 3-6: Pathways of change to aquatic habitat (arrows: green = positive effect; red = negative effect; black = neutral effect; thicker lines indicate greater magnitude of effect; triangles represent mitigation: 1 = selection of 159 m reservoir elevation and 1 m operating regime; 2 = habitat structure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