Keeyask Generation Project

Environmental Impact Statement

Supporting Volume

Physical Environment

Keeyask Hydropower Limited Partnership

June 2012

APPENDIX 9A

DESCRIPTION OF MODELS AND ANALYSIS

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9A.0 MODEL DEVELOPMENT

The Danish Hydraulic Institute (DHI) has a suite of models (called MIKE) than can simulate water temperature and dissolved oxygen in one, two, or three dimensions. The MIKE2 model was used for 2-D modelling of the water regime and sedimentation. For consistency and efficiency, the DHI modelling suite was selected for the water temperature and dissolved oxygen assessment. DHI provides a highly credible, state-of-the-art model for 3-D flow and water temperature modelling, as well as a complex biological simulation module called ECO LAB. This module uses model templates that can be modified to develop any level of model complexity and therefore, was very suitable for the creation of the dissolved oxygen-modelling template required for the Surface Water Temperature and Dissolved Oxygen study.

Prior to initiation of the Water Temperature and Dissolved Oxygen study, the MIKE models (MIKE 21) for the water regime and sedimentation studies were configured and calibrated. The water temperature and dissolved oxygen analysis used the 2-D mesh developed for the sedimentation modelling and modified it to a 3-D mesh. For this model, the water column was divided into ten vertical layers, which were thinner at the top and thicker at the bottom for summer simulations (Figure 9A- 1), while the layers for winter were reversed, being thicker at the top and thinner at the bottom. In order to decrease the model computation times, the number of elements in the model were reduced by modelling a smaller area while also making the horizontal mesh from the 2-D sediment model coarser (element sizes were increased). Thus the model domain used in the Surface Water Temperature and Dissolved Oxygen Study is smaller than the overall study area as well as the model domain used in the water regime and sedimentation models (Map 9A- 1). This reduction in the domain to increase efficiency can be justified because it focuses on newly flooded areas and areas most impacted by the Project in terms of water regime changes. The areas within the water temperature and dissolved oxygen model domain include the deepest portions of the future Keeyask reservoir, as well as the vast majority of the newly flooded areas, particularly the areas of flooded peat.

% of depth at: Top	Bottom	Layer Number
0%	5%	10
5%	10%	9
10%	15%	8
15%	20%	7
20%	30%	6
30%	40%	5
40%	50%	4
505	60%	3
60%	80%	2
80%	100%	1

Figure 9A- 1: Model Layers for Summer Analyses

The flow files used in this study were developed in the Surface Water and Ice Regimes study (Physical Environment Supporting Volume (PE SV), Section 4). The flows used for the Surface Water Temperature and Dissolved Oxygen study included:

- The 50% flow for modelling the most likely scenarios for both water temperature and dissolved oxygen.
- The 5% low-flow for modelling the low-flow conditions analogous to the use of a 7-Q10 (as is discussed later in this section).
- The lowest flow on record for the worst-case sensitivity analysis assessing potential for stratification (summer simulation).
- Historic flow for existing environment conditions in summer 2004 when water temperatures were continuously monitored in Gull Lake.
- Dynamic flows for a typical Post-project operating condition.

For a full discussion on how these files were developed, the reader is referred to the Surface Water and Ice Regimes section (Section 4).

In order to create "stable" hydraulic conditions, the hydraulic model was run for one week before the scenario simulation began. This period is referred to as the "spin-up" period and is not reported in the results.

9A.1 OTHER MODEL PARAMETERS FOR TEMPERATURE MODELLING

An important parameter in modelling water temperature is the transmissivity of the water column. Transmissivity has been measured along the Nelson River by taking secchi disk readings at numerous locations over a number of years (Aquatic Environment Supporting Volume (AE SV)).

Among the monitoring sites considered, the peak average secchi depth is 1.05 m. For sites more directly on the lakes or Nelson River, peak readings were typically no more than about 0.90 m.

To determine the boundary conditions for modelling summer water temperature, the water temperature records for monitoring sites along the Nelson River were reviewed. One of the higher summer values of 23°C was selected as the inflow water temperature while the initial water temperature in the Keeyask reservoir was set at a more typical temperature of 18°C. Thus warmer, more buoyant water is flowing into a cooler, denser reservoir; a condition that may favour the development of stratified conditions.

Based on winter temperature measurements, boundary conditions for the winter stratification analysis were set to a more buoyant 0.1°C for the inflow and a warmer, denser 4.0°C initially in the reservoir, again producing a condition that might favour stratification.

9A.2 DISSOLVED OXYGEN MODELLING

The key processes included in the simple dissolved oxygen template of the DHI model are photosynthesis and re-aeration which add dissolved oxygen to the water column; and respiration, sediment oxygen demand, and biochemical oxygen demand which remove dissolved oxygen from the water column.

The proposed formulation of the dissolved oxygen model for the Surface Water Temperature and Dissolved Oxygen study does not include consideration of algal (phytoplankton) effects. Due to relatively low concentrations of phytoplankton biomass expected in the aquatic ecosystem (AE SV), the impact of phytoplankton on oxygen dynamics will be minimal. An analysis was done to estimate the maximum potential changes in dissolved oxygen that may occur at the expected concentration of algae and a daily variation of only about 0.29 mg/L above and below the daily average dissolved oxygen level would be expected. This indicates that a more complex model incorporating algae effect on dissolved oxygen was not warranted.

Re-aeration in the simple dissolved oxygen model is the transfer of oxygen between the water column and the atmosphere. The re-aeration formula used in the simple dissolved oxygen model incorporates flow velocity effects as applied in river conditions and wind speed effects as applied in lake conditions.

The model requires the user to specify Sediment Oxygen Demand (SOD) and BOD rates at a standardized temperature (*i.e.*, 20°C) and the model calculates the temperature-specific rates using a temperature correction factor, which may also be specified by the user.

Research studies covering a range of conditions have found that the temperature co-efficient may vary over a range of roughly 1.0 to 1.2, although values of about 1.04 to 1.07 appear to be more common (Bowie 1985). There is no single value that is applicable in all conditions. A temperature correction value of 1.047 is routinely used in water quality studies in North America, and for this reason a value of 1.047 was also used in the Surface Water Temperature and Dissolved Oxygen study. Using a temperature co-efficient of 1.047, the SOD and BOD rates at 30°C and 4°C will be roughly 50% higher and lower, respectively, than the standard rate at 20°C.

9A.3 SEDIMENT OXYGEN DEMAND

Use of oxygen by organisms in the sediments is expressed as SOD. In the modelling, the SOD is considered fixed on the bottom of the reservoir, as opposed to BOD, which is also related to consumption of oxygen by organic decay; but is suspended in the water column and is therefore mobile.

General literature on SOD shows SOD ranging from 0.05 $g/m^2/d$ to 10 $g/m^2/d$. SOD is usually reported in rivers influenced by municipal waste discharges and no literature directly determining SOD rates for newly flooded reservoirs could be located. There is considerable recent work done on Greenhouse Gases (GHG) from reservoirs across Canada, and Manitoba in particular. GHGs, consisting predominately of carbon dioxide (CO_2) and generally small quantities of methane (CH_4) are typically released at greater rates post-impoundment in reservoirs. The GHGs are generated by decay of organic matter in newly flooded areas. Therefore, rates of CO_2 production reported for boreal reservoirs in the literature were used as a proxy for estimating the SOD rates that may be expected after impoundment and in the newly flooded areas.

Numerous sources were found in which CO_2 measurements in newly flooded reservoirs were reported. At the Experimental Lakes Area (ELA) in northwest Ontario, the Department of Fisheries and Oceans (DFO) has flooded a specific lake (Lake 979) and monitored CO_2 over the past decade. In addition, the Canadian National Inventory on GHG (Environment Canada 2006) has compiled CO_2 measurements for various reservoirs in Manitoba and across Canada. The results cover a scattered range of values; however they dissolved oxygen show a decreasing trend from Year 1 to Year 20. The general trend in CO_2 production ranges from a high of about 4.5 $g/m^2/d$ in Year 1 to a low of about 1.0 $g/m^2/d$ after 20 years.

Furthermore, Manitoba Hydro has monitored GHG at several reservoirs; the most relevant being Kettle GS on Stephens Lake, a location that is considered a very good proxy for the proposed Keeyask reservoir located just upstream of Stephens Lake. The measured levels of CO_2 flux for the years 2004 to 2006 show that CO_2 production covers a wide range and is quite variable. CO_2 production in the range of 4.5 $g/m^2/d$ does occur at the Kettle GS.

North/South Consultants monitored the generation of CO_2 and CH_4 at several sites on Stephens Lake for the Keeyask Project. Although monitoring took place over a short time (in August 2006), the information provides a measure of the spatial distribution of GHG generation on a reservoir that can act as a proxy to a proposed Keeyask reservoir, albeit the information was collected more than 30 years post-flood (Cooley 2008). Rates of CH_4 production were relatively low at less than 0.4 $g/m^2/d$ over the period, compared with CO_2 production, which ranged from 0.01 $g/m^2/d$ to 11.7 $g/m^2/d$. The results indicated that areas on the mainstem of the Nelson River at Kettle Dam and Gull Rapids had a relatively low level of CO_2 production in the range of 0.1 $g/m^2/d$ to 0.6 $g/m^2/d$. Sampling in areas where the reservoir flooded existing peatland showed CO_2 fluxes in the range of 0.9 $g/m^2/d$ to 4.8 $g/m^2/d$. These results were very useful as they indicated that areas of newly flooded peatland in the Keeyask reservoir may be expected to have much higher SOD than areas within the existing Nelson River shoreline.

Considering the many sources of information discussed above, an estimated CO_2 flux of 4.5 $g/m^2/d$ for the Keeyask reservoir may be somewhat high, but it is reasonable for CO_2 in the first year over a seven-day period. Using this estimate for CO_2 production, a relatively high value (6 $g/m^2/d$) of SOD is estimated for newly flooded peat. GIS mapping of existing shorelines and classification of the terrain as either organic or mineral was used to determine what rate of SOD (*i.e.*, 6 $g/m^2/d$ or 0.5 $g/m^2/d$) would be used throughout the Post-project forebay (Map 9A- 2). The higher SOD used for this study results in conservative estimates of oxygen demand and conservative estimates of Project effects on dissolved oxygen concentration in the reservoir.

The GHG production, as the associated SOD, should be expected to decrease over time as shown in some studies discusses above. The assessment focused on quantifying the largest effects in the first year with an understanding that the effects will decrease over time.

9A.4 BIOCHEMICAL OXYGEN DEMAND (BOD)

BOD is a term used to quantitatively describe the amount of oxygen that would be consumed in a known volume of water by microorganisms where they consume substrate such as organic carbon. A BOD value represents the total amount of dissolved oxygen that would be consumed in the decay of all the organic carbon in the water.

Predictions of the amount of peatland disintegration (ECOSTEM 2008) were used to develop estimates of the mass, and thus the concentration, of organic matter in the water column in newly flooded areas. Using the estimated concentrations of organic matter, an estimate of the BOD in the water column was produced.

The analysis of peatland disintegration divided the Keeyask Project area into 12 peat transport zones (Map 9A- 3). Peat that floats or remains suspended is assumed to contribute to BOD in the water column while the material that sinks is assumed to contribute to the SOD discussed previously. For this analysis, it is assumed that the BOD attributed to each peat transport zone is evenly distributed through the entire volume of water in each zone. The total BOD in each peat zone represents the cumulative BOD estimated from the mass of suspended and floating peat generated by shore peat breakdown and flooded peat resurfacing within the Shoreline Erosion Processes study (PE SV Section 6.0).

Laboratory tests were performed that measured the fraction of peat that sinks, floats or is suspended (ECOSTEM 2007) and used these values to calculate peat masses within these classifications for the Peatland Disintegration Study (ECOSTEM 2008). The settling period however was relatively short (*i.e.*, 2 minutes). Therefore, for the calculation of BOD, the suspended peat masses identified in the Peatland Disintegration study were reduced to account for the possibility that much of the suspended material could settle out within a period of less than a day; much of the mass may then go to create SOD rather than BOD. Of the mass identified as suspended by ECOSTEM, it is assumed that particles greater than 63 µm would sink rapidly. Some fraction of the remaining material less than 63 µm, about 17% to 45% of the mass, may also settle rapidly. The low, expected and high estimates of the amount that remains suspended are 25%, 75% and 100% respectively.

For each peat transport zone in Year 1 the calculated BOD mass was divided by the volume of the zone, as determined using the MIKE3 model, resulting in a BOD load expressed in mg/L for expected and high load conditions. The expected initial BOD concentrations in each of the peat transport zones range from 0.15 mg/L in Zone 3 mg/L to 11.63 mg/L in Zone 8 (Map 9A- 3). The expected and high BOD loads for Year 5 were calculated in similar fashion (Map 9A- 4) and ranged from 0.21 mg/L in Zone 3 to 5.64 mg/L in Zone 8. However, the Year 5 peat disintegration estimate calculated by ECOSTEM represents the expected cumulative disintegration over Year 2 to Year 5. There is uncertainty as to how this disintegration would occur over these 4 years, therefore the water temperature and dissolved oxygen modelling assumed this cumulative mass of peatland disintegration all occurs in Year 5, thus representing a large loading event that is four times greater than what might be expected if the peat disintegration occurred evenly over the Year 2 to Year 5 period. The expected Year 1 and Year 5 BOD concentrations are used as the initial starting conditions for the expected event scenarios while the high loads, which are about 7 to 10 times larger, are used in severe event scenarios. A sensitivity analysis for Year 1 critical conditions was also performed using the high BOD values multiplied by 10, a scenario that may be used to identify areas that will remain unaffected by BOD.

It was noted that in order to decrease computation time the forebay area considered in the models excluded part of peat transport Zone 1 and all of Zone 4, which are upstream of the main reservoir area. Because these areas were not modelled, the potential effects of the proposed Keeyask Project on the water temperature and dissolved oxygen regime in these zones is assessed qualitatively by considering effects in similar areas that were modelled. Zone 4 is closest to Zones 8 and 11 in terms of Year 1 labile carbon per hectare: the three zones have areal loadings of 0.078, 0.074 and 0.067 t/ha respectively. For this reason, it is assumed that dissolved oxygen conditions in Zone 4 would be similar to the conditions in Zones 8 and 11. BOD loadings in Zones 8 and 11 are about 11.6 and 8.8 mg/L respectively, so it is likely that Zone 4 BOD rates would be of this magnitude as well.

9A.5 MODEL CONFIRMATION/VERIFICATION

Water temperature and dissolved oxygen data obtained in the study area upstream of the proposed Keeyask Project does not show thermal stratification occurring while dissolved oxygen is typically at or near saturation (TetrES 2008a). The largest source of uncertainty associated with the model for Post-project conditions is the rate of SOD and the concentration of BOD that may be generated from peat disintegration. Therefore, calibration of the model to existing dissolved oxygen conditions in Gull Lake is of limited utility. As a result, the approach taken in the Surface Water Temperature and Dissolved Oxygen study was to conduct sensitivity analyses of key variables to provide ranges of potential effects and to provide an estimate of uncertainty.

A single "validation" run comparing temperatures measured in the existing environment and results from a scenario that simulates the existing condition was performed and confirmed the model and confirmed the temperature model is working as expected.

The model also simulated full dissolved oxygen saturation as expected; however, this scenario has very low values of BOD and SOD. This simulation cannot be considered a validation of the dissolved oxygen model. A full test of the oxygen depletion modelling was performed on Post-project scenarios in the flooded areas. General confirmation that the dissolved oxygen model was producing expected results was obtained by comparing model runs to results from areas that are similar to Post-project condition in Gull Lake. One small bay in Gull Lake with organic sediment and an area in Stephens Lake that was flooded over 30 years ago were monitored in 2008 and showed similar water temperature and dissolved oxygen patterns as the results from the Post-project modelling in similar areas (*i.e.*, some localized stratification of water temperature and dissolved oxygen can occur at low wind conditions).

A simple model of Lake 979 in the ELA in Ontario using SOD values similar to those assumed in the flooded area at Keeyask did show results similar to those monitored after Lake 979 was flooded.

Additionally, an idealized model of a rectangular channel with a 1 m ice-cover was also analyzed to ensure that the ice conditions were properly modelled since this is a new function in the computer package used in this study.

9A.6 SENSITIVITY ANALYSIS

Sensitivity analysis is a process to understand which of the key parameters are most important to the prediction of dissolved oxygen conditions in the Keeyask study area. These scenarios should not be considered as possible events; however, they are useful to understand how uncertainty in the selected parameter values may affect the model predictions. Three key parameters that were tested are:

- There is uncertainty in the expected SOD value of 6 $g/m^2/d$. Model sensitivity under average typical conditions was tested using a high SOD estimate of 12 $g/m^2/d$ while BOD was set to zero. Sensitivity in Year 1 was also tested for the critical weather conditions using a low, expected and high SOD values of 3, 6 and 12 $g/m^2/d$ respectively. These critical week sensitivity scenarios used preliminary estimates for the expected BOD and decay rate k and were not re-analyzed using the finalized BOD values because they still demonstrate the effect of changing SOD during the critical week.

- Wind conditions can vary and results from the expected and potential severe events indicate that wind is a critical parameter in the dissolved oxygen predictions. The sensitivity of the model to wind conditions was tested by setting the wind to zero for a Year 1 critical condition using expected SOD and BOD. Zero winds dissolved oxygen occur but typically last for only an hour or two, not for a week as used in the sensitivity analysis. Results from this analysis can also be used to estimate what might happen if some of the floating peat remained in place in a backbay and blocked the wind from re-aerating the reservoir in these areas.

To help identify areas in which it is unlikely that any large dissolved oxygen impact due to peat would occur, a sensitivity analysis was performed using a high SOD of 12 $g/m^2/d$ combined with extreme BOD values equal to ten times the high BOD estimates (Map 9A- 3), which represents a BOD load of 70 to 100 times greater than the expected BOD loads.

9A.7 ASSESSING NON-MODELLED AREAS

The dissolved oxygen conditions areas upstream of the modelled were estimated based on the predicted dissolved oxygen conditions from the model for areas with similar conditions. The main-stem will have high dissolved oxygen throughout and Zone 4 (not modelled) was considered to have a similar dissolved oxygen distribution as Zones 8 and 11(Map 9A- 3).

9A.8 REFERENCES

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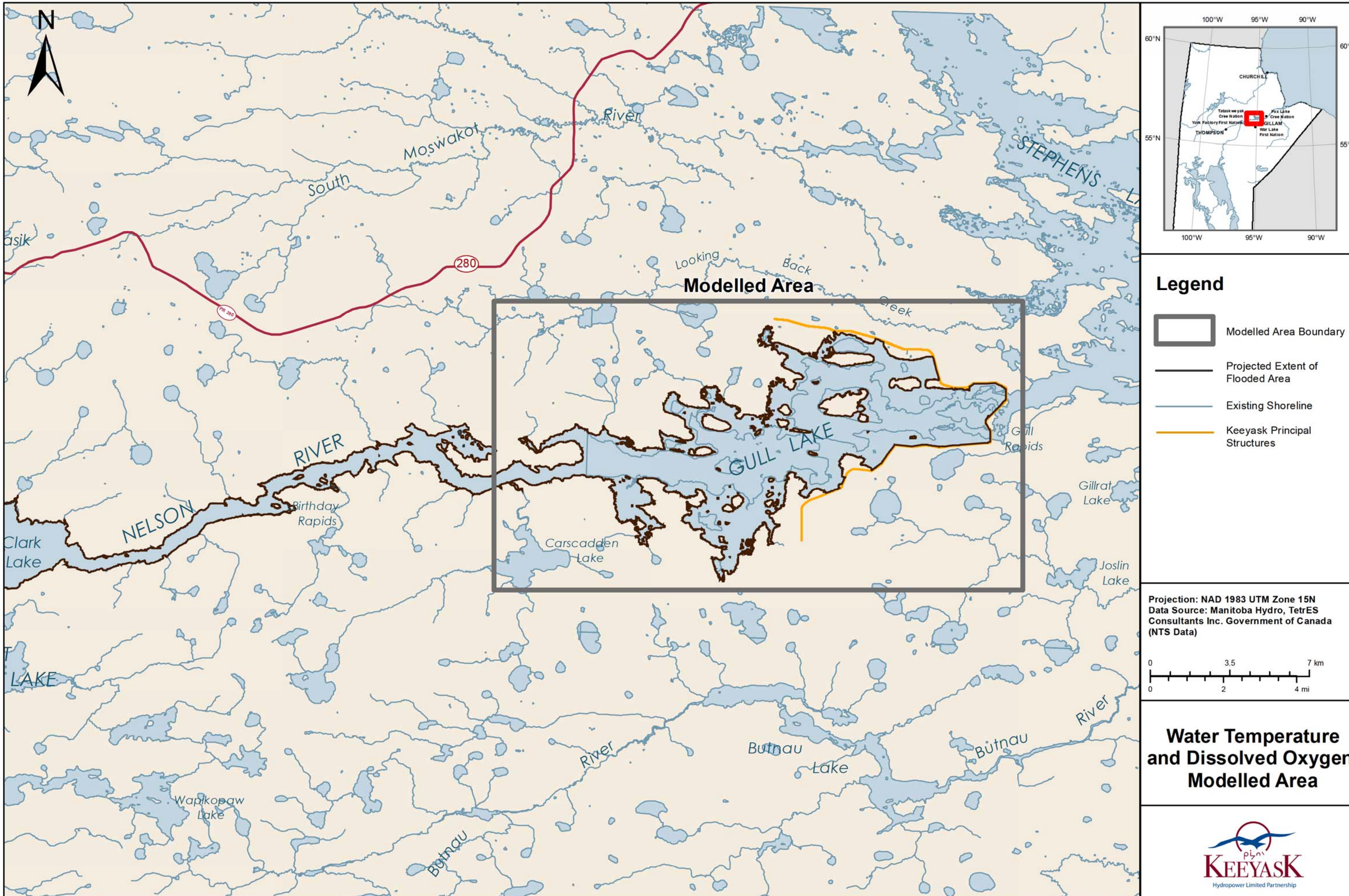
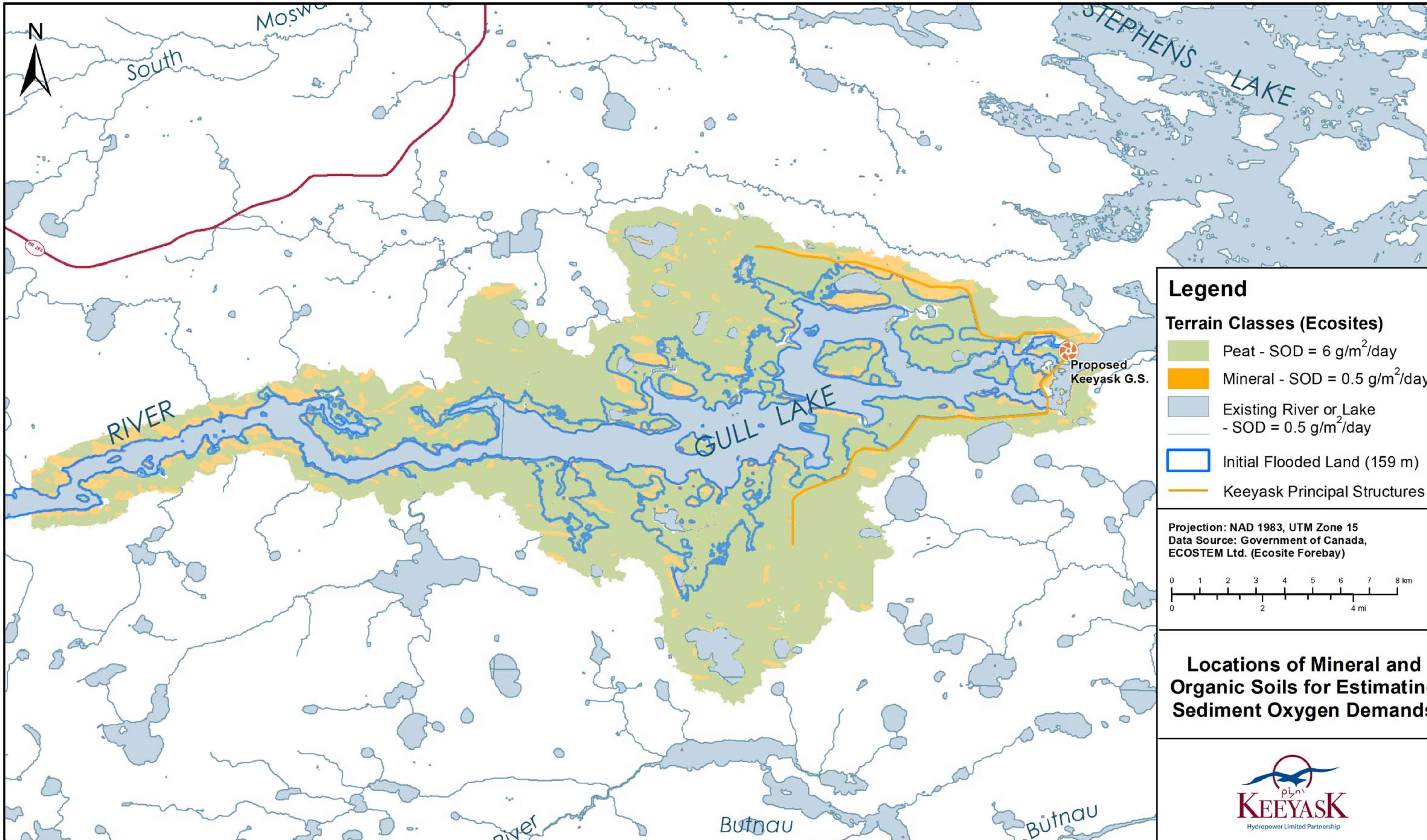
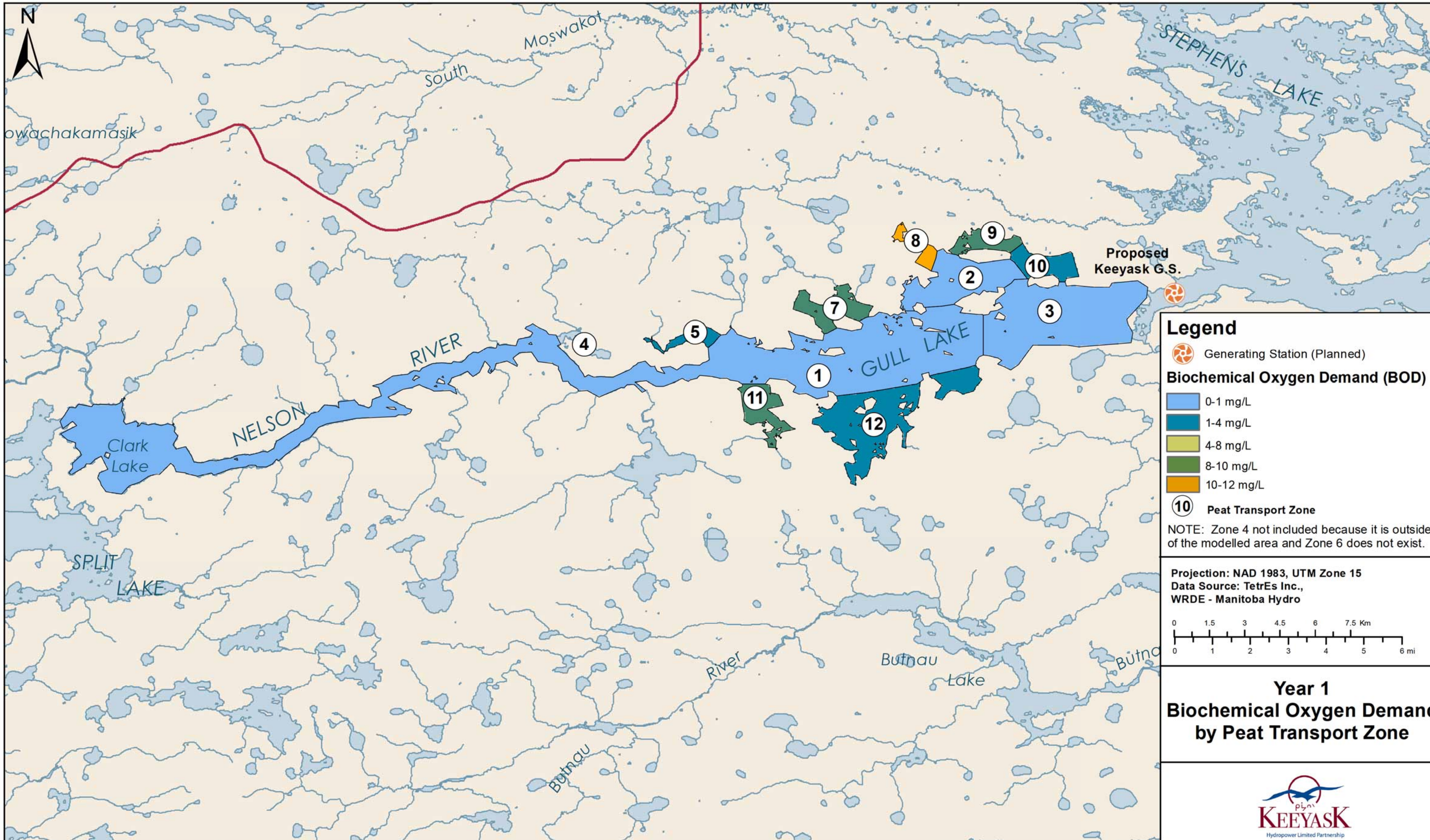

N
Moswakot
South
River
asik
280
PR 280
Looking
Back
Creek
STEPHENS
Modelled Area
GULL LAKE
Gull
Rapids
Gillrat
Lake
NELSON
RIVER
Birthday
Rapids
Clark
Lake
Carscadden
Lake
Joslin
Lake
LAKE
River
Butnau
Lake
Butnau
River
Wapikopaw
Lake
Butnau
100°W
95°W
90°W
60°N
55°N
CHURCHILL
Tataskweyak Cree Nation
York Factory First Nation
THOMPSON
Fox Lake Cree Nation
GILLAM
War Lake First Nation
Legend
Modelled Area Boundary
Projected Extent of Flooded Area
Existing Shoreline
Keeyask Principal Structures
Projection: NAD 1983 UTM Zone 15N
Data Source: Manitoba Hydro, TetrES Consultants Inc. Government of Canada (NTS Data)
0
3.5
7 km
0
2
4 mi
Water Temperature and Dissolved Oxygen Modelled Area
KEEYASK
Hydropower Limited Partnership

Map 9.A-1



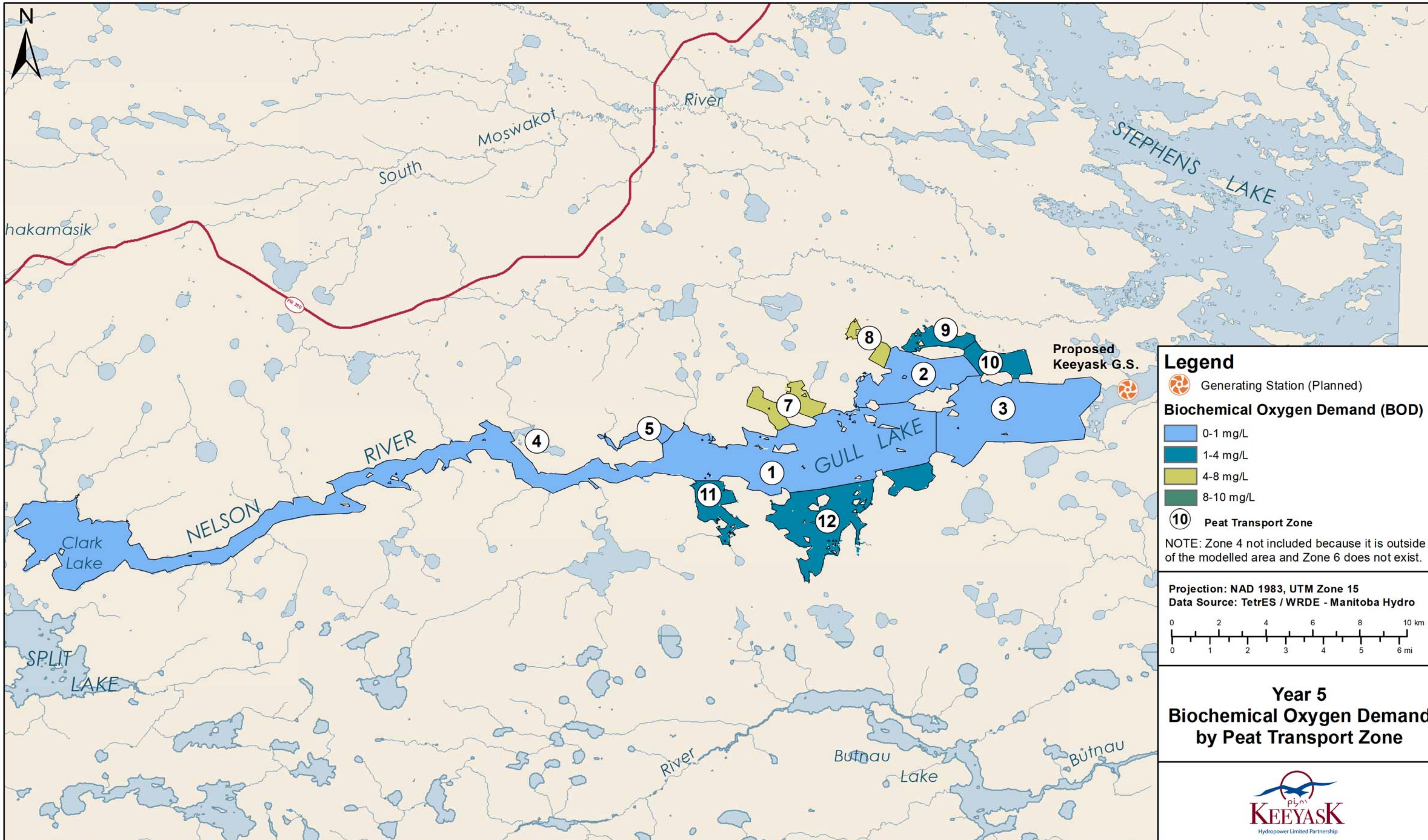
Locations of Mineral and Organic Soils for Estimating Sediment Oxygen Demands

Map 9.A-2



N
Moswakot
South
River
owachakamasik
STEPHENS LAKE
Proposed Keeyask G.S.
NELSON RIVER
GULL LAKE
Clark Lake
SPLIT LAKE
Butnau River
Butnau Lake
Butnau
1
2
3
4
5
7
8
9
10
11
12
Legend
Generating Station (Planned)
Biochemical Oxygen Demand (BOD)
0-1 mg/L
1-4 mg/L
4-8 mg/L
8-10 mg/L
10-12 mg/L
10 Peat Transport Zone
NOTE: Zone 4 not included because it is outside of the modelled area and Zone 6 does not exist.
Projection: NAD 1983, UTM Zone 15
Data Source: TetrEs Inc.,
WRDE - Manitoba Hydro
0 1.5 3 4.5 6 7.5 Km
0 1 2 3 4 5 6 mi
Year 1
Biochemical Oxygen Demand by Peat Transport Zone
KEEYASK
Hydropower Limited Partnership

Map 9.A-3



Year 5
Biochemical Oxygen Demand by Peat Transport Zone

Map 9.A-4

APPENDIX 9B

POST PROJECT DISSOLVED OXYGEN CONCENTRATIONS IN THE SURFACE AND BOTTOM MODEL LAYERS

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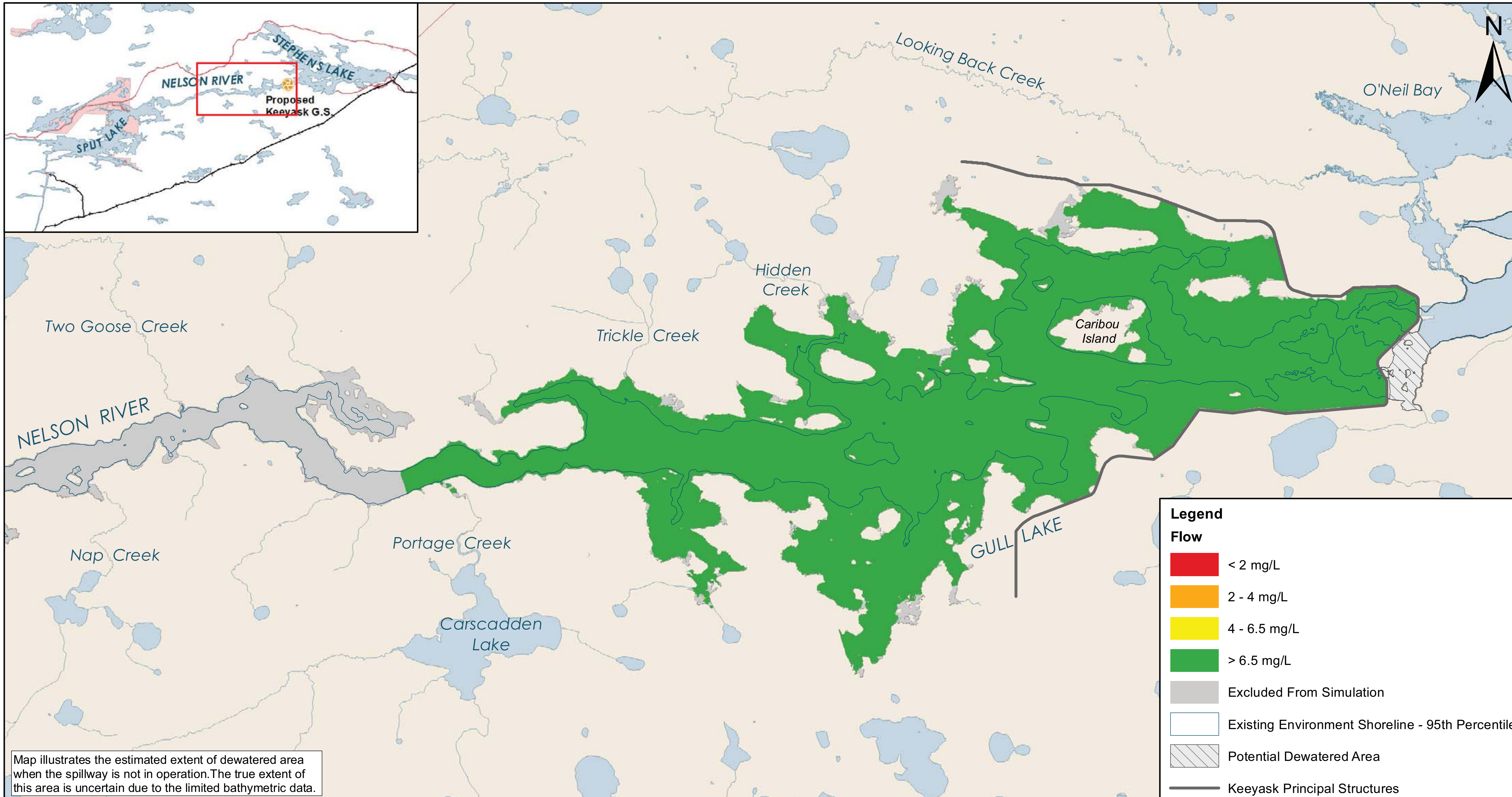


KEEYASK
Hydropower Limited Partnership

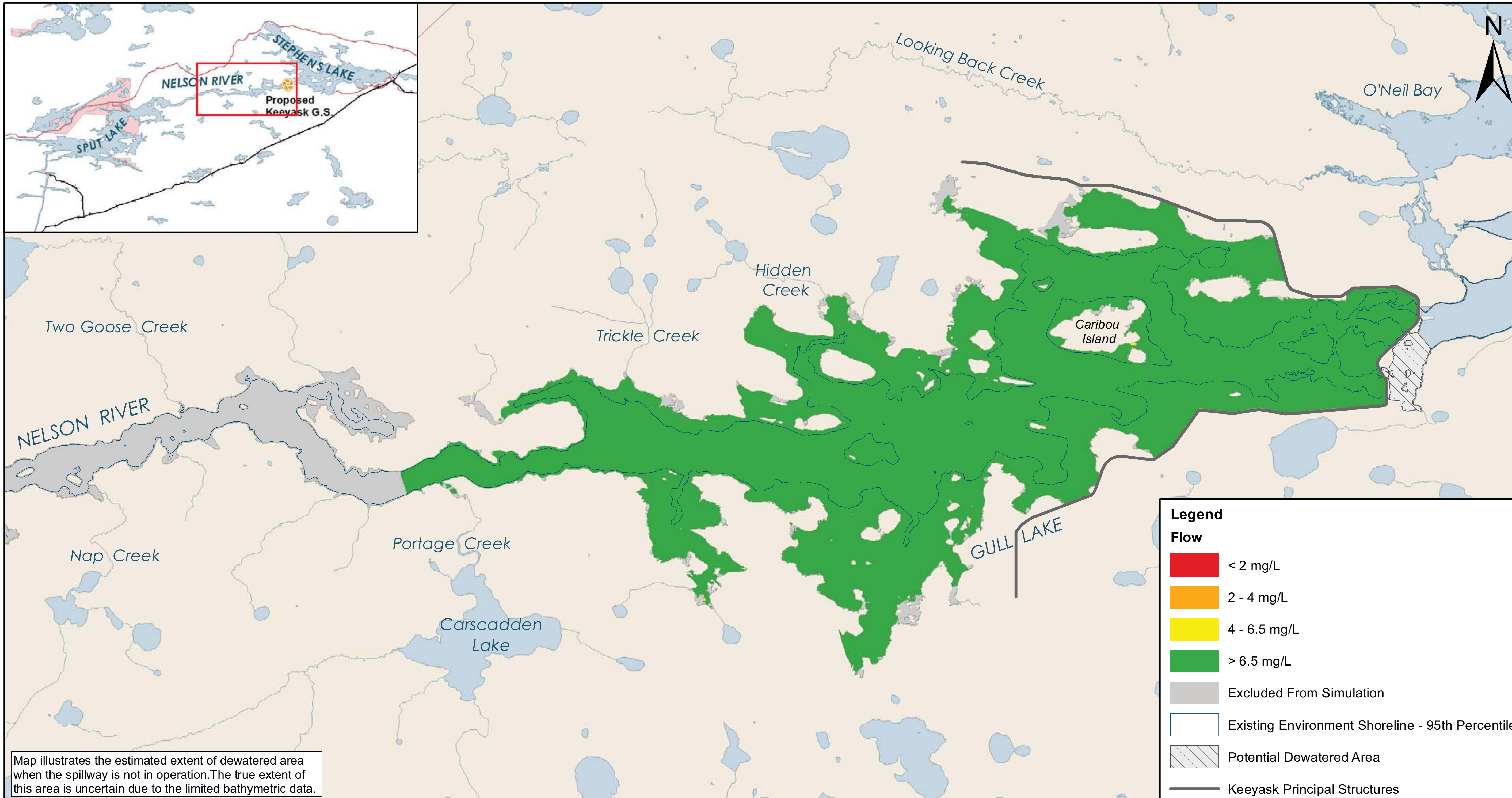
0 3 6 Kilometres
0 1.5 3 Miles

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

Typical Summer Week Average Flows - Surface Dissolved Oxygen

Post-Project Base Loaded Mode - Year 1 - Time of Greatest Effect

Map 9.B-1



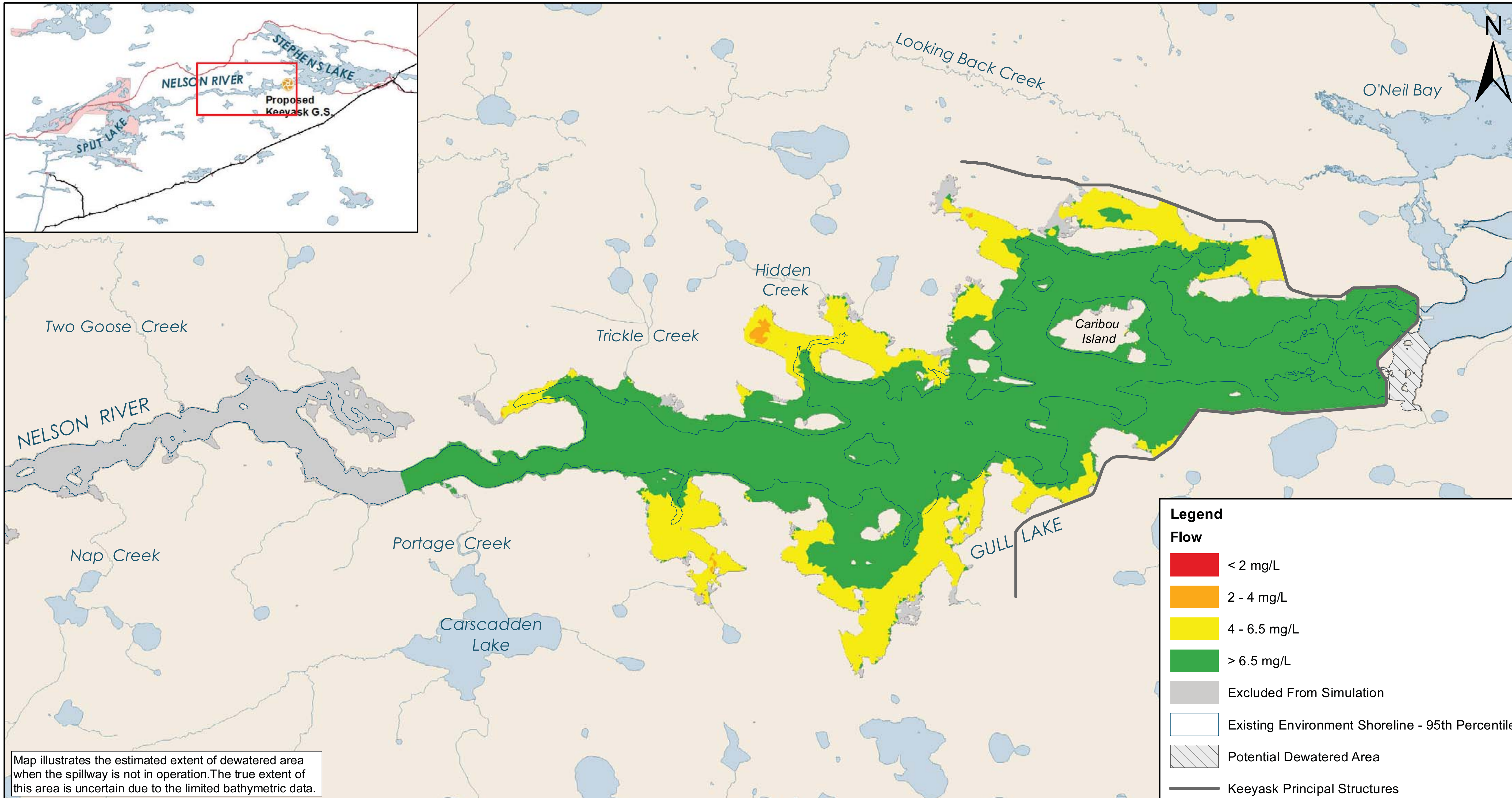
KEEYASK Hydropower Limited Partnership

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

Typical Summer Week Average Flows - Bottom Dissolved Oxygen

Post-Project Base Loaded Mode - Year 1 - Time of Greatest Effect

Map 9.B-2

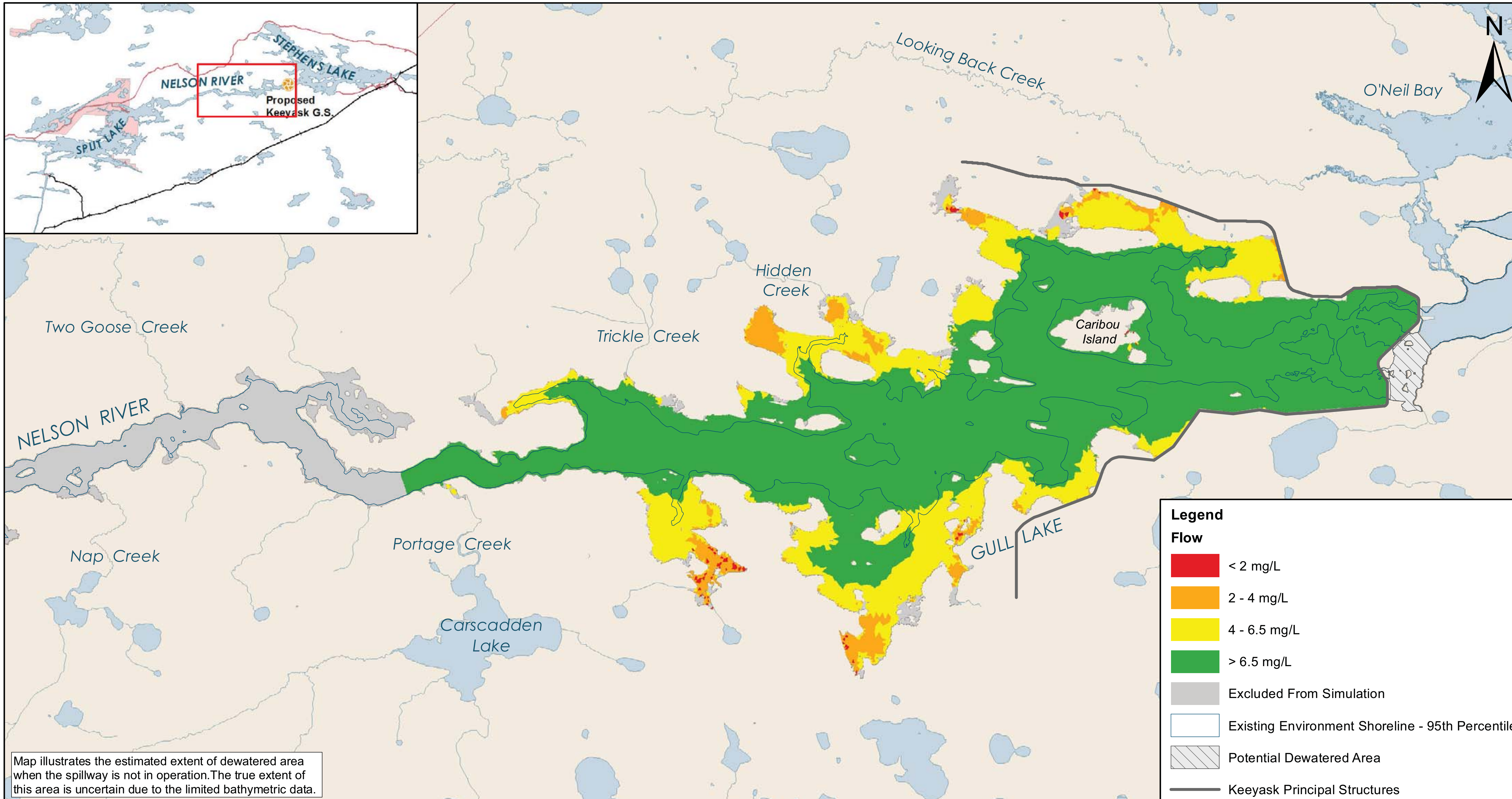


Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Stephens Lake Shoreline - Quickbird@Digitalglobe, 2006
Nelson River Shorelines modelled by Manitoba Hydro

Critical Summer Week Average Flows - Surface Dissolved Oxygen

Post-Project Base Loaded Mode - Year 1 - Time of Greatest Effect

Map 9.B-3



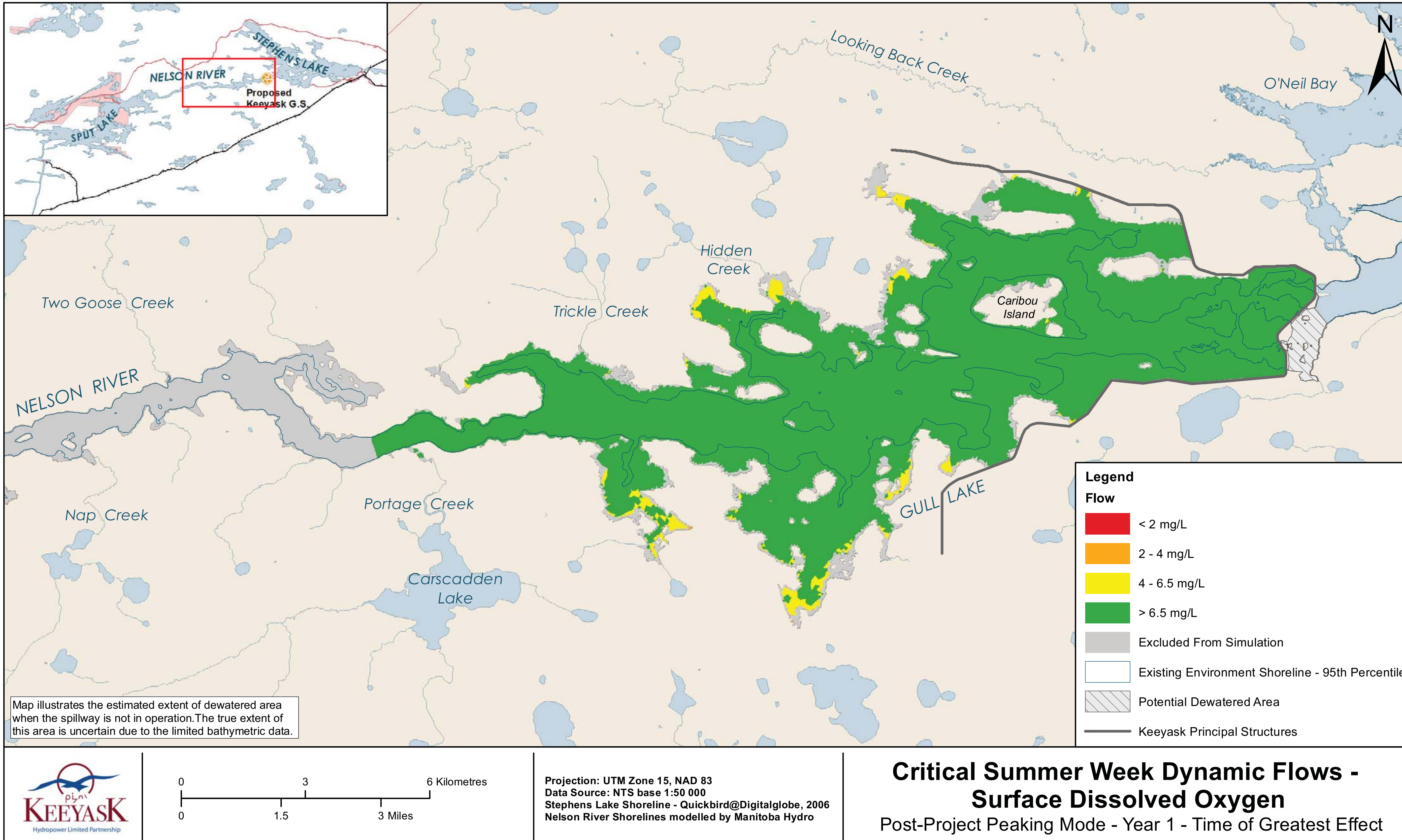
KEEYASK Hydropower Limited Partnership

0 3 6 Kilometres
0 1.5 3 Miles

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

Critical Summer Week Average Flows - Bottom Dissolved Oxygen

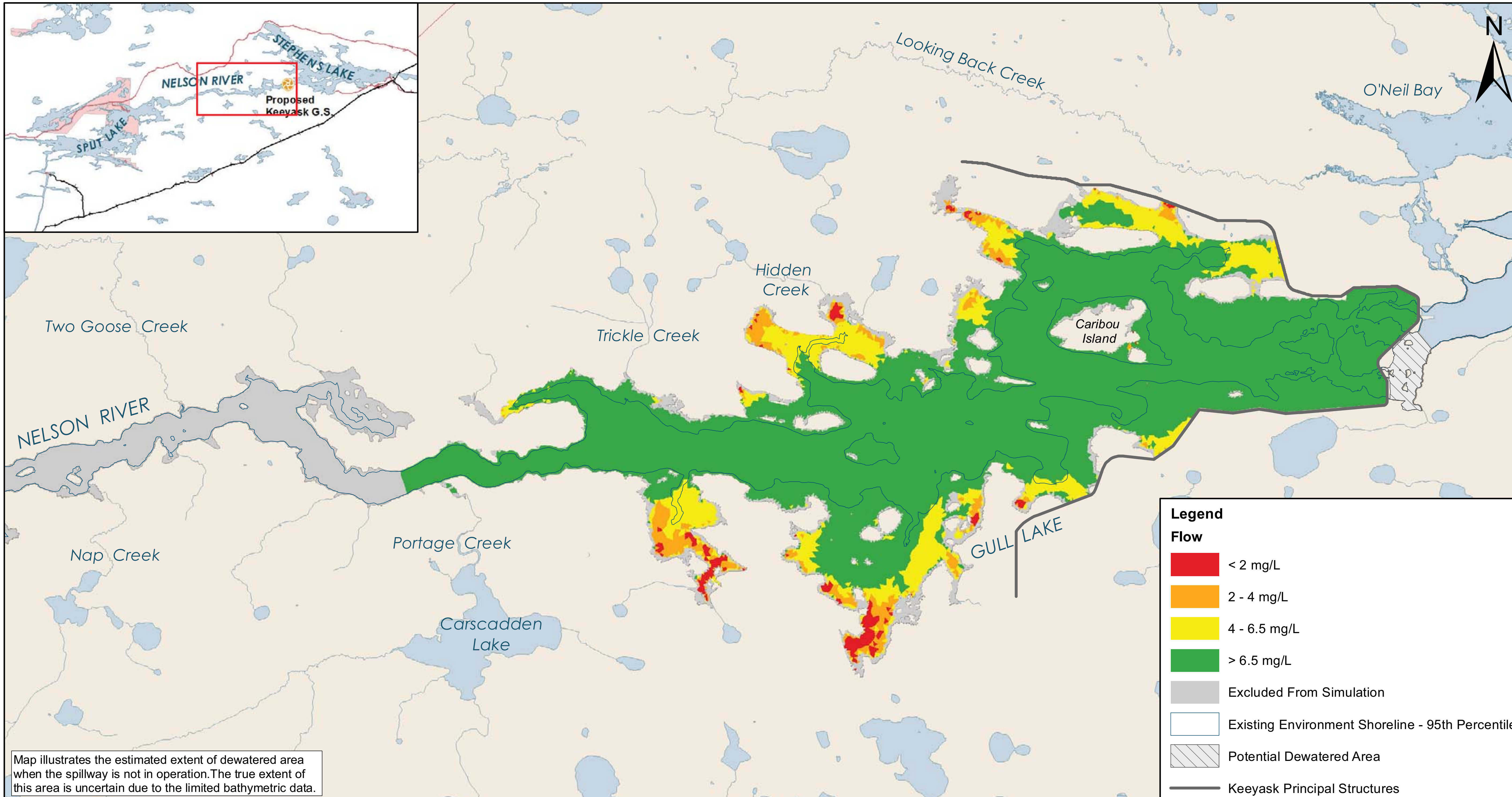
Post-Project Base Loaded Mode - Year 1 - Time of Greatest Effect



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

Critical Summer Week Dynamic Flows - Surface Dissolved Oxygen

Post-Project Peaking Mode - Year 1 - Time of Greatest Effect



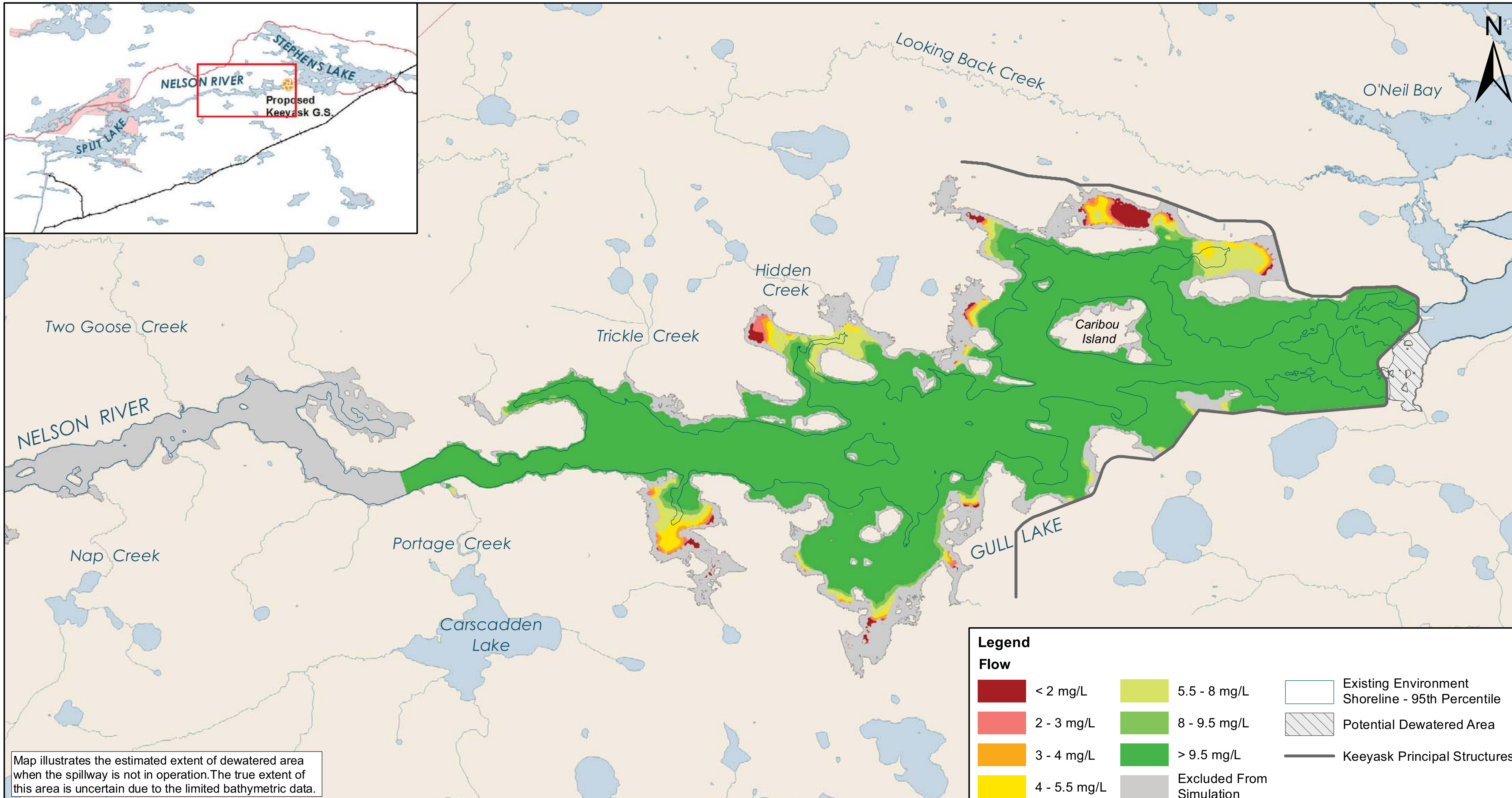
KEEYASK
Hydropower Limited Partnership

0 3 6 Kilometres
0 1.5 3 Miles

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

Critical Summer Week Dynamic Flows - Bottom Dissolved Oxygen

Post-Project Peaking Mode - Year 1 - Time of Greatest Effect



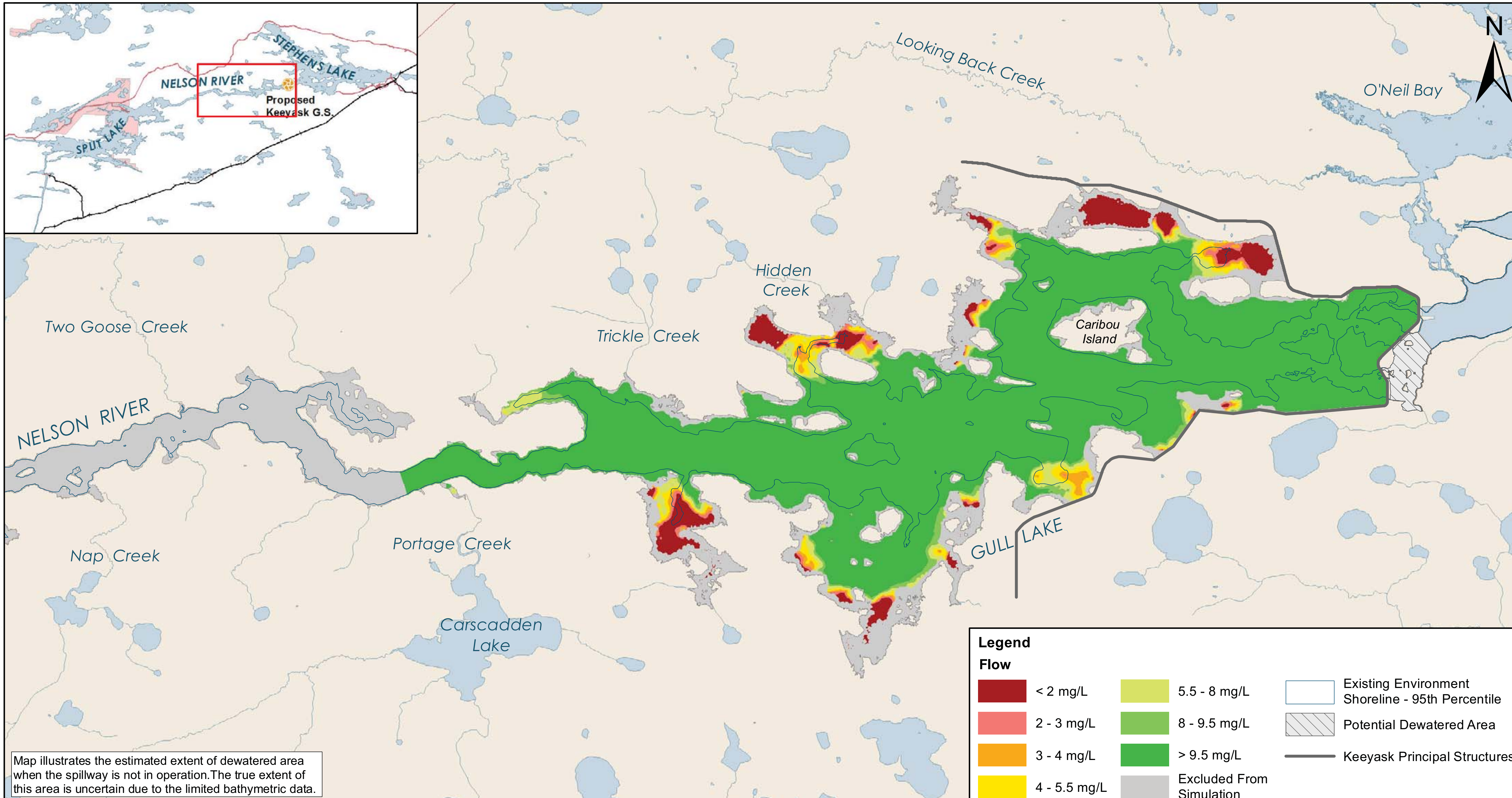
Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Stephens Lake Shoreline - Quickbird@Digitalglobe, 2006
Nelson River Shorelines modelled by Manitoba Hydro

KEEYASK Hydropower Limited Partnership

Winter Average Flows - Surface Dissolved Oxygen

Post-Project Base Loaded Mode - Year 1 - End of Run

Map 9.B-7

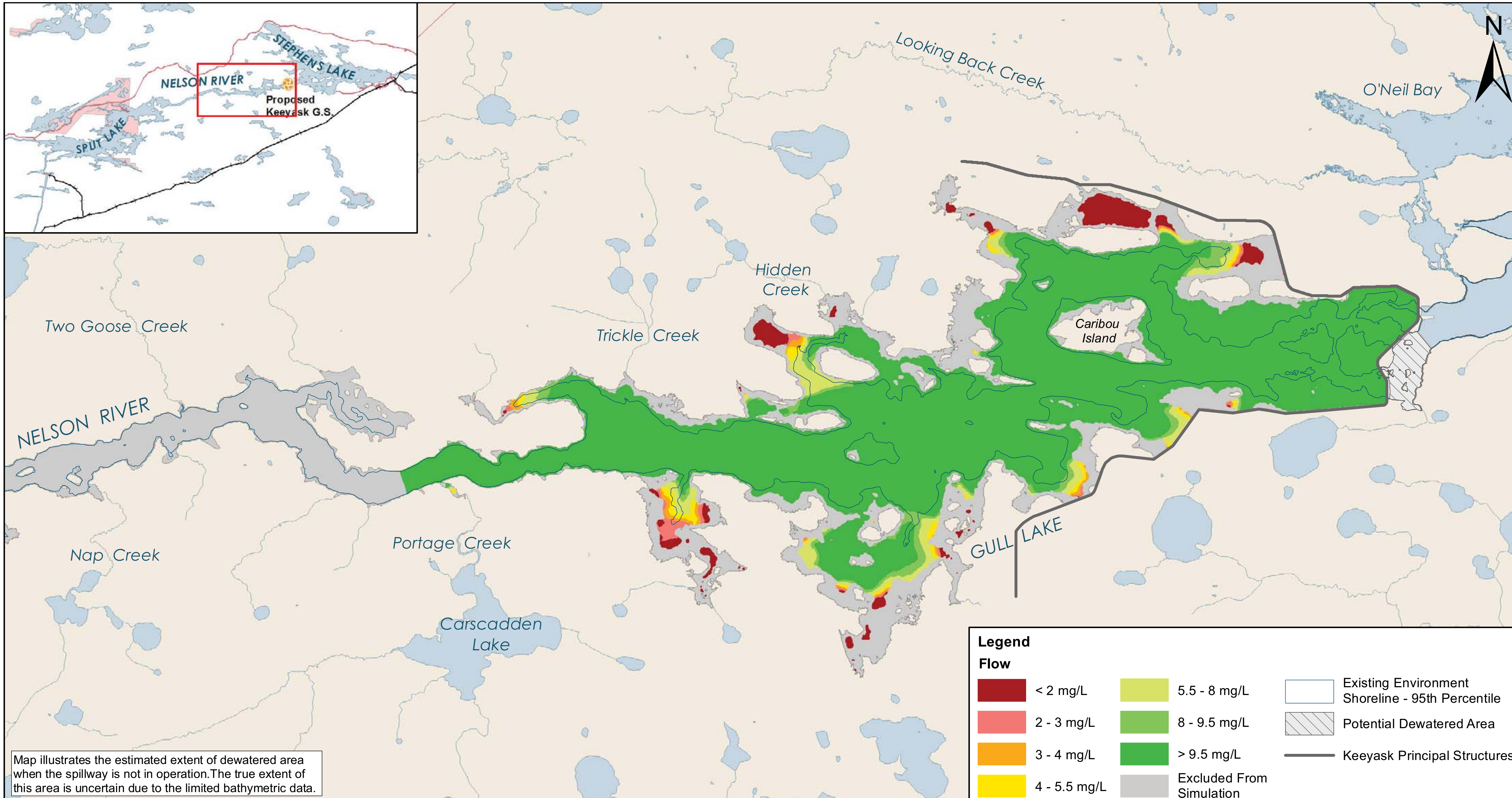


Projection: UTM Zone 15, NAD 83
Data Source: NTS base 1:50 000
Stephens Lake Shoreline - Quickbird@Digitalglobe, 2006
Nelson River Shorelines modelled by Manitoba Hydro

Winter Average Flows - Bottom Dissolved Oxygen

Post-Project Base Loaded Mode - Year 1 - End of Run

Map 9.B-8



KEEYASK Hydropower Limited Partnership

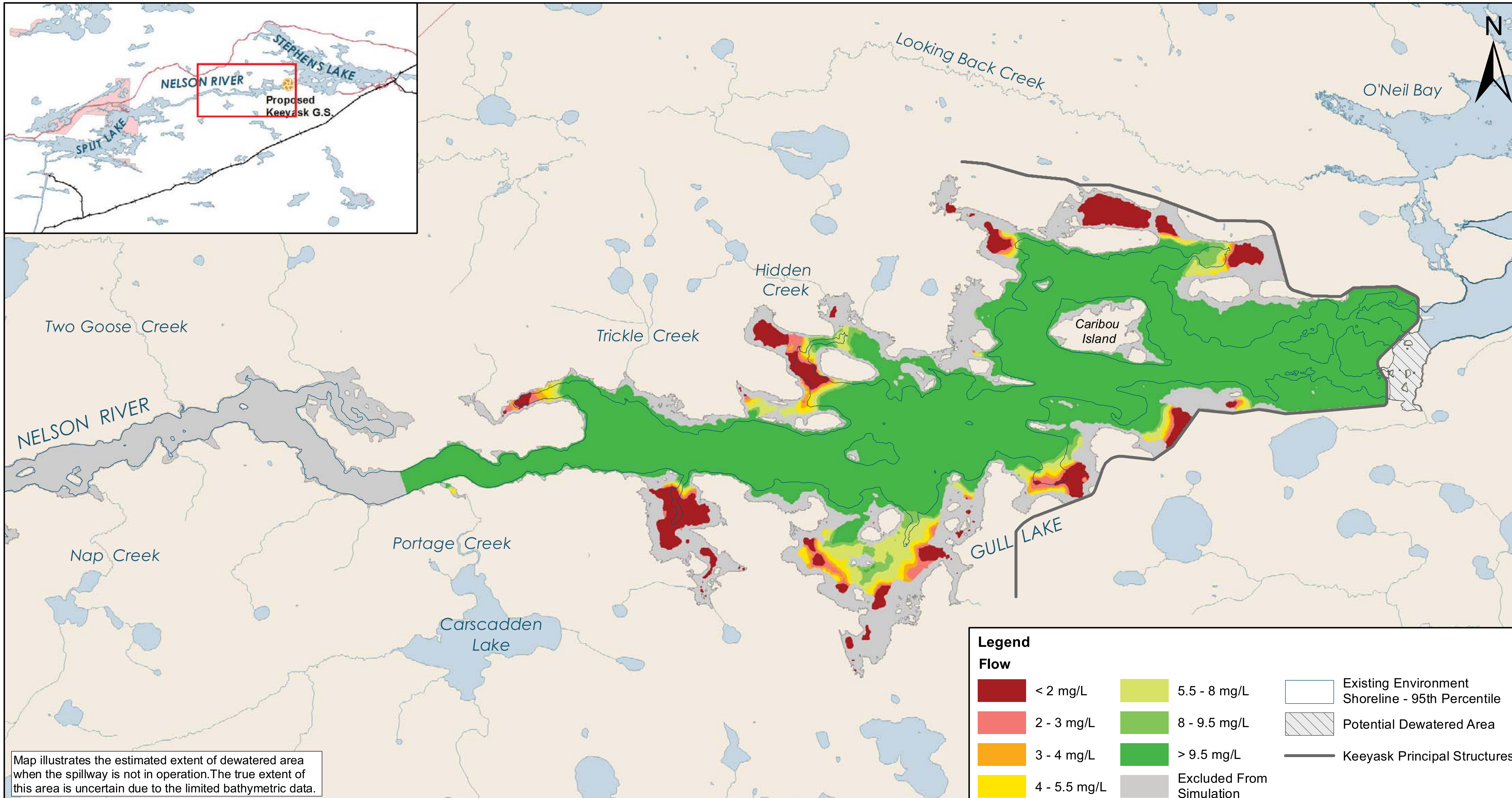
0 3 6 Kilometres
0 1.5 3 Miles

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

Winter Dynamic Flows - Surface Dissolved Oxygen

Post-Project Peaking Mode - Year 1 - Time of Greatest Effect

Map 9.B-9



KEEYASK Hydropower Limited Partnership

0 3 6 Kilometres

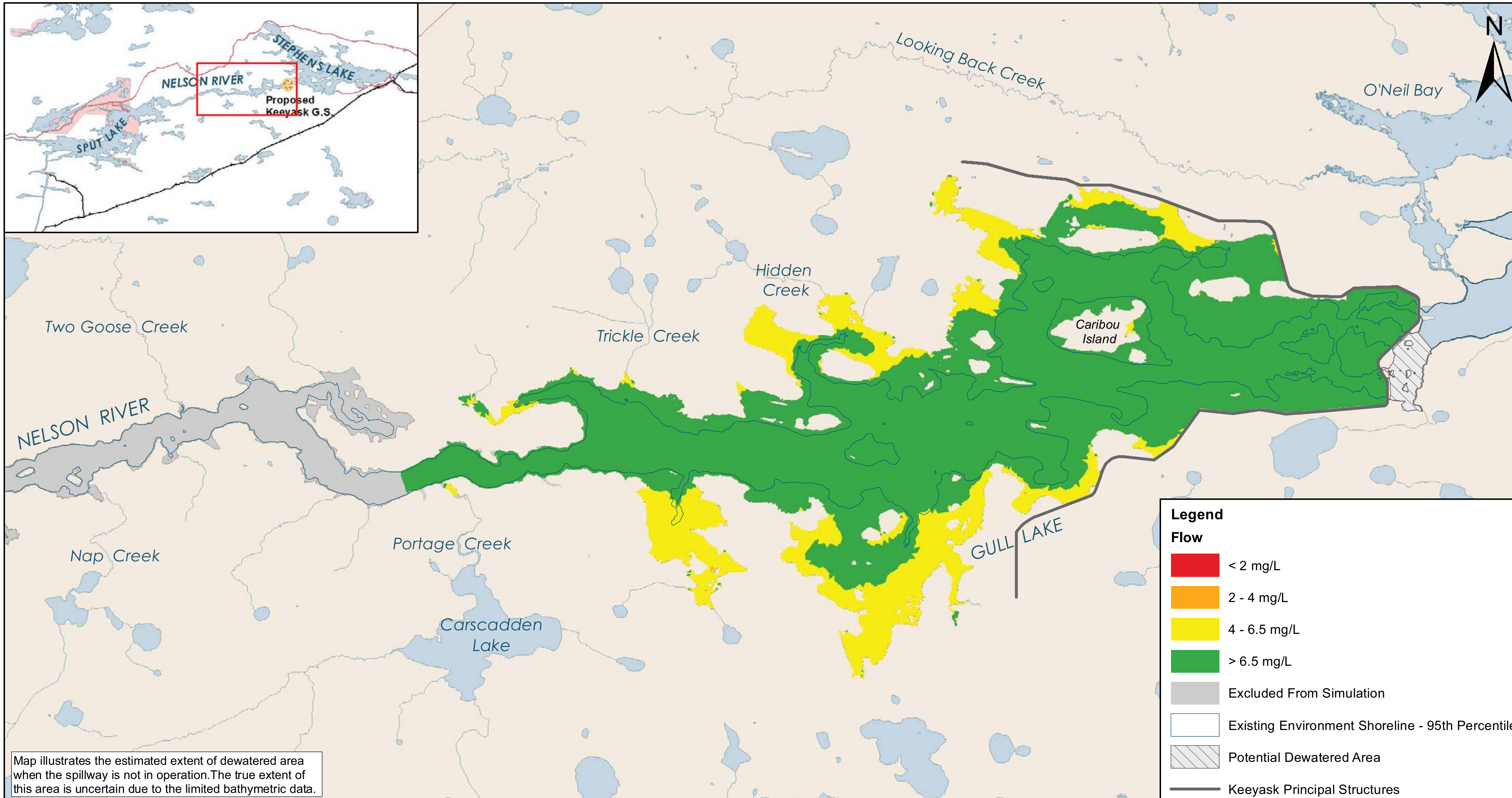
0 1.5 3 Miles

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

Winter Dynamic Flows - Bottom Dissolved Oxygen

Post-Project Peaking Mode - Year 1 - Time of Greatest Effect

Map 9.B-10



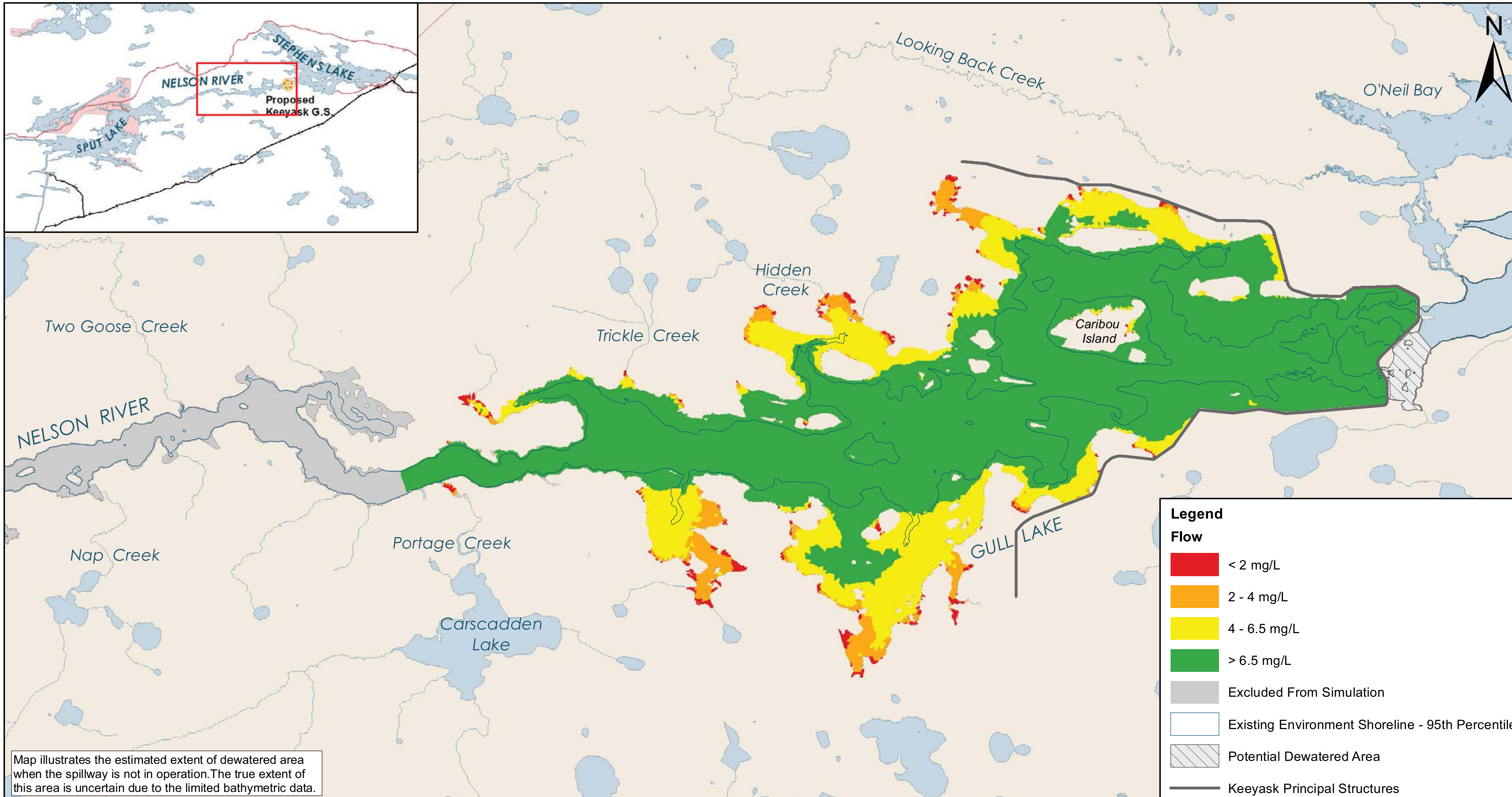
KEEYASK Hydropower Limited Partnership

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

Critical Summer Week Average Flows - Surface Dissolved Oxygen

Post-Project Base Loaded Mode - Year 5 - Time of Greatest Effect

Map 9.B-11



KEEYASK Hydropower Limited Partnership

0 3 6 Kilometres
0 1.5 3 Miles

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

Critical Summer Week Average Flows - Bottom Dissolved Oxygen

Post-Project Base Loaded Mode - Year 5 - Time of Greatest Effect

Map 9.B-12