Keeyask Generation Project

Environmental Impact Statement

Supporting Volume

Aquatic Environment

KEEYASK

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

3C.1 INTRODUCTION

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

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

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

The objectives of the model development were as follows:

Objective 1:

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

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

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

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

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

Objective 2:

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

3C.2 METHODS

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

3C.2.1 PREDICTIVE MACROPHYTE MODEL

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

3C.2.1.1 Wave Energy

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

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

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

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

3C.2.1.2 Landcover

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

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

3C.2.1.3 Distance to Mineral Soil and Peat Depth

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

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

3C.2.1.4 Shoreline Delineation, Bathymetry, and Slope

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

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

3C.2.1.5 Data Attribution and Extraction

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

3C.2.1.6 Macrophyte Model Building Using Discriminant Analysis

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

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

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

3C.2.2 USE OF POTENTIAL HABITAT BY MACROPHYTES

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

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

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

3C.2.2.1 Classification of Macrophytes Using Satellite Data

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

3C.2.2.2 Constraint Criteria Used to Define Potential Habitat

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

3C.3 RESULTS

3C.3.1 PREDICTIVE MACROPHYTE MODEL

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

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

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

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

The results of each LDA sensitivity trial are described below.

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

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

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

3C.3.1.3 Model 2: The Existing Environment Model

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

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

3C.3.1.4 Model 3: The Predictive Reservoir Model

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

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

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

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

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

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

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

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

3C.3.1.7 Discriminant Model Equations

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

3C.3.1.8 Classification Agreement

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

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

3C.3.2 USE OF POTENTIAL HABITAT BY MACROPHYTES

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

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

3C.4 SUMMARY AND CONCLUSIONS

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

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

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

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

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

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

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

3C.5 REFERENCES

3C.5.1 LITERATURE CITED

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

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

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

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

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

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

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

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

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

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

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

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

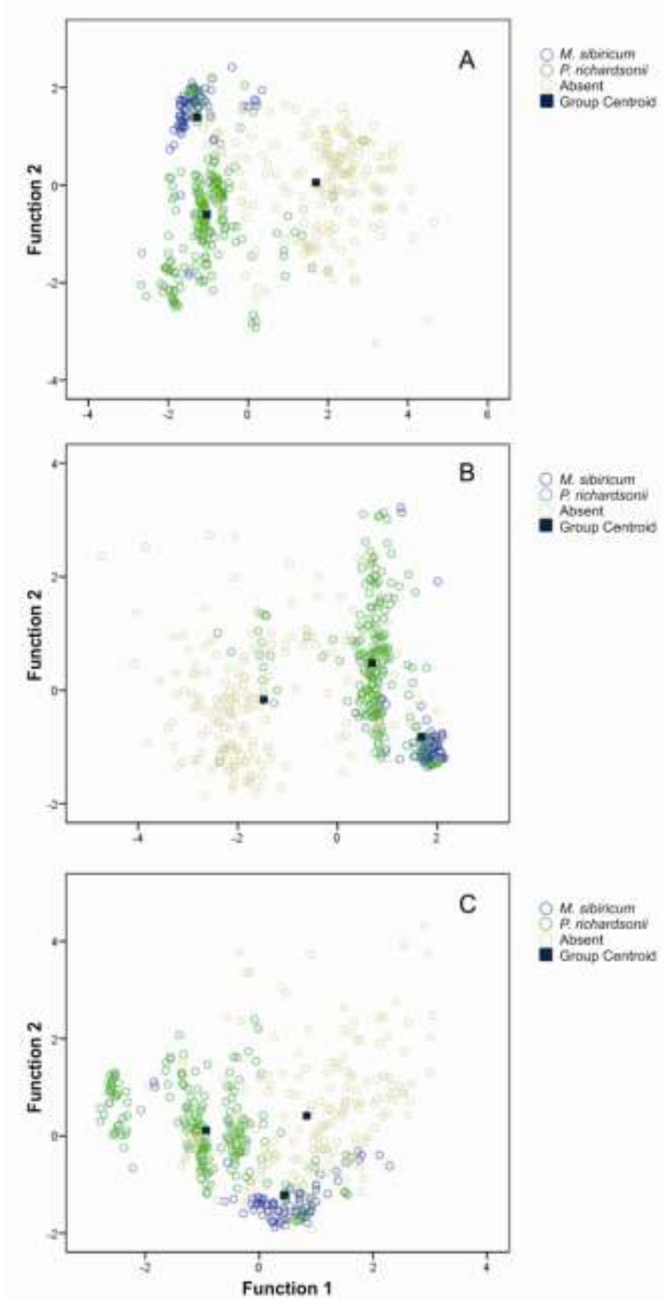


Figure 3C-1: Discriminant analysis scatter plots showing three variants of the predictive aquatic macrophyte model using data from the existing environment (EE) and/or pre-flood (PF) within Stephens Lake. (A) Model 1: full model comprised of all six variables; 4 from the EE and 2 from PF data; (B) Model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

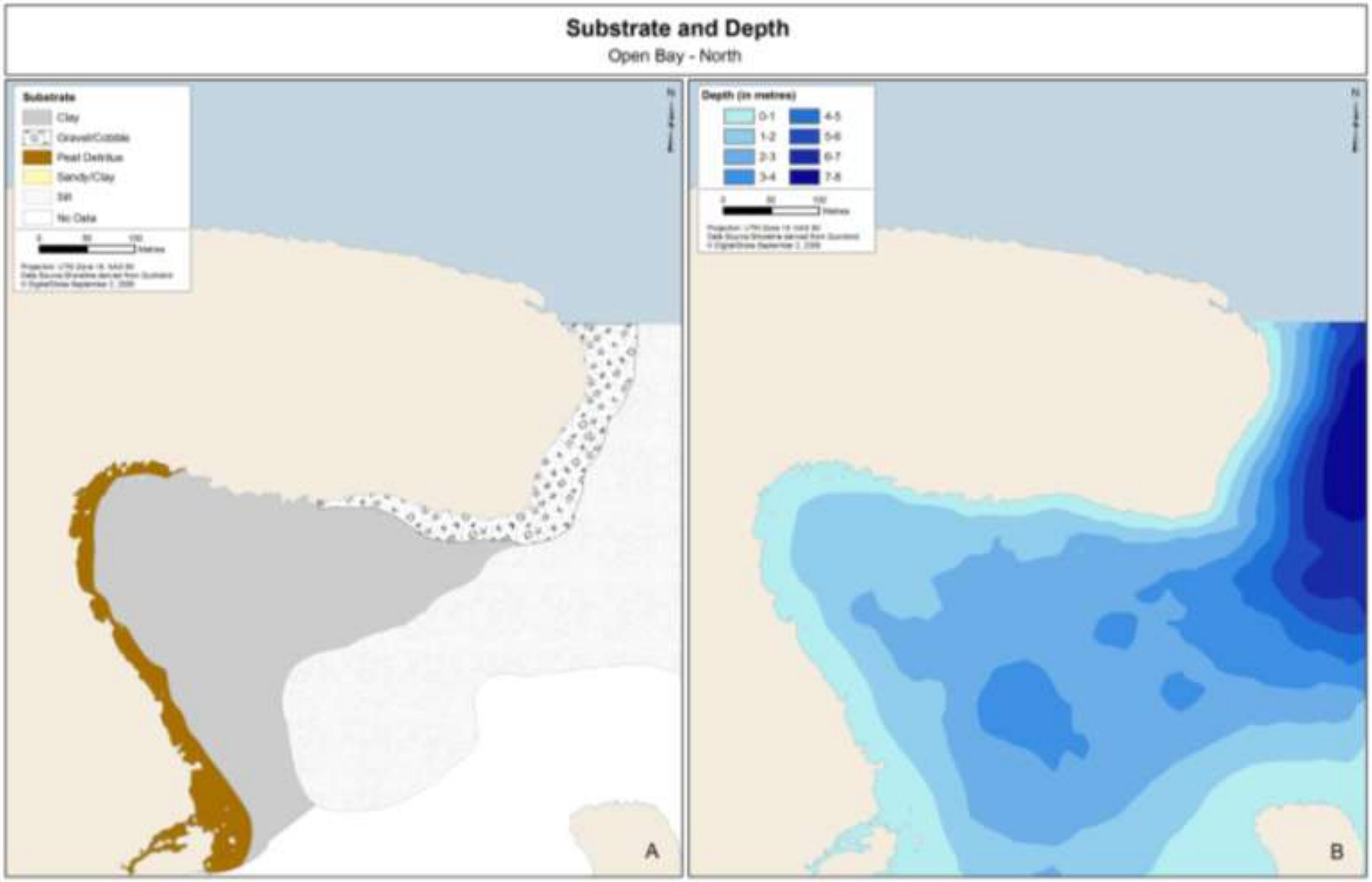


Figure 3C-2: Substrate (A) and water depth (B) distributions for the North validation study areas in Stephens Lake representing a 95th percentile water elevation

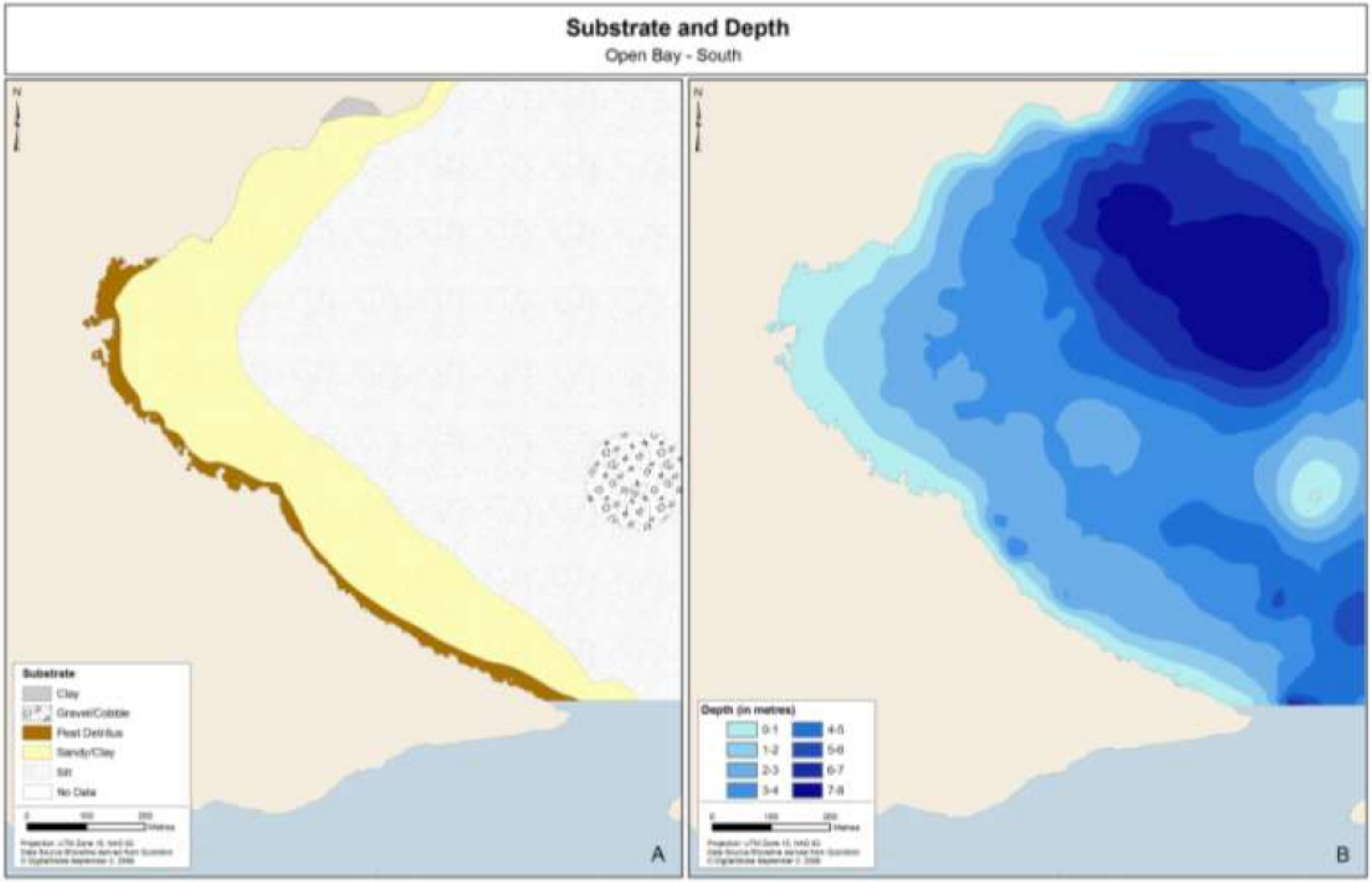


Figure 3C-3: Substrate (A) and water depth (B) distributions for the South validation study areas in Stephens Lake representing a 95th percentile water elevation

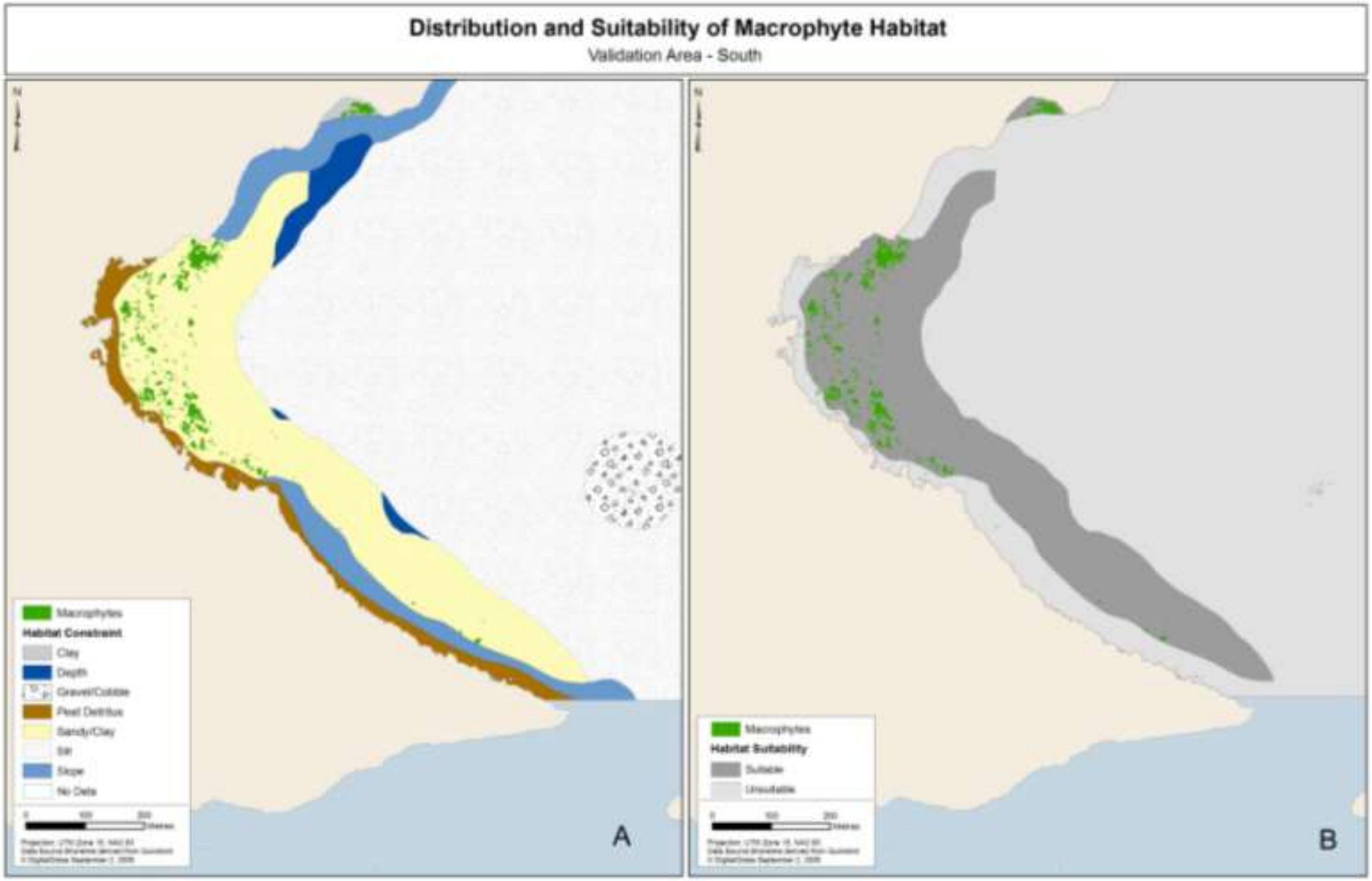


Figure 3C-4: Distribution of habitat constraints on aquatic macrophyte presence (including slopes more than 6 %) (A), and suitability of macrophyte habitat also showing the area occupied by plants relative to that available (B) in the South validation study area in Stephens Lake

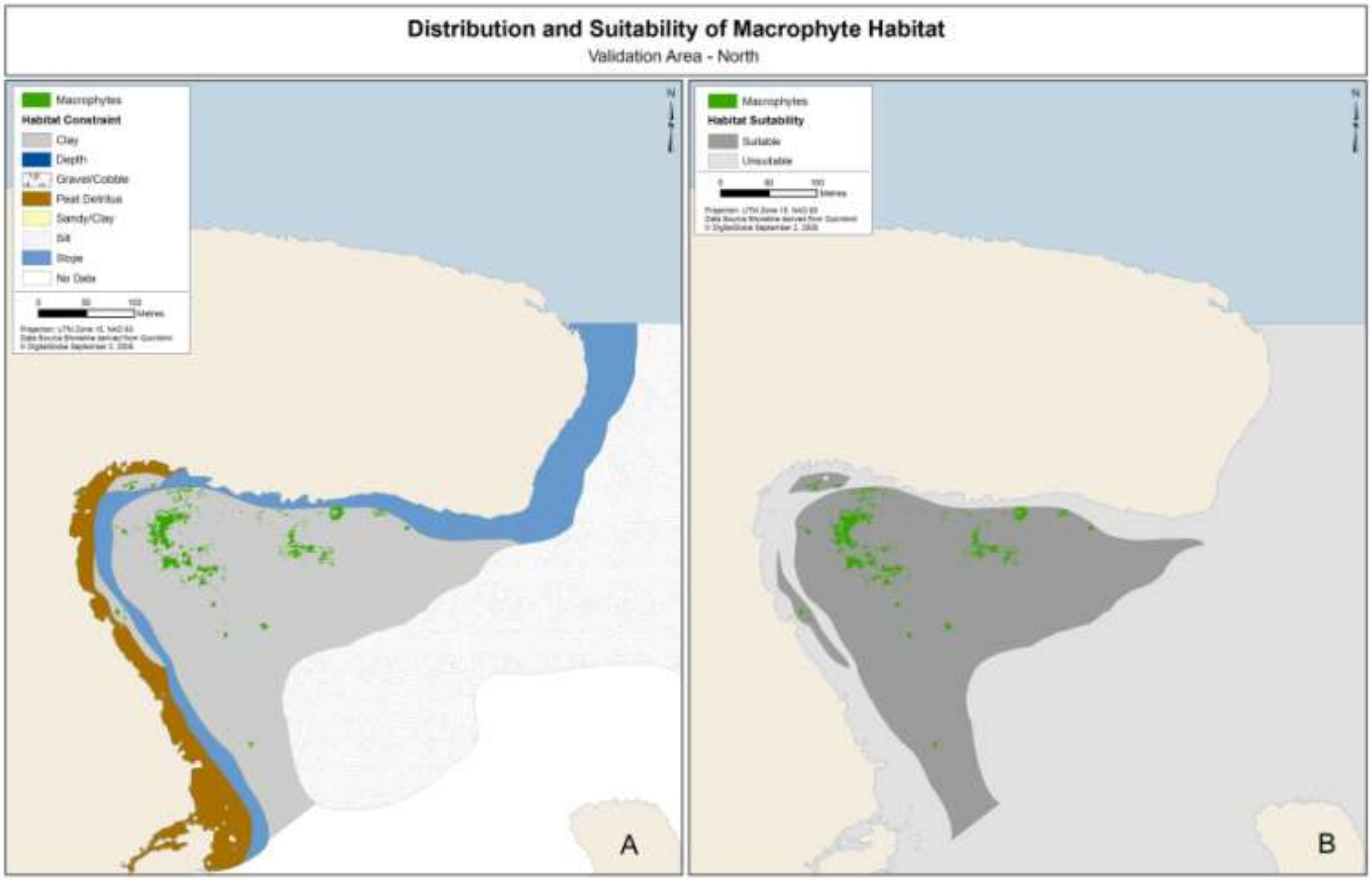


Figure 3C-5: Distribution of habitat constraints on aquatic macrophyte presence (including slopes more than 6 %) (A), and suitability of macrophyte habitat also showing the area occupied by plants relative to that available (B) in the North validation study area in Stephens Lake

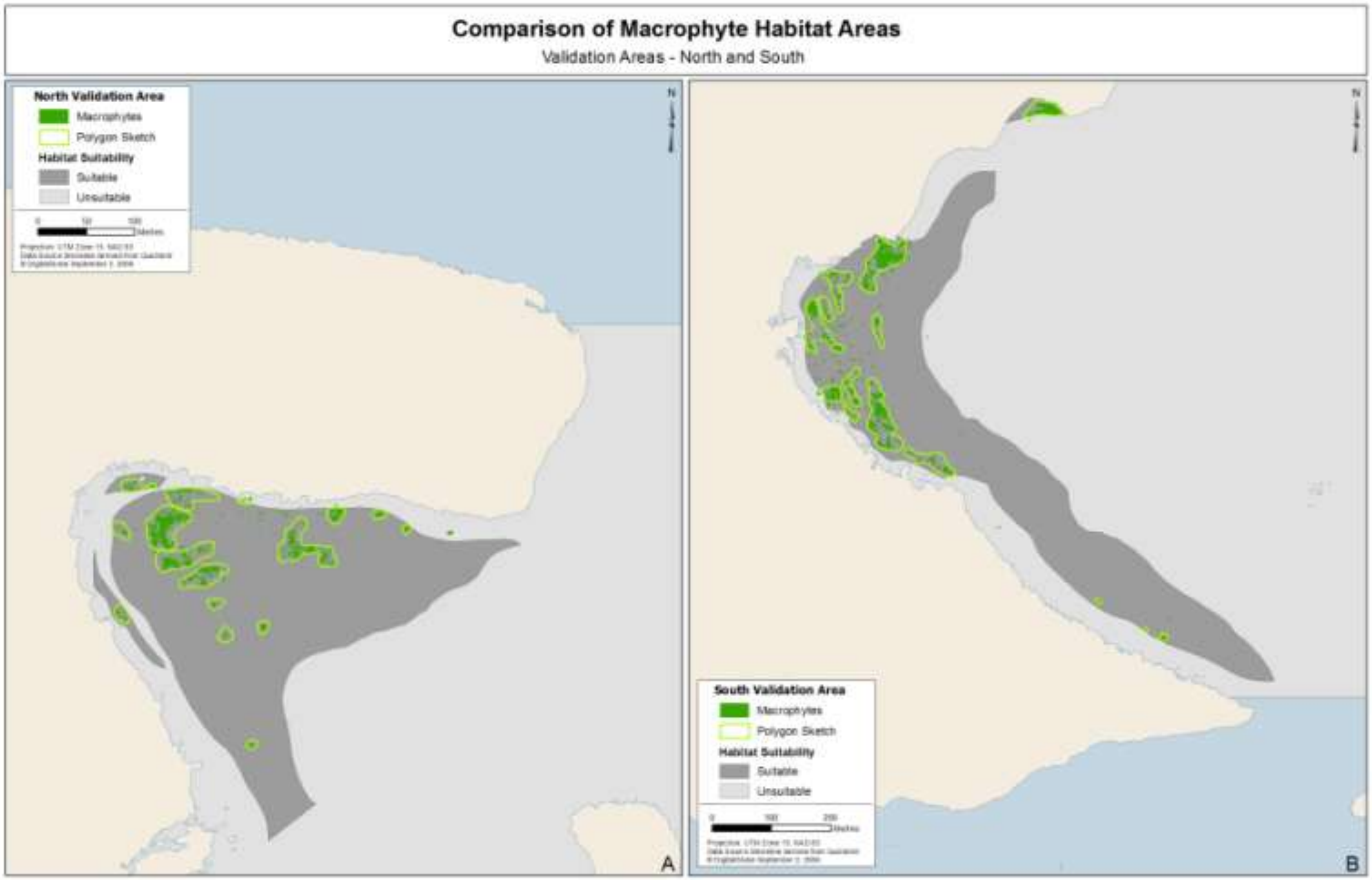
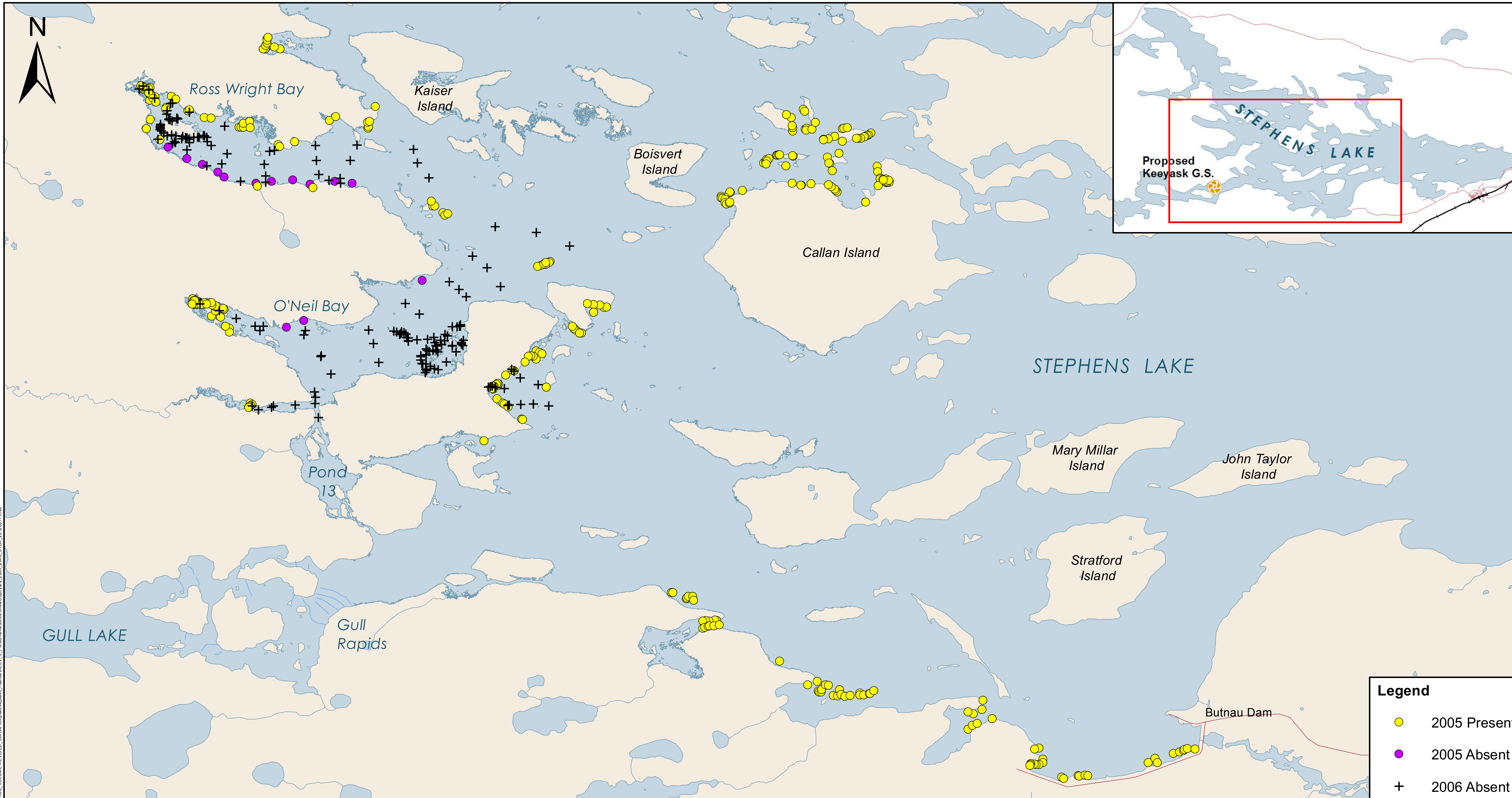


Figure 3C-6: Comparison of the distribution macrophyte beds captured using high resolution optical satellite imagery (described in preceding figure) and aerial polygon sketches for the north and south validation study areas in Stephens Lake



KEEYASK Hydropower Limited Partnership

0 2.5 5 Kilometres

0 1.25 2.5 Miles

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

Presence/Absence of Macrophytes 2005 - 2006

Stephens Lake Area

Map 3C-1

0 5 10 Kilometres
0 2.5 5 Miles

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

Macrophyte Habitat Suitability Validation Areas
Stephens Lake

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

3D.1 INTRODUCTION

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

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

3D.2 HABITAT ANALYSES

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3D.2.4.1 Peaking Mode of Operation

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

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

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

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

3D.2.4.2 Base Loaded Mode of Operation

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

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

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

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

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

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

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

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

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

Access Road Watercourse Crossing Description

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

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

Keeyask Access Road
Stream Crossing Assessment

Location

UTM: 0360595 / 6250077–NAD 83
Date: 7 October, 2004

Watercourse Name: Looking Back Creek
Site: SC – 1

Site Description

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

Riparian Vegetation: The creek lies within a relatively narrow, well-drained floodplain containing grasses and willows. The valley forest is composed of black spruce and jack pine with an understory of moss, shrubs, and forbs.

Aquatic Vegetation: Yes

Unique Features: n/a

Summary: This crossing is located in the lower portion of the creek, approximately 4 km from Stephens Lake. Habitat in the creek consists primarily of run habitat less than 1 m deep, with some side channel pools. Small areas of gravel/cobble riffle occur further upstream from the crossing. The creek substrates are primarily fines with some boulder and cobble/gravel. The presence of beaver dams began 2 km upstream of the crossing, continuing upstream to the headwaters.

Fisheries Assessment

Capture Method: Fall 2004–Backpack Electrofishing, 1.5" and 3.5" gill net.
Spring 2005 – Hoop net, kick net.

Species Present: Fall 2004–None.
Spring 2005 – walleye, northern pike.

Life History Stage: Fall 2004–n/a
Spring 2005 – pre-spawn and post-spawn adults. One northern pike egg.

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

[2] For example: sticklebacks, minnows

Fisheries Assessment

Large-bodied Species[1]

Spawning: Yes

Migration: Yes

Rearing: Yes

Overwintering: Possibly

Small-bodied Species[2]

Open-water Presence: Yes

Overwintering: Possibly

Fish Use and Fish Habitat Summary

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

North/South Consultants Inc.
AQUATIC ENVIRONMENT SPECIALISTS

Access Road Watercourse Crossing Description

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

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

Keeyask Access Road
Stream Crossing Assessment

Location

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

Site Description

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

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

Fisheries Assessment

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

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

[2] For example: sticklebacks, minnows

Fisheries Assessment

Large-bodied Species[1]

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

Small-bodied Species[2]

Open-water Presence:	Possibly
Overwintering:	No

Fish Use and Fish Habitat Summary

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

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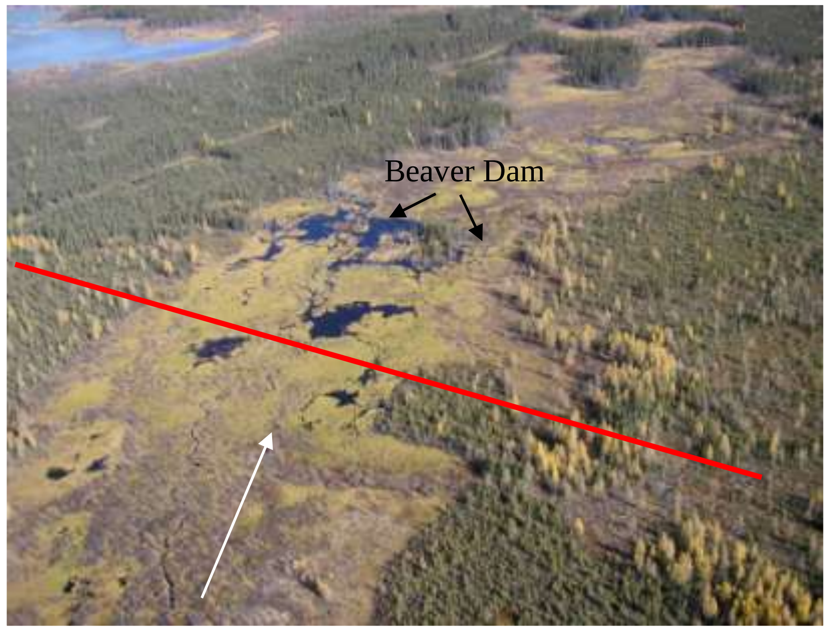

Figure 1: Aerial view of Gull Rapids Creek with the crossing location indicated by the red line and the direction of flow by the white arrow.


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

Keeyask Access Road
Stream Crossing Assessment

Location

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

Site Description

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

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

Fisheries Assessment

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

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

Fisheries Assessment

Large-bodied Species[1]

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

Small-bodied Species[2]

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

Fish Use and Fish Habitat Summary

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

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Access Road Watercourse Crossing Assessment

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

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

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

Keeyask Access Road
Stream Crossing Assessment

Location

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

Site Description

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

Riparian Vegetation: The creek lies within a relatively broad, saturated floodplain dominated by sedges and willows. The valley forest is composed of black spruce and tamarack with an understory of willow, Labrador tea, and moss.

Aquatic Vegetation: Yes

Unique Features: Approximately 100 m downstream of the crossing, the creek enters a forested area with a narrow floodplain and thick willow growth, where the channel is well defined containing some areas with boulder.

Summary: The small creek drains a small-unnamed lake (approximately 750 m upstream of the crossing) into Stephens Lake approximately 400 m downstream of the crossing. The creek channel is braided, shallow and not well defined at the crossing. Beaver dams occur upstream of the crossing, but not downstream.

Fisheries Assessment

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

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

Fisheries Assessment

Large-bodied Species[1]

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

Small-bodied Species[2]

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

Fish Use and Fish Habitat Summary

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

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Access Road Watercourse Crossing Assessment

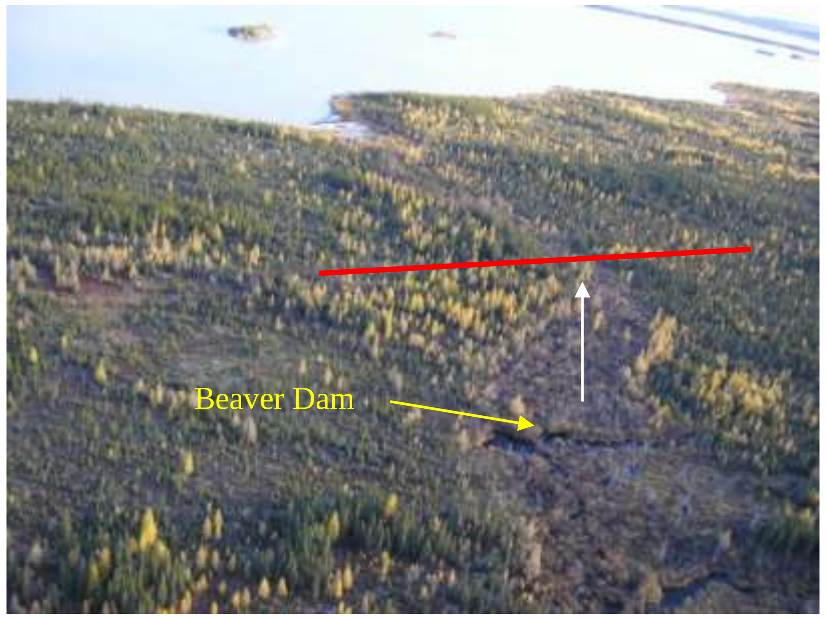

Figure 1: Aerial view of Gillrat Lake Creek with the crossing location indicated by the red line and the direction of flow by the white arrow.

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

Keeyask Access Road
Stream Crossing Assessment

Location

UTM:	0372880 / 6244078–NAD 83	**Watercourse Name:**	Gillrat Lake Creek
Date:	4 October, 2004	**Site:**	SC – 5

Site Description

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

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

Aquatic Vegetation: Yes

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

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

Fisheries Assessment

Capture Method:	Backpack Electrofishing
Survey Length:	20 m
Species Present:	Northern pike
Life History Stage:	Juvenile
Abundance (#fish/min.):	0.25

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

[2] For example: sticklebacks, minnows

Fisheries Assessment

Large-bodied Species[1]

Spawning:	Yes
Migration:	Unlikely
Rearing:	Yes
Overwintering:	No

Small-bodied Species[2]

Open-water Presence:	Yes
Overwintering:	No
Habitat Quality:	Good

Fish Use and Fish Habitat Summary

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

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