Submitted to:
City of Greater Sudbury

Ramsey Lake Subwatershed Study and Master Plan

Phase 2 Report

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Reference: 66019
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1.0 Introduction

The following subheadings describe the regional and site-specific context of the Ramsey Lake Sub-watershed, and the study objectives.

1.1 Background

Ramsey Lake is a key natural feature located in the southeast portion of the City of Greater Sudbury. The lake is an important municipal drinking water source and has the unique geological features of exposed bedrock and thin surficial soil cover, as well as a rich mining history and related impacts that are heritage of the Sudbury area. Greater Sudbury's natural environment, including Ramsey Lake, is a defining feature of the City's image and appeal, and the conflicts between urban development, industry and the desire to protect natural areas are ongoing and challenging for the community.

The City of Greater Sudbury Official Plan (2006) recognizes that sensitive surface water features, sensitive groundwater features, and their hydrologic functions and linkages should be determined through a watershed-based planning approach. This Subwatershed Study and Master Plan has been undertaken by the City to identify and assess the sensitive environmental features and functions within the Ramsey Lake subwatershed and to identify constraints, opportunities, and environmental impacts associated with existing urban development as well as proposed future land use changes. The findings are then used to develop a Subwatershed Management Plan, including stormwater management and natural heritage recommendations, which will protect, rehabilitate and enhance the environmental resources within the Ramsey Lake study area.

1.2 Study Objectives

Based on the above, the overarching goal of this study may be stated as follows:

> ***Develop a Subwatershed Management Plan to protect, maintain and enhance the surface water, groundwater, and natural resources of Ramsey Lake and its tributaries through environmentally sound policy and management actions.***

On this basis, key objectives of the study include:

- Protect and enhance the quantity and quality of surface water;
- Protect and enhance groundwater resources;
- Protect and restore aquatic, wetland and terrestrial resources;
- Develop strategies to minimize the risk of flooding, erosion, and other impacts on the natural systems due to urban development and climate change;
- Identify specific projects needed to achieve the goals identified by the subwatershed study;
- Produce an implementation and monitoring plan to allow for adaptive management and to guide future activities in the subwatershed;
- Develop a reporting plan to communicate the results of the study, plan implementation, monitoring and future activities.

1.3 Study Area

The Ramsey Lake Subwatershed study area, as illustrated in **Figure 1.1**, is approximately 4246 gross hectares in the southeast portion of the City of Greater Sudbury. Several smaller lakes and tributaries drain to Ramsey Lake, including:

- Minnow Lake, Bethel Lake, Lake Laurentian, and Perch Lake;
- Frobisher Creek (also referred to as Korpela Creek), Rogers Creek, Eugene Creek, and Keast Creek.

The Ramsey Lake subwatershed outlets to the larger Junction Creek watershed system via Lily Creek near Paris Street at the west end of the study area.

INSERT FIGURE

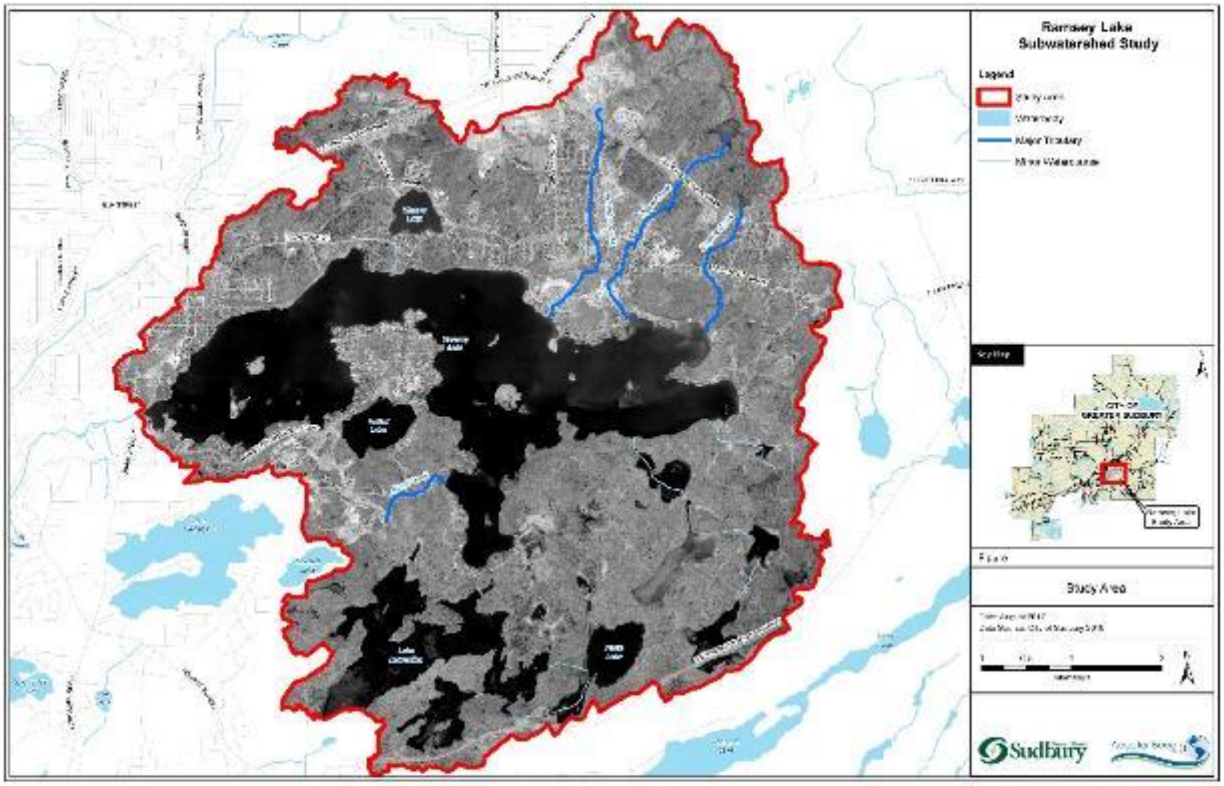

Figure 1.1: Study Area of the Ramsey Lake Subwatershed Study and Master Plan

1.4 Land Use

Much of the northern and southwestern shores of Ramsey Lake have been developed with a mix of residential, commercial, and institutional land use (Figure 1.2). Laurentian University occupies a significant area of land to the southwest. Much of the southeast portion of the study area is designated as parks and open space.

Several areas of planned future urban development have been identified by the City, including pockets of residential development in the northeast and northwest portions of the study area, and to the south of Bethel Lake. In addition, a large area of future industrial and commercial development has been identified along the Kingsway Highway in the headwaters of Frobisher, Rogers and Eugene Creeks in the northeast.

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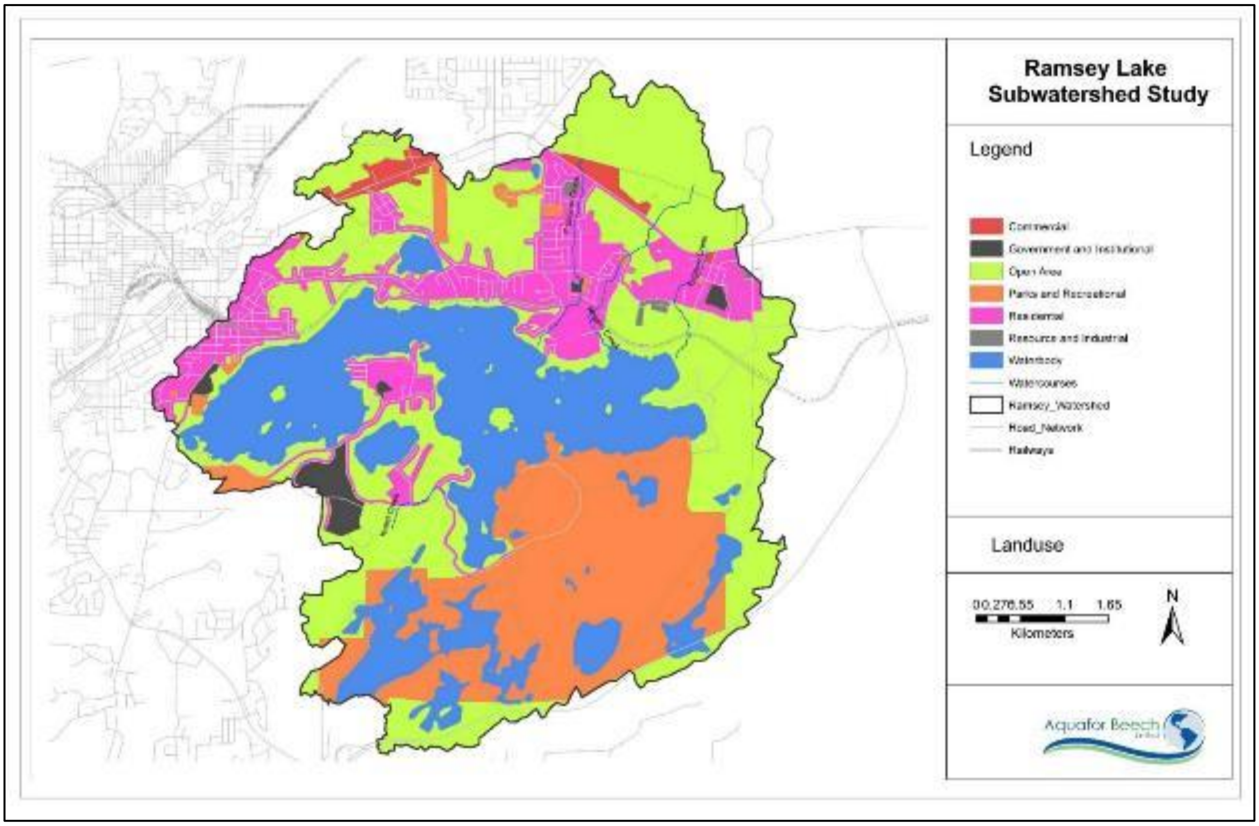


Figure 1.2: Land use designations within the study area

1.5 Study Phasing

The Subwatershed Study is undertaken in five phases. The key tasks and objectives of each phase are summarized below:

Phase 1: Background Data Collection & Review

- collection and review of existing background mapping, reports, and data;
- field surveys to collect additional field data.

Phase 2: Existing Conditions Characterization & Impact Analysis

- characterization of water quality conditions, including known and potential sources of pollution;
- characterize the existing groundwater system;
- modelling to quantify flood hazards and storm drainage system capacity constraints;
- characterize the tributary streams and identify erosion issues;
- identify key natural heritage features, including sensitive aquatic and terrestrial resources to be protected
- summarize environmental constraints and opportunities;
- assess the impacts of future urban development and climate change;
- based on the above, develop the study's guiding problem/opportunity statement.

Phase 3: Develop Alternative Subwatershed Management Strategies

- define the goals, objectives and targets that will guide the development of the Subwatershed Management Plan;
- identify protective measures (best management practices, or BMP's) that, when implemented, will protect, enhance or restore the environmental features and functions;
- formulate alternative subwatershed management strategies;
- evaluate each strategy, based on a range of technical, environmental, social and cost considerations.

Phase 4: Recommended Subwatershed Management Plan

- select, from the alternatives, a Recommended Subwatershed Plan, based on the Phase 3 evaluations, together with stakeholder input;
- develop an Implementation Plan to ensure the long-term integrity of the Recommended Plan, including the identification of issues and areas where further detailed studies may be required.

Phase 5: Finalize the Subwatershed Management Plan

- reporting and documentation;
- completion of the Master Plan and Class EA process.

1.6 Class Environmental Assessment (EA) Process

The Subwatershed Study is being conducted as a Master Plan, Approach #2, under the Municipal Class Environmental Assessment (Class EA) process. In order to meet the intent of the Environmental Assessment Act, the study will need to satisfy Phases 1 and 2 of the Class EA process:

- Phase 1 – identification of the problem (deficiency) or opportunity; and
- Phase 2 – identification of alternative solutions to address the problem or opportunity by taking into consideration the existing environment, and establish the preferred solution taking into account public and review agency input.

The relationship between the components of the Subwatershed Study process (Section 1.5) and the Class EA process is depicted in **Figure 1.3**.

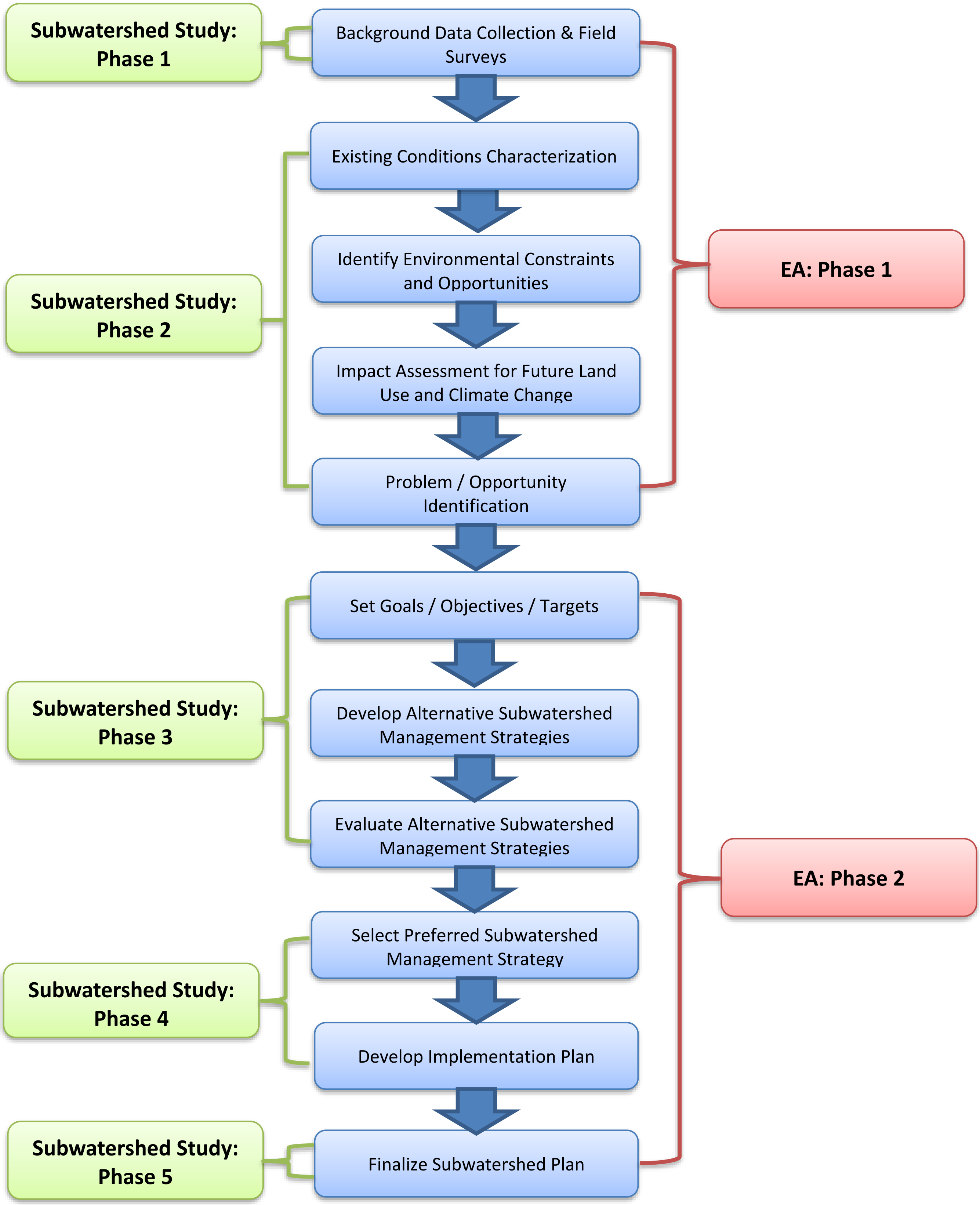
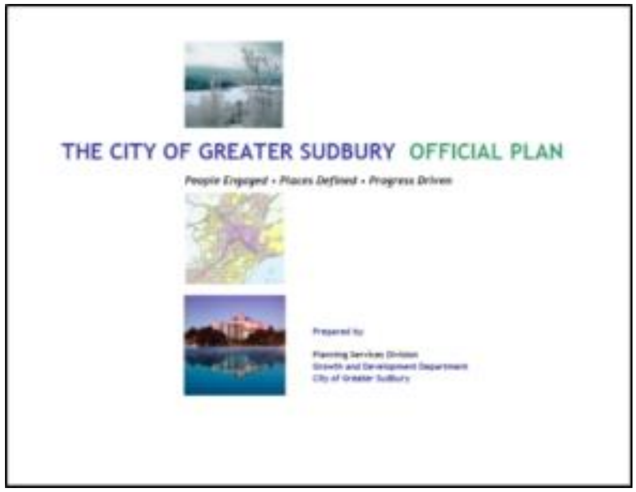


Figure 1.3: Subwatershed Study & Environmental Assessment Study Process

2.0 Background Information

A series of historical study reports and background information was provided by the City of Greater Sudbury and Sudbury Conservation for background review and consideration during the Ramsey Lake Subwatershed Study. Key documents are reviewed below.

The City of Greater Sudbury Official Plan



The City's Official Plan (OP) recognizes the sensitive nature of the natural resourses of the Ramsey Lake watershed and notes that the lake is to be maintained as one of the main drinking water sources for the City. The Plan recommends that Subwatershed Plans be developed to protect the natural resources for key watersheds such as Ramsey Lake. The Plan also documents key stormwater management planning objectives for future urban development applications, such as water quality, erosion and flood controls and notes that retrofit opportunities should be identified to remedy existing stormwater problems.

The OP emphasizes protecting local species and important habitats including wetlands and wildlife habitat in order to preserve their environment, and their ecological and social benefits. The City's significant natural features and areas include the following:

- Significant Habitat of Endangered and Threatened Species;
- Wetlands;
- Fish Habitat;
- Signficant Wildlife Habitat;
- Signficant Areas of Natural and Scientific Interest; and,
- Sites of Geological Interest.

Official Plan Stormwater Background Study (City of Greater Sudbury, January 2006)

This document provides a set of "fact sheets" listing the key features and stormwater issues for each of the City's watersheds. It also outlines stormwater criteria, design storms, and capacity standards for the design of stormwater infrastructure. Recommendations are also provided regarding the potential impacts of climate change.

The background study identifies the following primary stormwater issues in the Ramsey Lake subwatershed:

- Potential negative impact on water quality due to uncontrolled stormwater discharges from urban areas;
- Poor water quality (high nutrient levels) in several lakes, likely due to past industrial pollution and use of lawn fertilizers in urban areas;
- Growth potential will require stormwater quality and quantity control;
- Winter salting of roads;
- Some historic flood events within local storm drainage systems due to uncontrolled urban runoff;
- Extremely sensitive area with multiple lake uses at the City's centre; and
- The lake is a major municipal drinking water source.

The document recognizes that there is already significant urbanization and therefore recommends stormwater management retrofit opportunities wherever possible to promote a higher level of quality control for stormwater runoff entering the lakes and rivers.

With respect to climate change, the report discusses a suggested 15% increase in rainfall depths and notes that such an increase would decrease the level of service for the existing storm sewer network. For example, the level of service may decrease from 5 years to 2 years, since the 5-year storm is approximately 15-20% greater than a 2-year storm. On this basis, it recommends that stormwater management facilities target a release rate of 85% of pre-development rates for the

100-year storm to offset the potential climate change impacts, but no recommendations are provided for smaller storm events.

Ramsey Lake Water Management Plan – Standard Operating Procedure (City of Greater Sudbury, July 2015)

This document identifies the lake levels between which the City must operate and the reporting requirements to the MNR and MECP. The lake level is controlled by stop logs on the Ramsey Lake dam, located at the outlet of the lake near Science North. The primary objective of the dam operations is to control flooding and reduce damages to docks and shoreline erosion. The normal operating range for the lake is between 248.7m and 249.5m.

Development and Application of a Water Quality Model for Lakes in the City of Greater Sudbury (Hutchison Environmental Science Ltd., January 2014)

This study provides water quality management recommendations for lakes in the City of Greater Sudbury with respect to phosphorus loadings. The document recommends planning policies to:

- prevent additional phosphorus loads for those lakes classified for "Enhanced" management;
- minimize phosphorus loads as much as possible to avoid degradation of water quality in "Moderate" management lakes; and
- foster best management practices that would mitigate phosphorus loads in "Standard" management lakes.


Hutchinson
Environmental Sciences Ltd.

Development and Application of a Water Quality Model for Lakes in the City of Greater Sudbury

Prepared for: The City of Greater Sudbury
Job #: J110057

January, 2014

Final Report

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Within the Ramsey Lake Subwatershed Study area, bluegreen algal blooms have been documented in both Ramsey Lake itself and Bethel Lake, and the existing phosphorus loads to the lakes is 50% greater than the natural "background" load. However, the study also noted significant decreasing total phosphorus levels in both lakes. On this basis, the study recommends "Enhanced" water quality management for these lakes. "Moderate" management is recommended for Minnow Lake, Lake Laurentian and Perch Lake.

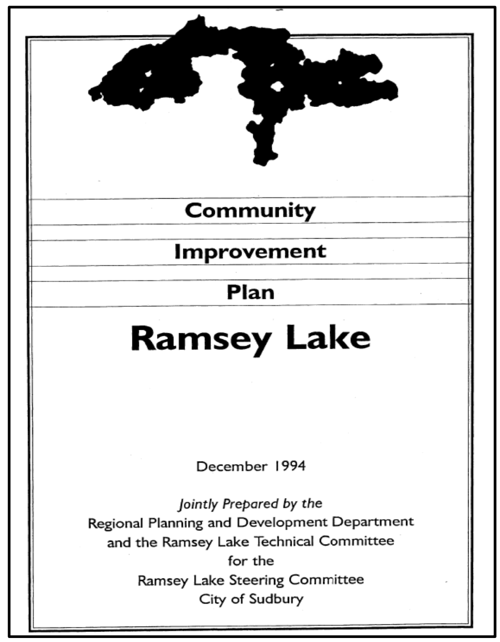
Ramsey Lake Watershed Report Card 2013 (Conservation Sudbury)

Conservation Sudbury's report card offers the following environmental grades for various natual resources in the subwatershed:

- Surface Water Quality: B
- Groundwater Quality: B
- Forest Conditions: C
- Wetland Conditions: C

<u>Ramsey Lake Community Improvement Plan (December 1994)</u>

The purpose of this plan was to propoase a long-term vision for the Ramsey Lake Area, including a set of programs, projects and policy directions to guide future development in the area. One of the key goals outlined in this plan is to maintain high water quailty in Ramsey Lake through preventative and remedial measures in the entire watershed. Recommendations are put forth with respect to the compatibility of land uses, urban development, and restrictions on hazardous materials to ensure water quality is protected. Reductions or elimination of the use of road salt and pollution from storm drainage is also recommended.


Community
Improvement
Plan
Ramsey Lake

December 1994

Jointly Prepared by the
Regional Planning and Development Department
and the Ramsey Lake Technical Committee
for the
Ramsey Lake Steering Committee
City of Sudbury

<u>Storm Drainage Report for the City of Greater Sudbury (Dillon and Lewis Ltd, April 1964)</u>

This study was undertaken to review the storm sewer requirements for future development areas and to assess the existing trunk sewer systems at the time. Of relevance to the current study are general catchment plans and profile plots for a number of older sewershed areas in the city.

3.0 Existing Subwatershed Conditions

The following sections provide an overview of the environmental features and functions of the Ramsey Lake Subwatershed Study Area. The natural ecosystem that existed prior to human settlement has been altered. Activities that have resulted in change include urban development, construction of roads, railways, highways, and buildings as well as impacts from the nearby mining industry.

Defining the current state of the environment, as well as the relationship between each feature is necessary in order to characterize key environmental functions, define opportunities and constraints associated with future development, and to ultimately establish alternative strategies to protect, enhance or restore the environmental features over time.

3.1 Groundwater Resources

The following subheadings outline the groundwater resource conditions of the Ramsey Lake Sub-watershed.

3.1.1 Physiography

The Ramsey Lake watershed straddles the boundary between two physiographic regions, including the Cobalt Plain to the north and the Penokean Hills to the south (Bostock, 1970). As noted in Burwasser, 1979, these broad physiographic regions are, however, overshadowed by the Sudbury Basin structure. The Sudbury Basin valley structure is thought to have been created as a result of a meteor impact over 1.8 billion years ago. The center of the basin, a low-lying impact valley infilled with quaternary sediments, is located north west of Ramsey Lake. The study area watershed is located outside of this zone of quaternary sediments, on the southeast rim of the larger basin. The topography of the watershed is shown in **Figure 3.1**. Total topographic relief is less than 100 m, rising from Ramsey Lake, which is maintained at approximately 250 mASL.

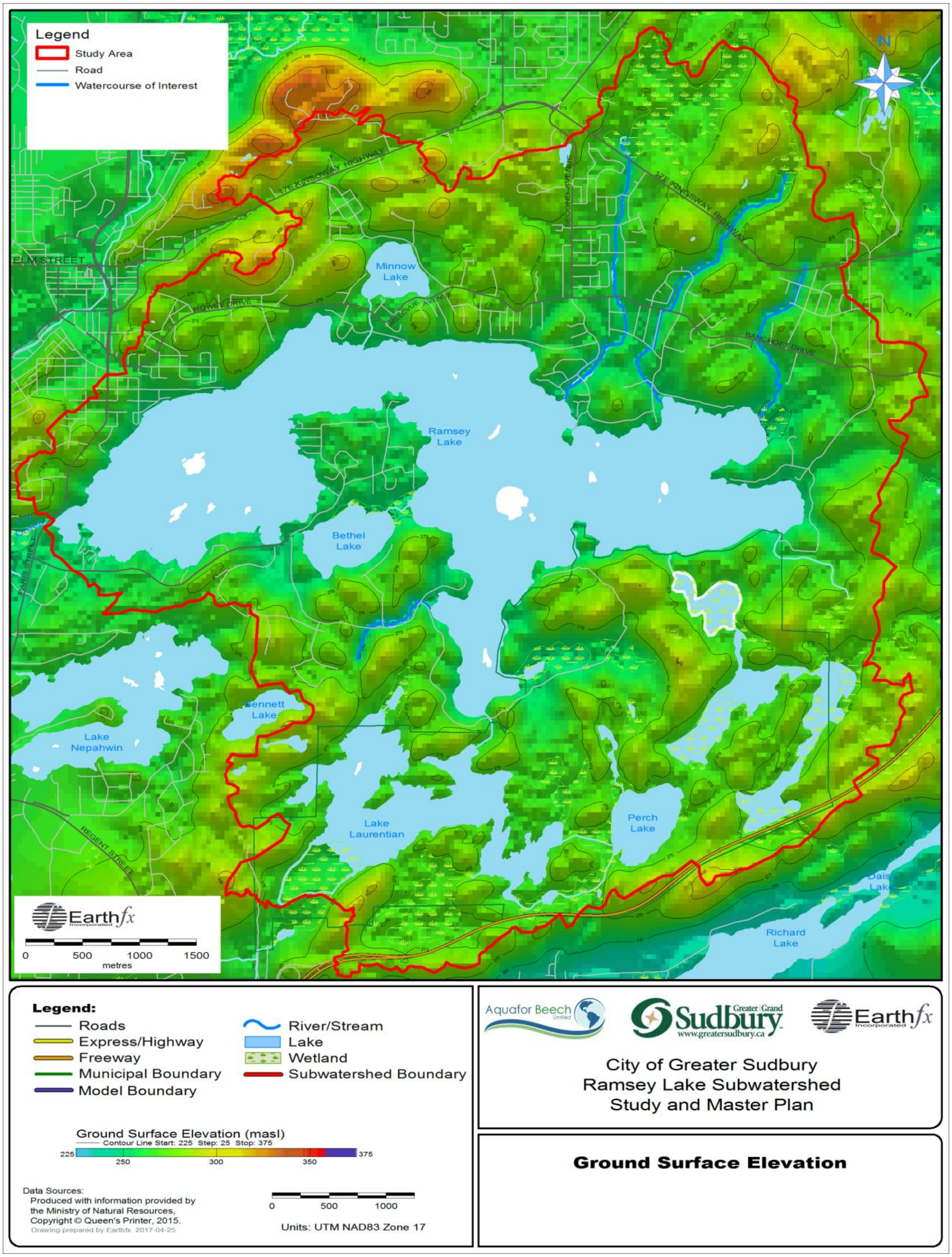


Figure 3.1: Digital Elevation Model

The northwest and southeast watershed boundaries are defined by bedrock ridges, which are characteristically described as ringing the basin. The other significant landform in the area is the Wanapetei Esker, a 20 to 40 m high ridge of sand and gravel deposits that extends from Lake Wanapitei, north east of the study area, towards Ramsey Lake. While the esker does not extend into the study area, it may supply groundwater recharge to the sands and gravels that do extend into the northern portion of the watershed.

3.1.2 Geology

The Precambrian bedrock units within the Sudbury Basin Structure represent a highly complex geologic history that has been extensively studied for the purposes of mineral extraction. As noted, the Ramsey Lake watershed is located on the periphery of this complex setting, with only a small outcrop, in the northwest portion of the watershed, of mafic rocks that host the nickel-copper Sulphide ores. A detailed description of the regional geologic setting is included in Golder, 2005.

The surface geologic materials across the majority of the watershed consist of Precambrian age bedrock units (**Figure 3.2**). These units include mafic intrusive rocks (greenstones) and metamorphosed sedimentary rocks. Greenstones are metamorphosed mafic to ultramafic volcanic rocks with corresponding metamorphosed sedimentary rocks.

3.1.2.1 Bedrock Units

Nipissing Gabbro

A zone of mafic intrusive rocks occurs in the northwest portion of the watershed (**Figure 3.2**). Included in this collection of mafic rocks is the Nipissing Gabbro. These gabbros are important because they are rich in the easily weathered, calcium-containing minerals plagioclase and pyroxene. Pearson et al. (2002) noted that that there are outcrops in the Ramsey Lake watershed where up to 0.5 cm of acid rain induced weathering is visible. The gabbros contain up to 10% CaO by weight and Pearson speculates that this CaO buffers the effects of acid rain on the lake. Not all Sudbury lakes with exposed gabbro have, however, responded in the same manner as Ramsey Lake (Jeffries et al. 1984).

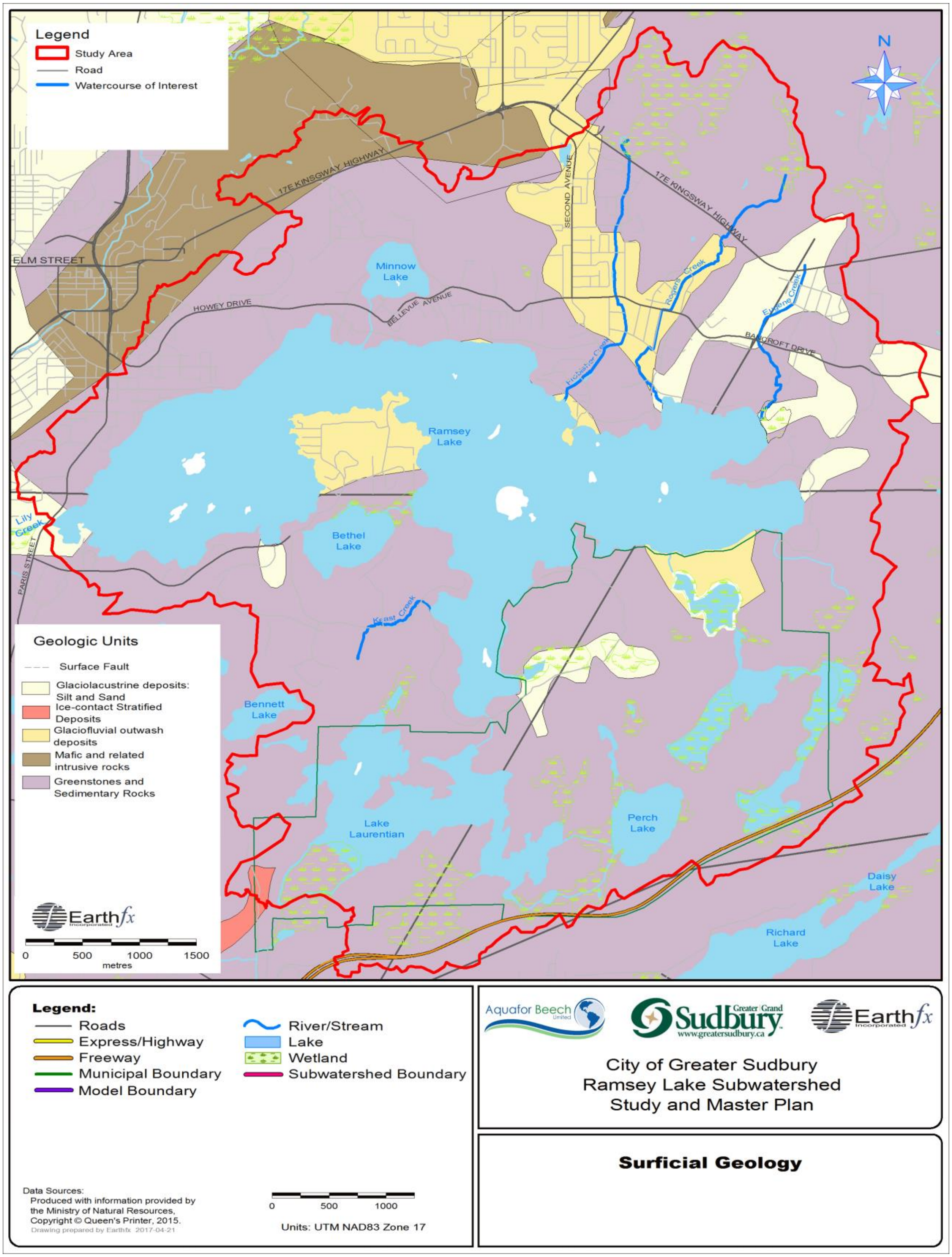


Figure 3.2: Surficial Geology

Ramsay Lake Formation

The Ramsay Lake Formation is a metamorphosed sedimentary rock characterized by thick to very thick beds of massive clast-rich sandy diamictite (Rousell and Brown, 2009). The unit is interpreted by some geologists to have formed by glacial processes more than 2 billion years ago. This unit occurs extensively along the south side of Ramsey Lake, and thus the name. A good exposure of Ramsay Lake Formation can be seen from the Science North ramp windows on the first landing to the second floor. Clasts within the diamictite are typically rounded to subrounded and include dispersed boulders, cobbles and pebbles, in a matrix of muddy, medium- to coarse-grained sandstone. Most of the sandstone units appear massive, although ripple cross-lamination is present locally.

Mississagi Formation

North, and stratigraphically above, the Ramsay Lake Formation is the metamorphosed Mississagi Formation. Regionally this unit is characterized by medium- to coarse-grained sandstone of arkosic to subarkosic composition, with abundant planar and trough cross-stratification. The formation is predominantly fluvial in origin, and was deposited by shallow braided rivers that flowed from a series of tributary basins in the Cobalt Embayment over 2 billion years ago (Rousell and Brown, 2009).

Kirchhefer (1987) notes, because of its history of metamorphism, the Mississagi is only permeable through fractures.

3.1.2.2 Faults

The Pecors Formation, normally found between the Ramsay Lake and Mississagi Formation, is not present in the watershed because it has been displaced by movement of the Creighton Fault.

The Creighton Fault passes in an east-west direction through the long axis of Ramsey Lake. This major fault is well documented at Science North, and is clearly visible in the underground tour at the site (**Figure 3.3**). The fault shows a displacement of approximately 700 m laterally, and approximately 80 m vertically. The fault shows right-lateral movement, making it a strike-slip fault similar to San Andreas fault system in California.

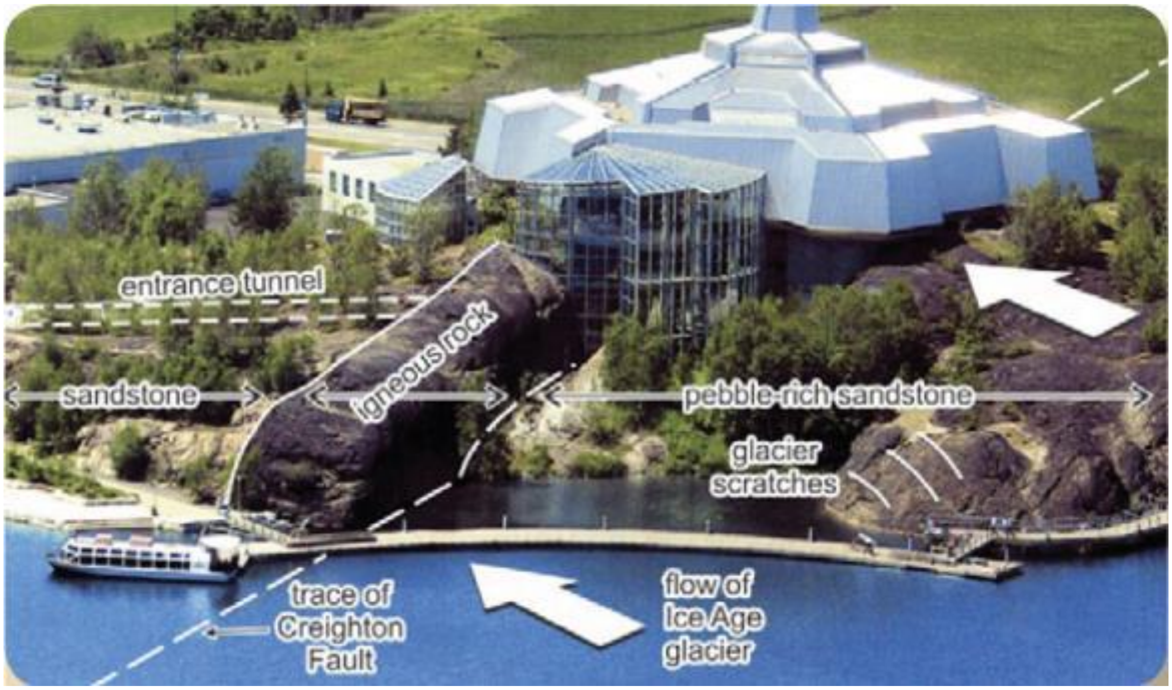


Figure 3.3: Location of Creighton Fault, western shore of Ramsey Lake (Source: ScienceNorth.ca)

The Creighton Fault is also observed on the eastern shore of Ramsey Lake at Moonlight Beach (Kirchhefer Ltd, 1987). At this beach the Creighton fault intersects a north-northwest trending fault that intersects sand and gravel deposit north of the beach. These faults are thought to be a major factor in the formation of sinkholes and corresponding zones of artesian groundwater upwelling. These groundwater conditions have been a source of significant concern, as the loss of a human life was attributed to the development of a sinkhole at Moonlight Beach in 1973 (Kirchhefer Ltd, 1987).

3.1.2.3 Quaternary Units

Throughout the watershed the low-lying areas and bedrock depressions are frequently infilled with quaternary sediments (**Figure 3.2**). These sediments include glacialfluvial sands and gravels as well as recent deposits including peat. As Rousell and Jansen (2002) note, compared with the vast amount of research and study of the bedrock geology and mineral potential of the Sudbury area, the Quaternary geology of the region has received very little attention.

The quaternary sediments and resulting ground water conditions at Moonlight Beach are insightful and likely typical of the watershed. Kirchhefer (1987) suggests that the north end of Moonlight

Beach was once the mouth of a river, and that the silty and sandy sediments of the beach are those of the small delta built into Ramsey Lake. Quaternary materials, which may be as much as 45 m (150 feet) thick under the beach, and are likely coarser with depth. Kirchhefer (1987) suggests that they will be the "tail of a buried boulder train following the valley of the peri-glacial river".

Frobisher Creek, Rogers Creek and Eugene Creek discharge into Ramsey Lake within a similar quaternary sediment configuration as that found at Moonlight Beach.

3.1.3 Groundwater Wells and Permits to Take Water

The MECP Water Well Record Information System is the primary source of subsurface information in the study area. A second data source, the Urban Geology Automated Information System (UGAIS) provides shallow geotechnical borehole data. The location of the wells is shown in **Figure 3.4.** Most of the Ramsey Lake Watershed is serviced by municipal water supply, so the water well distribution is limited to the south shore of the lake and the Bethel Lake area.

Two provincial Groundwater Monitoring Network (PGMN) wells are located in the Ramsey Lake watershed. Well W0000455 is located near Frobisher Creek, south of Bancroft Drive, in the northern part of the watershed. The well is located in glaciofluvial deposits and exhibits approximately 0.5 m of seasonal and inter-annual fluctuation (**Figure 3.5**), which is typical of southern Ontario wells in these materials.

PGMN Well W0000482 is located on the southern shore of Ramsey Lake. The well is completed in the Ramsay Lake Formation, and exhibits approximately 4 m of seasonal and inter-annual fluctuation. Each year the well shows long term summer decline in water levels, reflecting the limited recharge in summer as shown in **Figure 3.6.** The well likely behaves in a similar manner to many of the fracture inflow limited bedrock wells in the Ramsay Lake formation.

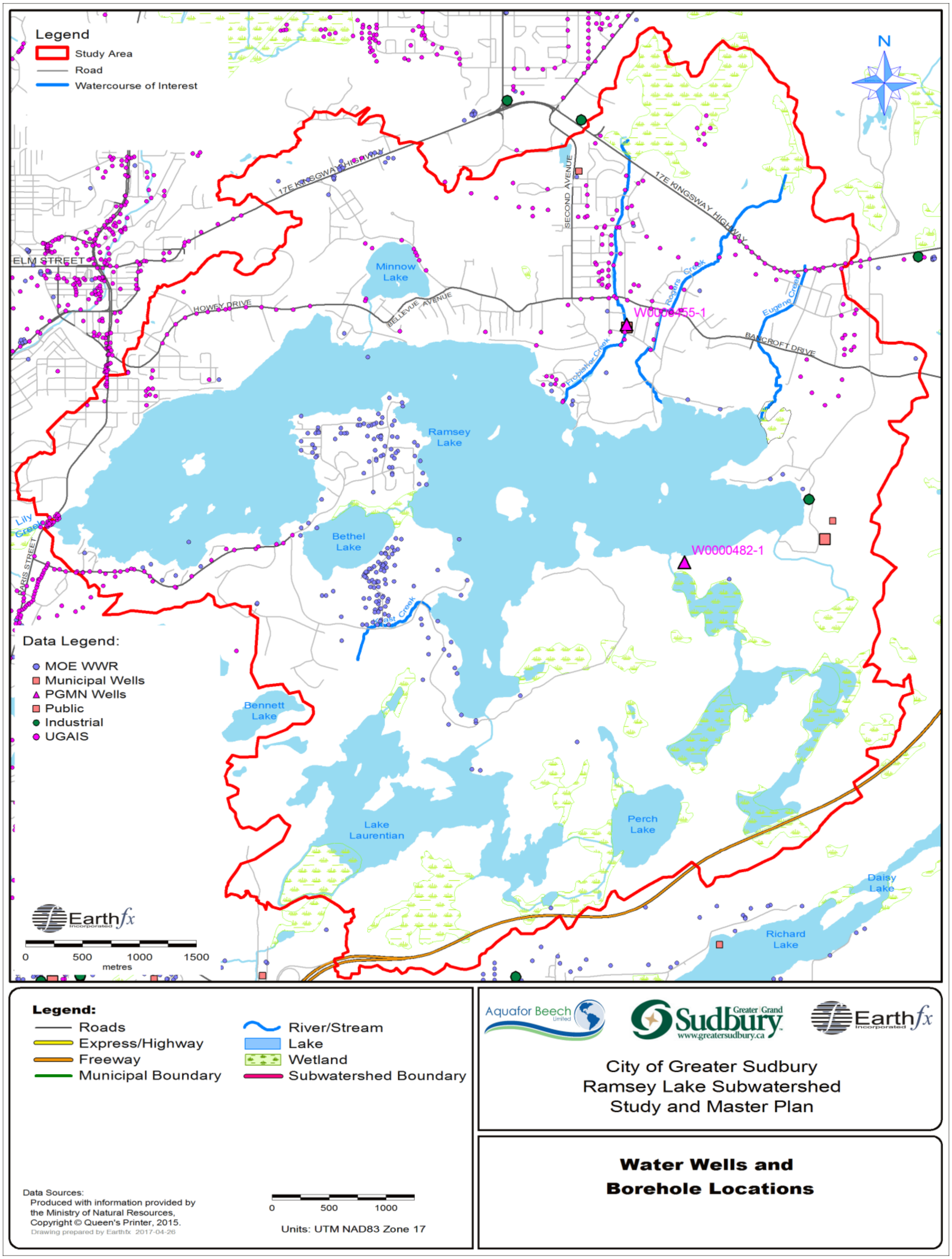


Figure 3.4: Water Wells and Borehole Locations

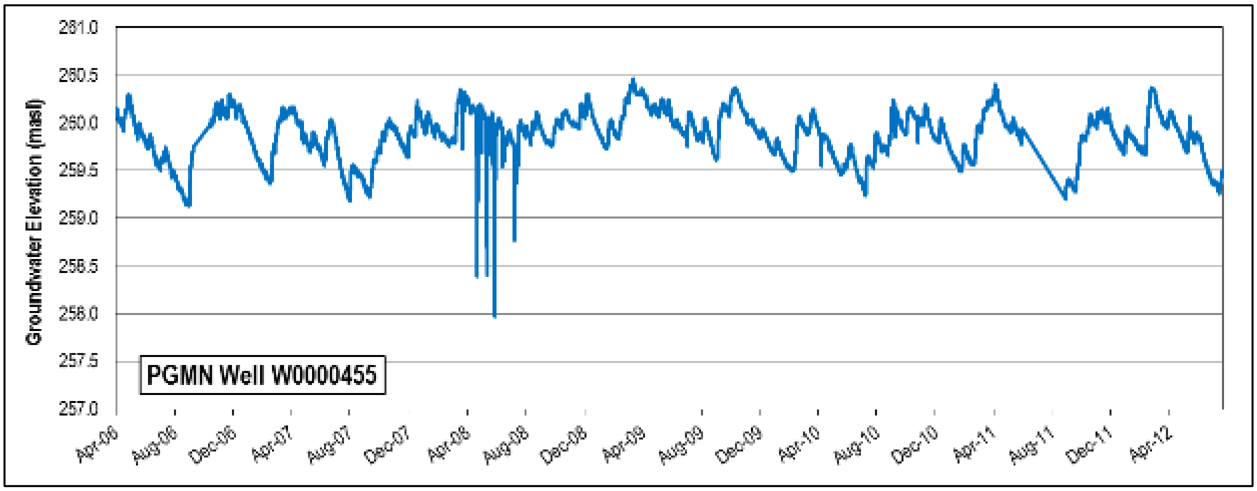


Figure 3.5: Water Levels from PGMN Well W0000455

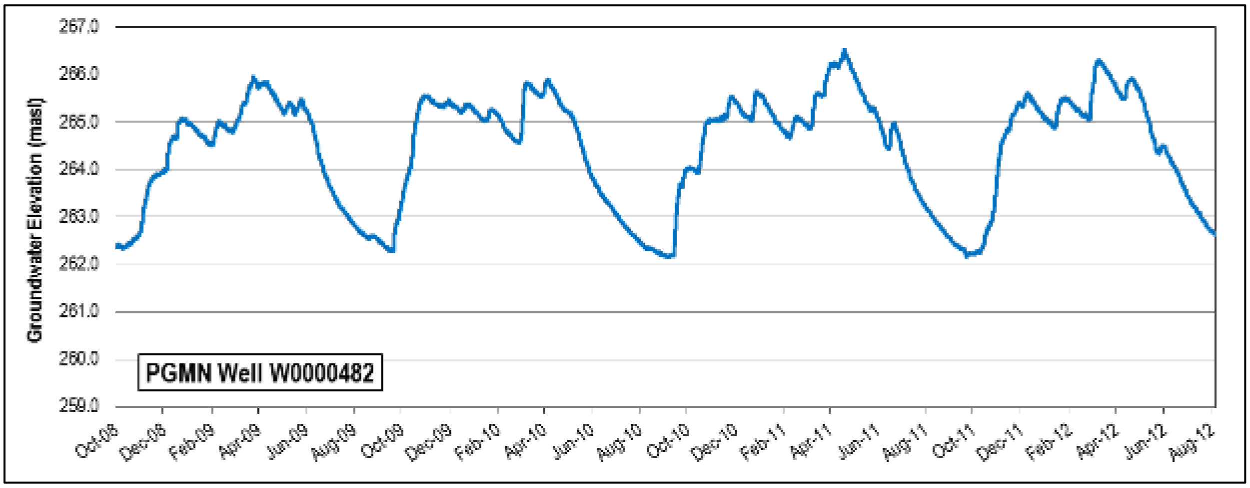


Figure 3.6: Water Levels from PGMN W0000482

The location of the provincial Permit to Take Water locations are shown in **Figure 3.7**. The two permits that are shown in the western portion of Ramsey Lake are held by the City of Greater Sudbury for municipal water supply.

Ducks Unlimited holds a permit for water taking from an unnamed lake/wetland in the south eastern portion of the watershed.

The City also holds a surface water permit for Aesthetics on Frobisher Creek (listed as Korpela Creek.) A temporary construction permit, now expired, is listed in the north east.

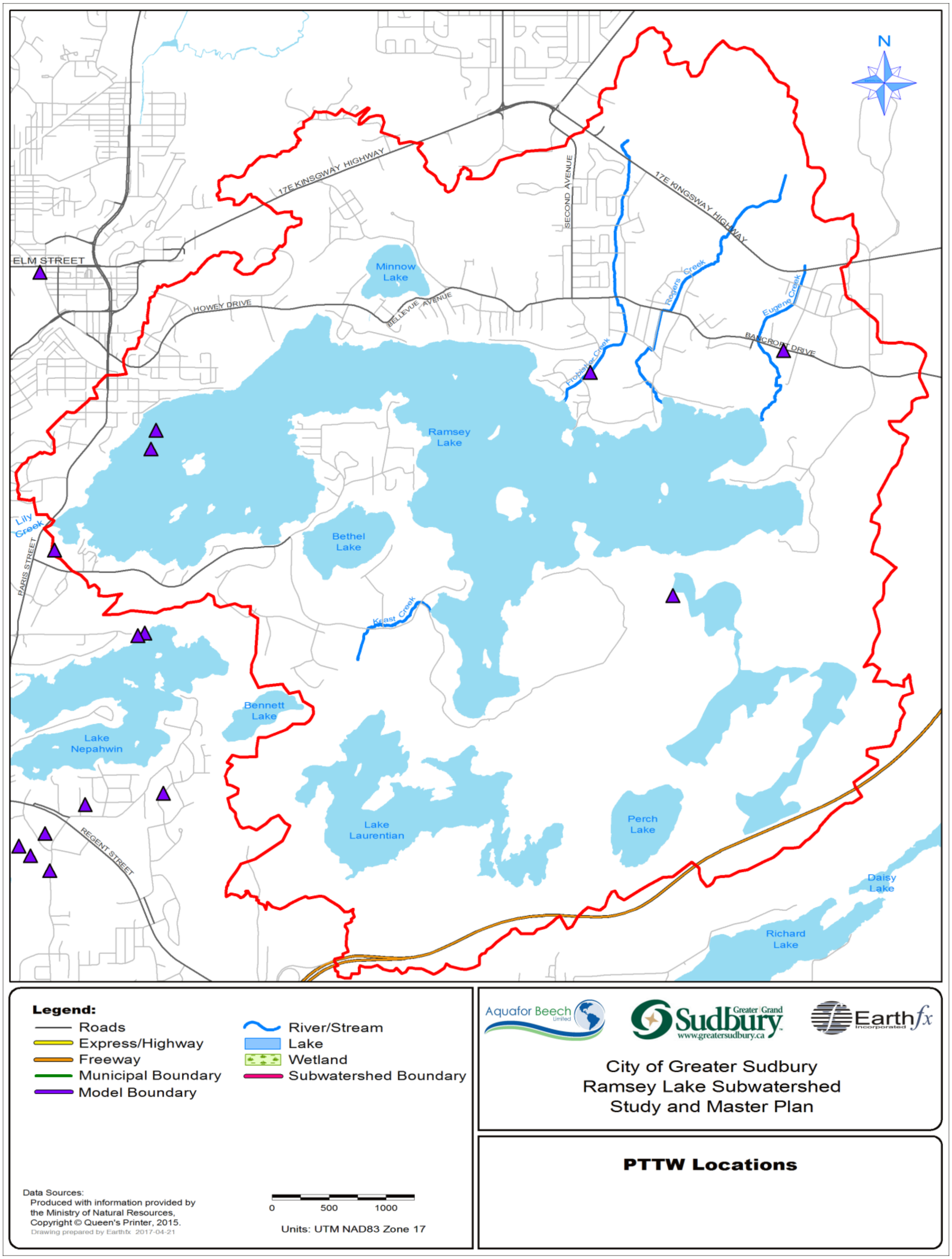


Figure 3.7: Permit to Take Water Locations

3.1.4 Hydrogeology

The long and complex geologic history, and resulting suite of highly metamorphosed bedrock formations, has resulted in a largely impermeable bedrock, making it a very poor source of any significant quantities of potable groundwater. While some highly localized sources of groundwater may yet be identified, the borehole coverage in the watershed is too limited at this time to clearly identify any patterns or potential new sources.

The depth to bedrock, as identified from the water well records, confirms that there are limited quaternary overburden sand and gravel deposits **(Figure 3.8**).

The depth to "water found", as recorded by the drillers, illustrates that in many cases the wells are drilled as much as 50 m into bedrock before a fracture or combination of fractures can support even a small private water supply (**Figure 3.9**). The PGMN well located in the Ramsey Lake metasedimentary unit illustrates the typical summer recession (decline) in water levels that likely occurs at many similar private wells.

A water table map, developed from a combination of private water well data and known water table control points (such as river and lake levels), shows the expected pattern of groundwater flow converging on the lake (**Figure 3.10**). Large data gaps are common, so the map should be used with care.

The regional Source Water Protection work completed in the basin has provided a map of Significant Groundwater Recharge Areas (**Figure 3.11**). These areas generally correspond to the location of surficial sand and gravel deposits.

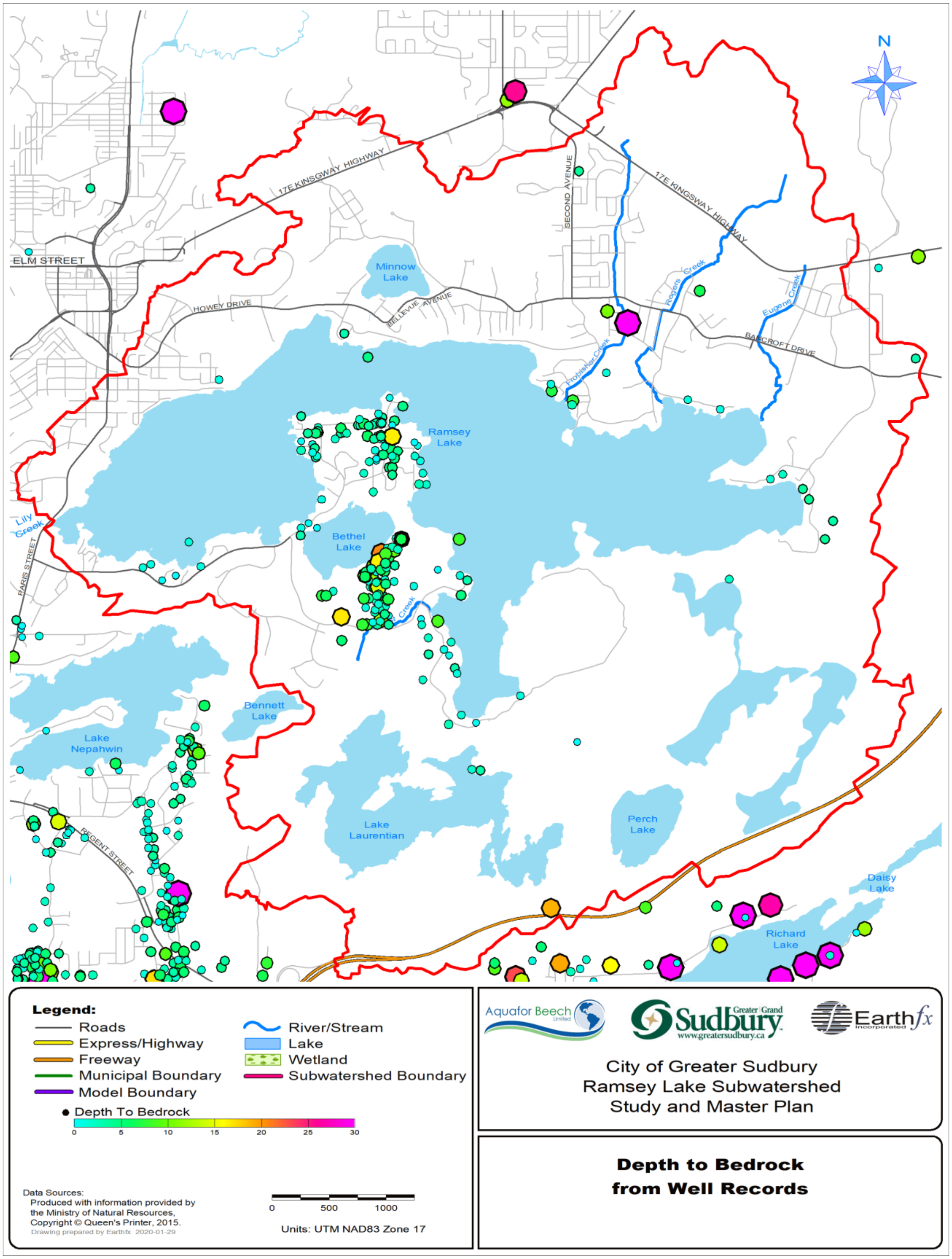


Figure 3.8: Depth to Bedrock from Well Records

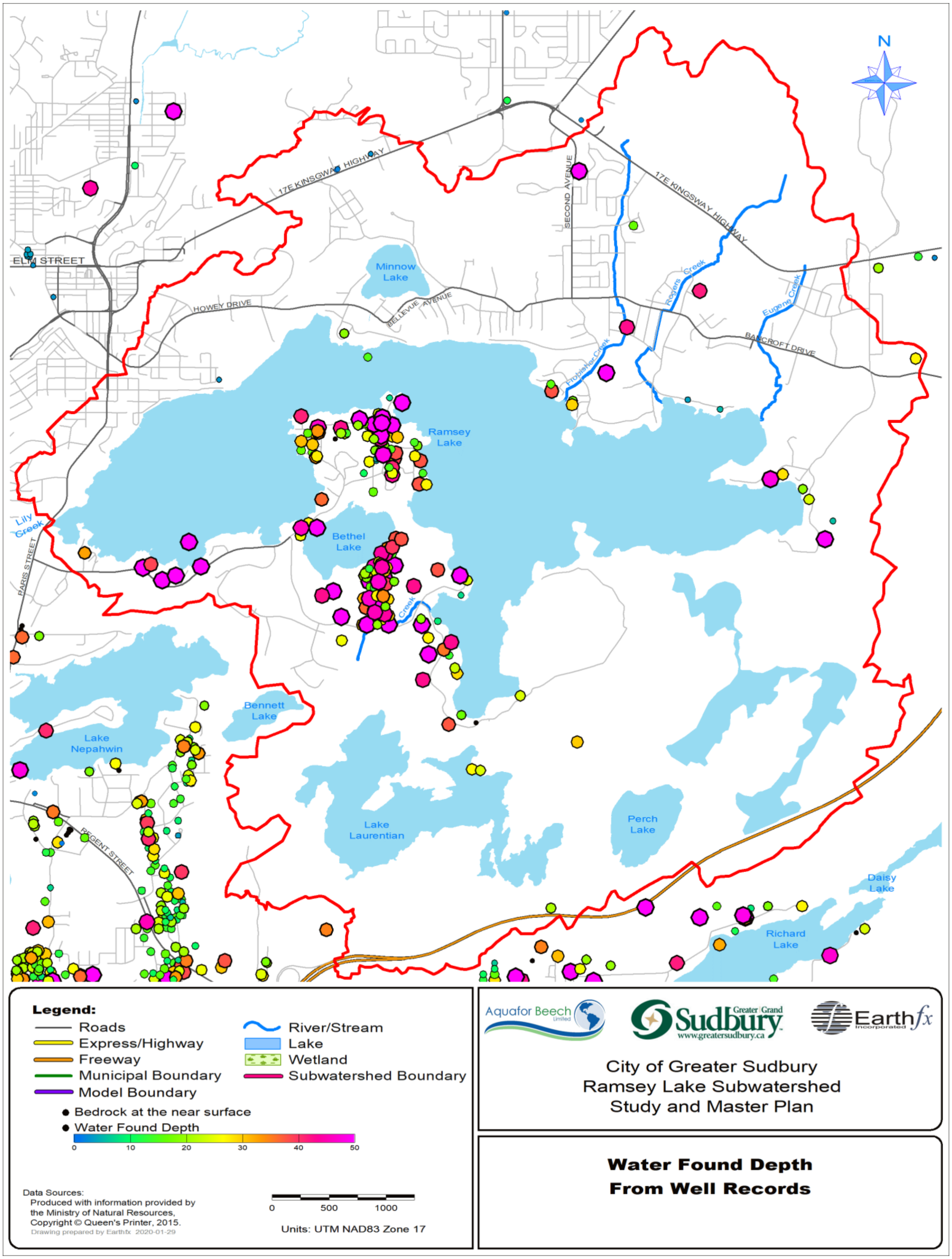


Figure 3.9: Water Found from Well Records

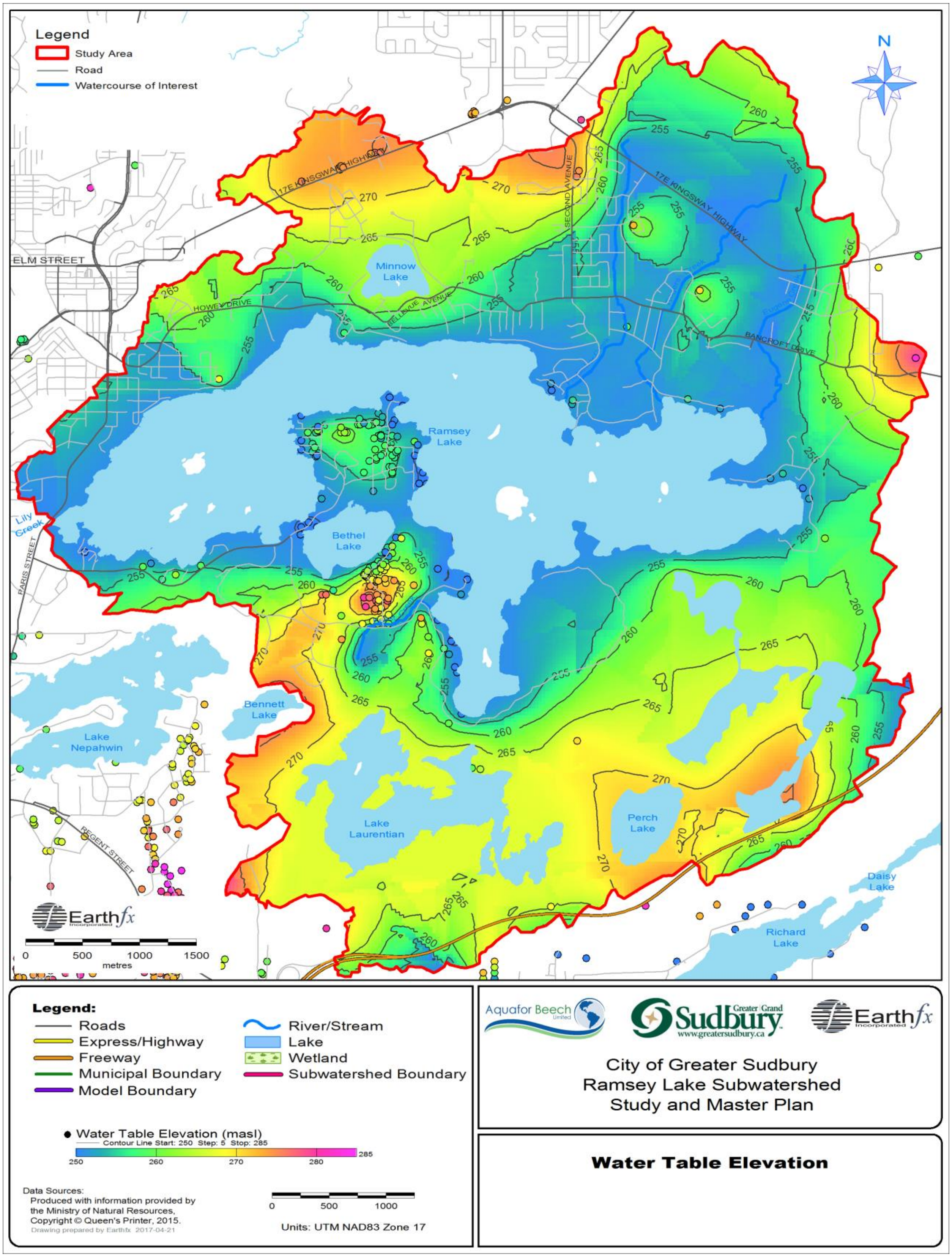


Figure 3.10: Water Table Elevation

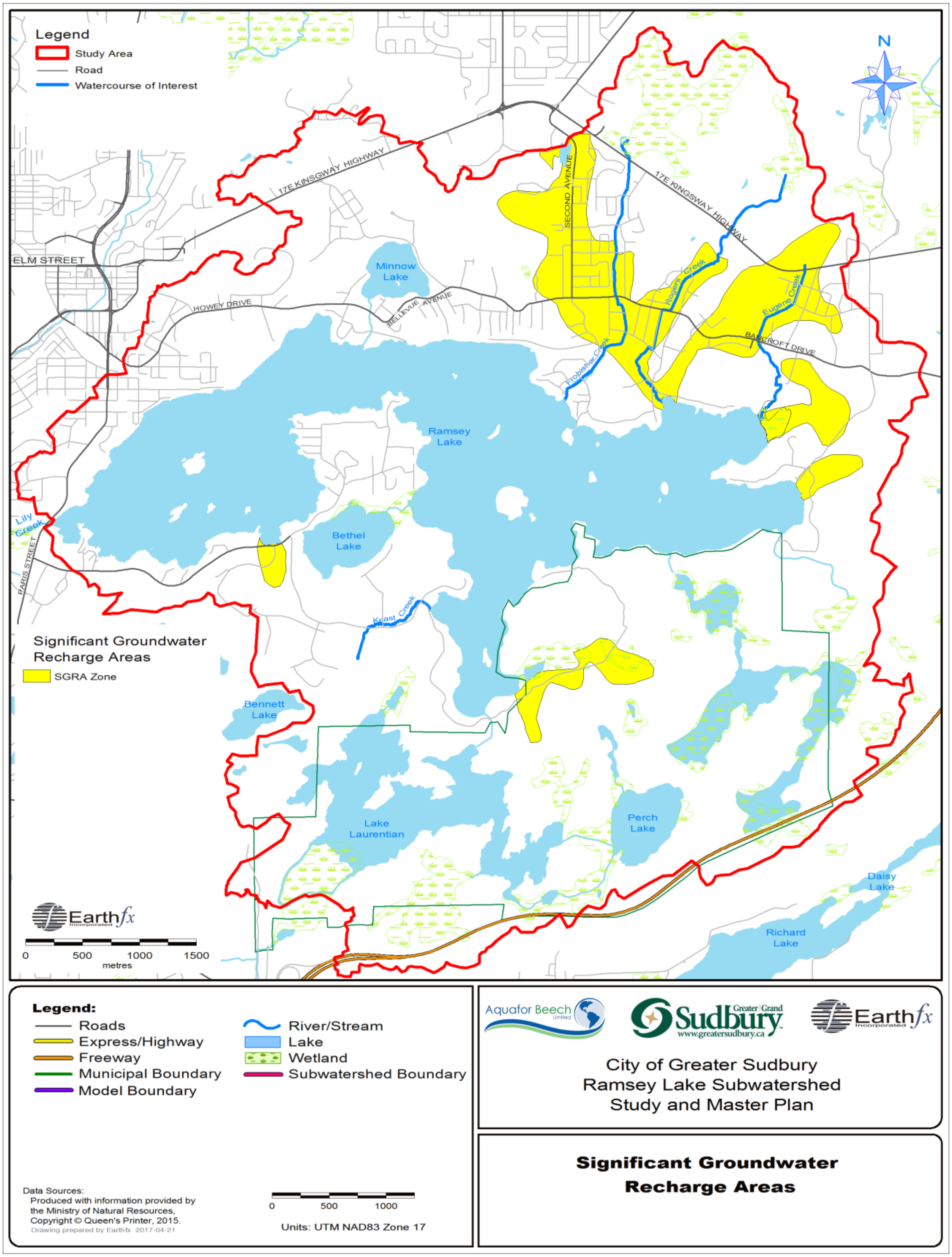


Figure 3.11: Significant Groundwater Recharge Areas

3.1.5 Summary of Groundwater Resources

In summary, the groundwater resources in the Ramsey Lake Watershed are limited. Within this review, however, a few notable groundwater issues have been identified, including:

- The weathering of the mafic gabbros may have buffered the effects of acid rain on the lake.
- The Creighton Fault, extending from Science North in the west to Moonlight Bay in the east, illustrates how faulting and fracturing can create localized but highly irregular groundwater flow conditions. There is sufficient local topographic relief to generate potentially significant artesian upwelling conditions through the network of fractured bedrock.
- The surficial sand and gravel deposits in the northeast of the watershed may be connected into the regional groundwater flow system and, potentially, the Wanapitei Esker. These lateral groundwater inflows into the watershed may support the wetlands and headwaters of Frobisher, Rogers and Eugene Creek. Groundwater data is very limited in this area, however, because it is serviced by the municipal system. The installation of 3-5 shallow monitoring wells north of Highway 17E would be necessary to confirm and quantify this potential inflow pattern.

3.2 Surface Water Resources

The following sub-sections outline surface water resources within the study area.

3.2.1 Fluvial Geomorphologic Resources

Aquafor undertook a geomorphic assessment of the four main creeks (i.e., Frobisher, Roger, Eugene and Keast Creek) within the Ramsey Lake sub-watershed. The assessment provided an understanding of the morphological processes and identified any major erosional concerns. To complete the assessment the four creeks were walked and visually assessed in October 2016. The creeks were assessed by walking in-and-out from road crossings, and were not accessed on private property unless permission was granted by the land owner. During the field investigations, the field staff completed two main tasks:

1. Geomorphic reach assessments representative channel observations/dimension; and
2. Erosion site identification and characterization

The following summarizes the existing fluvial geomorphic conditions and erosional issues for the four main creeks within the subwatershed.

3.2.1.1 Drainage Network

The Ramsey Lake subwatershed has four main rivers draining the lands; Frobisher, Roger, Eugene and Keast Creek. Frobisher, Roger and Eugene Creek drain the lands on the north eastern part of the subwatershed, and Keast Creek drains a small area within the southwestern part of Ramsey Lake. A map of the four creeks is shown below in **Figure 3.12** and a summary of the creek lengths and drainage areas for each of the creeks is provided in **Table 3.1**.

Table 3.1: Summary of Creek Lengths and Drainage Areas

Creek	Approx. Length	Sub-Catchment Area	Percent of Ramsey Lake Subwatershed Drainage Area
	km	ha	%
Frobisher	2.85	378.17	11%
Roger	2.90	166.17	5%
Eugene	1.80	221.59	6%
Keast	1.06	96.87	3%

3.2.1.2 Geologic Setting

Aquafor reviewed the Ontario Geological Survey mapping to gain an understanding of the bedrock formations within the Ramsey Lake subwatershed (**Figure 3.13**). The formations within this area are part of the Precambrian formation, specifically within the Paleoproterozoic, Huronian Supergroup. The majority of the area is dominated by a quartz-feldspar sandstone, argillite and conglomerate with surrounding deposits of mafic, siltstone and volcanic rock. There are three faults and two dikes identified within the Ramsey Lake subcatchment.

The bedrock in the area is extreme shallow, with several outcroppings observed throughout the subwatershed. The remaining lands are dominantly covered with sandy loam soil, with some localized areas of sand and loam deposits (**Figure 3.14**).

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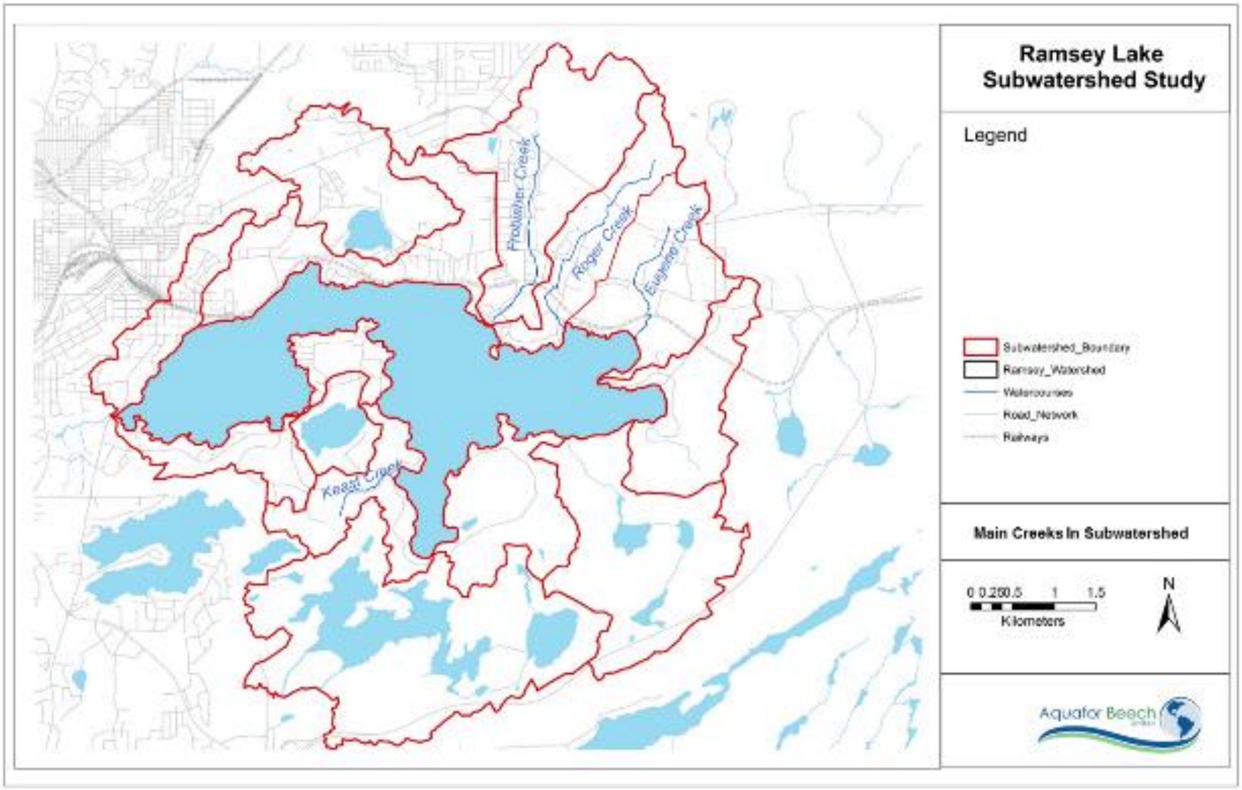

Figure 3.12: Main Creeks within the Ramsey Lake Subwatershed

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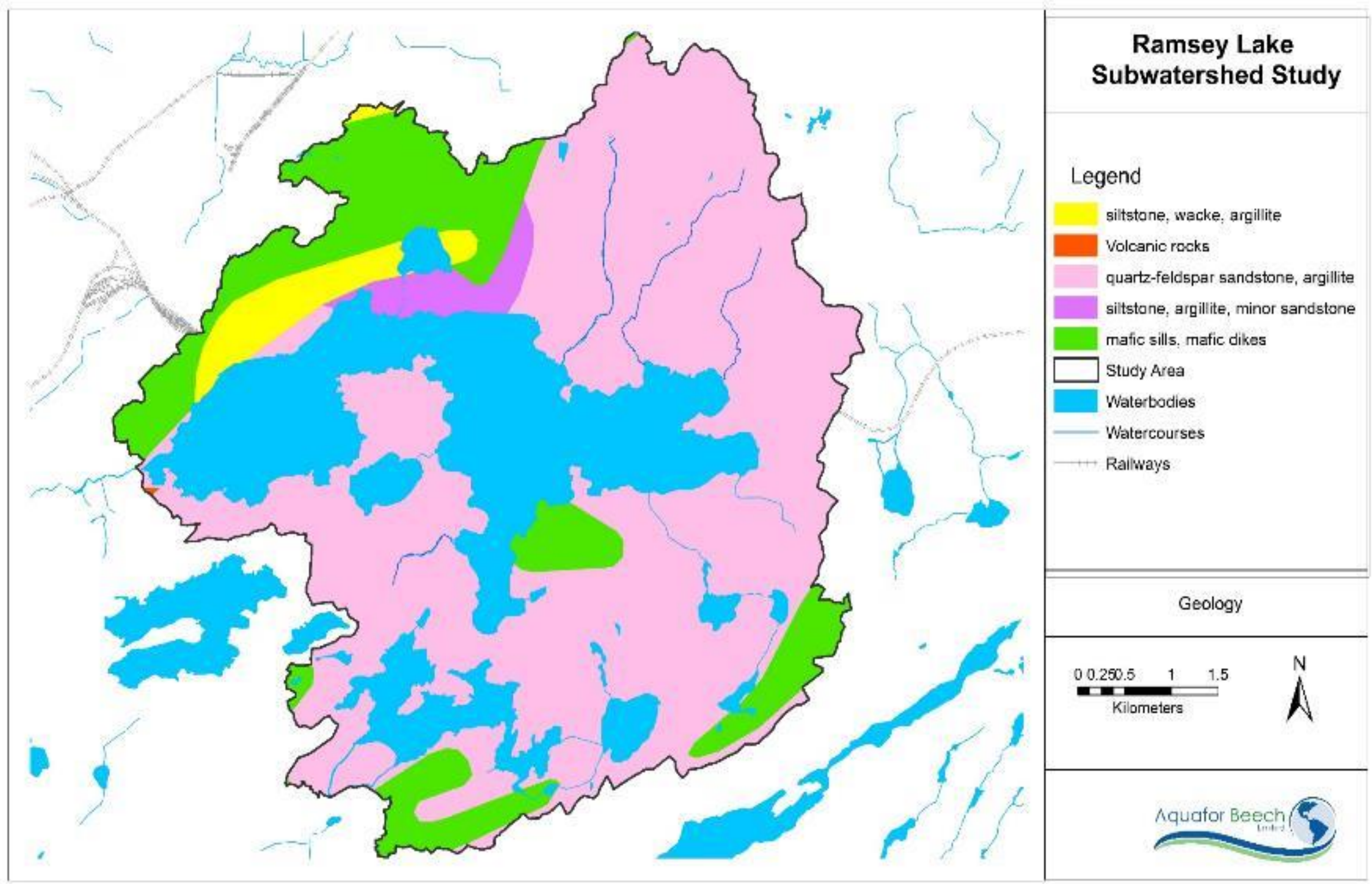

Figure 3.13: Map of bedrock within the study area

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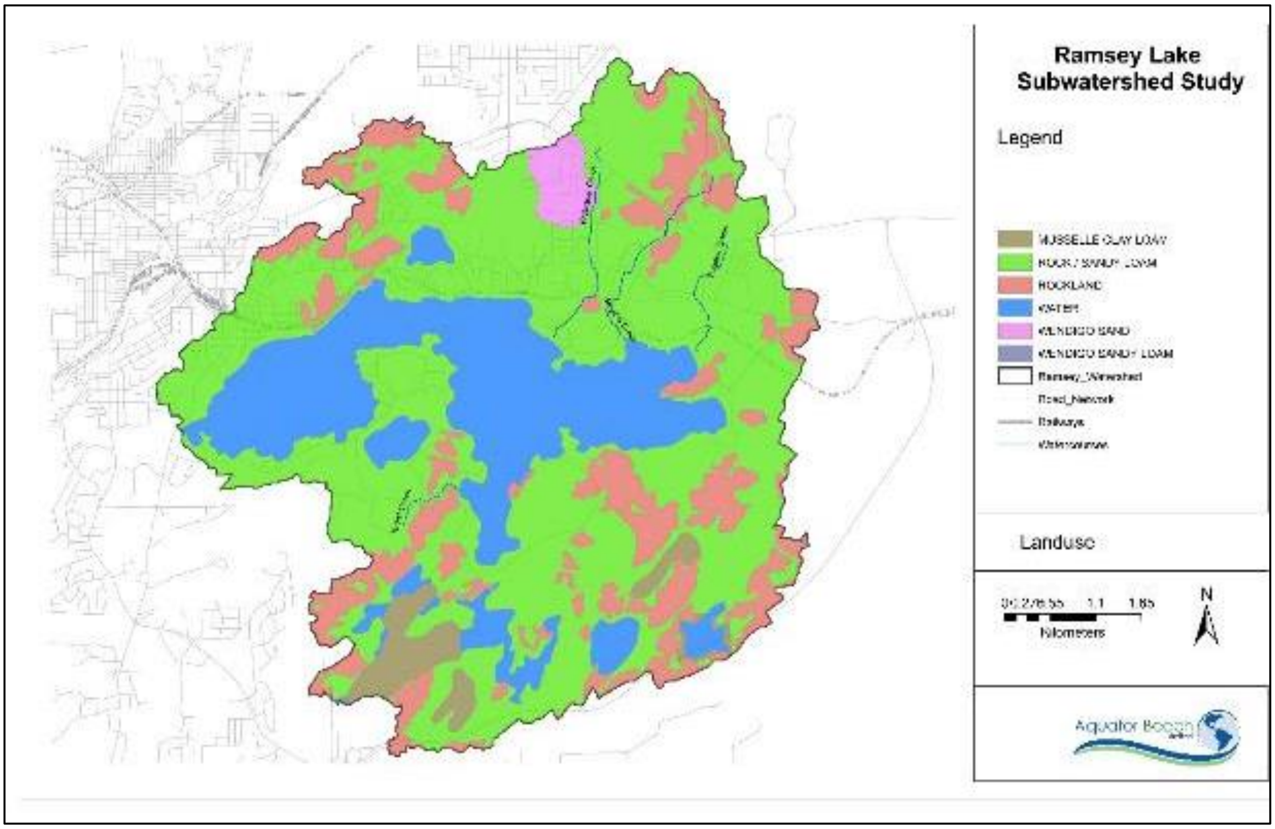

Figure 3.14: Soils within the Ramsey Lake Subwatershed

3.2.1.3 Geomorphic Stream Reaches

Geomorphic stream reaches are defined as lengths of channel with relatively uniform hydrology, slope, boundary materials, and vegetation that control dominant geomorphic processes and sediment transport dynamics. In other words, the physical channel processes and resulting stream morphology are relatively consistent over the length of the reach as compared the differences between adjacent reaches. While in practice this requires that reaches be discretely divided by "reach breaks", in reality reach changes may be abrupt or may transition gradually depending on changes in the controlling variables. For example, a sudden change in channel slope may cause an abrupt change in channel processes and thus represent a distinct reach break. In contrast, a gradual change in the boundary materials (increasing sand supply for example) would result in a gradual change in channel processes and the mapped reach break would only approximate the location of this transition.

Examining the above processes, geomorphic stream reaches were defined and mapped for each of the creeks. These reaches were used to define the boundaries of major geomorphic processes, natural and anthropogenic. The reach breaks are presented below in **Figure 3.15** and **Figure 3.16**.

A summary of the representative geomorphic reaches within each of the watercourse is presented below, which presents a general description of the existing channel conditions within each reach, defining the type of channel (natural, concrete, rehabilitated, or restored), the observations regarding channel migration, riparian cover and aquatic habitat. For each system, a sub-catchment map is included to show the geographic location, geomorphic stream reaches and the approximate watershed boundary. Average channel dimensions are included where relevant. A representative photograph of each reach is provided.

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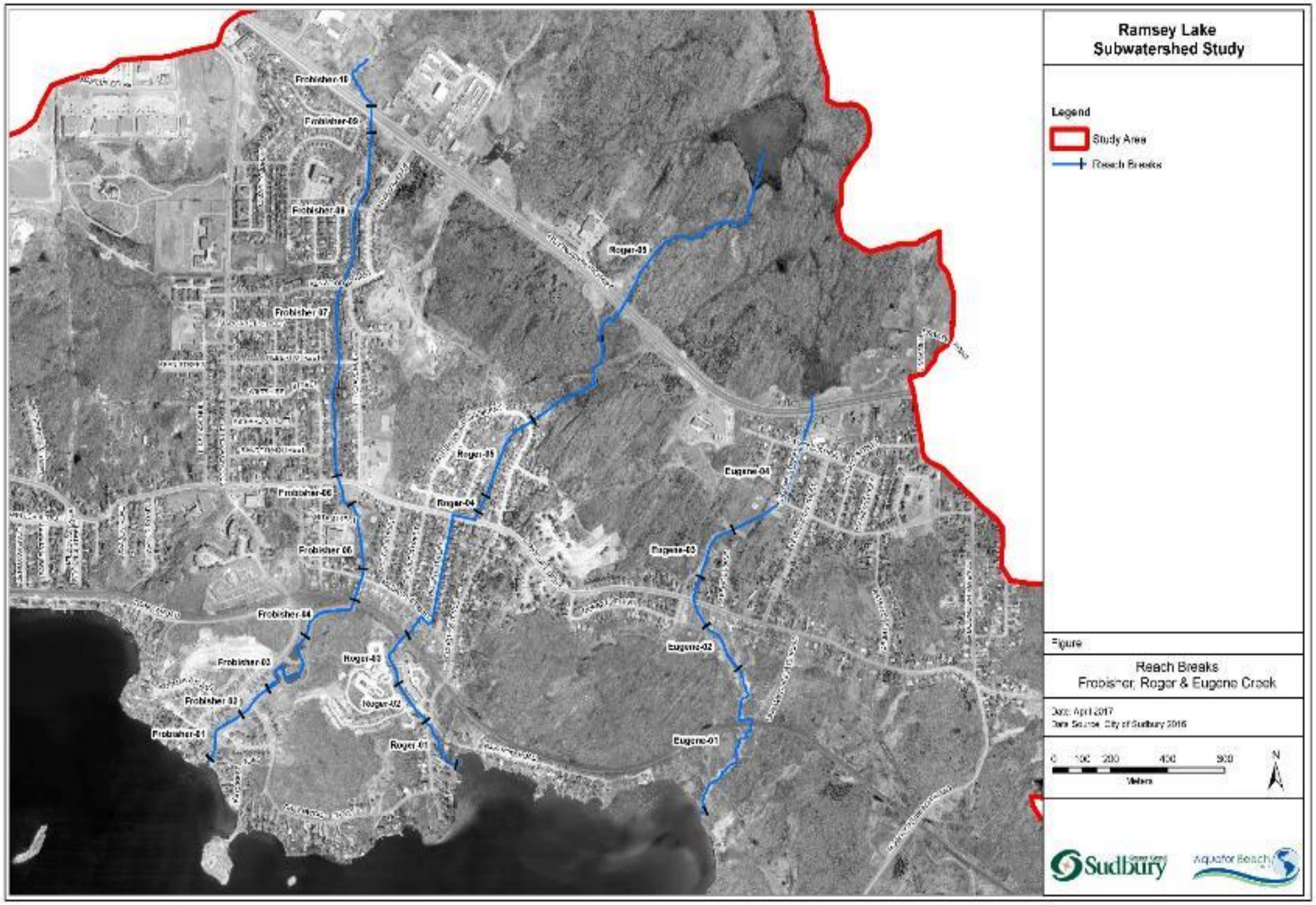

Figure 3.15: Defined Reach Breaks for Frobisher, Roger and Eugene Creek

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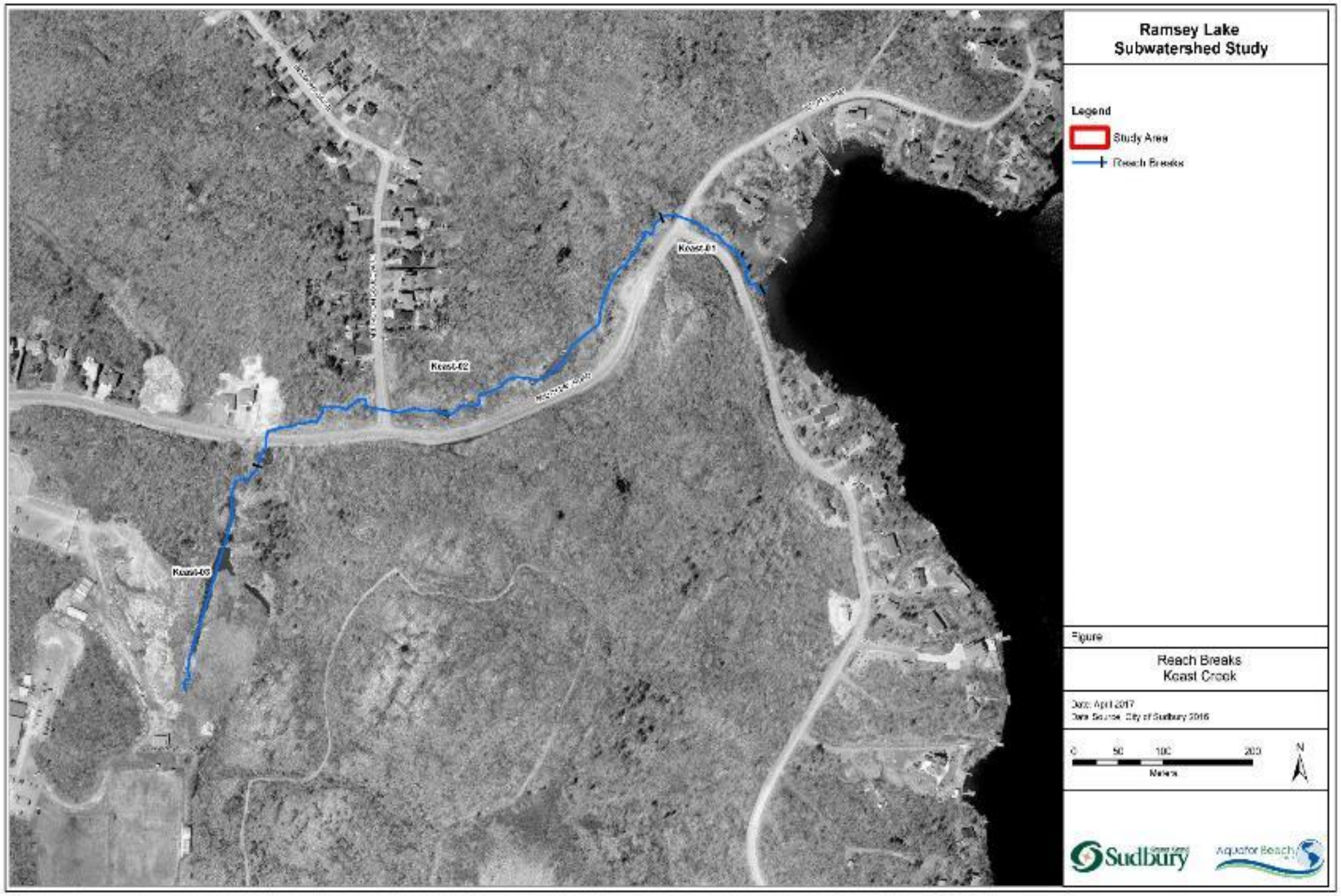

Figure 3.16: Defined Reach Breaks for Keast Creek

3.2.1.3.1 Frobisher Creek

Representative Reach	Summary	Representative Photograph
Reach 01 (Ramsey Lake to downstream of Greenwood Drive)	Channelized riprap system within confined corridor. Residential development adjacent to creek. Limited riparian vegetation along the channel banks. Limited floodplain access. Fine sediment deposits were noted at the lake confluence. Low to moderate energy gradient. Low quality physical aquatic habitat and riparian cover along the banks. No major evidence of erosion. **Average Channel Dimensions** Width ~ 2 - 3 m Depth ~ 1 - 1.5 m Average Slope ~ NA Average Sinuosity ~ 1.1	
Reach 02 (Downstream of Greenwood Drive to Storm Water Pond Outlet)	Channelized riprap system, with dense channel vegetation (e.g., bulrushes). No cover vegetation (i.e., trees or shrubs) within the riparian corridor. Moderate floodplain access. Fine sediment deposition throughout vegetation. Low to moderate energy gradient. Low quality physical aquatic habitat and riparian cover along the banks. No major evidence of erosion. **Average Channel Dimensions** Width ~ 1 - 2 m Depth ~ 0.25 - 0.5 m Average Slope ~ NA Average Sinuosity ~ 1.77	

Representative Reach	Summary	Representative Photograph
Reach 03 (Storm Water Pond outlet to Finlandia bridge)	In-line storm water ponds. Constructed within bedrock. Limited vegetation cover. Good floodplain access. Fine sediment accumulation was observed within the channel. Low energy gradient. Moderate quality physical aquatic habitat and low-quality riparian cover along the banks. No major evidence of erosion. **Average Channel Dimensions** Width ~ NA Depth ~ NA Average Slope ~ NA Average Sinuosity ~ NA	
Reach 04 (Finlandia bridge to CN train tracks)	Narrow, shallow, entrenched channel with till banks and bed (i.e., bedrock overburden), creating a wetland like feature. Grass and shrub vegetation maintain channel alignment and stability. Channel has excellent access to floodplain terrace. Low energy gradient. Moderate to High quality physical aquatic habitat and riparian cover. Some minor evidence of bank erosion, however no major risks (i.e., infrastructure, private property, roads) within the vicinity of the erosion. **Average Channel Dimensions** Width ~ 2.5 - 3.5 m Depth ~ 1.5 - 2 m Average Slope ~ 0.11% Average Sinuosity ~ 1.05	

Representative Reach	Summary	Representative Photograph
Reach 05 (Mildred Street to upstream of Rita Street)	Entrenched, channelized system with grassy banks. Corridor has dense shrubbery and trees, and is surrounded by park lands and residential properties. There are limited morphologic features (i.e., riffles, pool, runs) due to the channelization of the system. The channel has access to the floodplains. Moderate energy gradient. Moderate quality physical aquatic habitat and Moderate to High quality riparian cover. Channel shows signs of erosion, including downcutting, undercutting and slumping. **Average Channel Dimensions** Width ~ 1 - 3 m Depth ~ 0.25 - 0.75 m Average Slope ~ 0.17% Average Sinuosity ~ NA	
Reach 06 (Upstream of Rita Street to Bancroft Drive)	Narrow, shallow, entrenched channel with till banks and bed (i.e., bedrock overburden), creating a wetland like feature. Grass and shrub vegetation maintain channel alignment and stability. Channel has excellent access to floodplain. Low energy gradient. Moderate to High quality physical aquatic habitat and riparian cover. No evidence of major erosion. **Average Channel Dimensions** Width ~ 1.5 - 2.0 m Depth ~ 0.3 - 0.7 m Average Slope ~ 1.06% Average Sinuosity ~ 1.17	

Representative Reach	Summary	Representative Photograph
Reach 07 (Bancroft Drive to Kenwood Street)	Channelized system, maintained to narrow City corridor between residential developments. Gravel bed channel with mature trees along the banks. Several large woody debris (LWD) jams observed throughout the reach. Channel has access to the floodplain, but flooding is generally contained to the City corridor. No major vegetation control within channel. Moderate to High energy system. Moderate quality physical aquatic habitat and Moderate to High quality riparian cover. Some erosion observed which indicated signs of widening (i.e., minor bank erosion and leaning/fallen trees). **Average Channel Dimensions** Width ~ 2.5 - 3.5 m Depth ~ 0.25 - 0.75 m Average Slope ~ 0.8% Average Sinuosity ~ 1.02	

Representative Reach	Summary	Representative Photograph
Reach 08 (Kenwood Street to downstream of the Kingsway)	Channelized system, maintained to narrow City corridor between residential developments. Channel is vegetated with dense wetland plants (e.g., sedges, phragmites and cattails). Several debris jams observed at the culverts through the reach. Channel has access to the floodplain, but flooding is generally contained to the City corridor. Moderate energy system. Low to Moderate quality physical aquatic habitat and Moderate quality riparian cover. With the exception of localized scour at the culverts, no major erosion was observed. **Average Channel Dimensions** Width ~ 1.5 - 2.5 m Depth ~ 0.25 - 0.75 m Average Slope ~0.17% Average Sinuosity ~ NA	
Reach 09 (Downstream of the Kingsway to upstream of the Kingsway)	More natural, gravel bed system, between residential developments. Shallow, narrow channel, with dense grasses and shrubbery along the banks and tree cover through the riparian corridor. Channel has excellent access to the floodplain. Moderate energy system. Moderate to High quality physical aquatic habitat and riparian cover. No evidence of major erosion observed. **Average Channel Dimensions** Width ~ 1 - 2 m Depth ~ < 1 m Average Slope ~ NA Average Sinuosity ~ NA	

Representative Reach	Summary	Representative Photograph
Reach 10 (Upstream of the Kingsway)	Narrow, shallow, entrenched channel with till banks and bed (i.e., bedrock overburden), creating a wetland like feature. Grass and shrub vegetation maintain channel alignment and stability. Several LWD jams were observed. Channel has excellent access to floodplain. Low energy gradient. Moderate to High quality physical aquatic habitat and riparian cover. No evidence of major erosion. **Average Channel Dimensions** Width ~ 1.5 - 3 m Depth ~ 1 - 2 m Average Slope ~ NA Average Sinuosity ~ NA	

3.2.1.3.2 Roger Creek

Representative Reach	Summary	Representative Photograph
Reach 01 (Ramsey Lake to Fourth Avenue)	Small, natural, gravel bed channel, draining through a forested corridor. Channel has some space to meander and generate morphological features (i.e., riffles and pools). Moderate energy gradient. Moderate to High quality physical aquatic habitat and riparian cover. No major evidence of erosion. **Average Channel Dimensions** Width ~ 0.5 - 1.5 m Depth ~ 0.25 - 0.75 m Average Slope ~ NA Average Sinuosity ~ 1.11	
Reach 02 (Fourth Avenue to upstream of private road in Finlandia)	Grass lined channel contained to a narrow corridor. There is gabion lining through part of the corridor, which is supporting the parking lot above. There is mature tree growth along the southern bank. Fine sediment accumulation was observed within the channel. Moderate energy gradient. Low quality physical aquatic habitat and Low to Moderate quality riparian cover. Slumping of the gabions was observed, however no other major channel erosion was noted. **Average Channel Dimensions** Width ~ 1.5 - 2.5 m Depth ~ 0.5 - 0.75 m Average Slope ~ 0.37% Average Sinuosity ~ NA	

Reach 03 (upstream of private road in Finlandia to CN train tracks)	More natural, gravel bed system, within the Finlandia Retirement Community. Shallow, narrow channel, with dense grasses and shrubbery along the banks and tree cover through the riparian corridor. Channel is contained to corridor, but has access to floodplain. Moderate energy system. Moderate to High quality physical aquatic habitat and riparian cover. Some evidence of minor bank erosion, but no major erosion observed. **Average Channel Dimensions** Width ~ 1.0 - 2.0 m Depth ~ < 0.5 m Average Slope ~ 1.91% Average Sinuosity ~ 1.07	
Reach 04 (upstream of Bancroft Drive)	Manicured grass lined channel contained to riprap valley corridor within residential development. No riparian cover provided. Moderate energy gradient. Low quality physical aquatic habitat and riparian cover. Slumping of the gabions was observed, however no other major channel erosion was noted. **Average Channel Dimensions** Width ~ 0.75 - 1.5 m Depth ~ < 0.25 m Average Slope ~ 1.42% Average Sinuosity ~ NA	

Reach 05 (Upstream of Brancroft Drive to Autumnwood Crescent)	Channelized system, contained to narrow City corridor between residential developments and park lands. Channel is vegetated with dense wetland plants (e.g., sedges, phragmites and cattails). Channel has access to the floodplain, but flooding is generally contained to the City corridor or park lands Low to Moderate energy system. Low to Moderate quality physical aquatic habitat and riparian cover. With the exception of localized scour at the culverts, no major erosion was observed. **Average Channel Dimensions** Width ~ 1.5 - 2.5 m Depth ~ 0.25 - 0.75 m Average Slope ~ 1.40% Average Sinuosity ~ NA	
Reach 06 (Upstream of Autumnwood Crescent)	Natural, channel within the forest bedrock outcropping. Shallow, narrow channel, with mature tree cover along the banks and through the riparian corridor. Low gradient creates wetland like features through the reach. Channel has excellent floodplain access. Low to Moderate energy system. Moderate to High quality physical aquatic habitat and riparian cover. Some evidence of minor bank erosion, but no major erosion observed. **Average Channel Dimensions** Width ~ 1 - 2 m Depth ~ < 1 m Average Slope ~ NA Average Sinuosity ~ NA	

3.2.1.3.3 Eugene Creek

Representative Reach	Summary	Representative Photograph
Reach 01 (Ramsey Lake to upstream of CN train tracks)	Natural, narrow, entrenched channel with till banks and bed (i.e., bedrock overburden), creating a wetland feature through the forested lands. Grass and shrub vegetation maintain channel alignment and stability. Channel has excellent access to floodplain. Low energy gradient. Moderate to High quality physical aquatic habitat and riparian cover. With the exception of localized scour at the culverts, no major erosion was observed. **Average Channel Dimensions** Width ~ 0.5 - 1.5 m Depth ~ < 0.5 m Average Slope ~ NA Average Sinuosity ~ 1.50	
Reach 02 (Upstream of CN train tracks to downstream of Bancroft Drive)	Channelized system, maintained to corridor within forested and residential lands. Channel is vegetated with dense wetland plants (e.g., sedges, phragmites and cattails). Several debris jams observed. Fine sediment accumulation was observed. Channel has access to the floodplain, but flooding is generally contained to the corridor. Moderate energy system. Low to Moderate quality physical aquatic habitat and Moderate quality riparian cover. With the exception of localized scour at the culvert, no major erosion was observed. **Average Channel Dimensions** Width ~ 0.5 - 1.5 m Depth ~ < 0.5 m Average Slope ~ NA Average Sinuosity ~ NA	

Reach 03 (Upstream of Bancroft Drive to upstream outlet)	Channelized system, maintained to City corridor within residential area. Extensive fine sediment accumulation was observed, expected to be a result of the neighbouring develop. Channel has limited access to the floodplain, but flooding is generally contained to the corridor. Moderate to High energy system. Low quality physical aquatic habitat and riparian cover. No major erosion was observed. **Average Channel Dimensions** Width ~ 5.0 - 6.0 m Depth ~ 2 - 3 m Average Slope ~ NA Average Sinuosity ~ NA	

3.2.1.3.4 Keast Creek

Representative Reach	Summary	Representative Photograph
Reach 01 (Ramsey Lake to upstream of Keast Drive)	Creek has been channelized to a roadside ditch, with limited riparian cover. The channel bed is sandy and gravelly and has floodplain access only on the north side (which is private lands). Moderate to High energy system. Low quality physical aquatic habitat and riparian cover. Significant erosion was observed, with evidence of channel widening (i.e., bank erosion) and downcutting (i.e., channel bed erosion. There is potential risk to the neighbouring road embankment and loss of private lands. **Average Channel Dimensions** Width ~ 2.5 - 3.5 m Depth ~ 1 - 2 m Average Slope ~ NA Average Sinuosity ~ NA	
Reach 02 (Upstream of Keast Drive to South Bay Road)	Natural, narrow, entrenched channel with till banks and bed (i.e., bedrock overburden), creating a wetland feature through the forested lands. Grass and shrub vegetation maintain channel alignment and stability. Several LWD jams were observed, and could be natural or constructed by beavers. Channel has excellent access to floodplain. Low energy gradient. Moderate to High quality physical aquatic habitat and riparian cover. With the exception of localized scour at the culvert, no major erosion was observed. **Average Channel Dimensions** Width ~ 1.5 - 2.5 m Depth ~ < 1 m Average Slope ~ 1.12% Average Sinuosity ~ 1.29	

Reach 03 (Upstream of South Bay Road)	Natural, channel within the forest bedrock outcropping. Shallow, narrow channel, with mature tree cover along the banks and through the riparian corridor. Bedrock and cobble bed create a steep gradient, which oxygenates water. Channel has excellent floodplain access. Moderate to High energy system. High quality physical aquatic habitat and riparian cover. No evidence of major erosion observed. **Average Channel Dimensions** Width ~ < 1 m Depth ~ < 1 m Average Slope ~ NA Average Sinuosity ~ 1.21	

3.2.1.4 Erosion Assessment Methods

The erosion assessment involved identifying erosion sites and potential maintenance issues along the four main creeks with the purpose of identifying restoration and maintenance opportunities.

Erosion sites (ES) were identified as locations with erosional issues that posed risk to surrounding infrastructure or public health and would require intervention to be mitigated. Erosion sites were visually identified in the field and locations were recorded on maps. The approximate extents of the erosion sites were measured, and photographs of the sites were taken and cross referenced.

To standardize the erosion risk and environmental opportunity during the field assessments, a semi-quantitative technical scoring methodology was developed. Each erosion site was given a score out of 100, with larger scores representing sites with high levels of erosion risk and/or higher degrees of environmental opportunity. This scoring methodology has been used by Aquafor for several other erosion assessments. A detailed explanation of the technical scoring is provided in Appendix C.

Each of the erosion sites was given a general priority ranking (i.e., High, Moderate or Low), based on technical score. The priority ranking is intended to help guide which issues should be addressed first, and which issues can wait to be addressed. The technical scores associated with the general priority ranking are described below in **Table 3.2**.

Table 3.2: Erosion site priority ranking definition

General Priority	Technical Score
High	≥ 80
Moderate	< 80 and ≥ 60
Low	< 60

A total of 11 erosion sites were identified on the four creeks, with only one site receiving a high priority. The only High priority erosion site identified was within Reach 01 of Keast Creek (ES-K-01). At this location, active downcutting and widening of the river was observed, which could compromise the structural integrity of the South Bay Road embankment and result in a loss of lands for the adjacent private property. This erosion is likely due to changes in the channel hydraulics along Keast Creek as a result of increased development within the drainage area. Furthermore, it was noted an earthen/straw bale dam has been constructed immediately upstream of the Keast Road culvert, which results in a very steep channel upstream of the culvert. The steep channel will have increase velocities and shear forces and would increase the erosional potential. Prior to any restoration works on this area, it is recommended that the dam be removed and the channel regraded to a more moderate inclination.

It was noted that the majority of the erosion site identified are scour pools at culvert outlets and sediment depositions at culvert inlets, which are both issues that can be addresses with relative minimal intervention to the existing infrastructure. Scouring at outlets can be prevented with appropriate protection at the outlets (e.g., stone protection or runoff aprons) and much of the sediment deposition can be prevented with appropriate maintenance of the channel vegetation. It is recommended that this measures and maintenance programs be established for any future development.

A summary of the erosion sites is provided below in **Table 3.3** and a map of the erosion sites is provided in **Figure 3.17** and **Figure 3.18**.

Table 3.3: Summary of Erosion Sites along Streams

Creek	ID	Reach	Description of Erosion	Approx. Length	Risks	Total Score	Priority Ranking
Eugene	ES-E-01	1	Scour pool has formed at culvert outlet	localized	Scour has started to undermine concrete structure and could compromise the long-term stability of the culvert	52	Low
Eugene	ES-E-02	2	Sediment deposition at culvert outlet resulting in backwatering of culvert.	~50m	Deposition is reducing culvert capacity, could increase the risk of flooding at Bancroft Drive	53	Low
Eugene	ES-E-03	3	Fine sediment deposition within creek is creating deteriorate habitat conditions and decreasing the hydraulic capacity of the channel. Assumed to be a result of the runoff from the surrounding development. Straw bail dam at culvert inlet is creating a back-water condition.	50-100m	Increased flooding risk to residential development	63	Moderate
Frobisher	ES-F-01	4	Erosion along channel banks has resulted in undercutting	~80m	None	50	Low
Frobisher	ES-F-02	5	Erosion along channel banks has resulted in undercutting and slumping	~150m	Erosion of private lands and park lands, and potential impact the culvert at Rita Street.	59	Low
Frobisher	ES-F-03	7	Scour pool has formed at outlet of eastern CSP.	localized	Scour has started to undermine eastern CSP and could compromise the long-term stability of the culvert.	67	Moderate
Frobisher	ES-F-04	8	Sediment deposition at culvert inlet	~300m	Deposition is reducing culvert capacity, could increase the risk of flooding at Highgate Road	66	Moderate
Keast	ES-K-01	1	Erosion along the channel bed and banks has resulted in channel widening and impingement of the private property and road embankment	100-150m	Private property and Chemin South Bay Road	80	High
Roger	ES-R-01	2	Slumping gabion baskets along retaining wall. (Note: On Private Property)	~25m	Private property (Finlandia Retirement Community parking lot)	57	Low
Roger	ES-R-02	3	Scour pool has formed at culvert outlet (Note: On Private Property)	localized	Scour has started to undermine concrete structure and could compromise the long-term stability of the culvert	67	Moderate
Roger	ES-R-03	5	Scour pool has formed at culvert outlet	localized	Erosion is minor, however should be mitigated before culvert is compromised	60	Moderate

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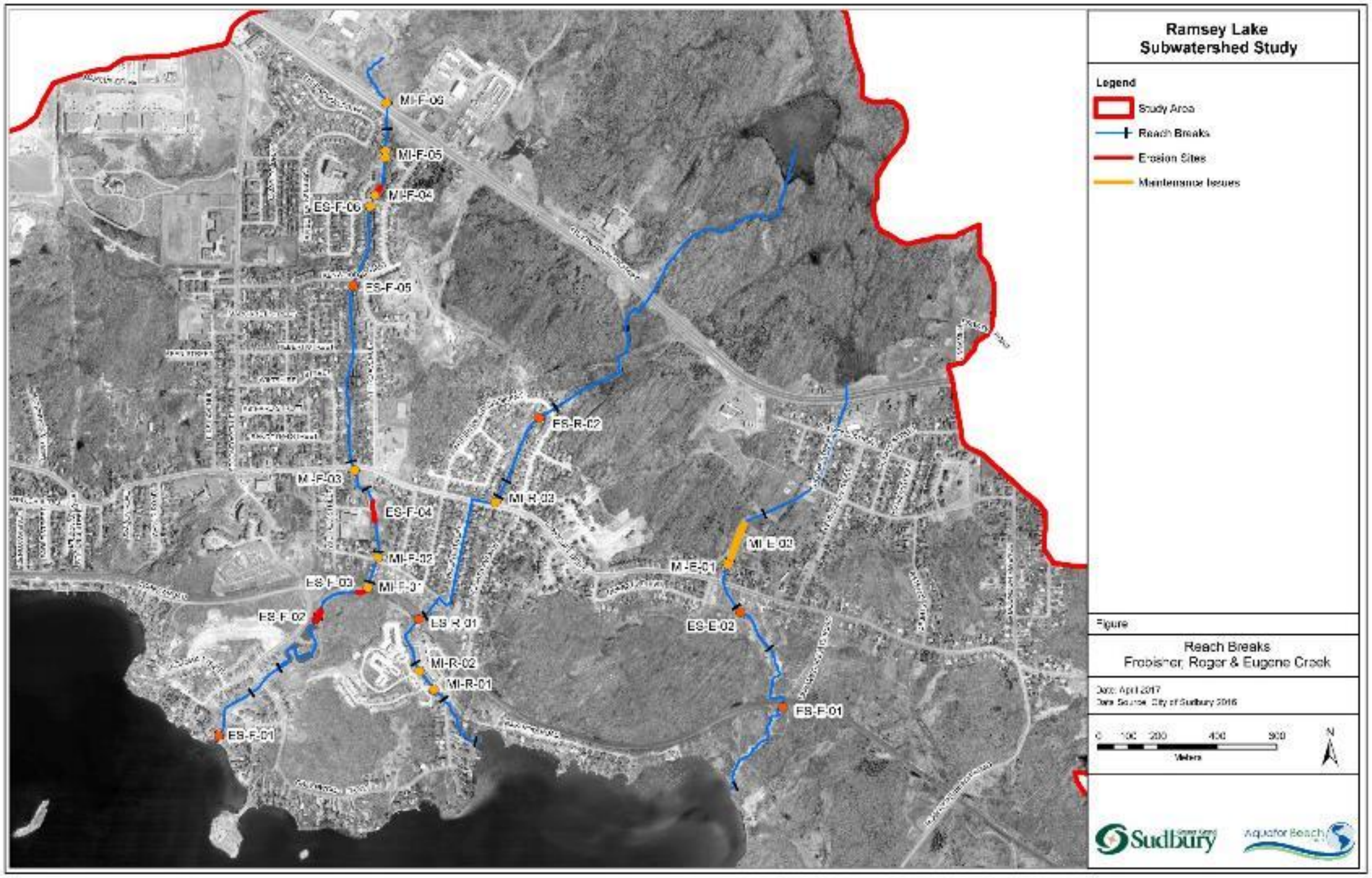

Figure 3.17: Erosion Sites and Maintenance Issues along Frobisher, Roger and Eugene Creek

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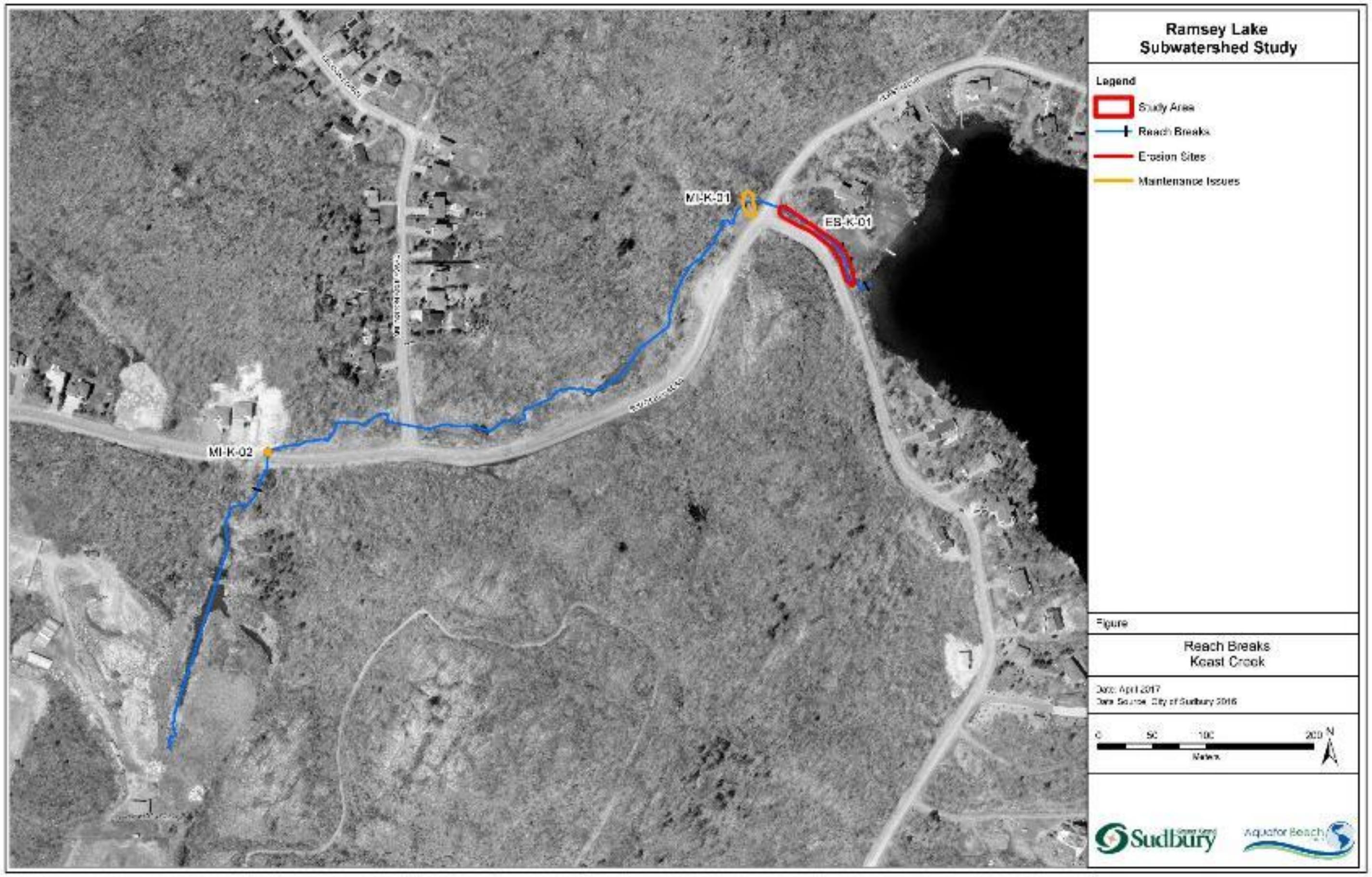


Figure 3.18: Erosion Sites and Maintenance Issues along Keast Creek

Maintenance issues (MI) were identified as localized erosion, deposition, structural failures or disrepairs, or flow obstructions. The maintenance issues differ from the erosion sites in that the effects of the maintenance sites were very localized and/or associated with city infrastructure included within regular operations and maintenance responsibilities.

To identify and evaluate the maintenance sites during field walks, Aquafor used a modified version of a reach inspection form. The form was modified to customize the maintenance inventory as part of the overall erosion assessment, ensuring that issues that were identified were related to the watercourse, or watercourse infrastructure (i.e., culverts, bridges or weirs).

Maintenance sites were identified using three main categories; (1) external influences, (2) maintenance defects and (3) capital defects (Appendix C). External influences are maintenance sites that are caused by a non-riverine process, such as animal activity. Maintenance defects are issues with the condition or functioning of the natural watercourse, and capital defects are issues with the engineered and constructed assets within the drainage system.

The evaluation criteria are scored on a scale of one (1) to five (5) with a higher score indicating that the maintenance issue is at a more degraded state, and a lower score indicating that the maintenance issue is minor. Some criteria are noted evaluated just based on presence (i.e., yes/no).

Each maintenance issue was given a general priority ranking (i.e., High, Moderate or Low), based on score of the evaluation criteria. The priority ranking is intended to help guide which issues should be addressed first, and which issues can wait to be addressed. The scores associated with the general priority ranking are described below in Table 3.4.

Table 3.4: Erosion site priority ranking definition

General Priority	Score
High	5
Moderate	3 – 4 or Yes
Low	≤ 2

A total of nine (9) maintenance issues were identified on the four creeks, with only one being given

Table 3.5: Summary of Maintenance Issues along Creeks Within Ramsey Creek Subwatershed

Creek	ID	Reach	Description of Maintenance Issue	Maintenance Code[1]	Score	Priority Ranking	Recommended Maintenance Action
Frobisher	MI-F-01	1	Sediment deposition at confluence with lake	C4	Y	Low	Dredge creek to remove sediment
Frobisher	MI-F-02	4	Sediment deposition upstream of storm water pond	C4	Y	Moderate	Dredge creek to remove sediment
Frobisher	MI-F-03	4	Debris jam (i.e., rail track ties and other woody debris) at culvert outlet has resulted in the outlet being half blocked.	M2	3	Moderate	Remove debris and sediment
Frobisher	MI-F-04	5	Debris jam (i.e., leaves and organic matter) is blocking culvert inlet and resulting in a backwater condition.	M2	3	Moderate	Remove debris
Frobisher	MI-F-05	6	Dense vegetation in channel at culvert outlet is reducing the culvert capacity	C1	5	High	Maintain vegetation through the growing season to ensure capacity is maintained.
Frobisher	MI-F-06	10	Rill erosion along the road embankment has created scour around the Kingsway culvert inlet	C6	3	Moderate	Implement headwall and hardened, mitered slope treatment
Keast	MI-K-01	2	Rill erosion along the road embankment has created scour around the South Bay Road culvert outlet.	C6	3	Moderate	Implement headwall and hardened, mitered slope treatment
Roger[2]	MI-R-01	3	Debris jam (i.e., leaves and organic matter) is blocking culvert inlet and resulting in a backwater condition.	M2	4	Moderate	Remove debris
Roger[2]	MI-R-02	4	Slumping gabion baskets within headwall/road embankment	C6	4	Moderate	Secure or reinforce gabions or replace entire retaining wall with a longer-term solution.

[1] Maintenance Codes are based on a classification system developed by the City of Kitchener and adapted by Aquafor Beech on similar erosion assessment projects. Maintenance codes are described in Appendix C.

[2] Location is on private property and partly deals with private infrastructure.

a high priority. The High Priority site, MI-F-05, associated with dense vegetation growth at the outlet of the Bancroft Drive culvert on Frobisher Creek. The vegetation is blocking more than 80% of the outlet (approximately), which could cause backwatering. Due to the low rise of the culvert, the vegetation causes flooding issues. It is recommended that the vegetation growth be maintained (e.g., cut back) through the growing season to ensure capacity is maintained.

Again, most of the maintenance issues identified are associated with the culvert inlets. A maintenance program could help alleviate many of the issues associated with vegetation growth and debris jams, and installing headwall treatments on new culverts will prevent some erosional risk.

A summary of the maintenance issues is provided below in **Table 3.5** and a map of the maintenance issues is provided in **Figure 3.17** and **Figure 3.18**.

3.2.1.5 Preliminary Tractive Force Assessment

A preliminary tractive force assessment was completed for representative locations along the four creeks. The tractive force assessment was used to identify the potential for sediment movement, or erosion within the rivers. This analysis will be refined as Stage 2 (Analysis) and Stage 3 (Alternative Management Strategies) phases of this project.

To evaluate the potential for sediment transport and erosion within the rivers, the channel shear force was compared to critical threshold values for the representative bed material. The HEC-RAS model (discussed below in **Section 3.2.2**) was used to calculate the existing channel shear for the full range of design storms (i.e., 2-year to 100-year 6-hour Chicago storms and the Regional). Data published by Fischenich (2001) was used to identify representative threshold values for the different sediment and vegetation types. The preliminary analysis identified the flooding events that resulted in channel shear stress exceeding the critical threshold for the bed material. The results of the analysis are presented below in **Table 3.6**, with orange cells representing events where the shear thresholds have been exceeded.

Downstream boundary conditions are set for each river in a HEC-RAS model. For all creek systems, a “Known Water Surface Elevation” was used as the boundary condition, with a downstream hydraulic control set to represent the water surface elevation of Ramsey Lake. A value of 249.5 m was used, which represented the highest water surface elevation within the operational range of the control dam for Ramsey Lake.

It is noted that there are locations along all four creeks where the critical thresholds are exceeded for all storm events. Furthermore, the channel shear calculated within the HEC-RAS model is very high at some locations, which could result in high rates of erosion.

For Stage 2 of this project erosion rates and critical discharge values will be calculated for the creeks to understand the potential impacts of development within the sub-watershed.

Table 3.6: Tractive Force Analysis for Creeks within Ramsey Lake Subwatershed

Location	HEC-RAS Cross Section	Bed Material Classification	Critical Shear (Pa)	Average Channel Shear (Pa)[1]						
				2-yr	5-yr	10-yr	20-yr	50-yr	100-yr	Timmins
Frobisher Creek										
Kingsway Highway	2474	Gravel-Fine	**20.59**	15.01	18.53	20.48	21.61	22.31	21.13	22.27
Trail at Greenbriar Drive	2312	Reed-Like Vegetation (Sand-Medium)	**28.73**	20.19	28	33.44	38.5	44.11	48.03	43.1
Highgate Road	2117	Reed-Like Vegetation (Sand-Medium)	**28.73**	7.99	11.8	14.55	17.35	21.32	24.68	20.28
Kenwood Street	1939	Gravel-Coarse	**32.08**	126.53	159.19	187.66	204.94	157.9	123.45	220.89
Hebert Street	1636	Cobble-Small	**95.76**	30.51	43.18	57.38	73.08	93.17	98.99	79.74
Bancroft Road	1216	Reed-Like Vegetation (Gravel-Fine)	**28.73**	77.08	84.45	96.97	91.81	82.54	84.79	81.83
Rita Street	1045	Gravel-Coarse	**32.08**	20.38	20.98	20.07	17.63	17.81	18.16	17.63
Wilfred Street	926	Gravel-Coarse	**32.08**	57.27	54.4	41.96	49.57	44.4	35.79	50.7
Downstream of CN Train Tracks	798	Reed-Like Vegetation (Sand-Medium)	**28.73**	18.13	15.88	21.37	25.33	28.68	31.92	25.86
Bridge to Finlandia	615	Bedrock	**598.50**	22.96	27.76	31.31	33.61	38.62	53.85	34.26
Greenwood Road	238	Reed-Like Vegetation (Sand-Medium)	**28.73**	40.98	45.83	69.73	89.75	93.42	95.74	110.1
Ramsey Lake	7	Cobble-Large	**191.52**	197.4	231.25	67.75	79.89	85.83	94.61	97.57
Roger Creek										
Upstream of Autumwood Cres.	1568	Gravel-Coarse	**32.08**	22.42	27.59	31.22	36.4	44.82	52.42	43.93
Downstream of Autumwood Cres.	1440	Reed-Like Vegetation (Sand-Medium)	**28.73**	30.98	36.54	39	41.22	43.16	43.89	41.94
Cherrywood Cres. Trail	1281	Concrete	**598.50**	34.81	41.58	48.76	57.28	67.48	72.67	86.93
Upstream of Bancroft Road	1187	Grass lined channel	**47.88**	50.91	55.48	52.72	47.64	41.48	38.78	62.63
Downstream of CN Train Tracks	529	Gravel-Medium	**15.80**	28.66	34.79	37.3	40.14	43.72	45.83	53.16
Finlandia Bridge	453	Gravel-Medium	**15.80**	56.74	66.15	70.88	86.68	71.26	73.84	78.14
Finlandia Hill Drive	252	Reed-Like Vegetation (Gravel-Fine)	**28.73**	2.32	4.24	5.92	7.76	10.67	13.14	15.06
4th Avenue	183	Gravel-Fine	**20.59**	23.8	24.16	25.95	26.71	27.28	28.19	28.9
Ramsey Lake	50	Gravel-Fine	**20.59**	42.5	36.45	15.87	7.26	2.88	19.51	21.02

Location	HEC-RAS Cross Section	Bed Material Classification	Critical Shear (Pa)	Average Channel Shear (Pa)[1]						
				2-yr	5-yr	10-yr	20-yr	50-yr	100-yr	Timmins
Eugene Creek										
Upstream of Bancroft Road	1012	Silt-Medium	**2.15**	0.64	0.78	0.88	0.96	1.06	1.2	1.54
Downstream of Bancroft Road	771	Reed-Like Vegetation (Silt-Coarse)	**28.73**	15.64	18.69	21.39	23.72	26.29	28.35	33.93
CN Train Tracks	364	Reed-Like Vegetation (Gravel-Fine)	**28.73**	26.94	46.65	59.85	71.22	87.59	100.15	140.57
Keast Creek										
South Bay Road	737	Gravel-Medium	**15.80**	108.01	120.82	134.27	141.09	158.07	172.07	140.54
Arlington Blvd	631	Reed-Like Vegetation (Gravel-Very fine)	**28.73**	22.34	11.17	7.18	4.77	2.45	2.74	3.77
Upstream of Keast Road	151	Silt-Coarse	**3.59**	8.43	9.4	11.02	11.45	13.04	14.33	16.92
Downstream of Keast Road	91	Sand-Fine	**12.45**	67.83	77.97	85.88	54.36	54.68	54.74	59.01

NOTES:

1. Orange boxes represent events where the average channel shear has exceeded the critical threshold, and there is potential for erosion.
2. The model was not able to produce the specified water surface elevation of 249.5 for the specified flow regime, so the program instead used critical depth as the starting water surface. This resulted in supercritical flow conditions at the downstream-most cross section (Fobisher-01, ST 7) under the 2-year and 5-year events, as well as higher average channel velocity and channel shear than the higher flow events. If different downstream boundary conditions were to be applied, the trend in average channel shear from the 2-year event to Timmins event at Cross Section 7 is more typical of that seen at other Frobisher Creek cross sections.

3.2.2 Hydrology, Hydraulics and Flood Hazards

The following sections outline the hydrology, hydraulics, and flood hazards within the Ramsey Lake Sub-watershed.

3.2.2.1 Hydrology

Hydrology is the science which deals with the interaction of water and land, and the processes by which precipitation is transformed into runoff to the receiving watercourse or infiltrated into the groundwater system. These processes are generally called the hydrologic cycle.

One of the most dramatic changes brought about by urbanization is the change in hydrological cycle and stream hydrology. These changes can result in increases in flooding, channel erosion, sediment transport, and pollutant loadings which can cause deterioration in natural channel morphology, fish and wildlife habitats, recreational opportunity and aesthetics.

It is important that the existing hydrologic characteristics of the study area and its watercourses be established. This information is critical in defining existing flood characteristics, defining regulatory floodplain limits, and providing key information on the selection and design of stormwater management facilities for future urban development lands.

The City of Greater Sudbury provided flood hazard limits associated with high lake levels (see **Figure 3.19**). For this study, further hydrologic modeling was undertaken to define flood hazards associated with the four main creeks draining to Ramsey Lake. Selection of appropriate design storms will be important to ensure that the model evaluations meets the project objective. This will be dictated by whether runoff volume or peak flow is most critical.

3.2.2.2 Design Storm Events

The City of the Sudbury Official Plan Stormwater Background study (2006) suggests that for flood assessment and design of major overland flow conveyance systems, the design peak flow utilized should be the largest of those generated by the 100-year design storm or the regional storm.

The City of the Sudbury Official Plan suggests that the "Timmins" storm is an actual rainfall event measured near the city of Timmins in 1961, and is generally considered the extreme rainfall event characteristic to Northern Ontario.

The 100-year storms suggested by the City of the Sudbury Official Plan Stormwater Background Study (City of the Greater Sudbury, 2006) include the "100-year 6-hour Chicago" and "100-year 24-hour AES" storms.

Therefore, of the three storms listed below, the storm that produces the largest flow should be used as the design storm for flood conveyance.

- 100-year 6-hour Chicago (design storm)
- 100-year 24-hour AES (design storm)
- Timmins Storm (regional)

For stormwater management facility and conveyance design, the potential for rainfall plus snowmelt exceeding design rainfall without snowmelt was considered. The City of the Sudbury Official Plan provides a 10-day rainfall plus snowmelt distribution.

The design storms depths and distributions obtained are based on the long-term data collected by Environment Canada at Science North and Sudbury Airport. Updated IDF curves and the distributions for the three above storms as well as the rain-snow event are presented in **Appendix A**.

3.2.2.3 Climate Change

As part of the development of design storms for the City of Greater Sudbury, a 15% increase in rainfall depth was suggested (Hengeveld, 2000; Ciarmatiori et al, 2000; Watt et al, 2003). The sensitivity to climate change was analyzed with a focus on the impacts to flood rates. This was achieved through adjustment to the IDF curves by an increase of 15% based on assessment of local data (City of the Greater Sudbury, 2006).

3.2.2.4 Model Selection and Setup

The hydrologic model selected for application in this study was PCSWMM 2016. PCSWMM 2016 has the capacity of using a number of versions of SWMM5 for performing the hydrologic and hydraulic calculations. For the existing condition model, SWM5.1.010, which is the latest version of SWMM model, was selected.

The model was setup in PCSWMM 2016 using the NAD83 UTM zone 17N coordinates system. All the GIS files prepared for this reason used the same coordinate system.

3.2.2.5 Subcatchment Delineation

The total contributing area to Ramsey Lake was delineated into 13 large subcatchments. A finer level of delineation (34 subcatchments) was completed within some of those subcatchments in order to define flood flows along the creeks of interest (Frobisher, Rogers, Eugene, and Keast). The subcatchment delineations are illustrated in **Figure 3.20** and **Figure 3.21**. Required parameters include area, flow length, width, infiltration parameters, depression storage, percent directly connected impervious area, manning's roughness for pervious and impervious areas and slope.

3.2.2.6 Summary of Key Parameters

3.2.2.6.1 Subcatchment Area

The area of each of the subcatchments were calculated using the auto-length feature within the SWMM5 model. This method provides an approximate area based on the NAD83 UTM zone 17N coordinate system.

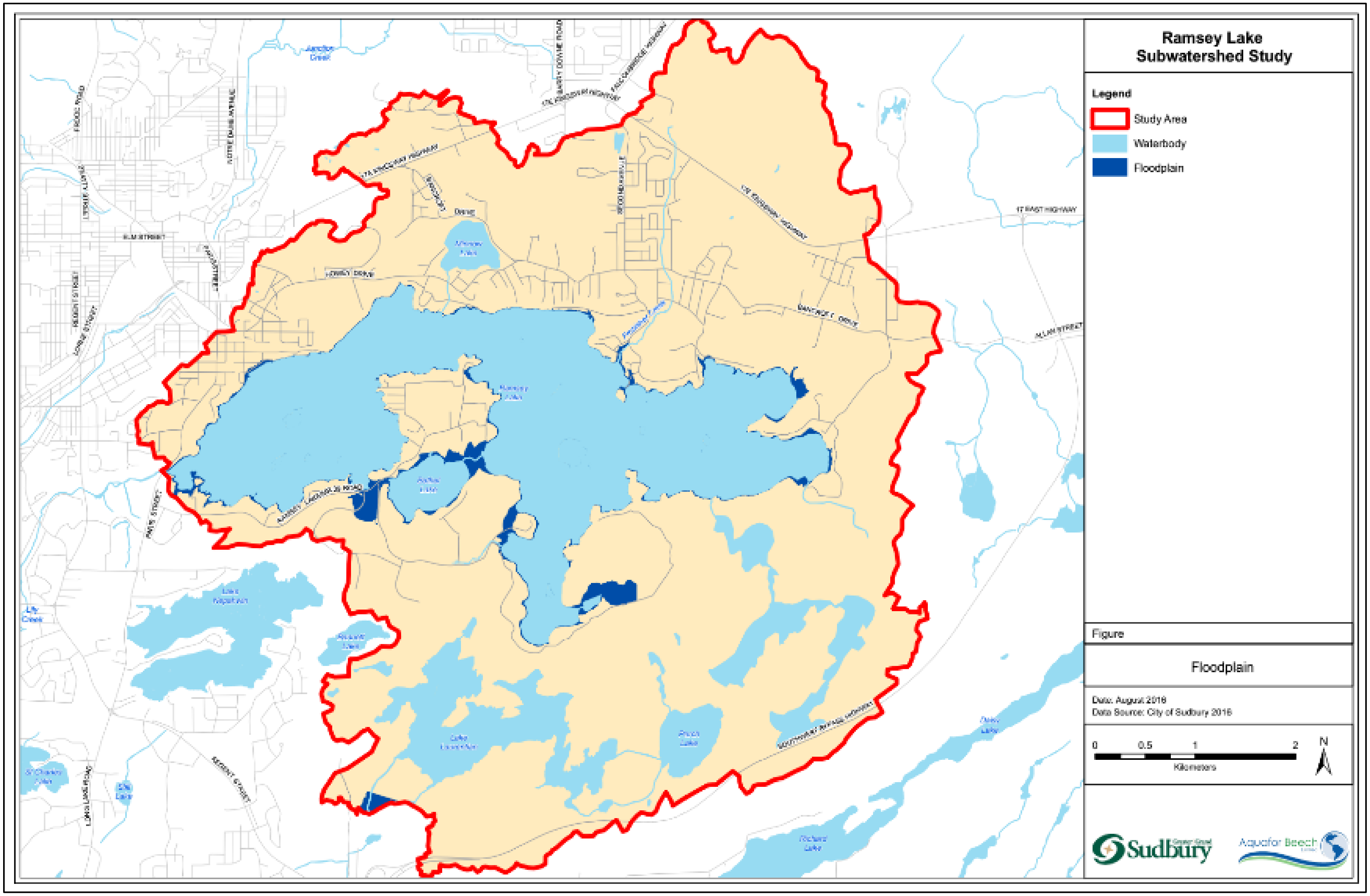


Figure 3.19. Flood hazard limits associated with high lake levels (City of Greater Sudbury)

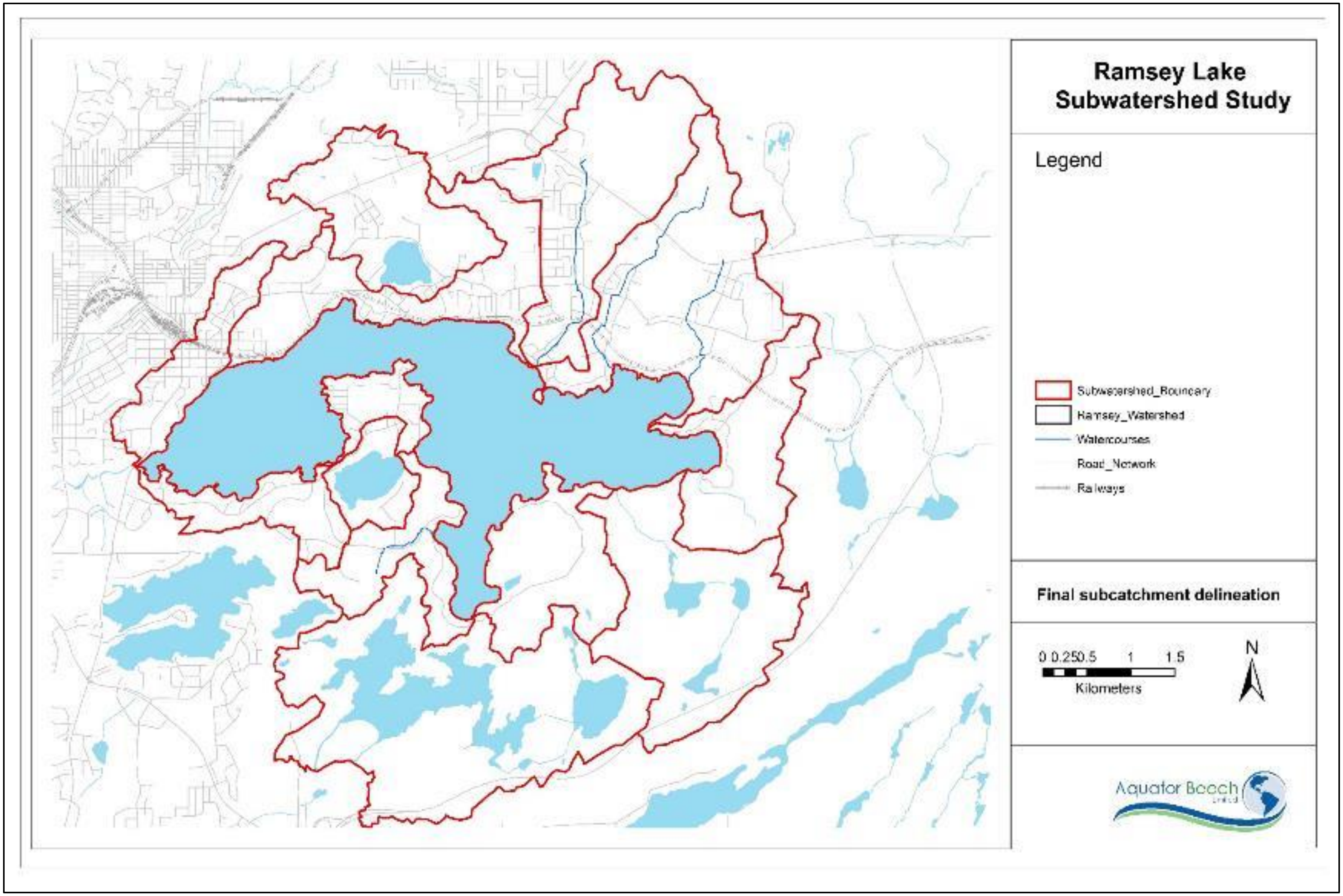


Figure 3.20. Large-scale subcatchments (City of Greater Sudbury)

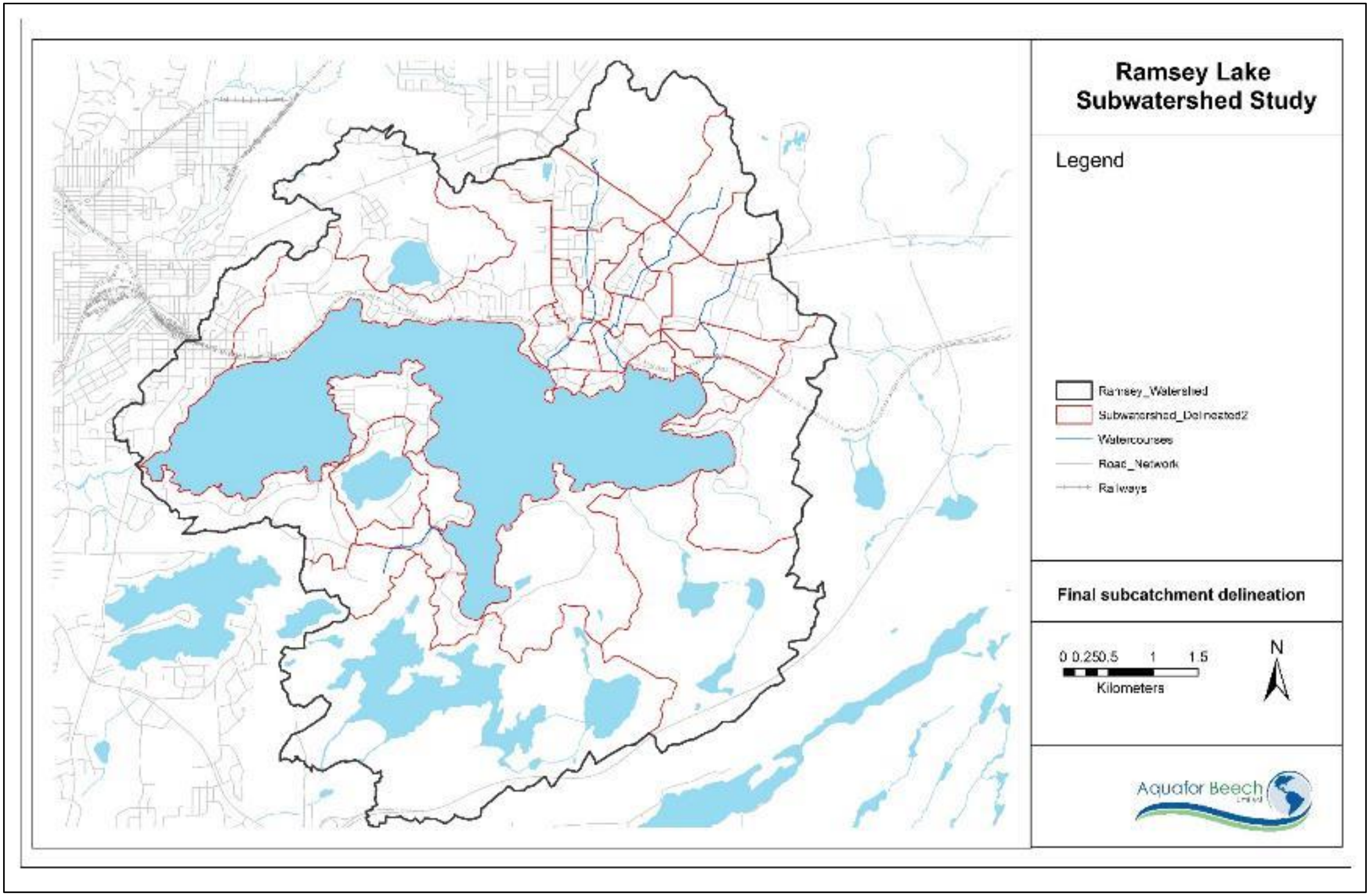


Figure 3.21. Subcatchment delineation for PCSWMM model

3.2.2.6.2 Subcatchment Width and Length

The width is a calibration parameter which is not easily measurable in the field. One method for initial estimation of subcatchment width is to calculate it by dividing the area by an assigned flow path length. This parameter may be adjusted significantly during the model calibration. Although it is often suggested that the subcatchment width be treated as a calibration parameter whereby the width is adjusted to best simulate runoff in the receiving system; however, in cases where calibration data is not available, the subcatchment width parameter must be estimated recognizing the impact of assumptions on model output and considering the potential limitations of these assumptions.

The flow length for a subcatchment is the length of the overland sheet flow in meters. Measuring the length of the overland flow requires some judgment and approximation as well as use of a DEM to define the major overland flow path.

One of the most significant effects of urban development on flow velocity is less retardance to flow. In small non-urban watersheds, much of the travel time results from overland flow in upstream areas. Typically, urbanization reduces overland flow lengths by conveying storm runoff into a pipe or channel as soon as possible. Since channel designs have efficient hydraulic characteristics, runoff flow velocity increases and travel time decreases.

In the case of the Ramsey Lake model development, both urban and rural subcatchments are present and many of the subcatchments are irregularly shaped and relatively large in size. The subcatchments discretization was completed recognizing that the model is not intended to be used for detailed pipe-by-pipe and /or dual drainage assessment design, but rather for peak flow estimation at key conveyance points within the watershed. Therefore, in the case of the Ramsey Lake watershed with different types of the subcatchments in terms of urbanization and also the shapes, an approach was developed to estimate the length of the flow using some judgment and experience.

In this method, the first step involves defining the main drainage channel. The main drainage channel has been defined as the primary longest roadway network from the upstream end of the upstream end of the subcatchment to the downstream end, with a defined drainage slope towards the outlet. In urban subcatchments. The length of the 30 m was assumed for overland flow reach to the channel. Beyond this distance, the flow normally becomes channelized in the urban environments. However, for the rural area this length was assumed to be 150 m. A summary of the approach used for the Sudbury model flow length estimation is presented in **Figure 3.22**.

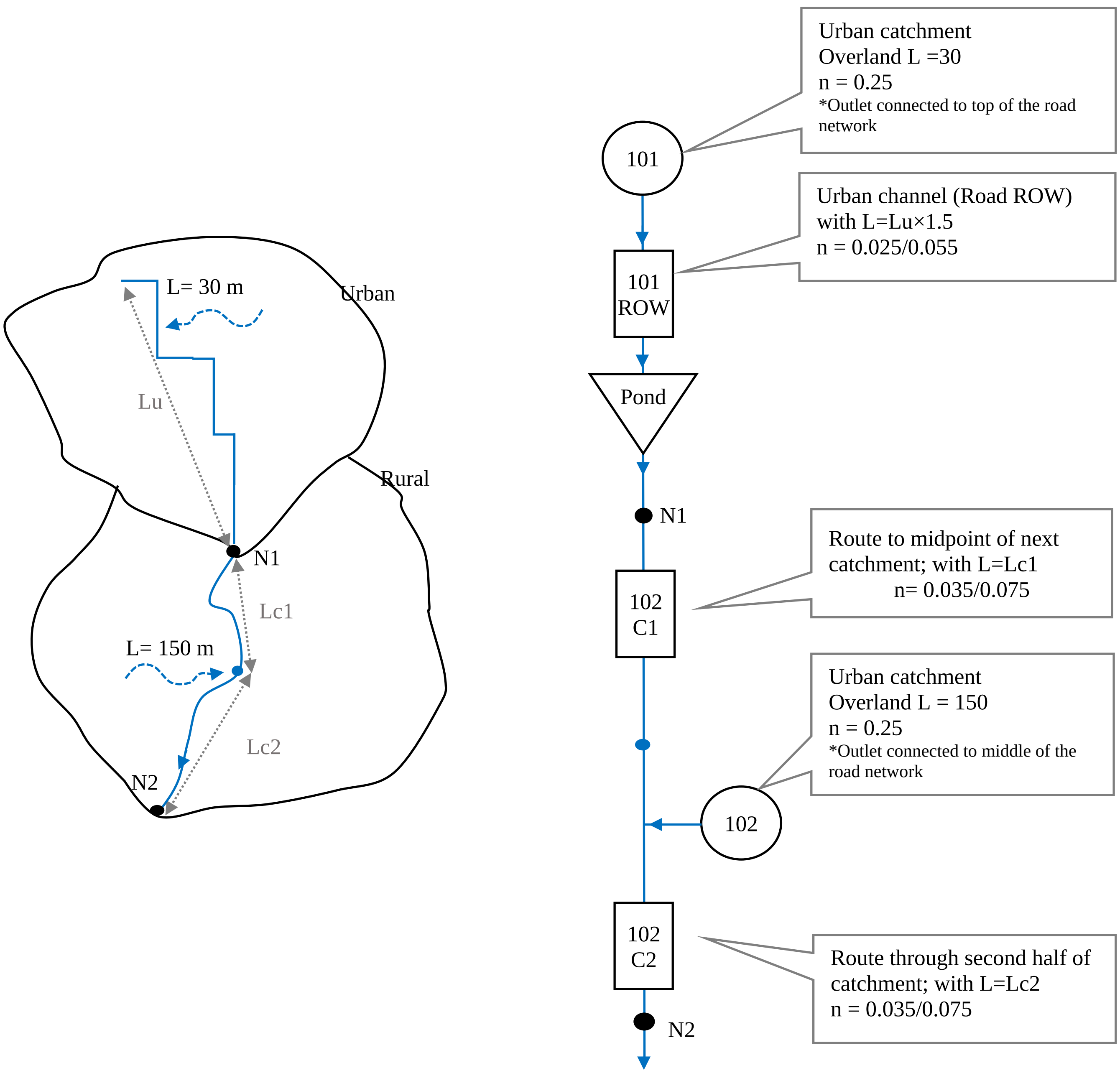


Figure 3.22. Schematic of model development

3.2.2.6.3 Infiltration Parameters

Subcatchment infiltration is the process of rainfall infiltration into the pervious area of the ground surface into the unsaturated soil zone of pervious subcatchment areas. There are three methods available in SWMM5 for modelling infiltration including Horton's Equation, Green-Ampt Method and Curve Number Method. The method selected for the Ramsey Creek subcatchments was Curve Number Method. The CN values for subcatchments are listed in **Table 1** in **Appendix A**. A map of the project area with indicated soil and land use properties are presented in **Figure 3.23** and **Figure 3.24**.

3.2.2.6.4 Depression Storage

Depression storage is the ability of a particular area of land to retain water in its pits and depressions, thus preventing flow. Depression storage is defined in units of length. The depression storage falls into two categories; impervious and pervious depression storage. The impervious storage is the depth of depression storage in the impervious portion of the subcatchment while the pervious depression storage is the depth of depression storage on the pervious portion of the subcatchment. The typical values, in mm, for depression storage based on impervious lands can be found in **Table 3.7**.

Table 3.7. Typical depression storage values for a defined land use

Land Use Type	Depression storage (mm)
Impervious surfaces	1.27-2.54
Lawns	2.54-5.08
Pasture	5.08
Source: ASCE, (1992). Design & construction of Urban Stormwater Management Systems, New York, NY.	

3.2.2.6.5 Percent Directly Connected Impervious Area (DCIA)

The percent of imperviousness land in each subcatchment was calculated using the land cover map layer. Each land use was assigned into one of two categories; pervious and impervious. Once the subcatchments were discretized, the percent of impervious land in each subcatchment was calculated using aerial photographs. A complete description of each land use type and its imperviousness is provided in **Table 3.8**. The imperviousness values for subcatchments of Ramsey lake subwatershed are presented in **Table 1** of **Appendix A**.

Table 3.8. Typical Imperviousness for a defined land use

Land use	Impervious Percentage (%)
Commercial	95
Government and Institutional	60
Open Area	2
Parks and Recreational	2
Residential	40-50
Resource and Industrial	95

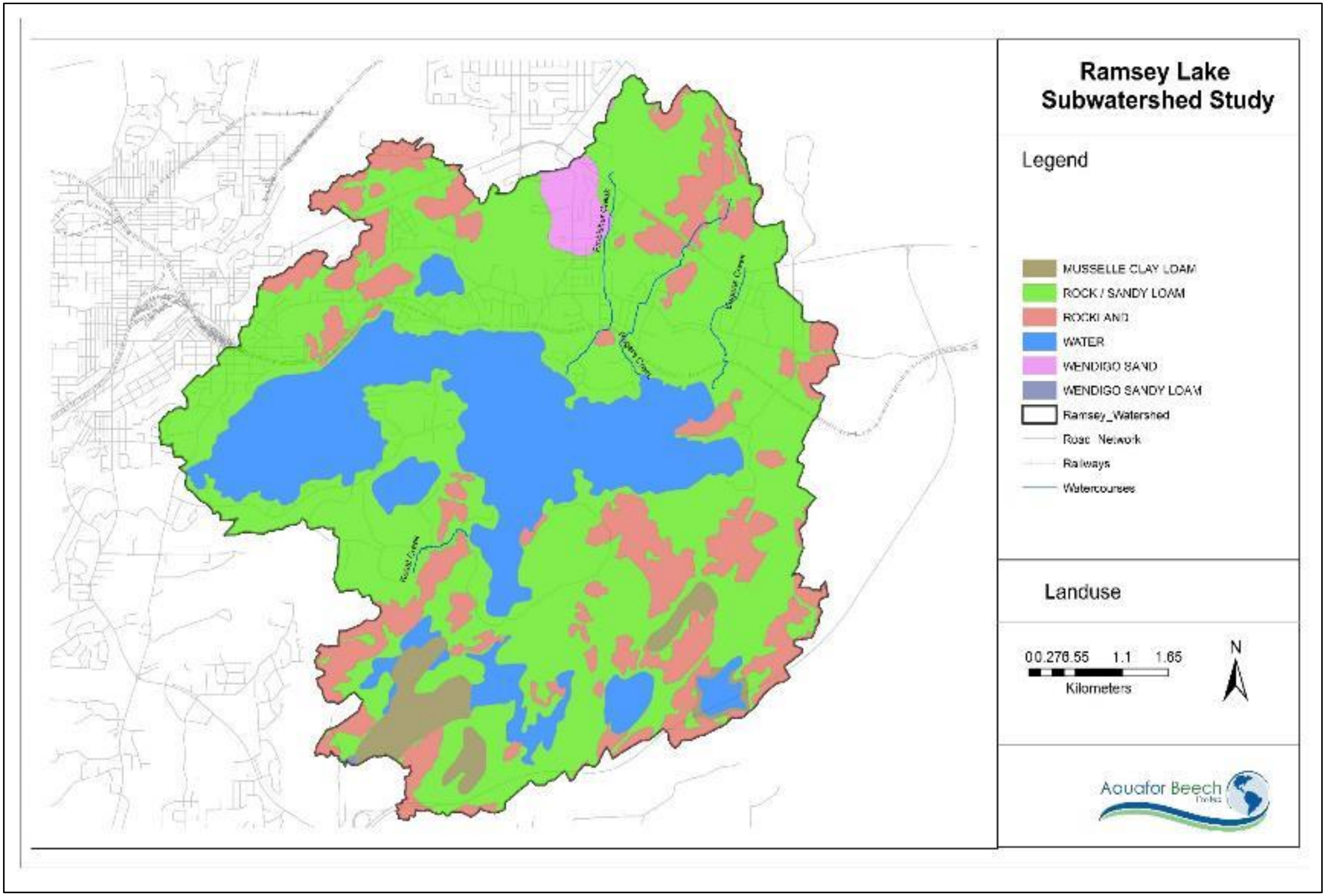


Figure 3.23. Soil map

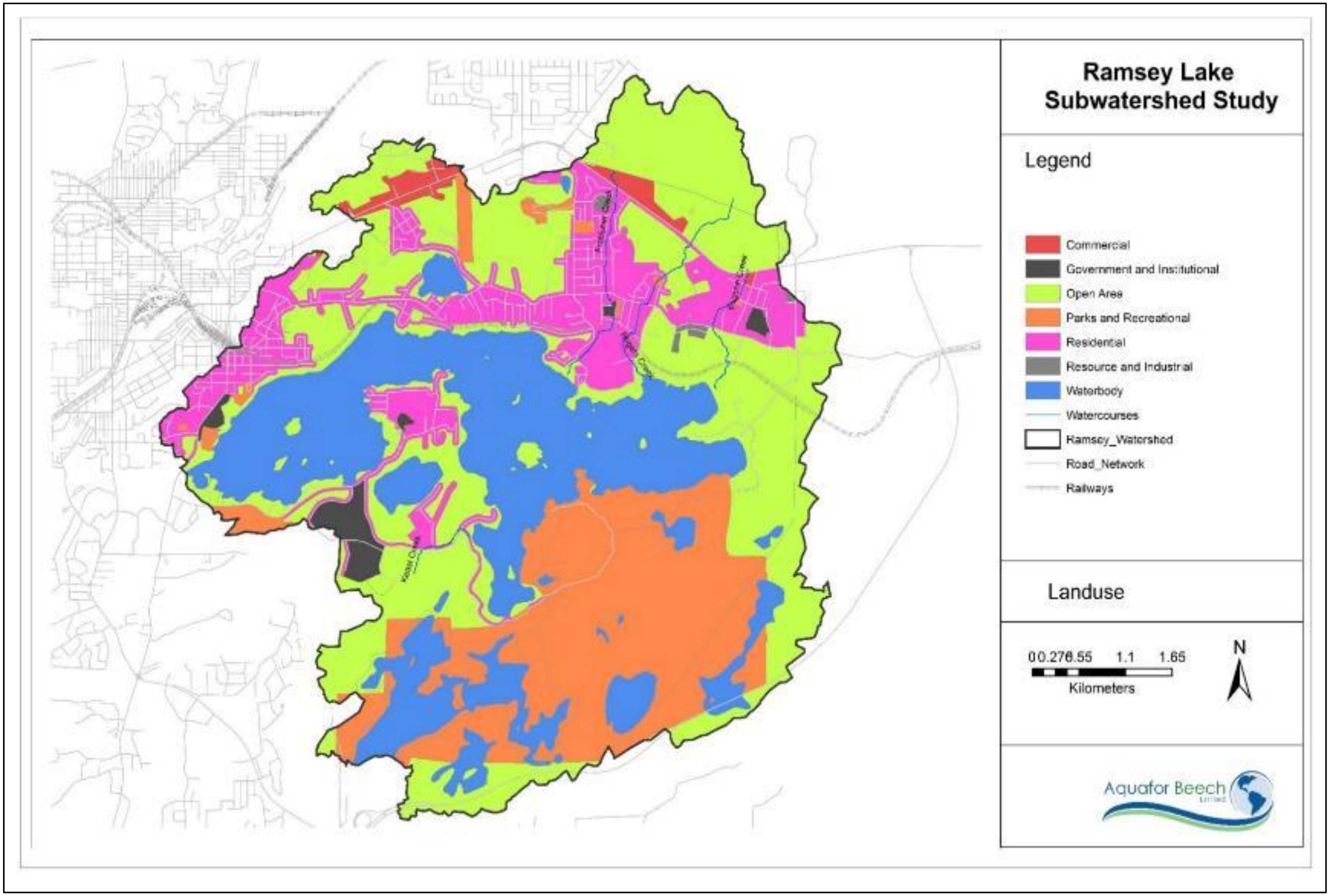


Figure 3.24. Existing land use map

3.2.2.6.6 Manning's Roughness for Pervious and Impervious Areas

Manning's roughness coefficient (n) is the resistance from the channel bed to the flow of water in it. Manning's n values were entered into the SWMM5 model for both the pervious and impervious areas. These values were assigned in this layer as it allows for the Manning's n values to be adjusted depending on the land use. The Manning's n values are presented in **Table 3.9**. For the impervious and pervious areas, initial values of 0.015 and 0.41 were used (James. 2005). These values can be changed depending on the land use effects and the need for verification.

Table 3.9. Manning's Roughness for pervious and impervious surfaces

Areas	Manning's Range
Impervious (concrete)	0.011-0.025
Pervious (Grass)	0.15-0.41

3.2.2.7 Flood Flows Summary

The Ramsey Lake hydrologic model was applied to estimate flood flow rates for use in floodplain mapping at key locations throughout the four creeks across the project area. In order to estimate the peak flows for the study area, the approach by the Official Plan Stormwater Background study (2006) was used. Based on this approach the design peak flow utilized should be the largest of those generated by the 100-year design storms (100-yr 6-hr Chicago and 100-yr 24-hr AES) or the regional storm (the Timmins storm).

The 6-hour Chicago storm distribution was found to produce the higher flood flow rates compared to 24-hour AES storm. Flood flow rates for the 2-year through 100-year return periods for the 6-hr Chicago storm were then estimated using the PCSWMM model.

The resulting flood flow estimates at key locations in the study area for the 2-year through 100-year return periods for the 6-hr Chicago distribution, Regional Storm event (Timmins) and for the 10-day rain-snow events are summarized in **Table 3.10**.

Long-term flow monitoring data is not available on these small creeks, therefore detailed model calibration was not undertaken. However, model parameters were adjusted until flood flow estimates were within a reasonable range based on past experience.

Table 3.10. Summary of Estimated Flood flows (m3/s)

Node	Area (ha)	6-hour-Chicago						10-Day Snow-Rain	Regional Timmins
		2-yr	5-yr	10-yr	20-yr	50-yr	100-yr		
FrobisherNode1	177.8	1.19	1.72	2.13	2.56	3.15	3.67	1.646	6.057
FrobisherNode2	263.52	4.06	5.97	7.42	8.93	10.95	12.66	2.454	10.57
FrobisherNode3	303.54	5.09	7.39	10.25	12.82	15.77	18.23	2.831	13.84
FrobisherNode4	319.96	5.96	7.75	11.42	14.59	17.17	20.34	2.986	14.98
FrobisherNode5	345.03	7.30	9.53	13.49	16.90	20.57	24.00	4.222	17.64
FrobisherNode6	370.1	8.25	10.97	17.68	24.25	25.85	26.88	4.531	33.65
RogersNode1	66.12	0.18	0.28	0.38	0.50	0.71	0.96	0.621	3.27
RogersNode2	89.21	0.17	0.26	0.34	0.47	0.70	0.95	0.824	3.32
RogersNode3	111.11	0.94	1.41	1.78	2.17	2.72	3.21	1.03	4.65
RogersNode4	141.28	1.68	2.56	3.24	3.94	4.92	5.78	1.314	6.41
RogersNode5	166.17	2.15	3.29	4.20	5.11	6.40	7.52	1.548	8.35
EugeneNode1	43.58	0.35	0.51	0.65	0.80	1.02	1.24	0.409	2.25
EugeneNode2	149.88	0.26	0.42	0.54	0.65	0.79	1.01	0.409	2.24
EugeneNode3	189.19	0.68	1.33	1.91	2.58	3.65	5.46	1.772	9.34
EugeneNode4	221.59	0.73	1.54	2.29	3.15	4.53	8.65	2.549	11.53
Keast1	58.68	0.88	1.29	1.67	2.09	2.76	3.43	0.552	4.58
Keast2	96.87	1.44	2.10	2.68	3.32	4.29	5.27	0.911	7.26

As shown in **Table 3.10**, the estimated Regional Flood flow rates at the downstream limit of the Frobisher, Rogers and Keast creeks are slightly higher than the 100-year 6-hr Chicago. Based on the above comparisons, the peak flow estimates from the Sudbury PCSWMM model for the regional Timmins storm produces the largest flow and will be used as the design storm for the flood conveyance.

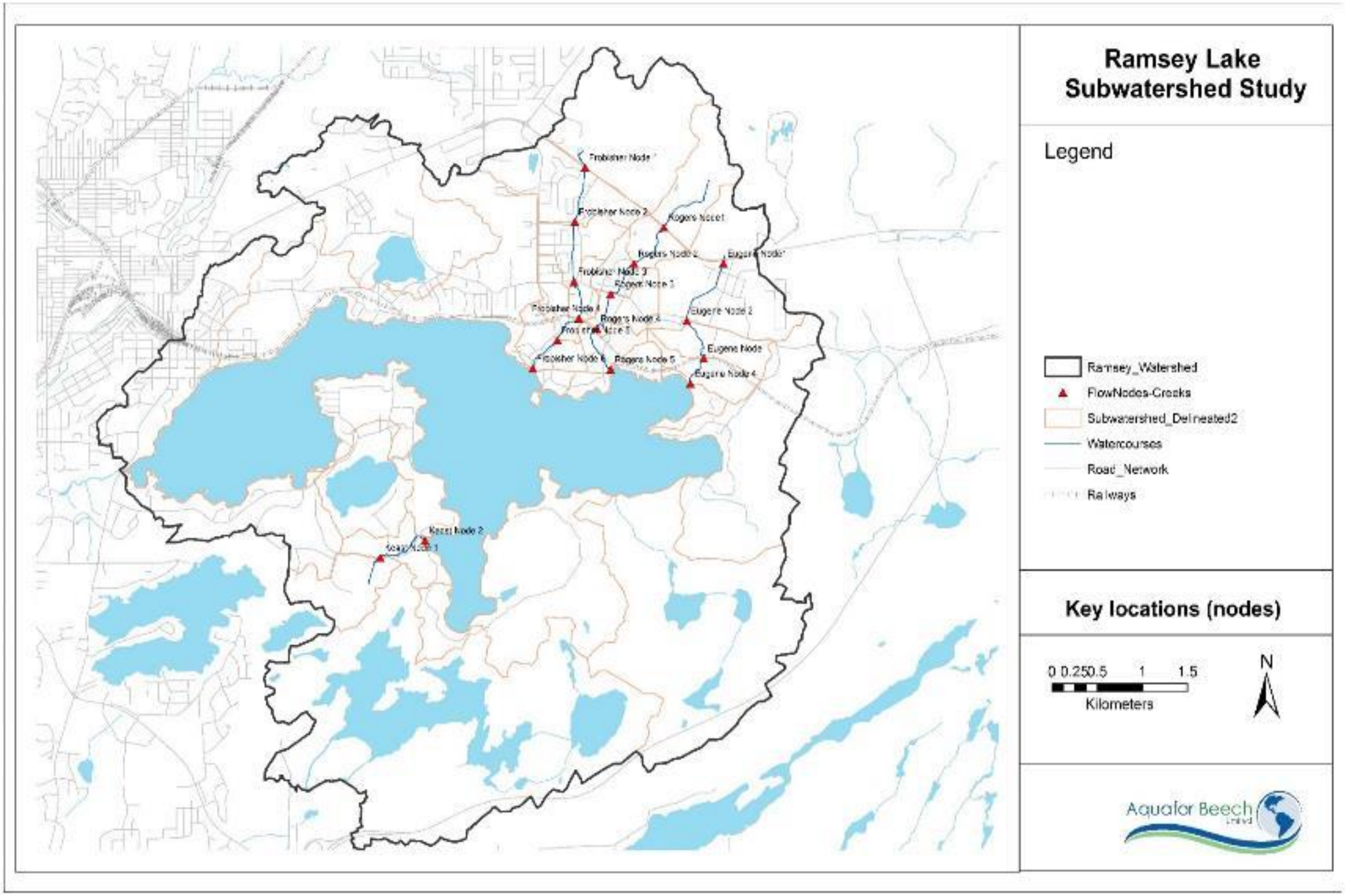


Figure 3.25. key locations throughout the four creeks

3.2.2.8 Climate Change

The PCSWMM model was re-run to estimate the flood flow rates at key locations throughout the Sudbury study area watercourses under future climate change scenarios considering a 15% increase in rainfall depth (City of the Greater Sudbury, 2006).

The resulting flood flows along the four creeks for the 2-year through 100-year return periods for the 6-hr Chicago and 10-day Rain-Snow events are summarized in **Table 3.11**.

Table 3.11: Summary of Estimated Flood flows (m3/s) under climate change conditions

Node		6-hour-Chicago						10-Day Snow-Rain
	Area (ha)	2-year	5-year	10-year	20-year	50-year	100-year	
FrobisherNode1	177.8	1.388	2.025	2.527	3.063	3.803	4.4	1.928
FrobisherNode2	263.52	4.797	7.028	8.787	10.606	13.07	15.008	2.875
FrobisherNode3	303.54	5.686	9.543	12.583	15.283	18.799	21.59	3.341
FrobisherNode4	319.96	6.346	10.605	14.246	16.698	21.291	23.428	3.535
FrobisherNode5	345.03	7.92	12.535	16.397	19.798	25.241	28.723	4.832
FrobisherNode6	370.1	9.15	13.957	24.07	25.895	27.914	31.924	5.025
RogersNode1	66.12	0.212	0.353	0.498	0.683	1.02	1.294	0.732
RogersNode2	89.21	0.206	0.319	0.471	0.682	1.013	1.289	0.779
RogersNode3	111.11	1.109	1.676	2.131	2.629	3.314	3.837	1.036
RogersNode4	141.28	2.003	3.051	3.877	4.763	5.965	6.895	1.392
RogersNode5	166.17	2.577	3.946	5.038	6.203	7.779	9.082	1.679
EugeneNode1	43.58	0.41	0.611	0.788	0.999	1.296	1.541	0.485
EugeneNode2	149.88	0.315	0.51	0.641	0.773	1.075	1.325	0.481
EugeneNode3	189.19	1.091	2.089	3.038	4.144	5.744	6.997	2.165
EugeneNode4	221.59	1.198	2.421	3.588	4.986	7.053	8.633	2.530
Keast1	58.68	1.021	1.571	2.079	2.683	3.59	4.306	0.654
Keast2	96.87	1.669	2.527	3.293	4.183	5.53	6.624	1.080

As mentioned above, the 6-hour Chicago design storm was found to produce the highest flood flow rates. **Table 3.12** presents the comparisons for the four creeks of Sudbury Subcatchment. The simulated flow rates showed average flow rates increased about 18% (1.63 m^3/s) along four creeks due to climate change.

Table 3.12. Increase in peak flow rates due to climate change for the 100-yr 6-hr Chicago event

Node	100-yr 6-hr Chicago No climate change	100-yr 6-hr Chicago No climate change	Increase due to climate change
FrobisherNode1	3.67	4.4	0.73
FrobisherNode2	12.66	15.008	2.348
FrobisherNode3	18.23	21.59	3.36
FrobisherNode4	20.34	23.428	3.088
FrobisherNode5	24	28.723	4.723
FrobisherNode6	26.88	31.924	5.044
RogersNode1	0.96	1.294	0.334
RogersNode2	0.95	1.289	0.339
RogersNode3	3.21	3.837	0.627
RogersNode4	5.78	6.895	1.115
RogersNode5	7.52	9.082	1.562
EugeneNode1	1.24	1.541	0.301
EugeneNode2	1.01	1325	0.315
EugeneNode3	5.46	6.997	1.537
EugeneNode4	8.65	8.68	0.03
Keast1	3.43	4.306	0.876
Keast2	5.27	6.624	1.354

3.2.3 Creek Hydraulics and Floodplain Mapping

A hydraulic model was developed to understand the potential flooding impact of Frobisher, Roger, Eugene and Keast Creeks within the Ramsey Lake subwatershed.

The model was developed using GeoHECRAS, which is an integrated software that utilizes both GIS and HEC-RAS in model development. This was used to produce a one-dimensional, georeferenced HEC-RAS model (version 4.1.0) for the four creeks. The digital elevation model (DEM) that was provided was utilized to develop the geometry for the model, with the topographic survey data being utilized for the low flow channel dimensions. A summary of the HEC-RAS model geometry is included in **Appendix B**.

The design flows for the model were taken from the PCSWM model described above. Both the 24-hour SCS and 6-hour Chicago design storms were included in the hydraulic model for the 2-year, 5-year, 10-year, 20-year, 50-year and 100-year floods, and the Regional storm, representing the Timmins storm, was also included in the hydraulic model.

For each of the creeks, a downstream, hydraulic control was set to represent the water surface elevation of Ramsey Lake. A value of 249.5 m was used, which represented the highest water surface elevation within the operational range of the control dam for Ramsey Lake. Therefore, it is expected that this is a conservatively high estimate for the downstream lake levels and that the levels are lower than 249.5 m for the majority of the year.

The Manning's roughness for the channel were taken from Stormwater Background Study, as part of the Greater Sudbury Official Plan (2006) and other published literature for Manning's value used in HEC-RAS models (Chow, 1959). **Table 3.13** shows the Manning's values that were used within the model.

Table 3.13: Manning's Values Used in HEC-RAS Model

Conditions	Value
Channel	
Clear gravelly channel	0.035
Vegetated channel	0.05
Bedrock	0.025
Overlands	
Swamp lands	0.06
Forests or Dense Brush	0.08
Grass Lands	0.055
Manicured Grass Lands	0.045
Bedrock	0.025
Pipes	
Concrete	0.013
CSP	0.024
Corrugated PVC	0.023

Aquafor modeled each of the culverts and road crossings along the creeks. Inverts and obverts were collected as part of the topographic survey and other parameters such as material type, headwall structures and sediment blockages were also noted. A structural summary of the all culverts is included within **Appendix C**.

Along Roger and Eugene Creek there are long sections of the creek that are piped through storm sewers. These sections of the pipes include bends, drops, and changes in pipe material and size, which HEC-RAS cannot simulate. Therefore, to ensure that the appropriate amount of energy loss was considered through the system a roughness equivalency was estimated for these pipes, which provided a single pipe with the same amount of energy loss as would be expected for the multiple pipe system. This was done for the piped sections along Eugene Street (HEC-RAS station 1409) and Bancroft Road (HEC-RAS 927) on Eugene Creek, and the piped section from Bancroft Road to the CN tracks (HEC-RAS station 1064) on Roger Creek. The calculation sheets for the roughness equivalency are included in **Appendix B**.

Using the GeoHECRAS software, floodlines were generated for the Regional flood and then manually refines to define the estimated limits of the flood. The flood lines are included within **Appendix D**.

In reviewing the floodlines and profiles some observations were made for each of the creeks.

<u>Frobisher Creek:</u>

- The majority of the flooding is contained to the river corridor, with a few exceptions.
- A total of 13 buildings are within the flood limits.
- Under the Regional flood conditions three roads (Bancroft Road, Rita Street and Greenwood Drive) are overtopped.

<u>Roger Creek:</u>

- The majority of the flooding is contained to the river corridor, with the exception of a small spill within the Finlandia Retirement Community.
- Only two (2) buildings are within the flood limits, both within the Finlandia Retirement Community.

- Under the Regional flood conditions one road (4th Avenue) is overtopped, however another culvert and bridge within the Finlandia Retirement Community are also overtopped.

Eugene Creek:

- Through the residential area, the flooding is contained to the river corridor.
- No buildings are within the flood limits and no roads are overtopped.
- However, it is noted that the Bancroft culvert is close to capacity under the Regional conditions, and any increases to the Regional flows could result in backwatering or flooding in the new development upstream of Bancroft Road.

Keast Creek

- No buildings are within the flood limits
- Under the Regional flood conditions all three roads (South Bay Road, Arlington Bulevard and Keast Road) are overtopped.
- Some spilling is anticipated along South Bay Road and Keast Road.

Please noted that the numbers of buildings within the flood limits were identified from the 2009 aerial imagery provided by the City. Only commercial buildings and primary residential buildings (i.e., not sheds or garages) were included in the count. Aquafor interpreted which buildings were sheds and garages from the aerial imagery and this should be confirmed with City staff.

3.2.4 Trunk Storm Sewer Hydraulics and Capacity Assessment

- The primary objective of the Hydraulic and Capacity Assessment is to establish a baseline model of the storm sewer system draining to Ramsey Lake using PCSWMM 2016 and identify and assess the hydraulics of the minor and major systems and identify any capacity deficiencies as a result of modelling the storm sewer system.

3.2.4.1 General

The study area is serviced by a separated sewer system comprised of sanitary and storm sewers. In general, the sanitary sewer is a system of underground pipes that carries sewage from bathrooms, sinks, kitchens, and other plumbing components to a wastewater treatment plant where it is filtered, treated and discharged. The storm sewer is a system designed to carry rainfall runoff and other drainage (excess rain and ground water from impervious surfaces such as paved streets, parking lots, sidewalks and roofs, as well as runoff not infiltrated from pervious surfaces). Provided below illustrates the schematics of different types of sewer systems (**Figure 3.26)**.

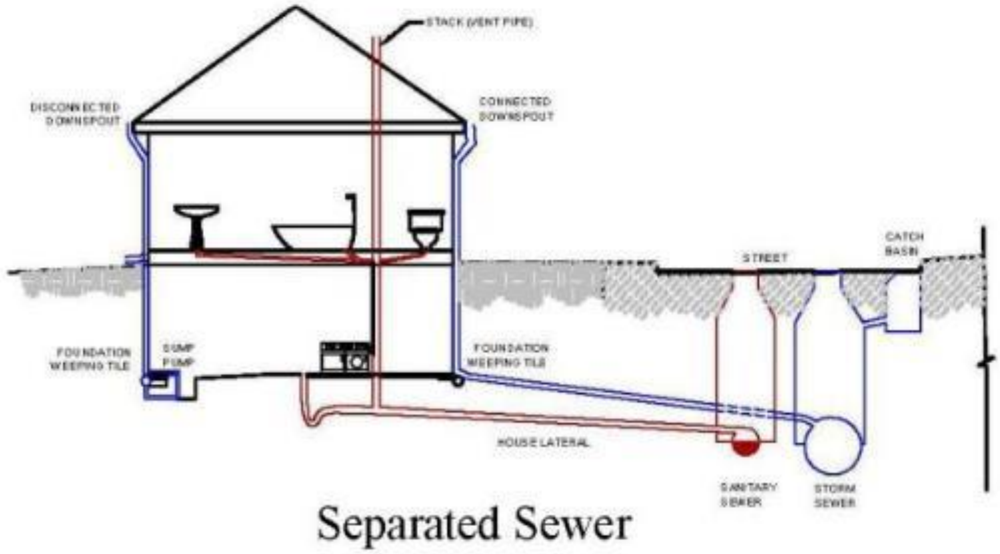


Figure 3.26: Typical Sewer System Profile

The City required that storm sewers of 600 mm in diameter or greater be incorporated into the model for analysis and assessment of the storm sewer system pipes.

Figure 3.27 depicts the storm sewer network including all pipes, maintenance holes, ditches and lake outfalls. The sewer infrastructure data was provided by the City in GIS format and was imported to the PCSWMM model. Missing or suspect data was collected by reviewing plan and profile drawings provided by the City to establish the required information. In situations where it was not possible to collect the information in the field, a data inference process was used to establish the remaining missing information. Inferred information is noted within the model. The major system was inputted into the PCSWMM model using a dual drainage (major and minor systems) scenario and inlet control (catchbasins) with the road cross-sections defined manually. The study team defined all of the sub-catchment areas and information draining towards a maintenance hole into the minor system and input the data into the PCSWMM model. Catch basin inlet rating curve was applied to control drainage into the minor system. The model was run and results generated and compared to the Level of Service requirements in the City of Greater Sudbury Official Plan Stormwater Background Study (2006).

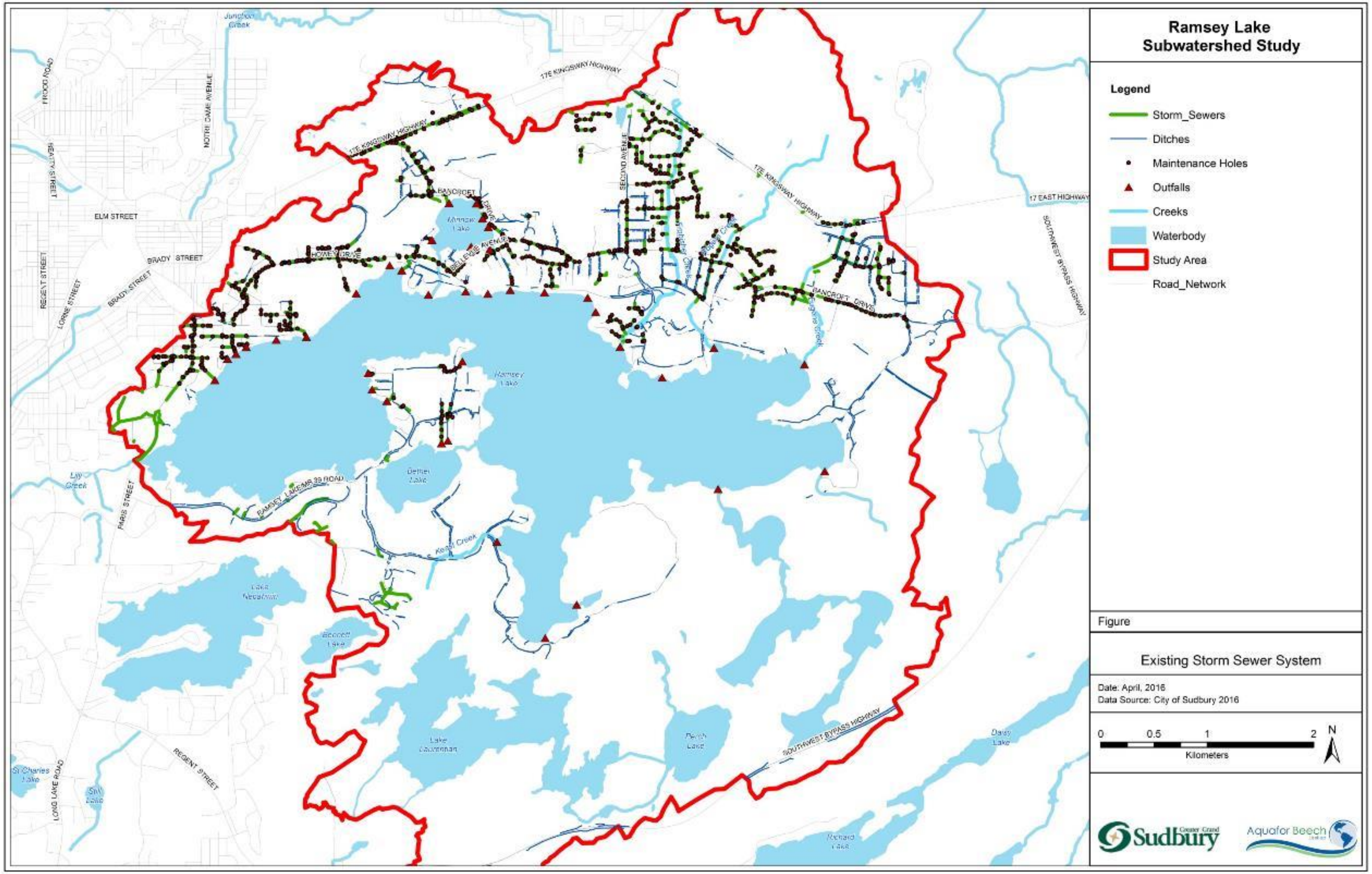


Figure 3.27: Ramsey Lake Storm Sewer Network

3.2.4.2 PCSWMM Model Set-up

As mentioned in **Section 3.2.2.1**, the hydrologic model selected for application in this study was PCSWMM 2016. Through discussions with City and Study Team staff, detailed modelling and capacity assessment was done for the trunk storm sewer system with smaller sewers and ditches included where necessary to complete connections and provide outlet nodes for the delineated storm subcatchment. A total of 357 (14.7 km) of storm sewers of size 600 mm diameter or greater, 202 (8.1 km) storm sewers less than 600 mm diameter and 22 (2.6 km) ditches were input into the model to complete the storm sewer network. Storm subcatchment areas were delineated from maintenance hole to maintenance hole.

To meet the modeling objectives of this study, it was necessary to ensure that the sewer system model was representative of the current physical collection system. The City of Greater Sudbury maintains a GIS database which contains sewer network and manhole data for the storm sewer system. The main source of data for the pipes and manholes is the current City GIS database. The City provided sewer infrastructure information which included pipe diameters, invert elevations, pipe lengths, and maintenance hole ground elevations. The GIS database was then imported into the PCSWMM model. Considerable effort was made to correct data, fill in the data gaps and missing sewer infrastructure information by reviewing as-built and field drawings, and use of best professional judgment to develop an accurate model.

3.2.4.3 Data Gaps

The City provided a series of databases associated with the storm collection system. Databases associated with pipes, manholes and catchbasins provided geometric information such as length, diameters and elevations in order to develop the storm system model.

Data gaps were identified, which could be classified into the following categories:

- Isolated manholes not connected to the network;
- Isolated storm sewers not connected to the system;
- Missing manhole ground surface elevations;
- Missing ditch inlet, outlet and storm outfall information; and

- Missing pipe information such as pipe invert elevations, material

A total of 758 the 937 manhole elevations for the study area were provided. In addition, 244 sewer lengths in the modelled storm sewer network were affected by gaps in the database. Most of the gaps were filled using the digital sewer plan and profile drawings and topographic elevations provided by the City.

Sewers

All sewers were assumed to be circular and there were no indications of different shape. Where pipe material information was not available, the sewer was assumed to be concrete. A Manning's roughness value of 0.013 was applied to all concrete pipes and 0.024 for corrugated steel pipes (assuming 12.5 mm corrugations) as per the Greater Sudbury Engineering Design Manual (2012).

When no information is available, the following assumptions were also considered to complete the sewer network model:

- Missing pipe inverts were assigned inverts based on the average slope of pipe up and downstream of the missing inverts or assigned the downstream invert of the upstream pipe and the upstream invert of the downstream pipe respectively;
- Physical sewer connections that did not have a manhole at the connection point (i.e. private property sewers or laterals connected to collectors) were connected in the model using a dummy manhole.

Ditches

Ditch drainage is either road-side or an off-road channel. Ditch elevations from the DTM were assumed to be the ditch invert (bottom). Typical ditch cross-sections for road-side and off-road were referenced from the Storm Drainage Report for the City of Greater Sudbury (Dillon and Lewis Ltd, April 1964). Where ditch invert elevations were not available, elevation was inferred through review of the topograhic data and professional judgement.

A Manning's roughness value of 0.04 was applied to all ditches in the model..

Any assumed information made in determining model input parameters by Aquafor Beech was documented and flagged in the GIS database.

3.2.4.4 Sub-catchment Area Delineation

Based on the review of the data provided, there are no sub-catchment areas that were defined by the City within the study area. The sub-catchment areas were defined manually by Aquafor Beech and the approach for defining the sub-catchment areas was based on the size of the sewer running through it.

As a requirement from the City, storm sewers greater than 600 mm were included in the model. In areas where the storm sewers are not modelled, (as the sewer size does not meet the minimum size) the sub-catchment areas are aggregated (broken lines) and the lumped subcatchment tributary to the downstream maintenance hole is defined. For other areas (solid lines) where the storm sewer is modelled, the sub-catchment area tributary to the storm sewer is used. **Figure 3.28** illustrates the difference between the pipes that were included in the model (solid lines) and pipes which were not modelled (broken lines) for the storm sewer system.

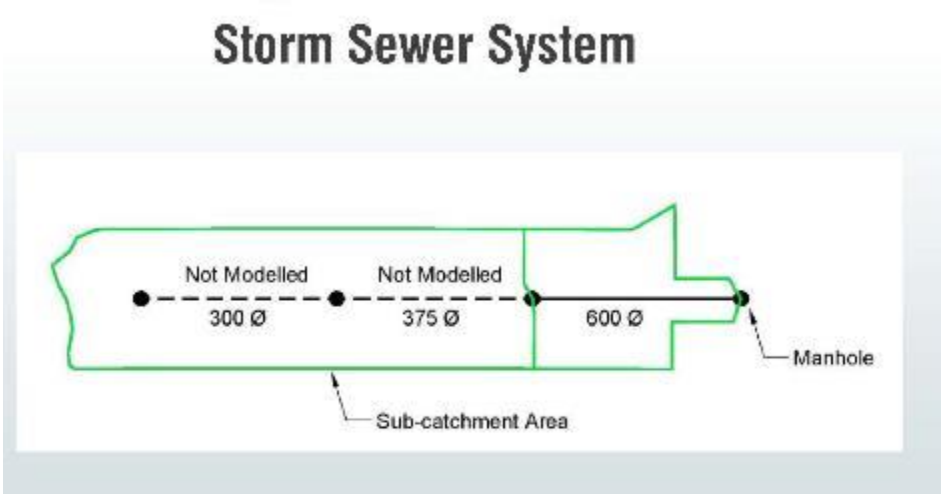


Figure 3.28: Modelling Approach

The storm sewer model was assembled using the database provided by the City and considering every maintenance hole as a node.

Storm system catchment areas were delineated manually in GIS using manual interpretation of urban features and topography. Overland flow routes and low-points were generated from the DEM provided by the major drainage areas which were subsequently broken down to individual subcatchments based on the major/minor system network. Topographic layers and ortho images were used in conjunction with storm system elements (pipes, maintenance holes and catchbasins) to delineate subcatchments boundaries in GIS. Each delineated subcatchment was associated with a maintenance hole as the load point to the major and minor system storm model.

Figure 3.29 shows an overview of the modelled sewers, ditches and delineated subcatchment areas draining to the sewer network.

Required parameters for each storm subcatchment area similar to the hydrologic model as described in Section 3.2.2.1 and include area, flow length, infiltration parameters, percent directly connected impervious area, and slope that were inputted into the model once the subcatchment areas were delineated. The parameters for each subcatchment are tabulated in **Appendix A**.

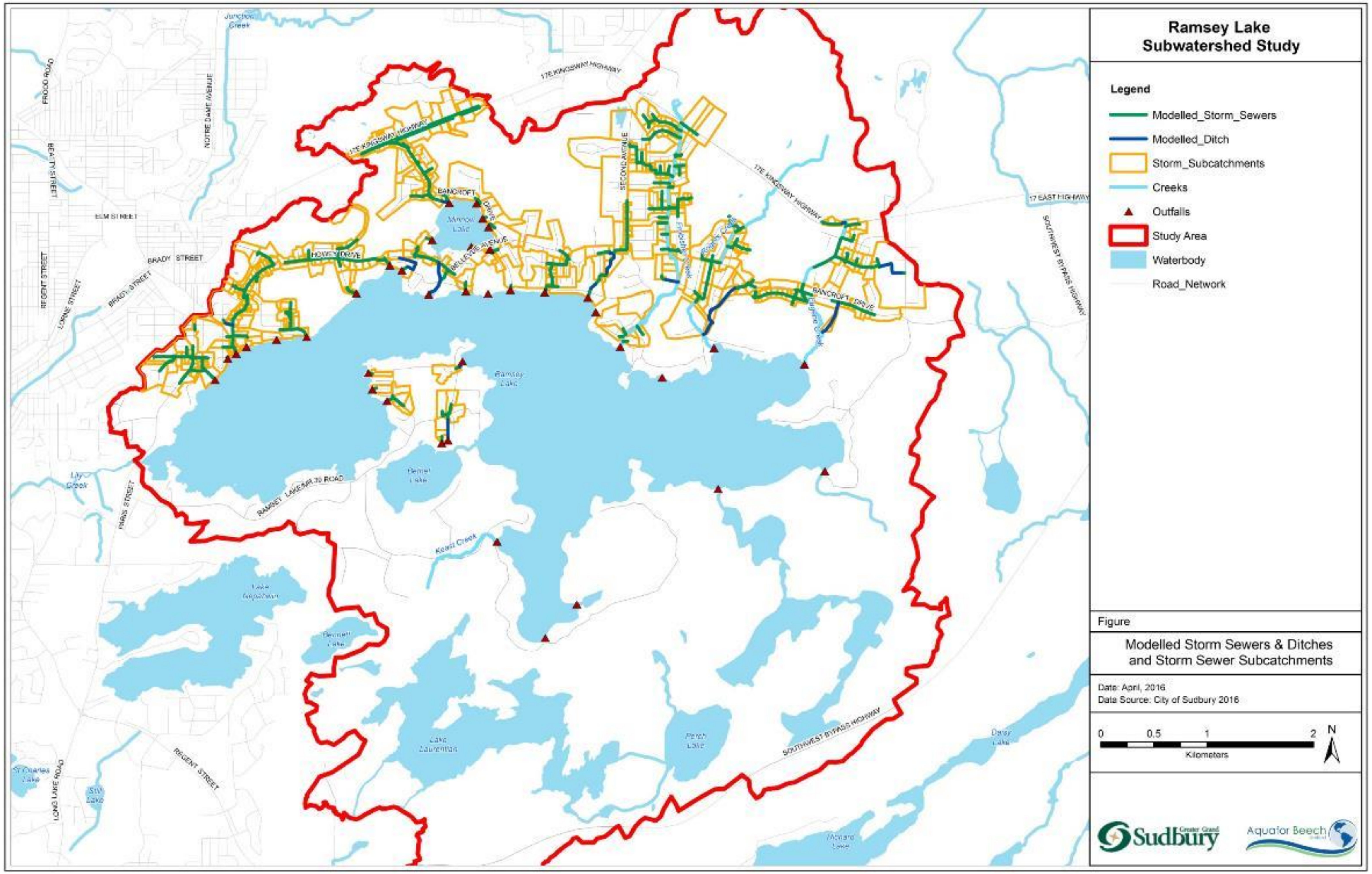


Figure 3.29: Storm Subcatchment Areas

3.2.4.5 Connectivity with Smaller Pipes and Ditches

Smaller pipes and ditches were also included where the network needed to be built out for connectivity to address flows entering the trunk system at junctions forming a "T" or where sewers outlet into ditches and in some cases back into sewers.

Figure 3.30 below shows a case in the model where an 825 mm diameter trunk storm sewer comes to a "T" junction at an upstream maintenance hole where flows enter from the west and east. Upstream to the west are pipes that are less than 600 mm diameter. The first length of local sewer upstream of "T" junction is 300 mm diameter and is included in the model with the storm subcatchment area tributary defined. Further upstream, the local sewers are not modelled and the lumped subcatchment area tributary drains to the downstream node.

Figure 3.30: Connectivity with Pipes < 600 mm Diameter

Figure 3.31 shows a case where the sewer system connects with a ditch flowing downstream. In this case, the downstream MH of the 750 mm diameter pipe is actually a ditch outlet that was defined by viewing ortho images. In many cases the invert elevation of the downstream end of the trunk sewer at the ditch outlet was not in the database and had to be assumed to be equal to the upstream elevation of the ditch.

Figure 3.31: Connectivity with Ditch

3.2.4.6 Land Use and Runoff

Percent impervious was estimated from a combination of land use mapping and ortho images. A total of twelve representative subcatchment areas where developed using ortho imagery to define impervious area contributions from impervious area (roofs, paved driveways and roads) and pervious area. A total of 10 representative land use areas were defined with percent impervious and pervious calculated as shown in**Table 3.14**.

Table 3.14: Representative Land use Areas

Subcatchment ID	Nearest Intersection	Primary Land Use	Secondary Land Use	OP Code	Total % Impervious	Total % Pervious
330	Third Ave. & Highgate Rd.	Residential	Single Family	RSF1	43.38%	56.62%
341	Garland Cres. & Hebert St.	Residential	Single Family	RSF2	64.19%	35.81%
45	Annie St. & Sunday St.	Residential	Single Family	RSF3	28.26%	71.74%
311	Greenbier Dr. & Scarlet Rd.	Residential	Mixed Density	RMD	45.78%	54.22%
48	Morris St. & Annie St.	Residential	High Density	RHD	63.65%	36.35%
289	Carmichael Village Rd & Camelot Dr.	Residential	Townhouse	RTH	48.91%	51.09%
211	Bancroft Dr. & Trans-Canada Hwy.	Commercial - Residential	Mixed – Use	RC	51.67%	48.33%
193	Trans-Canada Hwy & Bancroft Dr.	Commercial	Shopping Area	COM	85.00%	15.00%
329	Trans-Canada Hwy & Third Ave.	Industrial	Industrial Area	IND	72.00%	28.00%
233	Bancroft Dr. & Lonsdale Ave.	Institutional	Schools	INS	26.68%	73.32%
9	Any	Intersection	Intersection	INT	98.00%	2.00%
7	Facer St. & Ramsey Rd.	Open Space	Parks	OSP	10.00%	90.00%

For each of the representative areas, the overall impervious values were determined through a weighted average of the proportion of areas of roof, road, parking / driveway as well as topography.

The Ramsey Lake Study Area is assumed to be a fully separated area. For fully separated systems, runoff will ultimately make its way to the storm sewer. It is however, still important to understand the flow path for water which originally falls on the roofs of buildings. For example, if the roof downspout is directly connected to the storm sewer then virtually all of the water will make its way to the storm sewer system. Alternatively, if the downspout discharges to the ground then some of the flow will infiltrate into the ground, thereby reducing the amount of flow which makes its way to the storm sewer system. An example of this type of system is illustrated in **Figure 3.32** below.

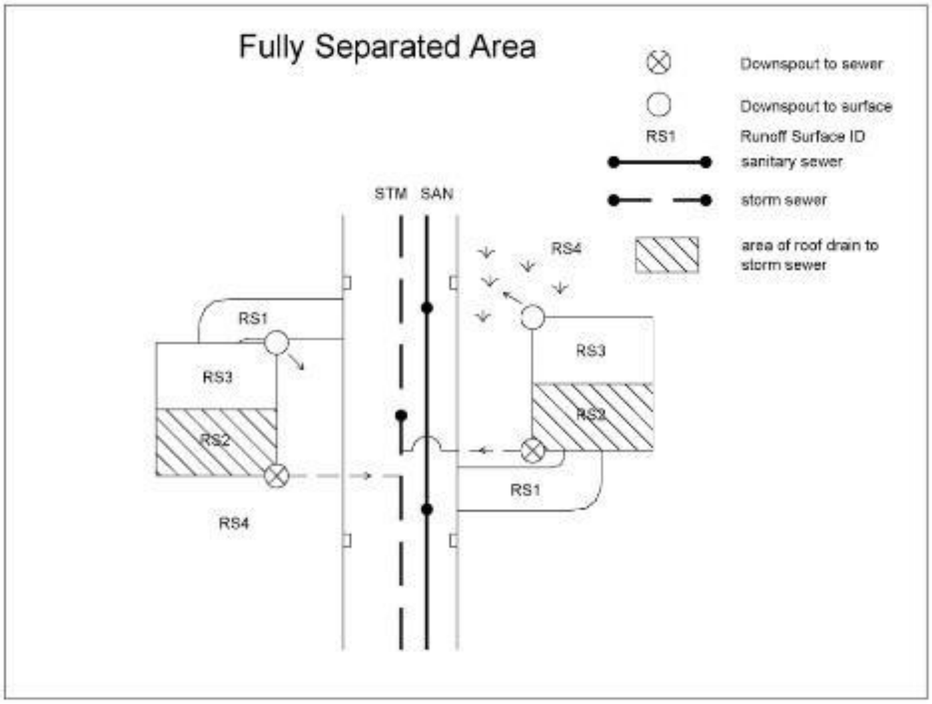


Figure 3.32: Direction of Runoff in Fully Separated Areas

The above figure describes four types of runoff surfaces (RS) that exist in every subcatchment:

- Runoff Surface 1 is for the impervious surfaces (street pavement, sidewalks, driveways, etc.).
- Runoff Surface 2 is for roof areas which are connected directly to the sewer.
- Runoff Surface 3 is for disconnected roof areas and for flows spilled from the roofs to the ground
- Runoff Surface 4 is for the pervious surfaces (grass open space areas).

In the case of the storm system, the runoff from Runoff Surfaces 1 and 2 (**Figure 3.32**) are directed into the minor system, but are restricted by the inlet capture curve and number of catch basins assigned to the manhole within the subcatchment. When the surface runoff exceeds the maximum inlet capacity to the minor system, the excess runoff cascades overland where it either reaches the major system outlet or is captured by the minor system further downstream.

In establishing the general flow patterns for the Ramsey Lake Subwatershed storm sewer system, the representative land use areas were examined to visually using Google Earth to determine the percentage of downspouts that discharge to the ground verses those that are directly connected to the sewer. A 50% downspout disconnection (disconnected roof) rate was assumed for residential areas RSF1, RSF3 and RTH in **Table 3.15** with half of the roof runoff directed to pervious surface. All other areas assumed 100% connection of downspouts.

Table 3.15: Runoff Curve Numbers for Urban Areas

Land Use Description	A	B	C	D
Cultivated land				
Without conservation treatment	72	81	88	91
With conservation treatment	62	71	78	81
Pasture or range land				
Poor condition	68	79	86	89
Good condition	39	61	74	80
Meadow				
Good condition	30	58	71	78
Wood or forest land				
Thin stand, poor cover, no mulch	45	66	77	83
Good cover[2]	25	55	70	77
Open spaces, lawns, parks, golf courses, cemeteries, etc.				
Good condition: grass cover on 75% or more of the area	39	61	74	80
Fair condition: grass cover on 50-75% of the area	49	69	79	84
Commercial and business areas (85% impervious)	89	92	94	95
Industrial districts (72% impervious)	81	88	91	93
Residential[3]				
Average lot size (% Impervious[4])	77	85	90	92
1/8 ac or less (65)	61	75	83	87
1/4 ac (38)	57	72	81	86
1/3 ac (30)	54	70	80	85
1/2 ac (25)	51	68	79	84
1 ac (20)				
Paved parking lots, roofs, driveways, etc.[5]	98	98	98	98
Streets and roads				
Paved with curbs and storm sewers[5]	98	98	98	98
Gravel	76	85	89	91
Dirt	72	82	87	89

Impervious surfaces have a CN value of 98 while lower CN values indicate a lesser degree of imperviousness.

Surface infiltration was simulated using the Curve Number Method in PCSWMM. A composite curve number was calculated based on the percent impervious (connect roof, paved driveway, road) and pervious surfaces (open space, woodland) under class D hydrologic soil group using the Runoff Curve Numbers for Urban Areas shown in **Table 3.15**. The CN values calculated for each subcatchment area are shown in **Table 5** of **Appendix A**.

3.2.4.7 Flow Path Length

The length of the flow path is used to approximate the lag time observed between the commencement of rainfall and the occurrence of flows in the storm sewer system. In cases where the sub-catchment area drains directly to a sewer, the travel time from the subcatchment area to the sewer needs to be defined. In cases where the sub-catchment area drains to a sewer which is not modelled then the travel time in the sewer also has to be determined.

The general calculation for flow length is defined below adapting the approach used in the hydrologic model to the storm sewer model:

Flow Length = L + Lu,
where L = Overland Flow Length and Lu = Length of Main Drainage Channel

Subcatchment Area Draining to Modelled Storm Sewer Segment

Using the approach developed for the hydrologic model for urban subcatchment areas as basis, the main drainage channel (Lu) is defined as the storm sewer segment from the upstream maintenance hole to the downstream maintenance hole. The length of the 30 m was assumed for overland flow length (L) to the storm sewer in urban areas and 150 m for rural and industrial areas. For the storm subcatchment areas where L is less than 30 m, the flow length is simply the length of the storm sewer segment.

Lumped Subcatchment Area Draining to Downstream Modelled Storm Sewer Segment

For storm sewer segments not modelled, but connected downstream to modelled storm sewers, the flow length calculation is similar. However, Lu is defined as the primary longest roadway network from the upstream end of the subcatchment to the downstream end, with a defined drainage slope towards the outlet (the upstream maintenance hole of the downstream /receiving storm sewer segment).

Subcatchment Area Draining to Modelled Ditch

For storm subcatchment areas draining to off-road ditches with outlets either to a storm sewer or to a creek, the flow length calculation was based on rural overland flow length with the main drainage channel defined as the length of the ditch from the upstream end to the downstream outlet. The flow path length calculations and results for each subcatchment area are shown in **Appendix A**.

3.2.4.8 Catch Basin Inlet Capacity (Inlet Control)

Road drainage throughout the City consists of surface drainage, conveyance elements and sewer inlets which are either pipes or ditches. Sewer inlets play a key role in road drainage because they affect both the rate of runoff removal from the road surface and the degree of utilization of the conveyance elements. It is generally necessary to incorporate inlet control in the sewer system analysis in order to characterize the existing storm sewer capacity.

In general, the storm sewer minor system is typically designed for the 2-year to 10-year storm. Under the assumption that all surface runoff enters the sewer system unimpeded for frequent storm events, then the capacity of sewer system should be sufficient to carry these smaller events. For larger storm events, flows from the runoff module will typically exceed the capacity of the catch basin inlets. If the model does not limit the capacity of the inlets, issues arise relating to associated flooding and unrealistic surcharging of the system as the inflow are not be appropriately represented.

In the model, inlet control is applied at all maintenance holes defining each node as a gully and applying the catch basin inlet rating curve. The City of Toronto Basement Flooding Modelling

Guidelines (2014) was used as a reference guide to define typical catch basin inlet capacity curves. Catch basin inlet types were defined based on identifying the type of catch basin inlet seen in the representative land use areas in the Ramsey Lake Study Area on Google Earth. Based on a review of catch basins in the Ramsey Lake subwatershed, a majority of catch basin inlets appear to be of the parallel slot or fishbone type single catch basins or double catch basins at low points. An inlet capacity of 60 L/s was applied by inputting a typical catch basin inlet curve for fishbone inlet at a 0.5% to 3.99% slope (**Figure 3.33**).

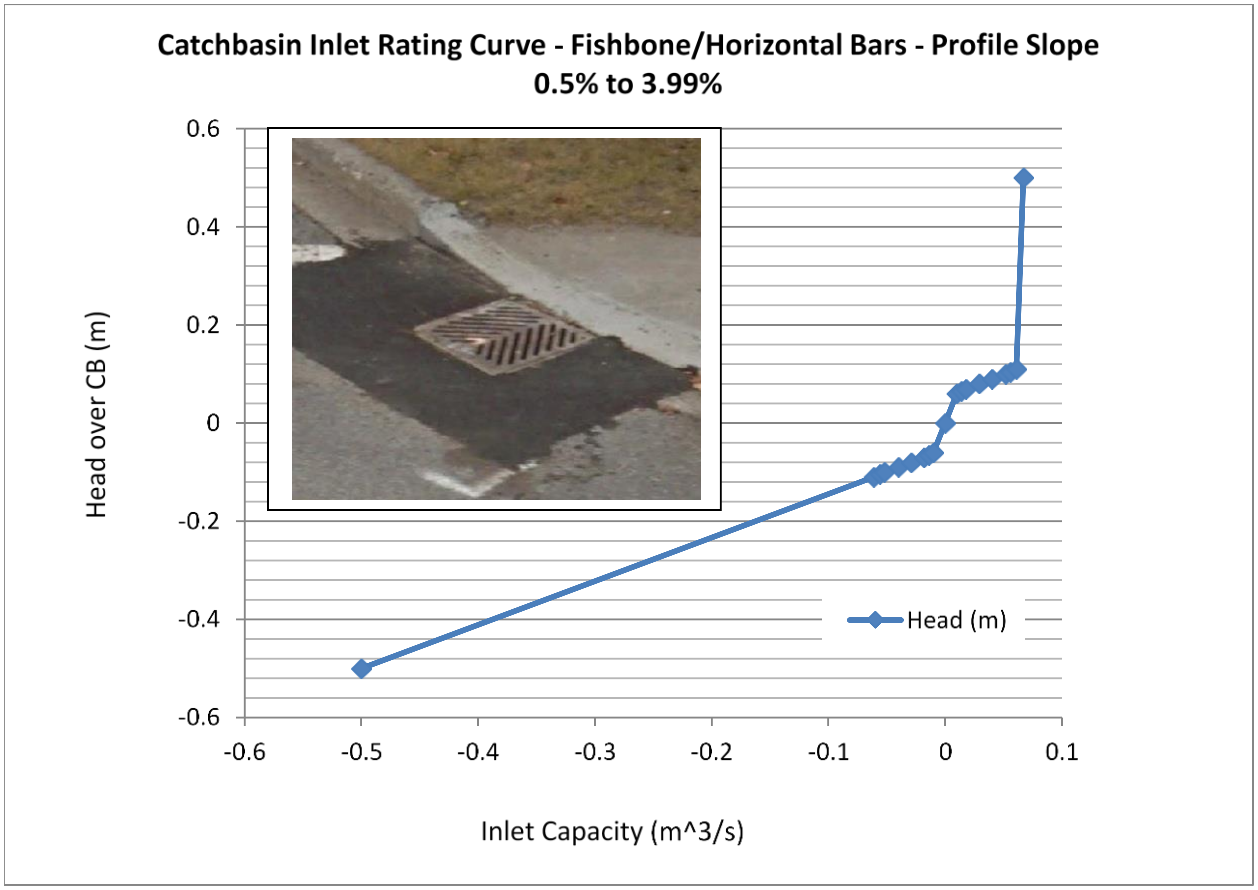


Figure 3.33: Catch Basin Inlet Rating Curve

3.2.4.9 Major System

The major system considers flow that is channeled overland into the minor system via the catch basins and depth of surface ponding if the rainfall intensity is greater than the catch basin capacity or if the minor system is in a state of surcharge. The major system model was set up in PCSWMM by selecting the "Dual Drainage" option and defining the major system cross section. The cross section applied used a 20 m road right-of-way width and a curb depth of 0.3 m was used to represent a typical road and major system channel.

For the aggregated subcatchment areas, surface flow is assumed and directed to the downstream node where is enters the minor system through the upstream node of the downstream subcatchment. In some cases, a dummy node is defined where flows are conveyed via a ditch into the minor system. Excess flow from the aggregated areas is modelled as flow through the major system to the next catch basin/node.

3.2.4.10 Design Storms

The City of the Sudbury Official Plan Stormwater Background study (2006) suggests that for the design of the minor system, the design storm shall be based on the classification of the road to be serviced. The design criteria are listed in **Table 3.16** below:

Table 3.16: Storm Sewer Level of Service

Road Classification	Design Storm Return Period
Urban Arterial	10 Year
Rural Arterial / Collector Road	5 Year
Local Road	2 Year

Storm events were generated using IDF data from the Stormwater Background Study (2006). For rainfall scenarios considering climate change, 15% was added to the event. For the minor system, the following storms were modelled: 1:2-year, 1:5-year, 1: 10-year, 1:25-year, 1:50-year and 1:100-year return periods. Results of the model output show total lengths of surcharged storm sewers; these results are presented in the report for the design storms per **Table 3.16** with the remaining results in **Appendix A**.

For the major system, the City of the Sudbury Official Plan Stormwater Background study (2006) suggests that the design peak flow utilized should be the largest of those generated by the 100-year design storm or the regional storm.

Based on the results of the hydrologic model, the design storms for the assessment of the major system included the used included:

- 100-year 6-hour Chicago (design storm)
- Timmins Storm (regional)

3.2.4.11 Results

The Ramsey Lake Hydraulic and Hydrologic Model was applied to assess the performance of the minor system (state of surcharge of the sewers) as well as to assess the major system flow depths under the 100-year storm. **Figure 3.34** through **Figure 3.36** show the results of the model simulations for the minor system for the 2-year through 10-year design storm (assessment of 2-year through 100-year events for the minor system in **Appendix A**). **Table 3.17** summarizes the total length of sewers at capacity and surcharged.

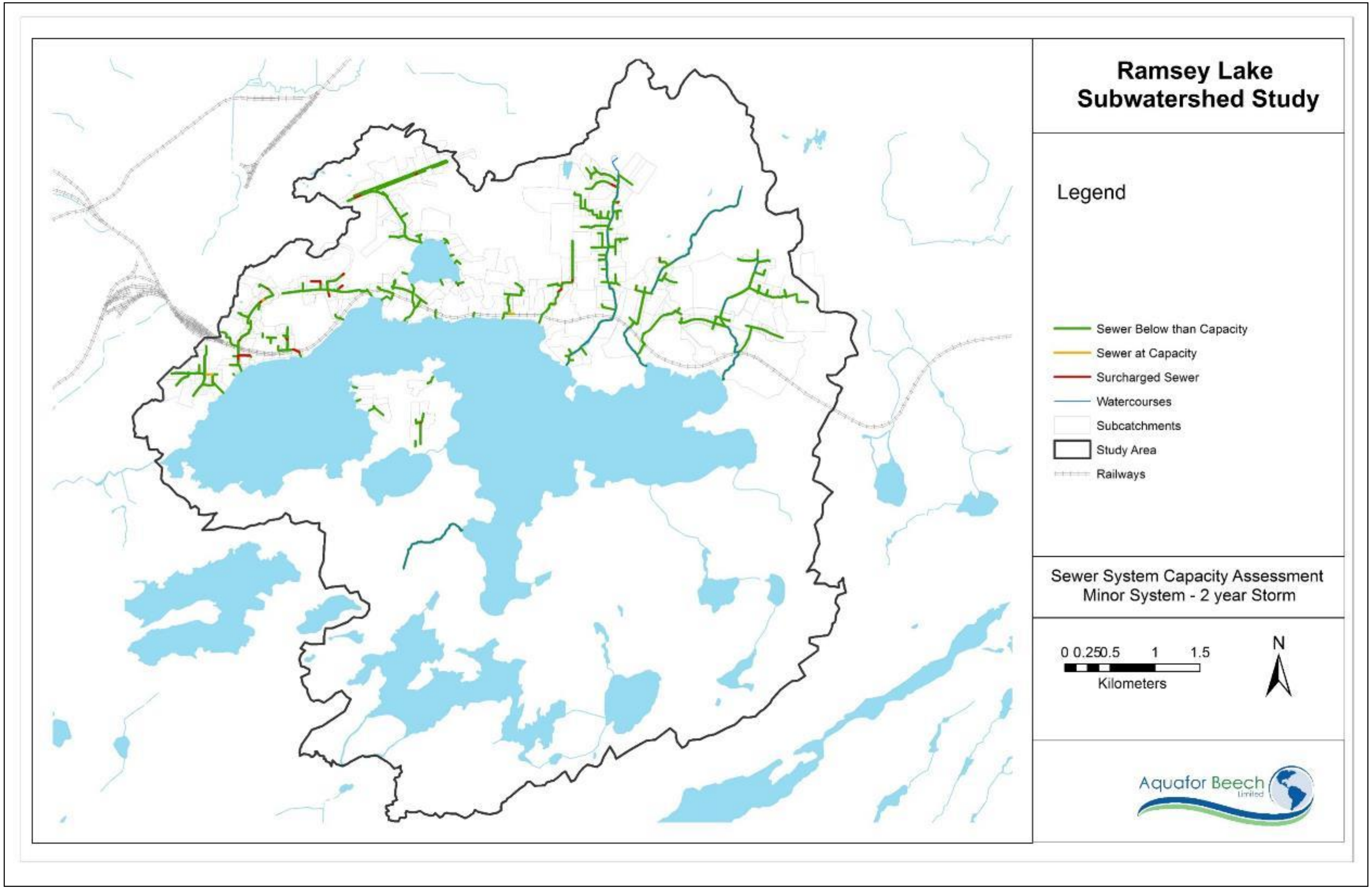


Figure 3.34: Storm Sewer Capacity Assessment: 2-Year Design Storm

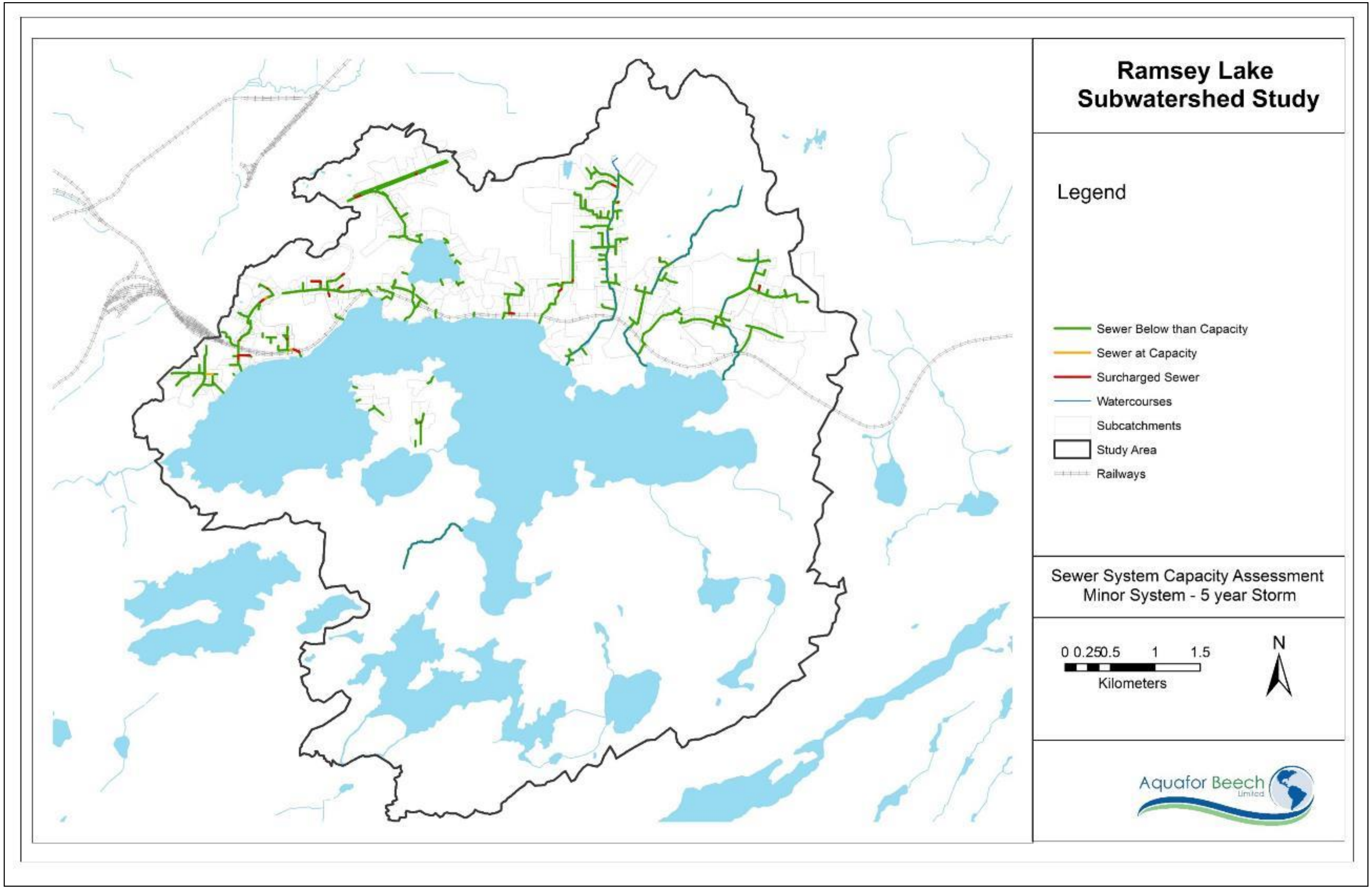


Figure 3.35: Storm Sewer System Capacity Assessment - 5 Year Design Storm

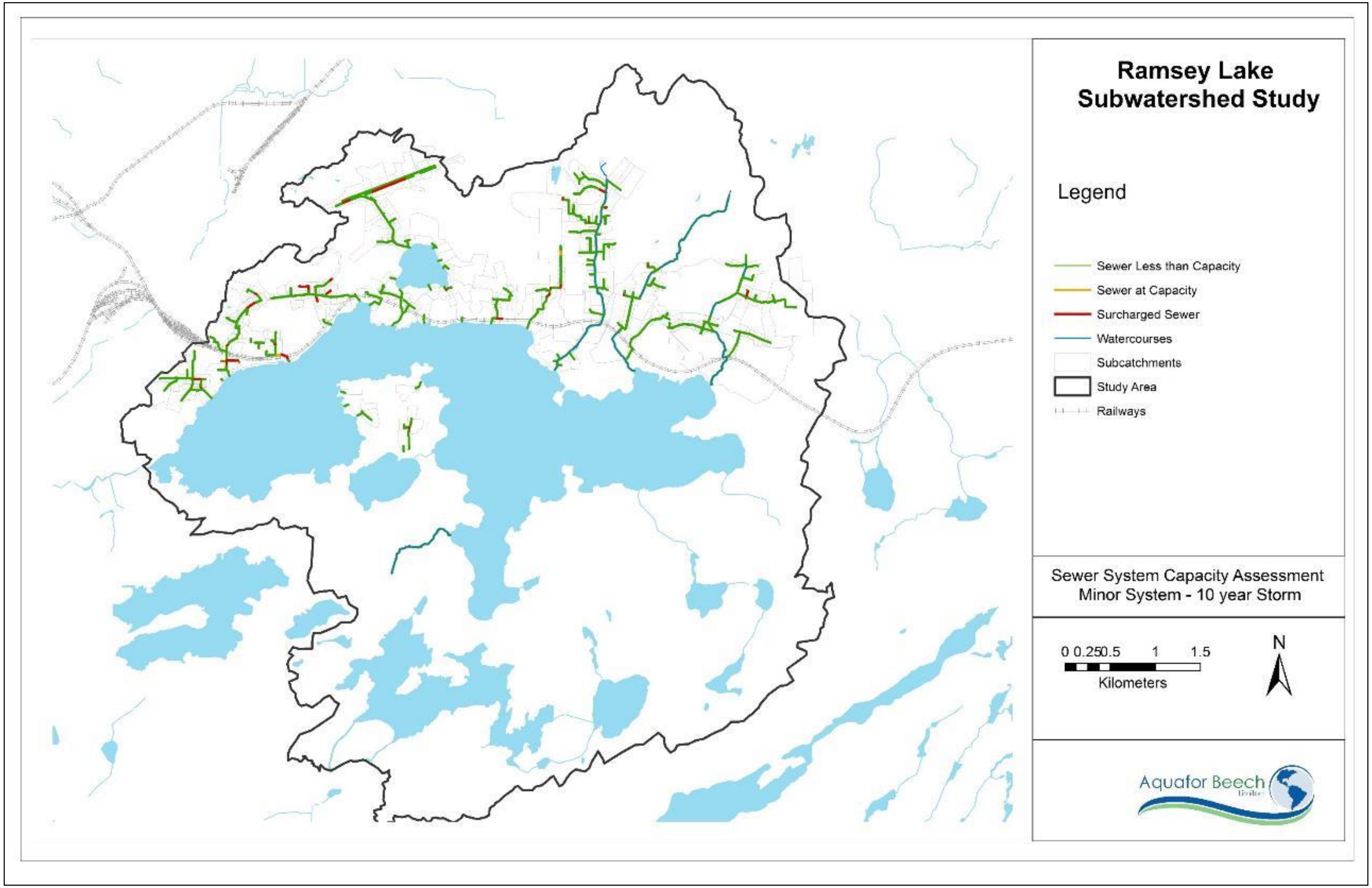


Figure 3.36: Storm Sewer System Capacity Assessment: 10 Year Design Storm

Table 3.17: Model Results for Existing Design Storm for Minor System

Scenario (Level of Service)	Length of Storm Sewer at Full Capacity / Surcharged (m)	
	Full Capacity[1]	Surcharged[2]
2-yr Design Storm	229	975
5-yr Design Strom	221	1,143
10-yr Design Storm	102	1,634

[1] Full capacity is a hydraulic grade line between pipe obvert and surface grade

[2] Surcharged is hydraulic grade line greater than the surface grade

Of the 14.7 km of sewers modelled 1.6 km or 11% of the storm sewers area in a state of surcharge under the 10-year design and does not meet the design criteria as per the City of Greater Sudbury Official Plan Stormwater Background Study (2006). The relatively low number of surcharged sewers modelled is the result of inlet control being applied the entrances to the minor system via the catch basins.

Figure 3.37 and **Figure 3.38** summarizes the major system flow depths based on a 20 m road right-of-way with a 300 mm curb depth for the 100-year Chicago and the Regional (Timmins) Design Storm respectively. When the ponding depth exceeds the curb depth the right-of-way is considered as in a flood state. Major system links shown in red indicate areas where the model shows the depth of stormwater exceeding the curb depth. Inlet control restricts flows into the minor system that can form surface ponding conditions during the 100 year and Regional events.

The results are summarized below:

- Under the 100-year Chicago Design Storm., the model indicates that 5,003 m of the road right-of-way is flooded;
- Under the Regional (Timmins) Design Storm, the model indicates that 2,914 m of the road right-of-way area is flooded

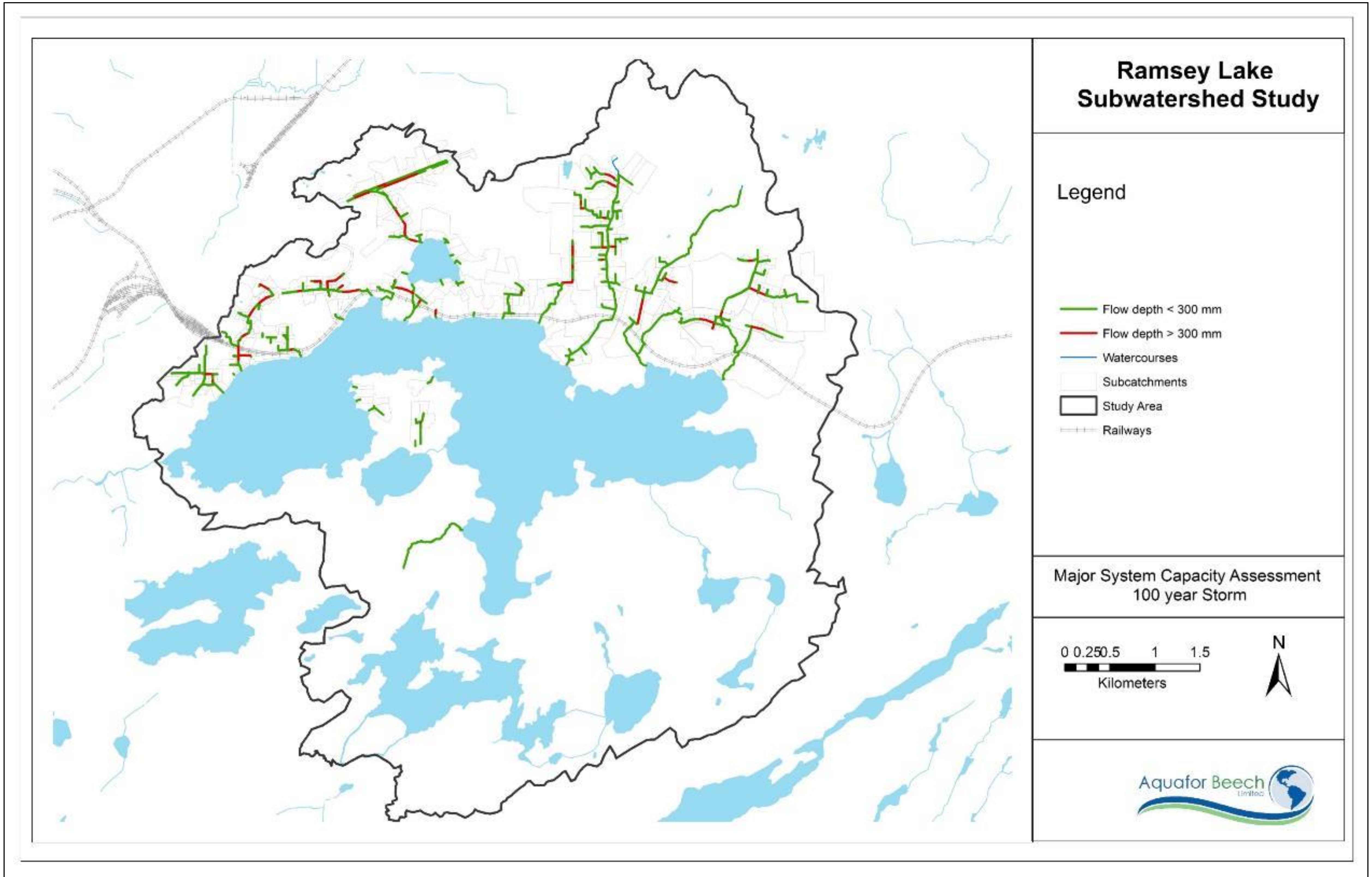


Figure 3.37: Major System Capacity under 100 Year Design Storm

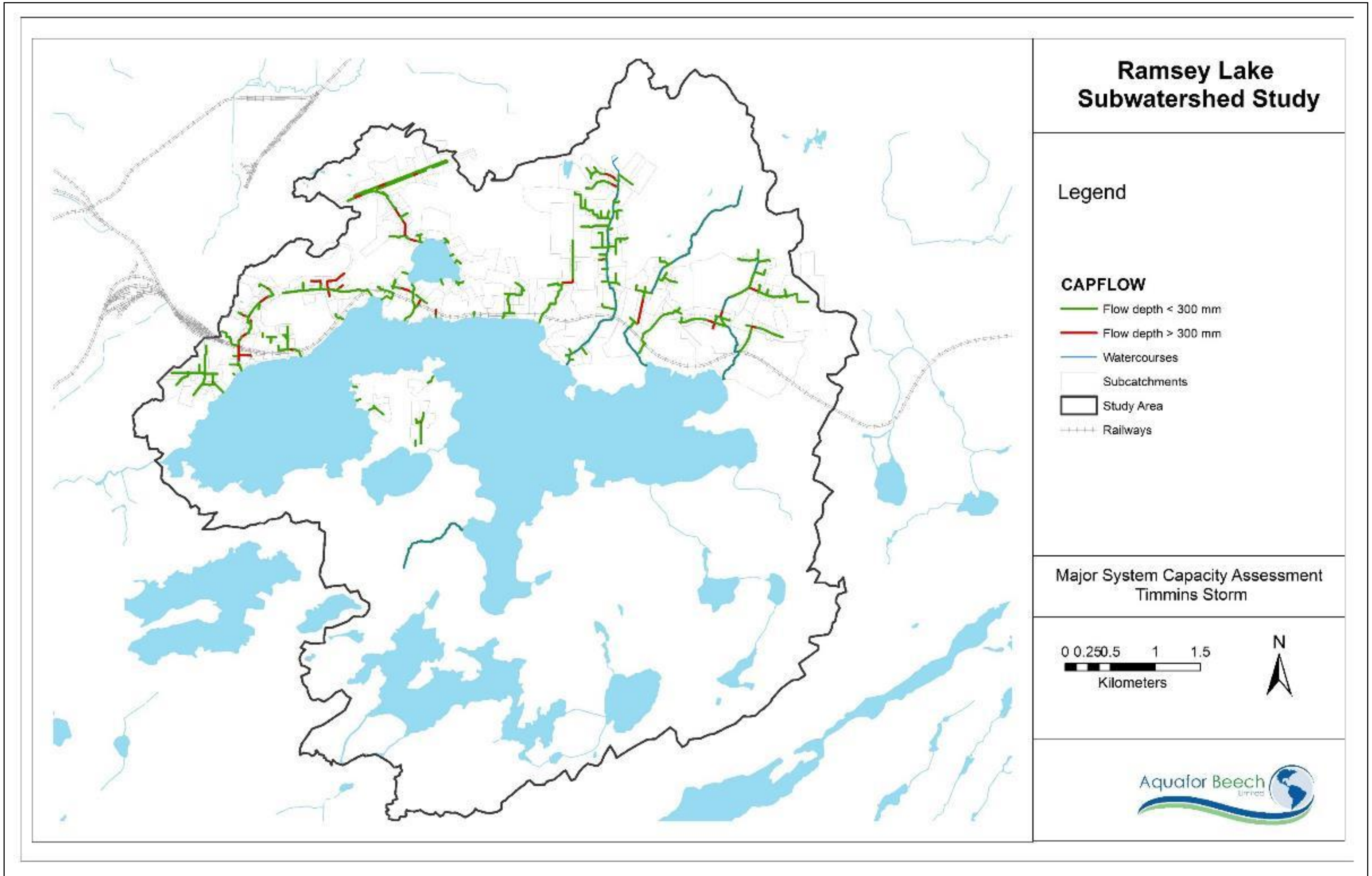


Figure 3.38: Major System Assessment - Regional Design Storm

3.2.5 Water Quality

3.2.5.1 Ramsey Lake

Water in Ramsey Lake is a slightly alkaline (pH 7.3) with moderate conductivity (272 µS/cm) and high surficial concentrations of dissolved oxygen (typically ~12 mg/L). The lake has a high buffering capacity (alkalinity ~30 mg/L), explaining why the Lake has avoided acidification impacts unlike many other lakes in the region (Keller, 1992; Gunn and Keller, 1995). Visibility in Ramsey Lake is currently generally good (Secchi disk depth ~4 m).

Ramsey Lake has, historically, been classified as oligotrophic and able to support a coldwater fishery (City of Greater Sudbury 2013). Historically, natural background concentrations of phosphorus were probably between about 3 and 5 µg/L (Hutchinson Environmental Sciences Ltd., 2014). Runoff from urban land use resulted in an increase in phosphorus concentrations that have varied since the 1970's between about 10 and 17 µg/L (**Figure 3.39**). The lake currently classifies as meso-eutrophic or moderately nutrient enriched. Extensive beds of macrophytes throughout Ramsey Lake (see photograph **Figure 3.48**) are one result of higher-than-natural phosphorus loads. Secchi disk depth in the lake in the late 2000's has been consistently between 3.5 and 4 m, reflecting the meso-trophic status of the lake.

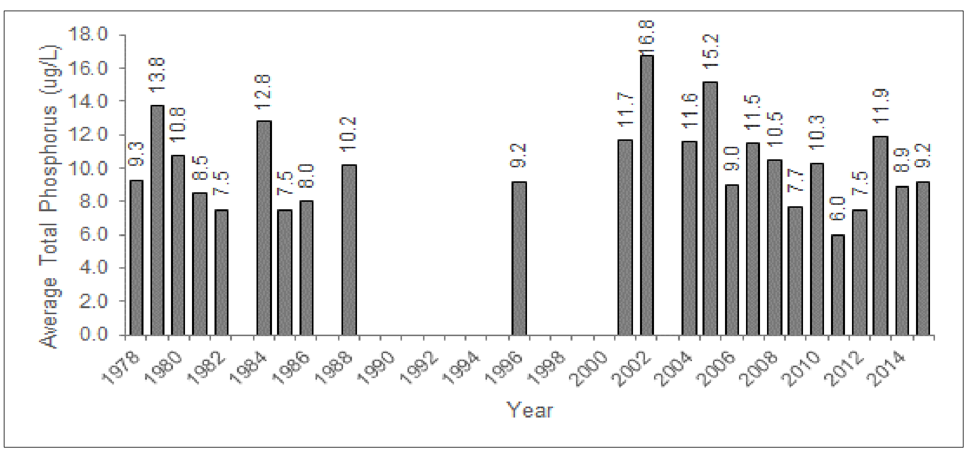


Figure 3.39 Spring Phosphorus Concentrations, Ramsey Lake 1978-2014.
Figure note: Data between 1978 and 2005 and between 2007 and 2015 provided by the City of Greater Sudbury, 2014. Data for 2006 provided by Bergeron, J. M., 2012. Data for 2015 provided by MECP: Lake Partner Program online interactive map (https://www.ontario.ca/environment-and-energy/map-lake-partner).

There has been an increase in both sodium and chloride concentrations since 1991, although most of this increase occurred between 1991 and 2000 (**Figure 3.40**). The Ontario Drinking Water Standard for sodium is 200 mg/L. The City is, however, required to notify the medical officer of health when concentrations exceed 20 mg/L. Sodium concentrations in Ramsey Lake, as a drinking water source for the City, is currently a concern as concentrations have been above 20 mg/L since before 1991. However, sodium concentrations have not followed a significant upward trend since 2003. The long-term water quality guideline for chloride for the protection of aquatic life is 120 mg/L. After a steep increase between 1996 and 2001, chloride concentrations generally stabilized until 2007 before gradually increasing to 2013. Despite annual fluctuations, there has been a slight decline in chloride concentrations from 2013 to 2017 when the most recent data are available.

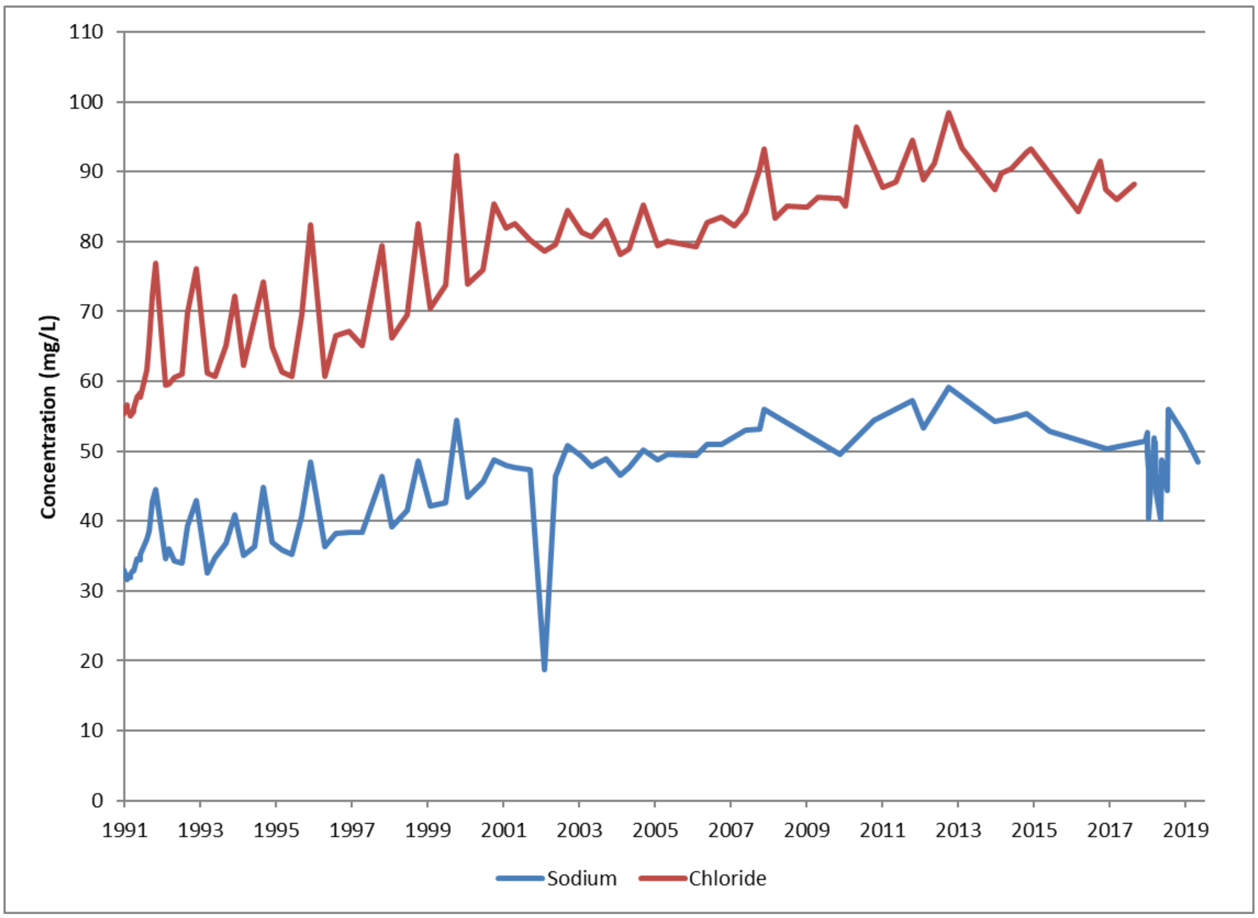


Figure 3.40 Variations in sodium and chloride in Ramsey Lake

Related to high concentrations of phosphorus and increasing concentrations of sodium, Ramsey

Lake has been subject to subject blooms of cyanobacteria, which upon die off can result in the release of cyanotoxins. The released toxins pose risks to the domestic water supply. Blooms of cyanobacteria were reported from the lake in 2008, 2010, 2011 and 2012 (City of Greater Sudbury, 2014).

Metals concentrations in lakes in the Sudbury area have been elevated from natural levels as a result of exposure to emissions from local smelter operations. Ramsey Lake was no exception. Copper (~12 µg/L) and nickel (~ 55 µg/L) concentrations in Ramsey Lake have recently (Keller et al., 2004) been reported above their respective PWQO's (5 µg Cu/L; 25 µg Ni/L) (MECP, 2019). Nickel concentrations are about one half of what they were in the late 70's (Nriagu et al., 1982; Nriagu et al., 1998; Shumaimi-Othman et al., 2006). Metals generally, including copper and nickel have decreased in response to a reduction in emissions of metal particulates from smelters (Keller et al., 2004, Shumaimi-Othman et al., 2006).

3.2.5.2 Lily Creek

Lily Creek is located at the western end of Ramsey Lake and is the sole outflow of the lake. The upstream limit of Lily Creek is an extensive cattail marsh which flows into a defined channel downstream. Lily Creek has slightly alkaline water (pH 7.7) with moderate conductivity (481 µS/cm), and moderate water hardness (92 mg/L) (MOE, Lake Partner Program). Total Phosphorus has been measured regularly in Lily Creek by the Ministry of the Environment, and concentrations there provide an integration of concentrations (and thus loads) of phosphorus leaving the lake. Phosphorus in the outflow of Ramsey Lake tended to vary between 2 and 60 µg/L, with a few concentration spikes reaching up to 98 µg/L. In general, phosphorus concentrations in Lily Creek tended to be higher than in Ramsey Lake itself (

Figure 3.41). Total Phosphorus levels in Lily Creek were above the Provincial Water Quality Objective (PWQO, MECP, 2019) for creek (30 µg/L) in 10 samples over in 10 years.

Chloride levels in Lily Creek were measured by the MOE between 2007 and 2016 (

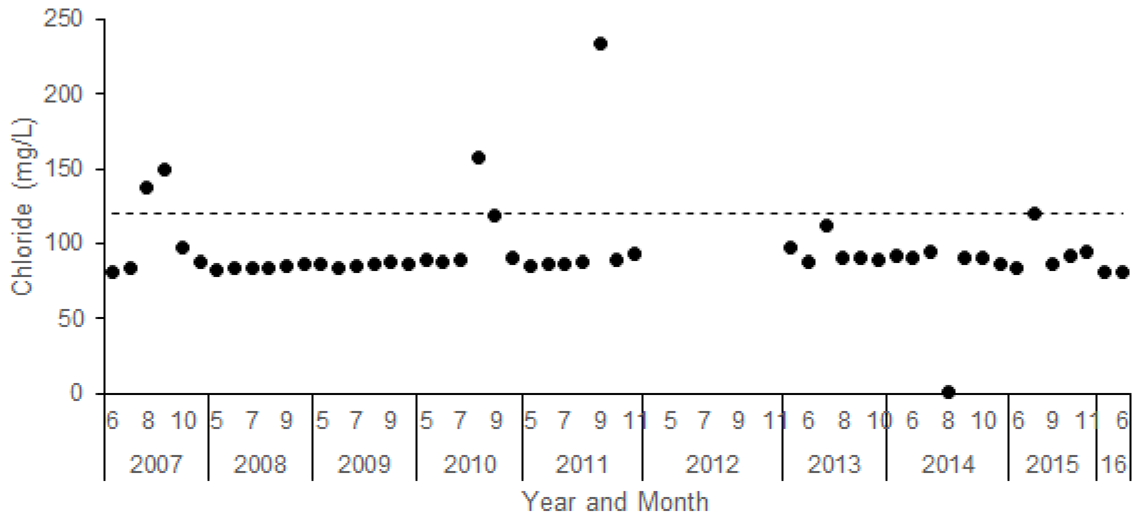


Figure 3.42). Chloride levels varied between 1.1 and 120 mg/L, with a few concentration spikes reaching up to 233 mg/L. These concentrations were higher than what was typically found in Ramsey Lake. Chloride levels never exceeded the CCME (2001) short-term guideline (640 mg/L), but did exceed the long-term guideline (120 mg/L) on several occasions.

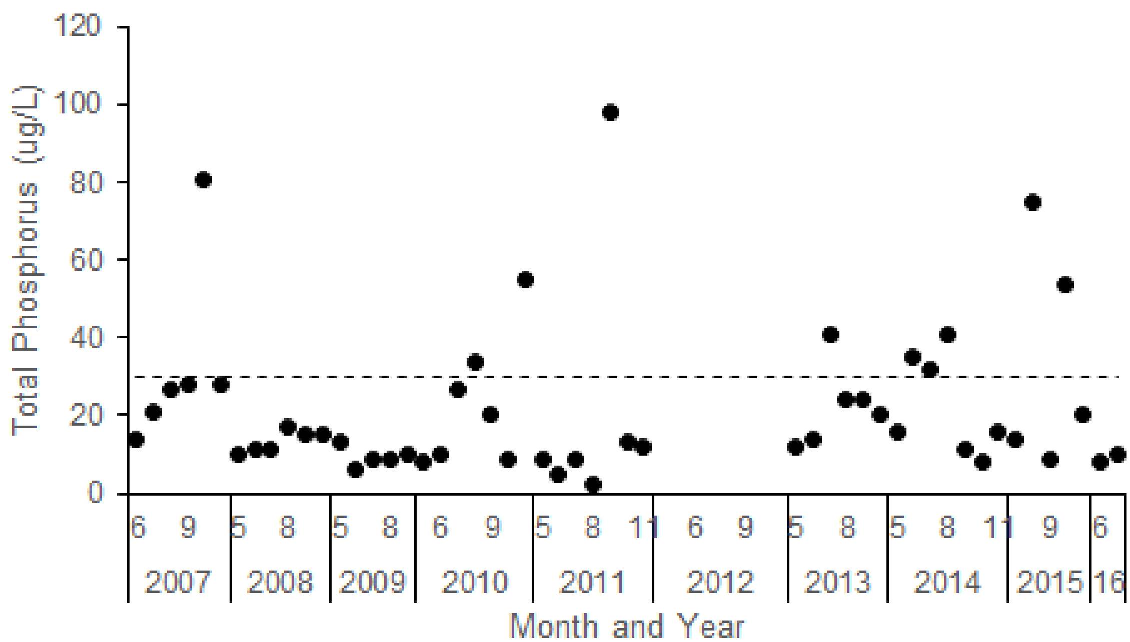


Figure 3.41 Total Phosphorous in Lily Creek over time. Dashed line shows the PWQO of 30 µ/L
Figure Note: Data are from Ontario Ministry of the Environment

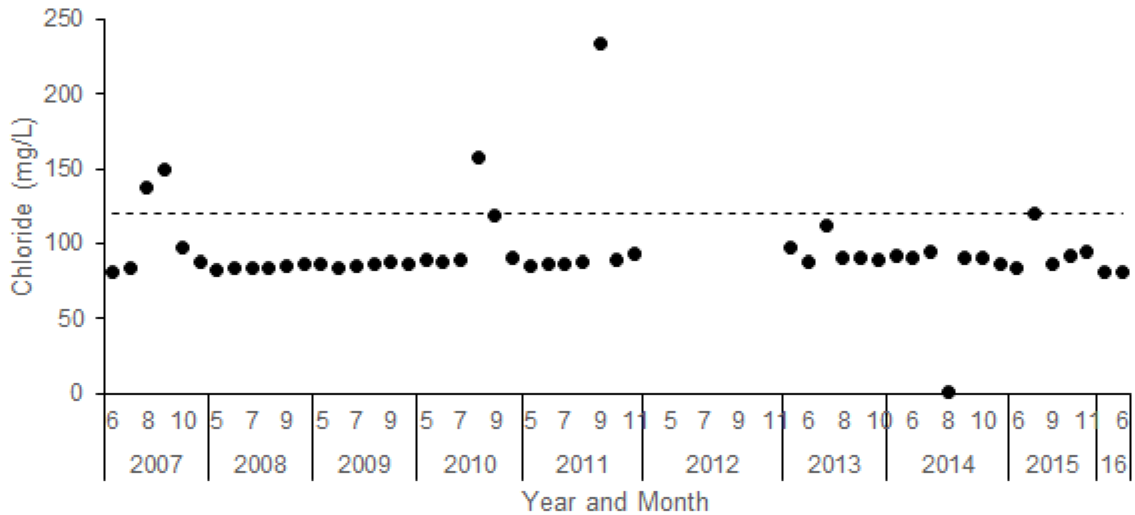


Figure 3.42 Chloride levels in Lily Creek over time. Dashed line shows the CCME long-term guideline of 120 mg/L

Figure Note: Data are from Ontario Ministry of the Environment

3.2.5.3 Minnow Lake

A sawmill mill on Minnow Lake operated for a 23-year period between 1885 and 1908, during which time sawdust and wood waste were dumped in the southwest bay of the lake. Prior to the early 1960's, when sanitary sewers were installed in the Minnow Lake area, water quality was also impacted by runoff from private septic systems. Today the largest impact on water quality is from surface runoff from the catchment. A recently installed large OGS will treat runoff from north of the lake, and may improve water quality entering the lake. Water quality in Minnow Lake is 'poor'. Visibility in the lake is low (Secchi disc depth 0.9 m; City of Greater Sudbury, 2007). Phosphorus concentrations have recently varied between about 20 and 60 µg/L (**Figure 3.43**). Dissolved oxygen concentrations have been low, related in part to the decay of a layer of sawdust on the bottom of the lake that is 1 to 2 m in thickness (Minnow Lake Community Improvement Plan, 1991; Pearson et al., 2002). In an effort to improve bioavailable oxygen in the lake, a fountain was installed in 2000, which helps to aerate the water (Bergeron, 2012). Dissolved oxygen in 2010 as measured by the Ministry of the Environment, Lake Partner program, was between 7.8 and 10.1 mg/L, and which is high enough to support a fish community. Water is slightly alkaline water (pH 7.9) and moderate conductivity (612 µS/cm). Metals levels also tend to be high in Minnow Lake (7.7 µg Cu/L; 31.2 µg Ni/L), both of which exceed their respective PWQO's (MOE: Lake Partner Program; Minnow Lake Community Improvement Plan, 1991; MECP, 2019). Chloride levels in Minnow Lake are high, likely due to the de-icing activities on the many paved roads surrounding the lake. Chloride levels as measured by the MOE, Lake Partner Program in 2010 varied between 110 and 169 mg/L, frequently exceeding the CCME (2001) guideline of 120 mg/L.

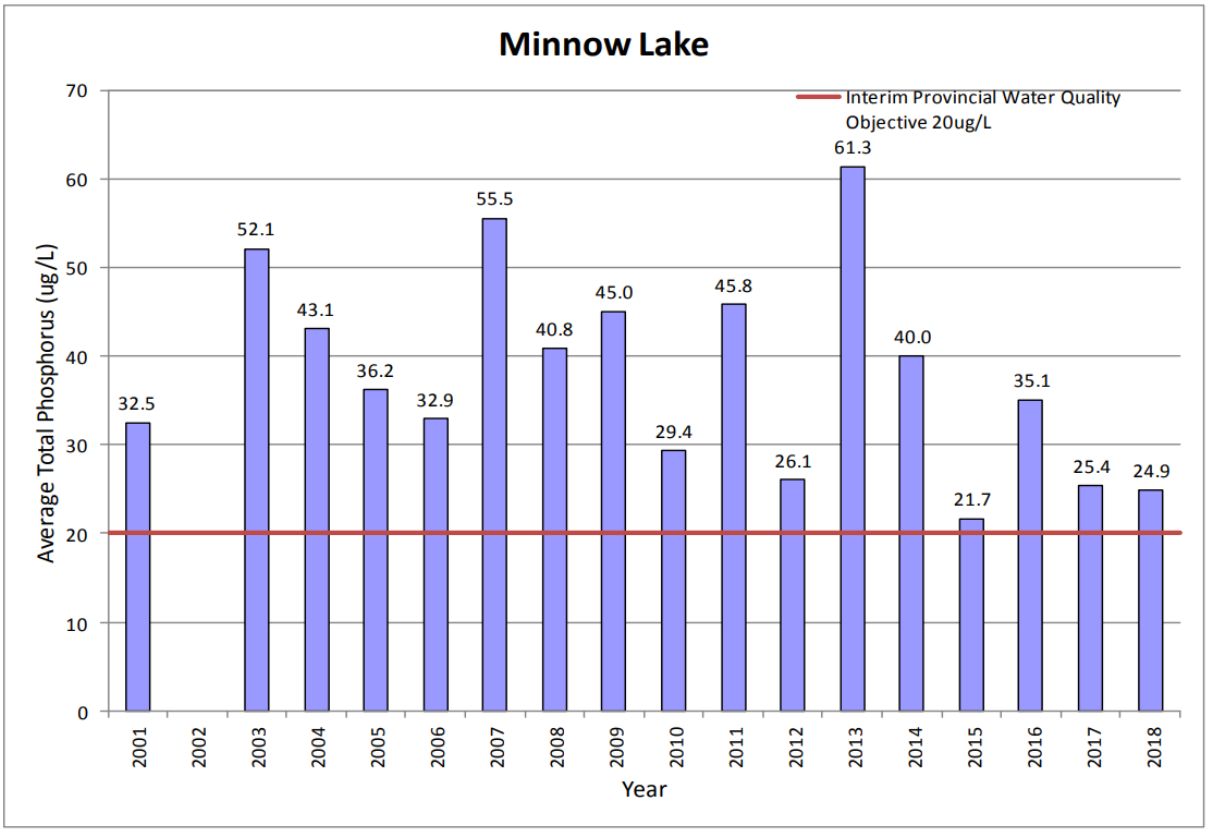


Figure 3.43 Spring Phosphorus Concentrations, Minnow Lake
Figure Note: Figure is from https://www.greatersudbury.ca/live/environment-and-sustainability1/lake-health/pdf-documents/2018-annual-report-lake-water-quality-program/).

3.2.5.4 Bethel Lake

Bethel Lake shows advanced signs of cultural eutrophication due to the release of raw sewage into the lake that continued until the late 1980's (Pearson et al., 2002; Sarrazin-Delay, 2014). Nuisance algal blooms and fish kills due to algal decay have been documented on the lake (Gunn and Keller, 1995; Pearson et al., 2002). Spring phosphorus concentrations have declined in Bethel lake since the 1980's but remain near the PWQO for phosphorus (

Figure 3.44) (MECP, 2019). Water quality in Bethel Lake is slightly alkaline water (pH 7.7) and conductivity is moderate (264 µS/cm). Surface water is characterized by high nutrient levels likely due to the release of sewage which occurred up until 1986 (

Figure 3.44) (City of Greater Sudbury, 2014; Pearson et al., 2002; MOE, Lake Partner Program). Bethel Lake metal levels however, are typically only marginally above the PWQO (Copper 5.8 µg/L and Ni 25.2 µg/L) (MECP, 2019). Chloride levels were measured in Bethel Lake in 2010 by the Ministry of the Environment. Chloride in Bethel Lake varied between 33 and 56 mg/L; well below the CCME (2001) long-term guideline for the protection of aquatic life (120 mg/L) and below the chloride concentration typically found in Ramsey Lake.

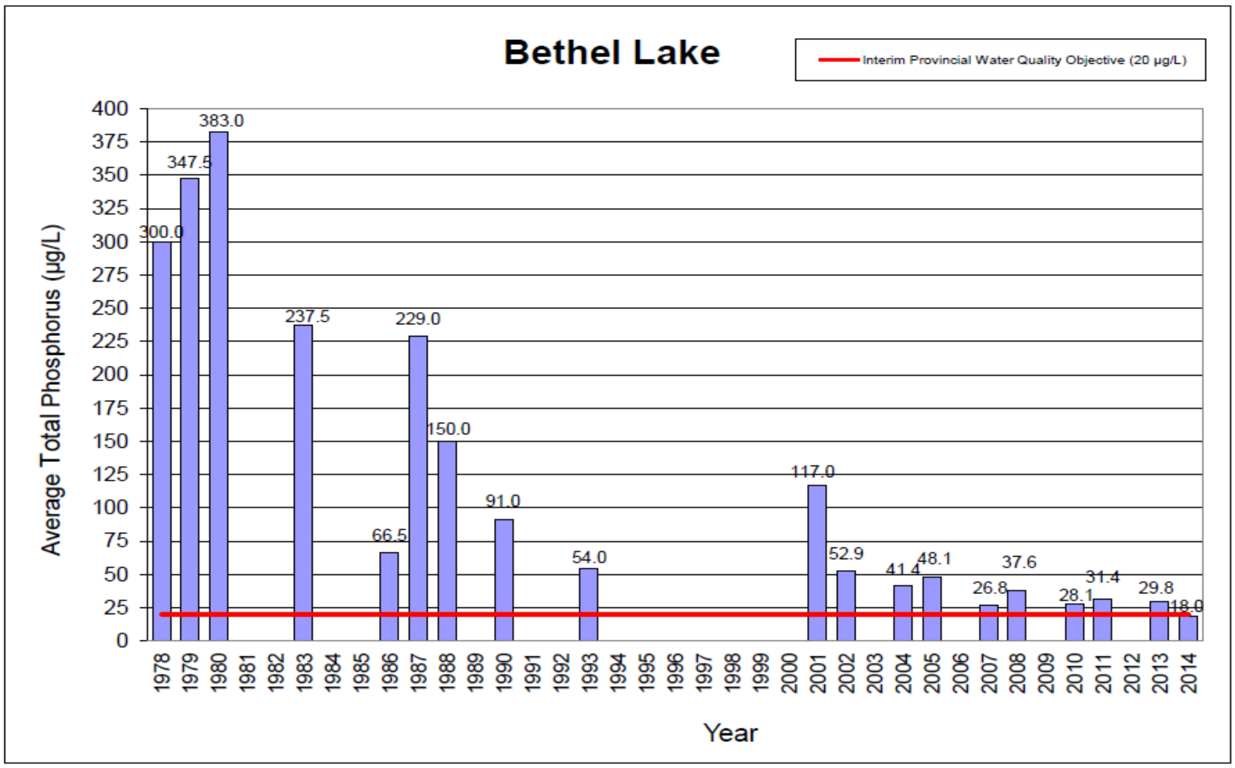


Figure 3.44 Spring Phosphorus Concentrations, Bethel Lake
Figure Note: Figure from https://www.greatersudbury.ca/linkservid/5A752B86-B4DE-0B79-A084306B65D5412C/showMeta/0/).

3.2.5.5 Lake Laurentian

Water in Lake Laurentian is neutral (pH 6.9) with moderate conductivity (168 µS/cm). Total Phosphorus (TP) levels in Lake Laurentian have historically been high (>30 µg/L) and it is suspected that inflows from Laurentian Lake have contributed to Ramsey Lake's high TP levels in the past. Sampling completed by the MECP Lake Partner Program in 2010 found that TP was at times in excess of 120 µg/L (September 2010), and as low as 7.2 µg/L (May 2010). Note that sample depths from the Lake Partner Program are deeper than the Spring Phosphorus sampling, so they are not directly comparable.

Because Lake Laurentian is not located in close proximity to major roads, chloride levels are well below the CCME (2001) long-term guideline for the protection of aquatic life (120 mg/L) **(Table 3.18**). Metals concentrations in Lake Laurentian are quite high. Nickel is often more than twice the PWQO of 25 µg/L and Copper exceeded the PWQO for of 5 µg/L on every sampling occasion in 2010 (**(Table 3.18**) (MECP, 2019). These results have been found historically as well (Keller et al., 2004).

Table 3.18: Average water quality parameters for surface water features in the Laurentian Lake Conservation Area.

Surface Water Features	pH	Conductivity (µS/cm)	DO (mg/L)	Chloride (mg/L)	Total Copper (g/L)	Total Nickel (g/L)	Total Phosphorus (g/L)
Lake Laurentian	6.9	168	9	33.9	12.1	47.7	32.5
Laurentian Creek	6.7	355	10.2	97.9	19.3	53.6	30.2
Laurentian Creek East			4.5		24	94	
Perch Lake	6.5	56		7	18	86	
Sources: Data for Laurentian Creek, Lake Laurentian and Perch Lake are from Pearson et al., 2002. Data for Laurentian Creek East are from Sarrazin-Delay, 2014.							

3.2.5.6 Perch Lake

Perch Lake is a small warm-water system that flows into Lake Laurentian. Water quality in Perch Lake is similar to water quality in Lake Laurentian, being slightly acidic (pH ~ 6.5) with low conductivity (56 µS/cm) and alkalinity (4.7 mg/L). Chloride levels in the lake are low (7 mg/L) but metals concentrations exceed the PWQO (18 µg Cu/L and 86 µg Ni/L; MECP, 2019, Pearson et al., 2002).

3.2.5.7 Laurentian Creek

Laurentian Creek east is a small, headwater stream with low dissolved oxygen (4.5 mg/L) and high organic acids (DOC 10.3 mg/L) (Sarrazin-Delay, 2014). The creek drains a series of small wetlands which may be storing historical metals loads from mining practices. The creek has metals concentration which are well above the PWQO for both copper (24 µg/L) and nickel (94 µg/L) (MECP, 2019).

3.2.5.8 Frobisher Creek

Water in Frobisher Creek is slightly alkaline (pH 7.7) and hard (hardness 150 mg/L), with high conductivity (1051 µS/cm) and high dissolved oxygen (9.5 mg/L). Total phosphorus is generally high in the creek (15-38 µg/L) and periodically exceeds the PWQO for streams (30 µg/L) (MECP, 2019). Enrichment in Frobisher Creek is thought to contribute nuisance algal blooms which have been known to occur periodically in Ramsey Lake (Bergeron, 2012). Metal concentrations in the creek are also high (copper 10.3 µg/L and Nickel 69.4 µg/L) and well above the PWQO (5 µg/L and 25 µg/L respectively) (MECP, 2019). Chlorides are high as well (257 µg/L) likely due, historically, to the close proximity of the creek to storage piles of road salts that the City of Greater Sudbury uses in winter road maintenance (Bergeron, 2012). Those storage piles have been moved more recently to an indoor storage facility (Bergeron, 2012).

3.2.6 Summary of Surface Water Resources

The following subheadings summarize the components of surface water resources within the Ramsey Lake Sub-watershed.

3.2.6.1 Summary of Fluvial Geomorphologic Resources

In summary there are four main creeks within the Ramsey Lake subwatershed: Frobisher, Roger, Eugene and Keast Creek. Reach breaks were delineated along the four creeks, establishing lengths of the river with similar geomorphic attributes. A summary of each of the reaches is provided above.

An erosion assessment was completed for the four creeks which identified 11 erosion sites and nine (9) maintenance issues along the four creeks. There was only one erosion site and maintenance issue received a ranking of “high” priority and should be addressed first.

Opportunities

It was noted that the majority of the erosion sites and maintenance issues identified are associated with the culverts and include such issues as scour pools and vegetation/sediment depositions. These issues can be addressed with relative minimal intervention to the existing infrastructure. Also, a maintenance program could help alleviate many of the issues associated with vegetation growth and debris jams. Finally, installing headwall treatments on new culverts (which was observed at some sites) will prevent some erosional risk.

Constraints

The preliminary tractive force assessment indicated that erosional forces could be very high during flood events. Due to the narrowness of the river corridor there will be limited opportunities to reduce these forces with natural channel treatments. Further tractive force analysis is required to confirm the preliminary results.

3.2.6.2 Summary of Hydrology

A hydrologic model and assessment of the flow at number of nodes defined along the four creeks in Sudbury area.

- The total contributing area to Ramsey Lake was delineated into 13 large subcatchments. A finer level of delineation (34 subcatchments) was completed within some of those subcatchments in order to define flood flows along the creeks of interest (Frobisher, Rogers, Eugene, and Keast).
- The estimated Regional Flood flow rates at the downstream limit of the Eugene, Frobisher, Rogers and Keast Creeks are slightly higher than the 100-year 6-hr Chicago.
- The peak flow estimates from the Sudbury PCSWMM model for the regional Timmins storm produces the largest flow and will be used as the design storm for the flood conveyance.

- The sensitivity to climate change was analyzed with a focus on the impacts to flood rates. This was achieved through adjustment to the IDF curves by an increase of 15% based on assessment of local data.

3.2.6.3 Summary of Creek Hydraulics and Floodplain Mapping

The following observations were made with regards to the flood limits for each of the creeks:

Frobisher Creek:

- The majority of the flooding is contained to the river corridor, with a few exceptions.
- A total of 13 buildings are within the flood limits.
- Under the Regional flood conditions three roads (Bancroft Road, Rita Street and Greenwood Drive) are overtopped.

Roger Creek:

- The majority of the flooding is contained to the river corridor, with the exception of a small spill within the Finlandia Retirement Community.
- Two (2) buildings are within the flood limits, both within the Finlandia Retirement Community.
- Under the Regional flood conditions one road (4th Avenue) is overtopped, and another culvert and bridge along a private road within the Finlandia Retirement Community are also overtopped.

Eugene Creek:

- Through the residential area, the flooding is contained to the river corridor.
- No buildings are within the flood limits and no roads are overtopped.

Keast Creek

- No buildings are within the flood limits
- Under the Regional flood conditions all three roads (South Bay Road, Arlington Bulevard and Keast Road) are overtopped.
- Some spilling is anticipated along South Bay Road and Keast Road.

Opportunities

It would be desirable to remove all buildings from the flood limits; therefore, an opportunity exists to implement stormwater management controls along the watercourse to reduce the flooding limits along creeks. This is particularly applicable along Frobisher Creek where 13 houses are within the flood limits. Stormwater management practices such as retention ponds and low impact development could assist in this regard.

As identified above seven (7) roads are overtopped under the Regional flood conditions, therefore there is an opportunity to increase the hydraulic capacity of several culverts to reduce road flooding, which could also reduce the number of buildings within the flood limits along Frobisher Creek.

Constraints

Several buildings have been built very close to the creeks, in particularly along Frobisher Creek. It is possible that even with stormwater management strategies in place, these houses will still be within the flood limits.

The capital cost required to replace a culvert can be very high and could be prohibitive in trying to increase the hydraulic capacity. It is recommended that these works try to coincide with when the culverts structural end of life, in an effort to reduce capital costs.

3.2.6.4 Summary of Trunk Storm Sewer Hydraulics

In summary, a baseline hydraulic model and assessment of the storm sewer system was conducted for the Ramsey Lake Subwatershed. The model set-up is included:

- All trunk storm sewers (600 mm in diameter and greater) were modelled along with segments of smaller storm sewers and ditches to more accurately address flows entering the trunk sewer system and connectivity to the creek and lake outfalls;
- Catch basin inlet control was included using a standard inlet rating curve (rated for 60 L/s) for fishbone/parallel slot inlets;
- Major system was assumed to follow the sewer system and defined using a roadway cross section of 20 m width and 0.3 m depth;

- Ten representative land use types were identified to calculate impervious and pervious runoff surface areas;
- Data gaps included missing invert and ground elevations; these were filled using the provided City-as-built drawings or inferred based on the available GIS and as-built data;
- Design storms of < 2-year through 100-year return period were modelled for the minor system. The major system model included the 100-year 6-hour Chicago storm and the Regional (Timmins) storm.

The Level of Service for the storm sewer system was defined according to the Greater Sudbury Official Plan based on road classification to service the <2-Year through <10-Year design storms.

The results of the modelling exercise show that for the 10-Year design storm, 7% of the storm sewers are in a state of surcharge. Major system assessment indicates a larger number of areas where flow depths exceed 0.3 m for the 100-Year Chicago storm than for the Regional storm.

Opportunities

The major / minor model provides a baseline to evaluate the major/minor flow capacities of the storm drainage system. Further work should involve a field verification of storm infrastructure that was inferred based on as-built drawings and ortho images and flow monitoring with the goal of producing a calibrated model to more accurately represent the existing conditions of the storm system.

Constraints

This is an uncalibrated model and, as such, provides a baseline from which to carry forward more detailed modelling to improve the level of accuracy.

Storm sewer Level of Service in the City of Greater Sudbury Official Plan Stormwater Background Study (2006) is defined as meeting the 2-year through 10-year design storms. The model results indicate that relatively small parts of the system do not meet this basic requirement, however implementing inlet control in the model produced results where much of the system did not surcharge. Evaluation of the major system indicates flooding of the road right-of way under the

100-year Design Event and Regional event.

These results for the major/minor are affected by data gaps where sewer data such as invert elevations and connections to ditch outlets and inlets as well as connections to outfalls had to be inferred based on professional judgement.

Using the percent impervious cover calculated from 10 representative land use areas, infiltration was determined with the Curve Number Method. GIS ortho images from the City database and Google Earth were used to calculate the area of the different runoff surfaces. Flows from the various runoff surfaces were estimated based on surface type and land use. A 50% downspout disconnection was assumed for three single family neighbourhoods based on Google Earth images that translated into 50% of the roof area contributing runoff along the ground.

The ortho images found to be dated when compared to Google Earth with locations of new development not shown. In areas where sewers were defined in a series of broken links, Google Earth revealed the presence of new development incorporating SWM best practices that were not included in the model. Stormwater Management (SWM) ponds were not modelled.

3.2.6.5 Summary of Water Quality

Table 3.19 summarizes water quality results for the following water bodies. Results presented in the table are based on sampling since the year 2000.

Table 3.19: Summary of water quality results

Water Feature	Parameter	Guideline		Results
Ramsey Lake	Alkalinity (mg/L)	-	-	~30
	Chloride (mg/L)	120	CCME[1]	~90
	Conductivity (µs/cm)	-	-	272
	Copper (µg/L)	5	PWQO[2]	~12
	DO (mg/L)	-	-	~12
	Nickel (µg/L)	25	PWQO	~55
	pH	6.5-8.5	PWQO	7.3
	Total phosphorus (mg/L)	20	PWQO	6-17
	Sodium (mg/L)	200	ODWS[3]	~50

Water Feature	Parameter	Guideline		Results
		20	PHSD[4]	
Lily Creek	Chloride (mg/L)	120	CCME	1.1-233
	Conductivity (µs/cm)	-	-	481
	Hardness (mg/L)	-	-	92
	pH	6.5-8.5	PWQO	7.7
	Total phosphorus (mg/L)	30	PWQO	2-98
Minnow Lake	Chloride (mg/L)	120	CCME	110-169
	Conductivity (µs/cm)	-	-	612
	Copper (µg/L)	5	PWQO	7.7
	DO (mg/L)	-	-	7.8-10.1
	Nickel (µg/L)	25	PWQO	31.2
	pH	6.5-8.5	PWQO	7.9
	Total phosphorus (mg/L)	20	PWQO	20-60
Bethel Lake	Chloride (mg/L)	120	CCME	33-56
	Conductivity (µs/cm)	-	-	264
	Copper (µg/L)	5	PWQO	5.8
	Nickel (µg/L)	25	PWQO	25.2
	pH	6.5-8.5	PWQO	7.7
	Total phosphorus (mg/L)	20	PWQO	18-117
Lake Laurentian	Chloride (mg/L)	120	CCME	33.9
	Conductivity (µs/cm)	-	-	168
	Copper (µg/L)	5	PWQO	12.1
	DO (mg/L)	-	-	9
	Nickel (µg/L)	25	PWQO	47.7
	pH	6.5-8.5	PWQO	6.9
	Total phosphorus (mg/L)	20	PWQO	32.5
Perch Lake	Alkalinity (mg/L)	-	-	4.7
	Chloride (mg/L)	120	CCME	7
	Conductivity (µs/cm)	-	-	56
	Copper (µg/L)	5	PWQO	18
	Nickel (µg/L)	25	PWQO	86
	pH	6.5-8.5	PWQO	6.5
Laurentian Creek	Chloride (mg/L)	120	CCME	97.9
	Conductivity (µs/cm)	-	-	355
	Copper (µg/L)	5	PWQO	19.3
	DO (mg/L)	-	-	10.2
	Nickel (µg/L)	25	PWQO	53.6
	pH	6.5-8.5	PWQO	6.7

Water Feature	Parameter	Guideline		Results
	Total phosphorus (mg/L)	30	PWQO	30.2
Frobisher Creek	Chloride (mg/L)	120	CCME	257
	Conductivity (µs/cm)	-	-	1051
	Copper (µg/L)	5	PWQO	10.3
	DO (mg/L)	-	-	9.5
	Hardness (mg/L)	-	-	150
	Nickel (µg/L)	25	PWQO	69.4
	pH	6.5-8.5	PWQO	7.7
	Total phosphorus (mg/L)	30	PWQO	15-38

[1] CCME (2001) Water Quality Guidelines for the Protection of Aquatic Life (long-term)
[2] Provincial Water Quality Objectives (PWQO) (MECP, 2019)
[3] Ontario Drinking Water Standards (ODWS, 2018)
[4] Public Health Sudbury and Districts (PHSD, 2016) notifies community when sodium concentration exceeds 20 mg/L

Opportunities

Some of the sources contributing to poor water quality have been removed or modified to reduce their impact on these water bodies. For example, intentional releases of raw sewage into Minnow Lake and Bethel Lake no longer occur; and salt storage piles in the Frobisher Creek watershed have been moved to an indoor storage facility. The fountain on Minnow Lake has effectively increased dissolved oxygen levels to a level high enough to maintain a fish community.

Constraints

The impacts from historic activities continue to impact water quality. High sawdust loading into Minnow Lake and the historical metals loads being stored and released throughout the watershed continue to result in impaired water quality. Stored metals will continue to be released into water bodies by contaminated sediments and it will be a slow process to bury these sediments with cleaner sediments. Especially in lakes such as Minnow Lake, where the largest threat to water quality is currently due to surface runoff from the catchment, the new sediments deposited in the lake may continue to impair water quality. The application of de-icing salts throughout the subwatershed will continue to result in elevated chloride concentrations since there is no way to removed dissolved chloride from water.

3.3 Ecological Resources and the Natural Heritage System

The following sub-sections characterize the ecological components of the Ramsey Lake Sub-watershed.

3.3.1 Ramsey Lake

The surface area of Ramsey Lake is 792 ha. Development along the shoreline of the lake is extensive, including more than 800 private dwellings as well as public spaces such as Bell Park, Moonlight Beach, and Lake Laurentian Conservation Area (Sarrazin-Delay, 2014). The lake drains a watershed that is 43 km^2 in size.

The lake has two large, shallow basins and a single deep main basin that thermally stratifies (**Figure 3.45**). The deep basin begins the process of stratification in June and by August is fully stratified. The warm layer of water overlaying the thermocline, the epilimnion, extends to 7 m below surface which is typical of moderately sized lakes. Surface water temperatures typically range between 20 and 25°C during the summer months (**Figure 3.45**). Dissolved oxygen in the epilimnion of Ramsey Lake is high, approximately 8 mg/L in August (**Figure 3.45**). The thermocline in Ramsey Lake typically sets up at about 10 m depth (Bergeron 2012). Deeper water in the hypolimnion experiences oxygen depression during the summer, with the deepest waters at the sediment-water interface experiencing anoxia in the fall.

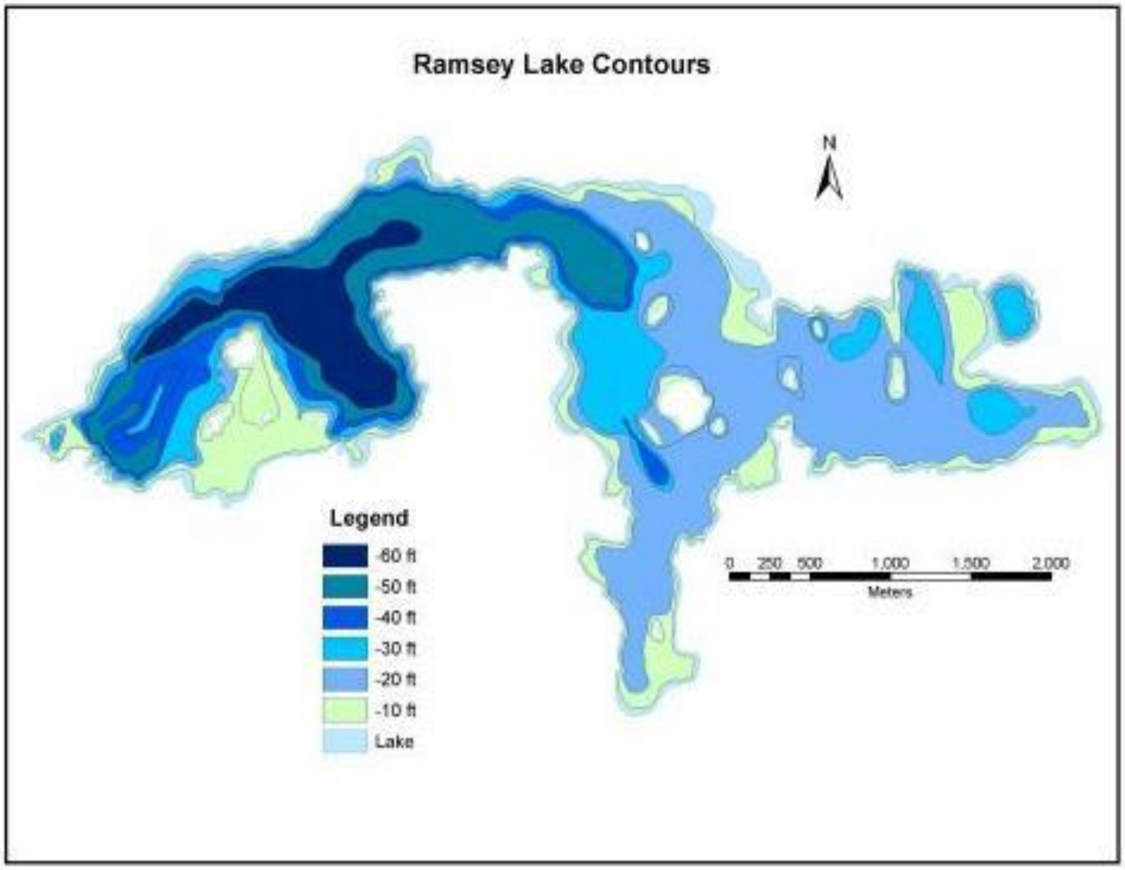


Figure 3.45. Ramsey Lake Contour Map
(Source: http://www.greatersudbury.ca/living/ lakes-facts/local-lake-descriptions/ramsey-lake/maps-of-ramsey-lake).

The shoreline of Ramsey Lake has been heavily developed and altered by infilling and the construction of break walls and docks (**Figure 3.46**, **Figure 3.47**, and **Figure 3.48**). Large portions of the shoreline including the areas adjacent to the Canadian National Railway tracks, the eastern end of the Lake and shoreline adjacent to the Lake Laurentian Conservation Area have remained natural. Excessive aquatic vegetation growth is evident in shallow portions of the lake adjacent to heavily urbanized areas (3). Vegetation within these dense beds (milfoil and Canada waterweed) appears to be heavily coated with algae.

Figure 3.46. Shoreline of South Bay of Ramsey Lake.

Figure 3.47. Northern Shoreline of Ramsey Lake.

Figure 3.48. Dense Mat of Aquatic Vegetation in Shallow Water, Northern Shoreline of Ramsey Lake.

Aquatic sediment was sampled in Ramsey Lake in the mid-1990s by the Ministry of Natural Resources and summarized in Keller et al.'s 2004 report. Samples representing the top 2 cm of sediment collected with an Ekman dredge. Three replicate samples were collected in the Lake's deepest basin. Copper and Nickel concentrations in sediments in Ramsey Lake were higher than the severe effects level (SEL) prescribed within Provincial Sediment Quality Guidelines (PSQG), 110 and 75 µg/g respectively (Keller et al., 2004). Copper concentrations were 30 times higher than the SEL guideline while nickel concentrations were more than 50 times the guideline (Keller et al., 2004). Cobalt was on average greater than the PSQG of 50 µg/g while lead was just below the guideline (250 µg/g) on average (**Table 3.20**) (Keller et al., 2004).

Phytoplankton are free-floating microscopic plants. In a typical summer, a lake water sample usually contains 20 or more blue-green algal species, along with dozens of other species of algae. The algae can become a nuisance by rapid increases in numbers, called a 'bloom'. This can be a natural phenomenon, but it is often due to accelerated eutrophication caused by human activities (CCME, 2001). Attached algae are usually filamentous or colonial forms that adhere to some form of substrate (rocky substrate and aquatic vegetation) and may become so abundant as to obscure the true nature of the substrate.

Table 3.20. Sediment chemistry collected in Ramsey Lake.

Sample No.		Rep 1	Rep 2	Rep 3	Average	PSQG	
						SEL	LEL
Aluminum	ug/g dry	19000	20000	21000	20000		
Barium	ug/g dry	69	51	140	87		
Beryllium	ug/g dry	<0.75	<0.79	<0.81	0.78		
Cadmium	ug/g dry	7.3	8.5	6.4	7	10	0.6
Chromium	ug/g dry	62	70	76	69	110	26
Cobalt	ug/g dry	**160**	**190**	**160**	**170**	50	
Copper	ug/g dry	**2900**	**3200**	**2700**	**2933**	110	16
Iron	ug/g dry	**43000**	**47000**	**44000**	**44667**	40000	20000
Lead	ug/g dry	240	**270**	220	243	250	31
Manganese	ug/g dry	430	420	420	423	1100	460
Molybdenum	ug/g dry	<1.5	<1.2	<1	1.2		
Nickel	ug/g dry	**4100**	**4900**	**3900**	**4300**	75	16
Strontium	ug/g dry	32	33	38	34		
Titanium	ug/g dry	710	750	840	767		
Vanadium	ug/g dry	52	54	57	54		
Zinc	ug/g dry	400	460	360	407	820	120
Note* Bolded text indicates values higher than the SEL							

Phytoplankton data was collected in Ramsey lake as yearly composite samples between the years of 2005 and 2008 (Bergeron, 2012). There appeared to be a decrease over time in overall biomass of phytoplankton and then a spike in 2008 (Bergeron, 2012). In addition to the biomass increase in 2008, the composition changed with a greater proportion of phytoplankton composed of chlorophytes and cyanobacteria (blue-green algae). Cyanobacteria biomass was compared to data from 99 temperate lakes from around the world (Bergeron, 2012). When compared to these lakes, cyanobacteria biomass in Ramsey Lake was low (Bergeron, 2012).

A biweekly phytoplankton sampling protocol was completed on Ramsey Lake in 2009 and 2010 due to a cyanobacterial bloom that had occurred in the lake in 2008 (Bergeron 2012). The objective of this program was to document seasonal changes in phytoplankton biomass and community composition and the relationship to water chemistry to identify possible triggers of nuisance blooms.

Bi-weekly Chlorophyll *a* and phytoplankton samples were collected simultaneously in Ramsey Lake. Both distributions showed a typical seasonal variability common to dimictic, oligotrophic lakes in that biomass was high during the spring and fall and low during the summer months (Bergeron, 2012). The early spring spike in phytoplankton biomass is likely caused by increased light and nutrient levels. The decrease in abundance through the summer is often due to an increase in biomass of zooplankton grazers which prey on phytoplankton. Furthermore, as the lake stratifies and the water column becomes stable, diatom sedimentation rates increase. Since diatoms make up a large proportion of the phytoplankton community, this would greatly and negatively affect the overall biomass of phytoplankton. After the lake mixes again in the fall, diatoms re-suspend in the water column, causing a spike in phytoplankton biomass.

Blue-green algae are present in Ramsey Lake and are a source of concern when nuisance blooms reported. During the 2009 and 2010 sampling seasons, cyanobacteria were almost never a major contributor to the overall phytoplankton biomass with the exception of sampling completed in early September 2010 when cyanobacteria comprised 28% of the total community (Bergeron, 2012). Though the proportion of Cyanobacteria increased temporality during this time, overall phytoplankton biomass was considered to be low (Bergeron, 2012). Nonetheless, the small peak in biomass of Cyanobacteria was enough to create a nuisance bloom when aggregated on the surface and at inshore sites.

Diatom assemblages from sediment cores have been analyzed in several different studies, yielding consistent results. Cores indicate how the diatom assemblage changed from the early 19th century to the 1980s. During that time, major changes in the composition of diatom communities has occurred. Prior to 1930, oligotrophic taxa (e.g. *Cyclotella stelligera* and *Tabellaria flocculosa* strain IIIp) dominated the diatom community (Dixit et al., 1996; Tropea et al. 2011). These taxa are indicative of soft water and have a pH tolerance of between 6.2 and 6.3. Species that are more tolerant of enrichment were also present in Ramsey Lake at this time, although, in low relative abundances which suggest that historically, the system was naturally productive (Dixit et al. 1996; Tropea et al. 2011).

Beginning in the 1950's, local residents began to complain about nuisance algal blooms in Ramsey Lake. This was reflected in the taxa composition which in the 1960s was comprised of 50% mesotrophic and 22% eutrophic species; far higher than the 19% for both of these species types prior to industrialization in the 1930s (Tropea et al., 2011). Metals tolerant species (*Brachysira vitrea)* were also found in Ramsey Lake at this time (Dixit et al. 1996). In more recent years, after extensive development within the watershed, taxa composition in the lake included higher abundances of species that are considered to be tolerant of eutrophication (*A. Formosa, F. crotenensis*) (Bergeron, 2012; Tropea, 2011). Though species that are generally indicative of cool, clear water (*Cyclotella sp.*) were still present, relative abundance was low (Bergeron, 2012).

Species composition of zooplankton has generally been consistent between sampling years (Keller et al., 2004). All species observed in 1990 were also observed in 2003 with the exception of two new species observed in 2003 (*Mesocyclops edax* and *Bosminia sp)* **(Table 3.21).** Most zooplankton found in Ramsey Lake are considered ubiquitous in the region. The presence of the acid/metal sensitive species *Daphnia mendotae*, however, during the two years of sampling was indicative of favourable water quality conditions.

Along-shore benthic communities were having low diversity and are dominated by chironomids and Hyalellidae amphipods (Sarrazin-Delay, 2014). Ceratopogonid flies were also abundant along shore, as were empidids. Mayflies (Caenidae, Heptageniidae, Leptophlebiidae) and caddisflies (Hydroptillidae, Leptoceridae, Phryganeidae, Polycentropidae) were present along shore. Molluscs consisted primarily of fingernail clams (Pisisiidae) and snails (Planorbidae; Sarrazin-Delay, 2014).

Table 3.21: Zooplankton species detected in Ramsey Lake

Species	Ramsey lake	
	1990	2003
Bosminia sp.		X
Daphnia mendotae	X	X
Diacyclops bicuspidatus thomasi	X[1.]	X
Epichura lacustris	X	X
Leptodiatomus minutus	X	X
Mesocyclops edax		X
Skistodiaptomus oregonensis	X	X
Calanoid copepodid	X	X
Calanoid nauplius	X	X
Cyclopoid copepodid	X	X
Cyclopoid nauplius	X	X

Notes:
1. Only one individual detected
Source: Keller et al. (2004)

The number of mayflies and caddisflies, presented as a percentage of the total number of fauna, was generally considered by Sarrazin-Delay (2014) (with one exception near the confluence of the outlet from Bethel Lake) to be generally similar to what had been found in reference lakes. Sarrazin-Delay (2014) considered the along-shore benthos of Ramsey Lake to differ only subtly from other reference lakes in the region. Keller at al. (2004) reported the appearance/presence of a sensitive genus of mayfly (*Stenonema*) considered to be relatively sensitive to water quality. *Stenonema* had not been detected in previous assessments conducted in the mid 1990's.

Walleye, pike and Smallmouth Bass are native to Ramsey Lake (Howey, 1938). Lake Trout are also considered native to the lake although the occurrence of this species is not well documented, and they are currently not present in the lake. A fisheries assessment completed in 1989 resulted in the capture of 369 Walleye, 6 Northern Pike, 3,025 Yellow Perch, 1 Smallmouth Bass, 10 Rock Bass, 8 Brown Bullheads, 15 White Suckers, 7 Pumpkinseeds, 1 Black Crappie and 362 Golden Shiners (Dolson and Niemi 1989). This study concluded that that the lake supported a healthy walleye population and abundant forage fish (Yellow Perch, Golden Shiners). Very few Smallmouth Bass were captured. No Lake Trout were captured. The study also concluded that suitable Walleye spawning substrate was very limited on the Lake. Aquatic vegetation which provides spawning habitat for pike and nursery habitat for Walleye, Northern Pike and small fish species was determined to be limited.

Prior to this assessment, Ramsey Lake had been stocked with young-of-the-year Walleye, cultured in a hatchery operated by the Sudbury Game and Fish Protective Association. A stocking assessment conducted in 1984 concluded that walleye was successfully reproducing in the Lake. Fork lengths for Walleye captured during the 1989 assessment ranged between 8.7 cm and 52.4 cm. Length frequency histograms show a strong size class between 30 and 40 cm which likely corresponded to fish stocked in the lake in 1987 by the Sudbury Game and Fish Protective Association through their CFIP hatchery. A smaller size class (20 to 26 cm) likely also corresponded to fish stocked by the Association in 1987 (Dolson and Niemi, 1989).

Northern Pike captured in Ramsey Lake ranged in size from 52.7 cm to 82.5 cm. These fish were all captured in the larger, six-foot trap nets (Dolson and Niemi, 1989).

The resident Walleye population of Ramsey Lake was assessed in 1996. Relative to other northeastern Ontario Walleye lakes, the Ramsey Lake population had below average abundance. The sample of captured walleye were made up of only three-year classes, suggesting low survival and high mortality (Morgan et al., 2002). The winter Walleye harvest was assessed in 2003 and found to be very high, relative to other area lakes (Keller et al. 2004).

Broad scale monitoring was conducted in Ramsey Lake in 2011 by the Ministry of Natural Resources using large and small gillnets (T. Johnston (MNRF), personal communication). Eight species of fish were captured during the surveys, the most abundant of which was Yellow Perch (**Table 3.22**). White Sucker and Walleye were the most abundant species captured in large mesh gill nets while Yellow Perch was the most abundant species captured in the small mesh nets. A single splake was captured. Splake have been stocked periodically in Ramsey Lake in order to provide put-and-take angling opportunities. Splake are unable to naturally reproduce.

Walleye spawning activity has been documented in Ramsey Lake (City of Greater Sudbury, 2013). The largest spawning ground is located along the southern shore of the lake at the confluence of Laurentian Creek East (**Figure 3.49)**. Three smaller spawning areas are located between the confluences of Minnow Lake and the outflow of the Lake (**Figure 3.50**; City of Greater Sudbury 2013).

In 2011, a contaminants analysis was completed on fish captured in Ramsey Lake by the Ministry of Environment and Climate Change (T. Johnston (MNRF), personal communication). Four species were analyzed for Mercury levels in tissues. Mercury levels in all fish species varied between 0.03 and 0.19 ppm, below the maximum level of mercury considered harmful to human consumers (0.5 ppm).

Table 3.22: Broad Scale Monitoring (BSM) Results for Ramsey Lake in 2011.

Species	Total Catch (large mesh)	Total Catch (small mesh)	Total Catch (all mesh sizes)
Walleye	39	27	66
Northern Pike	8	1	9
Smallmouth Bass	6	0	6
White Sucker	56	1	57
Brown Bullhead	9	0	9
Yellow Perch	5	266	271
Rock Bass	19	59	78
Splake	0	1	1
Source: T. Johnston (MNRF), personal communication.			

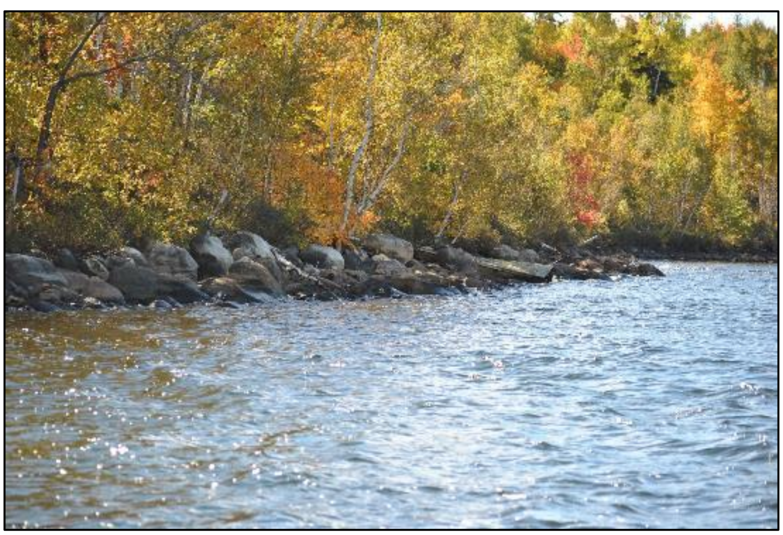


Figure 3.49. Walleye Spawning Location, Southeast Shoreline of Ramsey Lake.

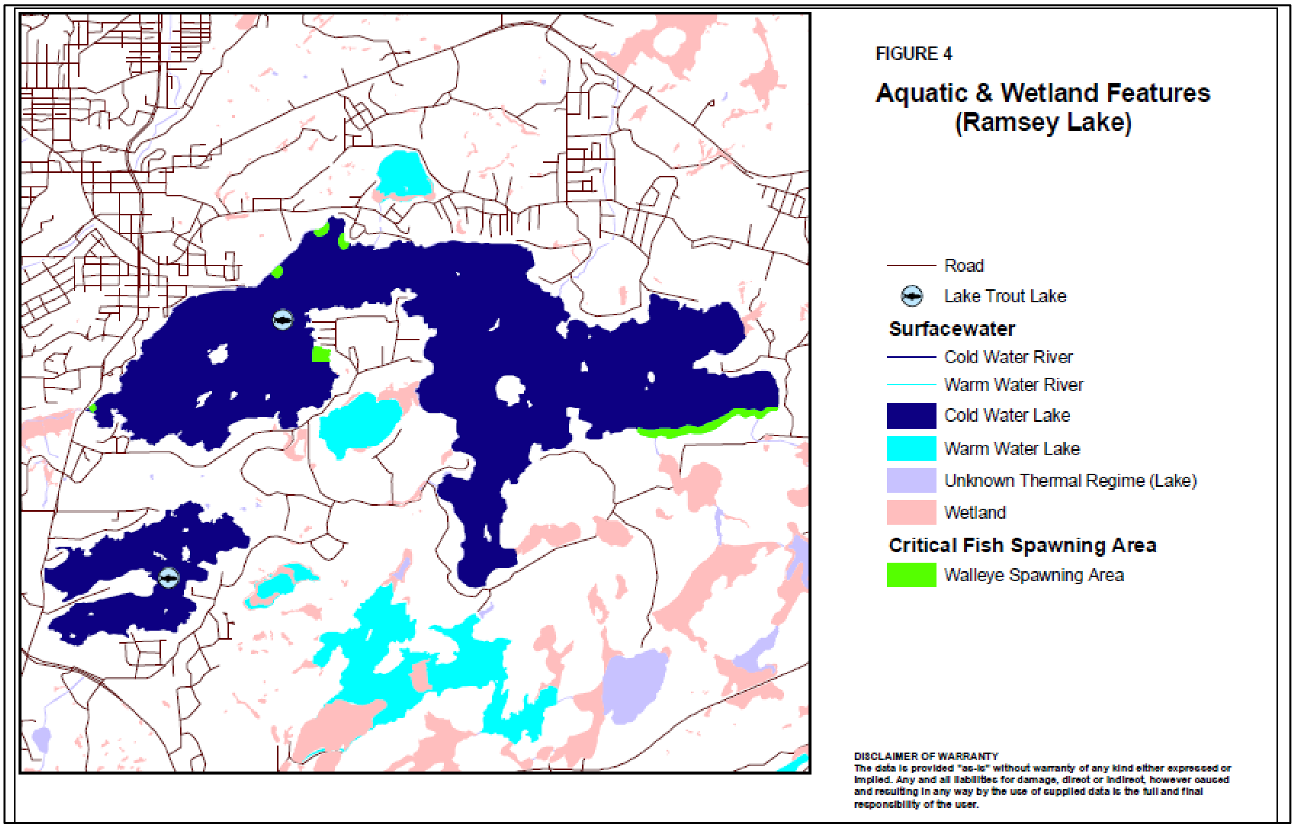


Figure 3.50: Ramsey Lake, Aquatic and Wetland Features
(Source: City of Greater Sudbury Natural Heritage Background Study 2005).

3.3.2 Minnow Lake

Minnow Lake has a surface area of 20.9 hectares. Minnow Lake has a total shoreline length of 2.1 km approximately 50 percent of which has been disturbed. Much of the shoreline of the lake is occupied by a narrow ring of emergent vegetation, primarily cattail (*Typha*) and bulrushes (*Scirpus*) (**Figure 3.51** through **Figure 3.54**). The southern shoreline appears to have undergone some infilling.

Figure 3.51: Northeast Shoreline of Minnow Lake.

Figure 3.52: Southeast Shoreline of Minnow Lake.

Figure 3.53: Eastern Shoreline of Minnow Lake.

Figure 3.54: Northeast Shoreline of Minnow Lake.

Minnow Lake is shallow, with a maximum depth of 3.0 m (

Figure 3.55). A Secchi disc depth reading of 0.9 m was recorded in 2007, which is indicative of low water clarity (City of Greater Sudbury, 2007). In 2010 the mean Secchi disc depth during the open water season was 1.6 (Bergeron, 2012). There is extensive aquatic vegetation growth in the southern portion of the Lake which, in addition to shoreline vegetation, likely provides important spawning and nursery habitats to resident fish (**Figure 3.56** and **Figure 3.57**). Eurasian water milfoil

(Myriophyllum spicatum), an invasive aquatic plant, has proliferated in Minnow Lake.

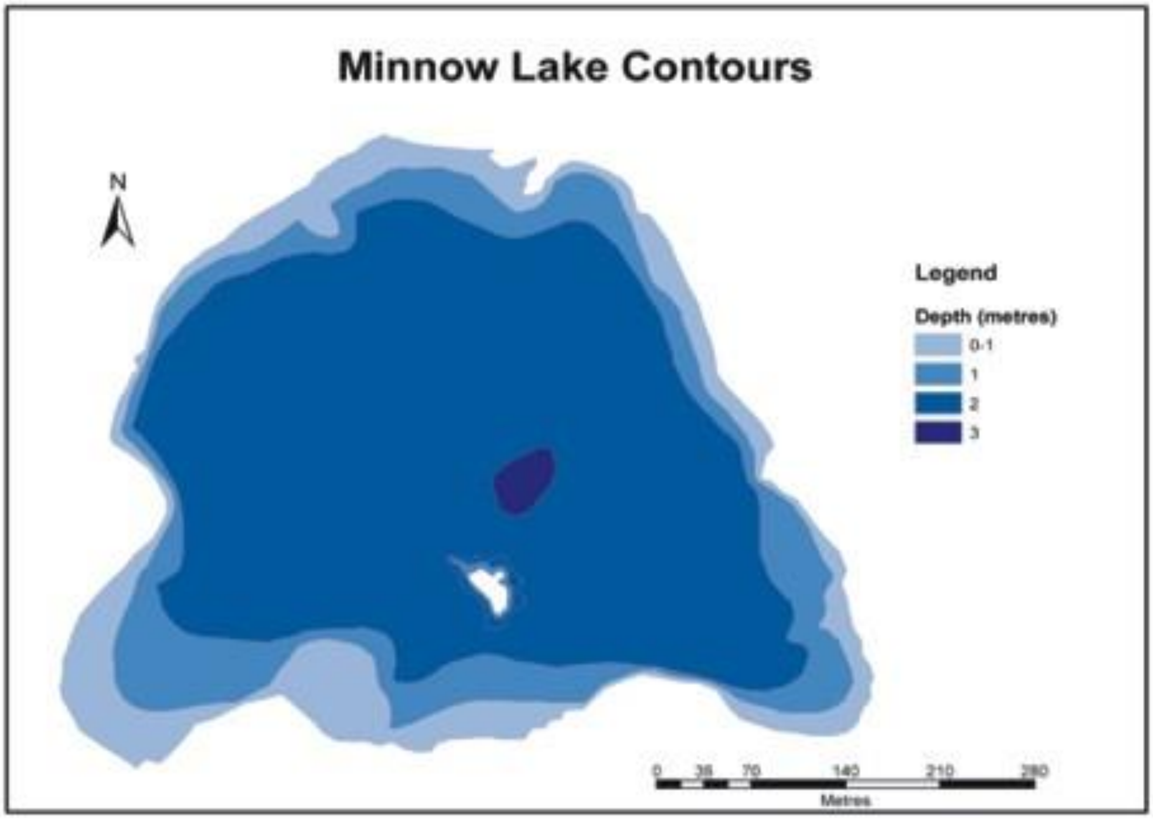


Figure 3.55: **Minnow Lake Contour Map**
(Source: http://www.greatersudbury.ca/living/lakes-facts/local-lake-descriptions/ramsey-lake/maps-of-ramsey-lake)

The lake catchment is highly urbanized and is surrounded by many private dwellings and public roads as well as a boardwalk along Bancroft Drive. Riparian vegetation often consists of open grass areas and cattails with limited buffer zones. Approximately 56 percent of the shoreline is protected by a buffer of terrestrial and/or aquatic vegetation although the width of this buffer is variable. Eurasian water milfoil (an invasive, non-native species) has been known to be prevalent in Minnow Lake (Bergeron, 2012). There is currently no in-water development in Minnow Lake and no beaches or boat launches are present. Outboard motors are not permitted on the Lake.

A fisheries assessment conducted in 1989 by the Ontario Ministry of Natural Resources documented the presence of Yellow Perch, Pumpkinseed, Fathead Minnows, Golden Shiners, Iowa Darters, Rock Bass, Northern Pike, Brown Bullhead and common White Suckers (Poulin et al, 1991The most abundant species captured were Yellow Perch and Bullhead. Only Yellow Perch, Brown Bullhead, common White Sucker and Golden Shiner presence was documented during an assessment conducted by the Freshwater Cooperative Unit (City of Greater Sudbury 2006a). No fish community assessment has been completed since 2007 and the current status of resident fish populations is unknown.

The outflow to Minnow Lake is located in the southwest corner of the lake. Water levels are maintained at a constant elevation. The stream connecting Minnow Lake with Ramsey Lake is approximately 400 m in length. It is low gradient except for a 4-m high bedrock outcrop that the stream flows over, immediately downstream of the CP Railway tracks. Substrate in the stream consists mainly of sand and gravel. The channel is deeply incised and is less than 0.5 m in width. Riparian vegetation provides extensive shading along most of the length of the creek (**Figure 3.56**). At low water, water depth is less than 0.20 m. The stream flows through culverts at Howey Drive, the CP railway track bed and Northshore Road before emptying into Ramsey Lake. No pool habitats were observed along the length of this stream. It is highly unlikely that the stream supports fish year-round.

The benthic invertebrate community was sampled in Minnow Creek in 2014 (Sarrazin-Delay, 2014). The community was dominated by Chironomidae and Hydropsychidae caddisflies. Subdominant taxa included Ceratopogonids, and molluscs including fingernail clams and snails. Mayflies were present, but they were only represented by the genus *Caenis*, a reasonably tolerant form. Larvae of dragonflies and damselflies were also present. Total abundances of benthic invertebrates were considered low in the creek. Stoneflies (being a sensitive group requiring cold water - groundwater) were absent from the creek potentially indicating degraded conditions.

Figure 3.56: Upper Minnow Creek.

3.3.3 Bethel Lake

Bethel Lake is a small (31.2 ha), shallow (2.7 m mean depth) lake located south of Ramsey Lake (**Figure 3.57**). The shoreline is 2.2 ha. in length and is mostly undisturbed despite development adjacent to the lake around most of its perimeter (**Figure 3.70**). The shoreline is dominated by bedrock along its southwest shoreline and wetland along its northeastern shoreline. Most of the shoreline is ringed by cattails and aquatic vegetation appears to be abundant throughout the lake (**Figure** 3.60). Ramsey and Bethel lakes are connected by a short, low gradient creek which flows through a narrow wetland located at the northeast corner of Bethel Lake **(Figure 3.61**).

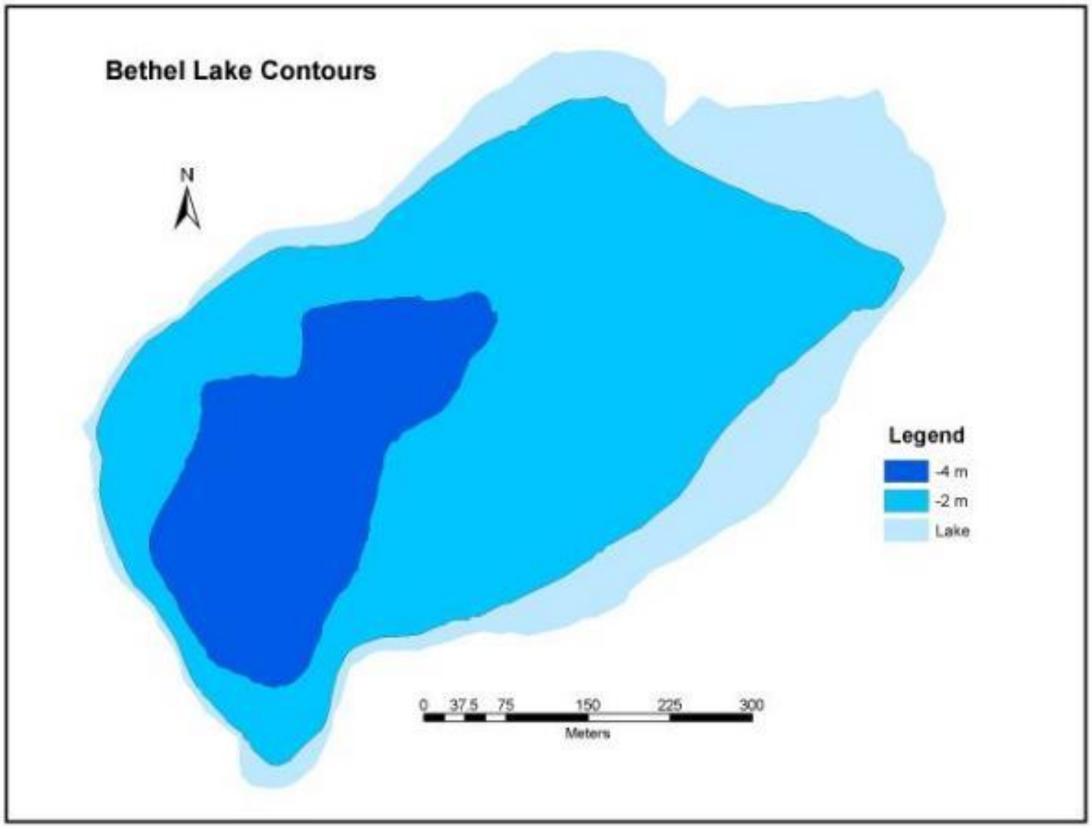


Figure 3.57: Bethel Lake Contour map
(Source: http://www.greatersudbury.ca/living/lakes-facts/local-lake-descriptions/bethel-lake/maps-of-bethel-lake/).

Figure 3.58: Southwest Shoreline of Bethel Lake.

Figure 3.59: Northeast Shoreline of Bethel Lake.

Figure 3.60:. Northern Shoreline of Bethel Lake, Looking Towards Lake Outflow.

Figure 3.61: Narrow Marsh Separating Bethel and Ramsey Lake.

Bethel Lake has a high phytoplankton biomass (1708 µg/L) compared to the other lakes in the Ramsey Lake sub-watershed (Bergeron, 2012). Cyanobacteria were present in Bethel Lake between June and October of 2010 but were not in high abundance relative to other phytoplankton species until the month of August, which is when the nuisance algal blooms likely occur (Bergeron, 2012).

Sarrazin-Delay (2014) indicated that the benthos of Bethel Lake were highly abundant (22,000 BMI), and suggesting that reflected the lake being nutrient enriched. The benthic community was dominated by ceratopogonids and Chironomidae, in addition to tolerant taxa such as mites (Arrenuridae), snails (Valvatidae) and water boatman (Corixidae). Mayflies (Caenidae, Ephemerellidae, Heptageniidae, Leptophlebiidae, and Siphlonuridae) were found in the lake as were Coenagrionidae damselflies. Caddisflies were also present, though abundances of all sensitive taxa were lower than expected based on comparison to benthic community data from reference lakes.

Five species of fish were captured in Bethel Lake using large (6') trap-nets and minnow traps during a study conducted in 1989 and 1990 (Poulin et al., 1990). The most abundant species captured was Golden Shiner followed by Fathead Minnow and Yellow Perch. Several Brown Bullhead and Northern Pike were also captured. White Sucker and Iowa Darter presence has also been documented in the lake (http://www.greatersudbury.ca/living/lakes-facts/local-lake-descriptions/bethel-lake/fish-species/).

3.3.4 Lake Laurentian

The Lake Laurentian Conservation Area (LLCA) is an undeveloped region in the Ramsey Lake watershed that is dominated by wetlands. Two main creeks drain the LLCA into Ramsey Lake, Laurentian Creek and Laurentian East Creek. There is also a small unnamed creek that drains the LLCA, originating in a wetland and draining into Moonlight Bay on the east end of Ramsey Lake. This creek has never been assessed.

Lake Laurentian is a moderately sized (157 ha) mesotrophic lake (**Figure 3.62**). Maximum depth of the Lake is 8 m. It flows into Ramsey Lake through Laurentian Creek and into South Bay. The lake is manmade. It was created in 1965 with the construction of a 2.4 m high stop log dam (**Figure 3.63)**. The lake was created to act as a reservoir, to augment potential low water levels, on Ramsey Lake. The water level on Lake Laurentian is held at a constant elevation in order to maintain recreational use. The shoreline of the lake is natural with the exception of an access point at its northeast corner. The lake water itself is brown in colour which is linked with the presence of higher levels of dissolved organic carbon (Bergeron, 2012).

Lake Laurentian dam only conveys water during periods of high precipitation. With the exception of a small wetland immediately downstream of the Lake Laurentian dam (**Figure 3.64**), it is unlikely that this creek supports fish. The creek channel is predominately moderate to high gradient and substrate consists of predominately bedrock and boulders (**Figure 3.65**).

The Lake Laurentian phytoplankton community was characterized by low over biomass early in the ice-free season (<120 µg/L), and high biomass between August and October (> 600 µg/L) (Bergeron, 2012). Cyanobacteria were found in the lake, but in low relative abundance; not enough to indicate a nuisance bloom. The low biomass of phytoplankton was considered likely due to the colour of the lake not allowing for good light penetration (Bergeron, 2012).

Benthic invertebrates were sampled at two stations in Laurentian Creek and one station in Laurentian Creek East during 2014 (Sarrazin-Delay, 2014). The benthic community in Laurentian Creek had low diversity and richness and was composed primarily of chironomids, Simuliidae flies and Pisidiidae clams (Sarrazin-Delay, 2014). EPT taxa (Ephemeroptera, Plecoptera, Tricoptera) were present in low relative abundances in the form of the mayfly (Leptophlebiidae) and the caddisflies Hydropsychidae, Limnephillidae, Philoptamindae, Phryganeidae, and Polycentropidae. Laurentian Creek East had a benthic community with low overall abundance, richness and diversity. The community there was principally comprised of chironomids with subdominant taxa including empidid flies, hydropsychid caddisflies, and Pisidiidae clams.

No fish community or fish habitat assessment has been completed in Laurentian Lake. Northern Pike and Yellow Perch presence has been documented in the lake. No fish community or habitat assessment has been completed in Perch Lake.

Figure 3.62. Lake Laurentian.

Figure 3.63. Water Control Structure, Outflow of Lake Laurentian.

Figure 3.64. Upper Reach of Laurentian Creek, Immediately Downstream of Control Structure.

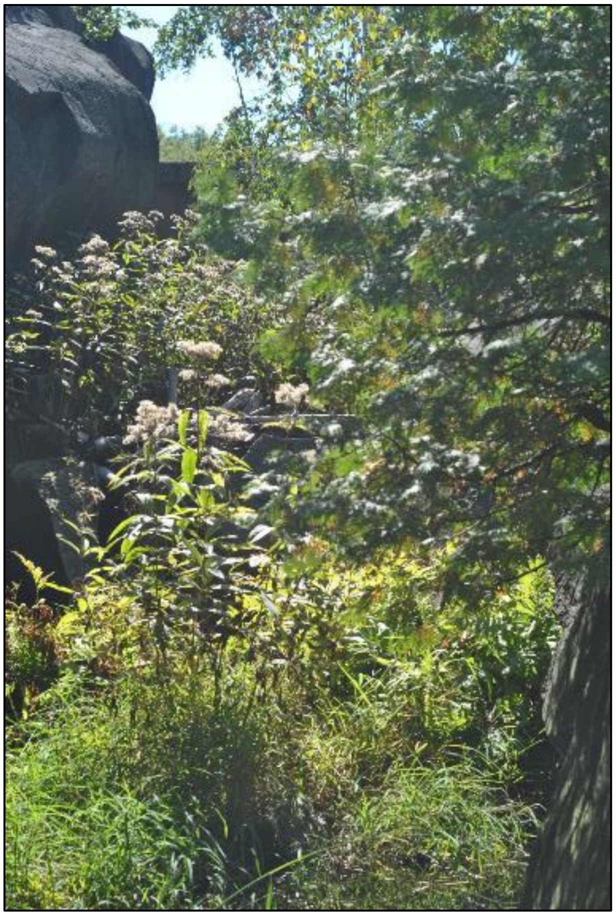


Figure 3.65. Laurentian Creek Channel.

3.3.5 Frobisher Creek

Frobisher Creek, also known locally as Korpela Creek, is a small, cobble bottomed creek with little canopy cover and which provides the most stream flow to Ramsey Lake (Bergeron, 2012; Sarrazin-Delay, 2014). The creek is approximately 2.5 km in length and its catchment has been heavily developed. The headwater of Frobisher Creek, north of Highway 17 and east of Falconbridge Road, consists of a large cattail marsh. The marsh has been partially infilled (**Figure 3.66**).

The central and lower portions of Frobisher Creek flow through a number of subdivisions. The creek channel appears to have been straightened to accommodate development. It is a low gradient channel along most of its length and has become deeply incised (**Figure 3.67**). A narrow, vegetated buffer exists along most of the creek, providing thermal protection. Substrate consists mainly of silt and flowing water is generally high in turbidity due to suspended silt (**Figure 3.68**, **Figure**

3.69).

Frobisher Creek is classified as warm-water habitat. However, the fish community has never been assessed. Fish from Ramsey Lake may have accessed the lower portions of the Creek historically. A beaver dam in the lower creek now acts a barrier to upstream fish movement. The dam, located downstream of Greenwood Avenue, has flooded the lower portion of the creek and adjacent riparian vegetation. This dam may also be acting as a sediment trap.

A series of large ponds were excavated in the lower portion of Frobisher Creek in 2002, in order offset changes to fish habitat that had occurred as the result of development adjacent to the stream (**Figure 3.69**). The ponds are several meters deep and were designed and constructed in order to support resident fish year-round.

The benthic community in Frobisher Creek is considered impacted by the surrounding urbanized environment (Sarrazin-Delay, 2014). Total abundance and richness are low in the creek, as are diversity and % of the community as EPT taxa. The community in Frobisher Creek is dominated by Simuliidae flies. Subdominant taxa included fingernail clams (Pisidiidae) and larval net-spinning (Hydropsychidae) caddisflies. Hydroptillidae and Limnephilidae caddisflies are also found in low relative abundances, but no other sensitive taxa have been noted in Frobisher Creek (Sarrazin-Delay, 2014).

Figure 3.66. Headwater of Frobisher Creek.

Figure 3.67. Stream Channel and Substrate, Lower Frobisher Creek.

Figure 3.68. Stream Channel, Upper Frobisher Creek.

Figure 3.69. Fish Habitat Compensation Pond, Lower Frobisher Creek.

3.3.6 Terrestrial Ecology

The following subheadings detail and describe the terrestrial components of the Ramsey Lake Sub-watershed.

3.3.6.1 Greater Sudbury Official Plan (2016)

Schedule 3 of the Official Plan has identified two candidate regional Areas of Natural and Scientific Interest (ANSIs), Walleye spawning grounds within Ramsey Lake, lakes suitable for Lake Trout (*Salvelinus namaycush*), and identified cold water and warmwater lakes within the study area (**Figure 3.70)**.

Osprey and eagle nesting sites, Moose wintering and feeding areas, Provincially Significant Wetlands (PSWs), Provincial ANSIs, Brook Trout and Lake Trout spawning areas have not been identified within the study area according to Schedule 3 of the Official Plan (**Figure 3.70)**, but should not be assumed absent without detailed investigation.

3.3.6.2 Soils

According to the Ramsey Lake and Watershed Community Improvement Plan, the Ramsey Lake watershed is comprised of rock outcrops and narrow valleys that resulted from the Wisconsin glaciation.

Recently, anthropogenic influences (e.g. fire, logging, mining, and urban development) have caused widespread erosion on the thin soils, resulting in exposed knobs and valleys of Precambrian bedrock (Moriyama & Teshima, 1991). Remaining soils have low organic material, and soil, wetlands, riverbeds, and lake sediments all have high levels of metals and sulphates – the residues of mining and smelting (Watershed Advisor Panel Input, 2016). On the north side of Ramsey Lake streams have been channelized, causing an increase of siltation into the lake and further degrading wetland communities.

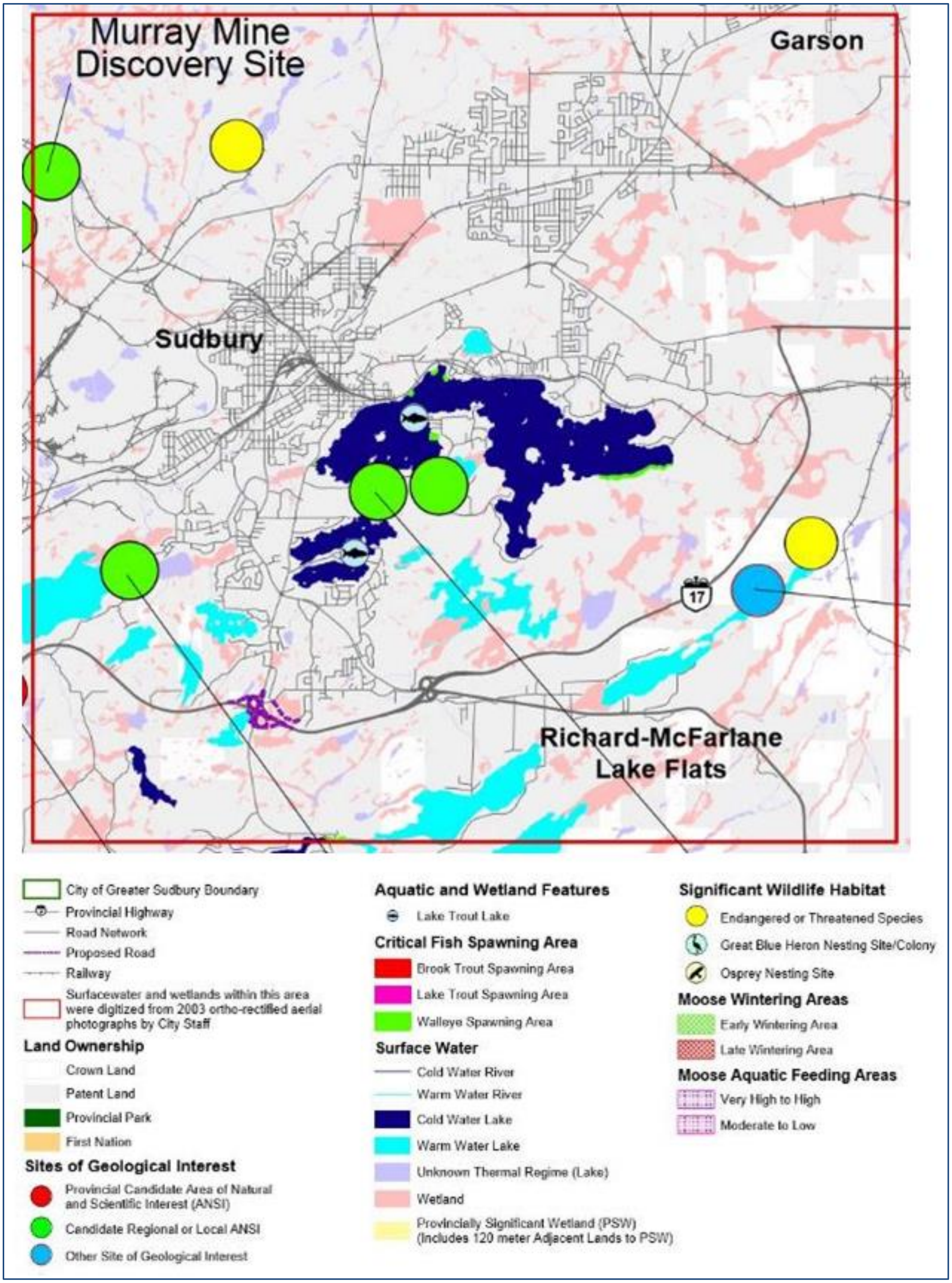


Figure 3.70: Excerpt from Official Plan Schedule 3

3.3.6.3 Vegetation Communities and Flora

Landscape mapping created by Aquafor Beech Ltd. with information obtained from the City of Greater Sudbury illustrates natural areas within the study site consisting of forests, thicket swamp, wetlands associated with lake edges, lakes, and rock barrens. Most natural areas are located on the south side of Ramsey Lake, within the Laurentian Lake Conservation Area. Of particular note within the Lake Ramsey Subwatershed, regreening efforts to introduce trees, shrubs, and herb layer vegetation to the landscape is likely to have altered vegetation composition over time. The following describes natural communities as they have been documented by past studies, and evaluates the likely effects of the Sudbury Regreening Program as a component of the current landscape.

The Ramsey Lake Subwatershed lies between the Boreal forest and the Hemlock – White Pine – Northern Hardwood Forest (Moriyama & Teshima, 1991). Data retrieved from the MNRF's Forest Resources Inventory (FRI) based on 1989 and 1990 aerial photography indicates that the majority of forest cover throughout the Lake Ramsey Sub-watershed consists of a Shade Intolerant Deciduous Vegetation Cover Type. Wetlands are mostly of the "Open" variety, or Thicket Swamp. The remaining land classification is either Rock or Developed Land (City of Greater Sudbury, 2013).

According to Moriyama and Teshima (1991), wetland types in the sub-watershed include alder (*Alnus spp*.) swamps, poor fens, and marshes. Alder swamps are dominated by alder and willow (*Salix spp*.) species. Bogs or poor fens include grass, rush, and sedge species. Nutrient rich marshes are abundant with cattails, reeds, sedges, and grasses. Frenchman's Bay has the largest reed shallow marsh on the lake, which is an important fish breeding area (Moriyama & Teshima, 1991). The creek within the Greenwood Drive area is an important water source for Ramsey Lake, and supports beaver dams which creates wetland habitats. According to Moriyama & Teshima (1991), there are over 100 species of flora in the wetlands and birch communities.

Terrestrial species present in acid/metal contaminated areas in the subwatershed tend to be remnants of pre-industrial compositions, and primarily include those tolerant to heavy metal and/or acid, have high tolerance to fire, or are part of the revegetation activities (Sinclair et. al., 1996). According to Moriyama & Teshima (1991), four disturbed forest communities lie within the Ramsey Lake Subwatershed: Birch Transition Community, Birch-Maple Community, Red Oak Community, and Poplar Lowland Community, generally consistent with FRI data from the same period. Other sources (Sinclair et. al., 1996) report similar communities in the Greater Sudbury Area. The following paragraphs describe the forest communities as stated in the *Ramsey Lake and Watershed Community Improvement Plan* (Moriyama & Teshima, 1991), and *Floristics, Structure and Dynamics in Plant Communities on Acid, Metal Contaminated Soils in the Sudbury Area* (Sinclair et. al., 1996).

Birch Transition Community: consists of open White Birch (*Betula papyrifera*) woods with an understory also composed of White Birch. The trees become more plentiful at increasing distances from the pollution sources until a Birch Transition Community is established. The Birch Transition Community occurs adjacent to the Barren Community type and forms transitions between the most damaged areas and the naturally occurring communities. In these areas, trees first appear in sheltered valleys where soil and moisture conditions are more favourable than on eroded hilltops (Moriyama & Teshima, 1991). A similar community is described in Sinclair, 1996, consisting of a birch monoculture throughout canopy and shrub layers, with a herb layer containing young Birch, Bryophytes and Tufted Hairgrass (*Deschampsia cespitosa*).

Birch-Maple Community: a mixed hardwood forest with conifer components increasing with distance from the pollution source. The major trees are White Birch and Red Maple (*Acer rubrum*). On rocky knolls or sandy outcrops, Red Pines (*Pinus resinosa)* occur in clumps and appear to have developed with little interference since lumbering days (Moriyama & Teshima, 1991). A review of temporal changes in community over time (Sinclair et al., 1996) suggest that Red Maple as a dominant canopy species is in decline, likely due to its intolerance to effects of mining. As a result, this community type may be become reduced or absent from the Ramsey Lake Subwatershed, but Red Maple in the shrub and herb layer is likely to persist. Replacement with other deciduous communities such as birch is likely.

Red Oak Community: a residual pre-industrial community found in drier habitats such as on hilltops and ridges. Red Oak (*Quercus rubra*) dominates, but White Birch is still common. Topography and soils rather than distance from pollution sources regulate the growth. Galliard Island has the oldest oak trees in the region (Moriyama & Teshima, 1991). White Birch, Red Maple, and Red Oak make up the shrub layer, while Blueberry (*Vaccinium* spp.), Bryophytes, Tufted Hairgrass, White Birch and Bracken Fern (*Pteridium aquilinum*) are common in the herb layer. This community appears to maintain itself through a combination of seeding and vegetative reproduction (Sinclair et al., 1996).

Poplar Lowland Community: developed in moist valleys throughout the watershed. Trembling Aspen (*Populus tremuloides)* dominates but Balsam Poplar (*Populus balsamifera)* is also abundant. Spruce, Fir, and Black Ash (*Fraxinus nigra*) may occur together with a dense understory of Alder and Willow (Moriyama & Teshima, 1991). This community is similar to the Trembling Aspen community of Sinclair (1996), in which the community is described as featuring species historically common in the area and occurs in finely textured soils. The shrub layer is dominated by Trembling Aspen and White Birch, the herb layer by Tufted Hairgrass, Bryophytes and Rough Bentgrass (*Agrostis scabra)*.

Birch/Pine Community: described only by Sinclair (1996) in the Greater Sudbury Area, but is projected to become increasingly prevalent in the subwatershed with the succession of regreening efforts and newly available seed source from mature trees. The community is dominated by White Birch and Pines, primarily including Jack Pine (*Pinus banksiana*) and Red Pine (*Pinus resinosa)*. The shrub layer is dominated by White Birch, Trembling Aspen and Pussy Willow [*Salix discolor*], the herb layer dominated by Blueberry, Bryophytes and White Birch, along with other species common in revegetation seed mixtures.

Big-toothed Aspen Community: a multi-tiered community with Big-Toothed Aspen (*Populus grandidentata)* present in the main and sub-canopies as well as the shrub and herb layer, also described only in Sinclair (1996). Other species in the shrub layer include Red Maple and White Birch. Rough Bentgrass, Sweet-fern (*Comptonia peregrina)*, Bush Honeysuckle (*Diervilla lonicera)* and Canada Mayflower (*Maianthemum canadense)* are common in the herb layer.

Treeless Community: an additional poorly vegetated community described by Sinclair (1996), lacking a treed canopy and generally sparse with expanses of exposed rock. Composition includes Rough Bentgrass, Tufted Hairgrass, Bryophytes and Lichens, Birdsfoot Trefoil (*Lotus corniculatus*) and Trembling Aspen, and other species included in seed mixes applied to restored areas. Any existing shrub layer contains White Birch, Trembling Aspen and Red Maple. Over time and with revegetation efforts, this community may mature and evolve into one of the above described, supporting a mature canopy.

Effects of Sudbury Regreening Program on Existing Communities

As mentioned above, reforestation efforts such as the Sudbury Regreening Program have seen approximately 80,000 tree seedlings and over 46,000 shrubs/understory trees planted across heavily impacted areas in the Greater Sudbury Area since 1978 (**Figure 3.71** and discussed further in **Section 6.1.5**), and have likely resulted in a shift in canopy dominance over time and introduced some species historically absent from the area. Seven species of deciduous understory trees, twenty-three shrub species and twelve tree canopy (conifer and deciduous) species have been used for restoration to date. Preliminary plantings in barren areas typically consist of a high proportion of Jack Pine, Red Pine, White Pine (*Pinus strobus*), White Spruce (*Picea glauca*) and Green Alder (*Alnus viridis*) with a mix of other dryland and wetland species in appropriate locations to promote diversity. Other common species used throughout the course of the program include White Cedar (*Thuja occidentalis)*, Black Spruce (*Picea mariana*), Red Oak, Black Locust (*Robinia pseudoacacia)*, Maple (*Acer* spp), Yellow Birch (*Betula alleghaniensis)*, Ash (*Fraxinus s*pp.), Serviceberry (*Amelanchier* spp.), Wild Raisin (*Viburnum nudum*), Red Osier Dogwood (*Cornus sericea*), Black Chokeberry (*Aronia melanocarpa*), Mountain Maple (*Acer spicatum*), Round-leaved Dogwood (*Cornus rugosa*), Red Elderberry (*Sambucus racemosa*), Alternate-leaf Dogwood (*Cornus alternifolia*), Striped Maple (*Acer pensylvanicum*), Bearberry (*Arctostaphylos uva-ursi)* and others. Cover crops and various seed mixes have also been used for the herb layer, often containing nitrogen fixing plants such as Birdsfoot Trefoil and Alsike Clover (*Trifolium hybridum)*, as well as nurse crops such as Redtop (*Agrostis gigantea*), Creeping Red Fescue (*Festuca rubra*), Timothy (*Phleum pratense*) and *Poa* spp. The level of reforestation effort specifically within the Ramsey Lake Subwatershed has been variable from year to year, with the largest area of lands south of Ramsey Lake being a prime focus. Several smaller pockets have also been historically restored north of the lake. Timing of planting by location varies from approximately early 1990's to present and it is likely that many of the restored areas have young forest or shrub communities reflective of the dominant species planted over the course of past regreening efforts.

Figure 3.71: The City of Greater Sudbury's Regreening App allows users to view the extent and types of regreening that have occurred within the City since 1978.

The Ramsey Lake Watershed Report Card (Conservation Sudbury, 2013) indicates extensive forest cover particularly to the south of Ramsey Lake. Although the age class and community classification associated with forest cover is not portrayed, much of the current forest cover and composition is likely the result of the aforementioned regreening. Based on more current aerial imagery (2019) and revegetation efforts to date, it is likely that the most common communities currently existing in the Ramsey Lake Sub-watershed contain a mix of deciduous species, likely with high contents of White Birch, Willow, and Trembling Aspen, as those species have been documented to readily colonize areas that have been treated with Lime (Sinclair et al., 1996). Trembling Aspen in particular is a clonal species that readily spreads via suckers on the landscape. Similarly, White Birch is able to reproduce vegetatively and has been documented as readily growing in all stratum layers of documented communities over time (Sinclair et. al., 1996). Long term, pines are likely to become dominant in local landscapes as a result of planting efforts favouring those species, favourable climate conditions, and retained historical stands outside of the impact zone. Mid-aged to mature interior forest may exist within any of the larger tracts of forest cover.

*Dark green shaded areas indicate forest cover

Figure 3.72: Conservation Sudbury's Watershed Report Card (2013) demonstrating forest cover surrounding Lake Ramsey.

Ecological Land Classification and botanical inventories on a site level would be required to develop a comprehensive list of floral species composition and distribution in the Lake Ramsey Subwatershed.

3.3.6.4 Fauna

The City of Greater Sudbury provides a matrix of habitat for a wide variety of terrestrial species types, including amphibians, reptiles, birds, mammals and insects. Fish are also present in Ramsey Lake, and in the small lakes and tributaries surrounding it. Pike also spawn at the union between Ramsey and Bethel Lakes. Fish and aquatic habitat are discussed further in **Sections 3.3.1** to **3.3.5**. Although not specific to the Ramsey Lake Subwatershed, the following have known records in the Greater Sudbury Area, and therefore have a high likelihood of occurring in appropriate habitats surrounding Lake Ramsey (City of Greater Sudbury, 2013):

Amphibians and Reptiles:

- 13 species of amphibians and nine species of reptiles have been recorded in the Greater Sudbury Area

Birds:

- 306 species of birds, including breeding, migrating, and accidental incidentals historically recorded in the Greater Sudbury Area.
- 183 species confirmed historically breeding in the City
- A high proportion of that number is likely to be forest birds, approximately half including area-sensitive species
- Wetland and Lake specialists are also common due to relatively large proportion of aquatic to semi-aquatic habitats (e.g. Bethel Lake Marsh known to support a high content of songbirds and waterfowl (Moriyama & Teshima, 1991))
- Galliard and associated islands provide nesting habitat for ducks, loons, geese, and gulls.
- Grass birds are also present within the Greater Sudbury Area, although are most likely to be associated with agricultural land absent or poorly represented directly within the Ramsey Lake Subwatershed.

Mammals

- 46 mammal species have been historically recorded within the Greater Sudbury Area
- Moose, White-tailed Deer, and Black Bear are known to occur within the Laurentian Lake Conservation Area (Moriyama & Teshima, 1991).
- Bethel Lake is known to support small mammal nesting (Moriyama & Teshima, 1991).

3.3.6.5 Significant Wildlife Habitat

Based on the abundance of wildlife species known to occur within the Greater Sudbury Area, potential for at least one type of Significant Wildlife Habitat for Ecoregion 5E is likely within the Ramsey Lake Subwatershed, particularly those that occur in association with common ELC communities or known natural features. Several wetland features have been identified by Moriyama & Teshima (1991) as having unique wildlife value in the subwatershed, and may be Candidate SWH or sanctuaries for any of the wildlife species types known to use it (e.g. birds, mammals, fish, etc.); these include the aforementioned Lily Creek Wetland and Bethel Lake Marsh. While current species and community data specific to habitats elsewhere within the subwatershed is not refined enough to conclusively make assertions about any specific location, the following Significant Wildlife Habitat types are most likely, although not inclusive of all that may exist within the Sub-watershed:

Amphibian Breeding Habitat (Woodland and Wetland): Wetland conditions favouring amphibian breeding is highly likely across the subwatershed, supported by the wide diversity of amphibians already known to exist within the General Sudbury Area (Greater Sudbury Natural Heritage Report, 2013). Amphibians can use a variety of wetland types, including marshes, fens, swamps, and other seasonally flooded woodlands, all of which are confirmed present in the subwatershed, as shown in existing habitat mapping and concentrated particularly in the Lawrentian Conservation Area (City of Greater Sudbury Official Plan, 2019). Amphibian breeding surveys at potential suspected breeding locations would be required to confirm either category of significant breeding habitat.

Bat Maternity Colonies or Hibernacula: These two SWH type are highly likely to exist within the subwatershed: Bat Maternity Colonies could occur in any mature deciduous forest with large trees, particularly Oak or Maple dominant; Hibernacula are possible in caves or deep cracks or fissures in the abundant exposed bedrock across the landscape. An evaluation of snag density and/or bat acoustic surveys would be useful in confirming these types of habitat use by Big Brown Bat and Silver-haired Bat, and may also reveal the presence of Endangered *Myotis* spp. and Tri-coloured Bat (*Perimyotis flavis*) with the same habitat criteria.

Mast Producing Areas: Mature Red Oak-dominant forests found in dry, ridge habitats throughout the subwatershed are likely to provide a long term, stable food supply meeting the criteria outlined in the SWH Criteria Schedule for Ecoregion 5E. Since mature oak stands are likely to be a limited habitat type, those that do exist would require an investigation confirming the size and abundance of mast producing trees within candidate locations to identify these areas. Other types of mast producing vegetation and habitat types could also qualify if present (e.g. Cherry, Basswood, Raspberry, etc.).

Turtle Wintering Areas: All natural open/shallow marsh type communities and deep rivers or streams/lakes throughout the watershed have the potential to serve as overwintering for turtles. Specific to those species identified in the SWH Criteria Schedule for Ecoregion 5E (Midland Painted, Northern Map, and Snapping Turtles), overwintering habitat for these species is likely abundant in open wetland types common across the subwatershed. Midland Painted and Snapping Turtle are both historically recorded as present in the general Greater Sudbury Area, but investigation into the characteristics of known aquatic features and species-specific surveys would identify and confirm specific overwintering locations in the subwatershed. Probable candidates include any moderately shallow wetland type containing thick, soft substrates.

Shrub/Early Successional Bird Breeding Habitat: With large regenerating vegetation areas common throughout the subwatershed, many of the bird species reliant on this type of habitat may be using them for breeding purposes. Alder Swamps are particularly common, as are young, low treed habitats forming thickets, many of which may be greater than 30 ha in size. Several bird species qualifying shrubby/early successional habitat as significant are already known to exist in the Greater Sudbury Area, including at least one Special Concern Species:

Golden-winged Warbler (*Vermivora chrysoptera*). Breeding bird surveys would confirm the species and numbers using suspected shrub or early successional habitats as it applies to the SWH Criteria Schedule for Ecoregion 5E.

Animal Movement Corridors (Amphibian, Cervid or Furbearer): Since all three of the stated wildlife groups are known within the Greater Sudbury Area, it can be assumed that at least one type of movement corridor is present, most likely in association with forest or wetland ecosites identified to contain species of interest or have high ecological value. The Lawrentian Conservation Area has already been identified by Moriyama & Teshima (1991) as a large valuable South to East Wildlife Corridor for animal movement, along with several smaller corridors north of Lake Ramsey that function to facilitate movement within city limits. Of particular interest are known local populations of Eastern Wolf (*Canis lupus lycaon* - Special Concern), and Elk (*Cervus canadensis*), which has been sighted in the southern extent of the City as a result of past re-introduction efforts in the 1990s and 2000s. Site-specific habitat analysis and/or species surveys would be required to identify areas with high wildlife value, and would aid in determining which corridors are most likely to connect these areas.

Reptile Hibernaculum: Rocky substrate abundant across the watershed provides ample opportunity for potential hibernaculum suitable to snakes. Features such as rock crevices, rock piles or slopes, old foundations, animal burrows, or any other deep fissure that extends below the frost line may serve as habitat, and are considered hibernaculum where conditions promote its use by multiple individuals, a diversity of reptile species, or the presence of a Special Concern species, as described in the SWH Criteria Schedule for Ecoregion 5E. One federally-listed Special Concern snake (Milksnake - *Lampropeltis triangulum*) is known to exist within the Greater Sudbury Area. Based on the widespread rocky substrate available, it can be assumed with a high degree of confidence that at least one hibernacula is in existence within the subwatershed.

Bald Eagle and Osprey Nesting, Foraging and Perching Habitat: Any forest communities featuring large supercanopy trees which are adjacent to large bodies of water (lakes, rivers or wetlands) may provide nesting habitat for these two raptor species. Although there are no records of this SWH type within the subwatershed, breeding data indicates that there are records for these two species present within Greater Sudbury area, and either could therefor be using any treed habitat nearby the numerous waterbodies throughout the Sub-watershed, provided large trees are present.

Waterfowl Stopover and Staging Areas (Aquatic): Historical records of ducks, loons, geese, and gulls on Galliard Island may suggest that Ramsey Lake is a Significant Aquatic Waterfowl Stopover/Staging Area based on the SWH Criteria Schedule for Ecoregion 5E. Investigation of species, numbers and duration of use would be required to confirm whether or not Ramsey Lake qualifies.

Late Winter Moose Habitat: With the high content of conifer plantings associated with the Sudbury Regreening program, it is possible that dense mature conifer forest suitable for Late Winter Moose Habitat may be present within the subwatershed or will be in the future. Not all potential conifer stands in the Greater Sudbury Area have been investigated as Candidate Late Winter Moose Habitat by the MNRF (City of Greater Sudbury, 2013), and winter surveys to confirm the presence of Moose would be necessary to identify them.

Woodland Raptor Nesting Habitat: This SWH type is possible in any tall-tree community, or specific forest swamps. Where tall-treed ELC communities are present in the subwatershed, they are likely to provide appropriate habitat opportunities for at least one of the woodland raptors listed within the SWH Criteria Schedule for Ecoregion 5E that is known to occur in the Greater Sudbury area (Broad-winged Hawk - *Buteo platypterus*). This habitat type is likely to become more common in the subwatershed as regenerating forest stands progress to maturity. Appropriately timed surveys (occurring mid-March to late May) would assist in identifying potential or confirmed habitat specific to the species in question.

Special Concern and Rare Wildlife Species: Species records indicate the presence of several species considered to be rare or Special Concern within the Greater Sudbury Area, including, but not limited to: Bald Eagle *(Haliaeetus leucocephalus*), Black Tern (*Chlidonias niger*), Canada Warbler (*Cardellina canadensis*), Common Nighthawk (*Chordeiles minor)*, Eastern

Wolf, Golden-winged Warbler, Milksnake, Monarch (*Danaus plexippus*), Olive-sided Flycatcher (*Contopus cooperi)*, Peregrine Falcon (*Falco peregrinus)*, Purplish Copper (*Lycaena helloides)*, Short-eared Owl (*Asio flammeus)*, and Snapping Turtle (*Chelydra serpentina*). Location information of documented species occurrences in combination with targeted surveys and habitat characteristics would help identify candidate or confirmed SWH within the subwatershed.

Rare Vegetation Communities: The following types of rare vegetation communities are most likely to have some potential within the subwatershed, based on the rocky landscape and known associated ELC communities:

- Cliffs and Talus Slopes
- Precambrian Rock Barren
- Alvar

Fine-scale Ecological Land Classification would be required to identify these, or any other potential rare vegetation communities not listed here.

3.3.6.6 Species at Risk and Other Species of Conservation Concern

For the purpose of this study, SAR are defined as species listed as Endangered (END), Threatened (THR), or Special Concern (SC) under the Ontario *Endangered Species Act* (ESA) and/or the federal *Species at Risk Act* (SARA). Other Species of Conservation Concern (SOCC) include those with Global Ranks of G1-G3 and/or Sub-national/Provincial ranks of S1-S3.

Aquafor Beech Limited consulted a number of secondary information sources to assess the presence of SAR and species of conservation concern within the study area. Sources such as the MNRF's NHIC Make-a-Map online database, the Ontario Reptile and Amphibian Atlas (ORAA), the Ontario Breeding Bird Atlas (OBBA), the Ontario Butterfly Atlas (OBA), the Atlas of the Mammals of Ontario (Dobbyn, 1994), the Greater Sudbury Natural Heritage Report (City of Greater Sudbury, 2013), iNaturalist and eBird were used to identify occurrence information on SAR and other species of conservation concern. **Table 3.23** provides an annotated list of SAR and other species of conservation concern previously recorded within the study area, or have potential to occur based on records in the Greater Sudbury Area. These species could potentially occur throughout the subwatershed in suitable habitat conditions.

Table 3.23: Species at Risk and Other Species of Conservation Concern within the Ramsey Lake Subwatershed

Species Name		SARO	COSEWIC	S Rank	G Rank	Sources
Scientific Name	**Common Name**					
Mammals						
Canis lupus lycaon	Algonquin (Eastern) Wolf	THR	THR	S2	G5	City of Greater Sudbury (2013)
Perimyotis subflavus	Tri-coloured Bat	END	END	S3?	-	Assumed present
Myotis leibii	Eastern Small-footed Bat	END	END	S2S 3	G3	Assumed present
Myotis lucifugus	Little Brown Myotis	END	END	S4	G5	City of Greater Sudbury (2013)
Myotis septentrionalis	Northern Myotis	END	END	S3	G4	City Greater of Sudbury (2013)
Reptiles						
Chelydra serpentina	Snapping Turtle	SC	SC	S3	G5	ORAA
Emydoidea blandingii	Blanding's Turtle	THR	THR	S3	G4	ORAA, NHIC
Lampropeltis triangulum	Milksnake	-	SC	S3	G5	ORAA
Birds						
Antrostomus vociferus	Eastern Whip-poor-will	THR	THR	S4B	G5	OBBA, eBird
Asio flammeus	Short-eared Owl	SC	SC	S2N, S4B	G5	City of Greater Sudbury (2013), eBird
Cardellina canadensis	Canada Warbler	SC	THR	S4B	G5	City of Greater Sudbury (2013), eBird
Chaetura pelagica	Chimney Swift	THR	THR	S4B, S4N	G5	OBBA, eBird
Chlidonias niger	Black Tern	SC	N/A	S3B	G5	City of Greater Sudbury (2013), eBird
Chordeiles minor	Common Nighthawk	SC	THR	S4B	G5	City of Greater Sudbury (2013), eBird
Contopus cooperi	Olive-sided	SC	THR	S4B	G4	City of Greater

Species Name		SARO	COSEWIC	S Rank	G Rank	Sources
Scientific Name	**Common Name**					
	Flycatcher					Sudbury (2013), eBird
Dolichonyx oryzivorus	Bobolink	THR	THR	S4B	G5	OBBA, eBird
Falco peregrinus	Peregrine Falcon	SC	SC	S3B	G4	NHIC, OBBA
Haliaeetus leucocephalus	Bald Eagle	SC	N/A	S2B	G4	City of Greater Sudbury (2013), eBird, iNaturalist
Hirundo rustica	Barn Swallow	THR	THR	S4B	G5	City of Greater Sudbury (2013), eBird
Insects						
Danaus plexippus	Monarch	SC	END	S2N, S4B	G5	OBA
Lycaena helloides	Purplish Copper	-	-	S3	G5	NHIC

3.3.6.7 Linkages and Corridors

The major natural corridor within the study area runs east to west on the south side of Ramsey Lake, and consists of the Laurentian Conservation Area, Laurentian University, and Idylwylde Golf and Country Club, and extends into Robinson and Kelley Lakes (Moriyama & Teshima, 1991). This large undeveloped tract contains a very large wooded area of particularly high value that supports feeding, nesting and denning sites for wildlife. The lands are a matrix of different habitat types, notably including the Perch Lake and associated Beaver Pond complex, as well as the Lily Creek Wetland Corridor.

The Perch Lake-Beaver Pond complex provides a north-south link promoting movement of wildlife from Ramsey Lake watershed into the surrounding regions. Large mammals including moose, deer, and bear are known frequent users of this corridor.

Lily Creek has also been identified as a valuable marsh wetland river corridor connecting Ramsey Lake to the Junction Creek watershed. This feature is known to support many species of wildlife, examples including Virginia Rail, Sora, Black Duck, Muskrat, Racoon and Mink.

Another known corridor runs south from Ramsey Lake to Richard Lake, across Laurentian Conservation Area and the south east Trans-Canada Highway bypass.

Two fragmented corridors have been identified by Moriyama & Teshima (1991): the north shore of Ramsey Lake along a creek into the Greenwood Drive neighborhood; and Minnow Lake to Ramsey Lake, west of Hillside Ave to CPR bay. Though these corridors are fragmented, they are regenerating and are considered to be functioning.

Aerial interpretation using more current imagery is a useful tool in identifying potential for additional wildlife corridors. A wedge of mostly undeveloped land northeast of the Highway 55 and 86 intersection contains a mosaic of wooded and wetland habitats likely to have high potential value as a bridge to natural lands to the north and the subwatershed, particularly as the habitat variety is likely to support a large range of different species types. Similarly, lands west of the

Barrydown neighbourhood contain an area of connected forest that abuts the Ponderosa Wetland, which has been evaluated as Provincially Significant and is known to contain Blanding's Turtle (Endangered). This area of forested land may also serve as a corridor to connect this PSW to Ramsey Lake, with the exception of those species unable to easily cross roadway boundaries. It is likely that additional wildlife corridors exist throughout the subwatershed, but habitat evaluation and documentation of species movement would be required to confirm any suspected corridors.

3.3.6.8 Data Gaps

Vegetation Communities and Flora

Vegetation communities were previously identified generally *in the Ramsey Lake and Watershed Community Improvement Plan: A 100 Year Vision* (Moriyama & Teshima, 1991) and in *Floristics, Structure and Dynamics in Plant Communities on Acid, Metal Contaminated Soils in the Sudbury Area* (Sinclair et. al., 1996). Ecological Land Classification (ELC) and comprehensive floral inventories have not been completed within the study area. It is recommended that ELC be completed and flora inventories be undertaken within the study area in subsequent stages of the planning process to identify potentially significant vegetation communities, and aid in the identification of SWH and potential habitat for SAR and/or other species of conservation concern.

Significant Wildlife Habitat

Significant Wildlife Habitat (Ecoregion 5E) cannot be completely assessed as there is insufficient data to confirm the presence of SWH for the majority of criteria. Specific surveys for vegetation communities, flora, amphibians, reptiles, mammals, and birds (songbirds and waterfowl) are required to accurately identify SWH within the study area.

3.3.7 Summary of Existing Ecological Conditions

The following subsections summarize the existing conditions of the Ramsey Lake Sub-watershed and describe constraints and opportunities to development.

3.3.7.1 Existing Ecological Conditions

Water quality in the Ramsey Lake catchment has historically been affected by mine-related smelting in Sudbury and by urbanisation in its watershed. Natural heritage features are still in the process of undergoing recovery now that sulphur dioxide levels have been substantially reduced. Much of the area is still ecologically limited. Although Ramsey Lake was never acidified, urban effects such as run-off from homes and roadways have influenced nutrient chemistry and dissolved oxygen levels, algal growths, and distributions and species of fishes present. The high abundance of aquatic plants in Ramsey Lake is the likely result of the presence of excess nutrients, historically. Nutrient levels have been below the Provincial guideline for lakes consistently since 1978 but were likely higher in the past. The depletion of oxygen in the hypolimnion of the lake reflects that the lake has a high total load of nutrients currently. Increased sediment loads, changes in shorelines and land use have also contributed to changes in aquatic habitats, and may have contributed to increased growth of some species of aquatic plants. Sodium and chloride concentrations are increasing over time, with sodium concentrations exceeding a threshold that requires consideration by the local health authorities.

Extensive algae blooms were reported in Ramsey Lake, beginning the 1950s. Although nuisance blooms continue to be documented periodically, improvements to sewage treatment systems has resulted in improved water quality in the Lake, and a reduction in algal blooms.

Water quality in Minnow Lake is poor, the result of historical land use (e.g. the former sawmill) and surface run-off. Minnow Lake is nutrient enriched and has high chloride concentrations. Ramsey Lake has lower levels of both nutrients and chloride than Minnow Lake.

The wetland separating Bethel and Ramsey Lake may capture nutrients before they enter Ramsey Lake since nutrient enrichment in Ramsey Lake is lower than Bethel Lake. Total Phosphorus levels in Bethel Creek are well above the Provincial guidelines for streams. Chloride concentrations are low in Bethel Lake.

Total phosphorus in Frobisher creek is high and periodically exceeds the Provincial guideline for streams (30 µg/L). Metal concentrations and chloride concentrations are also high.

The streams that flow into Ramsey Lake, with the exception of Laurentian Creek, have likely been physically altered extensively by adjacent land-use development and the stream channels are constrained by urban development. Vegetated buffers along stream banks are narrow, generally less than 5 m in width. It is unlikely that these streams are suitable to support fish communities year-round. The exception may be pool habitats (e.g., the fish habitat offsets in lower Frobisher Creek).

The small lakes, Bethel and Minnow, that flow into Ramsey Lake act as settling ponds for silt and reservoirs for nutrients. Where possible, improvements to water quality in these lakes should be sought. New development in these sub-catchments should be managed so that further deterioration of water quality is prevented. Improvements in water quality will be reflected in Lily Creek and the natural environment downstream of Ramsey Lake.

Soils within the sub-watershed are thin, and have been removed in some areas due to logging, mining, and urban development. Remaining soils have low organic content, and have high levels of metals and sulfates as a result of the abovementioned anthropogenic influences.

There are four (4) main forest communities within the study area, consisting of early pioneer successional species, and some hardwood species. The four main forest type vegetation communities are:

- Birch Transition Community (White Birch);
- Maple-Birch Community (White Birch and Red Maple with clumps of Red Pine);
- Red Oak Community (Red Oak and some White Birch);
- Poplar Lowland Community (Trembling Aspen);
- Big-tooth Aspen Community (Big-toothed Aspen); and,
- Treeless Community (Forbs and Graminoids).

Regreening efforts over the past four decades have likely increased the young-mid aged proportion of communities across the landscape, the likely result being Jack Pine or other conifer dominated communities of various ages dependant on when they were planted.

Wetland types within the study area include alder swamps, poor fens, and meadow and shallow water marshes, and are often in association with lake edges or flow corridors between lakes. Rock barrens are scattered throughout the forest communities in the south end of the study area, and on the north side, north of Minnow Lake and Bancroft Drive.

The wetlands and lakes within the study area support songbirds, waterfowl, small mammal nesting, and fish spawning. Large mammals observed within the sub-watershed include Black Bear, Moose and White-tailed Deer.

There is insufficient data to determine the full variety of SWH within the Ramsey Lake Sub-watershed; however, given the natural landscape composition and species documented, there is high potential for at least one SWH to be present within the sub-watershed.

SAR and other species of conservation concern previously observed within the subwatershed include:

- Eastern Wolf (THR)
- Tri-coloured Bat (END)
- Eastern Small-footed bat (END)
- Little Brown Myotis (END)
- Northern Myotis (END)
- Snapping Turtle (SC)
- Blanding’s Turtle (THR)
- Milksnake (S3)
- Eastern Whip-poor-will (THR)
- Short-eared Owl (SC)
- Canada Warbler (SC)
- Chimney Swift (THR)
- Black Tern (SC)
- Olive-sided Flycatcher (SC)
- Bobolink (THR)

- Peregrine Falcon (SC)
- Bald Eagle (SC)
- Barn Swallow (THR)
- Monarch (SC)
- Purplish Copper (S3)

Corridors and linkages include a large east-west corridor through the Laurentian Conservation Area, Laurentian University, and Idylwylde Golf and Country Club; a north-south corridor from Ramsey Lake to Richard Lake; and two smaller fragmented corridors, one on the north shore of Ramsey Lake, and one from Minnow Lake to Ramsey Lake. Potential for additional corridors such require further investigation into the habitat quality and evidence of use by target species.

3.3.7.2 Constraints

Ramsey Lake is a key municipal drinking water source for the City of Greater Sudbury, and as such, water quality has a significant human implication. Sodium concentrations have, like chloride, been increasing over time due to the use of de-icing salt. As seen in **Figure 3.40**, sodium concentration increased steeply between 1991 and 2001, but have largely stabilized since then at concentrations close to 50 mg/L, with a few exceptions in 2008, 2012, 2013 and 2018. The most recent sodium result was 48.5 mg/L in September 2019, which was in excess of 20 mg/L, a concentration that triggers consideration by Public Health Sudbury and Districts, given that Ramsey Lake is the main water supply for the City of Greater Sudbury. Rising sodium concentrations are thus an additional constraint in the Ramsey Lake watershed.

The lake has historically experienced blooms of cyanobacteria that produce cyanotoxins, and algae that cause taste and odor problems with the water supply. Existing internal and external loadings of phosphorus to Ramsey Lake are therefore a significant consideration for future additional development. Phosphorus concentrations in Ramsey Lake are currently below the PWQO of 20 µg/L, but the lake experiences significant oxygen depletion during summer stratification (MECP, 2019). The lake also has a significant challenge related to extensive beds of aquatic plants. The plants have been a significant sink nutrient including phosphorus, and over time with mitigation of external nutrient loads to the lake, macrophytes can be expected to become a source of nutrients as the plants senesce.

As seen in **Figure 3.40**, chloride concentrations in Ramsey Lake have increased substantially since 1991, although most of this increase occurred between 1991 and 2001. Since 2010, chloride concentrations have generally fluctuated between 85 and 98 mg/L. Chloride concentrations are currently below 120 mg/L, the concentration that poses risks to aquatic life. However, as climate change increases average air temperatures, salt application rates will likely increase (see **Section 9.3.10.1**). Increasing chloride concentrations are therefore a constraint in this watershed.

Constraints to development may also include the location of significant natural features "and areas" as defined by the City of Greater Sudbury Official Plan (2016), SAR and other species of conservation concern and their habitats, and SWH, pending further investigation and field studies at later planning phases.

3.3.7.3 Opportunities

If development in the upper portion of Frobisher Creek proceeds and it becomes necessary to construct a storm water pond, there may be an opportunity to create permanent fish habitat features as part of the storm water management system. Removal of the beaver dam located near the mouth of Frobisher Creek would restore fish movement between Ramsey Lake and the lower portion of the Creek.

Maintaining ecological corridors within the sub-watershed could be accomplished by developing lands that allow for natural environments to link to other natural areas unbroken. Corridors along the north shore of Ramsey Lake are subject to more severe development pressure when compared to the large tract of land south of Ramsey Lake, and therefore have high conservation value. Protection and/or further reforestation of lands north of Highway 55 (Kingsway) would preserve and potentially promote wildlife passage between natural areas to the north, and the north shore of Ramsey Lake. Wildlife underpasses beneath major road arteries (e.g. Highway 55 – Kingsway, Highway 67 – Howey Drive/Bancroft Drive) would be most beneficial to wildlife that are restricted by roads, or experience high rates of road mortality when migrating (e.g., turtles).

There are numerous opportunities throughout the sub-watershed to ecologically restore areas that have been damaged or degraded due to logging, fires, and from the effects of mining. A focus on areas where exposed bedrock persists despite past regreening activities or natural regeneration may be particularly beneficial in terms of wildlife value. Areas where urban development pressure already exists or is projected to occur (e.g. north of Ramsey Lake or within existing subdivisions) may be candidate priority areas to relieve some development driven habitat loss, or increase the value of existing habitat qualitatively and quantitatively. Examples include the aforementioned habitat found surrounding the Greenwood Drive neighbourhood, and land surrounding Frenchman's Bay or CPR Bay, as they are already documented as functional habitat for wildlife. Recent aerial imagery of the existing natural areas north of Highway 55 (Kingsway) appear to show both wooded and wetland habitat, but exposed ground appears evident and the forest mosaic is patchy. These areas have been a focus of regreening efforts in the past, but continued restoration would likely contribute to more complete vegetation cover throughout these areas and are likely to provide high quality habitat for a wide variety of species types that may use either wetlands, wooded areas, or both. Details on how the Sudbury Regreening Program intends to address restoration initiatives is described in **Section 6.1.5.**

Increased vegetation coverage is also likely to have the added value of buffering flows during storm events in areas where there is a high content of man-made impervious surfaces. Similar to areas highlighted for wildlife habitat restoration, existing green spaces surrounding Greenwood, Frenchman's Bay, and CPR Bay neighbourhoods are likely already acting as flow controls during stormwater events, but could be improved by reducing the amount of exposed rock remaining in these areas. These areas in particular, along with all other thin strips of vegetation surrounding the Lake and associated watercourses also likely play a role in contaminant catchment, ultimately minimizing the flow of hydrocarbons, sediments and other anthropogenic substances, as well as reducing quantities of superheated water flowing from paved surfaces into the coldwater Lake Ramsey. This is ultimately expected to improve water quality in the lake, benefiting both ecological systems and urban communities alike.

The following wildlife species groups are likely to benefit from restoration efforts in the following ways:

- **Amphibians**: Many species breed in both woodland and open marsh habitats. Increasing habitat quality through increased vegetation cover, and maintaining connections between wetlands/forest mosaics promotes diversity and genetic exchange.
- **Reptiles**: Several Species at Risk turtles and snakes are known within Ramsey Lake Subwatershed and may overwinter in wetlands (turtles) and/or use surrounding forest cover as travel corridors or foraging habitat. Restoration efforts could improve habitat connections particularly between waterbodies or hibernacula sites and other areas that support life functions. Introducing travel corridors under main roadways may introduce new corridors between fragmented habitats and promote dispersal and genetic exchange.
- **Birds:** a variety of bird species are known to inhabit the Greater Sudbury Area, many of which are area sensitive and use interior forest, forest edge, open wetland, and shrub thicket habitats. Since these species are more mobile over anthropogenic barriers (e.g. roads), inner-city forests and their connection corridors are uniquely beneficial to this species group.
- **Mammals:** A variety of small to large terrestrial mammals are known within the Greater Sudbury Area, requiring a range of habitat types and sizes. In-tact, high quality natural areas provide habitat for many critical mammalian life processes (e.g. breeding, foraging, cover, etc.). Value is increased by preserving or restoring large, unbroken tracts of natural land, particularly those demonstrating a large variety of habitat types.
- **Bats:** Maintaining forest cover throughout the Sub-watershed promotes the development of large diameter trees and late successional deciduous forest types (e.g. Oak dominant) that may serve as suitable maternity roosting for most bat species in Ontario, including SAR.

Fish: Increased vegetation cover in areas surrounding Lake Ramsey promotes increased water quality. A focus on watercourse buffer zones or wetlands are expected to be particularly beneficial as contaminant filtration, thermal regulation and provides additional habitat as overhanging vegetation cover and input of woody debris. Vegetated Buffer Zones (VBZ) are discussed further in **Section 6.1.4**.

4.0 Public Consultation

This section provides an overview of the consultation approach developed for this subwatershed study and presents community and agency feedback received during the Phase 1 Background Data Collection and Review stage of this plan.

Completion of this Subwatershed Study follows the **Municipal Class EA Master Planning process**, Approach #2, as described in section 1.6. This approach is a two-phase process through which the problem or opportunity is identified, followed by development of alternative solutions that are evaluated to establish a preferred solution to address the problem / opportunity. Consultation requirements of the Class EA process include:

- A consultation program that is innovative and tailored to address needs of the project and its stakeholders, providing two-way communications with consultation conducted early and throughout the planning process; Communications should encourage exchange of ideas and broaden the information base so as to lead to better decision-making;
- Completion of mandatory public consultation events for development and assessment of alternative solutions and recommendation of the preferred solution (stages 2 and 3 of the master planning process), respectively;
- Issuance of formal notices to advise of project initiation, public meetings and project completion;
- An approach whereby differences in points of view are resolved as the study proceeds and in the final study report.

The study process also integrates City communications standards and **watershed planning best practices** (Conservation Ontario, 2003). These practices overlap with the principles of openness, timeliness, relevance and encouraging of discussion expressed for the EA process as well as the following:

- Use of evolving tools and approaches to involve and communicate with the public;
- Application of a partnership approach to watershed planning and management;

- Encourage ongoing engagement in sub-watershed health with the intent of producing a final Plan that participants view as a shared accomplishment; and
- Development of a plan for watershed management that is based on solid science and that acknowledges and reflects the preferences of the people living in the watershed.

To address the EA requirements, watershed planning best management practices and City communications standards, the project team developed a study **Communications Plan** to establish a comprehensive public and community outreach program. The program provides the basis for timely, relevant and accurate information synthesis and that encourages a two-way exchange of ideas between the study team and Ramsey Lake sub-watershed stakeholders and residents. Involvement of citizens and stakeholders for Ramsey Lake to share their local knowledge on sub-watershed existing conditions and to provide input and feedback on the plan content throughout the study will result in definition of a strong management approach for the subwatershed that will be a shared responsibility between the City and study participants. The Communications Plan components include communications objectives, identification of Ramsey Lake Sub-Watershed stakeholders, key communications messages and outcomes, methods for communication, evaluation of the project communications effectiveness and a detailed workplan.

Stakeholders for the Ramsey Lake Sub-Watershed include all those individuals and groups with an interest in the planning for and long-term care of the ecosystem health of Ramsey Lake. These stakeholders include:

- City of Greater Sudbury staff and Council representatives with responsibility for planning and managing of surface water and groundwater quality and quantity control on behalf of residents;
- Agency representatives with a mandate common with the City's regarding aspects of watershed management, such as Conservation Sudbury, Public Health Sudbury and Districts, Greater Sudbury Source Protection Authority, Ontario Ministries of Natural Resources & Forestry (MNRF) and Environment, Conservation and Parks (MECP), Environment and Climate Change Canada (ECCC), Department of Fisheries and Oceans Canada (DFO);

- The City's Watershed Advisory Panel, comprised of citizens (8 members) and lakes and watershed technical experts (6), appointed by the City. This Panel includes representation from Public Health Sudbury and Districts, MNRF, MECP, Laurentian University and the Ramsey Lake Stewardship Committee.
- First Nations Communities with an interest in the Greater Sudbury area and of the Ramsey Lake Sub-Watershed.
- Educational Institutions, such as Laurentian University and the Vale Living with Lakes Centre;
- Community and Interest Groups of local organizations that work together on neighbourhood, community, business, recreational, lake stewardship and environmental matters. A number of community stewardship groups have an interest in the Ramsey Lake Sub-Watershed Study. These include groups with mandates that are:
    - City-wide, such as the Coalition for a Liveable Sudbury and the Greater Sudbury Watershed Alliance;
    - Ramsey Lake Sub-Watershed specific, including Ramsey Lake Stewardship Committee and the Minnow Lake Restoration Group; and
    - Specific to Sub-Watersheds that have connections to Ramsey Lake, such as Junction Creek Stewardship Committee and Vermilion River Stewardship.
- Landowners and Residents located within the sub-watershed.

Through the study communications workplan, Ramsey Lake Sub-Watershed stakeholders and community will be involved at each of the five key study phases identified in section 1.6. Methods of engagement include: regular meetings, approximately monthly, of the Technical Advisory Committee (City staff, Committee and Conservation Sudbury representatives), at least one meeting for each of the study phases for stakeholders and for public information sessions, study findings posted on the City website, paper and online surveys and the opportunity for exchange of questions, discussion and feedback with the project team throughout the study (by phone, letter, e-mail or social media). The purpose of the stakeholder and public information centre (PIC) meetings will be review of and input to / feedback on the study findings for:

1. Background Data Collection and Review;
2. Existing Conditions Characterization and Impact Analysis;

3. Development of Alternative Sub-Watershed Strategies;
4. Recommended Sub-Watershed Management Plan; and
5. Finalization of the Sub-Watershed Management Plan.

Meeting content and format for obtaining stakeholder and public input will be tailored to fit the type of information and feedback relevant to the study phase. For instance, the first stakeholder and PIC meetings focused upon presentation of the study process and collected information under review with a call for public help to identify additional data sources or problem/opportunity areas.

The Project Notice of Commencement was issued through newspaper advertisements and e-mails to identified stakeholders in November 2016. The stakeholder and public meetings for the first study phase were held on the afternoon and evening, respectively, of December 8, 2016. The study process and background information were presented for review and discussion on posters set up in an open house format at the Northern Water Sports Centre at 206 Ramsey Lake Road. A copy of the study notice of commencement and public meetings and the information centre posters are provided in **Appendix E**. **Appendix E** also presents a copy of the online and paper survey distributed at the time of the December 8th meetings in order to obtain stakeholder and community feedback on environmental issues to consider in the study, possible recommendations to address important sub-watershed issues, other data sources that the team should review, special and valued areas and features and other urban area impacts upon sub-watershed health.

The stakeholder session held on the afternoon of December 8th was well attended by about 35 people consisting of representatives from Public Health Sudbury and Districts, City of Greater Sudbury, Conservation Sudbury, Laurentian University, the City Watershed Advisory Panel, the Ramsey Lake and Junction Creek Stewardship Committees and the Minnow Lake Restoration Group. The evening public information centre less attended with visits by only a few local residents. Meeting timing in December and perhaps a somewhat shorter notice period than required for the meeting are anticipated to be responsible for the low attendance. For subsequent study meetings, the project team will ensure a longer notice period for the public meeting and use a greater variety of methods to encourage community participation and attendance.

A total of 10 comments were received in writing and through completed surveys. Respondents included individuals and submissions from the Ramsey Lake Stewardship Committee, the Coalition for a Liveable Sudbury and Public Health Sudbury and Districts. The nature of the comments received focus upon:

- Majority of survey respondents considered almost all listed environmental issues to be very important, with the factors of flooding from streams and lake sediment quality considered by an equal number of respondents to be somewhat and very important. One respondent noted that quality/quantity of water for recreation and recreational activities were not important factors for the study.

- Environmental concerns described for the Ramsey Lake Sub-Watershed included:
  - Recommendation for control of boats on the lake because of potential for pollution and introduction of invasive species;
  - Suggestion that all septic system locations be identified as potential phosphorus loading sources;
  - Impact of development (particularly the industrial development in the northeast portion of the watershed) upon wetlands, water quality, habitat and species at risk; and
  - A caution to carefully evaluate the effectiveness of stormwater management systems that are applied, ensuring the recommended system meets desired standards.

- Recommendations to address key sub-watershed issues include:
  - Implementation of a boat launching fee, cleaning station and restriction of the number of boats on the lake at any one time;
  - Mandatory septic system inspections and re-inspections;
  - Identify areas within the watershed that should not be developed;
  - Identify opportunities for Low Impact Development and to maintain green infrastructure assets;
  - Set watershed targets for wetland and vegetative cover areas;

    - To the extent possible, apply natural / low impact methods for stormwater management; and
    - Tuild on the City's reputation of re-greening to take an approach that keeps the Lake blue, not green.

- Disappointment was expressed with the meeting format by one respondent. The concern that there was not adequate information and opportunity for review and discussion by community experts of the data sources being compiled and analysed. It was suggested that a formal presentation to the Watershed Advisory Panel would be an appropriate way to tap into the wealth of community knowledge available for the Ramsey Lake Sub-Watershed. Another reviewer also expressed concern with the level of detail presented at the meeting, noting that it is difficult to comment upon the study without more information. The short notice period was also identified as having a negative impact upon adequate opportunity for community experts to participate. There is a strong desire from the community to share knowledge and be actively involved in this study.

- Local background knowledge recommended for study consideration included:
    - Ensuring that all hazard lands, such as the floodplain in the Bethel-Keast area, are mapped;
    - Ensuring that the GIS layers used are complete as some areas do not look accurate, such as wetland boundaries, lands designated as bedrock that are actually forests;
    - A copy of a wetland evaluation for the area along Frobisher Creek north of Kingsway was offered as a source of information on local chloride levels, possible introduction of iron-rich water into the wetland and presence of brook stickleback in the ponds, and a note of the presence of milfoil;
    - A detailed history on the human uses of and impact upon Lake Ramsey over the past century, provided by a study participant.

- Special features recommended for the study consisted of:
    - Ensuring inclusion of all stormwater inputs, especially at Bell Park Beach and David Street;

- Mapping of the habitat of all species at risk;
- Fully assessing the effectiveness of planned stormwater management systems before their implementation, including a process for public participation;
- Ensuring that natural system linkages are included in the description of existing conditions along with a description of how the terrestrial environment affects water quality and quantity;
- Ensuring identification of sensitive surface and ground water features and wetlands;
- Provision of specific direction to conditions related to the pace and scope of the Keast Drive housing development; and
- Evaluation of the effectiveness of current policy and regulatory measures in place to prevent introduction of contaminants to the lake.

- Urban impacts of concern were noted as:
  - The Keast development;
  - Impact of existing septic systems; and
  - Impact of potential leaching of contaminants from the rail bed and a request to monitor new builds, permits and applications for zoning exemptions from the perspective of evaluating the proposed projects to ensure protection of shorelines and water quality.

- Community groups are pleased to have this study proceed and look forward to actively participating in and supporting the plan development.

Appendix E presents a full listing of the comments received.

5.0 Goals and Objectives

As stated in Section 1.2 the overall goal of this study is to:

> ***Develop a Subwatershed Management Plan to protect, maintain and enhance the surface water, groundwater, and natural resources of Ramsey Lake and its tributaries through environmentally sound policy and management actions.***

On this basis a set of key objectives were developed to describe more specifically how this goal would be achieved. As part of the study a set of goals and objectives were developed in order to establish how the various management strategies would be in achieving the stated goals and objectives. The terms may be defined as follows.

Goals: Environmental goals are broad aims associated with the conservation or restoration of natural features and processes within the study area.

Objectives: Environmental objectives describe how an environmental goal can be achieved. Objectives often relate to specific technical principles. Objectives can be specific to geographical areas within your municipality or can be municipality-wide. A science-based approach was used to develop objectives for each goal. Goals and associated objectives are provided below.

Table 5.1: Summary of goals and objectives

Goals	Objectives
1. Enhance the Hydrologic Regime	1. Minimize flood risk; 2. Re-establish natural hydrologic cycle; 3. Ensure natural channel stability and protect against channel erosion and sedimentation; 4. Protect/Support aquatic communities; 5. Manage surface water withdrawals; and, 6. Support terrestrial communities.
2. Restore, Maintain, and Enhance Water Quality	1. Support reasonable uses for: 2. Aesthetics, and 3. Wildlife; 2. Prevent eutrophication/Algal growth; 3. Protect groundwater quality to support drinking water supply, aquatic and terrestrial communities; and, 4. Support aquatic communities.
3. Conserve, protect, and restore a healthy aquatic ecosystem	Contribute to achieving healthy aquatic communities, including warmwater or cool water fisheries as appropriate.
4. Conserve, protect, and restore a healthy terrestrial ecosystem	1. Protect, restore, or enhance native terrestrial plant and animal species, community diversity, and productivity; and, 2. Protect, restore, or enhance the integrity of the watershed ecosystem through an integrated approach of natural areas, habitats, and connected links.

Different management strategies and methodologies can be implemented to help achieve these objectives and goals for the Ramsey Lake subwatershed. The following chapters will present and evaluate several different possible solutions for existing development and proposed development. The evaluation and impact assessment will identify strategies and alternative solutions that should be carried forward and implemented.

Chapter 6.0 outlines the approach that was used for evaluate management strategies for Existing Lands while Chapter 7.0 outlines the approach for Proposed Development Lands.

6.0 Alternatives Strategies for Existing Lands

Within this chapter, alternative strategies for existing developed lands will be evaluated to determine a preferred solution to reach the Goals and Objectives outlined in **Chapter 5.0**.

The Environmental Assessment process, where applicable, will be used to assess Alternatives for Existing Lands while Municipal, Conservation Authority, Provincial and Federal policies, regulations and acts will be used to assess Alternatives for Proposed Development Lands.

An alternative is a measure, or series of measures, which, when implemented, will protect, enhance or restore the environmental resources.

This chapter will:

- provide a general description of the types of alternative solutions that were considered in order to address the goals and objectives as defined in **Chapter 5.0**;
- provide a description of the criteria that were used to screen the alternative solutions;
- provide an evaluation of the effectiveness of the alternative solutions; and
- discuss the rationale for selecting the preferred solution.

In undertaking this assessment and evaluation, the general approach has followed the three steps below:

1. Establish a long list of alternatives;
2. Screen the alternatives to determine feasibility and acceptance; and
3. Undertake a more comprehensive assessment for alternatives that are found to be feasible.

There are several items that need to be considered in evaluating the alternatives. The alternatives must address a wide range of environmental issues (e.g., groundwater, flooding, erosion, water quality, terrestrial and aquatic ecology) and a wide range of general measures should therefore be considered initially.

Implementation of the alternatives will take place using a variety of mechanisms and stakeholders.

For example, some measures will be implemented by homeowners as part of stewardship programs while other measures will be implemented as part of the other processes. Some of the alternatives may be subject to the Environmental Assessment Act which requires a defined evaluation and selection process. In this regard Approach #2 of the Master Planning process in the MEA Municipal Class EA document has been used.

6.1 Long List of Alternatives for Existing Lands

A long list of alternatives or management actions has been identified for the Ramsey Lake watershed. The list, together with a description of each alternative, is provided below. At the watershed level a wide variety of alternatives need to be considered to address the range of existing land uses and environmental resources.

Implementation of proposed measures will be based on general recommendations made for this study together with the findings/ recommendations of other studies.

The broad range of management actions recommended for the Ramsey Lake Watershed area are summarized below:

- Low Impact Development (LID) of Public Roads during Reconstruction
- Oil Grit Separators (OGS) or Stormwater Management Facilities
- Restoration Measures on Private Property
- Shoreline Works to Improve Habitat
- Ecological Restoration Works within the Watershed
- Stream Restoration
- Groundwater Protection
- Flood Mitigation
- Salt Management
- Management of Septic Systems

6.1.1 Low Impact Development (LID) of Public Roads during Reconstruction

Low Impact Development (LID) stormwater control measures are small-scale stormwater management practices located at the beginning of a drainage system where stormwater is captured and treated on-site or close to where the rainfall lands. These measures reduce the volume of stormwater entering the municipal storm sewer system and mitigate the loading of urban stormwater pollutants to end-of-pipe infrastructure and downstream receivers. Due to the relatively small area captured by individual measure, LIDs must be well distributed across catchments or subwatershed to form an integral part of the stormwater management system. The key principles of LID are to:

- Treat rainwater as a resource;
- Treat stormwater as close to the source area as possible;
- Utilize and preserve the existing natural systems;
- Focus on runoff prevention; and
- Create multifunctional landscapes.

LID stormwater control measures located within the municipal road rights-of-way are known as "**conveyance control measures**". These systems treat stormwater as it travels overland or through pipes on route to the downstream outlet. Traditional conveyance systems comprise curbs, gutters and buried concrete (or other) piping systems that carry stormwater away from a development area to a water body generally along the road network. In appropriate applications, conveyance control measures can be used to improve water quality conditions at lower cost to the municipality while still providing conveyance of the minor system.

Because residential streets account for a significant share of a community's impervious surfaces, conveyance control measures present an important opportunity to improve downstream water quality conditions (e.g. sediment, nutrient, bacteria, oil/grit, thermal impact reduction, etc.), promote groundwater recharge and minimize watercourse erosion.

Within the developed area of the Ramsey Lake subwatershed, conveyance control measures can most feasibly be incorporated into existing ROWs as part of planned road reconstruction works as storm sewers and inlets can be replaced and reconfigured during this process.

Within the Ramsey Lake subwatershed are two distinct types of cross sections which present different opportunities for LID retrofits. **Urban cross-sections** include curb and gutter profiles on the surface with catch basins and storm sewer to convey the minor system below the surface grade. **Rural cross-sections** have surface conveyance features such as roadside ditches or swales adjacent to the shoulder of the road. Rural cross-sections do not have catch basins or storm sewers. Conveyance control measures considered for implementation within the Ramsey Lake Subwatershed are identified along with representative images in the remainder of **Section 6.1.1**.

Implementation of LID facilities can be constrained by a number of factors present in the City of Greater Sudbury, including shallow bedrock, shallow groundwater table, and application of high volumes of sand for winter maintenance purposes. The presence of bedrock or groundwater within 1 m of the invert of the LID facility may require further hydrogeological studies or may require modifications in the LID design. Although clayey and silty soils limit infiltration, they do not prevent the implementation of LID control measures.

The use of sand instead of salt is common on local roads in the City (see **Section 8.3.8**), which can be a clogging and capacity concern if the sand is washed into the LID facilities. The Cities of Edmonton and Saskatoon provide guidance on minimizing the impacts of sand (City of Edmonton, 2014; City of Saskatoon, 2016), including:

- The use of pre-treatment, including vegetated buffer strips, settling basins, or forebays;
- Schedule regular maintenance of pre-treatment facilities;
- Start street sweeping in a timely manner in the spring;
- Promote the use of snow storage zones where snow containing large amounts of sand can be stored, and the runoff treated more easily;
- Apply sand strategically and only when needed.

An additional consideration is the extent of salt applied to the catchment area draining to the LID control measure. As salt cannot be removed from runoff water, dissolved salts will either be discharged to surface water features or will infiltrate into the native soil. Aquifer vulnerability should therefore be considered when designing infiltration facilities that will accept runoff from salted areas. In vulnerable areas, infiltration facilities should be designed to accept clean runoff, or filtration-only facilities should be used. See **Section 6.1.8** and **9.3.10** for additional salt management strategies.

A. Enhanced Grass Swales

Enhanced grass swales are vegetated open channels designed to convey, treat and attenuate stormwater runoff (also referred to as enhanced vegetated swales). Check dams and vegetation in the swale slows the water to allow sedimentation, filtration through the root zone and soil matrix, evapotranspiration, and infiltration into the underlying native soil. Simple grass channels or ditches have long been used for stormwater conveyance, particularly for roadway drainage. Enhanced grass swales incorporate design features such as modified geometry and check dams that improve the contaminant removal and runoff reduction functions of simple grass channel and roadside ditch designs. Enhanced grass swales are not capable of providing the same water balance and water quality benefits as bioswales, as they lack the engineered soil media and storage capacity of that best management practice.

Figure 6.1: An enhanced Grass Swale

B. Bioretention

Along municipal roads, bioretention areas can be placed at the edge of paved areas, either between the curb and sidewalk, or extending into the road in the approximate area of one parking spot. These 'low-tech' water quality treatment systems use plants and soil to trap and treat petroleum products, metals, nutrients, sediments and other pollutants that typically accumulate on asphalt surfaces.

When bioretention facilities are placed along the edges of pavements, the infiltrated water freezing beneath pavement surfaces can cause frost heaving. Design considerations to reduce this risk can include:

- Leaving a buffer between the edge of the bioretention facility and the pavement or installing a geotextile “curtain wall” at the edge of the bioretention facility to reduce water seeping beneath the pavement (Minnesota Department of Natural Resources, 2020); and
- Increasing the depth of gravel around the underdrain at the base of the bioretention facility to a minimum of 0.45 m (Lake Superior Streams, 2020).

Figure 6.2: Bioretention along residential streets

The flexible nature of bioretention design allows for integration into both urban and rural cross-sections. Bioretention variants that are best suited to ROWs with urban cross-sections are:

B.1 Bioretention Bump Outs (Curb Extensions)

Bioretention bump outs, also known as curb extensions are bioretention areas that extend into the roadway and are separated from the paved ROW by perimeter curbing. Bioretention bump outs can be used for traffic calming and can be arranged to allow for adjacent on street parking. The location, size and spacing of bioretention bump outs can be adjusted as needed to meet existing roadway conditions. It is possible to design these practices so the existing curb and inlets remain in place or repurposed.

Figure 6.3: Bioretention Bump Out

B.2 Boulevard Bioretention

Boulevard bioretention consists of shallow vegetated depressions located immediately behind the curb. For streetscapes with sidewalks, these units are located between the curb and inside sidewalk edge. In residential areas that do not have sidewalks, these cells are located on the municipally owned portion of the boulevard. Curb cuts typically direct road drainage to a bioretention cell, though other inlet types, such as side inlets, can be configured to meet site needs. The size and shape of boulevard bioretention units is flexible to accommodate site specific constraints.

Figure 6.4: Boulevard Bioretention

B.3 Bioretention Planters

Bioretention planters have vertical sidewalls and are often narrow and rectangular in shape. The walls allow bioretention planters to maximize the amount of stormwater retention within a small footprint. The self-contained structure of bioretention planters permits them to be installed in close proximity to utilities, driveways, trees, light standards and other urban features. Bioretention planters can be constructed immediately adjacent to the roadway, in the boulevard, or as a green feature within the pedestrian area (i.e. sidewalks and pathways). Given these characteristics, bioretention planters are ideal for integrating within highly urbanized streetscapes or within other road ROWs with tight space constraints. Planters are an ideal means to address multiple objectives in urban streetscapes, including street greening and improved aesthetics along with stormwater

Figure 6.5: Bioretention Planter

The most suitable bioretention variant for ROWs with rural cross-sections is:

B.4 Bioswales

Bioswales are vegetated open channels designed to convey, filter, and attenuate stormwater runoff. Similar to the bioretention variants described above, bioswales promote infiltration where native soils allow, reducing stormwater contributions to the municipal storm sewer. A unique feature of bioswales when compared to conventional vegetated swales is the bioretention soil media, granular storage layer, and optional underdrain components (which can replace a traditional storm sewer). Depending on the desired neighborhood aesthetic, bioswales can be vegetated with grass to blend in with the traditional streetscape or can be planted with a wide variety of shrubs, grasses and flowers for a garden-like visual.

Figure 6.6: Bioswale

C. Exfiltration Trench / Perforated Pipe System

Perforated pipe systems are long trenches that are designed for conveyance, detention and/or infiltration of stormwater runoff. These stormwater conveyance systems are composed of perforated pipes installed in gently sloping granular stone beds lined with geotextile fabric that allows infiltration of runoff into the gravel bed and underlying native soil where native soils allow. Perforated pipe systems can be used in place of conventional storm sewer pipes where topography, water table depth, and runoff quality conditions are suitable. Perforated pipe systems can be installed as a single larger diameter perforated pipe beneath the roadway surface or as two (2) parallel smaller diameter perforated pipes beneath a shallow swale beneath the boulevard area. With most perforated pipe designs, the streetscape remains largely the same as conventional curb-and-gutter. Due to their simple design, perforated pipe systems require very little maintenance and have a proven track record in Ontario for over 25 years.

Figure 6.7: Perforated Pipe installed adjacent to the roadway as part of a bioswale design

D. Permeable Pavement

Permeable pavement is a collective term that describes LIDs that can be used in place of conventional asphalt or concrete pavement. These alternatives contain pore spaces or joints that allow stormwater to pass through to a stone base for infiltration into underlying native soil or temporarily detained for flood control purposes. Permeable Pavements can be implemented as sidewalks, driveways, multi-use pathways, on-street (lay-by) parking, alleyways, road shoulders and even minor or local roadways themselves but are most commonly applied in parking lots. A study of permeable pavements installed on silty clay till in winter conditions indicate good winter performance, that frost heave or slumping is not a significant concern, and that less salt is required to maintain safe conditions than for conventional asphalt (Drake et al., 2012).

Figure 6.8: Perforated

E. Pervious Catch Basins

This technique involves a standard catch basin with a large sump which is physically connected to exfiltration storage media to make the walls or bottom of the catch basin pervious.

6.1.2 Oil Grit Separators (OGS) or Retrofits to Stormwater Management Facilities

Oil grit separators and stormwater management facilities are known as end-of-pipe controls because they are designed to receive water from a conveyance system and provide water quality control.

Oil grit separators (OGS) are proprietary devices that use hydrodynamic separation to remove sediment, screen debris, and separate floatables (gasoline, oil, grease, light petroleum products and other floating liquids) from stormwater. OGS units are well suited for small highly impervious catchments such as multi-residential and commercial parking lots or municipal rights-of-ways. To ensure these devices maintain their stormwater quality improvement abilities, sediment and oils must be removed from OGS units by vacuum trucks at a maintenance interval based on catchment characteristics and OGS unit design. The City has recently installed two larger OGS units, one in Bell Park along the west shore of Ramsey Lake, and one at the Sudbury Minor Hockey Association along the northwest shore of Minnow Lake.

Figure 6.9: A view of an Oil Grit Separator from a maintenance manhole.

Figure 6.10: Components of a wet stormwater management facility.

<u>Stormwater management facilities</u>, also known as "stormwater ponds" provide treatment via the settlement of suspended pollutants for urban catchments. These stormwater features are located at the end of conveyance system and typically discharge into a surface water feature such as a stream or river via pipes or swales.

Stormwater management facilities can be designed to be "wet" or "dry" facilities or engineered wetlands. The key component of a **wet stormwater management facility** is the permanent pool which promotes the settling of suspended pollutants as stormwater travels through the facility. To optimize pollutant removal capacities, design engineers usually aim to maximize the distance that stormwater must travel through these facilities to allow for greater settlement. Wet ponds are usually designed to provide flood mitigation by temporarily detaining large volumes of runoff.

<u>Dry stormwater management facilities</u> are designed to reduce flooding by shaving peak flows through the temporary detention of stormwater. Dry facilities provide minimal water quality benefit when compared to wet facilities because of inferior settlement and resuspension of sediment.

Figure 6.11: A dry stormwater management facility

Figure 6.12: An engineered wetland

Engineered wetlands are designed to settle and filter suspended stormwater pollutants and generally provide a high-level of water quality control. These systems include wetland vegetation and may be designed provide benefits to the terrestrial ecosystem. These facilities may be effective in reducing downstream erosion potential but their role in water quantity control is limited because of their limited storage volume and shallow water depth. Hybrid facilities that combine the function and aesthetics of wetponds and engineered wetlands are often designed for water quality purposes.

Subsurface Stormwater Chambers are prefabricated modular infiltration chambers designed to store large volumes of stormwater underground. These systems are typically installed in granular bedding and provide the structural support for land uses such as sports fields, parkland or parking lots on the surface above. Stormwater captured in these systems can be re-used (e.g. for irrigation or fire suppression), infiltrated into native soils, or released into storm sewers or receivers after detention.

Figure 6.13: A subsurface chamber system built underneath a soccer pitch.

6.1.3 Restoration Measures on Private Property

LIDs installed on private property are known as "**source control measures**". These LIDs can be implemented on residential, commercial, industrial and institutional land uses. In residential areas, source control measures provide treatment for the runoff generated by impervious surfaces such as rooftops and driveways. In commercial areas, these measures may target roof, private roads, and parking areas.

Source control measures remove pollutants from stormwater through a variety of mechanisms, including mechanical filtration, biological uptake, adsorption, and settling. Source control measures, considered on a lot-by-lot basis, include:

Disconnection of roof leaders: Roof leaders may flow into the municipal storm sewer system. This configuration is known as a 'directly connected roof leader' and can result in the overwhelming of municipal sewers during significant rainfall events. A relatively simple source control measure is to disconnect the roof leader from the municipal sewer so that stormwater generated on the roof can be filtered by vegetation and infiltrated into the native soils. The simplest forms of roof leader disconnection are to a depressed area in the lawn or to a rain barrel which becomes a garden irrigation source. More advanced systems utilize naturalized gardens and bioretention techniques.

Figure 6.14: Example of downspout disconnection.

Enhanced yard vegetation and rain gardens: On residential properties, rain gardens can be placed in the front or backyard where they will capture 'disconnected' rooftop and yard drainage and in doing so will prevent relatively clean stormwater from entering the conventional stormwater infrastructure system and mixing with more contaminated stormwater.

Figure 6.15: Rain gardens

Bioretention: Bioretention areas are a specialized rain gardens designed with engineered bimedia to maximize filtration and infiltration. For residential and commercial land uses, bioretention areas can be used to capture runoff from paved surfaces such as driveways and parking lots. Bioretention areas are relatively inexpensive to build, easy to maintain, and can add aesthetic value to a site without consuming large amounts of valuable land.

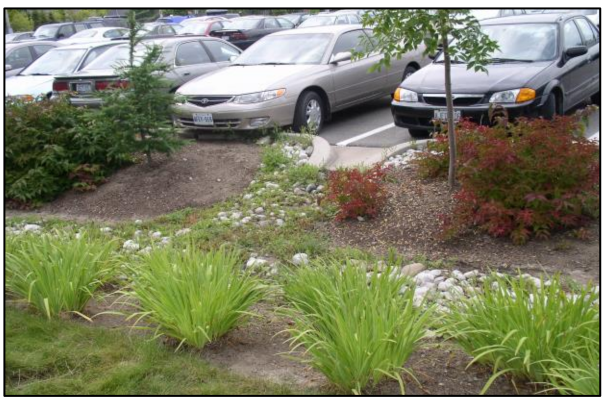


Figure 6.16: Bioretention facilities in commercial and residential settings

Reduced lot grading: Typical grading around buildings (≥ 2%) is reduced to slow overland flow and encourage infiltration.

Permeable driveways: Driveways can be built using permeable pavement systems. These systems allow runoff to drain through the pavement where it is stored in a granular layer before it is infiltrated into the soil or released into a conveyance system.

Figure 6.17: Typical Permeable pavement on residential and commercial properties

6.1.4 Shoreline Works to Improve Habitat

Significant portions of the Ramsey Lake shoreline have been hardened to protect properties from erosion caused by boat traffic. These hardened shorelines have a reduced capacity to filter runoff from properties that might contain pesticides or fertilizers. The removal of natural shore vegetation for the placement of structures has also reduced biodiversity along the lakeshore, and the intensified wave energy that results from hard shore edges poses long-term erosion risks related to scour that can be costly to mitigate. Shorelines can be bio-engineered (or 'softshore'-engineered, or 'landscaped') to 'absorb' wave energy and protect properties from boat and wind-induced waves and scour. These softer bioengineered shorelines also improve biodiversity, can reduce the runoff of various chemicals and nutrients from lawns into the lake, and can reduce the use of the shoreline by nuisance waterfowl (geese). Bioengineering of shorelines can involve the following treatment options:

Lowland Riparian Woods (LRW) can be re-established by planting a diversity of vegetation that includes native shrubs and trees with deep root systems. LRW are critical when improving shoreline habitat as they are known to improve ecological condition by increasing high quality riparian vegetation, increasing areas of primary production, and improving foraging grounds for aquatic and terrestrial species. LRW may also act as a structural element and help stabilize nearshore habitats with their deep root systems. Recently, the Toronto and Region Conservation Authority (TRCA) has created LRW areas along the shorelines of Tommy Thompson Park to establish vegetation zones and provide critical habitat components for wildlife communities within the Lake Ontario waterfront.

Log Piles (LP) and Log Tangles (LT) consist of a combination of natural woody debris (logs, stumps, and branches) that are strategically placed in nearshore environments and help improve ecosystem function. LP and LT are created by submerging woody debris and anchoring it using cobble and boulders, or by driving logs into sediment. LP and LT are critical when improving shoreline habitats as they are known to increase critical habitats for aquatic species, improve foraging grounds for aquatic species, and provide basking areas for reptiles. LP and LT also act as structural elements and help stabilize nearshore environments.

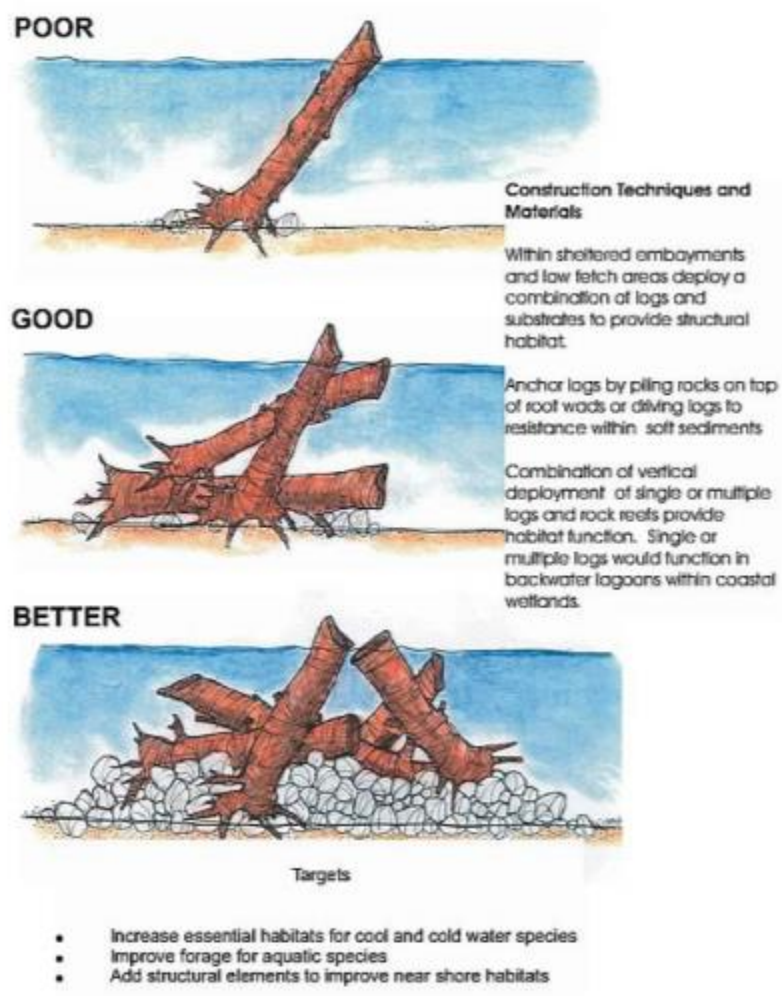


Figure 6.18 Diagram of log tangles
(from TRCA 2017; https://trca.ca/app/uploads/2017/08/TWAHRS_STRATEGY11.pdf)

Vegetated Buffer Zones (VBZ) consist of littoral landscapes that are comprised of a variety of native terrestrial and aquatic plants. VBZ are typically made up of emergent vegetation (e.g. cattails), floating vegetation (e.g. lily pads), and submerged vegetation (e.g. bladderwort). VBZ are known to have an assortment of positive effects with respect to shoreline habitat restoration. For example, VBZ can act as important nesting grounds for waterfowl, can provide forage grounds for terrestrial and aquatic species, and add structural elements to improve fish habitat. In addition, VBZ can also help protect shorelines from erosion by stabilizing soils with extensive root systems and absorbing incoming wave energy.

Sloped Rocky Revetments: are sloped structures (usually a combination of boulder, rubble, cobble, and gravel) positioned underwater on banks or cliffs within the wave zone. Vegetation can be planted among rocks to help provide additional natural protection against erosion caused by wave action. SRR act to provide additional stability and adds important structural habitat that functions offshore shoals and bars. Thus, SRR benefit shoreline restoration efforts as they enhance the ecological function and stability of open coast areas by providing offshore fish habitat and preventing erosion.

Figure 6.19: A typical lake shoreline before (left) and after (right) bioengineering to protect it from wave action
(from Michigan DEQ, Natural Shorelines for Inland Lakes, 2018
http://www.michigan.gov/documents/deq/wrd-natural-shorelines-inland-lakes_366530_7.pdf)

Figure 6.20: Before and after showing a shoreline improved with a rocky revetment, incorporating biodiversity
(from St. Clair River shoreline restoration report, 2014
[https://www.friendsofstclair.ca/www/pdf/resources/2014/Shoreline%20Restoration%20report.pdf])

6.1.5 Terrestrial Ecological Restoration Works within the Watershed

Ecological restoration presents an opportunity to improve degraded terrestrial and aquatic ecosystems, improve ecosystems' resiliency to the effects of climate change, improve water quality, create habitat, re-establish ecological linkages, and enhance ecological diversity. Ecological restoration has the potential to aid in reaching the goals and objectives presented earlier in Chapter 5 (see summary in **Table 5.1)**. Restoration also has the potential to foster a healthy relationship between nature and culture.

2018 marked the 40th anniversary of the City of Greater Sudbury's Regreening Program. From 1978 to 2017, over 3,400 ha of land were limed and grassed and over 9.7 million trees have been planted. The extent and types of regreening efforts that have occurred since the inception of the program can be viewed on the City's Regreening App (**Figure 6.21**); available on the City's Regreening Program webpage.

Figure 6.21: The City of Greater Sudbury's Regreening App allows users to view the extent and types of regreening that have occurred within the City since 1978.

Recommended priorities for terrestrial habitat enhancement within the Ramsey Lake subwatershed focus on restoration measures that will increase forest cover within the Subwatershed (**Figure 6.22** and **Figure 6.23**), enhance wetland form and function, establish connections between Natural Heritage Features, and enhance degraded ecosystems. Additional terrestrial habitat enhancement opportunities include the following:

- Rubbish removal;
- Invasive species management;
- Liming acidic sites in preparation for replanting (**Figure 6.24**);
- Replanting restored forested areas to add secondary species and contribute to forest canopy, subcanopy, and shrub-layer diversity;
- Forest floor transplants (**Figure 6.23**);
- Floodplain plantings;
- Riparian restoration (see Section 6.1.6);
- Native herbaceous and woody plant seed collection and dispersal, in support of ecological restoration efforts;
- Support of SAR recovery programs, in consultation with the MECP; and
- Protection and establishment of wildlife corridors.

Figure 6.22: Reforestation over time
(source: Vale Living with Lakes)

Further details on the recommended focus of restoration efforts within the Ramsey Lake subwatershed are as follows:

Reforestation: On a larger scale, reforestation is an important measure, not only for increasing terrestrial habitat but also for carbon sequestering, increasing evapotranspiration, improving local microclimates, improving stormwater management, and increasing opportunities for wildlife movement. Furthermore, incorporating a diversity of genera and species in reforestation plans will aid in creating climate change resilient ecosystems. Reforestation is the primary type of restoration measure being implemented within the Ramsey Lake subwatershed. Furthermore, the multi-year Terrestrial Aquatic Linkages for Ecosystem Recovery (TALER) research program coordinated by the Vale Living with Lakes Centre at Laurentian University has highlighted the positive effect terrestrial revegetation efforts has on the biological recovery of lakes and streams via allochthonous inputs (e.g., nutrients, organic matter, etc.) (VETAC, 2016).

Figure 6.23: Tree planting on limed land (left); forest floor transplants (right) (source: VETAC 2017)

Figure 6.24: Crew spreading lime on barren land (source: VETAC 2016)

Wetland rehabilitation: Wetland rehabilitation includes the concept of diversifying the habitat types surrounding wetlands in an effort to provide varied habitat for native species (including and not limited to SAR), manage flooding, and improve water quality.

- Creation of connections between woodlands and wetlands; and

- Wetland enhancements.

Wetland rehabilitation and enhancements can be implemented through the City of Greater Sudbury's existing Regreening Program. In recognition of the challenges that shallow soil systems pose for wetland creation, it is likely prudent to focus efforts and resources on enhancing and rehabilitating extant wetlands and areas where the hydrologic conditions are suitable for wetland plantings (e.g., areas where water pools on a regular basis for a period or periods of time sufficient for the establishment of hydrophytic plants).

According to the MNRF, the "MNRF is concerned about the threat that invasive Phragmites poses to our natural resources, our biodiversity, and the economy of Ontario. The boundaries of its northern distribution and spread have not been determined, however, stands of invasive Phragmites have previously been reported in Sudbury…" (Turl, 2017). Identification and eradication of Phragmites within urban and suburban will likely aid in controlling the spread of the invasive grass into natural areas.

Wetland enhancements can also consist of invasive species management. Removal and management of invasive species, including and not limited to the aggressive exotic giant reed grass (*Phragmites australis* subspecies *australis*), presents opportunities for the establishment of native flora and, ergo, native wildlife. Given the ongoing maintenance often required for invasive species management, opportunities for partnerships between the City and Conservation Sudbury, VALE Living with Lakes Centre, Junction Creek Stewardship Committee, and volunteer groups, etc. is strongly encouraged.

6.1.6 Stream Restoration

These include measures designed to address erosion and flooding problems and restore stream functions and stability. They are generally applied on a stream reach basis and include stream rehabilitation using natural or engineered channel design principles and naturalization of stream riparian zones using native materials. They may also include individual approaches such as streambank re-grading, gradient controls and floodplain contouring to address specific erosion and flooding problems. This approach can also include in stream practices, such as outfall restoration, riparian plantings, and open space re-vegetation improves the function of stream corridors. These approaches improve water quality, slow runoff, moderate stream temperatures, reduce erosion and improve aquatic and terrestrial habitat conditions.

Ecological restoration measures enhance the ability of the natural environment to improve water quality and to prevent watercourse erosion from further degrading water quality. Existing natural areas provide valuable ecological services, such as quality and quantity treatment of stormwater at no cost. If an existing natural area is degraded, it may be possible to restore the area and regain lost ecological services. Restoration of degraded habitats may be done in a number of ways. Representative restoration / enhancement programs are summarized below.

Reach Based Works: These include measures designed to address erosion and flooding problems and restore stream functions and stability. They are applied on a stream reach basis. Stream restoration programs include stream rehabilitation using Natural Channel Design (NCD) and Geomorphic Referenced River Engineering (GRRE) generally referred to as a hybrid type design. An important component of these projects is naturalization of stream riparian zones using native materials. They may also include individual structures, such as streambank re-grading, gradient controls and floodplain contouring to address specific erosion and flooding problems. These programs are often integrated with components for aquatic habitat enhancement such as spawning habitat creation, refuge pool construction, undercut bank structures, boulder placements, half log cover structures and flow deflectors.

Figure 6.25: Before and after example of stream restoration

Local Bank or Slope Stabilization Works: Local works reduce the level of risk by applying local bank or slope stabilization treatments using either hardened (engineered) type treatments, or more natural (vegetation and biotechnical engineered) type treatments. The intent of these works is to protect the adjacent features at risk (i.e., residential properties and infrastructure), both now, and in the future by anticipating channel activity that may occur in the vicinity of the at-risk areas.

Figure 6.26: Before and after example of local bank works

Realignment: These measures involve the realignment of risk (i.e., infrastructure) away from the channel. This alternative addresses the reoccurring issues associated with infrastructure and watercourse interactions, and looks at possible approaches of removing the interaction to provide the creek with sufficient space to naturally adjust and migrate without posing risks to municipal infrastructure or private property.

6.1.7 Flood Mitigation

These include a variety of structural and non-structural measures associated with alleviating flooding along water courses. Flood mitigation strategies are generally applied in areas where there are significant flood risks, such as buildings within the floodplain or roads that are frequently inundated. There are some flood mitigation strategies that could be implemented to the entire community to reduce overall risk, such as implementing stormwater management plans, however these strategies are generally implemented over a long term. Flood mitigation strategies ensure that during flood events, water levels are maintained at a safe level or flow are by-passed around areas that could be at risk. Structural and non-structural approaches include:

Structural flood damage reduction measures: These measures reduce risk of flooding by constructing or modifying structures along the water bodies that increase the flow capacity, without increasing the water level. The intent of these types of measures are to reduce the limits of the floodplain, and remove the risk to surrounding properties and utilities. Examples of this type of measure would include widening culverts, and raising/widening bridges.

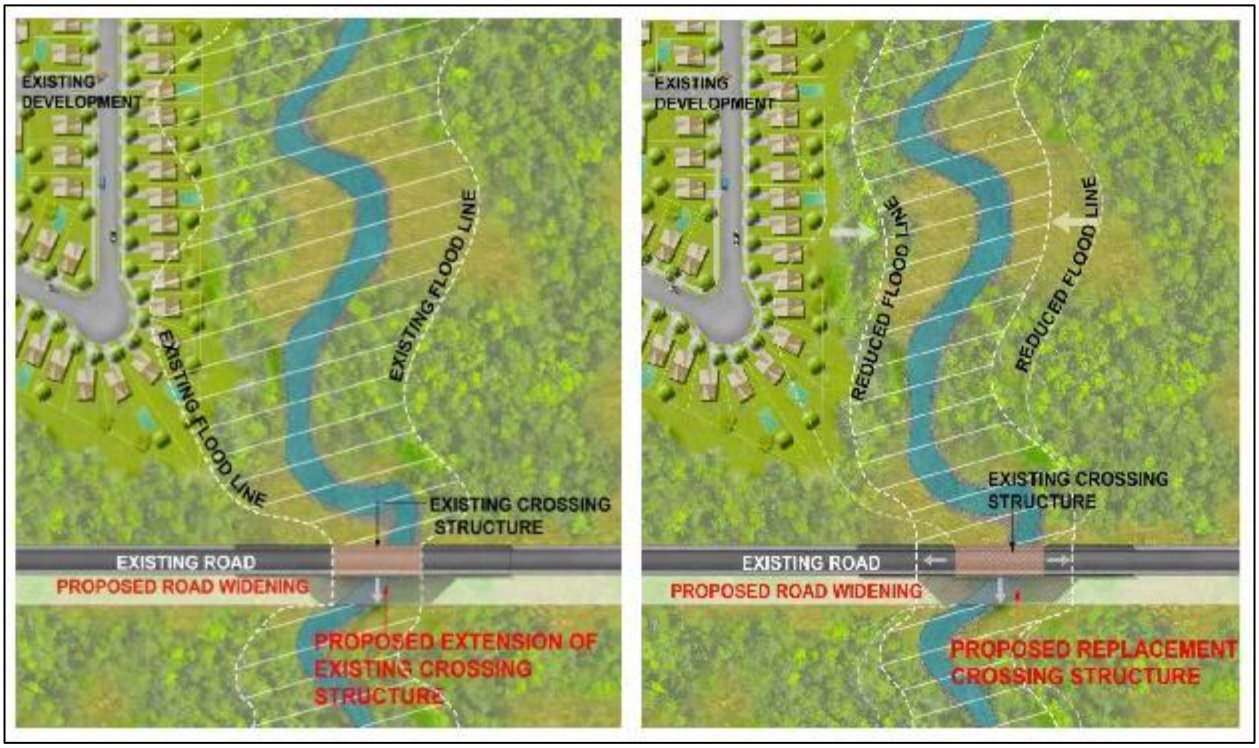


Figure 6.27: Example of how replacement bridge with a larger opening reduces the upstream flood hazard (taken from TRCA Crossings Guideline for Valley and Stream Corridors, 2015)

Preventative flood relief strategies or programs: These measures reduce risk of flooding by implementing plans to reduce peak flows within the watercourses. This involves continued implementing stormwater management plans, design to reduce peak flows. These plans are implemented over the course of several years, but have significant impact on flood reduction.

Emergency flood protection strategies: These measures reduce risk by diverting flood flows away from areas of risk. This generally involves a construction of structural watercourse infrastructure, such as berms, floodwalls or flood-relief channels. The intent of these types of measures are to provide a last line of defence from flood damages because other flood mitigation strategies can not provide sufficient protect.

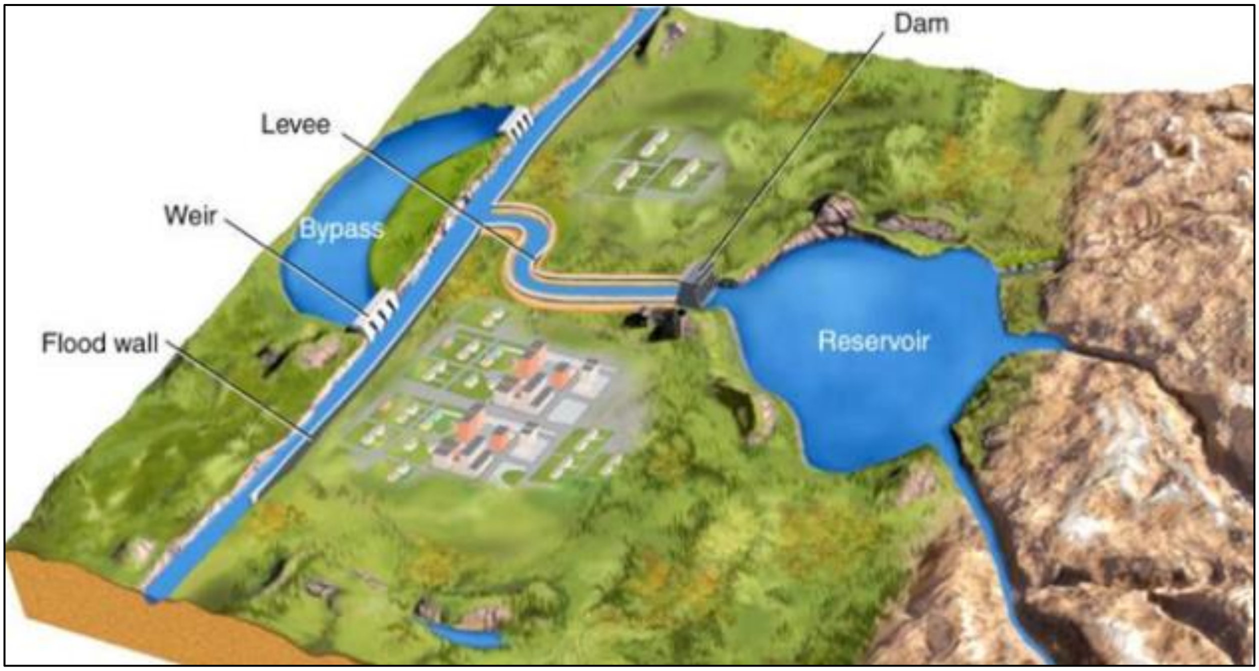


Figure 6.28: Examples of emergency flood protection strategies

Channel modifications: These mitigation strategies include channel restoration or rehabilitation works, designed to increase the conveyance or storage of flood flows. They can be applied on a stream reach basis or locally. As discussed above, natural channel design and restoration of the riparian corridor is an important part of improving the health of the watercourse and needs to be taken into consideration when proposing channel modifications for flood relief purposed. Channel modifications that could be undertaken to provide flood relief include widening, deepening or realignment. Other less invasive methods involving increasing the floodplain storage in low-risk areas (e.g., park lands), which will reduce peak flows downstream.

6.1.8 Salt Management

De-icing salt is used to control snow and ice formation, making winter driving safer and more efficient. It is used extensively in Canada because it is effective, relatively easy to transport and use, and low in cost (TRCA, 2018). De-icing salt enters the environment from the salt storage and snow disposal sites and through runoff and splash from the roadways. Due to concerns about the large quantities of chlorides being released to the environment, de-icing salts underwent a comprehensive five-year scientific assessment under the Canadian Environmental Protection Act,

1999. This assessment concluded that de-icing salt is entering the environment in quantities that may pose immediate or long-term environmental risks. Elevated concentrations of chloride salts may cause adverse effects to aquatic life, terrestrial vegetation, soil structure, and drinking water (TRCA, 2018).

A Code of Practice for the Environmental Management of Road Salts was created to reduce environmental contamination by road salts while maintaining road safety. This Code is applicable for any organizations that uses more than 500 tonnes of road salts per year and have vulnerable areas in their territory that could potentially be impacted by the road salts. The City of Greater Sudbury is required to follow this Code as an average of 19,876 tonnes of bulk coarse highway salt (NaCl) is used per season (GHD, 2017). Commercial operators responsible for clearing snow and ice from parking lots have the potential to use larger amounts of salt, in part because the commercial operators are compensated on the basis of use (Kilgour, 2014).

Treatment methods including Salt Management Plans and education programs have been implemented across Ontario to minimize the impacts of salt contamination on the surrounding environment.

Salt Management Plans

Approximately 60% of municipalities have source protection plans implemented with specific policies and regulations for salt management. As part of the City of Greater Sudbury's 2006 Official Plan, a Salt Management Plan was implemented to address issues surrounding the application of de-icing salt. The City's Salt Management Plan is routinely updated, most recently in 2017, and outlines the objectives, policies, winter maintenance program, materials used annually, continuous improvement practices and strategies, and monitoring and updating.

Smart About Salt

The Regional Municipality of Waterloo (RMOW) created "Smart About Salt" as part of a groundwater salt loading reduction strategy. This program is designed to promote improved safe snow and ice control practices on parking lots and sidewalks in an effort to reduce the amount of de-icing salt entering the environment. Generally, 40% of the salt used in urban areas is placed on parking lots and sidewalks at commercial, industrial, and institutional areas. As the climate in Sudbury differs from Waterloo, the proportion of salt applied may be different as 91% of the roads in the Ramsey Lake Subwatershed are sanded. While the Code of Practice addresses the use of salts on roadways, the Smart About Salt program is unique in specifically addressing parking lot and sidewalk salting issues.

To accomplish this, Smart About Salt provides training for companies in the snow control business and operators. Their training addressees the first two aspects of salt management by:

- promoting ice minimization strategies and best salt management practices; and,
- promoting proper salt storage and handling practices.

To ensure proper salt storage, salt must be stored on impermeable pads and covered. Liquid de-icing chemicals must also be stored on impermeable pads in tanks with collision protection.

For a facility to be certified they must review their operations with the purpose of identifying high salt use areas, and with that information developing improvements to reduce the salt requirement. 10 aspects of companies' operations are analyzed for this purpose, including:

1. Equipment calibration
2. Material Applications Rates
3. Material Tracking
4. Use of Liquids
5. Use of Low or Non-chloride Materials
6. Salt Storage
7. Sand/salt Mix Storage
8. Liquid Storage
9. Plowing
10. Salt management Training

The facility has a year to improve any of the above aspects that need improvement to continue their certification eligibility. A facility must also use a Smart About Salt Certified Contractor to maintain the site to ensure the best salt management practices are used.

6.1.9 Management of Septic Systems

There are several properties within the Ramsey Lake subwatershed that have private septic systems, meaning that all sewage is treated by the land owner on-site, using independent septic systems. The most common form of treatment is a below ground septic bed. Leaking or damaged septic beds can be a source of groundwater contamination, including bacterial loading, nitrates and phosphates. Leaking septic systems frequently go unnoticed, due to unawareness of the potential issue, and the fact that most septic systems are below ground and therefore cannot be easily inspected. The management of private septic systems helps to protect groundwater from contamination and identifies sources of contamination that can be mitigated. Approaches to management of septic systems include:

Septic system awareness programs: This method involves providing information about septic systems to the public. By providing information about how the systems work, what the risks are, how leaks occur and how to manage leaks, the owners of the septic systems will be more informed and can potentially mitigate the risks themselves. This information can be provided to the public in many ways, such as a series of workshops, printed manuals or online.

Septic system inspection programs: The potential impact of septic systems on water quality makes septic system inspection one of the primary un-serviced development issues in the City. Policies or programs influencing the inspection of septic systems are equally as important as policies governing new development.

In the City of Greater Sudbury, the Public Health Sudbury and Districts is responsible for the inspection of existing/old septic systems. At the time that the Official Plan was published, the Unit conducted site visits when they receive a complaint, although within the Ramsey Lake Source Protection Area, they conduct a septic system re-inspection program. A regular inspection program helps to identify leaks or deteriorating systems. Regular inspections help to protect against future leaks, as issues are identified as they develop.

Guidelines for septic system inspection and replacement: This would involve the City providing a recommended method and schedule for landowners to undertake septic system inspection, maintenance and recommendations for replacement infrastructure. These guidelines would inform landowners of the City's objectives to protect the groundwater, and would help to ensure that necessary maintenance is undertaken.

6.2 Alternative Strategies Subject to the Environmental Assessment Process

A series of ten (10) general types of measures were defined in the previous sections to form the Long List of Alternatives. Several of these measures are subject to review and assessment under the Environmental Assessment process while others are outside of the Environmental assessment process. Provided below is a table (**Table 6.1**) summarizing which measures fall within the Environmental Assessment process together with those that are outside of the process.

Table 6.1: Long List of Alternatives and Corresponding Evaluation and Implementation Process

Alternative	Description	Evaluation and Implementation Process
Low Impact Development (LID) of Public Roads during Reconstruction	• Low Impact Development measures to such as bioswales and bioretention facilities designed to provide water quality treatment and water balance benefits within the municipal right-of-way	Environmental Assessment
Oil Grit Separators (OGS) or Stormwater Management Facilities	• Implement OGS infrastructure at uncontrolled outlets • Retrofits to existing SWM facilities • Development of new SWM facilities in existing public spaces	Environmental Assessment
Restoration Measures on Private Property	• Encourage source control (lot level) programs for homeowners to increase infiltration • Self-assessment through the "Landowner Stewardship Guide for the Ontario Landscape" from www.stewardshipmanual.ca • Enforce existing policies (e.g. lawn watering)	City Planning Policy & Stewardship

Alternative	Description	Evaluation and Implementation Process
	• Restrict the use of fertilizers or top soil laden with phosphorus	
Shoreline Works to Improve Habitat	• Private property measures to naturalize shoreline and lake adjacent lands	City Planning Policy & Stewardship
Ecological Restoration Works within the Watershed	• improve degraded terrestrial and aquatic ecosystems, improve ecosystems' resiliency to the effects of climate change, improve water quality, create habitat, re-establish ecological linkages, and enhance ecological diversity	City Planning Policy & Stewardship
Stream Restoration	• Channel restoration and rehabilitation • Channel maintenance • Enhancements to the aquatic habitat	Environmental Assessment & City Operations and Maintenance
Flood Mitigation	• Increase hydraulic capacity of bridges and culverts • Implement flood protection infrastructure (e.g., berms or floodwalls)	Environmental Assessment & City Operations and Maintenance
Salt Management	• Reduce use of road salt • Reduce use of salt for private properties	City Operations and Maintenance & Stewardship
Management of Septic Systems	• Replacement of septic systems • Replacement of existing wells • Septic system inspection programs	City Planning Policy and Maintenance and Operations & Stewardship

As noted previously, in order to meet the intent of the Act, the watershed study is being conducted as part of a Master Plan (Approach #2) and will satisfy Phases 1 and 2 of the Municipal Engineer's Association (MEA) Class Environmental Assessment process, in accordance with the established principles for Master Planning. The Master Plan will then become the basis for, and used in support of, future investigations for any specific Schedule B and C projects identified within it. Therefore, screening and evaluations were undertaken for the following alternative strategies:

- Low Impact Development (LID) of Public Roads during Reconstruction

- Stormwater Management Facilities
- Stream Restoration
- Flood Mitigation

Provided below is a description of the screening and evaluation process, together with the selection of preferred solution for various alternatives that were considered.

6.2.1 Summary of the Evaluation Process – LID Retrofit of Municipal Road Reconstruction Projects

6.2.1.1 General

The section below explains how LID retrofits for municipal road reconstruction were evaluated. The alternatives that were considered are defined as were the criteria that were used to evaluate the alternatives and the prioritized opportunities.

6.2.1.2 Identification of Opportunities

In developing alternatives for LID retrofit implementation, the existing roads within the Ramsey Lake subwatershed were classified into two general categories; (1) roads with urban cross sections and (2) roads with rural cross sections. Roads with urban cross sections have integrated storm sewer connections incorporated into construction of the surface (i.e., curbs and gutters), where roads with rural profiles do not have the same storm sewer infrastructure (i.e., ditches). Examples of both cross sections are shown below in **Figure 6.29** and **Figure 6.30**.

Figure 6.29: Example of an urban cross section (curb & gutter) along Hebert Street in Sudbury (source: GoogleEarth)

Figure 6.30:Example of a rural cross section (ditches) along Roger Street in Sudbury

Roads with a rural cross-section are well suited for certain LID treatments, such as bioswales or enhanced swales, as the ditch profile reduces excavation and provides a foundation for the underground infrastructure. It can be more difficult, and expensive to implement LID treatments on roads with urban cross sections, especially if the road does not have a boulevard or adequate space for such treatments. For this reason, the roads were separated into the two categories for evaluation.

In order to identify rural and urban roads, Aquafor used the City's GIS data to identify all roads with ditches. A map of all the roads with rural profiles is provided below in **Figure 6.31.** A summary of the number and length of roads for each classification are provided below in **Table 6.2**, and lists the roads are provided in **Appendix F**.

Table 6.2: Summary of road cross section classification in Ramsey Lake subwatershed

CGS Road Classification	Roads with Urban Cross Sections		Roads with Rural Cross Sections	
	Number of Roads	Total Length (km)	Number of Roads	Total Length (km)
Highway	0	0	3	4.4
Major Road	58	7.9	40	11.3
Local Road	188	23.1	148	31.3
Lane	2	0.2	2	0.3
Private Road	35	6.0	23	9.6
TOTAL	**283**	**37.2**	**98**	**56.9**

6.2.1.3 Description of Preliminary Alternatives

Therefore, in evaluating the feasibility of implementing LID retrofits for municipal road reconstruction, the following three alternatives were evaluated:

1. Do Nothing
2. LID Retrofits on Rural Roads
3. LID Retrofits on Urban Roads

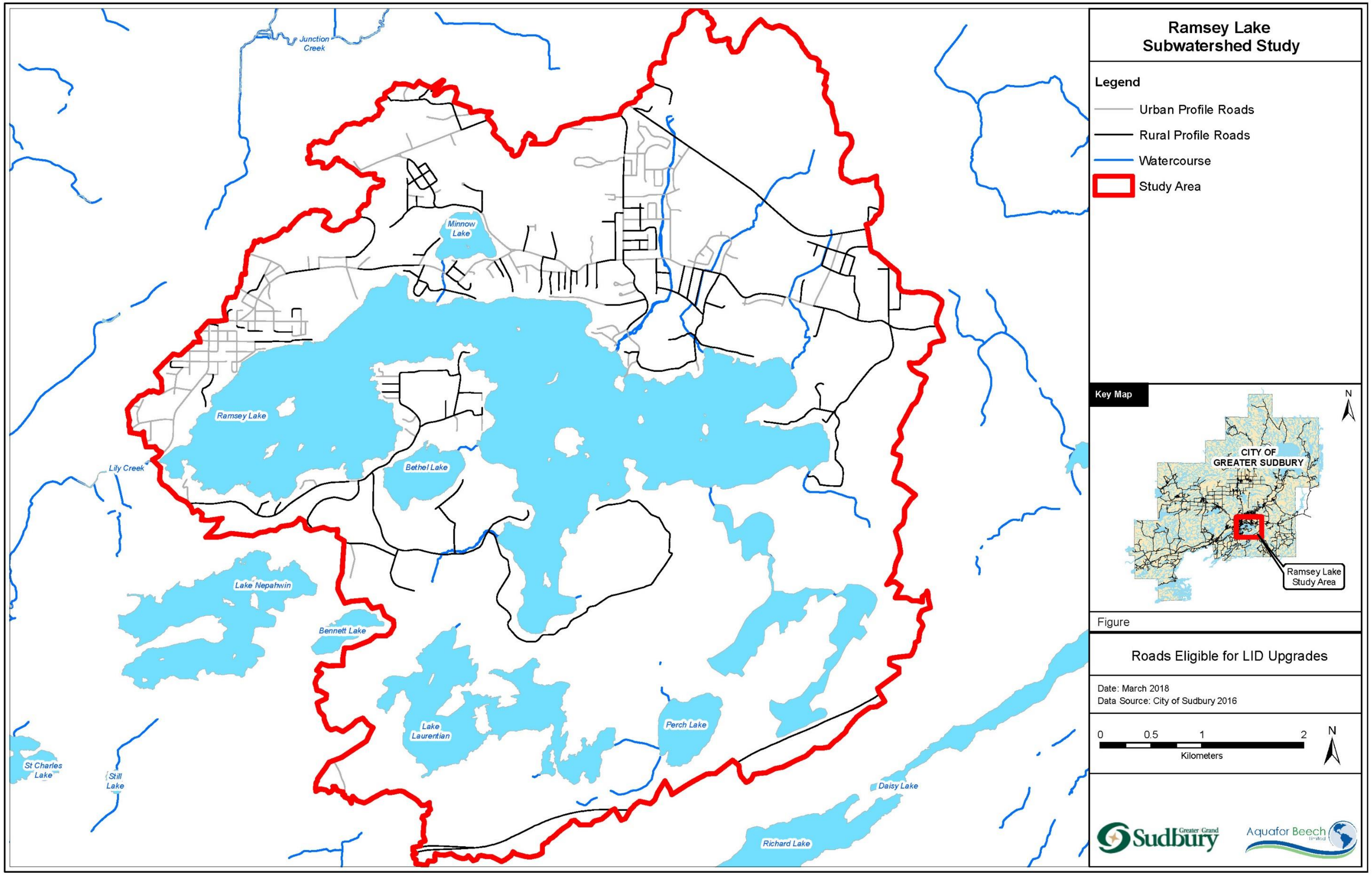


Figure 6.31: Roads within the Ramsey Lake subwatershed, divided by rural and urban cross sections

6.2.1.4 Evaluation Criteria and Scoring

In order to evaluate the alternatives identified in the previous sections, evaluation criteria have been developed in order to select the preferred solution. The evaluation criteria include natural environment, socio-cultural, and economic considerations. These criteria, together with a description of the criteria and measures for assigning scores are presented in **Table 6.3** and **Table 6.4**.

For each of the comparative criteria, a rating ranging from 0 to 4 was applied specific to the particular solution being evaluated where 0 represents the worst condition and 4 the best, as identified in **Table 6.3**. Based on this approach, an overall rating based on the total scoring was obtained for each alternative solution.

Subsequently a ranking was assigned for each alternative solution with the highest overall total assigned 1 and the others sequentially 2, 3, etc. based on the scoring. Where the total ratings are the same, the same ranking was assigned.

A Weighting Factor was assigned to category of criteria, which ensured that each category was valued appropriately, regardless to the number of criteria within the category. For this evaluation, the weighting factors used for this evaluation are shown in **Table 6.3**.

Table 6.3: Weight factors used for evaluation of LID retrofits of municipal road reconstruction projects

Category	Weighting Factor	Maximum Points for Category
Natural Environment Impact	0.3	30
Socio-Cultural Impact	0.3	30
Economic Impact	0.4	40
TOTAL	1	100

The evaluation of the alternative solutions is presented in **Table 6.4**.

Table 6.4: Evaluation criteria – LID retrofits for municipal road reconstruction

Criteria	Description of Criteria	Measures for Assigning Scores	Alternative 1 Do Nothing	Alternative 2 LID Retrofits on Rural Roads	Alternative 3 LID Retrofits on Urban Roads
Natural Environment Impact					
Potential Surface Flooding Benefit	Ability to reduce surface flooding associated with private properties and roads	Scores are assigned as follows: 4 - significant reduction in surface flooding risks 2 - potential reduction to surface flooding risks 0 - no change in surface flooding risk	NA	NA	NA
Potential Erosion Control Benefit	Potential to reduce erosional forces in receiving stream based on existing condition of stream and ability to provide required erosion control volume	Scores are assigned as follows: 4 - high potential to reduce erosional forces 2 - moderate potential to reduce erosional forces 0 - limited to no potential to reduce erosional forces	0	2	2
Potential Aquatic Habitat Benefit	Potential to improve aquatic habitats or systems, including possible impacts on aquatic life, features and functions	Scores are assigned as follows: 4 - significant improvement to aquatic habitat or systems 2 - moderate improvement to aquatic habitat or systems 0 - no impact to aquatic habitat or systems	0	2	2
Potential Water Quality Benefit	Potential to improve water quality based on existing water quality conditions in stream and ability to provide required water quality control	Scores are assigned as follows: 4 - high potential that the proposed treatment will improve the water quality 2 - moderate potential that the treatment will improve the water quality 0 - limited to no potential that the treatment will improve the water quality	0	2	2
Potential Hydrologic Flow Benefit	Ability to reduce the peak flow rate and total flow in the downstream receiving water system	Scores are assigned as follows: 4 – significant potential to reduce the peak flow and total flow downstream 2 – moderate potential to reduce the peak flow and total flow downstream 0 – limited or no potential to reduce the peak flow and total flow downstream	0	2	2
Potential Terrestrial Habitat Benefit	Potential to improve terrestrial habitats based on the existing conditions of the terrestrial ecology	Scores are assigned as follows: 4 - high potential to impact existing terrestrial habitat 2 - moderate potential to impact existing terrestrial habitat 0 - limited to no potential to impact existing habitat	NA	NA	NA
		Natural Environment Impact Subtotal	0	8	8
		Weighted Score for Natural Environment Impact Criteria (maximum of 30 pts)	**0**	**15**	**15**
Socio-Cultural Impacts					
Impact to Aesthetics / Recreation	Potential for retrofit facility to be an asset to the community by integrating facility into activities such as walking, jogging, hiking	Scores are assigned as follows: 4 - high potential to integrate facility into existing activities 2 - moderate potential to integrate facility into existing activities 0 - limited to no potential to integrate facility into existing activities	NA	NA	NA
Compatibility with Adjacent Land Uses	There are potential impacts associated with construction of facilities, particularly with respect to land uses such as residential, old age homes and schools. Access / egress also needs to be considered	Scores are assigned as follows: 4 - no impacts associated with construction and access / egress for operation / maintenance 2 - minor impacts associated with construction and access will be limited 0 - sensitive land uses are located adjacent to proposed facility and access / egress will be limited	4	2	2
Compatibility with Land Ownership	There are potential impacts associated with ownership of the land which could restrict access for construction and maintenance	Scores are assigned as follows: 4 - City owned lands or have easement 2 - most lands are owned by City, but some easements may be required 0 – lands are privately owned	4	4	4
Community Impact - Disruption to Community During Construction	Potential to impact the community in terms of access to the site, visibility, road access, construction of mitigation measure in valley lands / parks, possible noise / odour / light, short-term construction impact, etc.	Scores are assigned as follows: 4 – no impact on community 2 – moderate impact on community 0 – significant impact on community	4	2	2
Consistency with municipal, provincial and federal regulation and/or policy	Ability for the alternative to meet the governing, or soon to be implemented standards, regulations and policies.	Scores are assigned as follows: 4 - consistent with all standards/regulations/policies 2 - meets some standards/regulations/policies 0 – not consistent with standards/regulations/policies	0	4	4
		Socio-Cultural Impact Subtotal	12	12	12
		Weighted Score for Socio-Cultural Impact Criteria (maximum of 30 pts)	**22.5**	**22.5**	**22.5**
Economic Impacts					
Capital Costs	The relative estimated costs of implementing the proposed treatement based on factors such as location, access / egress and area to dispose material	Scores are assigned as follows: 4 - no capital costs 2 - moderate capital cost 0 - highest capital cost	4	2	0
Operation and Maintenance Costs	The relative cost of operating and maintaining the facility based on factors such as location, access / egress and availability of sediment drying area	Scores are assigned as follows: 4 - no operation and maintenance costs 2 - moderate operation and maintenance cost 0 - highest operation and maintenance cost	2	2	2
		Economic Impact Subtotal	6	4	2
		Weighted Score for Economic Impact Criteria (maximum of 40 pts)	**30**	**20**	**10**
		FINAL WEIGHTED SCORE (maximum of 100 pts)	**52.5**	**57.5**	**47.5**

6.2.1.5 Preferred Alternative

Based on the evaluation, the preferred alternative solution for implementing LID retrofit of municipal road reconstruction projects, is **alternative 2, prioritization of rural roads**. By implementing LID strategies, the roads will satisfy the pending MECP water balance and water quality requirements. Furthermore, implementing LID strategies on urban roads can be complicated and costly, depending on the surrounding constraints.

While the evaluation did prioritize the Do Nothing alternative above implementing LID retrofits on urban roads, it should be noted that implementing LID treatments on urban roads may be necessary to satisfy the MECP requirements as noted above. This will need to be considered for each project as it arises.

6.2.2 Summary of the Evaluation Process – Stormwater Management Facilities

6.2.2.1 General

Several municipalities in Ontario have recently undertaken Stormwater Management Facility Retrofit Studies. The primary objective of these studies is to assess the feasibility of retrofitting existing facilities in order to provide additional functions such as erosion and water quality control; thereby improving environmental conditions in downstream streams and rivers and lakes.

The objective of this study was to utilize information from studies that were recently completed and to develop evaluation criteria in order to prioritize the potential for developing stormwater management facilities into the existing stormwater network. Consistent with the overall approach of this study, the intent was to undertake the level of detail necessary to satisfy Phases 1 and 2 of the Class EA process.

Through the City of Greater Sudbury's Stormwater Background Report for the 2006 Official Plan, likely retrofit opportunities in urbanized areas currently experiencing stormwater quantity and quality problems were identified. **Table 6.5**, from the Stormwater Background Report, identifies the most likely retrofit opportunities in urbanized areas currently experiencing stormwater quantity and quality problems.

Table 6.5: Retrofit Opportunities for Stormwater Management in Urbanized Areas

Location	Type of Retrofit	Benefits
Existing stormwater detention facilities	• Usually retrofitted as a wet pond or stormwater wetland capable of multiple storm frequency management. • Addition of extended detention by retrofitting forebay in existing facility.	• Quality control • Peak flow control • Erosive flow reduction • Sediment removal
Immediately upstream of existing road culverts	• Often a wet pond, wetland or extended detention facility capable of multiple storm frequency management.	• Quality control • Peak flow control • Erosive flow reduction
Immediately below or adjacent to existing storm drain outfalls	• Usually water quality measures, such as sand filters, vegetative filters or other minor storm treatment facilities.	• Quality control • Sediment removal
Directly within urban drainage and flood control channels	• Usually small-scale weirs or other flow attenuation devices to facilitate settling of solids within open channels.	• Quality Control • Sediment Removal
Road right-of-way	• Usually ponds or wetland capable of multiple storm frequency management.	• Quality control • Sediment removal
Within large open spaces, such as golf courses and parks	• Usually ponds or wetland capable of multiple storm frequency management.	• Quality control • Peak flow control • Erosive flow reduction
Within or adjacent to large parking lots	• Usually water quality measures such as sand filters (e.g. bioretention), infiltration trenches, buffer strips, etc.	• Quality control • Spill containment • Sediment removal

6.2.2.2 Identification of Opportunities

A review of the existing stormwater network, drainage areas, landuse and property ownership was undertaken in order to identify potential locations for implementing SWM facilities. It was necessary to review all the information in conjunction to ensure that proposed locations could feasibly be developed into stormwater management facilities.

Below is a summary of each of the elements that was reviewed to identify feasible locations.

Existing Stormwater Network: In order to incorporate a SWM facility into the existing network, it is necessary to implement the facility in close proximity to the existing infrastructure. It is necessary that the inflows and outflows from the SWM facility be feasibly incorporated into the existing network, to ensure that construction efforts and costs are not obstacles. Therefore, only locations within close proximity to the existing storm sewer network were considered. For the purposes of this study, this included all the pipes that were included within the hydraulic pipe model, which is presented in Section 3.2.4 of this report.

Drainage Area: Drainage area is directly related to flow rate and volume during a rainfall event. In general terms, a SWM facility is only to accommodate a drainage area of 10-50 ha. The effectiveness of the facility starts to decrease as the drainage area increases. Additionally, for smaller catchments, the facilities will only provide a limited improvement to the stormwater management for the Ramsey Lake subwatershed, for a substantial cost.

Land Use: For this study park lands and green spaces, forested lands, parking lots and roads were considered for possible SWM facilities. For some of these land use types, only below ground facilities would be appropriate (i.e., roads and parking lots).

Property Ownership: Potential locations were restricted to City owned lands, or locations where the City has existing easements over the land.

In taking these factors into consideration, Aquafor and the City identified seven (7) potential locations were identified for SWM facilities to be integrated into the existing stormwater network. The potential locations are shown in **Figure 6.32**.

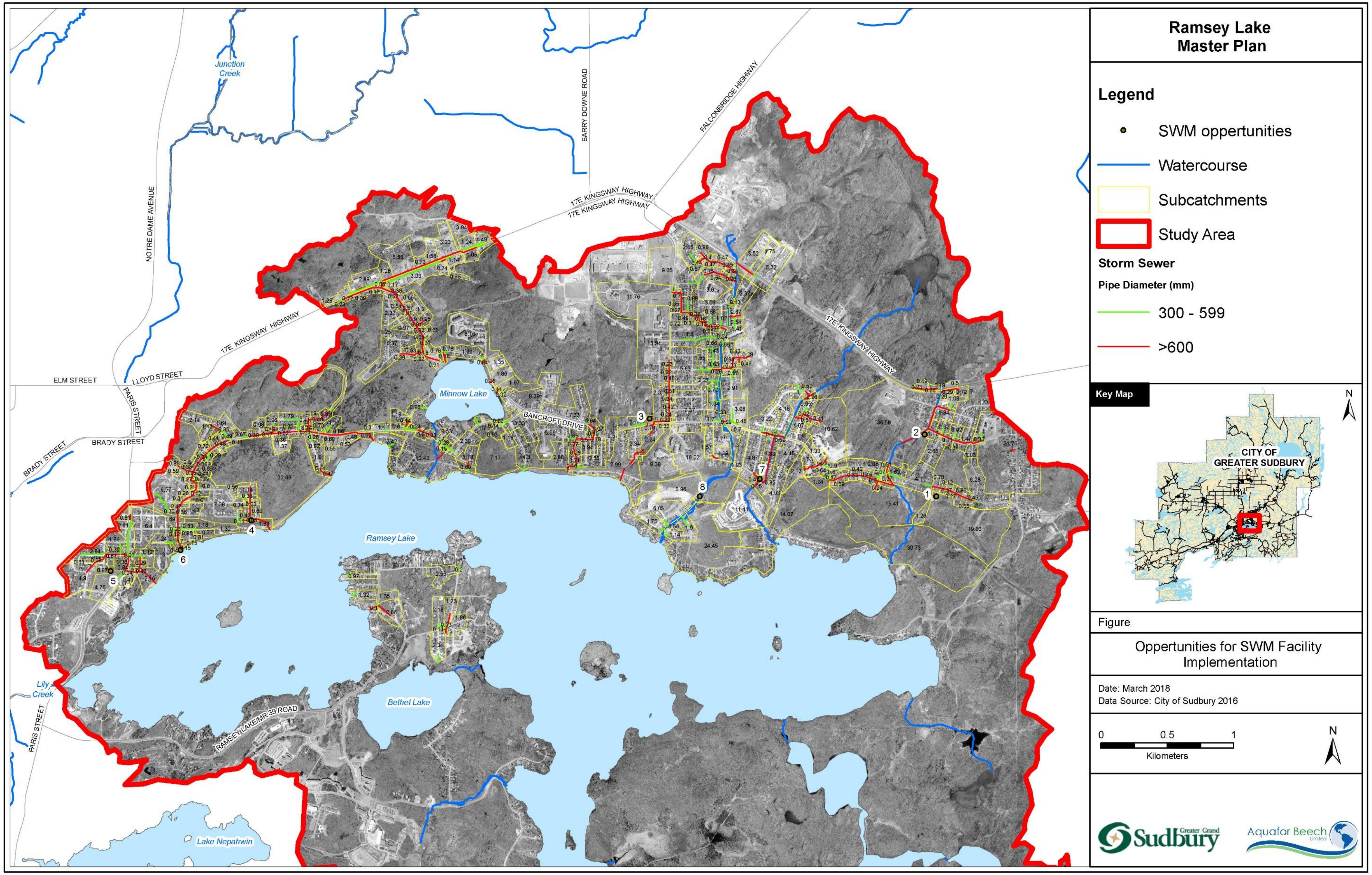


Figure 6.32: Potential locations for SWM facilities

6.2.2.3 Description of Alternatives

For this report, the following three (3) different preliminary alternatives were evaluated:

1. Do Nothing
2. Above ground SWM facility
3. Below ground SWM facility

As discussed in Section 6.1.2, there are several different solutions for both above ground and below ground SWM facilities, however there are significant cost differences, land use constraints and feasibility constraints that are associated with each method. Furthermore, there are general pros and cons for both above ground and below ground facilities, and in undertaking this evaluation the best type of treatment will be selected, and the freedom to select the specific type of facility (e.g., wetland verses dry SWM facility) can be made at the detailed design phase.

Due to some of the land-use constraints, some of the proposed SWM facility locations would have to be below ground. This is primarily a concern where facilities are proposed for roads and road right of ways (ROW). Therefore, for the SWM facilities proposed for these locations, the evaluation was only undertaken for two (2) alternatives; do nothing and below ground SWM facility. **Table 6.6** summaries the alternatives that were evaluated for each of the proposed facilities.

Table 6.6: Summary of alternatives evaluated for each potential SWM facility

Potential SWM Facility	Description	Alternatives Evaluated			Drainage Area (ha)	Current Land Use
		1 - Do Nothing	2 - Above Ground SWM Facility	3 - Below Ground SWM Facility		
1	Bancroft Dr. & Nottingham Ave.	Yes	Yes	Yes	10.087	Park
2	Rheal St. & Eugene St.	Yes	Yes	Yes	101.90	Vacant
3	Bancroft Dr. & First Ave.	Yes	Yes	Yes	81.18	Vacant
4	St. Antoine St.	Yes	No (road)	Yes	12.260	Roadway
5	Paris St.	Yes	No (road)	Yes	17.597	Roadway
6	McNaughton Terrace Park	Yes	No (road)	Yes	64.109	Roadway
7	Mildred St.	Yes	No (road)	Yes	133.102	Roadway

Each of the alternatives is evaluated using ranked criteria, considering how the project will affect the environment, the surrounding community, the feasibility and financial implications.

6.2.2.4 Evaluation Criteria and Scoring

In order to evaluate the alternatives identified in the previous sections, evaluation criteria have been developed in order to select the preferred solution. The evaluation criteria include natural environment, socio-cultural, technical and economic considerations. These criteria, together with a description of the criteria and measures for assigning scores are presented in **Table 6.7**.

For each of the comparative criteria, a rating ranging from 0 to 4 was applied specific to the particular solution being evaluated where 0 represents the worst condition and 4 the best, as identified in **Table 6.8**. Based on this approach, an overall rating based on the total scoring was obtained for each alternative solution.

Subsequently a ranking was assigned for each alternative solution with the highest overall total assigned 1 and the others sequentially 2, 3, etc. based on the scoring. Where the total ratings are the same, the same ranking was assigned.

Table 6.7: Evaluation criteria and measurement of scoring for potential SWM facilities

Criteria	Description of Criteria	Measures for Assigning Scores
Natural Environment		
Potential Surface Flooding Benefit	Ability to reduce surface flooding associated with private properties and roads	Scores are assigned as follows:
		4 - significant reduction in surface flooding risks
		2 - potential reduction to surface flooding risks
		0 - no change in surface flooding risk
Potential Erosion Control Benefit	Potential to reduce erosional forces in receiving stream based on existing condition of stream and ability to provide required erosion control volume	Scores are assigned as follows:
		4 - high potential to reduce erosional forces
		2 - moderate potential to reduce erosional forces
		0 - limited to no potential to reduce erosional forces
Potential Aquatic Habitat Benefit	Potential to improve aquatic habitats or systems, including possible impacts on aquatic life, features and functions	Scores are assigned as follows:
		4 - significant improvement to aquatic habitat or systems
		2 - moderate improvement to aquatic habitat or systems
		0 - no impact to aquatic habitat or systems
Potential Water Quality Benefit	Potential to improve water quality based on existing water quality conditions in stream and ability to provide required water quality control	Scores are assigned as follows:
		4 - high potential that the proposed treatment will improve the water quality
		2 - moderate potential that the treatment will improve the water quality

Criteria	Description of Criteria	Measures for Assigning Scores
		0 - limited to no potential that the treatment will improve the water quality
Potential Hydrologic Flow Benefit	Ability to reduce the peak flow rate and total flow in the downstream receiving water system	Scores are assigned as follows:
		4 – significant potential to reduce the peak flow and total flow downstream
		2 – moderate potential to reduce the peak flow and total flow downstream
		0 – limited or no potential to reduce the peak flow and total flow downstream
Potential Terrestrial Habitat Benefit	Potential to improve terrestrial habitats based on the existing conditions of the terrestrial ecology	Scores are assigned as follows:
		4 - high potential to impact existing terrestrial habitat
		2 - moderate potential to impact existing terrestrial habitat
		0 - limited to no potential to impact existing terrestrial habitat
Socio-Cultural Impacts		
Impact to Aesthetics / Recreation	Potential for retrofit facility to be an asset to the community by integrating facility into activities such as walking, jogging, hiking	Scores are assigned as follows:
		4 - high potential to integrate facility into existing activities
		2 - moderate potential to integrate facility into existing activities
		0 - limited to no potential to integrate facility into existing activities
Compatibility with Adjacent Land Uses	There are potential impacts associated with construction of facilities, particularly with respect to land uses such as residential, old age homes and schools. Access / egress also needs to be considered	Scores are assigned as follows:
		4 - no impacts associated with construction and access / egress for operation / maintenance
		2 - minor impacts associated with construction and access will be limited
		0 - sensitive land uses are located adjacent to proposed facility and access / egress will be limited
Compatibility with Land Ownership	There are potential impacts associated with ownership of the land which could restrict access for construction and maintenance	Scores are assigned as follows:
		4 - City owned lands or have easement
		2 - most lands are owned by City, but some easements may be required
		0 – lands are privately owned
Community Impact - Disruption to Community During Construction	Potential to impact the community in terms of access to the site, visibility, road access, construction of mitigation measure in valley lands / parks, possible noise / odour / light, short-term construction impact, etc.	Scores are assigned as follows:
		4 – no impact on community
		2 – moderate impact on community
		0 – significant impact on community
Consistency with municipal, provincial and federal regulation and/or policy	Ability for the alternative to meet the governing, or soon to be implemented standards, regulations and policies.	Scores are assigned as follows:
		4 - consistent with all standards/regulations/policies
		2 - meets some standards/regulations/policies
		0 – not consistent with standards/regulations/policies
Technical Impacts		
Level of Service provided	Anticipated level of treatment based on the size of the drainage area and the land available for the facility	Scores are assigned as follows:
		4 – technique expected to be highly effective
		2 – technique expected to be moderately effective
		0 – technique expected to be least effective
Constructability	Degree of difficulty in constructing the SWM alternative given the existing site conditions and constraints.	Scores are assigned as follows:
		4 – technique is easily implementable
		2 – there are some obstacles to overcome before implementing techniques
		0 – there are many obstacles to overcome before implementing techniques

Criteria	Description of Criteria	Measures for Assigning Scores
Maintenance Requirements	Degree of anticipated future effort required to maintain the SWM alternative in good working order.	Scores are assigned as follows:
		4 – limited to no maintenance required
		2 – moderate amount of maintenance is required
		0 – high amounts of maintenance are required
Economic Impacts		
Capital Costs	The relative estimated costs of implementing the proposed treatment based on factors such as location, access / egress and area to dispose material	Scores are assigned as follows:
		4 - no capital costs
		2 - moderate capital cost
		0 - highest capital cost
Operation and Maintenance Costs	The relative cost of operating and maintaining the facility based on factors such as location, access / egress and availability of sediment drying area	Scores are assigned as follows:
		4 - no operation and maintenance costs
		2 - moderate operation and maintenance cost
		0 - highest operation and maintenance cost

A Weighting Factor was assigned to category of criteria, which ensured that each category was valued appropriately, regardless to the number of criteria within the category. For this evaluation, the weighting factors used for this evaluation are shown in **Table 6.9**.

Table 6.8: Weight factors used for evaluation of potential SWM facilities

Category	Weighting Factor	Maximum Points for Category
Natural Environment Impact	0.25	25
Socio-Cultural Impact	0.25	25
Technical Impact	0.25	25
Economic Impact	0.25	25
TOTAL	1	100

The detailed evaluation of each SWM facility is included in **Appendix G**, and a summary of the scores for each alternative is provided below, highlighting the preferred alternative.

Table 6.9: Summary of evaluation scores for potential SWM facilities

Potential SWM Facility	Description	Alternatives Evaluated		
		1 - Do Nothing	2 - Above Ground SWM Facility	3 - Below Ground SWM Facility
1	Bancroft Dr. & Nottingham Ave.	53.33	55.83	56.67
2	Rheal St. & Eugene St.	50.83	69.17	56.67
3	Bancroft Dr. & First Ave.	50.83	67.50	53.33
4	St. Antoine St.	53.33	NA	66.88
5	Paris St.	50.83	NA	66.88
6	McNaughton Terrace Park	53.33	NA	54.17
7	Mildred St.	53.33	NA	56.67

6.2.2.5 Preferred Alternative

Based on the evaluation, the preferred alternative for each potential SWM facility is summarized below:

- Site 1 - Bancroft Dr. & Nottingham Ave. – Below Ground SWM Facility
- Site 2 - Rheal St. & Eugene St. – Above Ground SWM Facility
- Site 3 - Bancroft Dr. & First Ave. – Below Ground SWM Facility
- Site 4 - St. Antoine St. – Below Ground SWM Facility
- Site 5 – Paris St. – Below Ground SWM Facility
- Site 6 - McNaughton Terrace Park – Below Ground SWM Facility
- Site 7 - Mildred St. – Below Ground SWM Facility

6.2.3 Summary of the Evaluation Process – Stream Restoration

6.2.3.1 Identification of Opportunities

In assessing the existing fluvial and geomorphic conditions of the four main watercourses (i.e., Frobisher, Roger, Eugene and Keast Creek) an erosion assessment was undertaken which identified 11 erosion sites and nine (9) maintenance issues along the four creeks. There was only one erosion site and maintenance issue received a ranking of "high" priority and should be addressed first. The detailed results of the erosion assessment are presented in Section 3.2.1.4. Maps of the erosion site and maintenance issues are provided in **Figure 6.33** and **Figure 6.34**.

Each of the erosion sites was given a general priority ranking (i.e., High, Moderate or Low), based on technical score. The priority ranking is intended to help guide which issues should be addressed first, and which issues can wait to be addressed. It is intended that the High Priority erosion assessment opportunities be considered directly for integration within the system-wide prioritization and implementation plan, and Moderate and Low Priority erosion sites have been documented for the City to monitor, and may be considered for integration into other projects, but are not recommended for direct consideration in the Master Plan prioritization and implementation plan. The results of the erosion inventory are presented below in **Table 6.10**.

It was noted that the majority of the erosion sites and maintenance issues identified are associated with the culverts and include such issues as scour pools and vegetation/sediment depositions. These issues can be addressed with relative minimal intervention to the existing infrastructure. Also, a maintenance program could help alleviate many of the issues associated with vegetation growth and debris jams. Finally, installing headwall treatments on new culverts (which was observed at some sites) will prevent some erosional risk.

Only 1 project identified as a High Priority, which is ES-K-01, along Keast Creek at South Bay Road. The site was marked as a High Priority site (i.e., technical score of 80 pts), due to the length of the erosion and the risk to South Bay Road. Furthermore, the project is expected to be classified as Schedule B, and therefore an evaluation of alternative solutions will be necessary to satisfy the EA requirements.

Therefore, erosion site ES-K-01 represents the key project to be considered within Ramsey Lake subwatershed prioritization and implementation plan. Secondary opportunities (i.e., Moderate and Low priority sites) have lower levels of risk and rate of degradation and but may still be considered for integration with other City projects as they arise.

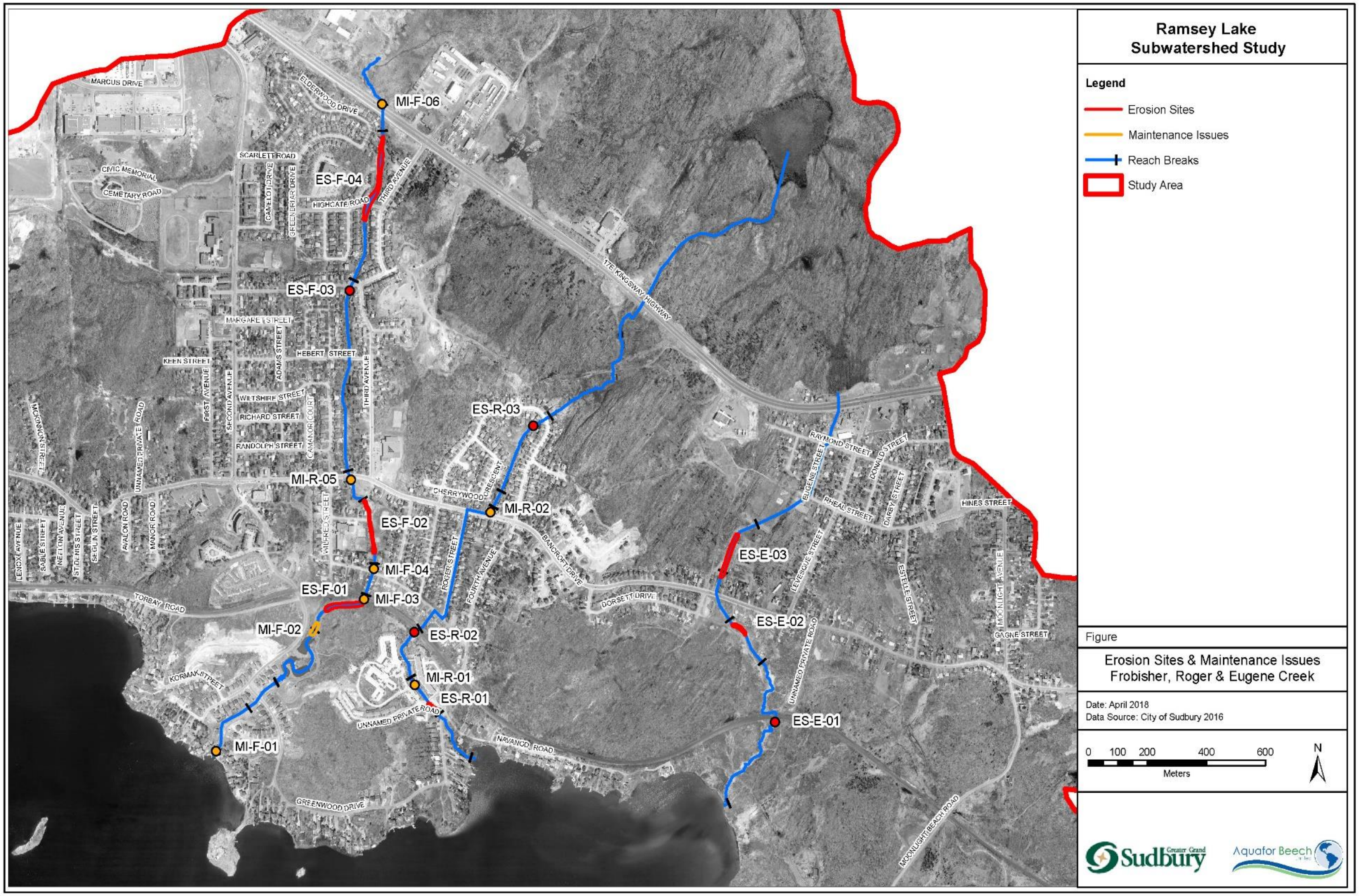


Figure 6.33: Erosion Sites and Maintenance Issues along Frobisher, Roger and Eugene Creek

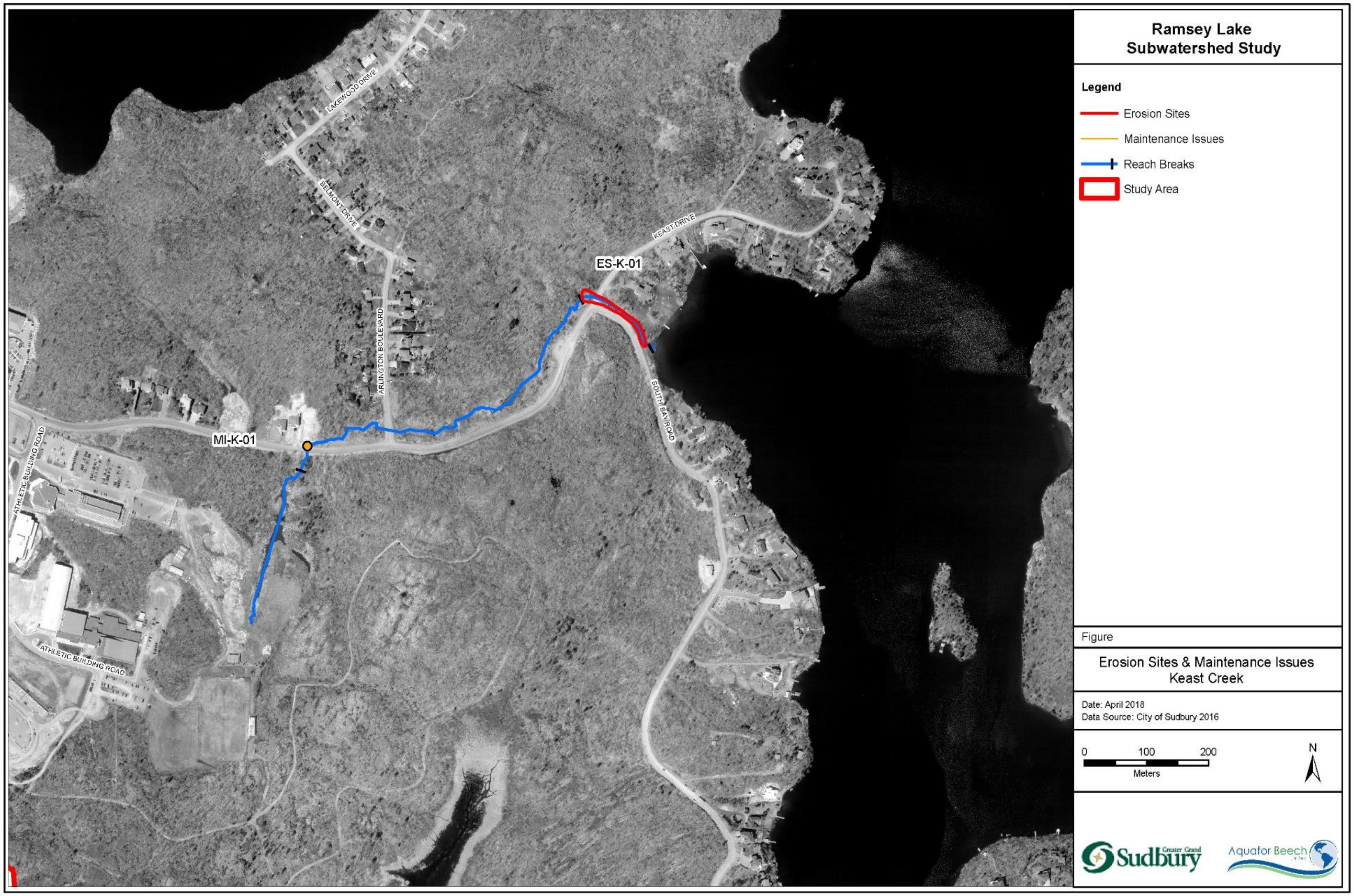


Figure 6.34: Erosion Sites and Maintenance Issues along Keast Creek

Table 6.10: Summary of erosion sites showing expected EA schedule classification

Creek	ID	Reach	Description of Erosion	Approx. Length	Risks	Priority Ranking	Total Technical Score
Keast	ES-K-01	1	Erosion along the channel bed and banks has resulted in channel widening and impingement of the private property and road embankment	100-150m	Private property and Chemins South Bay Road	High	80
Frobisher	ES-F-03	7	Scour pool has formed at outlet of eastern CSP.	localized	Scour has started to undermine eastern CSP and could compromise the long-term stability of the culvert.	Moderate	67
Roger	ES-R-02	3	Scour pool has formed at culvert outlet	localized	Scour has started to undermine structure and could compromise the long-term stability of the culvert	Moderate	67
Frobisher	ES-F-04	8	Sediment deposition at culvert inlet	~300m	Deposition is reducing culvert capacity, could increase the risk of flooding	Moderate	66
Eugene	ES-E-03	3	Fine sediment deposition/runoff within creek is creating deteriorate habitat conditions and decreasing the hydraulic capacity of the channel. Straw bail dam at culvert inlet is causing blockage.	50-100m	Increased flooding risk to residential development	Moderate	63
Roger	ES-R-03	5	Scour pool has formed at culvert outlet	localized	Erosion is minor, however should be mitigated before culvert is compromised	Moderate	60
Frobisher	ES-F-02	5	Erosion along channel banks has resulted in undercutting and slumping	~150m	Erosion of private lands and park lands, and potential impact the Rita St.	Low	59
Roger	ES-R-01	2	Slumping gabion baskets along retaining wall.	~25m	Private property (Finlandia Retirement Community parking lot)	Low	57
Eugene	ES-E-02	2	Sediment deposition at culvert outlet resulting in backwatering of culvert.	~50m	Deposition is reducing culvert capacity, could increase the risk of flooding at Bancroft Drive	Low	53
Eugene	ES-E-01	1	Scour pool has formed at culvert outlet	localized	Scour has started to undermine structure and could compromise the long-term stability of the culvert	Low	52
Frobisher	ES-F-01	4	Erosion along channel banks has resulted in undercutting	~80m	None	Low	50

Under the Municipal Class Environmental Assessment, works undertaken in a watercourse for the purposes of flood control or erosion control (which may include bank or slope regrading, deepening the watercourse, relocation realignment or channelization of watercourse, revetment including soil bio-engineering techniques, or reconstruction of a weir or dam) are classified as Schedule B projects and are subject to an evaluation of alternative treatment solutions. Projects that will replace traditional materials in an existing watercourse with material of equal or better properties, at substantially the same location and for the same purposes, are preapproved Schedule A activities and do not require an evaluation of alternative treatments. For this report, the erosion sites summarized in Section 3.2.1.4 were identified as projects that would be classified as Schedule A or B Environmental Assessments.

Therefore, as ES-K-01 is expected to be identified as a Schedule B project, four (4) preliminary alternatives were evaluated using baseline information and evaluation criteria for treatment options for erosion site ES-K-01. Scoring of the criteria produced a preferred alternative which was the developed into a conceptual design. Cost estimates for engineering services (i.e., design, background studies such as geotechnical investigations) and construction costs for each of the preferred alternatives was estimated for each of the preferred alternatives for each site.

6.2.3.2 Description of Erosion Site ES-K-01

Erosion site ES-K-01 is within the most downstream reach of Keast Creek, Reach-01, immediately downstream the Keast Drive culvert.

At the upstream extent of erosion site ES-K-01, a scour pool has formed at the outlet of the Keast Creek culvert and is causing channel bank and bed erosion. Downstream of the culvert, the western channel bank is adjacent to the South Bay road embankment and erosion here has resulted in an over-steepened bank and some slumping. The east bank of the channel is much lower, providing some floodplain access, however this is private property. The east bank was also experiencing some erosion and slumping, but less extensive then the western bank. The channel downstream of the culvert is noted to be over-widened and potentially downcutting. Upstream of ES-K-01 and the Keast Creek culvert is an earth dam, which has created a very steep channel at the culvert inlet.

There was some minor erosion noted here, however the vegetation appeared to be stabilizing the channel. The existing conditions of ES-K-01 are shown below in Figure 6.35.

The ongoing erosion poses risk of failure to the South Bay Road embankment, and loss of lands to the adjacent private property. South Bay Road is the only access route to several residential dwellings south of ES-K-01, and therefore failure of the road could restrict residents' access to and from their homes.

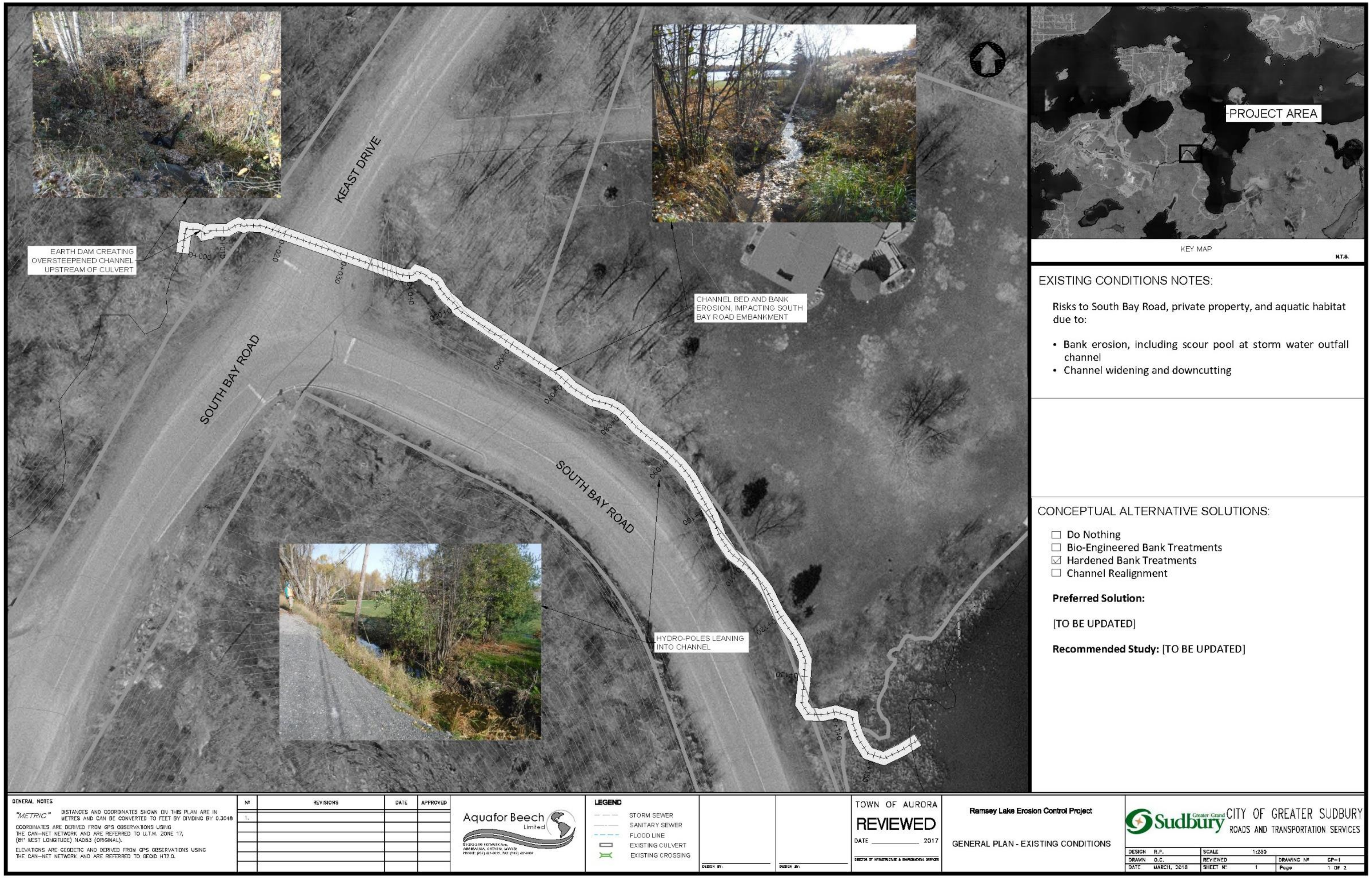


Figure 6.35: Existing conditions at erosion site ES-K-01

6.2.3.3 Evaluation of Alternatives

In order to ensure a transparent selection process (as part of the EA) that considers all possible alternatives, a two-phased evaluation process has been used to assess the alternative measures.

6.2.3.3.1 Screening Level Assessment

The screening level assessment is intended as a coarse screening tool, used to select the scale of works which are appropriate for the erosion site. This involves investing if (1) local works or (2) reach based works should be used to treat the erosion. The following subsections provide general descriptions for both scales of work.

Local Works: Local works would involve undertaking stream restoration works at strategic locations in order to limit the impact of existing erosion. Local works would reduce the level of risk by applying local bank or slope stabilization treatments using either hardened (engineered) type treatments, or more natural (vegetation and biotechnical engineered) type treatments. A key consideration for undertaking local works is the understanding that the observed instability and risks are locally focused within a reach, and that the decision to apply local treatments to address the observed instability is not anticipated to initiate instability resulting in increased erosion risk elsewhere within the reach.

The cost of the local works will vary from site to site depending on the type of treatment and the extent of the required works. It should be noted that the selective works can be implemented in stages based on monitoring results, level of risk and available capital budget. These costs do not include ancillary fees such as contract tendering and administration, contractor mobilization, insurance, restoration or monitoring and adaptive management.

Reach Based Works: Reach based channel restoration would involve a combination of Natural Channel Design (NCD) techniques and Geomorphic Referenced River Engineering (GRRE) generally referred to as a hybrid type design. This alternative would ultimately be selected for a reach if it is determined that "Local Works" would not address, or in fact exacerbate erosion risk at its current location or transfer those effects of erosion up and/or downstream within the reach.

It is an understanding that there is systematic instability within the water course requiring a systematic approach to address the risk.

The cost of the reach-based works will vary from site to site depending on the type of treatments and the extent of the required works. Generally, the costs of reach-based works will exceed the costs of the local works alternative, however as the approach take a capital approach to a larger area, it will be less likely that works will need to be completed in this area again. Furthermore, if the extent of the erosion covers a significant amount of the reach, the cost between local works and reach based works will be very similar.

To screen the scale of the project, four (4) screening level assessment criteria have been utilized to determine which scale of works are appropriate. Table 6.11 shows the primary criteria included, and threshold targets for each criterion and how erosion site ES-K-01 was evaluated.

Table 6.11: Screening criteria and evaluation for scale of works

Criteria	Local Works Recommended Threshold	Reach Based Works Recommended Threshold	Erosion Site ES-K-01	
			Summary	Preferred Scale of Works for Criteria
Reach Stability	Reach is stable, and upstream and downstream reaches are stable or transitional	Reach is transitional or unstable	Upstream reach = Stable Erosion Site Reach = Unstable	Reach based
Extent of Erosion	Length of erosion site is less than 25% of reach length	Length of erosion site is more than 25% of reach length	Reach Length = 150m Erosion Site Length = ~100m Percent of Reach Length = 67%	Reach based
Cause of Erosion	Localized issue identified to be causing erosion	Erosion expected to be cause by reach based fluvial or hydrological processes.	Dam and culvert are identified as causing the issue.	Local Works
Reach Health	No significant issues with aquatic or terrestrial habitat issues within the reach	Reach has degraded habitat conditions or barriers that could be addressed as part of the reach-based works.	Reach characterised as having low quality physical aquatic habitat and riparian cover.	Reach based

Based on the screening exercise, reach based works were recommended for three of the four screening criteria. Therefore, it is recommended that the detailed evaluation be completed for reach based approaches for erosion site ES-K-01.

6.2.3.3.2 Description of Alternatives

The scale of works carried forward for the stream restoration of erosion site ES-K-01 was reach based works. Following the EA procedure, ES-K-01 was then evaluated for different preliminary restoration alternatives. For this report, the following four (4) different preliminary alternatives were evaluated:

4. Do Nothing
5. Bio-engineered bank treatments
6. Hardened bank treatments
7. Channel realignment

Each of the alternatives is evaluated using ranked criteria, considering how the project will affect the environment, the surrounding community, the feasibility and financial implications.

The following subsections provide general descriptions of each of the preliminary alternative for the erosion site.

Preliminary Alternative 1 - Do Nothing

Under the Do Nothing alternative the City would monitor existing conditions with continued risks to South Bay road, and the adjacent private property.

Although the Do Nothing alternative has no capital costs assigned, it is expected that there could be maintenance repairs for the culvert outlet at Keast Drive and erosional damage will continue to appreciate.

Should the erosion continue it is possible that mass slumping of the embankment may occur, in which case it is possible that South Bay Road could be compromised and emergency repairs might be required.

Preliminary Alternative 2 - Bio-engineered bank treatments

Under alternative 2, the channel bed and banks would be stabilized using bio-engineered treatments. This would involve stabilized bank treatments using natural material (i.e., native soil and stone) integrated with vegetation. The channel bed will be protected from downcutting by constructing natural river grade control features, such as riffles, using natural stone. The bio-engineered treatments would enhance the aquatic habitat and riparian corridor and would integrate with some of the natural form and process of the river.

Immediately after construction **One month after construction** **10 months after construction**

Figure 6.36: Example of bio-engineered bank treatment

Upstream of the culvert, the earth dam would be removed, using a staged, controlled release of flows to ensure that no further erosion is exacerbated downstream. Following the dam removal bio-engineered bank and bed treatments would be implemented upstream of the culvert to stabilize the channel, as required.

Preliminary Alternative 3 - Hardened bank treatments

Under alternative 3, the channel bed and banks would be stabilized hardened treatments, such as an armour stone retaining wall, along the South Bay Road embankment. This will increase bank stability and maximize the available river corridor width along the roadway. A softer bank treatment, incorporating vegetation could be implement along the eastern bank. As with alternative 2, the channel bed will be protected from downcutting by constructing natural river grade control features, such as riffles, using natural stone.

Armourstone retaining wall and concrete floodwall

Armourstone retaining wall for culvert inlet protect and road embankment support

Figure 6.37: Examples of hardened bank treatments

Upstream of the culvert, the treatments would be similar to alternative 2, with the exception of localized hardened bank treatments at the culvert inlet, to provide long term protection to the Keast Drive culvert.

Hardened bank treatments, such as armourstone walls are more expensive than bio-engineered treatments, however there is less maintenance immediately following construction, as young vegetation within the bio-engineered structures must be monitored to ensure proper growth. If constructed correctly, both structures are expected to have approximately the same life span.

Preliminary Alternative 4 - Channel realignment

Under alternative 4, Keast Creek would be realigned away from South Bay Road. This would involve complete channel reconstruction, implementing natural channel strategies downstream of the culvert to the lake. The realignment would remove all risk to South Bay Road, and provide a buffer for the creek to naturally migrate.

Upstream of the culvert, the treatments would be similar to alternative 2, with the exception of localized hardened bank treatments at the culvert inlet, to provide long term protection to the Keast Drive culvert.

In order to undertake channel realignment, the City's would have to acquire the land rights through property purchase and easements as the property is privately owned.

6.2.3.3.3 Evaluation Criteria and Scoring

In order to evaluate the alternatives identified in the previous sections, evaluation criteria have been developed in order to select the preferred solution. The evaluation criteria include natural environment, socio-cultural, technical and economic considerations. These criteria, together with a description of the criteria and measures for assigning scores are presented in **Table 6.13**.

For each of the comparative criteria, a rating ranging from 0 to 4 was applied specific to the particular solution being evaluated where 0 represents the worst condition and 4 the best, as identified in **Table 6.13**. Based on this approach, an overall rating based on the total scoring was obtained for each alternative solution.

Subsequently a ranking was assigned for each alternative solution with the highest overall total assigned 1 and the others sequentially 2, 3, etc. based on the scoring. Where the total ratings are the same, the same ranking was assigned.

A Weighting Factor was assigned to category of criteria, which ensured that each category was valued appropriately, regardless to the number of criteria within the category. For this evaluation, all the categories were evaluated equal. The weighting factors used for this evaluation are shown in **Table 6.12**.

Table 6.12: Weight factors used for evaluation of stream restoration works

Category	Weighting Factor	Maximum Points for Category
Natural Environment Impact	0.25	25
Socio-Cultural Impact	0.25	25
Technical Impact	0.25	25
Economic Impact	0.25	25
TOTAL	1	100

The evaluation of the alternative solutions is presented in **Table 6.13**.

6.2.3.3.4 Preferred Alternative

Based on the evaluation, the preferred alternative solution for stream restoration works at erosion site ES-K-01, is **alternative 3, hardened bank treatments**. This solution provides the most protection to the South Bay road embankment while still enhancing the aquatic and terrestrial habitat within Reach 1 of Keast Creek.

An existing conditions and conceptual design of the preferred alternative treatments are shown below in **Figure 6.38** and **Figure 6.39**.

Table 6.13: Evaluation criteria for stream restoration alternatives

Criteria	Description of Criteria	Measures for Assigning Scores	Alternative 1 Do Nothing	Alternative 2 Bio-engineered bank treatments	Alternative 3 Hardened bank treatments	Alternative 4 Channel realignment
Natural Environment Impacts						
Potential Erosion Control Benefit	Potential to reduce erosional forces in receiving stream based on existing condition of stream and ability to provide required erosion control volume	Scores are assigned as follows: 4 - high potential to reduce erosional forces 2 - moderate potential to reduce erosional forces 0 - limited to no potential to reduce erosional forces	0	2	4	4
Potential Aquatic Habitat Benefit	Potential to improve aquatic habitats or systems, including possible impacts on aquatic life, features and functions	Scores are assigned as follows: 4 - significant improvement to aquatic habitat or systems 2 - moderate improvement to aquatic habitat or systems 0 - no impact to aquatic habitat or systems	0	2	2	4
Potential Terrestrial Habitat Benefit	Potential to improve terrestrial habitats based on the existing conditions of the terrestrial ecology	Scores are assigned as follows: 4 - high potential to benefit existing terrestrial habitat 2 - moderate potential to benefit existing terrestrial habitat 0 - limited to no potential to benefit existing terrestrial habitat	0	2	2	2
		Natural Environment Impacts Subtotal	0	6	8	10
		Weighted Score for Natural Environment Impact Criteria (maximum of 25 pts)	**0.00**	**12.50**	**16.67**	**20.83**
Socio-Cultural Impacts						
Impact to Aesthetics / Recreation	Potential for retrofit facility to be an asset to the community by integrating facility into activities such as walking, jogging, hiking	Scores are assigned as follows: 4 - high potential to integrate facility into existing activities 2 - moderate potential to integrate facility into existing activities 0 - limited to no potential to integrate facility into existing activities	4	2	4	0
Compatibility with Adjacent Land Uses	There are potential impacts associated with construction of facilities, particularly with respect to land uses such as residential, old age homes and schools. Access / egress also needs to be considered	Scores are assigned as follows: 4 - no impacts associated with construction and access / egress for operation / maintenance 2 - minor impacts associated with construction and access will be limited 0 - sensitive land uses are located adjacent to proposed facility and access / egress will be limited	4	2	2	0
Compatibility with Land Ownership	There are potential impacts associated with ownership of the land which could restrict access for construction and maintenance	Scores are assigned as follows: 4 - City owned lands or have easement 2 - most lands are owned by City, but some easements may be required 0 – lands are privately owned	4	2	2	0
Community Impact -Disruption to Community During Construction	Potential to impact the community in terms of access to the site, visibility, road access, construction of mitigation measure in valley lands / parks, possible noise / odour / light, short-term construction impact, etc.	Scores are assigned as follows: 4 – no impact on community 2 – moderate impact on community 0 – significant impact on community	4	2	2	0
Public Health and Safety	Public health and safety include risk to private property, parking lots, roads, footbridges and public trails	Scores are assigned as follows: 4 - low public risk 2 - moderate public risk 0 - significant public risk	0	2	2	4
		Socio-Cultural Impacts Subtotal	16	10	12	4
		Weighted Score for Socio-Cultural Impact Criteria (maximum of 25 pts)	**20**	**12.5**	**15**	**5**
Technical Impacts						
Impact to Surrounding Infrastructure	The potential impact to the surrounding infrastructure (e.g., buildings, bridges, roads) during and after constructions	Scores are assigned as follows: 4 - no negative impacts 2 - moderate impacts (e.g., regrading of roads or underpinning buildings) 0 - high impact (e.g., roads realigned, buildings taken down)	4	2	2	0
Ease of Implementation	The relative ease with which the alternative can be implemented taking into consideration approvals, adjacent landowner acceptance, length of time to implement	Scores are assigned as follows: 4 - easily implemented 2 - some obstacles to overcome in order to implement alternative 0 - significant obstacles to overcome in order to implement alternative	4	2	2	0
Agency Acceptance	The willingness or representative agencies (City of Greater Sudbury, NDCA, DFO, MNRF) to accept the alternative based on relevant policy constraints and discussions	Scores are assigned as follows: 4 - the alternative agrees with existing policies 2 - the alternative agrees with most of the existing policy 0 - the alternative does not agree with the existing policy	0	4	4	2
		Technical Impacts Subtotal	8	8	8	2
		Weighted Score for Technical Impact Criteria (maximum of 25 pts)	**16.67**	**16.67**	**16.67**	**4.17**
Economic Impacts						
Capital Costs	The relative estimated costs of implementing the proposed treatment based on factors such as location, access / egress and area to dispose material	Scores are assigned as follows: 4 - no capital costs 2 - moderate capital cost 0 - highest capital cost	4	2	0	0
Operation and Maintenance Costs	The relative cost of operating and maintaining the facility based on factors such as location, access / egress and availability of sediment drying area	Scores are assigned as follows: 4 - no operation and maintenance costs 2 - moderate operation and maintenance cost 0 - highest operation and maintenance cost	0	2	4	4
		Economic Impacts Subtotal	4	4	4	4
		Weighted Score for Economic Impact Criteria (maximum of 25 pts)	**12.5**	**12.5**	**12.5**	**12.5**
		FINAL WEIGHTED SCORE (maximum of 100 pts)	**49.17**	**54.17**	**60.83**	**42.50**

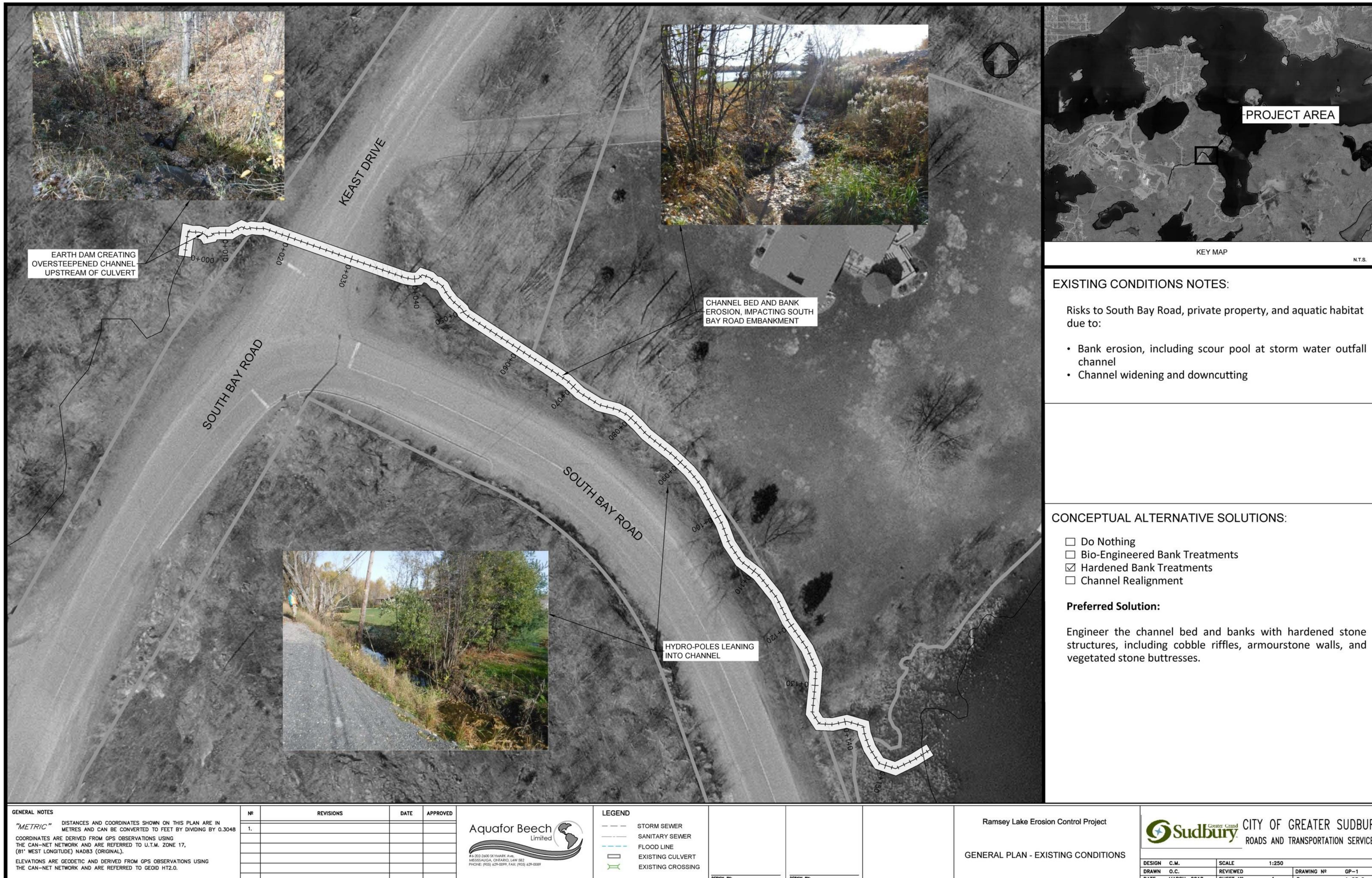


Figure 6.38: Existing conditions at erosion site ES-K-01

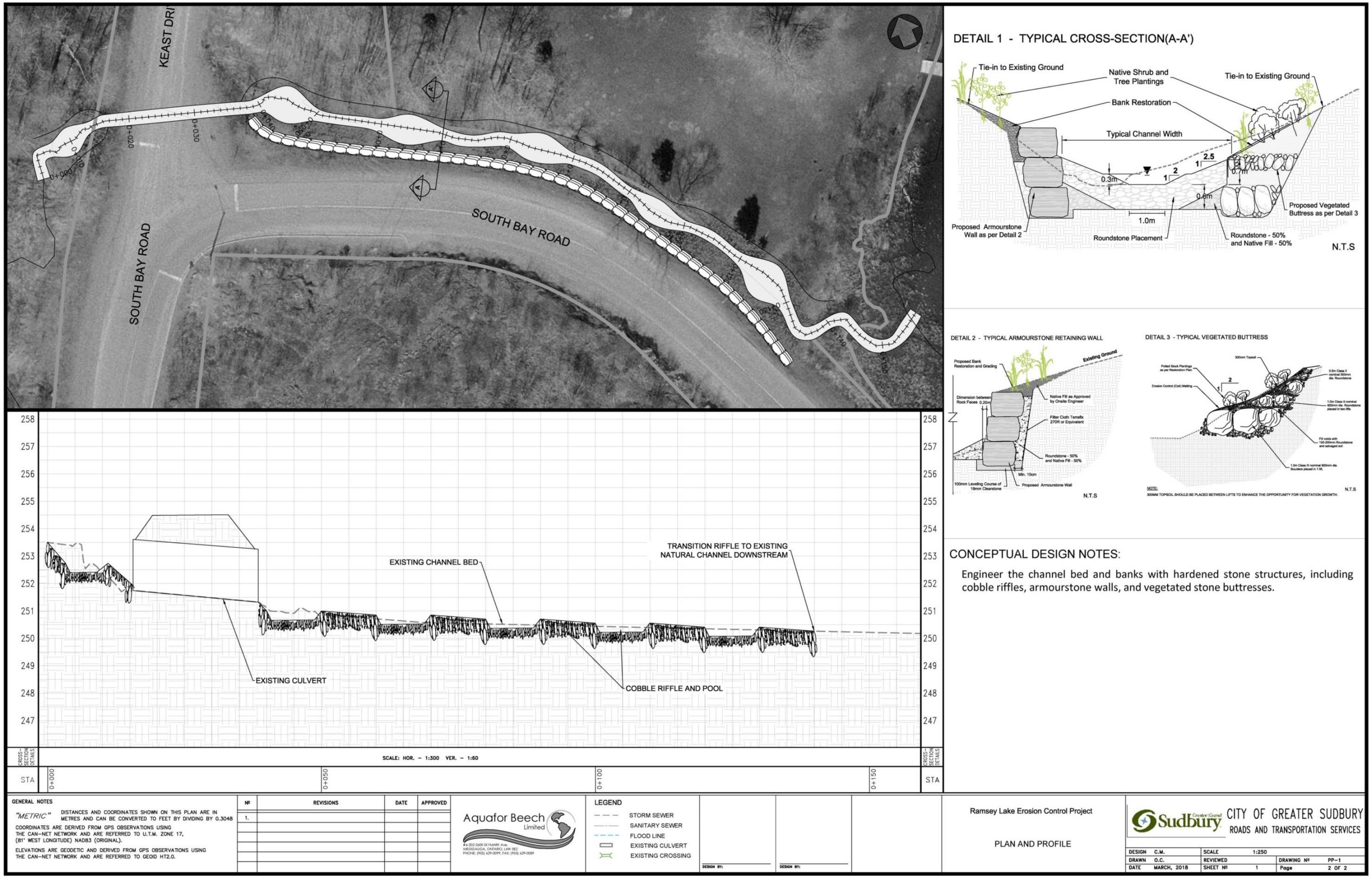


Figure 6.39: Conceptual design for the preferred alternative at erosion site ES-K-01

6.2.4 Summary of the Evaluation Process - Flood Mitigation

6.2.4.1 General

Opportunities to mitigate flood risks were investigated with the intention of removing buildings from the floodplain and reducing the frequency with which roads are overtopped. For this evaluation, flood risk areas were identified and opportunities for mitigating the flood impacts are presented.

In assessing flood risks, the hydraulic capacity of roads and culverts were evaluated in relation to the City of Greater Sudbury (CGS) design standards from the Stormwater Background Study, of the Official Plan and the MTO Drainage Policy. **Table 6.14** summarizes the CGS and MTO hydraulic design standards.

Table 6.14: CGS and MTO bridge and culvert design standards

Road Classification	CGS and MTO Standards for Design Storm Conveyance Capacity		MTO Standards for Freeboard
	Span < 6m	Span > 6m	
Urban Arterial	50 year	100 year	1.0m
Rural Arterial/Collector Road	25 year	50 year	1.0m
Local Road	10 year	25 year	0.3m

6.2.4.2 Identification of Opportunities

As part of the investigation of existing conditions for the Ramsey Lake subwatershed, floodlines were delineated for the regional flood event (i.e., the Timmins storm). The results of this analysis are presented in **Section 3.2.3**. In undertaking this assessment, 15 buildings were identified to be within the floodplain (13 buildings along Frobisher Creek and two (2) along Roger Creek). Furthermore, seven (7) road crossings were identified to be inundated during the regional event. The locations of buildings within the floodplain and overtopped road crossings are shown in **Figure 6.40**.

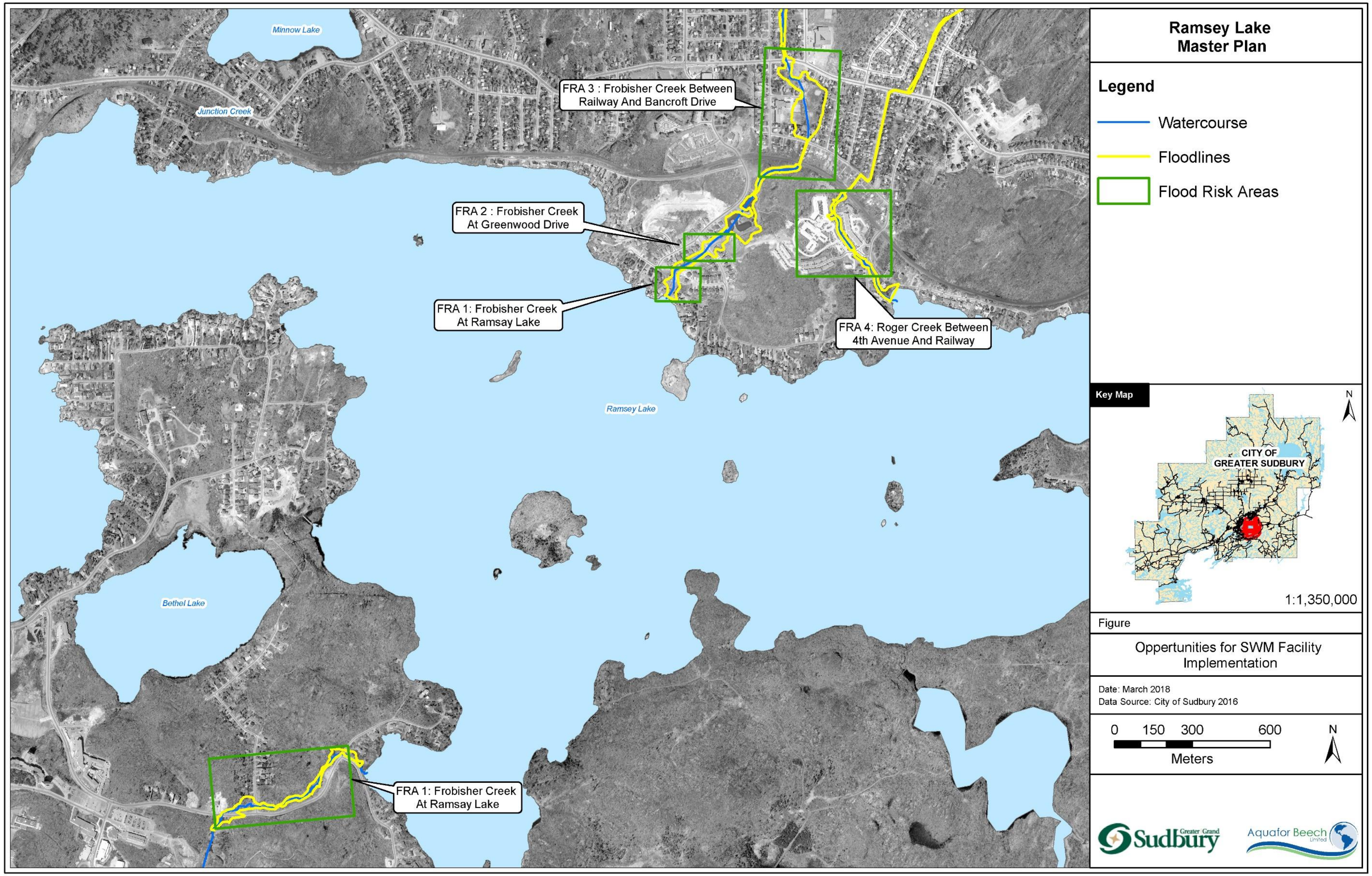


Figure 6.40: Locations of FRA within subwatershed

Five (5) flood risk areas (FRA) were identified, by identifying areas with buildings within the floodplain, significant spills or backwatering (poor sentence structure). By determining the FRA, localized causes of flooding could be defined, and mitigation solutions relevant to the problem can be suggested. The locations of the FRA are shown in **Figure 6.40**. Provided below is a description of each of the FRA's

FRA 1: Frobisher Creek at Ramsey Lake

Under the regional flood conditions, some backwater flooding is anticipated to occur in Frobisher Creek. This is expected to result in three (3) houses being within the floodplain.

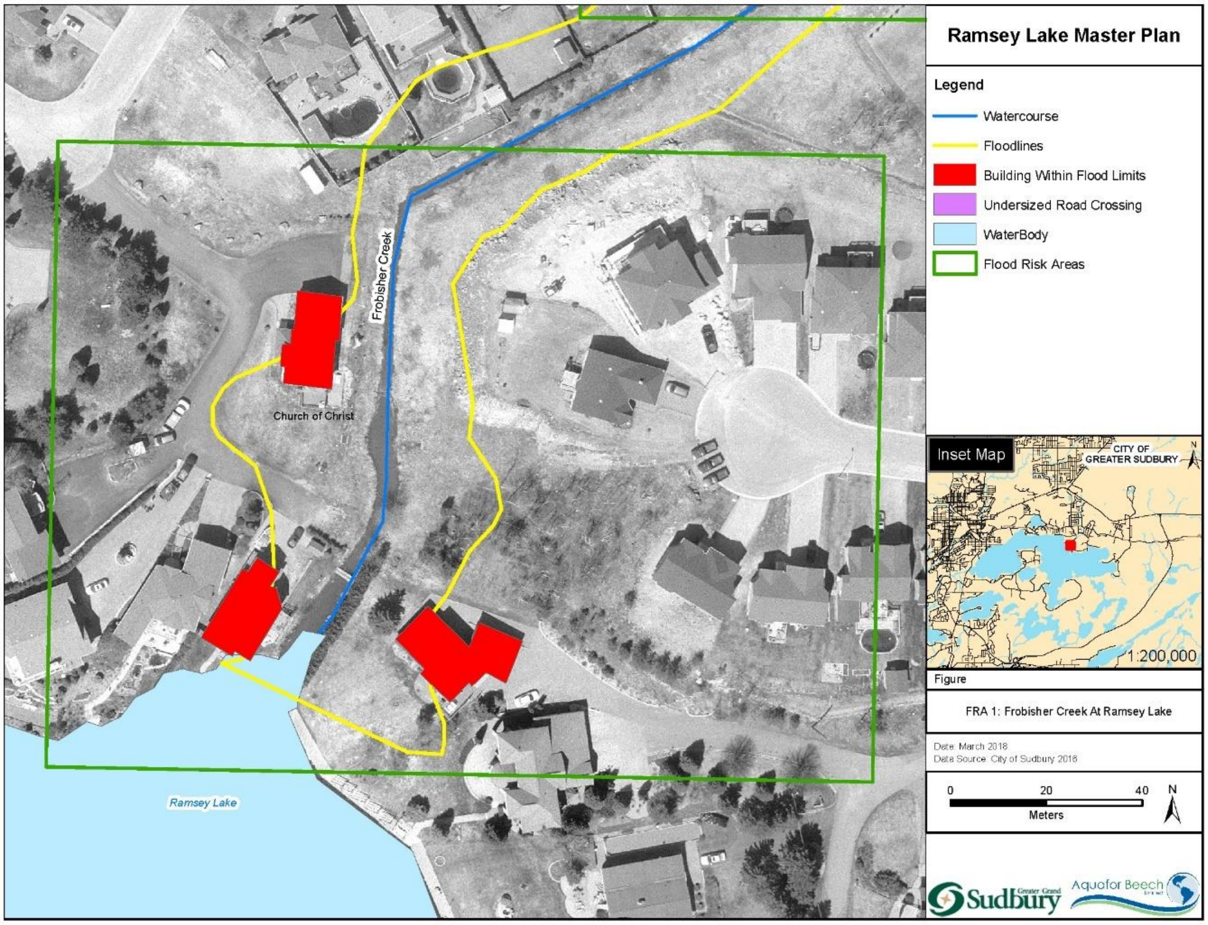


Figure 6.41: Flood risk area 1 - Frobisher Creek at Ramsey Lake

Figure 6.42: **Frobisher Creek at Ramsey Lake**

Figure 6.43: **Ramsey Lake at confluence with Frobisher Creek**

FRA 2: Frobisher Creek at Greenwood Drive

Under the regional flood conditions, Greenwood Drive is expected to be overtopped with approximately 0.7m of water, making the road inaccessible. Furthermore, two (2) buildings are also within the floodplain upstream of Greenwood Drive, likely as a result of backwater from the culvert.

There are two possible causes of flooding at this FRA. The first being backwater from Ramsey Lake, which is limiting the full hydraulic capacity of the culvert. Secondly, the culvert was constructed on a slight negative grade, within the inlet being slightly lower than the outlet. This could be causing the culvert to backwater approximately 0.5m, also reducing the hydraulic capacity of the culvert.

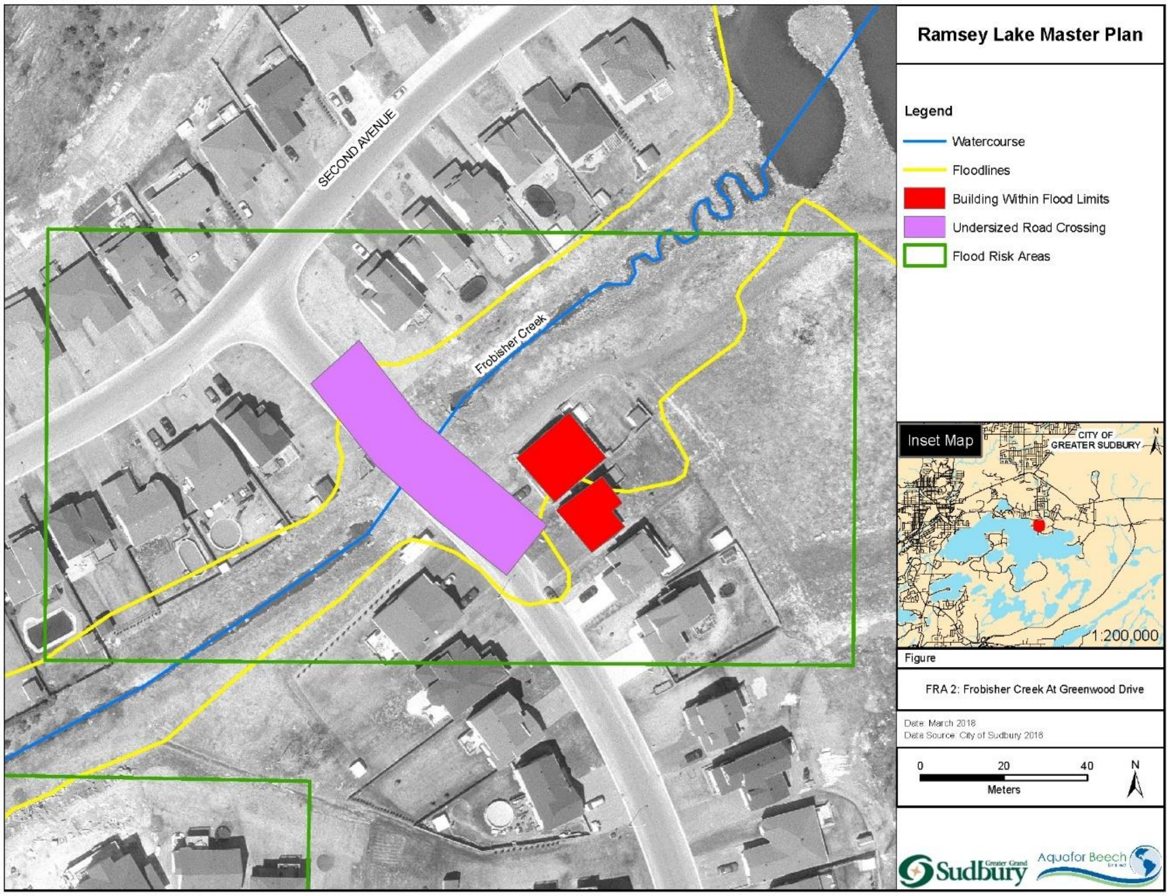


Figure 6.44: Flood risk area 2 - Frobisher Creek at Greenwood Drive

The culvert at Greenwood Drive is also undersized in relation to the CGS and MTO design standards. Greenwood Drive would be classified as a rural arterial road with a span less than 6m, and therefore should be designed to convey the 25-year flood event (~25.5 m^3/s), with 1m of freeboard. However, the maximum capacity of the culvert (prior to overtopping the road) is only 10.5 m^3/s.

Figure 6.45: Inlet to the Greenwood Drive culvert

Figure 6.46: Frobisher Creek upstream of Greenwood Dr.

FRA 3: Frobisher Creek between Railway and Bancroft Drive

Under the regional flood conditions, a larger area upstream of Mildred Street is expected to be impacted by flooding. In this FRA there are eight (8) buildings expected to be within the floodplain, and two (2) roads overtopped (Bancroft Dr. and Rite St.) (**Figure 6.47**). The majority of the flooding is contained to the Grace Tot Lot but does extend into several backyards and the yard of Ecole Separee Saint-Pierre.

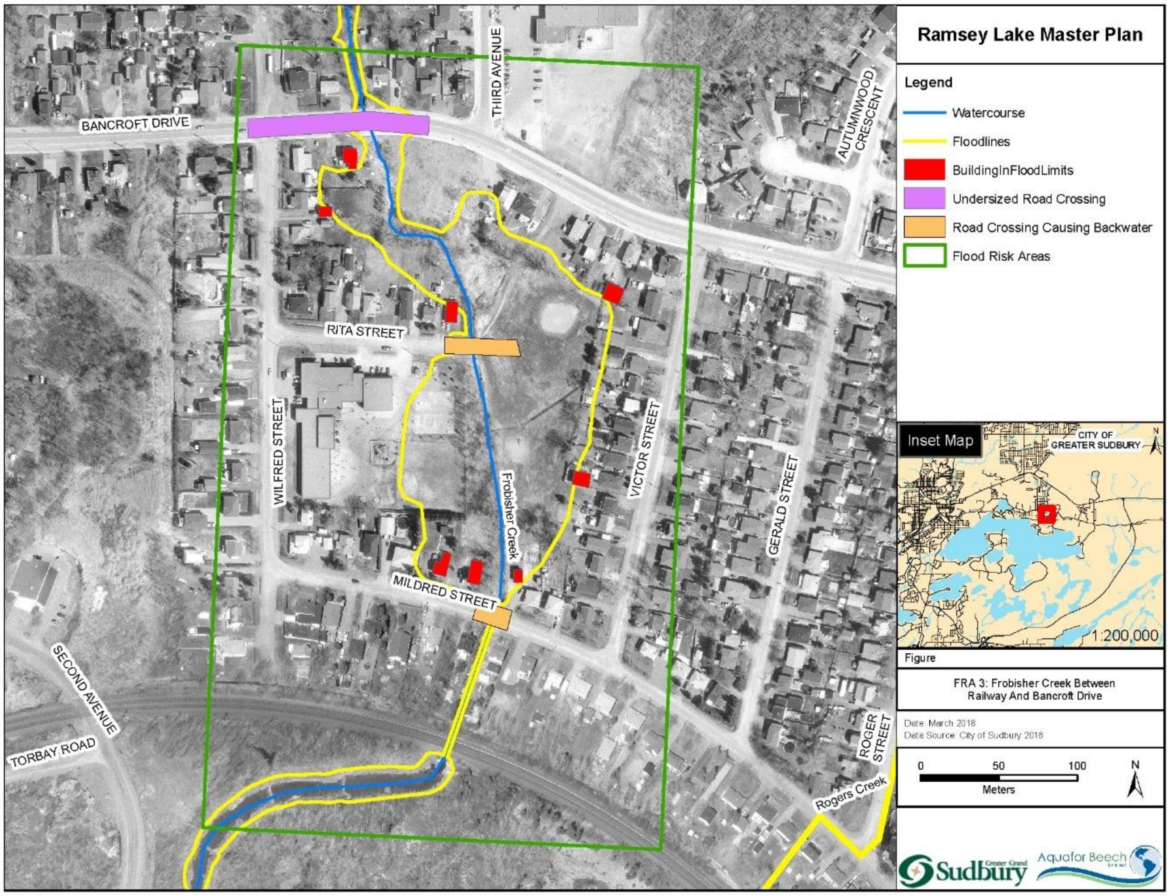


Figure 6.47: Flood risk area 3 - Frobisher Creek between Railway and Bancroft Drive

The main cause for the flooding in this area is due to backwatering from the storm sewer inlet at Mildred Street. At the inlet there is a grated cover over a larger drop structure (approximately 1.75m drop) which connects to a 2400 mm circular, concrete pipe. The pipe extends for approximately 100 m under several private properties (with buildings) and the railway, and then discharges to Frobisher Creek. The backwater from Mildred Street causes the culvert at Rita Street to overtop and might also be affecting the conveyance of the Bancroft Drive culvert.

Figure 6.48: Storm sewer inlet at Mildred St.

Figure 6.49: Storm sewer outlet downstream of railway

Figure 6.50: Culvert outlet at Rita St.

Figure 6.51: Culvert inlet at Bancroft Dr.

It is possible that culverts at Rita Street and Bancroft Drive are also undersized, however the true capacity of the culverts can't be evaluated with the HEC-RAS model, due to the backwater conditions.

FRA 4: Roger Creek between 4th Ave and Railway

Under the regional flood conditions, the Finlandia Retirement Community (between 4th Ave and the railway) experiences some flooding impacts. In this FRA there are two (2) buildings expected to be within the floodplain, and 4th Avenue is expected to overtop (**Figure 6.52**). The majority of the flooding is contained to valley within the retirement community.

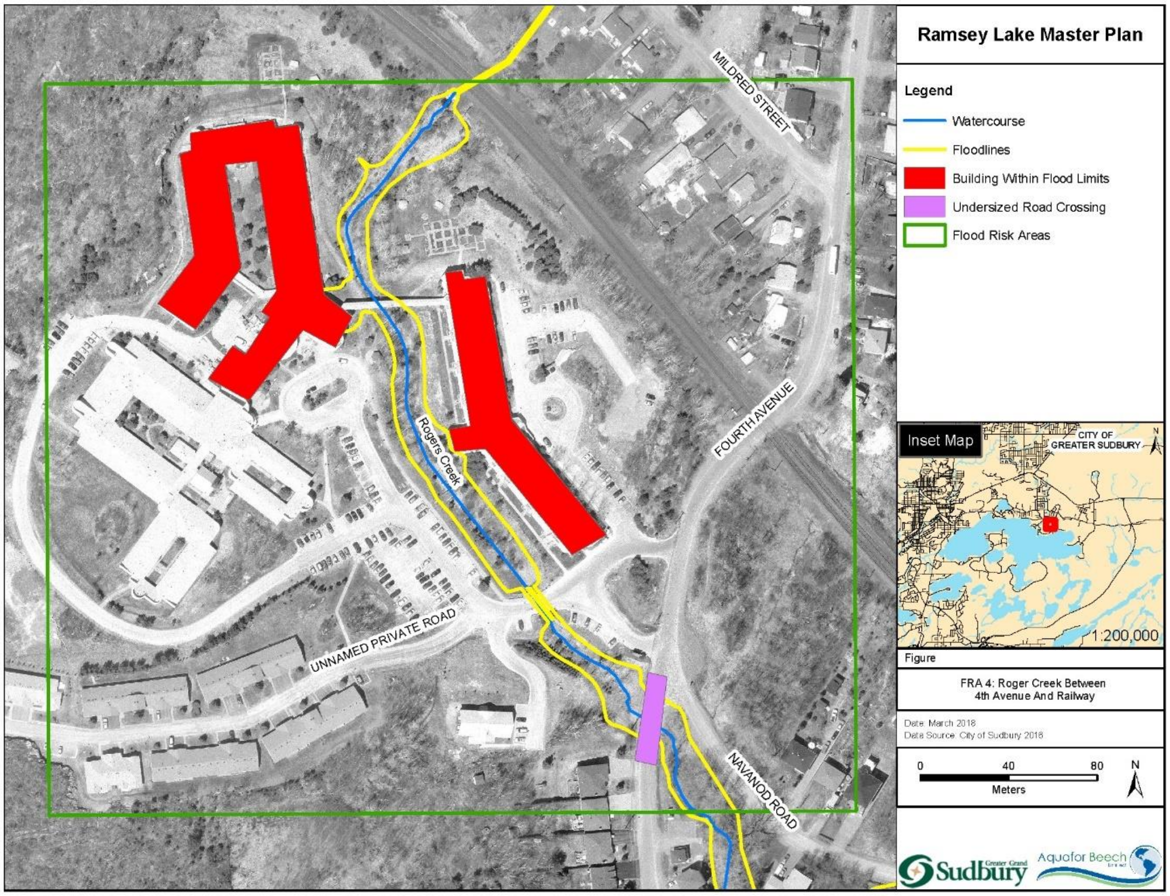


Figure 6.52: Flood risk area 4 - Roger Creek between 4th Ave and Railway

The main cause of flooding is expected to be from undersized culverts, unable to convey the necessary flows. The culvert at 4th Avenue is creating a backwater effect under the regional flows. 4th Avenue would be classified as a rural arterial road, and based on CGS and MTO design standard should be able to convey the 25-year flood event (~5.5 m^3/s), with 1m of freeboard. Currently, the maximum capacity of the culvert at 4th Avenue (prior to overtopping the road) is only 1.0 m^3/s. Furthermore, one of the culverts within the retirement community is expected to be causing a backwater effect, however this could be amplified by the backwater effect of the 4th Avenue culvert.

Figure 6.53: Culvert inlet at 4thAve.

Figure 6.54: Culvert at 4th Ave, showing road

FRA 5: Keast Creek

Under the regional flood conditions all three of the road crossings along Keast Creek (i.e., South Bay Rd, Arlington Blvd and Keast Dr) are expected to be overtopped. There are no buildings impacted by this flooding, however all three roads are primary access routes for the residential communities in this area and could cause limited access during flooding conditions.

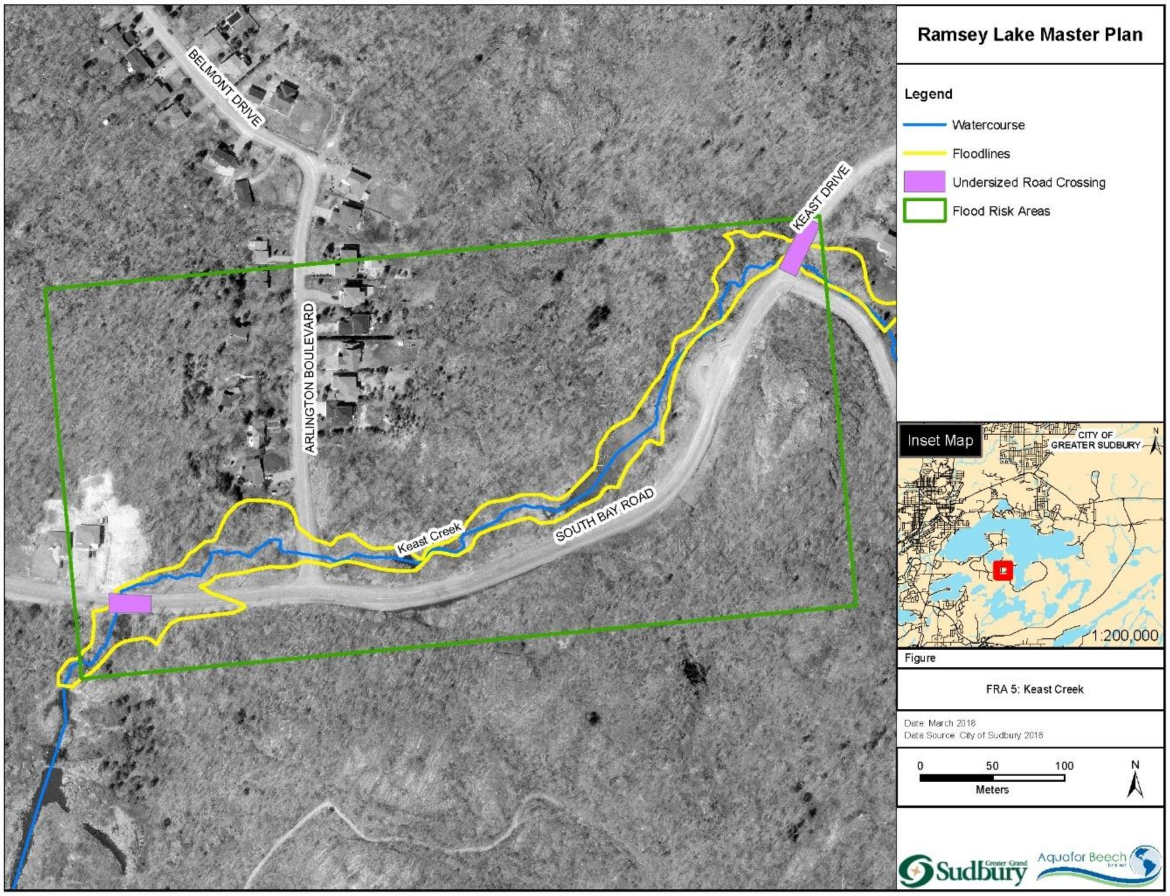


Figure 6.55: Flood risk area 5 – Keast Creek

The main cause of flooding is expected to be from undersized culverts, unable to convey the necessary flows. **Table 6.15** below summarizes the existing capacity and design standards for the each of the culverts along Keast Creek.

Table 6.15: Summary of culvert capacity and design standards for Keast Creek

Creek	Road Name and Classification	Approximate Flow of Overtopping (m^3/s)	CGS/MTO Design Standard
Keast Creek	South Bay Rd. (rural arterial)	0.7 (2 year event overtops)	25-year event (~2.5 m^3/s) + 1.0m freeboard
Keast Creek	Arlington Blvd. (rural arterial)	4.3 (50-year event overtops)	25-year event (~2.5 m^3/s) + 1.0m freeboard
Keast Creek	Keast Dr. (local road)	2.1 (5-year event overtops)	10-year event (2.68 m^3/s) + 0.3m freeboard

It can be seen that the culverts at South Bay Road and Keast Drive are not able to convey the minimum flow requirements, even under backflow conditions. The culvert at Arlington Boulevard is able to convey the design flows, however the freeboard requirements are not met.

Figure 6.56: Culvert at South Bay Road

Figure 6.57: Culvert at Arlington Boulevard

Figure 6.58: Culvert at Keast Drive

6.2.4.3 Description of Preliminary Alternatives

A list of preliminary mitigation solutions was identified for each of the FRA. This assessment is intended as a coarse evaluation tool, with the intent of selecting the preferred methodology, as opposed to the specific type of treatment. For each of the FRA the following flood mitigation treatment methods were considered:

1. Do nothing
2. Structural flood damage reduction measures (e.g., widening culverts, and raising/widening bridges);
3. Preventative flood relief strategies / programs (e.g., storm water management or flood proofing);
4. Emergency flood protection strategies (e.g., berms, floodwalls or flood-relief channels); and
5. Channel modifications (e.g., widening, deepening or realignment)

As discussed in Section 6.1.7, there are several different solutions for each of the flood mitigation strategies outlined above, however there are land use constraints and feasibility constraints that are associated with each method. Furthermore, there are general pros and cons for each strategy, and in undertaking this evaluation the best type of treatment will be selected, and the freedom to select the specific flood mitigation technique (e.g., berms, floodwalls or flood-relief channels) can be made at the detailed design phase.

At FRA 1, structural flood damage reduction measures were determined not to be an appropriate flood mitigation strategy to evaluate, as there are no dams, weirs, bridges or culverts that are impacting the flooding at this location, and therefore was not included in the evaluation for FRA 1.

Alternative treatment options were defined for each of the flood mitigation categories, for each of the FRA. The structural mitigation measures considered within the preliminary alternatives included retrofits to culverts that were identified to be causing backwater issues, or were inundated frequently. Where possible, the preventative programs corresponded to potential SWM management facilities, described in Section 6.2.2. Where SWM facilities were not feasible, flood proofing was considered. General berm and floodwall locations were provided, which were intended to protect the majority of the buildings that are expected to be impacted by flooding. Recommendations for extents of channel widening and/or deepening were provided, but are approximated based on the limits of the FRA and anticipated hydraulic relationships. The true extents of the channel works would need to be assess and refined at the detailed design stage. A summary of the preliminary alternatives for each FRA is provided below in **Table 6.16**.

Table 6.16: Summary of preliminary alternatives for flood risk areas

Flood Mitigation Strategy		Preliminary Alternatives				
		FRA 1	FRA 2	FRA 3	FRA 4	FRA 5
		Frobisher Creek at Ramsey Lake	Frobisher Creek at Greenwood Dr.	Frobisher Creek between Railway and Bancroft Dr.	Roger Creek between 4th Ave. and Railway	Keast Creek
1	Do Nothing	NA	NA	NA	NA	NA
2	Structural Measures	NA	Widen Greenwood Dr. culvert. Minimum hydraulic conveyance target meeting CSG and MTO design standards	Increase the hydraulic conveyance from Mildred Street to downstream of the railway (and potentially Bancroft Dr. culvert) (i.e., widen sewer or add parallel pipe)	Widen 4th Ave. culvert. Minimum hydraulic conveyance target meeting CSG and MTO design standards	Widen South Bay Rd. and Keast Dr. culvert. (potentially Arlington Blvd also). Minimum hydraulic conveyance target meeting CSG and MTO design standards
3	Preventative Programs	Retrofit to Frobisher Pond to increase peak flow storage	Retrofit to Frobisher Pond to increase peak capacity storage	Provide flood proofing for all buildings within the Regional floodplain	Construct below ground stormwater management facility to decrease peak flows	Construct a stormwater management facility upstream of South Bay Road
4	Emergency Strategies	Berm/floodwall construction along the banks of Frobisher Creek	Berm/floodwall construction along the banks of Frobisher Creek upstream of Greenwood Dr.	Construct a berm along the limits of the Grace Tot Lot and Frobisher Creek at Mildred St. and Bancroft Dr.	Construct a berm along the banks of Roger Creek through the Finlandia Retirement Community	Construct berms/floodwalls along road embankments to prevent roads from overtopping.
5	Channel Modifications	Widening and/or deepen Frobisher Creek upstream of Ramsey Lake to increase hydraulic conveyance	Widening and/or deepen Frobisher Creek upstream and downstream of Greenwood Dr. to increase hydraulic conveyance	Widening and/or deepen Frobisher Creek from Bancroft Dr. to Mildred Str. To increase the hydraulic conveyance.	Widening and/or deepen Roger Creek through the Finlandia Retirement Community to increase the hydraulic conveyance.	Widening and/or deepen Keast Creek (potentially from South Bay Rd to Keast Dr) to increase the hydraulic conveyance

6.2.4.4 Evaluation Criteria and Scoring

In order to evaluate the alternatives identified in the previous sections, evaluation criteria have been developed in order to select the preferred solution. The evaluation criteria include natural environment, socio-cultural, technical and economic considerations. These criteria, together with a description of the criteria and measures for assigning scores are presented in **Table 6.17**.

For each of the comparative criteria, a rating ranging from 0 to 4 was applied specific to the particular solution being evaluated where 0 represents the worst condition and 4 the best, as identified in **Table 6.17**. Based on this approach, an overall rating based on the total scoring was obtained for each alternative solution.

Subsequently a ranking was assigned for each alternative solution with the highest overall total assigned 1 and the others sequentially 2, 3, etc. based on the scoring. Where the total ratings are the same, the same ranking was assigned.

Table 6.17: Evaluation criteria and measurement of scoring for potential flood mitigation strategies

Criteria	Description of Criteria	Measures for Assigning Scores
Natural Environment		
Potential Erosion Control Benefit	Potential to reduce erosional forces in receiving stream based on existing condition of stream and ability to provide required erosion control volume	Scores are assigned as follows:
		4 - high potential to reduce erosional forces
		2 - moderate potential to reduce erosional forces
		0 - limited to no potential to reduce erosional forces
Potential Aquatic Habitat Benefit	Potential to improve aquatic habitats or systems, including possible impacts on aquatic life, features and functions	Scores are assigned as follows:
		4 - significant improvement to aquatic habitat or systems
		2 - moderate improvement to aquatic habitat or systems
		0 - no impact to aquatic habitat or systems
Potential Hydrologic Flow Benefit	Ability to reduce the peak flow rate and total flow in the downstream receiving water system	Scores are assigned as follows:
		4 – significant potential to reduce the peak flow and total flow downstream
		2 – moderate potential to reduce the peak flow and total flow downstream
		0 – limited or no potential to reduce the peak flow and total flow downstream
Potential Terrestrial Habitat Benefit	Potential to improve terrestrial habitats based on the existing conditions of the terrestrial ecology	Scores are assigned as follows:
		4 - high potential to impact existing terrestrial habitat
		2 - moderate potential to impact existing terrestrial habitat
		0 - limited to no potential to impact existing terrestrial habitat
Socio-Cultural Impacts		
Impact to Aesthetics / Recreation	Potential for retrofit facility to be an asset to the community by integrating facility into activities such as walking, jogging, hiking	Scores are assigned as follows:
		4 - high potential to integrate facility into existing activities
		2 - moderate potential to integrate facility into existing activities
		0 - limited to no potential to integrate facility into existing activities
		Scores are assigned as follows:

Compatibility with Adjacent Land Uses	There are potential impacts associated with construction of facilities, particularly with respect to land uses such as residential, old age homes and schools. Access / egress also needs to be considered	4 - no impacts associated with construction and access / egress for operation / maintenance 2 - minor impacts associated with construction and access will be limited 0 - sensitive land uses are located adjacent to proposed facility and access / egress will be limited
Compatibility with Land Ownership	There are potential impacts associated with ownership of the land which could restrict access for construction and maintenance	Scores are assigned as follows: 4 - City owned lands or have easement 2 - most lands are owned by City, but some easements may be required 0 – lands are privately owned
Community Impact - Disruption to Community During Construction	Potential to impact the community in terms of access to the site, visibility, road access, construction of mitigation measure in valley lands / parks, possible noise / odour / light, short-term construction impact, etc.	Scores are assigned as follows: 4 – no impact on community 2 – moderate impact on community 0 – significant impact on community
Technical Impacts		
Potential to Reduce Flood Limits	Ability to reduce flood limits by lowering the water surface elevation during flood events.	Scores are assigned as follows: 4 - significant reduction in flood limits 2 - potential reduction to flood limits 0 - no change in flood limits
Potential to Reduce Flood Risk	Ability to remove buildings from flood limits and decrease the frequency of road inundation.	Scores are assigned as follows: 4 - significant reduction to flood risks 2 - potential reduction to flood risks 0 - no change in flooding risk
Feasibility of Control Measure	The extent to which the alternative is feasible in terms of available space and accessibility	Scores are assigned as follows: 4 – there are no space and access constraints 2 – there are some space and access constraints 0 – space and access constraints could restrict the implementation of the alternative
Constructability	Degree of difficulty in constructing the SWM alternative given the existing site conditions and constraints.	Scores are assigned as follows: 4 – technique is easily implementable 2 – there are some obstacles to overcome before implementing techniques 0 – there are many obstacles to overcome before implementing techniques
Economic Impacts		
Capital Costs	The relative estimated costs of implementing the proposed treatment based on factors such as location, access / egress and area to dispose material	Scores are assigned as follows: 4 - no capital costs 2 - moderate capital cost 0 - highest capital cost
Operation and Maintenance Costs	The relative cost of operating and maintaining the facility based on factors such as location, access / egress and availability of sediment drying area	Scores are assigned as follows: 4 - no operation and maintenance costs 2 - moderate operation and maintenance cost 0 - highest operation and maintenance cost
Impact to Property Values	Potential impacts (positive or negative) to local property value, based on aesthetic benefits, potential land-use synergies and general economic incentives.	Scores are assigned as follows: 4 - high potential benefit to property values 2 - moderate potential benefit to property values 0 - no potential benefit property values

A Weighting Factor was assigned to category of criteria, which ensured that each category was valued appropriately, regardless to the number of criteria within the category. For this evaluation, the weighting factors used for this evaluation are shown in **Table 6.18**. The highest weighted category was given to the technical impact, on the premise that if flood risk can not be technically mitigated, implementing the strategy will not solve the problem, regardless of the impacts in other categories (**Table 6.19**).

Table 6.18: Weight factors used for evaluation of potential flood mitigation strategies

Category	Weighting Factor	Maximum Points for Category
Natural Environment Impact	0.20	20
Socio-Cultural Impact	0.20	20
Technical Impact	0.40	40
Economic Impact	0.20	20
TOTAL	1	100

The detailed evaluation of each FRA is included in **Appendix H**, and a summary of the scores for each alternative is provided below, highlighting the preferred alternative.

Table 6.19: Summary of evaluation scores for potential flood mitigation strategies

FRA	Description	Alternatives Evaluated				
		1	2	3	4	5
		Do Nothing	Structural Measures	Preventative Programs	Emergency Strategies	Channel Modifications
1	Frobisher Creek at Ramsey Lake	53.33	NA	59.17	39.17	52.50
2	Frobisher Creek at Greenwood Dr.	53.33	59.17	54.17	36.67	52.50
3	Frobisher Creek between Railway and Bancroft Dr.	53.33	28.33	50.00	54.17	52.50
4	Roger Creek between 4th Ave. and Railway	53.33	59.17	30.83	31.67	47.50
5	Keast Creek	60.00	62.50	47.50	49.17	52.50

6.2.4.5 Preferred Alternative

Based on the evaluation, the preferred alternative for each potential FRA is summarized below: A short description and recommendations regarding the preferred alternatives for each flood risk area are provided below. Some preliminary analysis using HEC-RAS was undertaken to identify minimum culvert sizing requirements to meet CGS and MTO design standards, however more detailed analysis should be undertaken as part of the detailed design process. Furthermore, is it noted that any works within natural watercourses should consider implications to the riparian corridor and aquatic habitat. Opportunities to improve both the terrestrial and aquatic habitats, including fish passage, should be taken into consideration when designing flood mitigation solutions.

The constraints and opportunities of each FRA were considered, and flood mitigation treatment methods were considered.

FRA 1: Frobisher Creek at Ramsey Lake

There are limited structural flood mitigation strategies that can be implemented due to the proximity of the buildings to Frobisher Creek, and the immediate confluence with Ramey Lake. Therefore, preventative flood relief strategies were selected as the preferred alternative at this location.

For this evaluation, retrofits to the Frobisher Pond was evaluated as the alternative for the preventative flood relief strategy. Further studies will be required to ensure that retrofitting the pond can provide the flood relief necessary to remove the buildings from the floodplain. If the analysis of the Frobisher Pond determines flood relief is not feasible, then other preventative flood relief strategies will need to be considered. Some strategies that can be considered are flood proofing the houses within the floodplain or expropriation.

FRA 2: Frobisher Creek at Greenwood Drive

Structural measures, specifically widening the culvert at Greenwood Drive, was selected as the preferred alternative at this location. It was noted that this culvert is potentially undersized, and increasing the capacity should remove the buildings from the floodplain, and reduce the frequency of inundation of Greenwood Drive.

It is noted, that the alternative for the preventative flood relief strategies (i.e., retrofits to the

Frobisher Pond) received the second highest score. This alternative was selected as the preferred alternative for FRA 1. It is recommended that the further studies into retrofits for FRA 1, also look at potential benefits to FRA 2. If the analysis of the Frobisher Pond determines that there is not sufficient flood risk relief at FRA 2, then the City should also implement the preferred alternative of increasing the hydraulic capacity of the Greenwood Drive culvert.

The culvert capacity should be increased to meet the CGS and MTO design standards. Greenwood Drive is expected to be classified as a rural arterial road and the proposed design would likely have a span less than 6m, therefore the culvert should be designed to convey the 25-year flood event with 1m of freeboard. The culvert should be designed to convey the 25-year event, under proposed future conditions.

A hydraulic capacity analysis was undertaken using the existing conditions HEC-RAS model. It was determined that the 25-year flood could be conveyed with a 6m wide, 2.5m high concrete box culvert (with an open bottom). While this culvert will satisfy the CGS and MTO capacity requirements, it is not able to meet MTO's recommended freeboard allowance. However due to the backwater condition from Ramsey Lake, and the required deck height of the road, only a very large span bridge would be able to provide the freeboard allowance, which is financially prohibitive.

Please note that the proposed culvert is only able to remove one building from Regional flood limits. Due to the backwater effect from Ramsey Lake, the second building could not be removed from the flood limits, even with a large span bridge.

FRA 3: Frobisher Creek between Railway and Bancroft Drive

The preferred alternative for FRA 3 is to implement emergency strategies, specifically construction of berms along the limits of the Grace Tot Lot and Frobisher Creek at Mildred Street and Bancroft Drive. While emergency strategies are generally a last resort solution, as they are not helping to mitigate flooding, and only providing flood protection, other mitigation solutions proved to be feasibly restrictive. Widening the storm sewer at Mildred Street could potentially require easement negotiations, or even expropriation, of the residential buildings above the sewer. It would also require coordination with railway, as the sewer would need to pass under the railway. No potential SWM facilities were identified upstream of Bancroft Drive, therefore significantly reducing the peak flows during flood events is unlike. Flood proofing is a viable solution, this does not reduce the risk of flooding to the buildings, or the neighboring school yard. Finally, while channel modifications are expected to provide some flood relief, this alternative is expected to be more costly, and require more maintenance.

Further analysis of the flood levels will need to be undertaken to determine the exact locations and required height of the berm. During the detailed design, it is recommended that an earthen berm be considered, and opportunities for ecological enhancement of the berm and surrounding areas also be considered. Furthermore, the berm should be designed for the proposed future flood flow conditions.

FRA 4: Roger Creek between 4th Ave and Railway

Structural measures, specifically widening the culvert at 4th Avenue, was selected as the preferred alternative at this location. It was noted that this culvert is potentially undersized and increasing the capacity could remove the buildings within the Finlandia Retirement Community from the floodplain and reduce the frequency of inundation of 4th Avenue.

Furthermore, culverts within the Finlandia Retirement Community were noted to have significant debris blockages. It is recommended that these culverts also be cleaned out, to increase the conveyance through the community.

The culvert capacity should be increased to meet the CGS and MTO design standards. 4th Avenue is expected to be classified as a rural arterial road and the proposed design would likely have a span less than 6m, therefore the culvert should be designed to convey the 25-year flood event with 1m of freeboard. The culvert should be designed to convey the 25-year event, under proposed future conditions.

A hydraulic capacity analysis was undertaken using the existing conditions HEC-RAS model. It was determined that the 25-year flood could be conveyed with a 2m wide, 2m high concrete box culvert (with an open bottom). It is noted that this analysis also assumed that the blockages in the culverts upstream had been removed. While this culvert will satisfy the CGS and MTO capacity requirements, it is not able to meet MTO's recommended freeboard allowance. A significantly larger bridge would be required to meet the freeboard requirements, which is financially prohibitive.

Please note that the proposed culvert is only able to remove one building from Regional flood limits. The second building within the Finlandia Retirement Community is very close to the river, and only extreme reduction in water levels would help to remove this building from the flood limits. It is recommended that a flow diversion structure (e.g., berm or floodwall) be implemented to protect this building.

FRA 5: Keast Creek

Structural measures, specifically widening the South Bay Road and Keast Drive culverts, was selected as the preferred alternative at this location. It was noted that these culverts are potentially undersized and increasing the capacity would reduce the frequency of inundation of both roads.

The culvert capacity should be increased to meet the CGS and MTO design standards. South Bay Road is expected to be classified as a rural arterial road and Keast Drive is expected to be classified as a local road. The culverts are expected have spans less than 6m at both roads, therefore the culvert at South Bay Road should be designed to convey the 25-year flood event with 1m of freeboard and the culvert at Keast Drive should be designed to convey the 10-year flood with 0.3m of freeboard. The culvert should be designed to convey the floods under proposed future conditions.

A hydraulic capacity analysis was undertaken using the existing conditions HEC-RAS model. It was determined that the 25-year flood could be conveyed with a 2m wide, 1.25m high concrete box culvert (with an open bottom) at South Bay Road and the 10-year flood could be conveyed with a 2m wide, 1m high concrete box culvert (with an open bottom). While this culvert will satisfy the CGS and MTO capacity requirements, it is not able to meet MTO's recommended freeboard allowance, however approximately 0.2m of freeboard is provided at each crossing. As noted above, a significantly larger culvert or bridge would be required to meet the freeboard requirements, which is financially prohibitive.

Improvements to the Arlington Boulevard culvert are not necessary at this time, as there are no backwater issues being caused by the culvert, and the conveyance does meet the CGS standards. When the culvert has reached its end-of-life, it is recommended that is be replaced with a larger culvert, able to provide the recommended MTO standard freeboard clearance of 1m.

It is also recommended that the replacement of the Keast Drive culvert correspond with the erosion restoration works at erosion site ES-K-01, if financially feasible. By undertaking both works at the same time, there would be some cost savings with regards to construction and restoration.

7.0 Evaluation of Alternatives – Proposed Development Lands

7.1 General

The conversion of rural lands to urban development increases the percentage of precipitation that contributes to runoff and decreases the percentage that is conveyed to the natural hydrologic pathways of infiltration and evapotranspiration. Alterations to the hydrologic regime resulting from development typically result in:

- Channel enlargement and increased erosion;
- Increased frequency and severity of flooding;
- Impaired water quality;
- Degradation of habitat and associate biota;
- Decline in aesthetic value and recreation potential of surface water features; and
- Change in groundwater flow; volume and direction.

In order to mitigate the symptoms of urbanization, appropriate stormwater measures should be applied to all new development.

7.2 Relevant Policy, Regulations and Acts

There are several documents that can be used as resources for the development of stormwater policy, regulations and acts for new development areas within the Ramsey Lake subwatershed.

7.2.1 City of Greater Sudbury Stormwater Background Study

In 2006 the City of Greater Sudbury undertook a Stormwater Background Study to present background information, policy options and technical information to be considered during the process of creating a new Official Plan. The Study also recommended technical and procedural guidance for stormwater management planning and design. General policy options and recommendations for subwatersheds that were identified in the Study were:

- Subwatershed studies for priority areas (of which Ramsey Lake was a high priority) and the implementation of Subwatershed Plan recommendations;
- Implementing of water quantity and quality control;
- Defining quality control criteria for subwatershed studies;
- Identification of stormwater management retrofit opportunities;
- Implement stormwater management design criteria for new shoreline development; and
- Utilize the City's Engineering Design Manual and the Ministry of Environment's Stormwater Management Planning and Design Manual to determine appropriate stormwater management measures on a site-specific basis.

The 2006 Stormwater Background Study specifies that development sites in areas of the City where subwatershed-level studies have been conducted must satisfy draft plan approval in accordance with the recommendations of subwatershed-level studies via the approval of stormwater management reports.

The 2006 Stormwater Background Study specifies that development sites in areas of the City where subwatershed-level studies have not been completed must demonstrate via stormwater management report that:

a) The overall drainage plan for the site, indicating upstream drainage areas conveyed across the site and the ultimate outlet (major overland flow route) from the site to the municipal drainage system;
b) A plan of proposed on-site stormwater quantity control measures that will satisfy downstream constraints. Post-development peak flow rates from the site will be limited to pre-development peak flow rates, unless detailed analysis shows that such storage is not required;
c) A plan for erosion control;
d) A description of the measures proposed to control quality on-site; and
e) A general grading plan, illustrating conformance with the City's overall stormwater management objectives.

Stormwater targets for new development within the City of Greater Sudbury are identified in the

Stormwater Background Study. The stormwater targets as identified in the study are included below:

Quantity Control

"Increased peak flow rates due to new development must be controlled before being discharged to approved outlets. In general, post-development peak flow rates must not exceed pre-development peak flow rates, or if a subwatershed plan exists, the peak flow rates identified in the subwatershed plan. A stormwater management report must detail how the peak flow rates will be controlled to satisfy downstream constraints and the requirements of the subwatershed plan if one exists.

In the absence of specific recommendations regarding peak flow control, the minimum level of peak flow control shall be control of the post-development 2-year design storm peak flow rate to pre-development levels prior to discharge into the minor system (storm sewers), and control of the post-*development Regional or 100-year design storm peak flow rate (which ever is larger) to pre-development levels prior to discharge into the major system (surface drainage system)."*

Quality Control

"In addition to peak flow control, stormwater quality control must be provided. Stormwater quality control options shall be subject to a selection process. The rationale for the selection of the recommended alternative for a specific site must be provided.

In each case, on-site quality control shall be considered first as part of an integrated design.

As a minimum, the proponent shall consider the use of wet ponds, constructed wetlands, infiltration techniques, and batch dry detention facilities for end-of-pipe stormwater quality control

For smaller sites (less than 10 ha) where wet ponds are not feasible, stormwater quality *control may have to be addressed exclusively with on-site measures."*

On-Site Quality Control

"It is preferred that stormwater quality be addressed as close to the source of runoff as possible. On-site controls are much more flexible and may include infiltration, oil grit separators (for commercial or industrial sites with high imperviousness), buffer strips, enhanced swales, or bio-retention areas. A preliminary assessment of feasible alternatives to address stormwater quality on-site shall be performed and then reviewed with the City prior to finalizing design.

Infiltration of stormwater will be encouraged for every site where local conditions make infiltration feasible and desirable."

7.2.2 City of Greater Sudbury Official Plan

The City of Greater Sudbury is currently reviewing and revising its Official Plan (OP). The current OP was adopted by City Council in 2006 and approved, with modifications, by the Minister of Municipal Affairs and Housing (MMAH (now Ministry of Municipal Affairs (MMA)) in 2007. The OP takes a broad perspective on the watershed approach, recognizing that at least three types of watershed-based plans may be developed in various areas of the City, each with a different focus. The three types of watershed-based plans discussed in the OP are Source Water Protection Plans, Subwatershed Plans, and Watershed Studies for Lake-based Recreational and Habitat Issues.

Section 5.6 of the OP specifically relates to stormwater management. Along with describing the impacts of new development on stormwater management, this section identifies the objectives of stormwater management within the City and outlines site specific stormwater policies and policies for the development of subwatershed plans.

Policies for Subwatershed Plans

1. Priority for subwatershed plan development will be based on existing stormwater

problems, sensitivity of the receiving waterbody, and/or development pressure.

2. Subwatershed plans will be developed as funding permits in their order of priority (note: Ramsey is priority #2 of 17).

3. All subwatershed plans will incorporate the primary objective of no net increase in peak flow rates, unless a more stringent criterion has been identified. Subwatershed plans will also assess means of stormwater quality control to ensure the protection of urban subwatersheds and provide opportunities to improve the quality of receiving waterbodies.

4. Existing watercourse will be left in their natural state whenever possible. The banks must be able to convey either the Regional or the 1:100-year storm peak flow.

Site-specific Policies

1. For all new developments, an overland flow route must be clearly defined to provide continuous overland drainage of major system flows to the nearest major watercourse. The overland flow route (major system) shall be entirely contained within the road right-of-way or easements. Conveyance of the 1:100-year or Regional design storm peak flow is required.

2. Applications for industrial development in areas where there are no municipal stormwater services will require a Stormwater Management Report.

3. Applications for draft plan approval of subdivisions and site plan approvals in areas where a subwatershed plan has been completed will demonstrate, through a Stormwater Management Report, how the proposed development will provide stormwater management in accordance with the subwatershed plan.

4. Applications for draft plan approval of subdivisions in areas where a subwatershed plan has not been finalized will include a Stormwater Management Report containing site-specific details as required by the City.

5. A Stormwater Management Report shall contain the following:
    a. The overall drainage plan for the site, indicating upstream drainage areas conveyed across the site and the ultimate outlet (major overland flow route) from the site to the municipal drainage system;
    b. A plan of proposed on-site stormwater quantity control measures that will satisfy downstream capacity issues. Post-development peak flow rates from the site will be limited to pre-development peak flow rates, unless detailed analysis shows that such storage is not required;
    c. A plan for erosion control;
    d. A description of the measures proposed to control stormwater quality on-site. In particular, special measures must be proposed where a site is intended for industrial development; and,
    e. A general grading plan, illustrating conformance with the City's overall stormwater management objectives.

6. The City will identify opportunities where retrofits can be effectively utilized to remedy existing stormwater problems.
7. For areas where a subwatershed plan has not advanced in sufficient detail to define regional downstream stormwater management facilities or where a development will result in unacceptable peak flow increases downstream, onsite stormwater management (storage) facilities for peak flow control will be required.

8. For small sites where it is impractical to implement on-site stormwater management measures (due to size or local site conditions), Council may collect cash-in-lieu of on-site stormwater management facilities to apply toward any regional stormwater facilities required.

9. Developers are required to construct, maintain and monitor the operation of all on-site quality ponds at their expense for a minimum period of two years after completion of housing. On-site stormwater management facilities will be designed in a manner that is compatible with the surrounding environment. Where appropriate, such facilities should

be connected to recreational trails.

10. Maintenance will consist of annual monitoring of sediment accumulation in the pond forebay and quarterly inspections for trash removal as well as sediment removal and lawn mowing as required.

11. Stormwater management facilities for subdivisions will be on lands transferred at no cost to the City, in addition to any lands required to be dedicated for park purposes under the Planning Act.

7.2.3 MECP Stormwater Management Planning and Design Manual

The "state-of-the-art" in stormwater management has been evolving rapidly. The MECP's Stormwater Management Planning and Design Manual (SWMPDM) provides a more integrated approach, as compared to its predecessors. The SWMPDM incorporates water quantity and erosion considerations. The SWMPDM provides technical and procedural guidance for the planning, design, and review of stormwater management practices. The focus of the manual was broadened to incorporate the current multi-objective approach to stormwater facility planning to address targets related to hazards, water quality, fish habitat and recreation. Fundamental stormwater management objectives which are included in the 2003 SWMPDM include:

- Groundwater and baseflow characteristics are preserved;
- Water quality will be protected;
- Watercourse will not undergo undesirable and costly geomorphic change;
- There will not be any increase in flood damage potential; and ultimately
- That an appropriate diversity of aquatic life and opportunities for human uses will be maintained.

A central theme of the SWMPDM is the application of a "treatment train", a term that is used to describe the combination of controls – source, conveyance and end-of-pipe controls - usually required in an overall stormwater management strategy to ensure that objectives are achieved. The SWMPDM states that:

> *"the recommended strategy for stormwater management is to provide an integrated* ***treatment train approach*** *to water management that is premised on providing control at the lot level and in conveyance (to the extent feasible) followed by end-of-pipe controls. This combination of controls is the only means of* ***meeting the multiple criteria for water balance, water quality, erosion control and water quantity****."*

The SWMPDM remains the go-to reference material for end-of-pipe stormwater management criteria and design requirements for wet ponds, constructed wetlands, hybrid wet pond/wetland systems, dry ponds and centralized infiltration facilities.

7.2.4 MECP LID Stormwater Management Guidance Manual

Since the publication of the 2003 SWMPDM, advancements have been made in the approaches used to manage stormwater and the technologies available to the stormwater practitioner. It is now understood that to effectively mitigate the impacts from urbanization, stormwater strategies must include a means to reduce runoff volume with the objective of maintaining the pre-development water balance. To meet the multiple objectives of stormwater management on a broad-scale, it is expected that a combination of source, conveyance and end of pipe controls will be required within Ontario's stormwater systems. To encourage stormwater solutions that treat stormwater as a resource and provide a high level of stormwater quality control, the MECP is in the process of finalizing a LID Stormwater Management Guidance Manual. The draft manual outlines a Runoff Volume Control Target (RVCT) to be used for new development.

The Runoff Volume Control Target (RVC_T) corresponds to the runoff generate from the regionally specific 90th percentile rainfall event. As a result, new projects in the Ramsey Lake subwatershed will have a water quality target corresponding to the runoff volume generated from the local 90th percentile event (i.e. the runoff generated from a 28 mm event). The runoff generated from a 28 mm rainfall event should be controlled using a control hierarchy whereby retention via LID retention technologies which utilize the mechanisms of infiltration, evapotranspiration and or re-use are preferred. The control hierarchy is applied to take into consideration the reality that site conditions can limit the application of these preferred mechanisms, and allows for the implementation of capture and release, or other detention and release as needed. The control hierarchy is shown below in **Figure 7.1**.

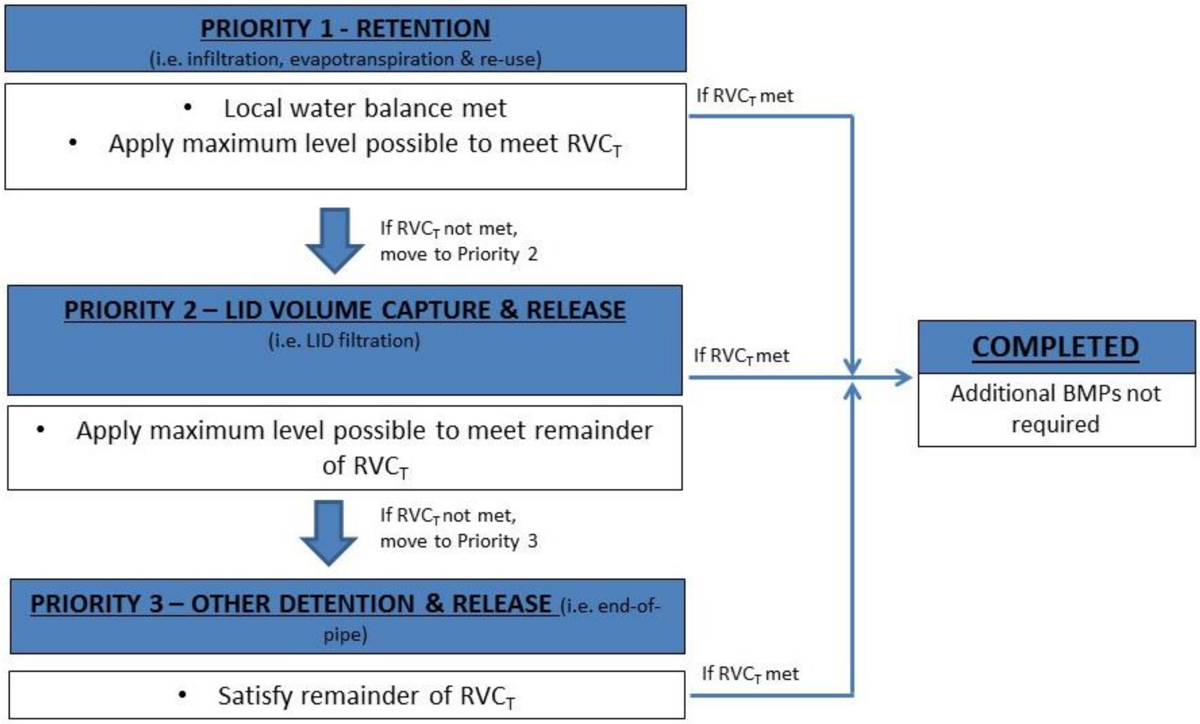


Figure 7.1: The runoff control hierarchy from the MECP LID Stormwater Management Guidance Manual

Following this approach new development areas within the Ramsey Lake subwatershed are recommended to follow the following water quality strategy:

1. The local water balance of the development area will be maintained at pre-development conditions by providing infiltration opportunities of source and/or conveyance control measures. Water balance modelling results which are summarized in **Appendix I** indicate that proposed development has little impact to infiltration due to the surface conditions in the watershed. Given the potential for project specific opportunities and constraints including depth to bedrock, varying native soils, and varying groundwater table depths, the water balance target will be developed during a site-level analysis for each new development area. As each new development area may vary significantly from areas of shallow bedrock to sand deposits in the Significant Groundwater Recharge Areas, it is not feasible to develop a watershed-based water balance target.

2. The remainder of the runoff volume generated form the 28 mm rainfall event will be treated

using capture and release LID filtration practices.

3. Where technical constraints prevent infiltration and filtration practices from treating the runoff generated from the 28 mm event, conventional end-of-pipe systems including oil and grit separators and stormwater management facilities will be implemented to provide the appropriate level of treatment (enhanced-level corresponding to a log-term TSS load reduction of 80%).

7.3 Proposed Development Lands

Within the Ramsey Lake subwatershed, there are several undeveloped areas that are at different stages of the land use planning process. **Figure 7.2** was created based on GIS data provided by the City and on discussions with planning and engineering staff. The evaluation of alternatives for proposed development lands focuses on development sites that are greater than five (5) ha in total area. Stormwater management for development sites that are smaller than five (5) ha will be addressed through site plan or draft plan of subdivision; however, a similar approach should be taken. On development sites that are smaller than five (5) ha, end-of-pipe alternatives may be limited due to the inability to support a stormwater management facility with a permanent pool.

Figure 7.2 shows the catchment areas within the Ramsey Lake Subwatershed delineated in yellow. These catchments are based on the existing pipe network in developed areas and topography in undeveloped areas. Where new development is proposed, the new development areas were added to existing catchments and split drainage of these areas was avoided. This hydrologic mapping and modelling framework have been used in the analysis of stormwater management for new development areas.

In total, there are 24 new development sites within the Ramsey Lake subwatershed that are greater than five (5) ha in total area. Based on City of Greater Sudbury stormwater policy as outlined in the Sudbury Stormwater Background Study, all of these sites are required to be provided with stormwater quality control per MECP stormwater management guidance materials.

In terms of water quantity control, the City's recommendations for new development areas are founded in the 2006 Stormwater Background Study. In the absence of specific recommendations regarding peak flow control, the minimum level of peak flow control shall be control of the post-development 1:2-year design storm peak flow rate to pre-development levels prior to discharge into the minor system (storm sewers), and control of the post-development Regional or 1:100-year design storm peak flow rate (which ever is larger) to pre-development levels prior to discharge into the major system (surface drainage system). It is however recommended that runoff generated from the 1:5-year storms is also controlled to pre-development peak flow rates. See **Section 9.2.13** for further discussion of peak flow requirements. The City has identified 24 new development areas (**Table 7.1**) where the peak flow restrictions will not be required due to direct discharge to Ramsey or Bethel Lake. These locations are shaded turquoise in **Figure 7.2**. For these direct discharge sites, outlet designs should mitigate erosion during discharge events resulting form extreme rainfall. **Figure 7.2** identifies all proposed new development areas within the Ramsey Lake Subwatershed.

Table 7.1. Proposed New Development Areas in the Ramsey Lake Subwatershed

Site #	Area (ha)	Development Type	Community	Regulation Type
SUD-0103	20.1	Living Area 1	Minnow Lake	Water Quality and 2-100 yr
SUD-0212	21.0	Living Area 1	Minnow Lake	Water Quality and 2-100 yr
SUD-1030	23.5	Living Area 1	Minnow Lake	Water Quality and 2-100 yr
SUD-0009	6.9	Living Area 1	Minnow Lake	Water Quality
SUD-0777	11.8	Living Area 1	South End	Water Quality
SUD-1068	16.4	Living Area 1	Sudbury	Water Quality and 2-100 yr
SUD-0096	27.2	Living Area 1	Minnow Lake	Water Quality and 2-100 yr
SUD-0284	67.4	General Industrial	New Sudbury	Water Quality and 2-100 yr
SUD-0980	20.9	Living Area 1	Minnow Lake	Water Quality and 2-100 yr
SUD-0153	6.0	Living Area 1	Minnow Lake	Water Quality and 2-100 yr
SUD-1034	5.2	Living Area 1	Minnow Lake	Water Quality and 2-100 yr
SUD-0079	58.2	General Industrial	New Sudbury	Water Quality and 2-100 yr
SUD-0127	16.2	Living Area 1	Minnow Lake	Water Quality and 2-100 yr
SUD-0755	19.4	Living Area 1	South End	Water Quality
SUD-0060	10.4	Living Area 1	Minnow Lake	Water Quality and 2-100 yr
SUD-0993	13.4	Parks & Open Space	Minnow Lake	Water Quality and 2-100 yr
SUD-0278	11.2	Living Area 1	Minnow Lake	Water Quality and 2-100 yr
SUD-0037	5.8	Living Area 1	Minnow Lake	Assumed Water Quality and 2-100 yr
SUD-0090	6.6	General Industrial	New Sudbury	Assumed Water Quality and 2-100 yr
SUD-0239	6.3	General Industrial	New Sudbury	Assumed Water Quality and 2-100 yr
SUD-0302	8.7	General Industrial	New Sudbury	Assumed Water Quality and 2-100 yr
SUD-0304	6.9	General Industrial	New Sudbury	Assumed Water Quality and 2-100 yr
SUD-0367	10.0	General Industrial	New Sudbury	Assumed Water Quality and 2-100 yr
SUD-1060	5.5	Living Area 1	Minnow Lake	Assumed Water Quality and 2-100 yr

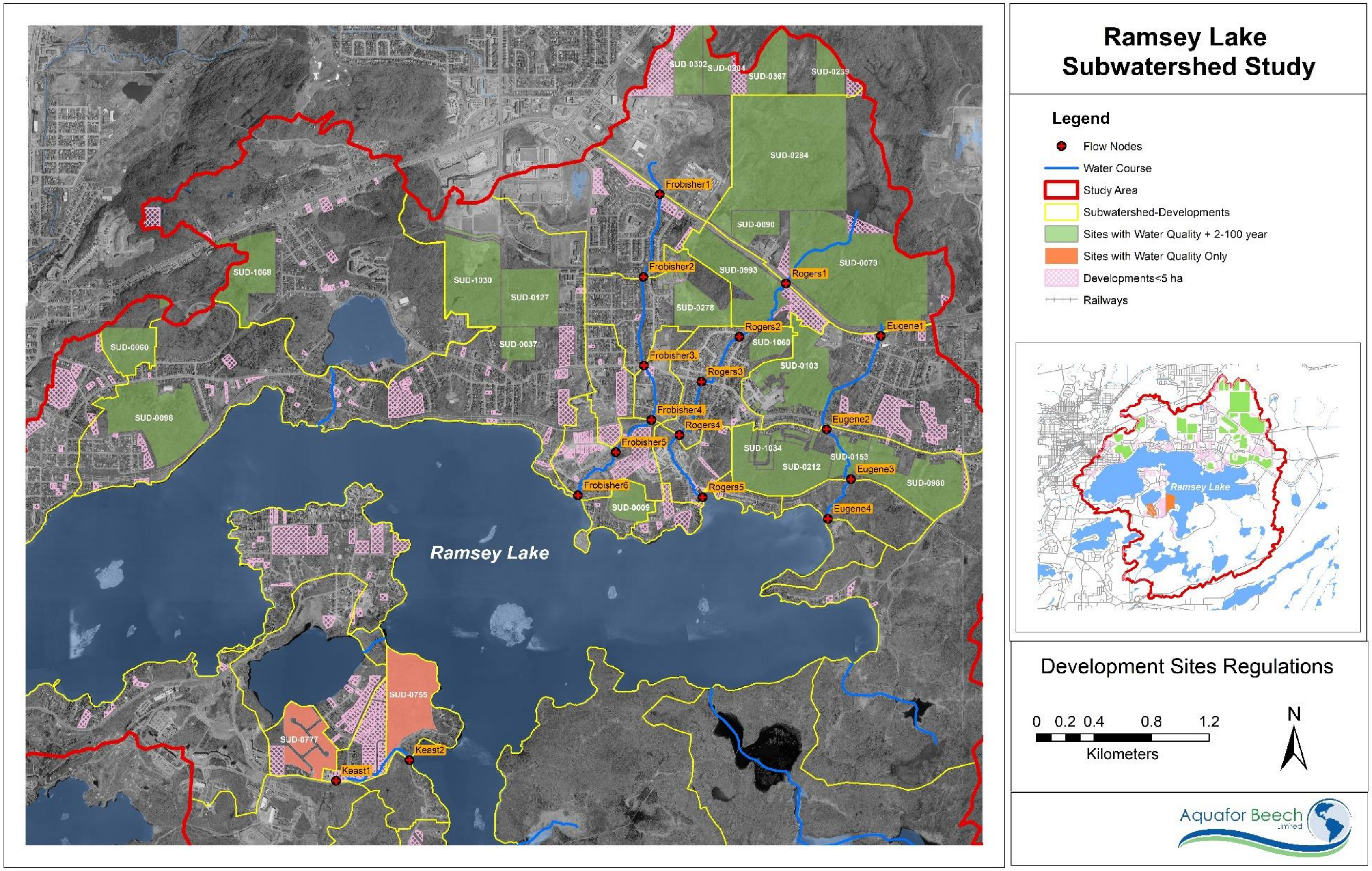


Figure 7.2. Development Areas in Ramsey Lake Watershed

7.4 Proposed Strategies

To meet the water quality and water quantity (including flood and erosion control) requirements two (2) stormwater management strategies are evaluated. This section describes the two strategies and compares their ability to mitigate the impact of new development on the Ramsey Lake subwatershed. The two (2) strategies are:

1. A "**traditional stormwater management**" approach relying primarily on end-of-pipe facilities for water quality and water quantity control.
2. A "**traditional stormwater management and LID approach**" relying primarily on source and conveyance controls to provide water quality control while relying on end-of-pipe facilities for flood mitigation requirements.

7.4.1 Traditional Stormwater Management

The traditional stormwater management approach involves establishing an end-of-pipe stormwater management facility (i.e. a wet pond or hybrid wetland-wet pond) within each new development area. For select new development areas, siting and preliminary design of the stormwater management facility has been undertaken by the developer and plans identifying the proposed stormwater management block are available. It is most technically and economically feasible to site stormwater management facilities at site locations that are conducive to gravity drainage without excessive land grading. Stormwater management typically discharge to natural drainage features (creeks, rivers, wetlands and lakes) or engineered conveyance structures such as ditches, swales, channels or pipes.

Wet ponds and or hybrid wetland-wet ponds use active storage detention and elongated flow paths through the facility to settle suspended sediments and associated pollutants. Both facility types require a forebay for pre-treatment and easier maintenance. While both facilities can be designed to meet MECP's enhanced level of water quality treatment corresponding to a long-term sediment removal efficiency of 80%, the wetland component of a hybrid design provides enhanced biological removal during the summer months. Individual design guidance for wet ponds and wetland-wet pond hybrids can be found in the 2003 MECP Stormwater Management Planning and Design Manual. Sizing requirements from the manual are summarized in **Table 7.2**.

Table 7.2: Water Quality Storage Requirements for Enhanced Level Protection

End-of-Pipe Facility Type	Storage Volume (m^3/ha) for Impervious Level [1, 2]			
	35%	**55%**	**70%**	**85%**
Hybrid Wet Pond/Wetland	110	150	175	195
Wet Pond	140	190	225	250

[1]*Of the specified storage volume for wet facilities, 40 m³/ha is extended detention, while the remainder represents the permanent pool.*

[2]*Hybrid Wet Pond/Wetland systems have 50-60% of their permanent pool volume in deeper portions of the facility (e.g., forebay, wet pond).*

7.4.2 Traditional Stormwater Management and LID Approach

The traditional stormwater management and LID approach uses both end-of-pipe facilities and LID stormwater management practices in the form of source and conveyance controls, including:

- Bioretention;
- Bioswales;
- Perforated pipe / Exfiltration trenches;
- Permeable Pavement;
- Soakaway Pits; and
- Infiltration Chamber.

The LIDs are incorporated into new development areas to provide water quality control via runoff volume reductions and filtration. Where these LIDs can treat the runoff generated from the 90th percentile event (see Section 7.2.4), the end of pipe facilities can be designed to provide water quantity control only. For these catchment scenarios, a dry stormwater management pond and/or multi-use flood storage facility may be feasible. Hydrologic modelling undertaken at the development stage may take runoff volume reductions achieved via LIDs into account when designing for quantity control.

In new development areas where LIDs can treat only a portion of the catchment, the end-of-pipe facilities will need to provide a volume of water quality storage. In this situation, the water quality volume can be reduced by subtracting the drainage area fully treated by LIDs before calculating the required water quality volume via **Table 7.2**.

8.0 Impact Assessment – Ramsey Lake

8.1 Existing Lands

The PCSWMM model setup under existing condition is illustrated in **Figure 8.1**. The Ramsey Lake hydrologic model was applied to estimate flow rates at key locations throughout the four three across the project area.

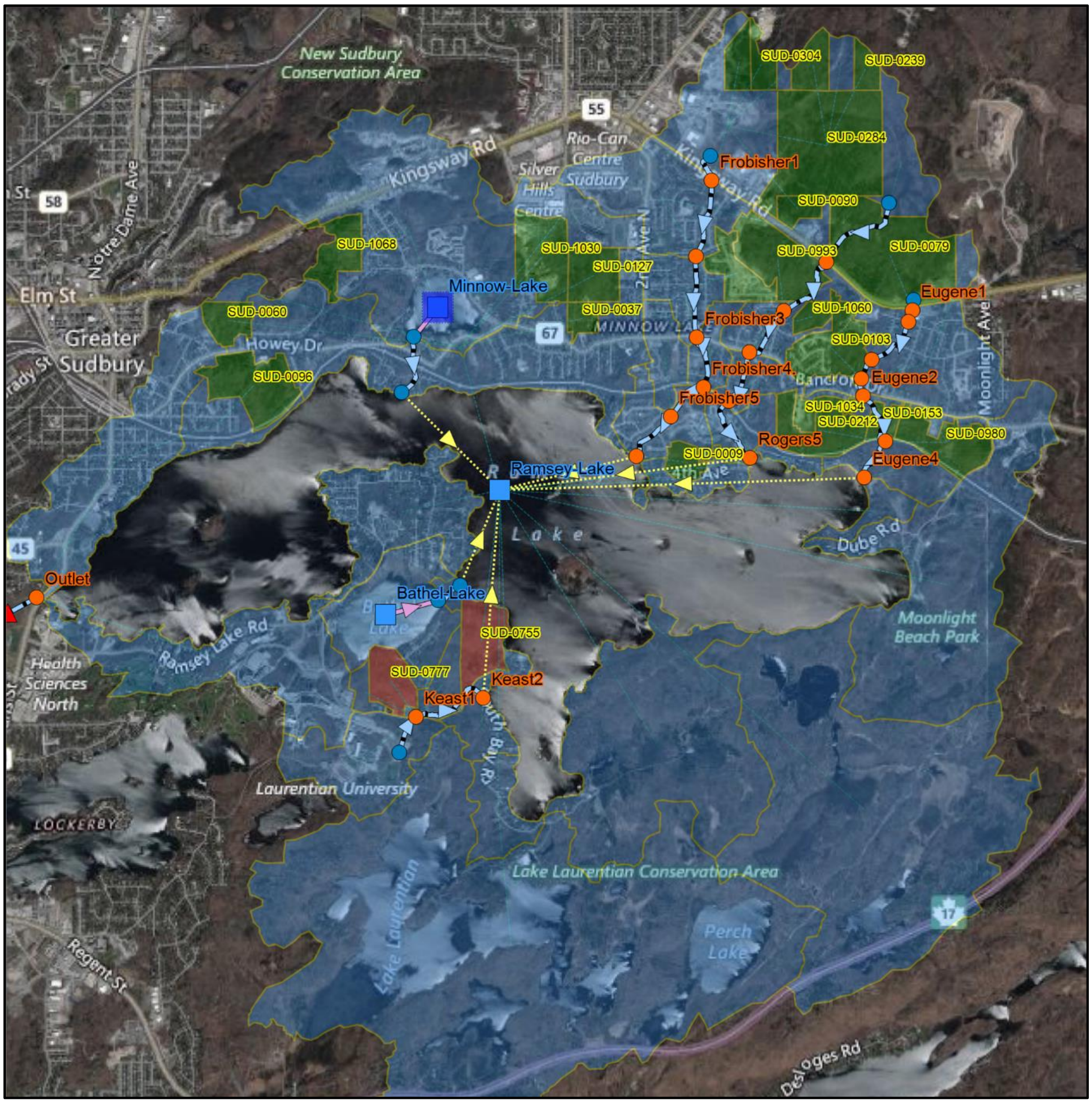


Figure 8.1: PCSWMM model setup

The resulting flow estimates at key locations in the study area for the 100-year return periods for the Design Storm (24-hour SCS), are summarized in **Table 8.1**.

Table 8.1: Summary of Estimated Flood flows (m^3/s) at key locations

Flow Node	Peak Flow Rate (m^3/s)
	Existing Conditions
Frobisher1	4.44
Frobisher2	15.33
Frobisher3	19.37
Frobisher4	22.28
Frobisher5	26.16
Frobisher6	32.13
Rogers1	0.75
Rogers2	2.05
Rogers3	4.04
Rogers4	5.10
Rogers5	6.20
Eugene1	2.25
Eugene2	9.69
Eugene3	12.39
Eugene4	12.74

8.2 Proposed Development Lands

8.2.1 Impacts of Development on Annual Water Balance

The annual water budget for existing conditions and future conditions was assessed on an annual basis using a continuous hydrologic model based on the U.S. Geological Survey (USGS) Precipitation-Runoff Modelling System (PRMS). PRMS is an open-source code for calculating all components of the hydrologic cycle at the watershed, subwatershed, or cell-based scale. PRMS is a modular, deterministic, physically-based, fully-distributed model developed to evaluate the impacts of various combinations of precipitation, climate, topography, soil type, and land use on streamflow and groundwater recharge. This methodology used is further discussed in Appendix I. The objective of this task is to estimate the various components of the water budget so as to protect and preserve both water quantity and water quality in the watershed. Using the PRMS model, the impact of proposed development on the annual water budget was determined by modifying land cover and hydrologic parameters associated with land development.

The model was re-run to assess the changes in the water budget. Both the current and future conditions water budget is summarized in **Table 8.2.**

Table 8.2: Current and Future Land Use Water Budget for Lakes

Lake Water Balance	Current	Percent	Future	Percent	Difference	Percent	Outflow	Percent
Inflows	(m3/sec)	of inflow	(m3/sec)	of inflow	(m3/sec)	Difference	(m3/day)	of outflow
Precipitation (directly into the lakes)	0.29976	34.88%	0.29976	34.85%	0.000000	0.032%		
Hortonian runoff to lakes	0.04943	5.75%	0.04944	5.75%	-0.000008	0.004%		
Lake Inflow from the Soil Zone	0.12873	14.98%	0.12877	14.97%	-0.000047	0.008%		
Groundwater Recharge	0.12759	14.85%	0.12713	14.78%	0.000456	0.066%		
Runoff to Streams	0.23296	27.11%	0.23419	27.23%	-0.001232	-0.119%		
Interflow to Streams	0.02082	2.42%	0.02077	2.41%	0.000050	0.008%		
Outflows:								
Actual ET							-0.1277	14%
Lake Outflows (from PCSWMM Model)							-0.8017	86%
Totals	0.8593	100%	0.8601	100%	-0.000781		-0.9294	100%
						Difference	-0.0701	
					Percent Difference		7.54%	

Overall, the change in the lake inflow water budget under future land use conditions is small. The largest change in the lake water budget is in the runoff to streams, which increases by 0.119 percent under future conditions.

While the change in the water budget is small, the local effects of the land development are more visible at select locations in the distributed model. In general, land development increases runoff, as illustrated in **Figure 8.2** , and a significant portion of the watershed area northeast of Highway 17 will change to "General Industrial" (**Figure 8.3**). Portions of this area include lowland/wetland areas that may or may not be infilled or preserved during re-development. Further, the proposed Kingsway development, including a new arena, hotel and casino, is planned to cover a portion of the Significant Groundwater Recharge Area (SGRA) zone located at the headwaters of Eugene Creek (**Figure 8.4**).

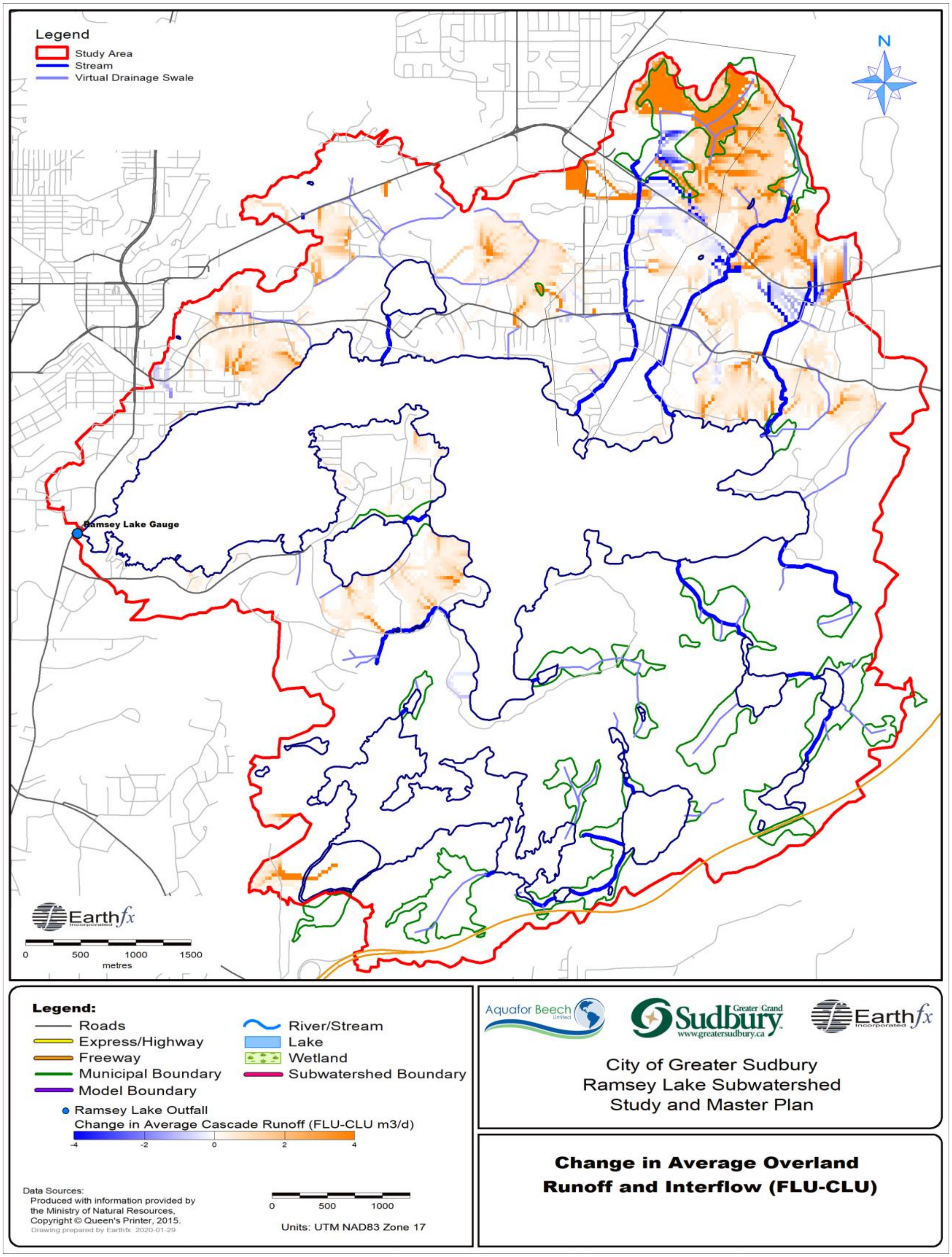


Figure 8.2: Change in overland runoff (Future land use - Current land use)

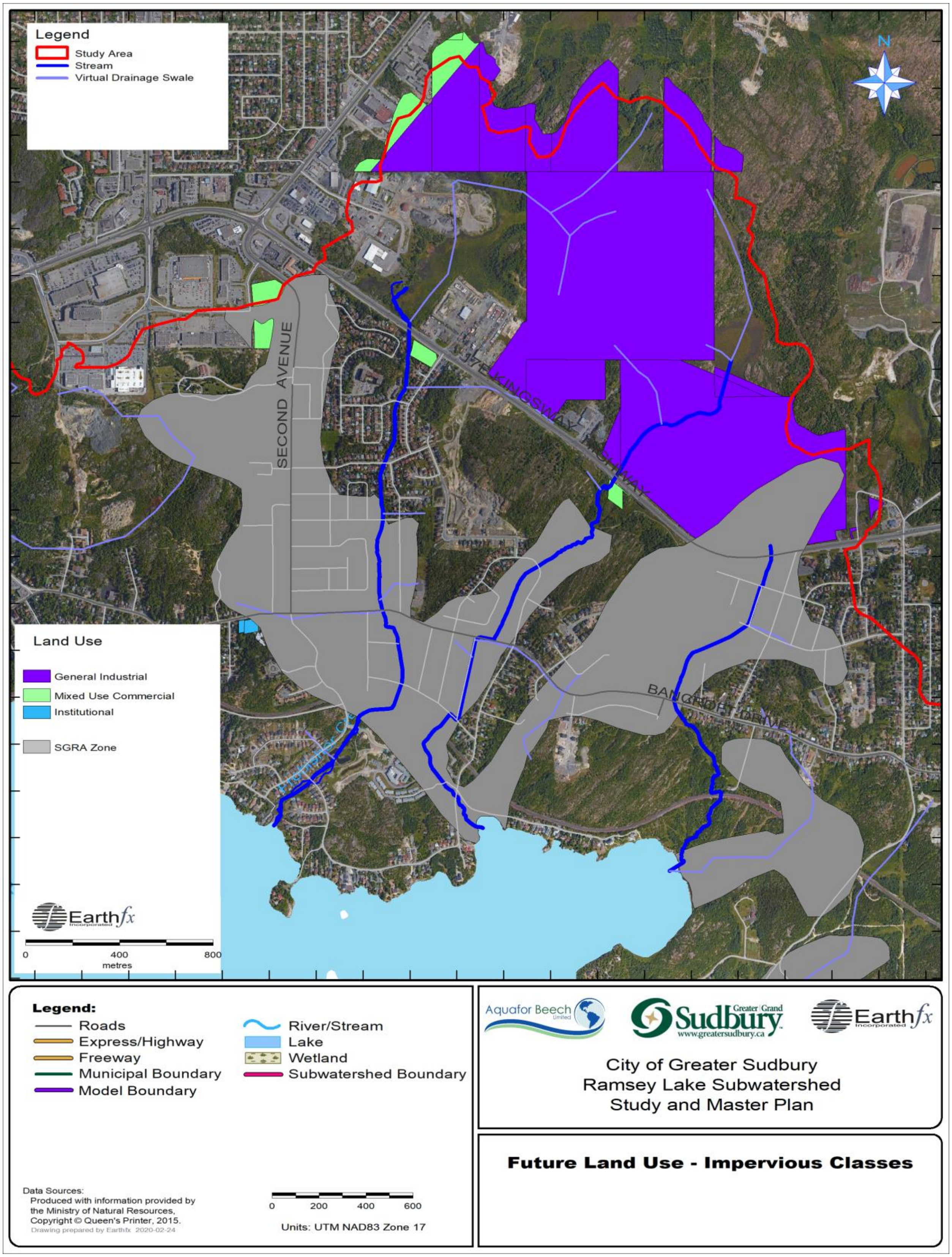


Figure 8.3: Future land use classes with high imperviousness (purple zones)

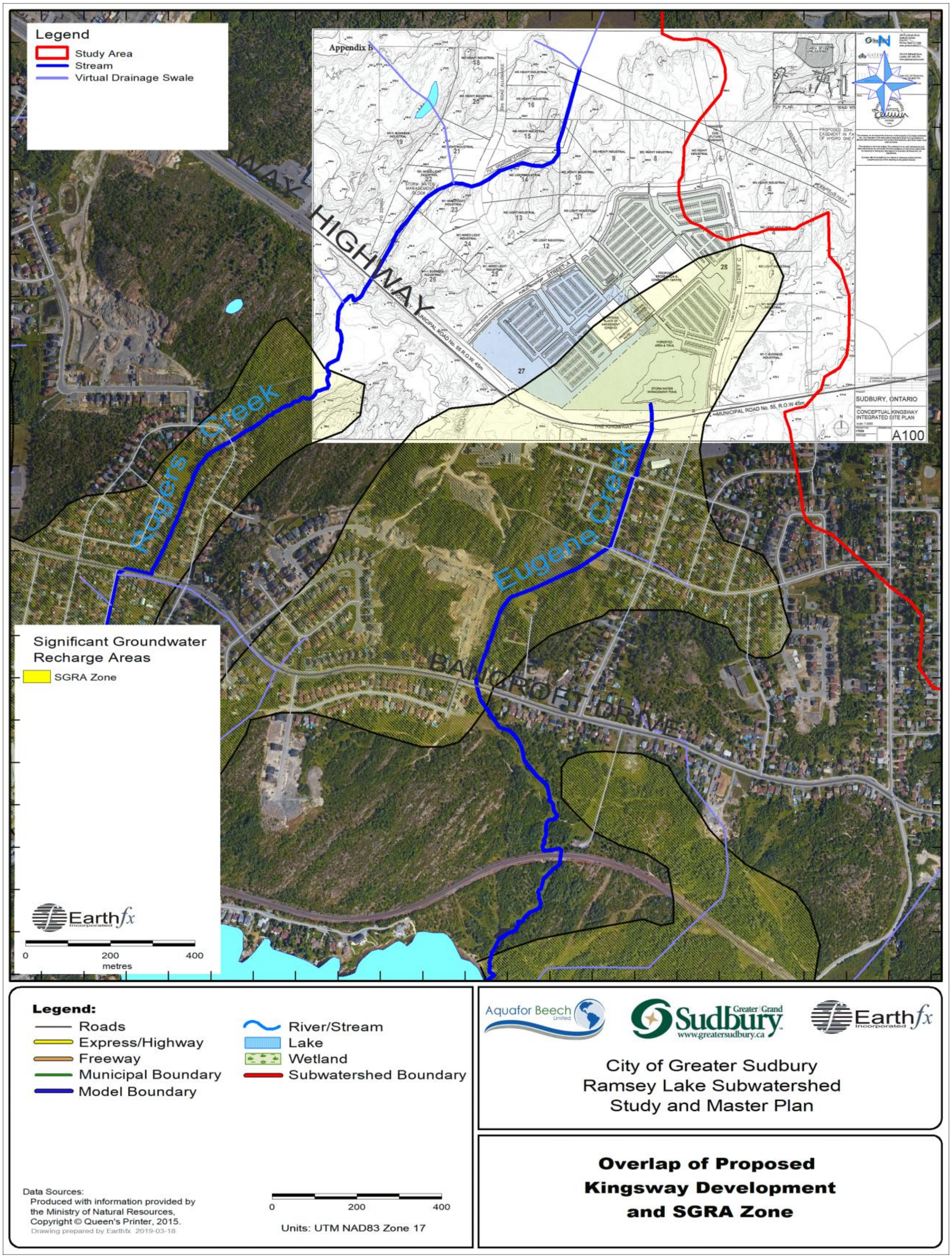


Figure 8.4: Overlap of proposed Kingsway development and SGRA Zone

To evaluate the effects of future land development on the SGRA zones in the north east portion of the watershed a number of figures have been prepared to illustrate the current and future conditions. Note that the specific development plans are not represented in the model, only the general change in land use. **Figure 8.5** shows the current runoff patterns in the area, while **Figure 8.6** shows runoff under the future conditions. The change in runoff is shown in **Figure 8.7**.

While the exposed bedrock in this area has a naturally high runoff potential, two aspects of the change to "general industrial" are of note:

1. Significant change in runoff and recharge is predicted to occur in and around the wetlands north of Frobisher Creek. Air photos indicate that there is already infilling of wetlands at the east end of Frobisher Street and at the south end of Westbourne Street. Further infilling of wetlands, as indicated by the land use change, will increase runoff **(Figure 8.7**) and reduce groundwater infiltration (**Figure 8.8**). Recommendations for wetland protection and enhancement can be found in **Sections 6.1.5** and **9.3.6.**

2. The change in land use in and around the SGRA zone near the headwaters of Eugene Creek will produce complex changes to the water budget. The proposed land development in the upland areas around the Eugene SGRA zone will increase runoff (**Figure 8.7**) due to both an increase in imperviousness and a reduction in ET. A portion of this will move downslope and be available to infiltrate within the SGRA zone. Land development within the SGRA zone will, to a degree, limit this new recharge and generate additional runoff. With more water entering the SGRA zone, the net change will be both an increase in recharge and an increase in runoff (as indicated in the Eugene Creek SGRA zone (**Figure 8.8**). The ecological impact of this additional runoff entering the SGRA zone will depend on whether the runoff water quality includes de-icing salt.

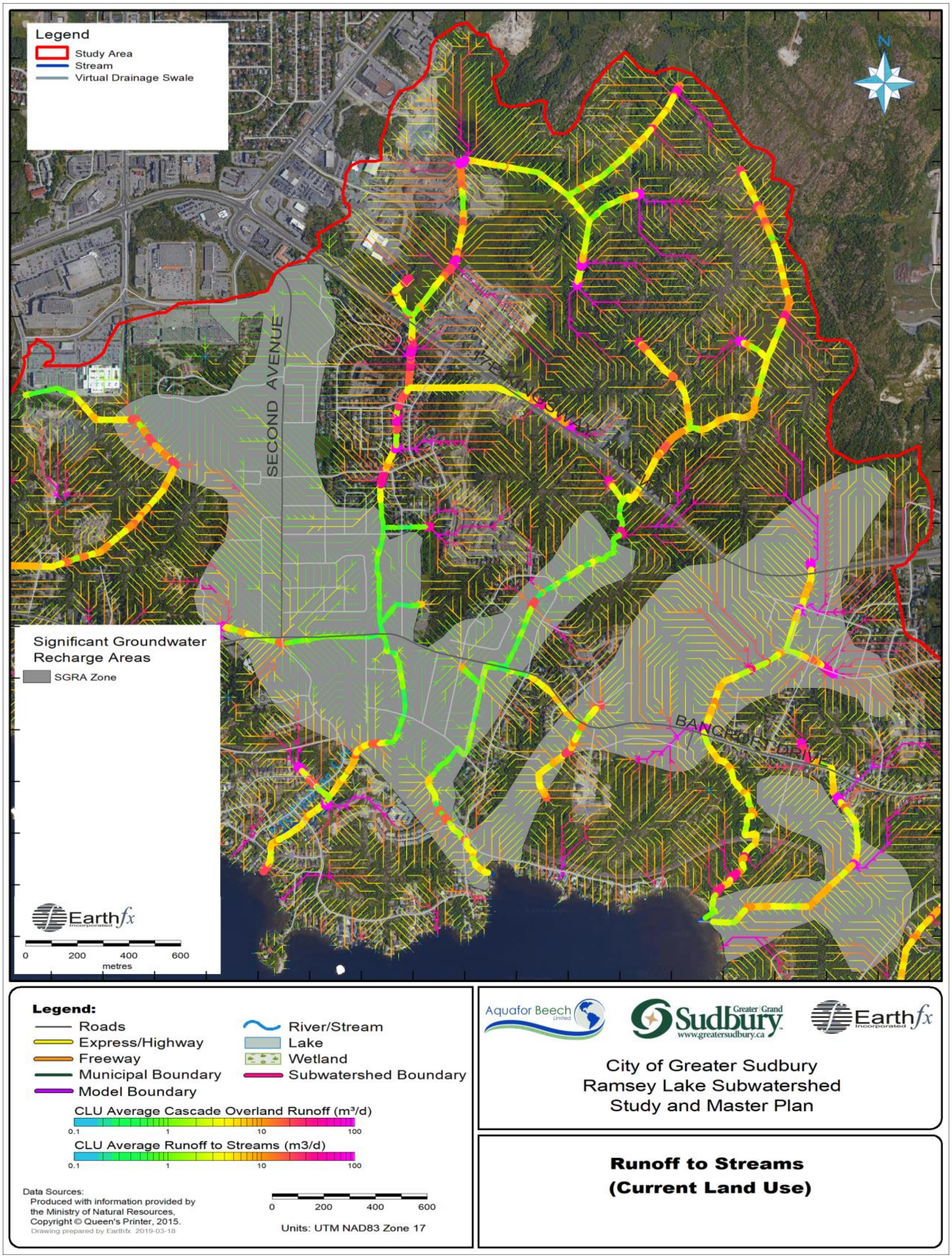


Figure 8.5: Runoff to streams - current land use

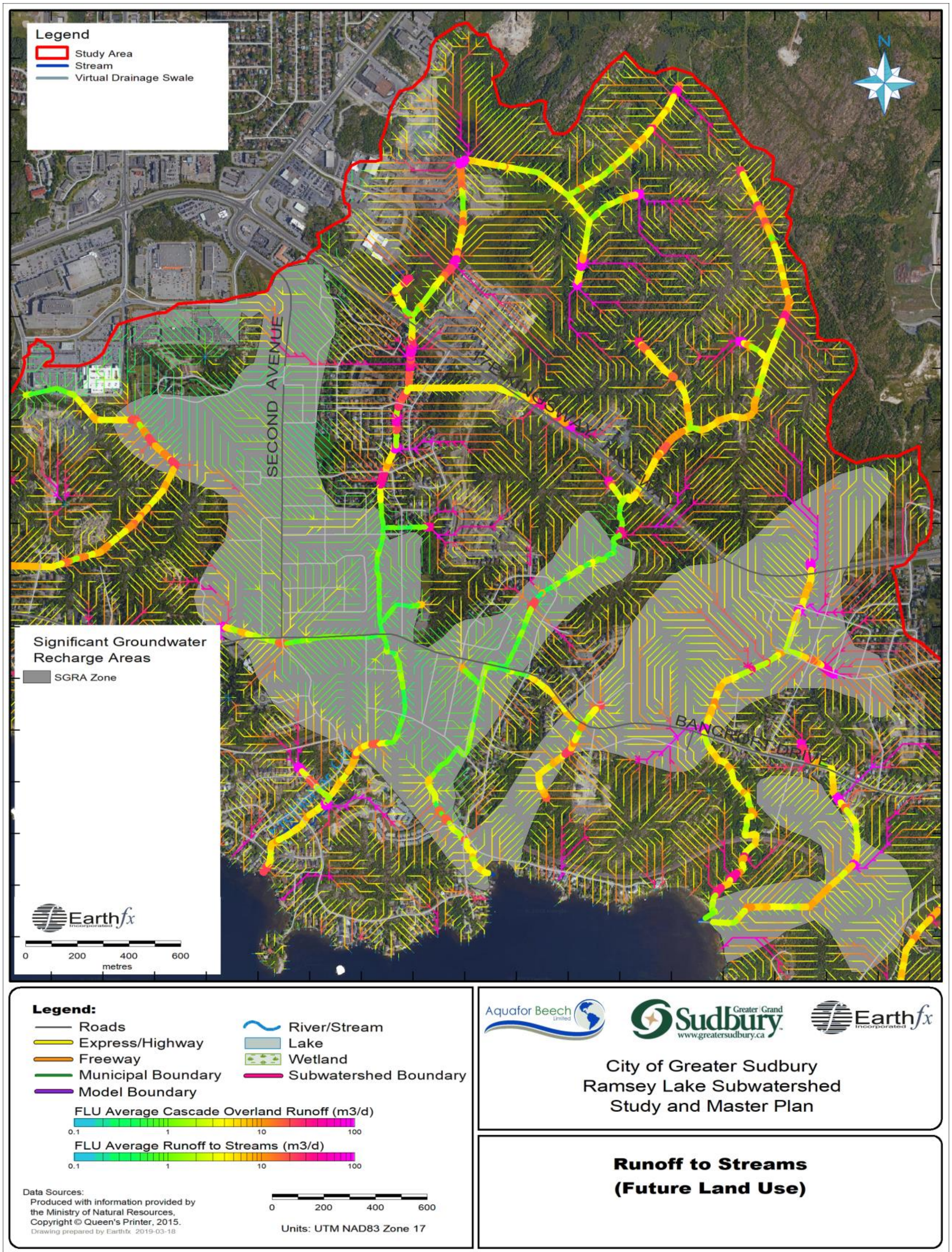


Figure 8.6: Runoff to streams - future land use

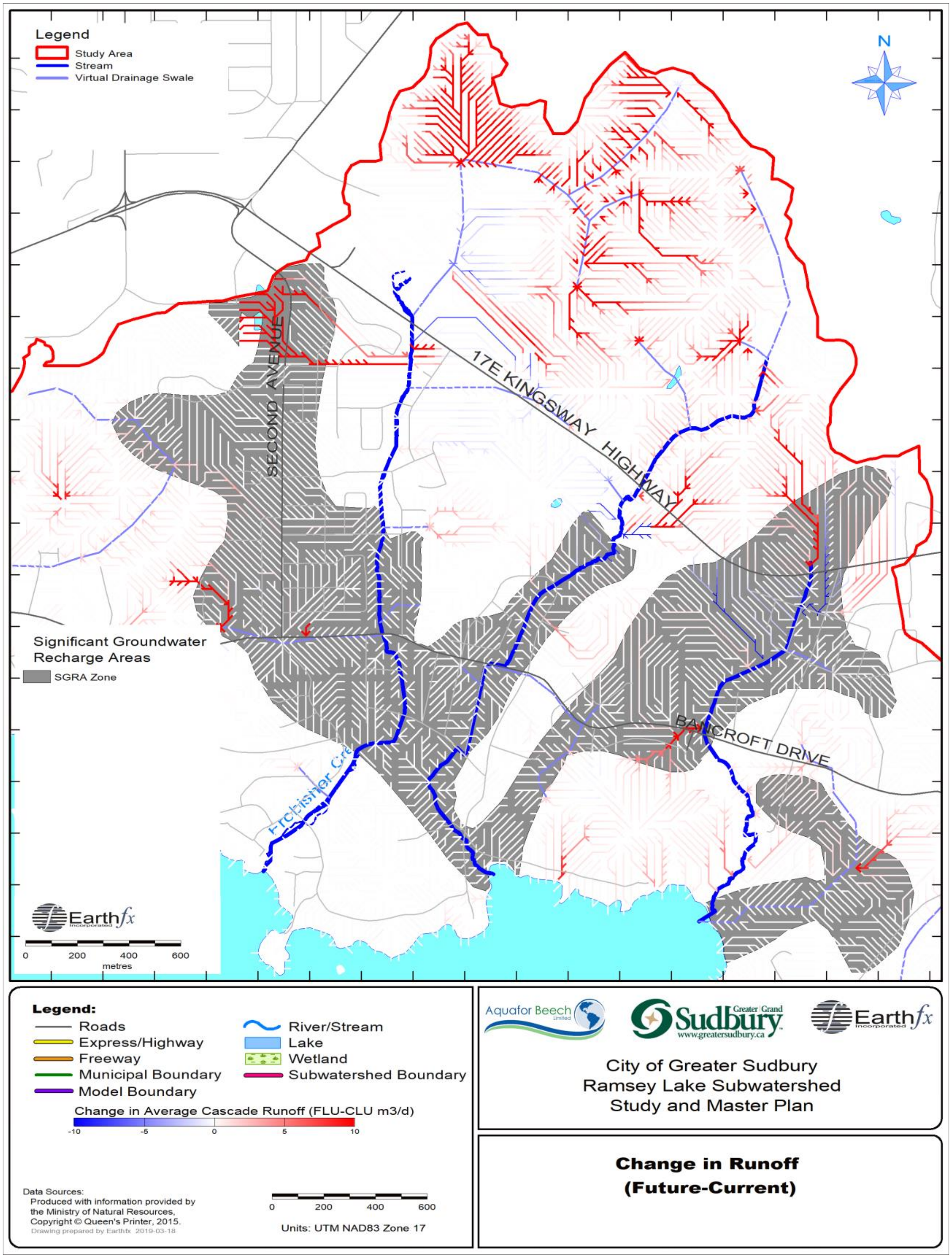


Figure 8.7: Change in runoff to streams (Future increase in runoff shown in red)

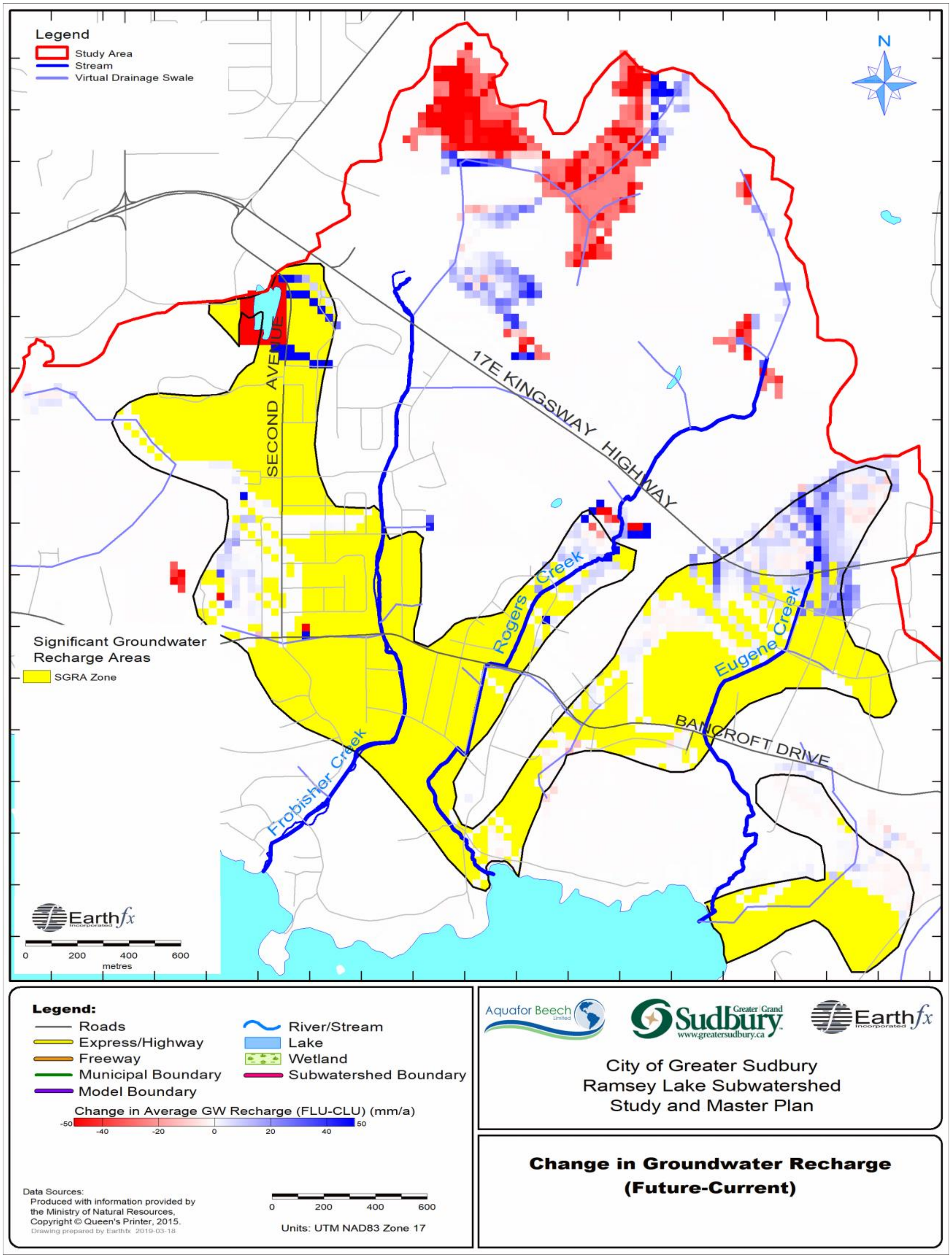


Figure 8.8: Change in groundwater recharge (Future reductions shown in red)

The analysis of the Ramsey Lake watershed indicates that there will not, on a watershed basis, be any major changes in the overall water budget under the future land use conditions. The northeast portion of the watershed, including the Frobisher, Rogers and Eugene Creeks and the surrounding SGRA zones, may, however, exhibit measurable impact under future land use in the Kingsway development area. Therefore, a site-specific water balance target should be developed for these new developments as described in **Section 7.2.4** and **9.3.1.2.** Land development in the upland areas around the wetlands and SGRA zones will likely increase runoff (due to both an increase in imperviousness and a reduction in ET), and depending on how the lowland wetlands and SGRA zones are managed and modified, groundwater recharge and headwater flows may be adversely affected. The enhanced runoff from the upland areas may locally increase downslope groundwater recharge, and the water quality of the runoff may be detrimental to the ecology of the headwaters if the runoff contains de-icing salt.

8.2.2 Traditional Stormwater Management- Modelling and Results

A subwatershed-level modelling exercise was conducted to determine the impact of end-of-pipe stormwater management facilities on flow rates at specific nodes in the subwatershed. PCSWMM is hydrologic and hydraulic modelling package using the EPA's SWMM5 engine that was developed by Computational Hydraulics International for comprehensive analysis of urban and rural water resources systems. This model was used for analysis of the Ramsey Lake Subwatershed because of its GIS integration and advanced LID modelling tools. **Figure 8.9** identifies catchment areas, new development areas, flow nodes and ponds within the subwatershed.

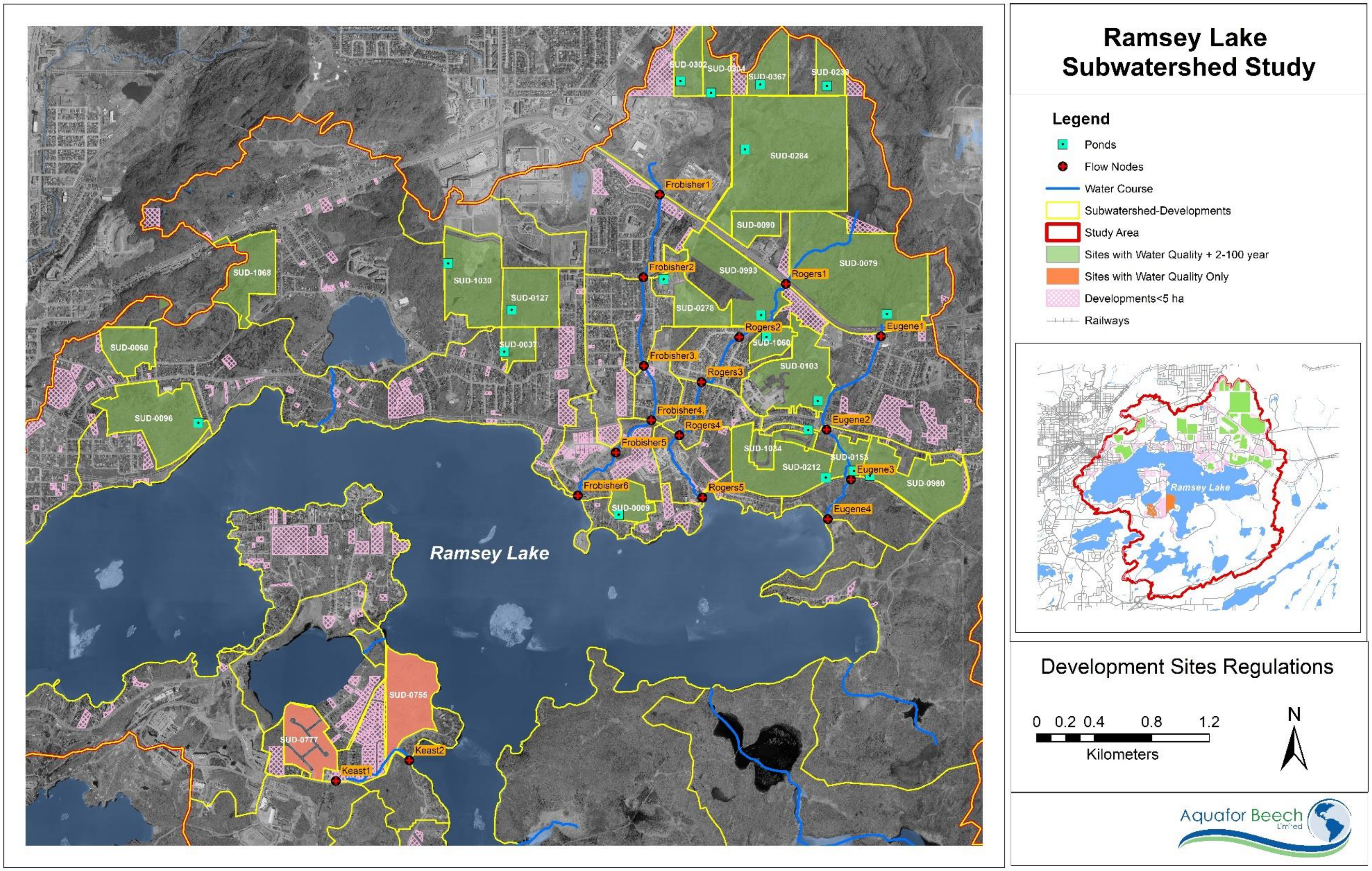


Figure 8.9: Development Lands and Proposed SWM Facilities

Ponds for each new development area were incorporated into the hydrologic model using the following approach.

- A stormwater management facility was allocated to each of the new development areas larger than five (5) ha
- Post-development impervious percentages were assumed based on proposed development type, discussions with city staff regarding development intensity.
- Water quality storage requirements were calculated using impervious percentages, development areas (ha) and required storage volume rates (m^3/ha) from **Table 7.4**.
- An orifice equation was used to model the required 24-hour (minimum) detention time of the water quality volume
- For new development areas requiring quantity control, post-development peak flow rates for the 1:2-year precipitation event, corresponding to 16.5 mm over 24 hours, were reduced to pre-development peak flow rates via an additional orifice and extended detention
- For new development areas requiring quantity control, post-development peak flow rates for the 1:100-year precipitation event, corresponding to 123.5 mm over 24 hours, were reduced to pre-development peak flow rates via an outlet weir and extended detention

Flow summaries at nodes within Frobisher Creek, Rogers Creek and Eugene Creek are summarized in **Table 8.3** Despite the required peak flow controls on individual new development sites, the cumulative effects of elongated hydrographs and variations to peak flow timing results in increased peak flow rates during the 1:2 year and 1:100-year precipitation events in some creek systems.

Table 8.3: Peak Flow Rates Under Existing, Future, and Future conditions with SWM Facilities

Flow Node	Peak Flow Rate (m^3/s)			% Increase in Peak Flow Rates from Existing to Future Conditions with SWM Facilities
	Existing Conditions	Future Conditions	Future Conditions with SWM Facilities	
Frobisher1	4.44	14.51	5.84	31.60
Frobisher2	15.33	23.29	17.38	13.38
Frobisher3	19.37	28.06	20.56	6.16
Frobisher4	22.28	30.55	23.34	4.78
Frobisher5	26.16	33.82	26.99	3.19
Frobisher6	32.13	39.58	31.86	-0.85
Rogers1	0.75	0.75	0.52	-30.88
Rogers2	2.05	3.30	0.25	-87.71
Rogers3	4.04	5.46	2.31	-42.88
Rogers4	5.10	6.41	3.76	-26.30
Rogers5	6.20	7.32	5.18	-16.48
Eugene1	2.25	16.54	1.58	-29.54
Eugene2	9.69	16.95	8.66	-10.58
Eugene3	12.39	27.35	11.15	-10.03
Eugene4	12.74	28.36	11.68	-8.32

8.2.3 Traditional Stormwater Management and LIDs- Modelling and Results

A subwatershed-level modelling exercise was conducted to determine the impact of Low Impact Developments on flow rates at specific nodes in the subwatershed.

The approach used to model LID measures is outlined below:

The PCSWMM model was used. Generally, there are two (2) approaches for placing LID controls within subcatchments: i) place the LID control in an existing subcatchment that will displace replace an equal amount of non-LID area from the subcatchment, ii) create a new subcatchment devoted entirely to just a single LID practice. The first approach which is a simplified approach, consistent with the requirements of the subwatershed study process was used (**Table 8.4**).

Table 8.4: LID key parameters

Parameters	Value in the Model	Default	Unit	Description
Berm height	100	N/A	mm	Maximum depth to which water can pond within the unit before overflow occurs (in inches or mm).
Vegetation volume (fraction)	0.0	N/A	-	The fraction of the volume within the storage depth filled with vegetation. Assuming perforated pipes are in the road way.
Surface roughness	0.3	0.1	-	Manning's n for overland flow over the surface.
Surface slope (%)	0.25	1.0	(%)	Slope
Thickness of Storage	450	N/A	(mm)	Thickness of the storage
Void Ratio of Storage	0.65	0.75	-	The volume of void space relative to the volume of solids. Typical values range from 0.5 to 0.75.
Seepage Rate	Varies (1.5-25)	0.5	(mm/hr)	The maximum allowable rate at which water infiltrates into the native soil below the layer (in inches/hour or mm/hour). This would typically be the Saturated Hydraulic Conductivity of the surrounding area.

This approach was used for all proposed development lands. Flow summaries at nodes within

Frobisher Creek, Rogers Creek and Eugene Creek are summarized in **Table 8.5**.

Table 8.5: Peak Flow Rates Under Existing, Future, and Future conditions with LIDs

Flow Node	Peak Flow Rate (m^3/s)			% Increase in Peak Flow Rates from Existing to Future Conditions with LIDs
	Existing Conditions	Future Conditions	Future Conditions with LIDs	
Frobisher1	4.44	14.51	12.61	184.01
Frobisher2	15.33	23.29	21.98	43.38
Frobisher3	19.37	28.06	26.40	36.29
Frobisher4	22.28	30.55	29.04	30.34
Frobisher5	26.16	33.82	32.43	23.97
Frobisher6	32.13	39.58	38.20	18.89
Rogers1	0.75	0.75	0.75	0.00
Rogers2	2.05	3.30	2.87	40.00
Rogers3	4.04	5.46	5.00	23.76
Rogers4	5.10	6.41	6.02	18.04
Rogers5	6.20	7.32	6.98	12.58
Eugene1	2.25	16.54	15.37	583.11
Eugene2	9.69	16.95	16.83	73.68
Eugene3	12.39	27.35	24.50	97.74
Eugene4	12.74	28.36	25.54	100.47

The results show that the LID implementation does not significantly decrease the future peak flows at different nodes along the creeks which is mainly due to soil texture and rock lands in the subwatershed.

A subwatershed-level modelling exercise was conducted to determine the impact of Low Impact Development and SWM facilities on flow rates at specific nodes. The results show that under scenario of “SWM ponds + LIDs”, The peak flows can be reduced to match the predevelopment conditions (**Table 8.6**).

Table 8.6: Peak Flow Rates Under Existing, Future, and Future conditions with LIDs + SWM Facilities

Flow Node	Peak Flow Rate (m^3/s)			% Increase in Peak Flow Rates from Existing to Future Conditions with LIDs +SWM Facilities
	Existing Conditions	Future Conditions	Future Conditions with LIDs + SWM Facilities	
Frobisher1	4.44	14.51	4.52	1.89
Frobisher2	15.33	23.29	15.79	3.05
Frobisher3	19.37	28.06	19.26	-0.55
Frobisher4	22.28	30.55	22.03	-1.11
Frobisher5	26.16	33.82	25.89	-1.04
Frobisher6	32.13	39.58	31.01	-3.49
Rogers1	0.75	0.75	0.51	-31.28
Rogers2	2.05	3.30	0.13	-93.86
Rogers3	4.04	5.46	2.31	-42.95
Rogers4	5.10	6.41	3.79	-25.58
Rogers5	6.20	7.32	5.28	-14.91
Eugene1	2.25	16.54	1.47	-34.79
Eugene2	9.69	16.95	8.20	-15.34
Eugene3	12.39	27.35	7.58	-38.80
Eugene4	12.74	28.36	8.66	-32.02

9.0 Implementation

9.1 General

The City of Greater Sudbury initiated the study for the Ramsey Lake Subwatershed Study and Master Plan with an overarching objective to "***Develop a Subwatershed Management Plan to protect, maintain and enhance the surface water, groundwater, and natural resources of Ramsey Lake and its tributaries through environmentally sound policy and management actions.***".

The Subwatershed Study and Master Plan is being completed in three stages:

Stage 1 – Existing Conditions Characterization: Primarily involved a review of background information and field assessments to collect information regarding the existing conditions of the subwatershed (**Chapters 2.0to 3.0**);

Stage 2 – Analysis: Investigate and define existing environmental conditions, including environmental constraints and opportunities for development. This involved undertaking detailed hydrologic, hydraulic and ecological assessments (**Chapter 3.0**);

Stage 3 – Alternative Subwatershed Management Strategies: Evaluate future land use impacts and develop a Subwatershed Strategy, comprised of recommended works and measures to address stormwater management and the maintenance, protection and enhancement of the study area's significant natural heritage features and ecological functions (**Chapter 6.0, 7.0 and 8.0**); and

Stage 4 – Recommended Subwatershed Management Plan: which is the premise of this Section, and its purpose is to develop an implementation plan to guide future work by the City of Greater Sudbury and development proponents, which is the purpose of this Section of the study.

The **Stage 1** and **Stage 2** components of this study characterized existing environmental conditions and identified opportunities and constraints to development based on background review, field investigations, and modelling. The **Stage 1** and **Stage 2** components also assessed potential land use impacts on the natural resources of the study areas and reviewed alternative management measures to mitigate these impacts. Both stages concluded with a recommended Subwatershed and RSA Plan that consists of a series of management controls and management measures to maintain, protect and enhance the study area's significant natural heritage features and ecological functions, including the identification of a recommended Natural Heritage System (NHS).

The purpose of the Implementation section of this study is to guide the future work required to implement successfully the components of the recommended solutions and strategies developed earlier (**Chapters 6.0, 7.0 and 8.0**). Key objectives include:

- Review of the key Subwatershed Strategy components;
- Identifying achievable targets that correspond to the objectives outlined in **Chapter 5.0**;
- Provide direction as to the types of future studies required for the successful implementation of the Subwatersheds Strategy;
- Provide additional design guidance and policy considerations for key Subwatershed Strategy components;
- Identify responsibilities and roles for each of the Subwatershed Strategy components; and
- Provide preliminary costing and fund opportunities.

9.1.1 Relevant Policy and Approach

The proposed new development sites are identified in **Figure 7.2**. These sites will be developed through either the draft plan of subdivision process or the site plan process. Per the City of Greater Sudbury OP, applications for draft plan approval of subdivisions and site plan approvals in areas where a subwatershed plan has been completed will demonstrate, through a Stormwater Management Report, how the proposed development will provide stormwater management in accordance with the subwatershed plan.

The water quality, water quantity and water volume targets identified in this study along with the implementation approach described below should be addressed by each site though draft plan approval of subdivisions and site plan approvals.

9.2 Stormwater Targets for New Development Areas

9.2.1 Water Quality Targets

Per Section 7.2.3 and 7.2.4, a hierarchical approach should be taken to providing water quality control in new development areas. The general water quality approach to be taken for each development is outlined in the MECP's Stormwater Management Guidance Manual (2018 Draft). The hierarchical approach to providing water quality control will be as follows for each new development area:

1. **Retention Volume:** Retain a volume of water, equivalent to the pre-development water balance volume contributing to infiltration, on site via LID infiltration techniques.

   Note: Retention volume will vary across the study area based on site specific conditions including but not limited to soil type, depth to bedrock and depth to groundwater table.

2. **Filtration Volume:** Capture and treat via LID filtration a water quality volume equivalent to the runoff volume generated from the 90th percentile event minus the retention volume.

3. **End of Pipe Water Quality Volume Control:** For the runoff volume corresponding to the runoff generated from the 90th percentile event minus the sum of the retention volume and the filtration volume, end-of-pipe water quality control in the form of a wet ponds or hybrid facilities should be implemented to provide an enhanced level of water quality protection per the 2003 MECP Stormwater Management Planning and Design Guide. These facilities will also have the design objective of providing peak flow control for storm events from the 1:2-year through the 1:100-year.

9.2.2 Water Quality in SGRAs

In section 8.3.1 the impact to local water balance from proposed development was discussed. Modelling indicated that based on proposed development in the headwater areas of Eugene and

Rogers Creeks, runoff volumes will increase as a result of decreased evapotranspiration as well as land grading and the development of urban drainage works. The modelling however did indicate that groundwater recharge will also likely increase in many areas of the Eugene Creek SGRA as a result of increased inflows from upstream development areas. This is especially evident in the proposed Kingsway development where much of the proposed parking is outside of the SGRA but stormwater is proposed to be conveyed to a SWM facility in the SGRA. Although site plans were not available for proposed development areas in the headwaters to Rogers Creek, it is possible that development in these areas will have a similar impact on runoff volume and groundwater recharge.

Maintaining infiltration in these SGRAs will ensure baseflow contributions to the annual flow regime are maintained which is essential for the ecological health of the stream systems. Water quality degradation is possible if proactive measures are not taken during development. The main concern will be chloride loading to the groundwater as a result of salt application for winter maintenance. Salt management planning and contractor certification for development areas in and draining to the headwater SGRAs will be essential to maintain water quality. Additionally, where feasible, water quality controls should be designed upstream of the SGRAs.

9.2.3 Water Quantity Targets

Several of the creeks located downstream of the future development lands have been classified as being susceptible to flooding. Peak flow rate increases are identified in **Table 8.3** and flood risk areas are identified in **Section 6.2.4.2**. To mitigate flooding along Frobisher Creek, Roger Creek, and Eugene Creek, the necessary stormwater detention storage will be provided within the end-of-pipe stormwater ponds, or within site-level detention features controls for sites less than 5 hectares.

The storage volumes required to provide peak flow control to pre-development levels during the 1:100-year storm event is identified in **Table 9.1**. It should be noted that the volumes are estimates based on expected development intensity, and that infiltration in industrial areas may be restricted to clean water (e.g. roof water). During draft plan of subdivision and site planning processes, volumes will need to be adjusted to reflect proposed impervious percentages. The required detention volumes can be reduced moderately by including the LIDs in the hydrologic model. Although the LIDs are designed for water quality control, they are able to reduce the post-development peak flows by directing a portion of the runoff event to infiltration pathways and providing temporary detention to additional water quality volume during every precipitation event.

Table 9.1: Storage volumes required to provide peak flow control

Site #	Area (ha)	Development Type	Future Impervious (%)	1:100-year Detention Volume (m^3)	1:100-year Detention Volume (m^3) with LIDs
SUD-0103	20.1	Living Area 1	55	7170	6460
SUD-0212	21	Living Area 1	55	9840	8750
SUD-1030	23.5	Living Area 1	55	7960	7870
SUD-0009	6.9	Living Area 1	55	1890	1850
SUD-0777	11.8	Living Area 1	55	4560	4560
SUD-1068	16.4	Living Area 1	55	7120	7150
SUD-0096	27.2	Living Area 1	55	8660	8550
SUD-0284	67.4	General Industrial	80	45020	43500
SUD-0980	20.9	Living Area 1	55	7670	6040
SUD-0153	6	Living Area 1	55	2080	1710
SUD-1034	5.2	Living Area 1	55	2310	1920
SUD-0079	58.2	General Industrial	80	38270	36870
SUD-0127	16.2	Living Area 1	55	5150	5090
SUD-0755	19.4	Living Area 1	55	5460	5460
SUD-0060	10.4	Living Area 1	55	3620	3580
SUD-0993	13.4	Parks & Open Space	15	2410	2820
SUD-0278	11.2	Living Area 1	55	3620	3540
SUD-0037	5.8	Living Area 1	55	1840	1820
SUD-0090	6.6	General Industrial	80	2560	2470
SUD-0239	6.3	General Industrial	80	2680	2600
SUD-0302	8.7	General Industrial	80	3620	3500
SUD-0304	6.9	General Industrial	80	2960	2870
SUD-0367	10	General Industrial	80	4360	4220
SUD-1060	5.5	Living Area 1	55	1180	1180

9.2.4 Required Studies for New Development Areas

A new development area requirement through the City of Greater Sudbury's Official Plan is that all applications through draft plan approval of subdivisions and site plan approvals must demonstrate, through a Stormwater Management Report, how the proposed development will provide stormwater management in accordance with the subwatershed plan. Per Section 8.6.3 of Sudbury's Official Plan, specific requirements for Stormwater Management Reports are outlined in Section 7.2.2 of this report.

9.2.5 Responsibility for Implementation

Developers will be responsible for the implementation of individual stormwater management facilities in new development areas with input from the City through the draft plan approval process. Construction costs shall be borne by the Developer, while long term responsibility for the stormwater management facility shall be assumed by the City.

Per the City's Stormwater Background Study (2006) and OP, developers are required to monitor and operate all on-site quality control ponds and shall ensure that the facility meets regulatory agency requirements prior to the City assuming ownership of the facility. Monitoring requirements will be established through consultation with the City. Monitoring requirements may include, but not be limited to, flow recording and sampling / laboratory analysis for specific water quality objectives.

Per the City's Stormwater Background Study (2006) and OP, developers will typically be responsible for maintenance of the facility for 2 years following initial acceptance by the City. Maintenance shall include monitoring sediment accumulation in the pond forebay, sediment removal and grounds keeping (i.e. lawn care, trash removal, etc.).

Stormwater management facilities for subdivisions will be on lands transferred to the City at no cost to the City. On-site stormwater management facilities, subject to site plan approval, will be on lands transferred to the City at no cost to the City. All costs associated with the construction and initial maintenance of on-site facilities shall be borne by the Developer.

9.3 Implementation – Existing Urbanized Lands

Environmental baseline conditions for the study area were described in **Chapter 3**, **Chapter 8** outlined potential impacts from future development. **Chapter 6** identified a suite of alternatives and selected a preferred alternative to meet subwatershed goals and objectives. Building on all of that, this chapter summarizes the overall Management Strategy for the portion of the study area that is already urbanized (i.e. excluding new development areas). For each component of the management strategy the following is discussed where feasible:

- Responsibility for implementation
- Targets/objectives
- Requirements for future studies
- Phasing considerations
- Additional design guidance and policy considerations
- Approvals

9.3.1 Low Impact Development for Public Roads

9.3.1.1 General

The incorporation of cost-effective road right-of-way (ROW) LID retrofits as part of road reconstruction and resurfacing projects presents a significant opportunity to improve SWM control (water quality, water quantity, erosion mitigation, water balance) within the Ramsey Lake subwatershed. Targeting uncontrolled roads in urban catchments is ideal because of the large volume of sediment and other pollutants that wash off of these surfaces on an annual basis, as well as the opportunity to reduce runoff volumes and mitigate thermal pollution impacts on receiving waters. In addition, ROW retrofits have the added benefit of providing an opportunity to enhance street aesthetics, mitigate and adapt to climate change and reduce heat island effects. LID options that can be implemented within the municipal ROW are discussed in **Section 6.1.1**. The conveyance control measures are:

A. Enhanced Grass Swales – rural cross-sections
B. Bioretention
    i. Bioretention Bump Outs (Curb Extensions) – urban cross-sections
    ii. Boulevard Bioretention – urban cross-sections
    iii. Bioretention Planters – urban cross-sections
    iv. Bioswales – urban and rural cross-sections
C. Exfiltration Trenches / Perforated Pipe Systems – urban cross-sections
D. Permeable Pavement – urban cross-sections
E. Pervious Catch Basins – urban cross-sections

9.3.1.2 Targets/Objectives

Conveyance controls measures are proposed primarily to improve the water quality in Ramsey Lake by reducing pollutant loading from associated catchment areas. The 2003 MECP Stormwater Planning and Design Manual has traditionally been used for establishing stormwater quality treatment targets with respect to long-term sediment removal via settlement in end-of-pipe stormwater management facilities. Conveyance control measures use filtration and volume reduction as the primary treatment mechanisms. Using the 2003 MECP Stormwater Planning and Design Manual approach to target setting is not appropriate for conveyance control measures.

As part of the soon to be released MECP LID Stormwater Management Guidance Manual, linear projects are defined as “construction or reconstruction of roads, trails, sidewalks, rail lines and transit infrastructure that are not part of a common plan of development or sale”. The LID Stormwater Management Guidance Manual (Draft) specifies that linear projects that create impervious surface(s) and/or fully reconstructs the existing impervious surface(s), like other development and re-development, are subject to a Runoff Volume Control Target (RVC_T) corresponding to the runoff generate from the regionally specific 90th percentile rainfall event. As a result, road reconstruction projects in the Ramsey Lake subwatershed will have a water quality target corresponding to the runoff volume generated from the local 90th percentile event (i.e. the runoff generated from a 28 mm event). The runoff generated from a 28 mm rainfall event should be controlled using a control hierarchy whereby retention via LID retention technologies which utilize the mechanisms of infiltration, evapotranspiration and or re-use are preferred. If site conditions prevent meeting the RVC_T through LID retention, the control hierarchy allows for the use of LID capture and release, and then other detention and release as shown below in **Figure 9.1**.

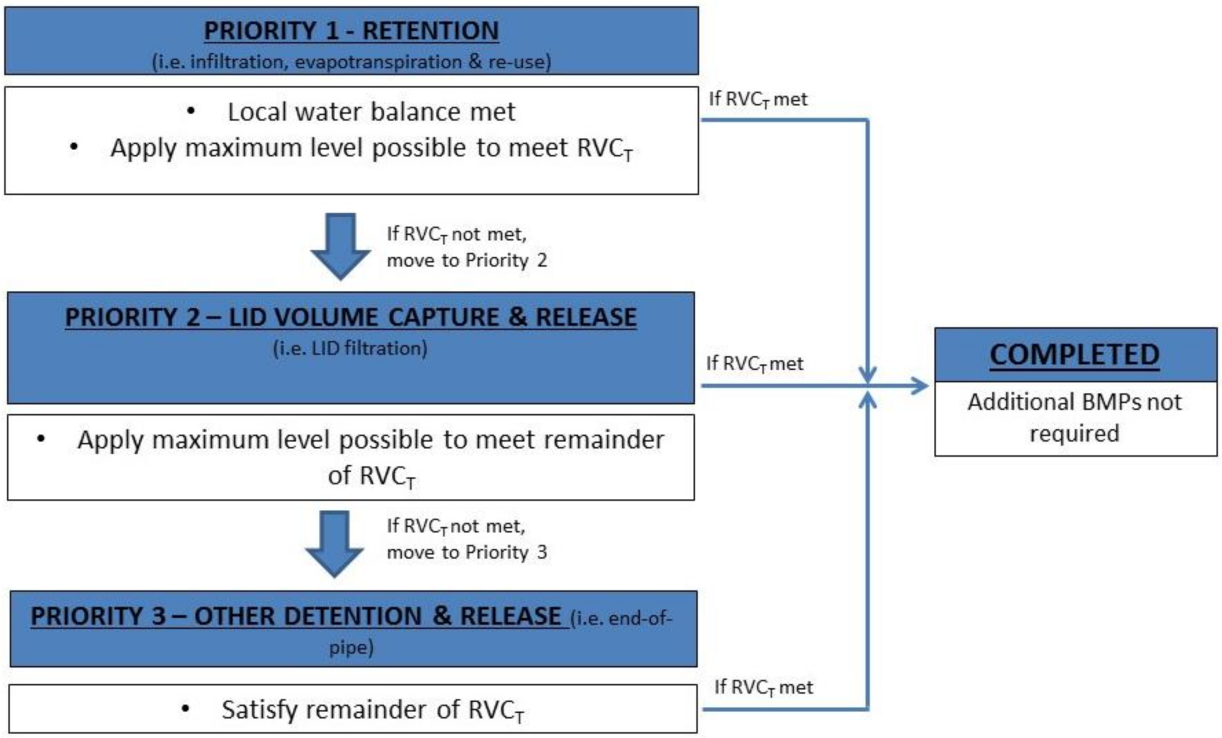


Figure 9.1: The runoff control hierarchy from the MECP LID Stormwater Management Guidance Manual

Following this approach new development areas within the Ramsey Lake subwatershed are recommended to follow the following water quality strategy:

1. The local water balance of the development area will be maintained at pre-development conditions by providing infiltration opportunities of source and/or conveyance control measures. Given the potential for project specific opportunities and constraints including depth to bedrock, varying native soils, and varying groundwater table depths, the water balance target for each new development area may vary significantly.

2. The remainder of the runoff volume generated form the 28 mm rainfall event will be treated using capture and release LID filtration practices.

   For example, a new development area will have an area weighted runoff coefficient of 0.45. The runoff volume generated from the 28 mm event is equivalent to 12.6 *mm across the entire new development area. LIDs that mimic the natural hydrologic functions of infiltration and/or evapotranspiration such as perforated pipes, bioswales or bioretention should be incorporated into the new development to capture a local water balance-based target. For this example, let's say this is 5 mm. In this example, the remaining 7.6 mm (12.6 mm minus 5 mm) will be filtered through an appropriately designed LID practice (typically the infiltration practice designed with additional filtration and detention capacity) before discharging to the conventional storm sewer system or outlet. Runoff from storms exceeding the 28 mm precipitation threshold may partially bypass the water quality treatment.*

3. Where physical constraints prevent infiltration and filtration practices from treating the runoff generated from the 28 mm event, conventional end-of-pipe systems including oil and grit separators and stormwater management facilities will be implemented to provide the appropriate level of treatment (enhanced-level corresponding to a log-term TSS load reduction of 80%).

To encourage municipalities to maintain rural cross-sections which provide some water quality benefits compared to curb and gutter, LID Stormwater Management Guidance Manual (Draft) specifies that "Linear Projects" which have an existing rural cross-section and are proposed to maintain the rural cross-section after development, without expansion, are considered a "Stormwater Retrofit". These projects do not have a 90th percentile volume target but instead are encouraged to meet the maximum achievable volume control, using all known, available and reasonable approaches.

9.3.1.3 Future Studies.

In order to implement conveyance control measures in an efficient manner, studies are recommended both at the city-wide level to prioritize projects and at the site-level to ensure technical feasibility.

A. City-Wide Feasibility and Prioritization of ROW Retrofits

Within the LID Stormwater Management Guidance Manual (Draft), municipalities are encouraged to undertake Linear Development Feasibility and Prioritization Studies to comprehensively and holistically assess stormwater and LID implementation opportunities and constraints within their respective rights-of-way networks to improve cost effectiveness, environmental performance and overall benefit to the receiver and the community. It is recommended that the City of Greater Sudbury undertake one of these studies using a Class EA approach that considers Social, Environmental, Financial, and Technical considerations. This approach will use the City`s ROW capital works schedule and will refine retrofit options, provide a framework for implementation, define future study needs, allocate available funding sources and define future funding needs. Feasibility screening considerations that should be addressed in the Linear Development Feasibility and Prioritization Study include, but are not necessarily limited to:

Suitable Outlet/ Overflow: The ability of the proposed LID options to discharge to a suitable outlet or overflow (storm sewer or watercourse) based on capacity, elevations and additional structure requirements is crucial to individual project implementation.

Elevation Constraints: The ability of the proposed LID options to be integrated with the constructed/ proposed grades (design elevations) without the need for significant alteration must be considered. This includes integration with all surface and sub-surface infrastructure.

Source of Stormwater: The ability of the proposed LID options to accept stormwater at surface or below grade given the constructed/ proposed roadway designs (top of pavement) must be evaluated at each project location.

Conflicts with Utilities: The ability of the proposed LID options to be integrated within the constructed/proposed roadway designs without conflicts to existing or proposed utilities must be considered. At the feasibility screening stage, the criteria are limited to conflicts which cannot be mitigated in design and would require relocations or present an unacceptable risk. This includes impact existing or proposed sanitary sewers, watermains, electrical lines including signalization and surface walkways/pathways. Follow-up via a review of engineering drawings is recommended to assist with this “high-level” screening.

Road Structure: The ability of the proposed LID options to be integrated into the constructed/

proposed roadway designs without compromising the road structure including sub-base soils, aggregate base and roadway surface must be considered at each potential project location. It is important that long-term design-life must not be compromised by conveyance control systems.

Sight-lines and Safety: The ability of the proposed LID option to be integrated into the constructed/ proposed roadway designs without compromising vehicle sight-lines or user safety must be considered.

Drainage Function: The ability of the proposed LID option to be integrated into the constructed/proposed roadway designs without compromising the existing drainage system design or capacity should be assessed at each project location. This selection criteria includes impacts related to transferring drainage from adjacent but previously separate drainage areas, reduced pipe/outlet capacity, risk of ponding on the roadway surface and storm sewer surcharging.

Cost Effectiveness: The relative cost of the proposed LID options should be factored into the feasibility study. To assist with this process, high level unit costing has been provided in **Section 9.3.1**. Criteria includes the screening of the options which present an unacceptably high construction costs based on the requirement for structural reinforcements, excessive infrastructure and or excavation or a high degree of disturbance to the built environment including the constructed roadway surface.

Integration with Neighborhood and Public Use: The potential for the proposed LID option to be accepted by the community and general compatibility with existing public use features such as sidewalks, trails and community green spaces should be considered as during the feasibility study.

Operation and Maintenance (O&M): Ability of the proposed LID option to have a low life-cycle cost and associated low maintenance burden for landscape elements and stormwater infrastructure (includes staff time, equipment and energy/utility fees) should be considered during the feasibility study.

Constructability: The potential for the proposed LID option to require complex construction methodology and/or many non-standard type design features should be considered. Options which do not have complex are preferred construction methodology and/or many non-standard type design features are preferred.

B. Project Specific Studies

Once the Linear Development Feasibility and Prioritization Study is complete, the following tasks must be completed for each ROW retrofit project:

Utility locates: Utility locates are undertaken prior to geotechnical investigations and related drilling activities. The company selected to complete the geotechnical investigation is usually responsible for obtaining utility locates. Utility locates can be scheduled by contacting the Ontario One-Call service.

Geotechnical Investigation: To determine soil and groundwater conditions it is recommended that boreholes and/or hand driven piezometers be used to determine groundwater conditions onsite. In both cases soil samples should be collected as part of geotechnical investigations in order to characterize the soil properties including natural moisture content, plasticity characteristics, particle size distribution, and analytical results for contaminates.

In-situ Infiltration Testing: In–situ infiltration testing characterizes the hydraulic properties of the existing native material on-site. On-site infiltration testing using the Guelph Permeameter test to determine the in-situ saturated hydraulic conductivity and the design infiltration rate per the LID Stormwater Planning and Design Guide is recommended. Testing should be performed within the approximate location and invert of proposed LID practices.

Figure 9.2: In-situ infiltration testing via Guelph Permeameter.

Topographic Survey: To produce base mapping for the detailed design phase, it is necessary to complete a topographic survey of the sites using total station survey or GPS equipment. At a minimum, surveys should include the following site features:

- Topography of the proposed site;
- Identification of above ground and below ground services
- Utility locate markings;
- Inverts and sizes for existing sewers, catch basins, manholes, etc.;
- Location and description of on-site structures;
- Available legal monuments;
- Borehole locations;
- Infiltration testing locations;
- Significant vegetation (coordinated with tree inventory assessment);
- Existing parkland features;
- Fence lines and existing landscaping; and
- Local benchmarks.

Hydrologic Assessment

A hydrologic assessment must be completed to accurately delineate the catchment area. This information is used to determine flow rates and storage volumes used for sizing bioretention components.

Regulatory Requirements

Based on recent experience with similar projects, it is expected that bioretention and bioswale facilities located within the municipal ROW will require an ECA from the Ministry of the Environment and Climate Change.

Gauge Neighbourhood Interest

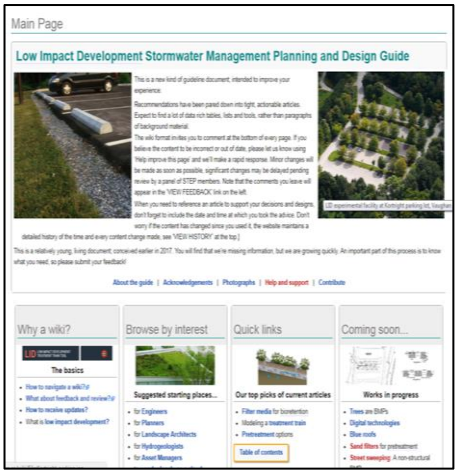
It is essential to have buy-in from the neighbourhood prior to implementing a LID feature within the ROW. A project launch BBQ was successfully held in a neighbourhood park on a weekend for the Lakeview Project in Mississauga.

Figure 9.3: Project Launch BBQ at Lakeview in Mississauga.

9.3.1.4 Design Guidance and Policy Considerations

Within the past decade, guidance documents have been developed to assist municipal engineers and planners with the implementation of LIDs in the road right-of-way. These documents can be used by the City of Greater Sudbury, and include:

Low Impact Development Stormwater Planning and Design Guide (CVC/TRCA, 2011)



The **Low Impact Development Stormwater Planning and Design Guide** was released by **Credit Valley Conservation (CVC)** and the **Toronto Region Conservation Authority (TRCA) is available on-line and is regularly updated** to provide engineers, ecologists and planners with up-to-date information and direction on landscape-based stormwater management planning and Low Impact Development stormwater management BMPs.

The Design Guide was not meant to be a stand-alone document. It is intended to augment the Ontario Ministry of the Environment's 2003 Stormwater Management Planning and Design Manual, which provides design criteria for "conventional" end of pipe stormwater management practices such as wet ponds and constructed wetlands. LID BMPs that are covered in this guide include:

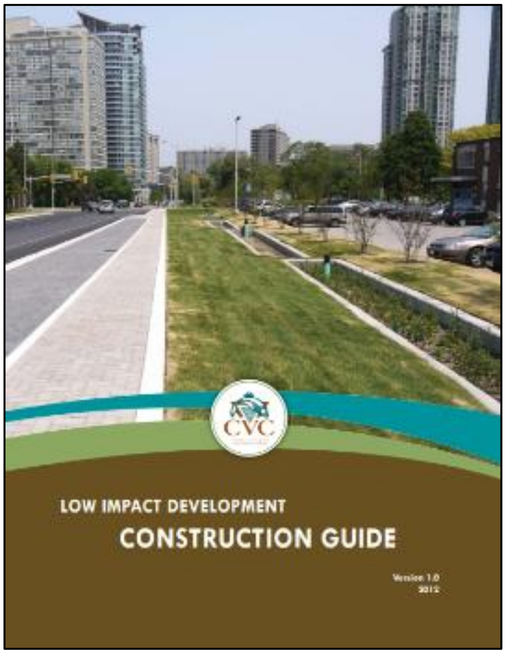
- Rainwater harvesting;
- Green roofs;
- Roof downspout disconnection;
- Soakaways, infiltration trenches and chambers;
- Bioretention;
- Vegetated filter strips;
- Permeable pavement;
- Enhanced grass swales;
- Dry swales; and
- Perforated pipe systems

Grey to Green Low Impact Development Road Retrofits (CVC, 2016)

The Grey to Green **Road Right of Way Retrofit Guide, released by Credit Valley Conservation (CVC),** provides guidance for municipal retrofits of road right of ways (ROWs) with innovative LID BMPs. The guide provides municipal planners, engineers and technical staff with guidance from screening LID options through lifecycle activities. Within the guide the implementation process is broken into nine phases:

- Building the project team
- Background review
- Screening the LID options
- Pre-design
- Detailed design
- Approvals
- Tender & contract documents
- Construction supervision & administration
- Lifecycle activities

Low Impact Development Construction Guide (CVC, 2013)



The **Low Impact Development Construction Guide** was released by **Credit Valley Conservation (CVC)** to provide guidance to design consultants, municipal engineers, plan reviewers, and construction project managers regarding common LID construction failures and how to avoid them. The goal of this document is to guide the proper construction of LID designs, and ultimately, the success of LID throughout Ontario.

The Construction Guide includes:

- A discussion of common LID construction errors;
- Information on how to protect LID BMPs through all phases of construction; and
- Recommendations on improving contracts, plans, specifications and communication to avoid construction errors.

9.3.1.5 Implementor / Approvals

Road right-of-way LID retrofits can most economically be implemented into road reconstruction projects due to shared construction staging, construction activities, and costs. Road retrofit projects should be incorporated into these projects based on economic and technical feasibility. Although the City should be the primary implementer, project support could be solicited from Conservation Sudbury due to their interest in water quality improvements within the Ramsey Lake subwatershed.

Based on recent experience with similar projects and discussions with MECP approvals staff, it is expected that bioretention and bioswale facilities located within the municipal ROW will require the municipality to submit Environmental Compliance Approval packages for review and approval. There are some circumstances where an ECA is not required; however, it is best to consult with the MECP for all road right-of-way retrofits.

9.3.1.6 Costing

The financial impact of implementing preferred road right-of-way LID retrofit alternatives as part of road reconstruction projects will vary depending on the retrofit type and scope of the project. **Table 9.2** identifies additional costs, beyond those incurred through standard road reconstruction for different retrofit alternatives. The costs are based on recent tendered project experience within other Ontario jurisdictions.

Table 9.2: Estimated Unit Costs for Retrofit (Conveyance Control) Measures

Treatment Measure	Unit Cost	
	$/m²	$/m
Perforated Pipe[1]	-	$150-250*
Bioretention (Boulevard or Bump Out)[2]	-	$225-250 **
Bioswales[3] ***	-	$325-350 **
Permeable Pavement[4]	$250-280	-
OGS with enhanced removal capacities	$ 75,000/unit	

[1] ROW Guide (CVC/MOE)
[2] Sunnyside (Ottawa), Regional Roads (Peel), Stewart Street (Ottawa)
[3] Lakeview (Mississauga), 7th Street (Cornwall), BFC (Brampton), Forest Glen (Newmarket)
[4] Huron Natural Area (Kitchener), Bentall Kennedy (Mississauga)
*Includes cost of road reconstruction
**Added cost to Road Reconstruction cost of $1,150 per linear meter (i.e. bioretention cost = $250 + $1,150 = $1,400
*** Bioswales were not a primary recommended option for streets within the 2017-2024 Capital Forecast, unit costs included for potential retrofit of rural cross-sections
Note: All values in 2016 CDN dollars

9.3.2 Oil Grit Separators

9.3.2.1 General

As described in Section 6.1.2, OGS units are proprietary devices that use hydrodynamic separation to remove sediment, screen debris, and separate floatables (gasoline, oil, grease, light petroleum products and other floating liquids) from stormwater.

An analysis was conducted on the Ramsey Lake Subwatershed to determine where OGS units could be added to the storm sewer network to reduce pollutant loading to Ramsey Lake and its tributaries. In total 52 storm sewer outlets to Ramsey Lake and local watercourses were found to be opportunities for OGS implementation. The locations are identified in **Figure 9.4**.

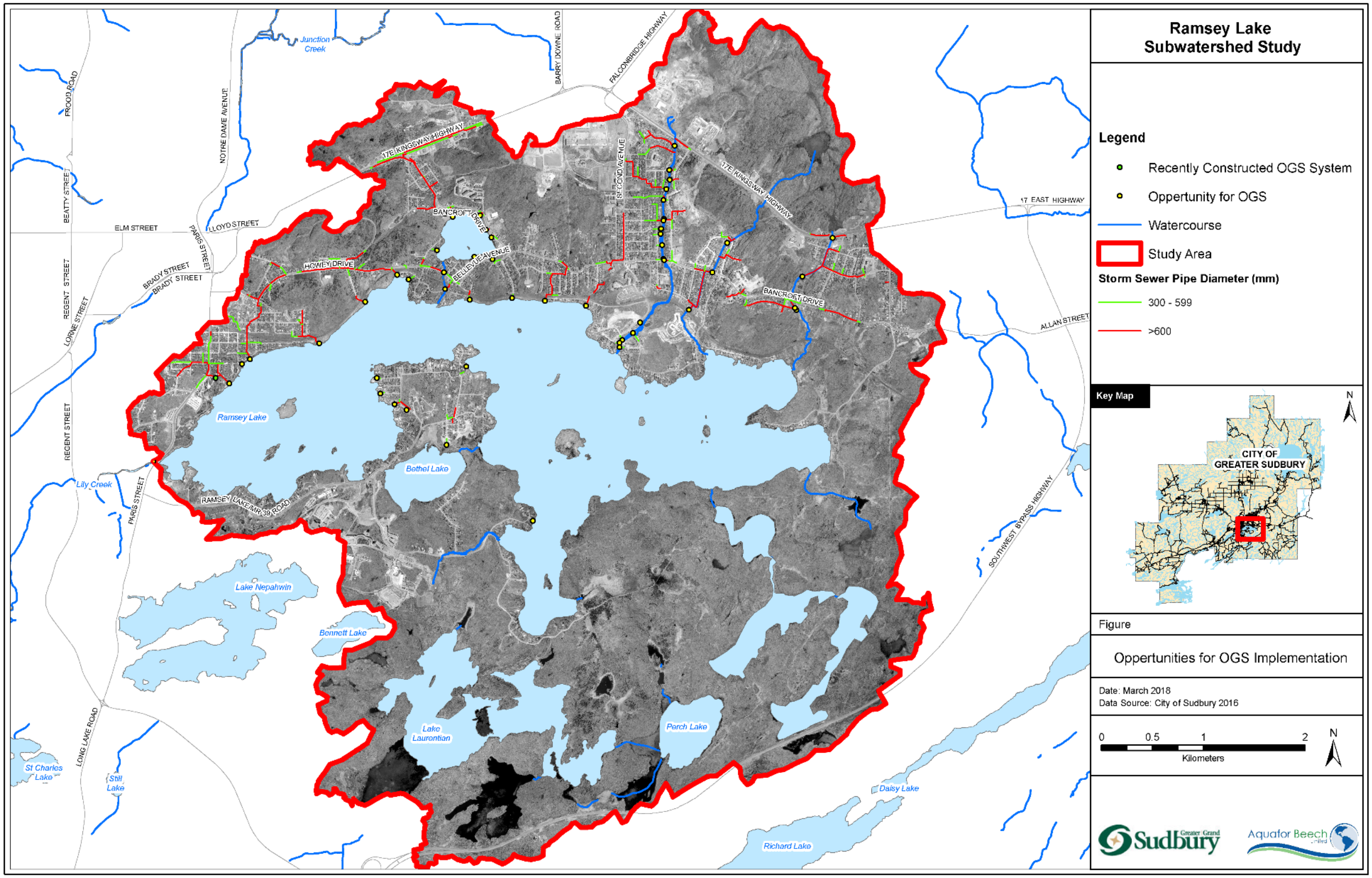


Figure 9.4. Opportunities for OGS Implementation

9.3.2.2 Targets/Objectives

90% Long-Term Volume Capture

An important factor when designing OGS units is what percentage of annual runoff is captured and treated by the proposed system. Small, regularly occurring storms are responsible for most of the annual urban runoff and result in most of the pollutant wash off from urban surfaces, therefore water quality practices are usually designed to treat all of the runoff from small storms events as well as a portion of the runoff from larger events. Although large storm events may also contain significant pollutant concentrations, they are less frequent and do not significantly contribute to the annual average pollutant load. An approach supported by many Canadian, US, and international jurisdictions is the selection of a performance target that controls 90% of the average annual rainfall volume. By controlling 90% of the volume, irreversible environmental degradation caused by poor water quality is minimized. An analysis of long-term rainfall event distribution conducted by the MECP in 2016 (LID Stormwater Management Guidance Manual – Draft) found a 90th percentile storm depth of 28 mm by averaging two Environment Canada rain gauges (Sudbury and Sudbury A) and using a minimum interevent period of 12 hours.

OGS units are designed for a maximum design inflow. Flows greater than this may partially bypass the treatment unit but have little impact on long-term treatment efficiency. Statistical analysis conducted for other Ontario municipalities has shown using a 2-hour design storm with 90th percentile rainfall depth is sufficient for design (City of Kitchener OGS Interpretation Memo - Aquafor Beech, 2018). The current practice of the City of Greater Sudbury is to design the OGS for the capacity of the pipe.

The Canadian Environmental Technology Verification (ETV) for OGS Units

Several protocols have been developed in different jurisdictions to evaluate the overall efficiency of new environmental technologies, including OGS units, in providing the required water quality benefits to stormwater runoff. The Canadian Environmental Technology Verification (ETV) protocol (http://etvcanada.ca/home/protocols-and-procedures/) provides an independent evaluation of new technologies to validate claims from manufacturers over the environmental benefits of their products so that users, developers, regulators, and other parties can make informed decision about purchasing, applying and regulating innovative technologies. Among the objectives of the ETV protocol are included:

- The quantification of sediment removal performance, by particle size fraction, of a device under different surface loading rates;
- The proposition of methodology for scaling the performance results obtained from this testing procedure to larger or smaller untested units within the same device classification;
- The quantification of the mass, by particle size fraction, of sediment particles that may be resuspended and washed out of the treatment device at high flow rates.

Among the OGS models available in Ontario, 5 (five) have been tested under the ETV protocol. As more models are tested, they are reported by ETV Canada which should be referenced for the most up-to-date list: https://etvcanada.ca/home/verify-your-technology/current-verified-technologies/

As a result of the verification process, TSS removal efficiency curves are available for each tested model based on the surface loading rate; these can be used to estimate the efficiency of the proposed OGS unit. **Table 9.3** presents the summary of results for five different OGS models evaluated as per the ETV protocol**.** The expression of the TSS removal efficiency based on the surface loading rate allows for the scaling of the OGS units, since by adopting a different OGS diameter than the tested one, the TSS removal efficiency can be estimated by comparing the design surface loading rate to the efficiency curve obtained for the tested similar unit.

Table 9.3: ETV TSS Removal Efficiencies per Surface Loading Rate – All Particle Sizes

OGS Model	**Surface Loading Rate (L/min/m^2)**							
	40	**80**	**200**	**400**	**600**	**1000**	**1400**	**1800**
SDD3	73	67	61	53	50	52	49	47
CDS	73.5	70.3	63.4	52.6	45.1	41.5	32.4	23
EF4/EFO4	70.4	63.8	53.9	47.5	46/41.7	43.7/39.7	49/34.2	N/A
HydroStorm	68.6	64.0	60.0	56.1	46.1	41.2	35.7	N/A
First Defense	66.5	59.5	55.4	50.2	44.9	45.2	40.5	N/A

The surface loading rate is a hydraulic loading factor expressed in terms of flow per sediment settling area, obtained for the OGS units from **Equation 1**.

$$SLR = \frac{240{,}000\ Q}{\pi\ D^2} \qquad (1)$$

Where:
SLR = surface loading rate (L/min/m^2)
Q = inflow rate (m^3/s)
D = OGS internal diameter (m)

Removal efficiencies are also dependent on the particle sizes and tend to be higher for sediment with coarse particle size distribution. The efficiencies shown in **Table 9.3** are obtained from a mass balance analysis of the sediment retained by the tested OGS model versus the sediment load introduced during the tests. These TSS removal efficiencies represent the overall efficiency for each surface loading rate considering all sediment particle sizes.

As part of the ETV protocol, all tests utilized sediment samples comprised of inorganic ground silica with a specific gravity of 2.65, uniformly mixed to achieve the Particle Size Distribution (PSD) shown in **Table 9.4**.

Table 9.4: ETV Particle Size Distribution

Particle Size (μm)	Percent Less Than	Particle Size Fraction (μm)	Percent
1000	100	500-1000	5
500	95	250-500	5
250	90	150-250	15
150	75	100-150	15
100	60	75-100	10
75	50	50-75	5
50	45	20-50	10
20	35	8-20	15
8	20	5-8	10
5	10	2-5	5
2	5	<2	5

9.3.2.3 Future Studies.

Because the removal efficiencies of OGS units are dependent on the particle sizes and tend to be higher for sediment with coarse particle size distribution, it is recommended that the City of Greater Sudbury undertake a sediment analysis to characterize the average particle size distribution of sediment in the City, due to the high use of road sand. For such a study it is recommended that sediment samples be collected from catch basins located in different areas within the City to ensure representative samples are analysed. Ideally the study would also estimate loading rates from different land uses by measuring sediment depth accumulated in catch basin sumps. To ensure results are applicable to all areas of the City, samples could be taken in:

1) industrial/commercial areas;
2) new subdivisions (immediately after assumption);
3) mature subdivision (minimum of 10 years post assumption); and
4) old subdivisions (minimum of 30 years post assumption).

Once an average representative particle size distribution is identified for the City, the removal efficiency of ETV certified OGS units can be approximated using the removal efficiencies and assumed surface loading rates in the ETV protocol.

9.3.2.4 Implementor/Approvals

MECP approval through the Environmental Compliance Approval (ECA) process is required for all OGS units. The Ministry has also developed the Checklist for Technical Requirements for a Complete Environmental Compliance Approval Submission, which will be used by Ministry staff to review and assess each application against the legislative and ministry requirements. For OGS units the following must be submitted for review:

- Engineering Drawings, stamped & signed by P.Eng.
- Manufacturer specifications and modeling
- Sediment capacity
- Oil capacity
- Total holding capacity
- Flow rate
- Catchment area
- Impervious area (%)
- Annual TSS removed (%)
- Annual runoff treated (%)

9.3.2.5 Costing

The material and installation costs associated with OGS units are considerable and depending on the unit type and size. Purchase costs for the units themselves can range from approximately $50,000 for those capable of treating areas smaller than 1 ha to $500,000 for those capable of treating 10 ha. Capital costs associated with construction will vary significantly depending on the location and site-specific constraints such as bedrock removal or dewatering requirements.

The removal of sediment and liquid waste (accumulated hydrocarbons) is a considerable cost associated with ongoing operation of OGS units. Contracting out the maintenance of municipal OGS units may be feasible to avoid staffing and equipment costs. Based on available tendered costs from Ontario municipalities, the cost of sediment removal is approximately $725/tonne while the cost of liquid waste removal is approximately $80/m^3.

9.3.3 Stormwater Management Facilities (Wet Ponds and Engineered Wetlands)

9.3.3.1 General

Based on the evaluation of stormwater management facilities discussed in Section 6.2.2. The preferred alternatives at each location are:

- Site 1 - Bancroft Dr. & Nottingham Ave. – Below Ground SWM Facility
- Site 2 - Rheal St. & Eugene St. – Above Ground SWM Facility
- Site 3 - Bancroft Dr. & First Ave. – Below Ground SWM Facility
- Site 4 - St. Antoine St. – Below Ground SWM Facility
- Site 5 – Paris St. – Below Ground SWM Facility
- Site 6 - McNaughtonTerrace Park – Below Ground SWM Facility
- Site 7 - Mildred St. – Below Ground SWM Facility

9.3.3.2 Objectives and Targets for Stormwater Management Facilities

Generally, stormwater management facilities proposed in areas of the Ramsey Lake Subwatershed that are already urbanized will be designed to improve water quality, mitigate flooding and reduce erosive flows to the greatest extend possible. Water balance benefits via infiltration are not generally a primary objective due to local bedrock conditions. The control hierarchy (**Figure 9.1)** indicates that the local water balance should be met while also controlling the 90th percentile rainfall (28 mm) (**Section 9.3.1.2**). While the water balance needs to be met through infiltration and evapotranspiration, the remainder of the 28 mm rainfall can be controlled through volume capture and release (Priority 2) or through other detention and release (Priority 3), as necessary.

The water quality target associated with of end-of-pipe stormwater management facilities will be designed to provide an enhanced level of water quality protection corresponding to a long-term sediment removal efficiency of 80%. To provide this water quality target, Section 3.3.2 of the Stormwater Management Planning and Design Manual (MECP, 2003) can be used to appropriately size wet ponds, engineered wetlands, hybrid wet pond / wetlands and infiltration. For subsurface facilities, these have been volumetrically sized in accordance with wet sedimentation facilities. The subsurface facilities will rely on sedimentation for water quality treatment. Inlet water quality enhancement devices may be considered to further improve water quality treatment efficiency of the system. **Table 9.5** identifies the water quality storage volume requirements needed to achieve an enhanced level of water quality protection. Of the specified storage volume for wet facilities, 40 m^3/ha is extended detention, while the remainder represents the permanent pool.

Table 9.5: Water Quality Storage Requirements for Enhanced Water Quality Protection

SWMP Type	Storage Volume (m^3/ha) for Impervious Level			
	35% Impervious	55% Impervious	70% Impervious	85% Impervious
Infiltration	25	30	35	40
Wetlands	80	105	120	140
Hybrid Wet Pond / Wetland	110	150	175	195
Wet Pond	140	190	225	250

In areas of the Ramsey Lake Subwatershed that are already urbanized, stormwater retrofits should be designed to provided peak flow attenuation through runoff volume detention under the following conditions:

1. Where there have been historical incidents of urban flooding associated with the minor or major system or studies indicating that the level of stormwater service associated with conveyance is lacking.

2. Where intensification or infill development has caused or is expected to cause an increase in runoff rate or runoff volume.
3. For stormwater catchments that drain to watercourses that have identified flooding concerns or erosion issues.

9.3.3.3 Preliminary Design of Stormwater Management Facilities

Figure 9.5 to **Figure 9.11** show the preliminary plan and profiles of each facility based on existing storm sewer connections, available land, and volumetric requirements. For subsurface stormwater management facilities, volumes were estimated based on MOECC Table 3.2 from the Stormwater Management Planning and Design Manual assuming similar sediment loading to that of a wet-SWM facility. At detailed design, layout and hydraulics would need to be evaluated in greater detail in order to maximize sediment capture, allow for regular maintenance and to avoid constraints.

For detailed design, long-term operational requirements associated with inspection and sediment removal will need to be addressed. In order to ensure long-term operational effectiveness of SWM facilities, it is crucial to remove accumulated sediment periodically per the conditions of the respective MECP Environmental Compliance Approval (ECA). The maintenance frequency depends on several aspects, such as type of facility, design storage volume, characteristics of the catchment area and municipal practices. Sediment accumulation compromises the effective storage volume and the long-term efficiency of suspended solids retention.

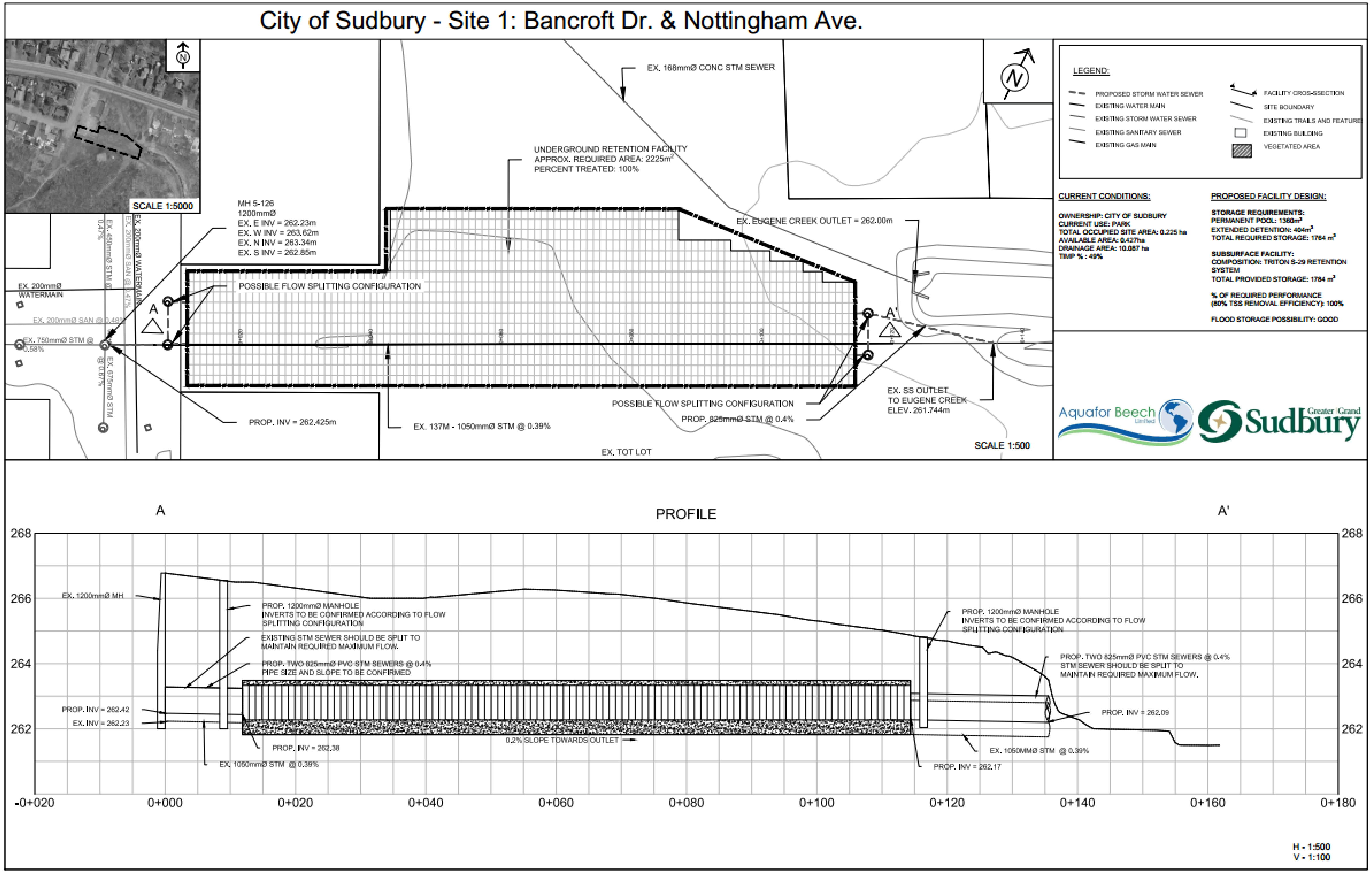


Figure 9.5: Site 1: Bancroft Dr. & Nottingham Ave

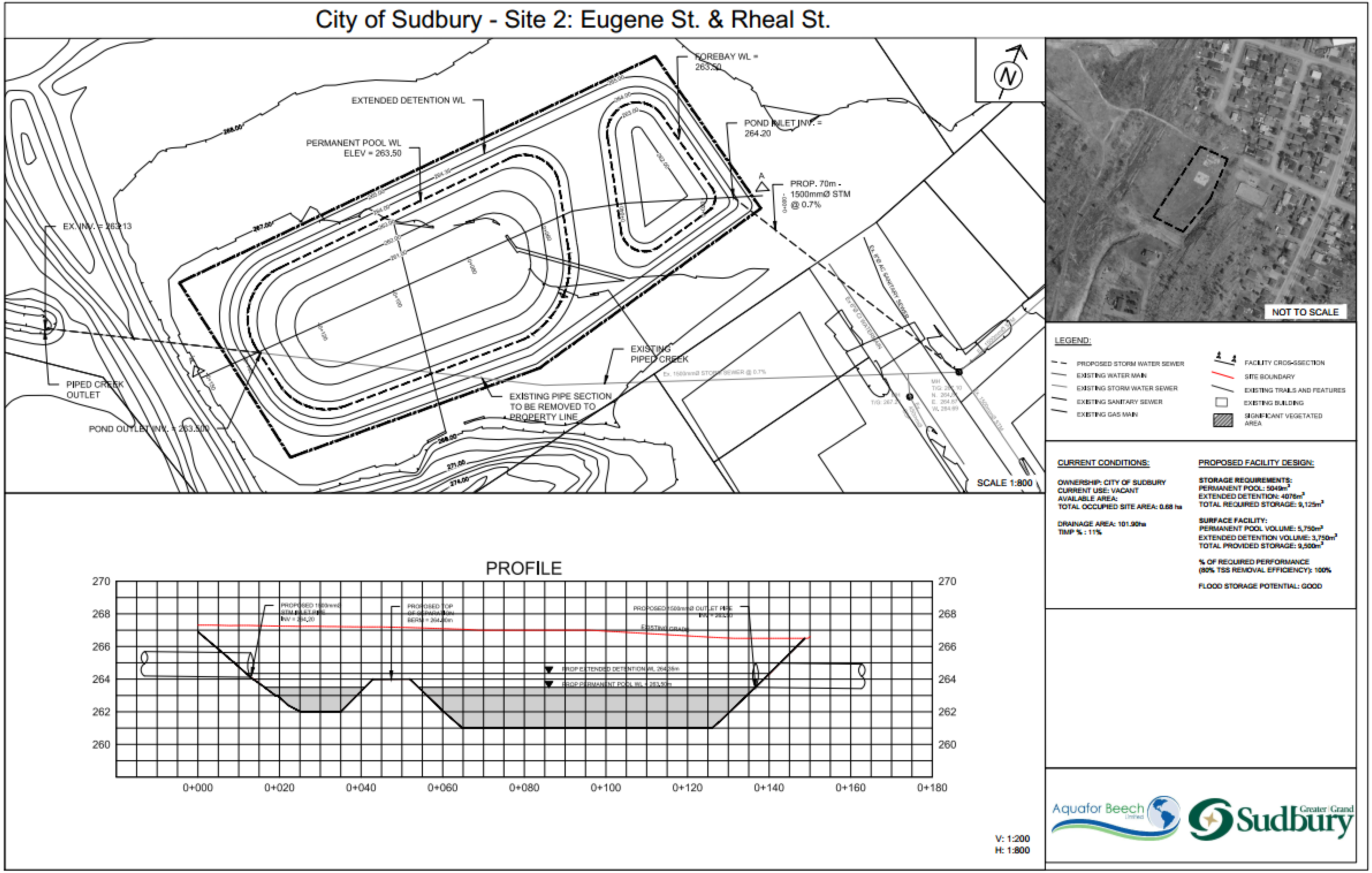


Figure 9.6: Site 2 – Eugene St. & Rheal St.

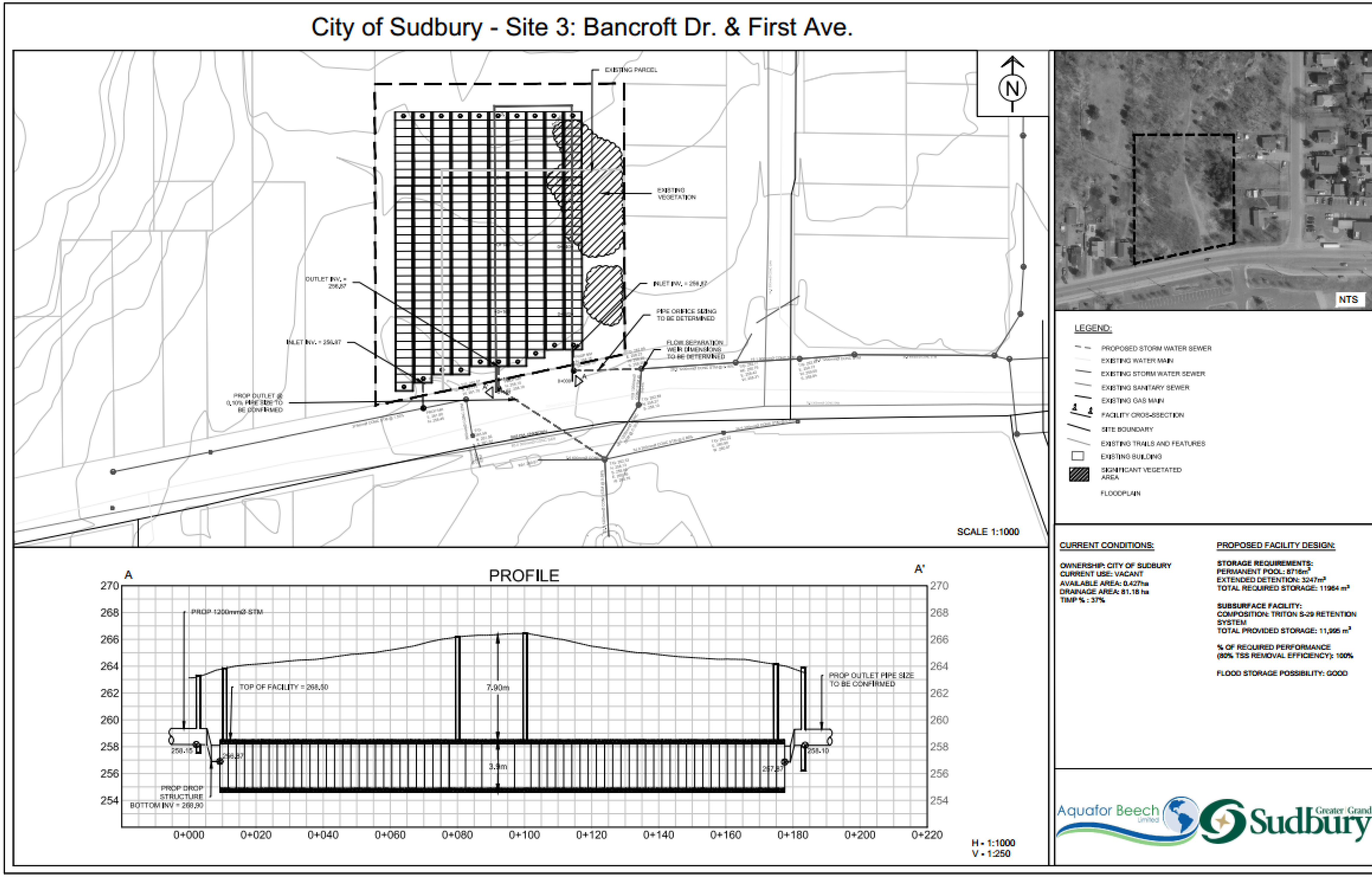


Figure 9.7: Site 3 – Bancroft Dr. & First Ave.

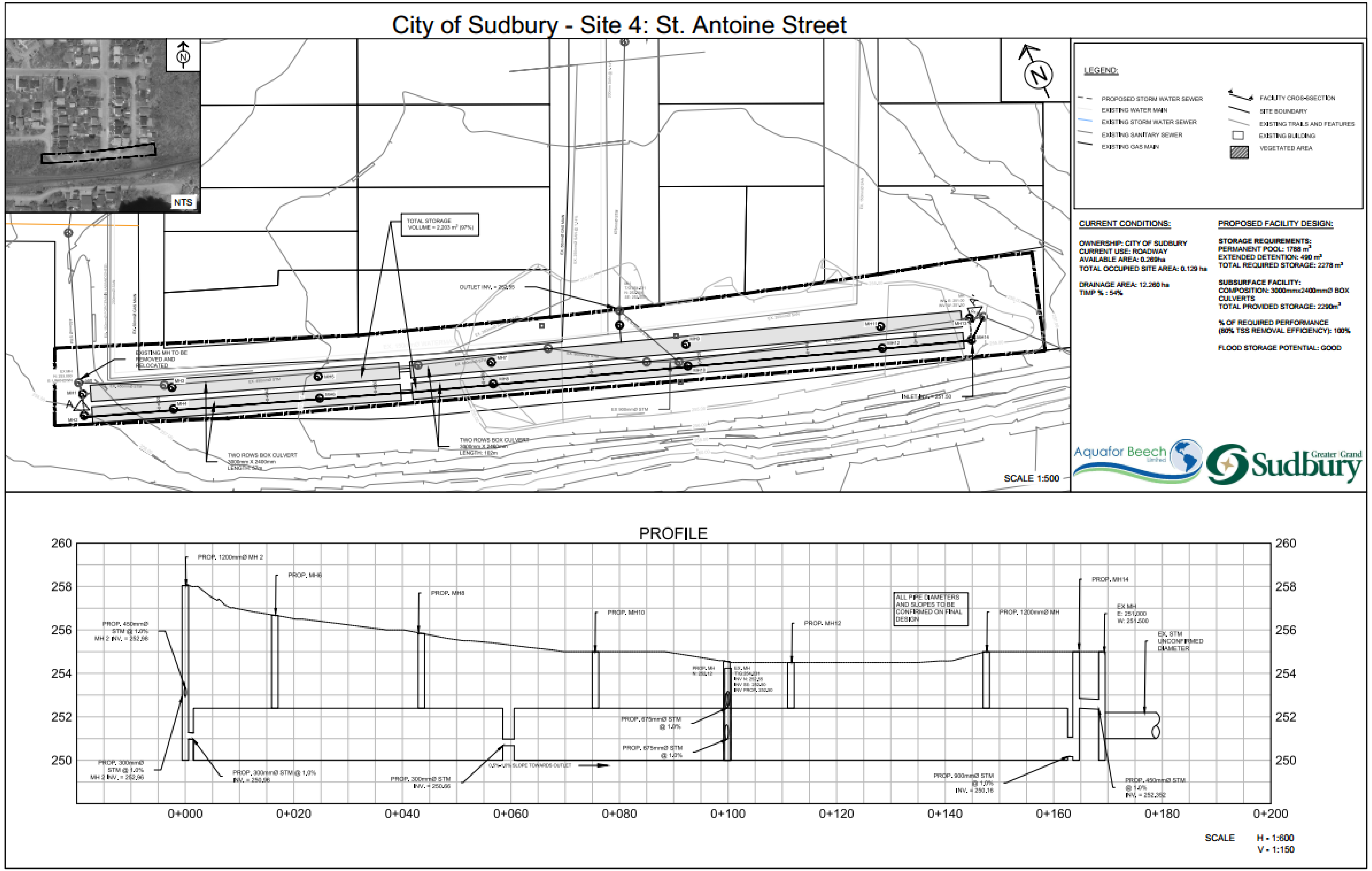


Figure 9.8: Site 4 – St. Antoine Street

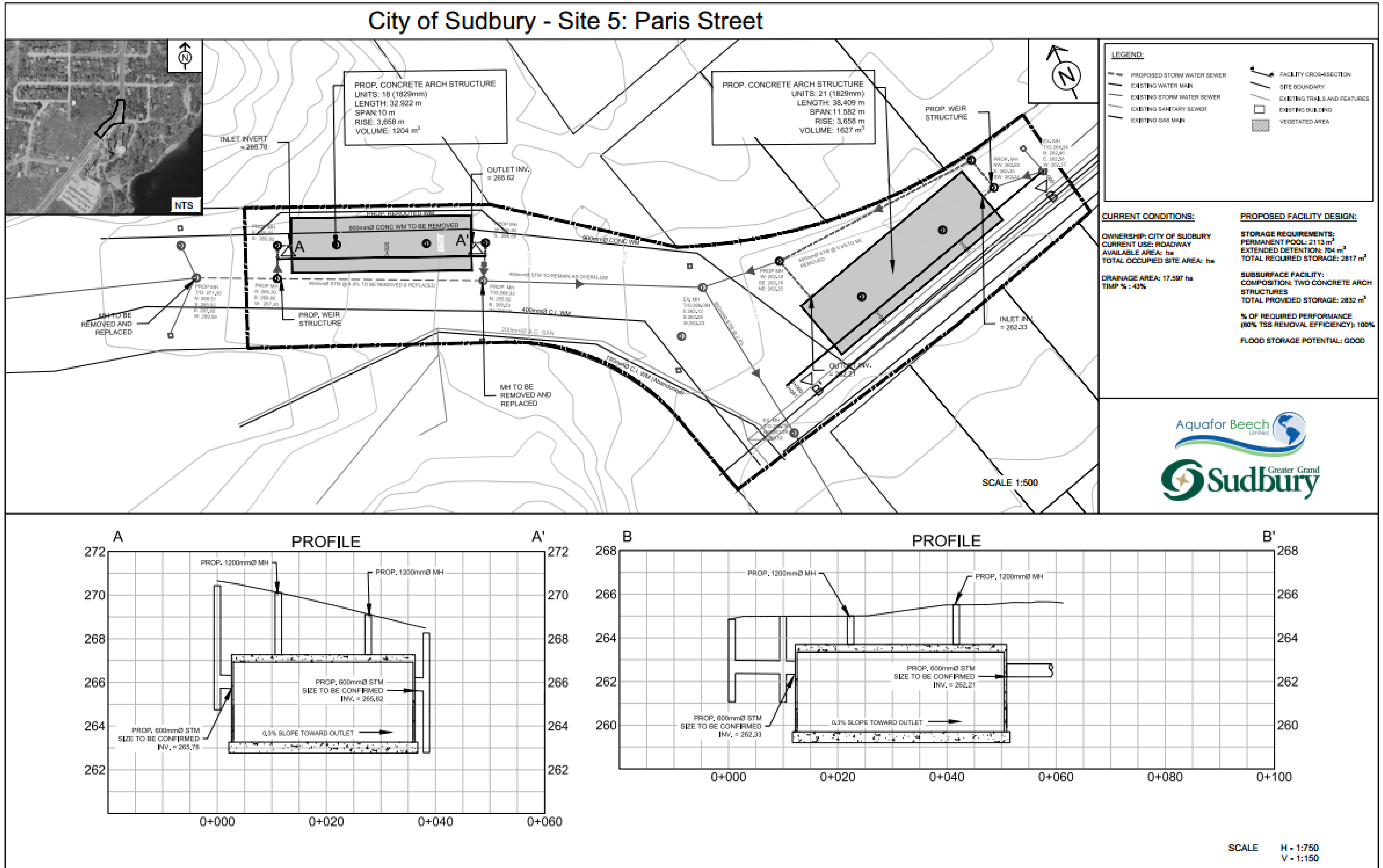


Figure 9.9: Site 5 – Paris Street

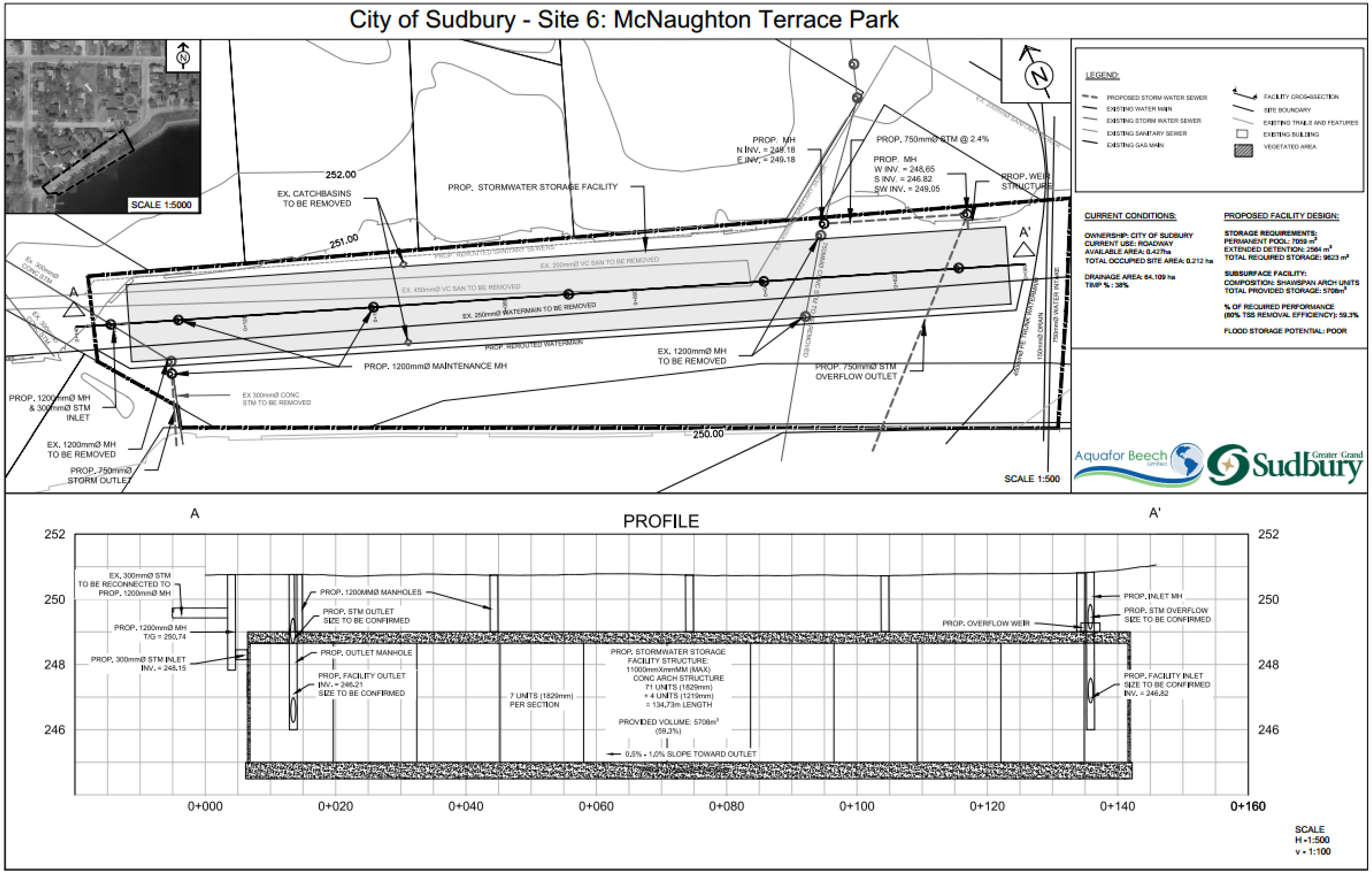


Figure 9.10: Site 6 - McNaughton Terrace Park

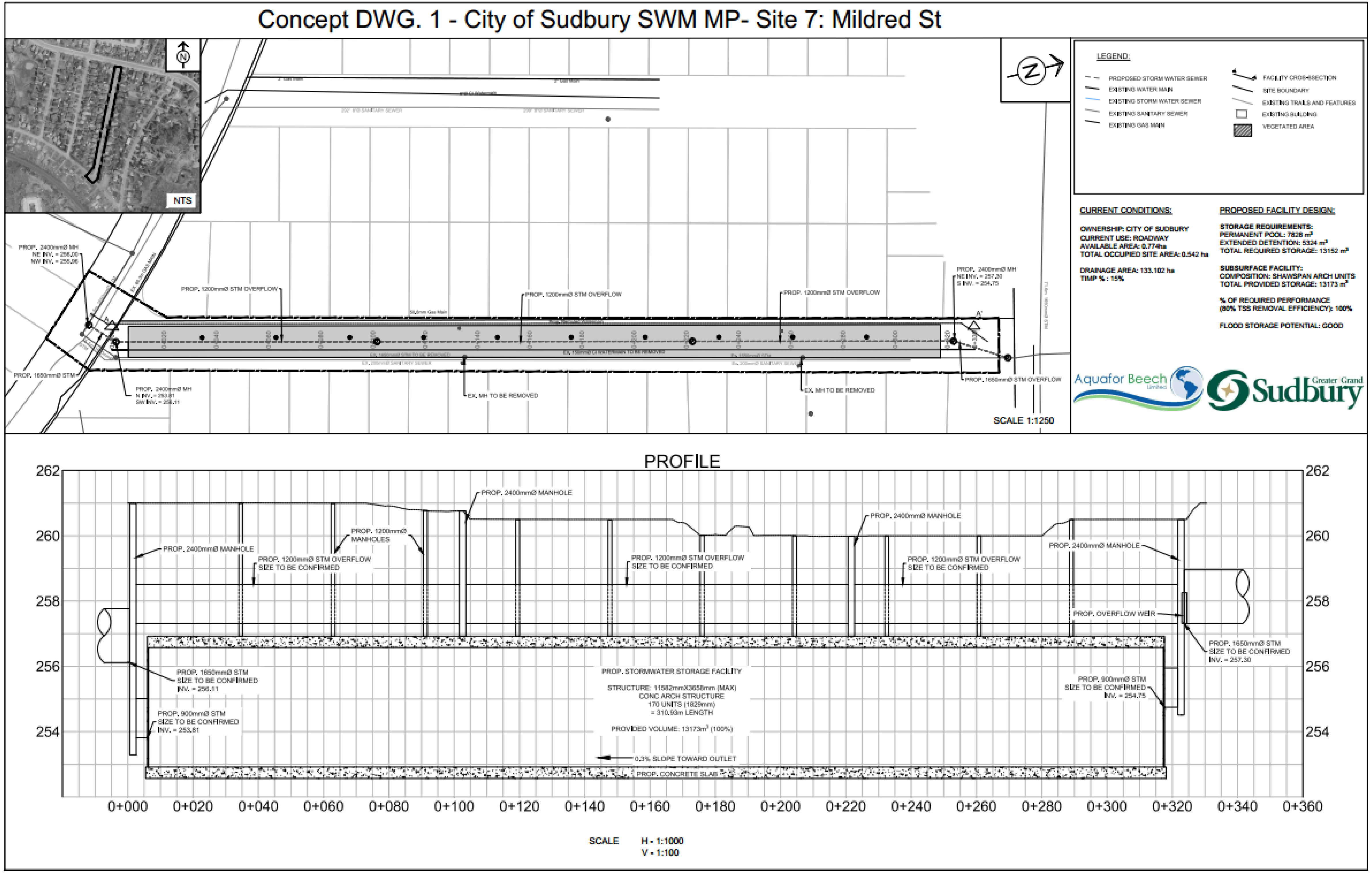


Figure 9.11: Site 7 – Site 7 – Mildred St.

9.3.3.3.1 Specific Constraints to be Addressed at Detailed Design

Upon detailed technical analysis, three sites have been identified as having constraints associated with design elements and site-specific constraints. These constraints are identified below to be considered during design optimization:

Site 4 – St. Antoine Street: The rail line immediately south of this location is elevated from the road grade by several meters. Excavation and construction of a subsurface stormwater management facility may pose associated risks to structural stability of the adjacent embankment. A geotechnical analysis would be required prior to detailed design.

Site 5 – Paris Street: There is a water main trunk that would require relocation if the layout identified in Figure 9.9 is constructed. To avoid costs associated with this utility constraint, a reconfiguration of the west chamber could be considered.

Site 6 – McNaughton Terrace Park: Given the water table in this area is around 248.5 meters above sea level, the subsurface stormwater management facility would be submerged. Dewatering would considerably impact construction costs but would not affect the overall functionality of the facility.

9.3.3.4 Implementor/Approvals

The City will be responsible for any works associated with end-of-pipe stormwater management facilities in existing urban areas. The study and resulting recommended retrofit works have been completed following Schedule B of the Municipal Class EA process and therefore can proceed directly to detailed design and implementation.

MECP Environmental Compliance Approval (ECA) per Section 53 of the Ontario Water Resources act / Application for Approval of Municipal and Private Sewage works will be required prior to retrofit construction.

MECP permits will only be required where projects may impact Species at Risk. Under the Endangered Species Act, the MECP can grant permits or other authorizations for activities that would otherwise not be allowed, with conditions that are aimed at protecting and recovering species at risk.

DFO administers development requirements relating to aquatic habitat under the Fisheries Act. This applies to work being conducted in or near waterbodies that support fish that are part of or that support a commercial, recreational or Aboriginal fishery. It is not anticipating that DFO approval will be required for any of the retrofits.

A permit under Ontario Regulation 156/06 - Development, Interference with Wetlands and alterations to Shoreline Watercourse will be required through Conservation Sudbury any facilities within regulations limits that is an on-line facility, impacts a wetland or requires the establishment of an outlet.

9.3.3.5 Costing

Approximate costs for new end-of-pipe SWM facilities are based on unit costs for blasting, excavation and disposal of rock in the City of Greater Sudbury as well as additional construction based on similar designs constructed in other Ontario municipalities. **Table 9.6** identifies approximate costs for each project.

Table 9.6: Approximate Costs for End-of-Pipe SWM facilities Proposed in Existing Urban Catchments.

Site	SWM Facility Type	Drainage Area (ha)	Volume of Facility (m^3)	Approximate Excavation Volume (m^3)	Approximate Excavation Volume (m^3)	Blasting, Excavation and Disposal Cost ($)*	Materials and Construction Cost ($)	Total Cost ($)
1	Subsurface	10.1	1,764	2,600	10,400	$1.8-2.2 million	$0.7 to 1.1 million	$2.6 to 3.2 million
2	Wet Pond	101.9	9,125	1,825	7,300	$1.3 -1.6 million	$0.2-0.3 million	$1.6-1.9 million
3	Subsurface	81.2	11,995	5,900	23,600	$4.0-4.9 million	$5.2-7.7 million	$9.7-12.7 million
4	Subsurface	12.3	2,278	1,360	5,440	$1.0-1.2 million	$1.0-1.5 million	$2.0-2.7 million
5	Subsurface	17.6	2,817	880	3,520	$0.6-0.8	$1.2-1.8	$2.3-3.1 million

Site	SWM Facility Type	Drainage Area (ha)	Volume of Facility (m^3)	Approximate Excavation Volume (m^3)	Approximate Excavation Volume (m^3)	Blasting, Excavation and Disposal Cost ($)*	Materials and Construction Cost ($)	Total Cost ($)
						million	million	
6	Subsurface	64.1	9,623	2,760	11,040	$1.9-2.3 million	$4.0-6.0 million	$6.0-8.4 million
7	Subsurface	133.1	13,152	6,400	25,600	$4.4-5.3 million	$5.8-8.4 million	$10.6-13.7 million

*Excavation costs were estimated at $150/m^3 including disposal. Blasting costs were estimated at $250/ m^3 for quantities up to 500 m^3 and $160/ m^3 for quantities greater than 500 m^3.

9.3.4 Restoration Measures on Private Property

9.3.4.1 General

Urban catchments that are not serviced by an adequate level of stormwater controls are common within the Ramsey Lake study area. This includes a large percent of residential lands that either lack stormwater controls or lack sufficient stormwater control to meet an expected level of service. Common pollutants from residential neighborhoods include nutrients from decaying plant matter and animal waste, metals from the breakdown of automotive components, and a complex list of hydrocarbons from spills, leaks and atmospheric deposition of oil and gas products. To provide both stormwater quality and stormwater quantity controls to residential catchments without the need for land acquisition for end-of-pipe facilities, restoration measures in the form of residential source controls are recommended.

Residential source controls are small-scale stormwater management practices located at the beginning of a drainage system where stormwater is captured and treated on-site or close to where the rainfall lands. These measures reduce the volume of stormwater entering the municipal storm sewer system and mitigate the loading of urban stormwater pollutants to end-of-pipe infrastructure and downstream receivers. Due to the relatively small area captured by an individual measure, lot level controls must be well distributed across catchments or subwatershed to form an integral part of the stormwater management system.

Securing an adequate coverage of source control measures across urban catchments requires the participation of private property owners in the residential sector. To support landowners implementing stormwater mitigation measures a Community Engagement Plan tailored specifically to the opportunities and constraints of the community is required. A successful Community Engagement Plan considers two primary strategies to drive uptake of residential source controls by private property owners, specifically:

1. The creation of drivers for at-source actions by private landowners and new construction through the development or modification of City policies and practices via enhanced integrated decision-making and programming across City departments and portfolios.

2. The strategic engagement of the marketplace to drive uptake of residential source control measures by property owners and builders/developers and create the impetus for market transformation.

This section of the Ramsey Lake Subwatershed Study and Master Plan outlines an implementation strategy for residential source control measures in the form of a Community Engagement Plan for residential areas of the Ramsey Lake Subwatershed. The stages of a successful Community Engagement Plan are outlined in this section along with the activities and costs associated with community engagement.

9.3.4.2 Objectives of Residential Source Control Measures

The general objective of residential source controls is to capture runoff from impervious surfaces on private properties resulting in a reduction in stormwater volume and associated pollutants of concern (i.e. phosphorus, sodium and chloride). The more homeowners that apply source control measures to their properties, the greater the beneficial environmental impact.

9.3.4.3 Future Studies

At the onset of a residential source control implementation program, a **review of existing municipal by-laws** should be conducted. This is because residential source controls do not conform to conventional design standards. By-laws that set standards for drainage, grading and landscaping may impact implementation of measures that rely on the detention and infiltration of stormwater. Amendments, special policies, or pilot project designations may be required to overcome these constraints.

Whether public outreach for residential source control measures is founded in education and outreach or incentive-based, low participation is a common challenge. Securing significant uptake of residential source control measures requires an understanding of the audience (the community) and the message that needs to be sent to connect with the audience. Municipalities across Ontario have found that despite promising initial uptake and steady funding, the number of residents implementing lot level stormwater control measures plateaus after the first few years of municipal implementation programs. This is largely due to the way municipal professionals (engineers, planners, etc.) are marketing these stormwater control to the public. Instead of using technical information, which may not resonate with the public, municipalities should focus material that inspires desires or wants rather than presenting an informed argument. Keeping this in mind, there are two approaches that can be followed for **residential source control community engagement**, these being:

1. A Community Engagement Plan based on Market Research

This approach uses primary research (focused research sessions on representative community sample groups) or secondary research (existing information on the market) to:

- Uncover homeowners’ fundamental motivations regarding their property;
- Understand residents’ perceptions of lot-level stormwater control measures;
- Identify images and messages pertaining to lot level stormwater that resonate with homeowners;
- Identify key stakeholders that directly influence the practices and attitudes of homeowners;
- Identify potential barriers towards the application of lot level stormwater control measures on a homeowner’s property; and

- Determine the preferred lot-level stormwater control measures for residential properties based on resident perceptions.

A marketing consultant is typically used to conduct market research. Market research provides an understanding of desires, perceptions, and drivers (Credit Valley Conservation, 2015). This research is used to create a Community Engagement Plan and deliver effective outreach program that will drive maximum residential uptake. Using primary research, a marketing consultant may provide dozens of questions to get a feel for the community. A few examples of question that can generate valuable responses include, but are not limited to:

Q1) What is the most important aspect of your home's landscape?

Q2) Who designed your home's landscape?

Q3) Where do you purchase flowers, trees and shrubs?

Q4) What is a rain garden?

Q5) Name a plant that is native to Ontario

Q6) Where does water collected in the storm sewer go?

A marketing consultant may also ask the sample group to draw landscape concepts to help understand property improvement motivations and constraints or ask the sample group to rate or rank photos of landscape features to better understand constraints to source control implementation.

2. A Community Engagement Plan that does not use Market Research

This approach does not use community-based market research to develop an understanding of property improvement motivations and constraints. For this approach, the successes of other municipalities should be studied and modified to best suit your target audience. Examples of successful approaches and community engagement plan components are discussed in Section 9.4.3.4.

9.3.4.4 Design Guidance and Policy Considerations

There are several component options to community engagement in the Ramsey Lake Subwatershed that have been used to promote the implementation of residential source controls on private property in other municipalities. A successful community engagement plan may use several of these program components:

Hosting Special Community Events

Open house events can be useful in launching the program and creating initial community interest. An approach that has worked in the Village of Alton is an "Ask a Designer Night". These events bring together interested homeowners, municipal program managers and landscape designers. Each home owner in attendance has the opportunity to show the designer photos of their property and receive advice tailored to their home landscape. During the City of Mississauga's Residential Market Research Study, 93% of respondent homeowners expressed interest in using a landscape advisory service if it was made available to them at no-charge (Freeman and Associates, 2008). Other community events that can provide interaction between the project team, expert advisors and the public include community BBQs and festivals.

Figure 9.12: A homeowner receiving advice from a landscape designer at the Ask a Designer night in Alton Village (CVC, 2015).

A Tour of Demonstration Sites

Once demonstration sites have been established on public properties or on properties of early adopters, a tour is a good way to show off the aesthetic benefits of lot level stormwater control measures. Depending on the geographic spread of these sites and the neighbourhood demographics, a tour could be conducted by bus, bike or on foot.

Signage within the Community

Community signage is easy to overlook if not designed and sited properly. Signs should avoid technical jargon and focus on simple visual concepts that resonate with homeowners. Figure 9.13 shows a sign used for the Region of Peel's Fusion Landscaping® program. Simple interpretive signage can also be incorporated into demonstration sites in heavily used public areas. The City of Ottawa has already incorporated interpretive signage along Pinecrest Creek and the Ottawa River to educate the public in stormwater management issues.

Figure 9.13: Signage used by the Region of Peel to market their Fusion Landscaping® program (Region of Peel).

Resource Booklets and Online Guidance

Resource materials can answer questions homeowners have about the program but can also be used as reference material for design purposes. These resources typically work best after the community interest has been established through other marketing tools. It is important to continue to use the highly aesthetic imagery in these resources and not make them too technical for the average homeowner to understand. Useful examples of resource materials include the **Region of Durham's Fusion Landscaping® Guide for Homeowners** and the **TRCA's Greening Your Grounds: A Homeowners Guide to Stormwater Landscaping Projects (**Figure 9.14**).**

Figure 9.14: Region of Durham's Fusion Landscaping® Guide for Homeowners (Left) and the TRCA's Greening Your Grounds: A Homeowners Guide to Stormwater Landscaping Projects (Right).

Integration with Existing Programs

Where existing residential landscape improvement programs already exists, there are advantages to integrating source control components into these programs as costs can be shared and residents may already be familiar with the program benefits. At the City of Greater Sudbury, the Shoreline Visit Home Program provides an integration opportunity. The one-on-one consultations with property owners ranging from 30 minutes to 2 hours provide opportunity to discuss landscape opportunities that will protect and enhance water quality in Ramsey Lake. It would be beneficial to extend this program to include properties within the subwatershed that are not lakeside.

9.3.4.5 Implementor/Approvals

In other Ontario jurisdictions, municipalities have been supported by local conservation authorities in their effort to implement residential source control measures. The City of Greater Sudbury and the Conservation Sudbury share an interest in the protection of Ramsey Lake and may be able to facilitate uptake in residential source controls by sharing expertise and resources. It is important to consider the interdisciplinary nature of a residential stormwater programs and roles project management and municipal staff may need to fill. The Community Engagement Plan may involve engineering, planning, marketing, communications (internal and external with residents), landscaping, operations and maintenance, and other tasks.

Based on the MECP's existing review framework for stormwater management works, residential source control measures on individual properties are not required to be submitted for review and approval through the Ministry's Environmental Compliance Approval program.

9.3.4.6 Costing

The cost of individual marketing components will vary considerably depending on the scope and duration of the community engagement plan for source residential source controls. Cost ranges for individual Community Engagement Plan components are provided in **Table 9.7**.

Table 9.7: Marketing Component Costs

	Marketing Components	Cost Considerations	Estimated Cost for 2-year Program
Development of a marketing plan	Qualitative research	in-person research session: $10,000 per session $100 per participant recruitment costs Report >$10,000	$24,000 - $60,000
	Marketing plan		$15,000 - $50,000
Potential marketing plan components	Social media campaign	$2,500 - $50,000 per month	$60,000 - $1,200,000
	Outdoor signage	Bus exterior - $150-$8,500 Shelter- $150-$2,500 Bench - $75-$500 Bus interior - $20-$125 Billboard - $700-$2,500 (4-week period)	$6,000 - $95,000
	Print advertising	Local paper: $250-$1,000/quarter page $500-$2,500/full-page	$6,000 - $36,000
	Web site		$10,000 - $150,000
	Creative	Total cost depends upon municipality's internal communication resources	$0 - $250,000
	Special events	$250 - $25,000 per event	$1,000 - $50,000
	Demonstration sites	$5,000 to $30,000 per site	$5,000 - $375,000
	Incentives and rebates		$25,000 - $1,000,000
Program benchmarking and tracking	Quantitative survey (telephone, email, on-line) – For tracking purposes only and dependent on size of survey		$10,000 - $100,000

Source: Freeman and Associates, 2008 - Updated for CVC, 2015

9.3.5 Shoreline Works

9.3.5.1 General

The overall goal of this study is to develop a subwatershed management plan to protect, maintain and enhance the surface water, groundwater, and natural resources of Ramsey Lake and its tributaries through environmentally sound policy and management actions (see Section 1.2). As noted in Section 6.1.4, hardened shorelines have a reduced capacity to filter runoff from properties that might contain pesticides or fertilizers, reduce levels of biodiversity along the lakeshore, and pose long-term erosion risks caused by high-energy wave action and scours along hard shore edges, situations which are costly to mitigate. Bio-engineering (or softshore-engineering) efforts are shown to have a variety of positive effects. Studies and previous restoration efforts report that softened shorelines have the ability to provide protection against erosion, reduce run-off and nutrient loading, improve biodiversity by promoting habitat colonization, create and enhance aquatic and terrestrial habitats, and improve overall ecosystem function (Hartig et al. 2011, Russell 2015, and TRCA 2017). Consequently, softening the shoreline of Ramsey Lake will not only create a more visually appealing and natural landscape, but will help protect, maintain, and enhance the natural habitats of Ramsey Lake.

A successful example of bio-engineering can be seen at Tommy Thompson Park (TTP), located minutes away from downtown Toronto, Ontario. TTP is a man-made spit that was created to preserve significant species, enhance aquatic and terrestrial environments, and protect environmentally significant areas. Using a variety of restoration strategies, including those listed in section 6.1.4, TTP has transformed to consist of a complex variety of aquatic and terrestrial habitats that support a diverse community of plant, terrestrial, and aquatic species (see Fig. 9.2). TTP now represents the largest area of natural habitat on the Toronto waterfront, and provides countless opportunities for bird watching, recreational angling, and educational programs. A number of other successful restoration projects have been completed around the Great Lakes (e.g. Great Lakes Areas of Concern; see EC 2011) and along the Detroit River (see Hartig et al. 2011, and Russell 2015).

Figure 9.15: Aerial view of Tommy Thompson Park, Toronto, Ontario, Canada.

9.3.5.2 Existing Programs

Approximately a third of Ramsey Lake shorelines have been artificially hardened through the addition of rip rap, concrete or other structures (**Figure 9.16**). The City currently has in place three programs to facilitate improvements in overall watershed condition and enhance shoreline condition. First, the City of Greater Sudbury's Regreening Program has been implemented for 40 years to rehabilitate area landscapes and watersheds that were affected by historical mining and smelting operations. The Regreening Program involves adding crushed dolomitic limestone and fertilizer, seeding with grasses, planting trees and transplanting forest floor flora. The program has rehabilitated a significant portion (40 to 50%) of the Ramsey Lake watershed. In some cases, shoreline riparian areas have been included in the program. The objectives of the Regreening Program are:

1. To develop and implement plans that facilitate the ecological recovery of Greater Sudbury's industrially damaged landscape;

2. To provide advice, information and expertise to the City's regreening operations that include grassing, tree and shrub planting and other techniques to increase biodiversity and create self-sustaining ecosystems;
3. To increase community involvement in the ecosystem recovery initiative by informing, educating and providing the public with various opportunities for participation;
4. To encourage and foster ecologically sound practices in all forms of human activity within the City of Greater Sudbury; and
5. To foster the continuing participation of the scientific community in the ecosystem recovery efforts.

The Regreening Program is flexible in order to take advantage of outside funding and partnership opportunities as they arise, and to accommodate changing community priorities. The current five-year plan includes priorities of planting to increase biodiversity, research and monitoring, and educational initiatives.

The Shoreline Home Visit Program is a component of the Lake Water Quality Program that is primarily focused on providing advice to landowners of lakefront properties. In this program (since 2012), City staff provide landowners information about: (1) fish habitats, and invasive and exotic species; (2) methods for controlling shoreline erosion and impacts on nearshore habitats; and (3) methods for controlling algae growths and aquatic plants.

The Love Your Lake program was developed by Watersheds Canada and the Canadian Wildlife Federation. The program assesses each property on a lake and provides each landowner with a report detailing their shoreline health and recommendations for they can take to improve lake health. Within the City of Greater Sudbury, 9 lakes have been assessed, including Ramsey Lake and Minnow Lake.

In 2009, a Natural Shoreline Demonstration project was established on Ramsey Lake by a partnership of the City of Greater Sudbury, Science North, and the Source Water Protection Program. Tours of the demonstration project are available, as are workshops to encourage homeowners to improve their shoreline health.

From a policy perspective, the City’s Zoning By-Law directs the establishment of shoreline buffers whereas the Official Plan provides direction for completing and implementing watershed plans, Section 4.41.3 of the Zoning By-Law states that “A shoreline buffer area is to remain in a natural vegetated state to a depth of 12.0 metres from the high water mark of a navigable waterbody.” On residential lots, up to a maximum of 25% of the shoreline area may be cleared adjacent to a navigable water body, but no more than 276 m^2 and no more than 25% of the shoreline length (23 m maximum). For commercial lots, up to 33% of the shoreline buffer area may be cleared. In addition, the Official Plan indicates that “Development or redevelopment on a lot on any shoreline of a lake or river will be subject to site plan control”.

City staff may provide technical assistance during site visits to supply information to property owners concerning current policy and procedures, rehabilitation options and permits that may be required. As part of Conservation Sudbury’s mandate to ensure that homes and people are protected from the threats of flooding and erosion, Conservation Sudbury regulates development and activities adjacent to or in water that may alter or interfere with river or stream valleys, lake shorelines, watercourses, hazardous lands and wetlands. City staff may advise landowners to contact Conservation Sudbury which either issues permits associated with shoreline works, or assists in obtaining permits from OMNRF or DFO, related to in-water works.

The third program, the City of Greater Sudbury Lake Stewardship Assistance Grant Program provides funding (up to $500/yr/recipient) to up to 11 recipients (total of $5500 /year) for activities or events related to environmental stewardship that protect and improve water quality and the natural environment. The funds are typically awarded to lake stewardship associations.

Figure 9.16: Map of Ramsey Lake showing shorelines hardened by land owners (red lines)
Figure Note: from https://www.greatersudbury.ca/content/div_lakewaterquality/documents/Ramsey_Lake_Map.pdf

Figure 9.17: Map of Ramsey Lake showing areas where riparian restoration efforts have been undertaken by the City (green).
[screen grab from http://sudbury.maps.arcgis.com/apps/webappviewer/index.html]

9.3.5.3 Funding Opportunities

In In addition to support from the City and Conservation Authority technical expertise and City funding programs, potential funding support for shoreline rehabilitation is also available from the following provincial grant programs:

1. Ministry of Natural Resources and Forestry's Land Stewardship and Habitat Restoration Program provides up to $20,000 per project per year for initiatives that contribute to the Ontario Biodiversity Strategy. Incorporated organizations such as municipalities, Aboriginal organizations, conservation and non-government organizations, and businesses may apply for funding for projects such as stream restoration, buffer establishment, fish habitat enhancement, upland or terrestrial improvements, wetland restoration, invasive species control or native species introduction. Eligible project costs include direct staff costs, administration, equipment, materials and supplies, and travel.
2. Trillium Foundation's *Investment Strategy for Building Healthy and Vibrant Communities* includes an Action Area for Green People. Three current funding programs are available to support community-based programs, such as shoreline rehabilitation initiatives, that would contribute to the priority outcomes of: 1) More ecosystems are protected & restored; and 2) People reduce their impact on the environment:
    a. **Capital funding** is available for projects to improve community infrastructure that meet the priority outcome of "Conservation and restoration efforts are better planned and more sustainable". Eligible expenses include equipment, direct purchase of land, development costs (plans, legal fees or survey costs), construction, repair or renovation. Grants range from $5,000 to $150,000 for one-year projects.
    b. **Grow funding** is available for: (1) existing projects that extend their reach; or, (2) new projects for the area that have been proven successful by another organization or adaptation of an existing successful project. Eligible project costs include direct staff costs, purchased services, workshops, supplies and materials, travel,

evaluation and other related project costs. Maximum funding of $750,000 is available for two- to three-year projects.

c. **Seed funding** is available for the development of new ideas and different approaches to achieve results for the Green People action areas of: 1) People participate in ecosystem, conservation and restoration efforts; 2) Conservation and restoration efforts are better planned and more sustainable; 3) People connect with the environment and understand their impact on it; 4) People and resource users take deliberate actions to benefit the environment; and 5) Mechanisms are developed to promote responsible resource stewardship. Grants range from $5,000 to $75,000 for one-year projects. Eligible project costs include direct staff costs, purchased services, workshops and meetings, supplies and materials, travel, evaluation and other direct project costs.

d. An upcoming **Transformation** grant program is being introduced to support collaborative initiatives that use collective strategy and transformative action to tackle complex community issues and create lasting change at the regional and provincial level.

3. TD Canada Trust's *Friends of the Environment Foundation* provides annual grants for initiatives such as Citizen science projects in public green spaces, park revitalization & restoration work on public lands. Eligible organizations include registered Canadian charities, educational institutions, municipalities and Aboriginal groups.

4. The *Evergreen Program (Evergreen Canada)* "actively engages Canadians in creating and sustaining healthy and dynamic urban environments in schools, public spaces, housing and transit systems, and communities at large". Grants are available for not-for-profit organizations for programs of school ground greening, safeguarding sources of fresh water, and supporting community gardens. Eligible projects under the safeguarding sources of fresh water include restoring native plants in riparian, wetland and shoreline areas, collecting water quality data and engaging the public in the care of local water systems.

The above noted expertise, policies and funding programs offer significant potential support for municipal, conservation authority and community led initiatives for softening or rehabilitating the

Ramsey Lake shoreline. The Ramsey Lake shoreline rehabilitation strategy is recommended to be led by the City of Greater Sudbury and delivered in partnership with Conservation Sudbury and committed community groups. These groups are expected to include some or all of the Ramsey Lake Stewardship Committee and the Coalition for a Livable Sudbury whose membership includes a number of organizations with interest in Ramsey Lake, such as: the Greater Sudbury Watershed Alliance, the Minnow Lake Restoration Group, Minnow Lake Community Action Network, Vermillion River Stewardship Committee, and Junction Creek Stewardship Committee.

9.3.5.4 Design Guidance and Policy Considerations

With the City and Conservation Authority working in partnership with committed community organizations, priority shoreline segments can be identified and an approach developed for hard shoreline structure removal and replacement with bioengineered shorelines that quickly establish native vegetation. The approach would include a combination of:

5. Shoreline landowner education efforts conducted by community experts (such as the Vale Living with Lakes Centre, Laurentian University, community organization and resident experts), Conservation Sudbury and Greater Sudbury staff;

6. Continued use and potential expansion of the Natural Shoreline Demonstration project to encourage softening of shorelines on City and Conservation Sudbury (public) lands along Ramsey Lake;
7. City, Conservation Authority and community partnership programs to encourage and support landowners in softening shorelines on private property. Landowner supports could include technical advice, lending of equipment, potential volunteer resources, provision of native shrub and tree stock for planting, and monitoring/repair of works after establishment.

After the City has developed a detailed strategy for softening the Ramsey Lake shoreline, an appropriate funding strategy could be developed that builds upon the City's current Re-Greening Program and accesses some or all of the provincial funding programs provided by MNRF, the Trillium Foundation, TD Canada Trust Friends of the Environment and Evergreen. The Ramsey Lake Shoreline Rehabilitation Strategy could have components led by the City, Conservation

Sudbury or a community organization, depending upon the grant eligibility requirements.

Benefits to Ramsey Lake that would result from shoreline softening include:

- Establishment of a native shoreline vegetation buffer area that becomes more effective over time;
- Long-term stabilization and protection of shorelines from erosion;
- Dissipation of wave energy to prevent erosion of adjacent shoreline areas;
- Improvements in water quality and stormwater management;
- Sustainable ecological functions that provide food and cover for wildlife, and drought resilience; and
- Improved aesthetics that more cost effective than hard structures (which degrade over time) to establish and maintain.

9.3.5.5 Future Studies.

The following next steps are recommended to provide further improvements to the shoreline of Ramsey Lake:

8. Prioritize shoreline areas for naturalization:
    a. Quantify public and private shoreline segments that are currently artificially hardened. Mapping in Figure 9.7 shows areas of hard shoreline, but some of those are naturally hard and would not be appropriate for rehabilitation / naturalization,
    b. Classify shorelines to identify opportunities for naturalized protection (see **Figure 9.18** for proposed categories);
    c. Quantify costs associated with naturalization of public and private shoreline segments. Costs per unit shoreline can be approximated from syntheses of previous works (e.g., Kilgour & Associates and AECOM, 2009, 2011);
    d. Prioritize shorelines for rehabilitation;
9. Estimate costs for rehabilitation / enhancement of shorelines that are highest priority;
10. Secure funding from City or other agency funds / programs;
11. Integrate shoreline rehabilitation /enhancement program components with those of other City programs as described above (City Re-Greening and Shoreline Home Visits Programs and Conservation Sudbury programs) and as follows:

a. Collection of data and market research to Gauge Community Interest in implementing lot-level stormwater management controls (see Section 9.3.2) can also include questions related to shoreline management and restoration on private property. This information on community preferences and understanding can then be applied to design program elements for shoreline restoration and enhancement;
b. Community Engagement Plan proposed for implementation of residential stormwater source controls (see Section 9.3.3) can be expanded to include information and incentives for shoreline restoration / enhancement. Relevant opportunities from the Community Engagement program include targeted "Ask a Designer" community events, demonstration site tours, promotional/educational signs and shoreline management guides;
c. Terrestrial Ecological Restoration initiatives to enhance habitat and improve natural heritage connections can complement shoreline restoration and potentially access funding for tree and shrub planting that may be obtained from Tree Canada and Forests Ontario (see Section 9.3.5);
d. Septic Systems management (see Section 9.3.10) program components of a proposed septic system inspection program, Community Improvement Program funding and a City/Conservation Authority Stewardship Program could include relevant assessment, funding support and information relevant to shoreline restoration and enhancement;

12. Develop designs for shoreline restoration and enhancement and implementation schedule;
13. Monitor structural integrity and effectiveness of the restored / enhanced shorelines and search for new erosion sites and deteriorated shoreline areas that may develop over time. Shoreline monitoring could be conducted as an extension of the proposed program for erosion monitoring of streams that is described in Section 9.3.6.

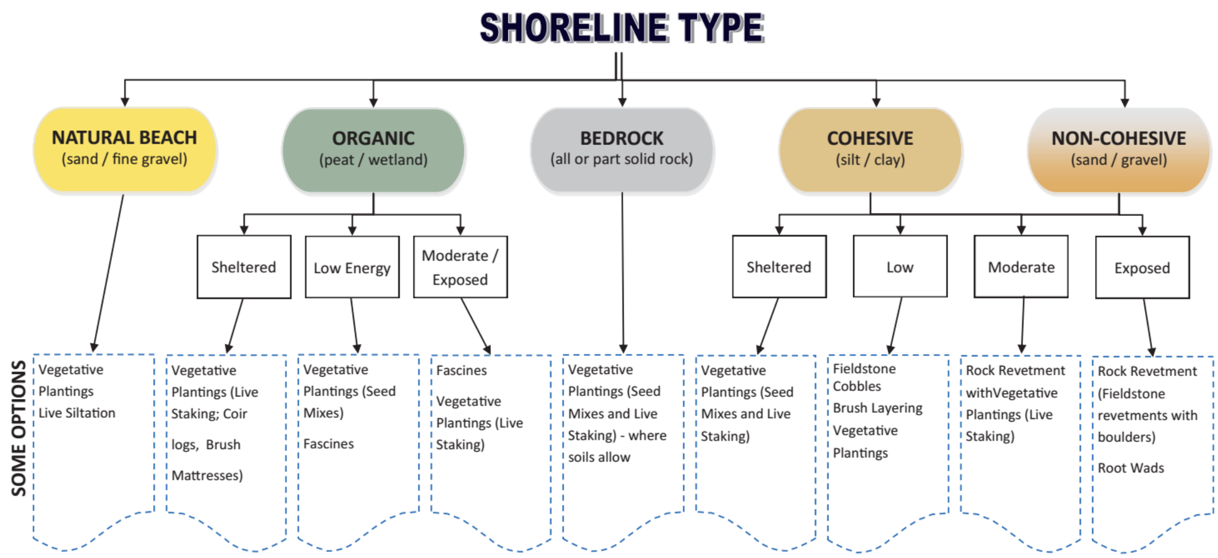


Figure 9.18: Shoreline classification scheme, with naturalized protection measures. Modified from DSSLSN and OMNRF (2014).

9.3.5.6 Implementor/Approvals

The City will be the primary implementor of this project. It is recommended that the City collaborate with Conservation Sudbury to acquire funding, develop a list of priority sites, develop specific detailed designs for shoreline restoration / enhancements and implement the identified shoreline improvements.

MNRF and/or MECP permits may be required if projects (shoreline enhancements) (1) encroach below the average lake water level onto lake-bed owned by the province (MNRF permit), or (2) are considered to impact Species at Risk (MECP permit). Under the Endangered Species Act, the MECP can grant permits or other authorizations for activities that would otherwise not be allowed, with conditions that are aimed at protecting and recovering species at risk. Shoreline improvements are likely to significantly enhance habitats for Snapping and Blanding's turtles, both of which have been reported as being present in or near Ramsey Lake (**Figure 3.50**).

DFO administers development requirements relating to aquatic habitat under the Fisheries Act. DFO review of shoreline works is not required if the work involves (1) shoreline/bank stabilization such as rock protection, plantings and bioengineering, (2) if there is no temporary or permanent increase in existing footprint below the high-water mark, and (3) if there is no new temporary or permanent fill placed below the high water mark (http://www.dfo-mpo.gc.ca/pnw-ppe/activities-activites-eng.html). DFO review may be required if structures are permanently placed on the lake bed.

Shoreline works (restoration / enhancement) will require review by Conservation Sudbury under Ontario Regulation 156/06 - Development, Interference with Wetlands and alterations to Shorelines and Watercourses, and may require a Permit depending on the nature of the proposed work.

9.3.5.7 Costing

Costing for shoreline works is variable, depending on the work that is required. Rough 'rules of thumb' costs for various restoration activities are provided in two reports by Kilgour & Associates Ltd. and AECOM (2009, 2011) to Fisheries and Oceans Canada. Those reports can be made available to the City upon request. Relevant estimates from those reports are provided in the **Table 9.8** below, with dollar values expressed in 2018 equivalents.

Table 9.8: costs for various restoration activities

<table>
<tr><th rowspan="2">Main Components of Shoreline Work</th><th rowspan="2">Unit</th><th colspan="2">Unit Rate ($ per unit)</th></tr>
<tr><th>Low</th><th>High</th></tr>
<tr><td>Inventory of shoreline categories</td><td>Survey</td><td>10,000</td><td>25,000</td></tr>
<tr><td>Shoreline restoration / enhancement</td><td>m^2</td><td>4</td><td>250</td></tr>
<tr><td>Riparian zone plantings</td><td>m^2</td><td>1</td><td>21</td></tr>
<tr><td>Shoreline Protection</td><td>m</td><td>1000</td><td>6000</td></tr>
<tr><td>Local access contingency</td><td>m^2</td><td></td><td>140</td></tr>
<tr><td>Construction contingency</td><td colspan="3">Up to 20% of construction estimate</td></tr>
<tr><td>Size of project contingency</td><td colspan="3">Up to 30% of construction estimate for small < $200,000 projects</td></tr>
<tr><td>Engineering Design</td><td colspan="3">Up to 10% of construction costs</td></tr>
</table>

Main Components of Shoreline Work	**Unit**	**Unit Rate ($ per unit)**	
		Low	**High**
Construction Management	Up to 10% of construction costs		
Post-construction monitoring	Up to 10% of construction costs		

Table Notes: estimates are adjusted from Kilgour & Associates and AECOM (2009, 2011).

As described above, there are opportunities for funding of initiatives for assessment, community engagement, design and implementation of shoreline restoration and enhancement initiatives. These opportunities include:

- MNRF funding of up to $20,000 per year through the Land Stewardship and Habitat Restoration Program for design and delivery of shoreline buffer establishment, invasive species control and introduction of native species;
- Trillium funding for innovative community engagement initiatives, available for municipalities and community groups;
- TD (available for municipalities, charitable and educational institute organizations) and Evergreen (available for non-government organizations) funding for community-based monitoring and restoration initiatives on public lands; and
- Tree Canada funding for tree and shrub planting along public space shorelines.

9.3.6 Terrestrial Ecologic Restoration

9.3.6.1 General

As discussed in **Section 6.1.5**, ecological restoration presents an opportunity to improve degraded terrestrial and aquatic ecosystems, improve ecosystems' resiliency to the effects of climate change, improve water quality, improve stormwater management, create habitat, re-establish ecological linkages, and enhance ecological diversity. For example, reforestation can utilize soil nutrients like nitrogen and phosphorus, sequester carbon, and stabilise soil, reducing sediment and nutrient loading to water bodies. Trees benefit stormwater management by increasing interception, evapotranspiration, and soil storage. The US EPA reports that a 7.5 m diameter tree can manage 25 mm of rainfall from approximately 220 m^2 of impervious area (EPA, 2016). Restoration also has the potential to foster a healthy relationship between nature and culture as people have more opportunities to interact with nature.

The City of Greater Sudbury's Regreening Program has had a significant effect on the ecology of the Ramsey Lake Subwatershed since the program's inception 40 years ago. The preferred alternatives described above include the use of LID measures within rural road rights-of-way (Section 6.2.1) and bioengineered bank treatments at erosion sites (Section 6.2.3). Implementation of both of these alternatives have the potential to contribute to the rehabilitation and enhancement of the natural heritage system. However, prioritizing other types of ecological restoration will likely result in a greater benefit to the ecological form and function of the NHS within the City of Greater Sudbury.

Recommended priorities for terrestrial habitat enhancement within the Ramsey Lake subwatershed include restoration measures that will increase forest cover within the Subwatershed, enhance wetlands, establish connections between Natural Heritage Features, and enhance degraded ecosystems. These measures are included as it is anticipated that they will provide the greatest ecological benefit for the amount of effort and resources required for their implementation. Additional terrestrial habitat enhancement opportunities are listed in **Section 6.1.5**.

9.3.6.2 Targets/Objectives

Table 9.9, reproduced below, summarizes the goals and objectives presented earlier in **Section 5**. Specific goals and objectives which ecological restoration has the potential to influence/aid are highlighted in bold, below **(Table 9.9**).

Table 9.9: Goals and Objectives Influenced by Ecological Restoration

Goals	Objectives
1. Enhance the Hydrologic Regime	1. Minimize flood risk; 2. Re-establish natural hydrologic cycle; 3. Ensure natural channel stability and protect against channel erosion and sedimentation; 4. Protect/Support aquatic communities; 5. Manage surface water withdrawals; and, 6. Support terrestrial communities.
2. Restore, Maintain, and Enhance Water Quality	1. Support reasonable uses for: i. Aesthetics, and ii. Wildlife; 2. Prevent eutrophication/algal growth; 3. Protect groundwater quality to support drinking water supply, aquatic and terrestrial communities; and, 4. Support aquatic communities.
3. Conserve, protect, and restore a healthy aquatic ecosystem	Contribute to achieving healthy aquatic communities, including warmwater or coolwater fisheries as appropriate.
4. Conserve, protect, and restore a healthy terrestrial ecosystem	1. Protect, restore, or enhance native terrestrial plant and animal species, community diversity, and productivity; and, 2. Protect, restore, or enhance the integrity of the watershed ecosystem through an integrated approach of natural areas, habitats, and connected links.

9.3.6.3 Future Studies

Addressing Data Gaps

As identified in Section 3.3.6.8, there are several gaps in the available state of knowledge regarding terrestrial ecological resources within the Ramsey Lake subwatershed. In particular, lack of data on vegetation communities and flora presents a limitation to restoration efforts. Increasing knowledge about the various vegetation communities and flora species present within the watershed can aid in restoration efforts in the following ways:

- Increase knowledge about reference communities for use in guiding future forest restoration projects and enhancement/supplementary plantings;
- Identify areas currently colonized by invasive species so that management plans can be developed and implemented;
- Increase opportunities for native seed collection for use in restoration efforts;
- Aid in identification and enhancement of significant wildlife habitat; and,
- Aid in creating habitat for SAR and other species of conservation concern.

As such, it is recommended that assessments of natural and semi-natural vegetation communities as well as botanical inventories of natural vegetation communities and sites planned for restoration be completed in support of the ecological restoration efforts being/to be implemented in Sudbury.

Emerald Ash Borer

The emerald ash borer (*Agrilus planipennis*, **Figure 9.19**) is an exotic insect pest specific to ash trees (*Fraxinu*s spp.). The insect larvae burrow under the bark of trees and feed upon living tissue, eventually causing tree mortality. As ash is a relatively ubiquitous mid-successioanl genus, ash mortality will have a major impact on the biodiversity of both natural and urban areas; especially in riparian and floodplain areas where the genus is commonly found. Some of the effects of ash mortality include alteration of nutrient cycles, reduction of habitat for fauna, alteration of the woodland understory through changes to natural successional patterns, and encouraging growth of invasive species (Ontario Biodiversity Council, 2015). First detected in Windsor, Ontario in 2002; the emerald ash borer (EAB) is spreading throughout the province. In 2013, EAB was recorded in Algoma district (Natural Resources Canada, 2016). The Canadian Food Inspection Agency (CFIA) considers the Muskoka-Sudbury corridor to be at high risk of

Figure 9.19: Emerald ash borer (photo credit: Ontario MNRF)

infestation (Kerr, 2010). Greater Sudbury is located within an Emerald Ash Borer Regulated Area as identified by the CFIA. Movement of firewood is cited as a major contributing factor in the insect's spread. Furthermore, warming temperatures may result in a decrease in wintertime laval die-offs.

Thousands of ash trees have been planted through the City of Greater Sudbury's Regreening Program (see summary in **Section 6.1.5**). To mitigate the potential negative ecological impacts of ash tree loss, the following proactive measures are recommended:

- Establishment of a mechanism for detection of emerald ash borer which may include education and outreach;
- Education regarding emerald ash borer dispersal mechanisms (e.g. movement of firewood), potentially in collaboration and/or consultation with the CFIA through:
    - Website content;
    - Brochures/handouts;
    - Stewardship outreach events;
    - Newspaper and radio ads.
- Supplementary tree planting in areas dominated by or with a significant percentage of ash trees, including prioritization of supplementary diverse plantings in riparian areas; and,
- Continually update the list of species planted as part of the Regreening Program.

Implementation of the above listed strategies is summarized below in **Table 9.10**.

Table 9.10: Summary of Implementation Strategy for Recommended EAB Strategies

Action	Responsibility for Implementation	Potential Partners	Suggested Timeframe
Establishment of a mechanism for detection of EAB	• CFIA • City of Greater Sudbury	• CFIA • MNRF • Conservation Sudbury • Citizens Groups	Short term (1-3 years)
Education regarding EAB detection, dispersal mechanisms,	• City of Greater Sudbury	• CFIA • MNRF • Conservation Sudbury	Short term (1-3 years)

Action	Responsibility for Implementation	Potential Partners	Suggested Timeframe
ecological impacts, etc.		• Citizens Groups	
Supplementary tree planting in areas dominated by or with a significant % of ash trees, including prioritization of supplementary diverse plantings in riparian areas.	• City of Greater Sudbury • Conservation Sudbury	• VETAC • Conservation Sudbury • Greater Sudbury Climate Change Consortium	Identification of priority areas: short term (1-3 years) Planting: Medium term (5-10 years)
Continually update the list of species planted as part of the Regreening Program.	• VETAC	• Conservation Sudbury	Ongoing

9.3.6.4 Design Guidance and Policy Considerations

It is recommended that the identification of priority areas for a) reforestation, b) wetland enhancement, c) establishment of connections between Natural Heritage Features, and d) enhancement of degraded ecosystems be guided by a science-based approach administered/implemented by the City of Greater Sudbury and Conservation Sudbury in partnership with the VALE Living with Lakes Centre and local community organizations. Restoration efforts could build upon the efforts already implemented through the City of Greater Sudbury's Re-Greening Program; potentially and not limited to establishing forested connections between natural areas, supplementary plantings in areas already subject to reforestation, enhancing wetlands and other ecosystems. It is suggested that restoration projects that aid in achieving the highest number of goals and objectives (see **Table 9.9**) be prioritized, especially if there is the potential to benefit SAR.

9.3.6.5 Approvals

Restoration efforts located within or in close proximity to hazard lands regulated by the Conservation Sudbury will require permits from the Authority prior to implementation. Restoration projects in or those that have the potential to impact SAR and their habitat will require consultation with the MECP and may also require a permit under the Endangered Species Act.

9.3.6.6 Funding Opportunities

In addition to the four potential funding sources detailed above in Section 9.3.5.3, potential funding sources for terrestrial ecological restoration include the following:

1. Trees Ontario provides community tree grants and partners with other organizations and companies to provide funding and support for tree planting and reforestation projects in Ontario. For example, the CN (Canadian Railway) Eco-Connections grant provides up to $25,000 in funding per project to municipalities, Indigenous communities, local community groups, business improvement associations, and not-for-profit organizations. Trees Ontario also provides community tree grants to projects which support community greening.
2. Forests Ontario (the collective name for the recent merger of Trees Ontario and the Ontario Forest Association) is a not-for-profit organization involved with tree planting, education and outreach. Forests Ontario is responsible for implementing the government of Ontario's *50 Million Tree Program*, whereby the province has committed to planting 50 million trees by the year 2025. To be eligible for the program, the following criteria must be met:
   a) At least one hectare (2.5 acres) of suitable land.
   b) Land that is open, or mostly open, and has not been defined as a woodland since December 31, 1989, per the Forestry Act.
   c) To sign a 15-year management agreement to maintain any trees that have been planted.
   d) Practice good forestry management habits.
   e) Assume the additional costs associated with the ongoing maintenance of planted trees
3. Ontario Aggregate Resources Corporation administers the *Management of Abandoned Aggregate Properties Program*, a program which fully funds and implements restoration programs on abandoned pits and quarries of all sizes that were not licenced following the establishment of the Aggregate Resources Act in 1990. There may be opportunities within the City of Greater Sudbury for such rehabilitation efforts.

9.3.7 Stream restoration

9.3.7.1 General

A fluvial geomorphic assessment of the four main watercourses (i.e., Frobisher, Roger, Eugene and Keast Creek) within the Ramsey Lake subwatershed was undertaken in the fall of 2017. Overall most erosion issues within the subwatershed were not considered urgent, thus do not require immediate mitigation. Of the 11 erosion sites and nine (9) maintenance issues were identified, corresponding to bank erosion, channel bed scour, culvert blockages, and sediment deposition, only one (1) erosion site (ES-K-01) was identified as a High priority site, due to the risk to the adjacent road embankment (South Bay Road). Furthermore, the erosion site was expected to be classified as Schedule B within the Municipal Class Environmental Assessment process. The remaining, erosion sites and all the maintenance issues were identified as secondary opportunities (i.e., Moderate and Low priority sites) as they have lower levels of risk and rate of degradation. Summaries of the erosion sites and maintenance issues are provided below **Table 9.11** and **Table 9.12.**

Table 9.11: Summary of erosion sites ranked based on priority

Creek	ID	Reach	Description of Erosion	Approx. Length	Risks	Priority Ranking	Total Technical Score
Keast	ES-K-01	1	Erosion along the channel bed and banks has resulted in channel widening and impingement of the private property and road embankment	100-150m	Private property and Chemin South Bay Road	High	80
Frobisher	ES-F-03	7	Scour pool has formed at outlet of eastern CSP.	localized	Scour has started to undermine eastern CSP and could compromise the long-term stability of the culvert.	Moderate	67
Roger	ES-R-02	3	Scour pool has formed at culvert outlet	localized	Scour has started to undermine structure and could compromise the long-term stability of the culvert	Moderate	67
Frobisher	ES-F-04	8	Sediment deposition at culvert inlet	~300m	Deposition is reducing culvert capacity, could increase the risk of flooding	Moderate	66
Eugene	ES-E-03	3	Fine sediment deposition/runoff within creek is creating deteriorate habitat conditions and decreasing the hydraulic capacity of the channel. Straw bail dam at culvert inlet is causing blockage.	50-100m	Increased flooding risk to residential development	Moderate	63
Roger	ES-R-03	5	Scour pool has formed at culvert outlet	localized	Erosion is minor, however should be mitigated before culvert is compromised	Moderate	60
Frobisher	ES-F-02	5	Erosion along channel banks has resulted in undercutting and slumping	~150m	Erosion of private lands and park lands, and potential impact the Rita St.	Low	59
Roger	ES-R-01	2	Slumping gabion baskets along retaining wall.	~25m	Private property (Finlandia Retirement Community parking lot)	Low	57
Eugene	ES-E-02	2	Sediment deposition at culvert outlet resulting in backwatering of culvert.	~50m	Deposition is reducing culvert capacity, could increase the risk of flooding at Bancroft Drive	Low	53
Eugene	ES-E-01	1	Scour pool has formed at culvert outlet	localized	Scour has started to undermine structure and could compromise the long-term stability of the culvert	Low	52
Frobisher	ES-F-01	4	Erosion along channel banks has resulted in undercutting	~80m	None	Low	50

Table 9.12: Summary of maintenance issues ranked based on priority

Creek	ID	Reach	Description of Erosion	Risks	Score	Priority Ranking	Recommended Maintenance Action
Frobisher	MI-F-05	6	Dense vegetation in channel at culvert outlet is reducing the culvert capacity	Increased flooding risk to residential area upstream of Bancroft Drive	5	High	Maintain vegetation through the growing season to ensure capacity is maintained.
Roger	MI-R-01*	3	Debris jam (i.e., leaves and organic matter) is blocking culvert inlet and resulting in a backwater condition.	Increased flooding risk to Finlandia retirement community	4	Moderate	Remove debris
Roger	MI-R-02*	4	Slumping gabion baskets within headwall/road embankment	Failure of retaining wall would compromise the structural integrity of Bancroft Road	4	Moderate	Secure or reinforce gabions, or replace entire retaining wall with a longer-term solution.
Frobisher	MI-F-03	4	Debris jam (i.e., rail track ties and other woody debris) at culvert outlet has resulted in the outlet being half blocked.	Flooding risk to the CN tracks	3	Moderate	Remove debris and sediment
Frobisher	MI-F-04	5	Debris jam (i.e., leaves and organic matter) is blocking culvert inlet and resulting in a backwater condition.	Increased flooding risk to area upstream of Wilfred Street, including school.	3	Moderate	Remove debris
Frobisher	MI-F-06	10	Rill erosion along the road embankment has created scour around the Kingsway culvert inlet	Culvert and Kingsway Road	3	Moderate	Implement headwall and hardened, mitered slope treatment
Keast	MI-K-01	2	Rill erosion along the road embankment has created scour around the South Bay Road culvert outlet.	Culvert and South Bay Road	3	Moderate	Implement headwall and hardened, mitered slope treatment
Frobisher	MI-F-02	4	Sediment deposition upstream of storm water pond	Flooding to neighbouring private lands	Y	Moderate	Dredge creek to remove sediment
Frobisher	MI-F-01	1	Sediment deposition at confluence with lake	Flooding to neighbouring private lands	Y	Low	Dredge creek to remove sediment

* Location is on private property and partly deals with private infrastructure.

9.3.7.2 Targets/Objectives

In reviewing the goals and objectives outlined in Chapter 5.0, the following objectives are specifically relevant to the stream restoration:

- Ensure natural channel stability and protect against channel erosion and sedimentation
- Protect/Support aquatic communities

9.3.7.3 Future Projects and Studies

Detailed Design for Erosion Site ES-K-01

The study and resulting recommended retrofit work for ES-K-01 have been completed following Schedule B of the Municipal Class EA process and therefore can proceed directly to detailed design and implementation. The preliminary conceptual designs and costing have been provided in Section 6.2.3.

Addressing Remaining Erosion Sites

It is recommended that the City also address the remaining erosion sites. The remaining sites have a lower priority than ES-K-01, however they still pose erosional risks, and should be addressed before the erosion is exacerbated and emergency works are required. It is recommended that the City implement a Channel Maintenance program and an Erosion Monitoring program to help address the remaining erosion issues.

Channel Maintenance Program

A channel maintenance program would involve small scale erosion maintenance, which could be undertaken by the City’s operations and maintenance staff. This would include things such as removing debris jams, vegetation maintenance, storm sewer outfall repairs. As noted above, most of the erosion site and maintenance issues identified are associated with the culverts and include such issues as scour pools and vegetation/sediment depositions. These issues can be addressed with relative minimal intervention to the existing infrastructure. The program can start with addressing the secondary erosion sites and maintenance issues identified as part of this report. Further monitoring would be required to identify issues as they arise.

Erosion Monitoring

It is recommended that the City continue to monitor the main watercourses within the subwatershed. By implementing a monitoring program, the City will be able to identify and track erosion sites. This will allow for more preventative erosion restoration works, which is generally more cost effective and smaller scale. Furthermore, monitoring of the watercourses can provide a context for erosion and channel adjustments within the Ramsey Lake subwatershed. As with this study, the primary deliverable will be a comprehensive inventory of erosion where each segment or issue is well documented at both the site and reach context. This allows identification of future projects, and reprioritization of old projects, should erosion have exacerbated. It is recommended that the same technical scoring and maintenance code scoring be used for later investigations, to allow for transparent comparison to the results presented in this report. The details of the scoring methodology are provided in **Appendix C**.

9.3.7.4 Design Guidance and Policy Considerations

The study and resulting recommended retrofit works have been completed following Schedule B of the Municipal Class EA process and therefore can proceed directly to detailed design and implementation. The City will consult with landowners where works on private property are required. It is recommended that the City retain an experienced consultant, that is able to collect the necessary data (e.g., topographic survey, sediment sampling, flow measurements), complete the necessary analysis (i.e., hydrologic, hydraulic and sediment transport assessment), acquire the necessary permits (e.g., DFO, Conservation Authority), and provide detailed drawings for construction.

As many of the erosion site and maintenance issues identified were associated with culverts and stormwater outfalls, more erosion and scour protection at these locations could protect against these issues. It is recommended that design guidance for inlet and outlet structures for culverts and stormwater outlets be incorporated into the City's stormwater design criteria. Inlet and outlet structures such as headwalls and wingwalls help to retain road embankments, and protect the culvert/pipe from scour and erosion. Wing walls also help with flow contraction and expansion at culverts, and reduce turbulent, erosional flows. There are a variety of OPSD and OPSS for outlet structures which can be used for examples or standard recommendations also. This design guidance can then be implemented during culvert or channel restoration projects, or when new culverts or stormwater outfalls are built.

9.3.7.5 Implementor/Approvals

The City will with the primary implementor of this project. It is recommended that the City collaborate with Conservation Sudbury to acquire funding and outline the requirements for the detailed design. Establishing the lines of communications early, ensures that the major stakeholders are aware of the City's intensions and can make the process of acquire permits easier.

MECP permits will only be required if the project may impact Species at Risk. Under the Endangered Species Act, the MECP can grant different types of permits or other authorizations for activities that would otherwise not be allowed, with conditions that are aimed at protecting and recovering species at risk.

DFO administers development requirements relating to aquatic habitat under the Fisheries Act. This applies to work being conducted in or near waterbodies that support fish that are part of or that support a commercial, recreational or Aboriginal fishery. DFO review will be required for works at ES-K-01.

A permit under Ontario regulation 156/06 - Development, Interference with Wetlands and alterations to Shoreline Watercourse will be required through Conservation Sudbury for in-water works.

9.3.7.6 Costing

A preliminary cost estimate for the construction of the preferred alternative for erosion site ES-K-01 (including engineering services and contingency) is provided below in **Table 9.13**. The estimated costs are based on similar projects that were completed within southern Ontario. Cost estimates for similar project in the Sudbury area were not available for comparison, therefore there could be some local variability in the costs that is not accounted in this cost estimate. A range of costs have been provided, representing the maximum and minimum anticipated costs for the project, based on previous projects. Please note that this estimate is preliminary and will need to be refined at the detailed design stages.

Table 9.13: Preliminary cost estimate for stream restoration works at ES-K-01

Main Components of Construction	Unit	Value	Unit Rate		Total		
			Low	High	Low	Moderate	High
Keast Creek at South Bay Road (Reach 01, Erosion Site ES-K-01)							
Preferred Alternative - Reach Based Works							
Construction Costs							
1. Comprehensive Channel Restoration (armourstone treatment along road embankment and vegetative buttress along opposing embankment)	m	150	$2,000	$2,250	$300,000	$318,750	$337,500
2. Vegetation Replanting Program	m	150	$200	$400	$30,000	$45,000	$60,000
Engineering Design & Approvals (15% of construction costs)	-	-	-	-	$49,500	$54,563	$59,625
Contingency (15%)	-	-	-	-	$56,925	$62,747	$68,569
				TOTAL	**$436,425**	**$481,059**	**$525,694**

9.3.8 Groundwater Protection

9.3.8.1 General

The Ramsey Lake Subwatershed is characterized by several unique geological features which result in significant variation in groundwater recharge. As a subwatershed average, approximately 14.8% of precipitation is directed to groundwater recharge, approximately 15.0% is directed to the Lake via inflow from the Soil Zone and 2.4% is directed to streams via interflow. The undulating topography and high bedrock in the watershed results in high rates of depression storage and evapotranspiration in many areas of the watershed.

9.3.8.2 Targets/Objectives

The primary objective of the groundwater management plan for the Ramsey Lake watershed should be on the preservation of groundwater recharge within the SGRA zones. The SGRA zones provide baseflow support for the riparian zones as well as storm flow runoff attenuation.

The SGRA protection plan must recognize that the SGRA zones receive significant runoff (and resulting groundwater recharge) from:

1. The surrounding upland areas; and
2. The upgradient riparian areas and streams where they enter into the SGRA zones.

The simulations indicate that a buffer of approximately 200 m around the SGRA zones would preserve the majority of the overland runoff that inflows to the SGRA features. LID infiltration and runoff management measures (including both water quantity and water quality measures) within this buffer may also be effective.

Where streams enter the SGRA zones (for example, where Rogers Creek enters the SGRA zone in **Figure 9.20**), this buffer should extend as much as 300 m upgradient of the SGRA zone. This will preserve riparian inflows into the SGRA zone.

There is also reason to believe, based on the depositional model of the glacial sediments, that a number of the wetlands may also overlie overburden sediments and locally significant aquifer system. These overburden deposits may provide both baseflow and deeper fracture flow throughout the year. For example, the groundwater upwelling noted in Moonlight Bay is likely supported by wetland and overburden storage that reaches the bay through the fracture and fault network. As with the SGRA protection plan, wetland protection should include a buffer to ensure runoff to the wetlands is preserved.

9.3.8.3 Future Studies.

Expanding the monitoring of surface water flows and both groundwater and lake levels is essential to improving the understanding and long-term management of the water budget. A priority should be placed on the monitoring of Frobisher, Rogers and Eugene Creek, as the water budget simulations indicate that they are all at risk of impact from the Kingsway development.

The results from the simulations, particularly around the headwaters of Eugene Creek, indicate the complex hydrologic response to land development that can occur in this watershed. Both recharge and runoff are predicted to locally increase, and the resulting increase in groundwater levels may affect drainage patterns, storm water pond design, and groundwater seepage across a larger area. Additional surface and groundwater investigations and simulations are necessary at the site plan design stage to confirm and mitigate these effects.

The City should consider compiling a central database of high-quality borehole logs and water levels to supplement and expand on the MECP water well record database. The MECP database structure is designed for private water wells and is not sufficient to support engineering investigations, watershed management and the analysis of surface water and groundwater interactions.

9.3.9 Flood Mitigation

9.3.9.1 General

In investigation the existing condition of the Ramsey Lake subwatershed 15 buildings were identified to be within the regional floodplain (13 buildings along Frobisher Creek and two (2) along Roger Creek). One building, the former Canoe Club building in Bell Park, is frequently flooded in the spring. Furthermore, seven (7) road crossings were identified to be inundated during the regional event. Details regarding the floodline delineation and hydraulic analysis can be found in **Section 3.2.3.**

Five (5) flood risk areas (FRA) within the Ramsey Creek subwatershed were identified, by identifying areas with buildings within the floodplain, significant spills or backwatering. By determining the FRA, localized causes of flooding could be defined, and mitigation solutions relevant to the problem can be suggested. The locations of the FRA are shown in Figure 9.20, and detailed summaries of each of the FRA can be found in **Chapter 6.2.4.**

Based on considerations of study objectives, existing environmental conditions, and the requirements of the Environmental Assessment Act as stipulated in the Municipal Class Environmental Assessment document (Municipal Engineers Association, 2007), a long list of traditional and non-traditional flood control measures were proposed for evaluation. For each of the FRA flood mitigation strategies were considered, which identified a method of mitigating the flood risks. A preliminary alternative solution was selected for each of the mitigation methods, which met the unique constraints and opportunities of each FRA.

Following evaluation criteria based on Natural Environment, Social/Cultural, Economic, and Technical considerations, the most effective alternatives in addressing criteria requirements were brought forward. and an evaluation of the preliminary alternatives was undertaken which identified a preferred treatment solution for each FRA. A summary of the preferred alternatives for each FRA is provided below in **Table 9.14** and further details regarding the evaluation can be found in **Chapter 6.2.4**. A summary of the recommended culvert sizes for the preferred alternatives for FRA 2, 4 and 5 is provided in **Table 9.15.**.

Table 9.14: Summary of preferred alternatives for flood mitigation

FRA	Description	Preferred Alternative	
		Mitigation Strategy	Treatment Solution
1	Frobisher Creek at Ramsey Lake	Preventative Program	Retrofit to Frobisher Pond to increase peak flow storage
2	Frobisher Creek at Greenwood Dr.	Structural Measures	Widen Greenwood Dr. culvert. Minimum hydraulic conveyance target meeting CSG and MTO design standards
3	Frobisher Creek between Railway and Bancroft Dr.	Emergency Strategies	Construct a berm along the banks of Roger Creek through the Finlandia Retirement Community
4	Roger Creek between 4th Ave. and Railway	Structural Measures	Widen 4th Ave. culvert. Minimum hydraulic conveyance target meeting CSG and MTO design standards
5	Keast Creek	Structural Measures	Widen South Bay Rd. and Keast Dr. culvert. (potentially Arlington Blvd also). Minimum hydraulic conveyance target meeting CSG and MTO design standards

Table 9.15: Summary of culvert dimensions for preferred alternatives

FRA	Road	Existing Culvert		Proposed Culvert	
		Dimensions	Capacity	Dimensions*	Capacity
2	Greenwood Dr.	Elliptical CSP 2m high, 3m wide	10.5 m^3/s	Concrete box culvert, 6m wide, 2.5m high	> 25 yr flood (~25.5 m^3/s)
4	4th Ave.	Circular concrete pipe, 0.6m diameter	1.0 m^3/s	Concrete box culvert, 2m wide, 2m high	> 25 yr flood (~5.5 m^3/s)
5	South Bay Rd.	Circular CSP, 0.6m diameter	0.7 m^3/s	Concrete box culvert, 2m wide, 1.25m high	> 25 yr flood (~2.5 m^3/s)
	Keast Dr.	Circular CSP, 1.0m diameter	2.1 m^3/s	Concrete box culvert, 2m wide, 1m high	> 10 yr flood (~2.68m^3/s)

**All culverts are assessed as open bottom*

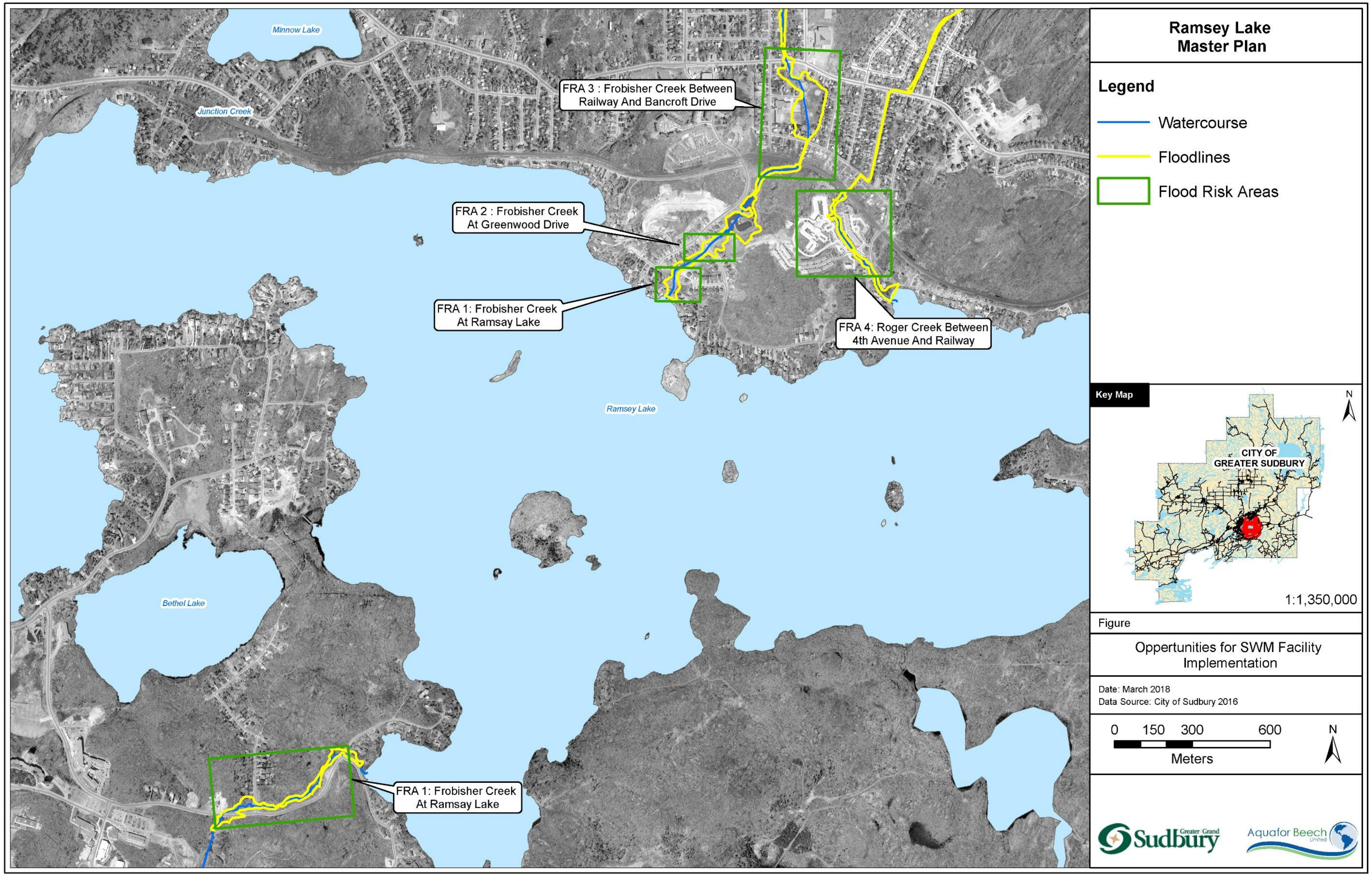


Figure 9.20: Locations of FRA within subwatershed

This chapter intends to summarize the implementation considerations associated with the various elements of the preferred alternatives described above.

9.3.9.2 Targets/Objectives

In reviewing the goals and objectives outlined in Chapter 5.0, the following objectives are specifically relevant to flood mitigation:

- Minimize flood risk; and
- Ensure natural channel stability and protect against channel erosion and sedimentation;

These will be achieved through the removal of all buildings from the regional flood limits; and the increase the hydraulic conveyance capacity of culverts and bridges to meet the CGS and MTO standards. Before culvert capacities are modified, all impacts to flood risk (upstream and downstream) and fluvial processes (i.e. erosional and depositional processes) should be considered.

9.3.9.3 Future Studies.

Future studies are required in order to complement the analyses, conclusions and recommendations of this study towards the implementation of each type of measure which constitutes the preferred alternatives.

The proposed construction of flood storage sites in the upstream locations and site-specific capacity upgrades and flood mitigation measures are subject to the Class Environmental Assessment Process. Projects undertaken by municipalities vary in their environmental impacts. Consequently, projects are classified according to Class EA Schedules ranging from A and A+ to B and C project schedules.

Since this study is considered a Master Plan under Schedule B and Approach 1, further steps will be needed to arrive to the implementation stage based on the Municipal Class Environmental Assessment process (Section 1.2). Accordingly, the Class EA process for this study follows Phases

1 and 2 as defined earlier, and then uses the Master Plan as a basis for future investigations of site-specific Schedule 'B' and 'C' projects. Therefore, future studies will include preliminary and detailed design for confirming the feasibility and determine sizing requirements for each measure prior to construction.

9.3.9.4 Design Guidance and Policy Considerations

Below are some recommendations and planning guidance that should be taken into consideration as the projects progress to the design stage:

Fish Passage Considerations for Culverts

When moving forward with the detailed designs of each of these culverts, it is important to take into consideration fish passage. The culvert styles and dimensions provided within this report, are intended to allow for a low flow channel, a more natural channel bed, and minimize high velocities. These considerations should also be carried forward to the detailed design stage.

9.3.9.5 Implementor/Approvals

The City will be the primary implementor of this project. It is recommended that the City collaborate with Conservation Sudbury to acquire funding and outline the requirements for the detailed design. Establishing the lines of communications early, ensures that the major stakeholders are aware of the City's intensions and can make the process of acquire permits easier.

MECP permits will only be required if the project may impact Species at Risk. Under the Endangered Species Act, the MECP can grant different types of permits or other authorizations for activities that would otherwise not be allowed, with conditions that are aimed at protecting and recovering species at risk.

DFO administers development requirements relating to aquatic habitat under the Fisheries Act. This applies to work being conducted in or near waterbodies that support fish that are part of or that support a commercial, recreational or Aboriginal fishery. DFO review will be required for works at ES-K-01.

A permit under Ontario Regulation 156/06 - Development, Interference with Wetlands and alterations to Shoreline Watercourse will be required through Conservation Sudbury for in-water works.

9.3.9.6 Funding Opportunities for Flood Mitigation

It is possible that the City might be able to apply for funding from the Disaster Mitigation and Adaptation Fund (DMAF). The DMAF was designated to fund large-scale infrastructure projects to "reduce the socio-economic, environmental and cultural impacts of natural hazards and extreme weather events when considering current and potential future climate change impacts." Projects must have a minimum of $20 million in eligible expenditures, although projects may be bundled if they work in a "complementary manner to reduce the risk within the same time period."

9.3.10 Salt Management

9.3.10.1 General

As discussed in Chapter 6.1.8, de-icing salt is used to control snow and ice formation, making winter driving safer and more efficient. However, the chloride salts entering the environment from the storage and runoff of these salts may cause adverse effects to aquatic life, terrestrial vegetation, soil structure, and drinking water.

The City's Source Protection Plan contains a section on Salt and Snow Policies outlining six (6) relevant policies for the management of salt with regards to water quality protection. In conjunction with theses policies and in adherence with the Code of Practice for the Environmental Management of Road Salts, the Salt Management Plan (SMP) sets out a policy and procedural framework to ensure the City's Road Operations Section continuously improves the effective delivery of winter maintenance services and the management of de-icing salt used in winter maintenance operations. The SMP also outlines the current winter operations schedule, including where and when salt and/or sand gets applied, as seen in **Figure 9.21**.

Figure 9.21 Salt/Sand Application Schedule

According to Table 5 of the Salt Management Plan, at temperatures below -12ºC, no salt is applied to any roads. However, climate change forecasts for the City of Greater Sudbury predict that winter temperatures could be 3.5ºC higher than the historical trends (City of Greater Sudbury, 2013). This will likely result in higher salt application rates, emphasizing the importance of implementing salt best management practices, as described below.

An inspection of the existing winter maintenance depots and snow dump sites was completed in 2016, the results of this inspection are summarized in the 2016 Salt Management Report. Some of the major environmental findings include the following:

- Ramsey Lake may be impacted by runoff from Highway 17.
- The current Frobisher Depot in the southeast section of Sudbury is located in close proximity to Ramsey lake. The drainage from this depot is within the headwater of the Ramsey Lake subwatershed IPZ3 area.

Of the many improvement options identified in the salt management plan, there are four (4) options for environmentally sensitive/vulnerable areas. Only one (1) of these options, *liaise with local potable water supply agencies within the city*, is currently implemented. The implementation of *monitoring groundwater and recharge areas* and *locating stockpiles and snow disposal sites outside of vulnerable areas* are not currently considered and need review. *Saltwater retention/treatment area installed at all yards* is also highly applicable because of Frobisher Depot's location; this option is a long-term goal that has no implementation date set.

Best management practices reduce both salt requirements and the opportunity for salt to enter the groundwater. According to the 2016 Salt Management Plan, the City already implements the following:

- Snow plows equipped with electronic control spreaders to set the rate of salt or sand for the conditions (90% of fleet)
- Automated vehicle location (GPS) (100% of fleet)
- On-board pre-wetting tanks to enhance salt melting capacity (60% of fleet)
- Direct liquid application (DLA), which reduces chlorides up to 10X (1% of fleet)
- On-board infrared thermometers to monitor pavement temperature (100% of road patrol and supervisor trucks)
- Road Weather Information System (RWIS) to influence salt application rates
- Covered storage areas for de-icing salt
- Annual training for winter maintenance staff, including salt management training
- Annual equipment calibration program

In addition to increasing the percentage of the fleet equipped with the above-listed items, the following best management practices can also be implemented:

- Carbon-reinforced front blades for better snow removal
- Magnesium chloride winter liquids, used at 50% less than previous liquids
- Controlled drainage at storage yards
- Enclosed or covered storage areas for pickled sand
- Reduced snow drifting on to roads by implementing snow fences in strategic locations and new hedgerows

Figure 9.22 below shows a map of the study area with salt route roadways highlighted. The area with the highest concentration of salt routes is northwest along Ramsey Lake; however, there are not many salt routes within the overall study area. A comparison of the water quality data from the northwest versus the other tributaries would be the best indicator of the impact of these routes on the Lake.

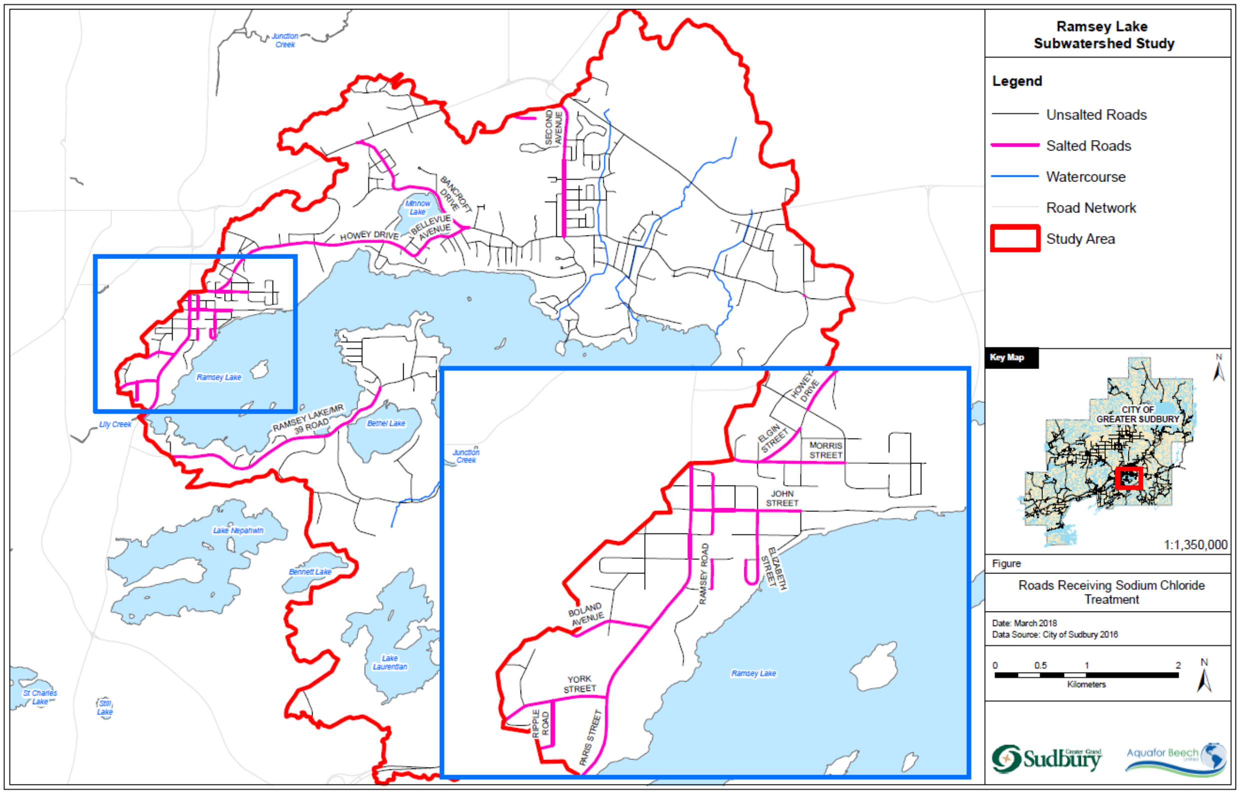


Figure 9.22: map of the study area with salt route roadways highlighted

9.3.10.2 Targets/Objectives

In reviewing the goals and objectives outlined in **Section 5.0**, the following targets and objects are specifically relevant to salt management (**Table 9.16**).

Table 9.16: Goals, objectives and targets related to salt management

Goals	Objectives	Related Targets
Restore, Maintain, and Enhance Water Quality	1. ***Support reasonable uses for:*** a. ***Aesthetics, and*** b. ***Wildlife;*** 2. Prevent eutrophication/Algal growth; 3. ***Protect groundwater quality to support drinking water supply, aquatic and terrestrial communities; and,*** 4. Support aquatic communities.	Restore, Maintain, and Enhance Water Quality

9.3.10.3 Future Studies.

Ramsey Lake tributaries are currently monitored for multiple contaminants including chlorides. This should continue to ensure adaptive management to reduce the Lake's chloride concentration. Frobisher Creek is a critical tributary to monitor, as the salt depot is located within IPZ3 in the subwatershed.

To address the private sector's salt use, the provision of education outreach opportunities is recommended to reduce salt loading form parking lots. Encouraging the use of Smart About Salt, or creating a City of Greater Sudbury course, to increase best management practice use will help the private industry reduce their salt contributions to the surrounding environment.

9.3.10.4 Implementor/Approvals

The City is the primary implementor of the salt management plan, education outreach opportunities, and best management practices within Greater Sudbury. As seen in other jurisdictions, stewardship groups such as local conservation areas may be involved throughout implementation.

9.3.11 Management of Septic Systems

9.3.11.1 General

Public Health Sudbury and Districts is responsible for the inspection and approval of private sewage systems. In order for approval, a three (3) step inspection process is required. This process involves:

1. A **preliminary site inspection** to stake out the location of the proposed sewage system and ensure that test holes are present in the location of the proposed sewage system. During this inspection, the public health inspector will verify that the sewage system design included in the application is accurate to on-site conditions and that the property is capable of supporting the construction of an on-site sewage system in accordance with the Ontario Building Code.
2. A **substantial inspection** is required once the sewage system has been installed and prior to the back-filling of the components. This post-permit approval inspection includes focus on septic system components.
3. A **final grading inspection** is required for once the grading is complete, the mantle has been covered with topsoil and the growth of shallow rooted vegetation covers a minimum 60% of the sewage system.

Once the system is approved and constructed, the onus is on the property owner to keep the system in proper working order through operation and maintenance practices. Should Public Health Sudbury and Districts receive a compliant regarding malfunctioning septic system, a complaint investigation is conducted. When a malfunctioning system is confirmed, an order may be issued under Part 8 of the Ontario Building Code.

Leaking or damaged septic beds can be a source of groundwater contamination, including bacterial loading, nitrates and phosphates. Leaking septic systems frequently go unnoticed, due to unawareness of the potential issue, and the fact that most septic systems are below ground and can’t be easily inspected. The management of private septic systems helps to protect groundwater from contamination and identifies sources of contamination that can be mitigated.

In order to better understand the potential issue within the Ramsey Lake subwatershed, it was necessary to understand which areas could be impacted by septic system leakage. No records of privately serviced lots were available at the time of this study, therefore it was necessary to approximate this using GIS data. As GIS data for the municipal water and septic services was available, it was assumed that any developed lots that was more than 50 m from the servicing lines was "un-serviced". A similar analysis was undertaken by the City for the entire and the results were provided to Aquafor (communications with the City, 2018). A map showing the serviced and un-serviced lots within the Ramsey Lake subwatershed are shown in **Figure 9.23** and a summary is provided in **Table 9.17**.

Table 9.17: Summary of serviced and un-serviced lots in CGS and Ramsey Lake subwatershed

	City of Greater Sudbury	Ramsey Lake Subwatershed	Comparison Notes
Total number of developed lots	61,356	4,892	Ramsey Lake subwatershed contains approximately 8% of all developed lots in the CGS
Serviced Lots	49,865 (81%)	4,635 (95%)	The percentage of unserviced lots within the Ramsey Lake subwatershed is approximately 11% less than the City as a whole
Unserviced Lots	11,491 (19%)	257 (5%)	

It was determined that while approximately 19% of all the lots within the City are un-serviced, only 5% of lots are un-serviced within the Ramsey Lake subwatershed.

No information was available with regards to the existing conditions of private septic beds. Currently, Public Health Sudbury and Districts is responsible for the inspection of existing/old septic systems. Within the Ramsey Lake Source Protection Area, they conduct a septic system re-inspection program. Citizens can request sewage system records for their property from the Health Unit, however if the property is not within the Source Protection Area and a complaint has never been filed for the property, there may not be any information available for the property.

At this time, it is unclear if there are any groundwater and surface water quality issues related to leaking septic systems, as there is no monitoring undertaken. While nitrate and phosphate concentrations are notably high within Ramsey Lake, the source of these pollutants can not be traced to septic leakage at this time. However, based on previous investigations within Ontario, and the information obtained from the water quality modelling it is probable that septic leakage is occurring within the subwatershed. Shallow surface soils and bedrock may exacerbate the effects of this leakage within the watershed.

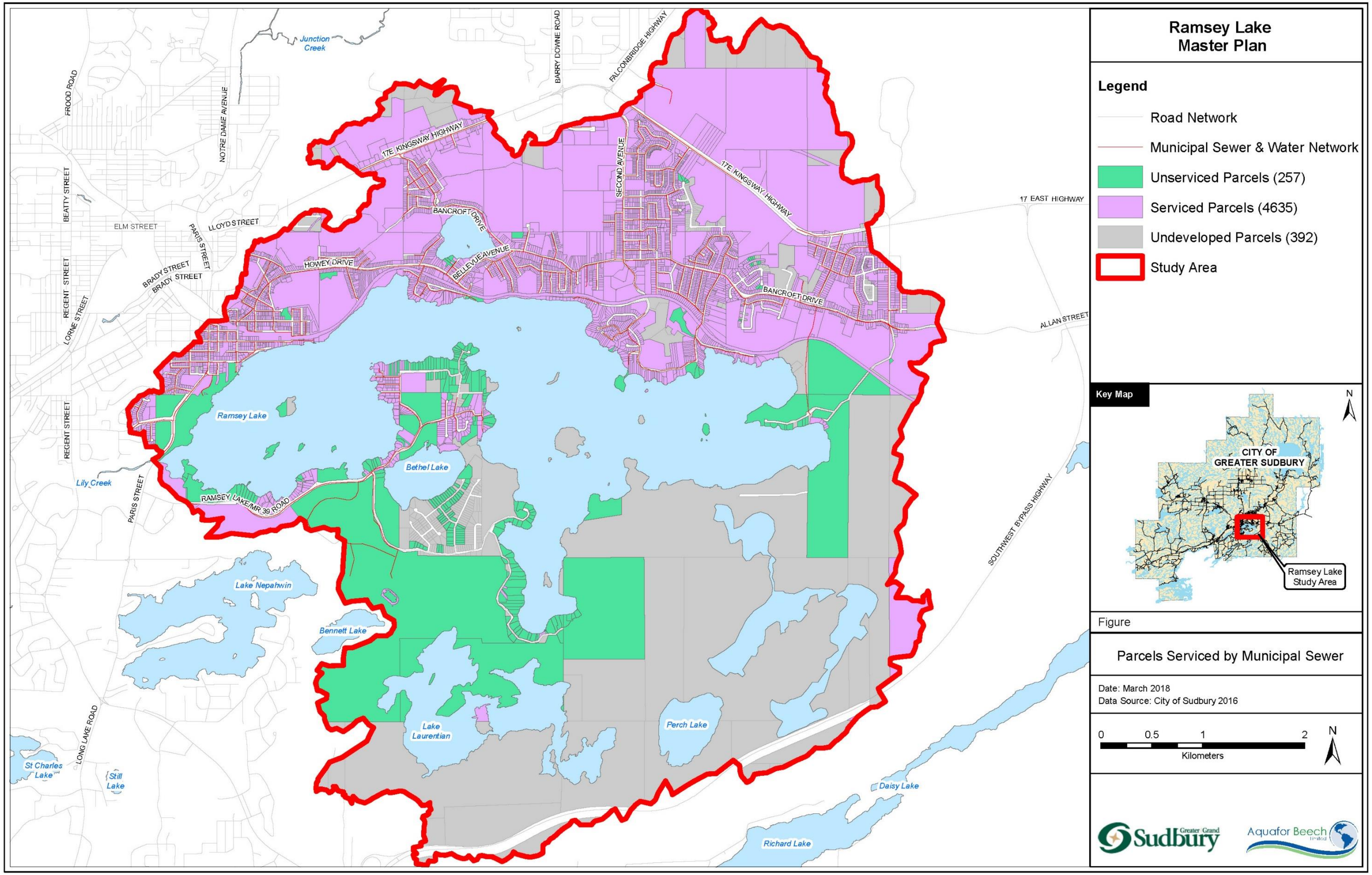


Figure 9.23: Serviced and unserviced lots within the Ramsey Lake subwatershed

9.3.11.2 Targets/Objectives

In reviewing the goals and objectives outlined in Chapter 5.0, the following objectives and target are specifically relevant to the management of septic systems in the Ramsey Lake Watershed.

Table 9.18: Goals, objectives and targets related to septic system

Goals	Objectives	Targets
Restore, Maintain, and Enhance Water Quality	1. Support reasonable uses for: • Aesthetics, and • Wildlife; 2. Prevent eutrophication/Algal growth; 3. Protect groundwater quality to support drinking water supply, aquatic and terrestrial communities; and, 4. Support aquatic communities.	Effluent not exceeding Ontario Drinking Water Objective (ODWO) of 10 mg/L of nitrate-nitrogen Effluent not exceeding the Interim Water Quality Objective of 20 µg/L of phosphorus

9.3.11.2.1 Policy Approaches and Implementation Recommendations for Monitoring

Due to the non-point source nature and of septic pollution, quantifying the nutrient inputs from septic system on a watershed scale can be challenging. Additionally, water quality testing of effluent is challenging as processes such as absorption, denitrification, filtration and biodegradation may attenuate contaminants as the effluent passes down through the unsaturated zone and moves into the saturated zone.

The Waterfront and Rural Background Study (WRBS) for the Official Plan (2004) provided a recommended policy approaches and implementation plan for various methods of monitoring septic systems. At the time of this report it is unclear if any of these recommendations had been implemented. Brief summaries of each of the recommended strategies are provided, and the details can be found in the Waterfront and Rural Background Study for the Official Plan (2004).

Required Upgrades at Time of Building Permit

The WRBS recommended that policy be updated/modified within building permit applications so that any expansions to the habitable living area or improvements to the plumbing would be conditional upon the sewage system meeting current standards. This would limit stress on system that are deteriorated, and potentially unable to handle the future inflows. The WRBS recommended that this could be incorporated into the Zoning By-Law, and would then be enforced by the Building Department, requiring certification from the Health Unit.

Initiate an Inspection Program in Key Areas

An inspection program would allow the City to identify potential sources of groundwater contamination. Priority can be given to areas of higher risk (e.g., lake front properties, properties with previous complaints to the Health Unit), and with time the program would expand to include all septic systems. At the time that the WRBS was completed, the inspection program had been identified as a long-term, ongoing commitment, and as a goal for the Greater Sudbury Lake Improvement Advisory Panel. The WRSB provides detailed examples of neighbouring communities, including costs, staffing programs and enforcement approaches.

Updating the GIS Systems

Maintaining a digital, spatial database of all septic information can be useful in identifying potential sources and paths contamination. This would also provide an excellent starting point for initiating the inspection program. Records of past septic systems permit approvals can be digitized, and spatial analysis (as undertaken for this report) can provide a preliminary network of private septic systems. This data will be refined as the inspection program continues.

Financial Compensation for Upgrading Septic Systems

As outlined in the WRBS, Due to the expense of upgrading or installing septic systems, the City may recognize that any program could create a financial burden for its citizens. One mechanism to reduce costs would be to apply a Community Improvement Plan, and allow the owners to borrow for the purposes of upgrade of the sewage system, while paying back the total or a portion of the cost over a number of years. Another method of providing financial assistance that could be investigated is a tax reduction incentive or grant program for upgrading faulty septic systems tied to municipal property taxes.

9.3.11.2.2 Recommendations for Information Programs

It is important to ensure homeowners are aware of their responsibilities with respect to septic system operation and maintenance. It should be noted that properly designed, constructed and maintained septic systems can provide long-term effective treatment of household wastewater, while unmaintained or improperly sized systems can contaminate surface and groundwater features and require expensive replacement. Information packages can take the form of a mail out but can also direct home owners to more detailed information online. Initial distribution should cover all unserviced properties, while future mailouts should occur when property ownership changes or development, redevelopment or intensification is proposed on an unserviced property. Information program mailouts and or online content should include the following:

1) How it Works: This section will outline typical septic system components and their purpose. Photos or simple diagrams can help illustrate the function of each of these. Components illustrated should include:
    - Septic tank, including inspection risers, manhole-lids, inlet pipe from house and outlet pipe with screen. It is beneficial to show septic sludge accumulation on the base of the tank and floatables at the top of the tank.
    - Pipe connections showing the direction of flow form the house to the septic tank and out to the drain field.
    - Drainfield showing flow direction and of wastewater percolating into the soil. In should be noted that treatment is occurring as water passes through the soil.

2) Importance of Septic System Maintenance: This component of the information program should highlight the consequences of a failing septic system. Regular maintenance can prevent expensive septic replacement projects and protect home value. Maintenance will also protect private drinking water wells from contamination and Ramsey Lake from ecological degradation.

3) How to Care for Your Septic System: This component of the information program should identify the basics of septic system care. Items discussed may include:
   - Ensuring a septic system is inspected by a professional (approximately every 3 years) to determine scum and sludge levels compared to design capacities. Contact information could be provided for Public Health Sudbury and Districts and or local septic professionals.
   - Ensuring a septic tank pumped out as recommended by an inspector (generally every 3 to 5 years).
   - Understanding that occupancy in a household can have a major impact on the amount of wastewater that is generated and that additional wastewater can overwhelm the system and/or increase the frequency of pump outs.
   - Understanding that efficient water use can improve operation of septic system and installing high efficiency toilets, washing machines and water fixtures can have a beneficial impact on septic system longevity.
   - Ensuring that only grass is planted over the septic tank and drainfield to prevent clogging with trees and shrubs with deeper roots. Annual inspection of these areas should be undertaken and larger vegetation should be removed.
   - Preventing excess water from infiltrating into the drainfield and septic tank by ensuring roof downspouts and sump pump drains do not flow into the septic area. This excess water from these sources may slow down the microbial treatment process.
   - Not building on, parking on or using the septic tank areas for storage of materials.
   - Preventing the clogging of septic system components by ensuring kitchen grease, diapers, wet-wipes, dental floss, cat litter, cigarette buts, coffee grounds and feminine hygiene products are not flushed down the drain.
   - Preventing items that could kill microorganisms that treat and digest waste from entering the septic system. This items oils, chemical drain cleaners, paint, antifreeze, pesticides, gasoline products, and household cleaning chemicals.

4) Signs of Septic System Failure: It is important that home owners are aware of the signs associated with a failing septic system. Further inspection by a professional should be undertaken if any of the following signs are observed:
    - Unusually slow draining toilets and sinks;
    - Sewage backups in the home;
    - Strong odours;
    - Patches of lush grass around the drainfield; and
    - Saturated ground or ponded water around the drainfield.

Along with the handouts to landowners the above information can also be presented in workshops, information sessions, online resources, interpretive signage & direct landowner contact to promote the proper maintenance of existing septic systems.

9.3.11.3 Implementor/Approvals

Due to the multiple levels of stakeholders involved in the preservation of water quality and septic system regulation, there will need to collaboration between multiple parties to ensure adaptive monitoring and outreach is effective. In general, Public Health Sudbury and Districts will be responsible for the following with support from the City of Greater Sudbury:

- Developing information sessions, literature, websites, public service announcements, interpretive signage & direct landowner contact to promote the proper maintenance of existing septic systems.
- Investigation of the feasibility of a tax reduction incentive or grant program for upgrading faulty septic systems.
- Upgrading and maintaining a digital, spatial database (GIS) of all septic information including approvals and sizing data.
- Updating building permit application policy so that any expansions to the habitable living area or improvements to the plumbing would be conditional upon the sewage system meeting current standards.

- Developing an inspection program to identify and concern potential sources of groundwater contamination, especially in high risk areas (e.g., lake front properties, properties with previous complaints to the Health Unit).
- Analyze existing water quality data for high levels of bacteria, chlorides, phosphorous, nitrates and TKN and cross reference the results against land use data to prioritize areas for education outreach and restoration.
- Coordinating with the City for the development of the GIS septic database and keeping the database up-to-date through the transfer of inspection information.
- Identifying areas of high-risk based on complaints.
- Coordinating upgrade requirements and conducting inspections as required through building permit applications.

9.3.11.4 Costing

Approximate costs for septic system recommendation components are outlines in **Table 9.19**.

Table 9.19: Summary of serviced and un-serviced lots in CGS and Ramsey Lake subwatershed

Task	Approximate Cost ($)	Notes
Requiring Septic System Upgrades at time of Building Permit	Staffing $30,000/year Program: $15,000	Costs assume 1/2 staff to run municipal program plus updates to permitting process
Inspection Program in Key Areas	Staffing $30,000/year	Costs assume 1/2 staff to run municipal program
Updating GIS System	$5,000/year	Assumes existing GIS platform used and some minor coordination with Public Health Sudbury and Districts
Financial Compensation for Upgrading Septic Systems	Varies	The approximate cost of a full septic system replacement will cost approximately $10,000. The level of financial compensation will dictate cost per project.

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The following subheadings list the various sources of information to complete this report.

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APPENDIX A: Hydrologic Model Setup

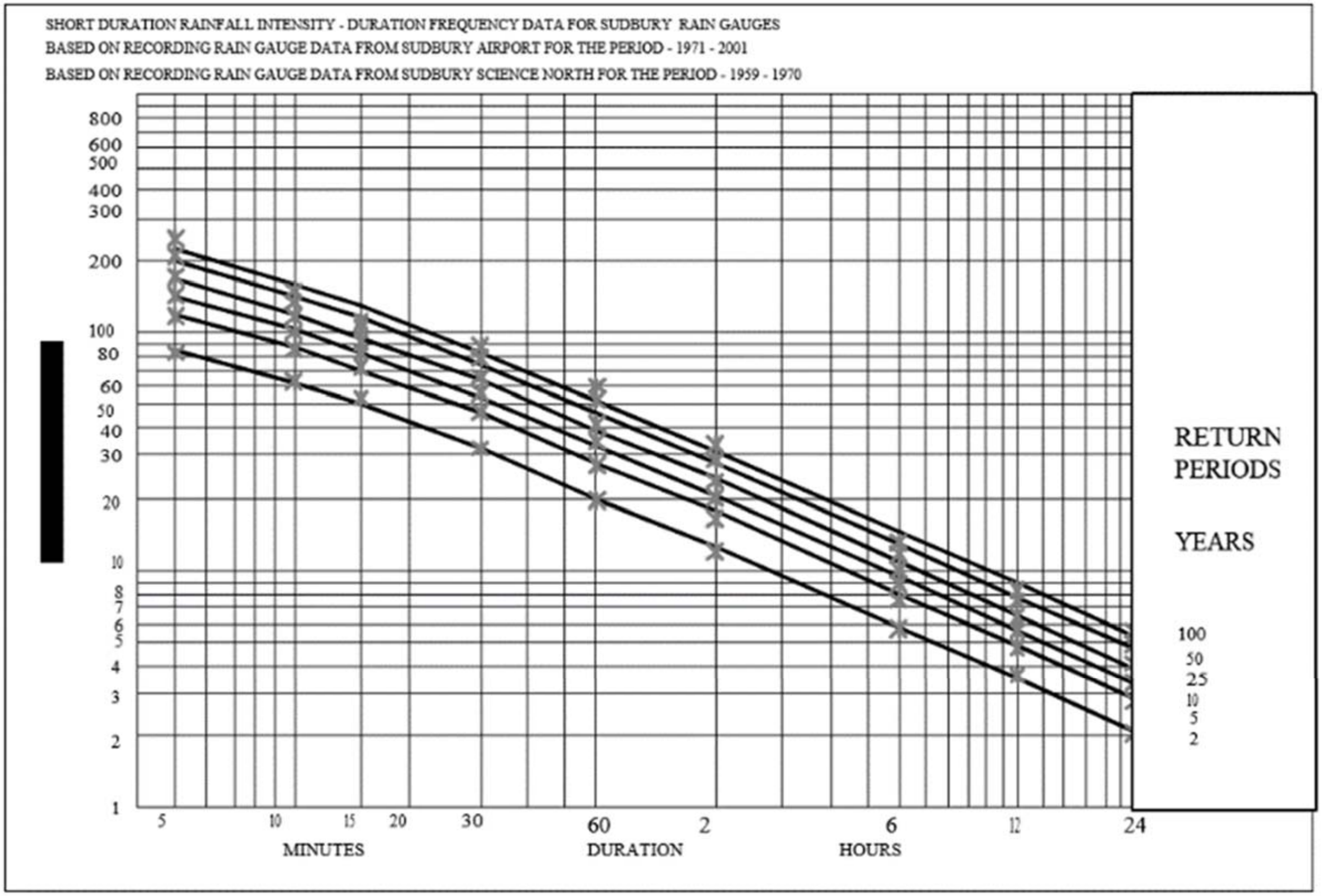


Figure A1. IDF curves

Table A 1. Subcatchment Parameters

Name	Area (ha)	Flow Length (m)	Imperviousness (%)	CN
Bethel_Lake	85.8	1226	50.0	53.2
Bethel_Lake_Peninsula	71.6	1193	34.0	79.4
East_South_Bay	216.2	1802	5.0	76.8
Frenchman's_Bay_Beach1	9.8	311	10.0	70.0
Frenchman's_Bay_Beach2	14.1	340	10.0	70.0
Frenchman's_Bay_Beach3	1.9	116	10.0	70.0
Frenchman's_Bay_Beach4	13.4	418	10.0	70.0
Frenchman's_Bay-Eugene1	43.6	850	6.0	77.7
Frenchman's_Bay-Eugene2	106.3	2500	21.0	87.9
Frenchman's_Bay-Eugene3	39.3	285	7.0	81.0
Frenchman's_Bay-Eugene4	32.4	324	5.0	78.9
Frenchman's_Bay-Rogers1	66.1	1210	2.0	77.7
Frenchman's_Bay-Rogers2	23.1	750	3.0	2.9
Frenchman's_Bay-Rogers3	21.9	787	29.0	88.4
Frenchman's_Bay-Rogers4	30.2	1350	25.0	90.4
Frenchman's_Bay-Rogers5	24.9	553	18.0	83.6
Frobisher_Beach	9.6	330	10.0	70.0
Frobisher1	177.8	2600	5.2	77.7
Frobisher2	85.7	1009	33.0	71.9
Frobisher3	40.0	534	42.0	82.9
Frobisher4	16.4	265	48.0	90.4
Frobisher5	25.1	473	50.0	90.7
Frobisher6	33.1	1894	41.0	7.6
Lake_Laurentian	697.4	2790	32.0	53.4
Laurentian_Wetland	403.8	2884	15.0	64.5
Minnow_Lake	256.4	1603	39.0	78.9
Moonlight_Beach	213.9	1126	4.0	9.2
North_Shore	277.6	1157	22.0	86.4
South_Shore	117.3	2201	32.0	79.1
Sudbury_Urban_Core	132.4	2648	4.0	90.3
West_South_Bay1	30.4	475	9.0	73.4
West_South_Bay2	27.8	463	7.0	74.9
West_South_Bay-Keast1	58.7	432	11.0	76.8
West_South_Bay-Keast2	38.2	588	11.0	76.8

Table A 2. 2 – 100 yr 6-hour Chicago Storm Distributions

Time	2 year	5 year	10 year	20 year	50year	100 year
0.25	1.70	2.20	2.60	3.20	3.80	4.10
0.50	1.80	2.40	2.90	3.40	4.00	4.50
0.75	2.00	2.70	3.20	3.70	4.40	5.00
1.00	2.30	3.10	3.60	4.20	5.00	5.70
1.25	2.60	3.50	4.20	4.90	5.80	6.50
1.50	3.20	4.20	5.00	5.80	6.90	7.80
1.75	4.00	5.40	6.30	7.40	8.80	9.90
2.00	5.70	7.60	9.00	10.50	12.50	14.00
2.25	11.50	15.50	18.50	21.50	25.30	28.30
2.50	49.20	68.50	82.40	96.10	113.50	127.10
2.75	13.30	17.90	21.30	24.80	29.10	32.60
3.00	7.30	9.80	11.60	13.60	16.00	18.00
3.25	5.20	7.00	8.30	9.70	11.50	12.90
3.50	4.20	5.60	6.60	7.70	9.10	10.30
3.75	3.50	4.70	5.60	6.50	7.70	8.70
4.00	3.00	4.10	4.80	5.60	6.70	7.50
4.25	2.70	3.60	4.30	5.00	5.90	6.70
4.50	2.40	3.30	3.90	4.50	5.30	6.10
4.75	2.20	3.00	3.50	4.10	4.90	5.50
5.00	2.10	2.80	3.30	3.80	4.50	5.10
5.25	1.90	2.60	3.00	3.50	4.20	4.80
5.50	1.80	2.40	2.80	3.30	3.90	4.50
5.75	1.70	2.30	2.70	3.10	3.70	4.20
6.00	1.60	2.10	2.50	2.90	3.50	4.00

Table A 3. 10-day Rainfall + Snowmelt Design Events (mm/hr Equivalent Rain)

Time (day)	2 year	5 year	10 year	25 year	50year	
1	0.35	0.5	0.5	0.55	0.7	0.75
2	0.45	0.45	0.5	0.65	0.65	0.8
3	0.55	0.75	0.75	1	1	1.15
4	0.7	1	1.1	1.25	1.35	1.55
5	1.6	2.1	2.4	2.8	3.1	3.4
6	0.95	1.25	1.45	1.7	1.9	2.05
7	0.7	0.75	0.9	1.05	1.2	1.3
8	0.5	0.6	0.75	0.75	0.9	0.9
9	0.4	0.55	0.6	0.7	0.75	0.85
10	0.4	0.4	0.55	0.6	0.6	0.65

Table A 4. Lengths of Storm Sewers at Full Capacity or Surcharged Under 2-Yr Through 100-Yr Design Storms

Scenario	Length of Storm Sewer at Full Capacity / Surcharged (m)	
	Full Capacity	Surcharged
2-yr Design Storm	229	975
5-yr Design Strom	221	1143
10-yr Design Storm	102	1634
25-yr Design	122	1635
50-yr Design Storm	254	1806
100-yr Design Storm	329	1889
Regional Design Storm	486	1273
Modelled 22884 m of Storm Sewer > 600 mm		

Table A 5. Subcatchment Parameters (Pipe Model)

Subcatchment ID	Area (ha)	Flow Length (m)	Imperv. (%)	Curve Number
1	0.154	10	0	50.00
2	0.405	27	50	40.00
3	0.184	12	40	20.00
5	0.174	12	20	40.00
6	0.121	8	40	25.00
7	0.230	15	25	40.00
9	2.164	144	40	60.00
10	2.999	200	60	2.00
11	1.123	75	2	40.00
12	0.428	29	40	50.00
13	0.434	29	50	80.00
14	0.213	14	80	70.00
15	0.841	56	70	60.00
16	0.038	3	60	50.00
17	0.384	26	50	90.00
18	0.293	20	90	80.00
19	0.016	1	80	50.00
20	0.007	0	50	100.00
21	0.012	1	100	100.00
22	0.110	7	100	100.00
23	0.522	35	100	70.00
24	0.381	25	70	60.00
25	0.395	26	60	60.00
26	0.669	45	60	60.00

Subcatchment ID	Area (ha)	Flow Length (m)	Imperv. (%)	Curve Number
27	4.765	318	60	40.00
28	0.972	65	40	40.00
29	0.052	3	40	40.00
30	0.092	6	40	50.00
31	0.032	2	50	10.00
32	4.903	327	10	90.00
33	0.631	42	90	50.00
34	1.861	124	50	60.00
35	2.615	174	60	60.00
36	0.810	54	60	60.00
37	6.405	427	60	70.00
38	1.240	83	70	60.00
39	1.694	113	60	70.00
40	0.833	56	70	70.00
41	2.843	190	70	60.00
42	6.576	438	60	60.00
43	0.347	23	60	50.00
44	0.362	24	50	80.00
45	0.423	28	80	50.00
46	1.423	95	50	50.00
47	0.306	20	50	30.00
48	0.085	6	30	90.00
49	0.259	17	90	100.00
50	0.027	2	100	100.00
51	0.607	40	100	100.00
52	0.200	13	100	90.00
53	0.797	53	90	90.00
54	0.228	15	90	80.00
55	0.124	8	80	50.00
56	1.179	79	50	80.00
57	0.773	52	80	10.00
58	0.307	20	10	80.00
59	0.556	37	80	70.00
60	1.144	76	70	30.00
61	0.379	25	30	40.00
62	0.124	8	40	50.00
63	0.742	49	50	70.00
65	0.318	21	70	50.00
67	0.106	7	50	20.00
68	0.062	4	20	70.00
70	0.036	2	70	60.00
71	0.053	4	60	60.00
72	0.005	0	60	80.00
73	0.689	46	80	60.00
74	0.246	16	60	100.00
75	0.015	1	100	70.00
76	0.025	2	70	100.00

Subcatchment ID	Area (ha)	Flow Length (m)	Imperv. (%)	Curve Number
77	0.011	1	100	70.00
78	0.147	10	70	70.00
79	1.322	88	70	100.00
80	1.828	122	100	50.00
81	0.006	0	50	100.00
82	0.169	11	100	2.00
83	0.592	39	2	20.00
84	0.893	60	20	20.00
85	0.500	33	20	100.00
86	0.327	22	100	80.00
87	0.252	17	80	90.00
88	0.032	2	90	50.00
89	0.406	27	50	80.00
90	0.188	13	80	50.00
91	7.288	486	50	70.00
92	0.412	27	70	90.00
93	0.358	24	90	60.00
95	0.686	46	60	60.00
96	0.250	17	60	40.00
97	0.336	22	40	60.00
99	0.294	20	60	60.00
100	1.135	76	60	60.00
101	2.139	143	60	50.00
102	0.095	6	50	60.00
103	0.266	18	60	70.00
104	0.056	4	70	70.00
105	0.346	23	70	60.00
106	0.366	24	60	50.00
107	0.438	29	50	30.00
108	1.616	108	30	20.00
109	0.479	32	20	80.00
110	0.340	23	80	100.00
111	0.013	1	100	90.00
112	0.413	28	90	50.00
113	0.487	32	50	50.00
114	0.387	26	50	50.00
115	0.667	44	50	50.00
117	0.982	65	50	80.00
118	0.223	15	80	90.00
119	0.957	64	90	60.00
120	0.174	12	60	60.00
121	0.019	1	60	70.00
122	0.007	0	70	30.00
123	0.186	12	30	2.00
124	0.364	24	2	50.00
125	1.373	92	50	95.00
126	0.622	41	95	30.00

Subcatchment ID	Area (ha)	Flow Length (m)	Imperv. (%)	Curve Number
127	0.716	48	30	80.00
128	0.132	9	80	100.00
129	0.435	29	100	100.00
130	1.787	119	100	70.00
131	0.413	28	70	50.00
132	0.201	13	50	10.00
133	0.187	12	10	50.00
134	0.490	33	50	50.00
135	0.138	9	50	60.00
136	0.145	10	60	60.00
137	0.920	61	60	30.00
138	1.597	106	30	40.00
139	0.139	9	40	50.00
140	0.473	32	50	50.00
141	0.552	37	50	40.00
142	0.815	54	40	80.00
143	4.058	271	80	70.00
144	0.264	18	70	40.00
145	0.731	49	40	40.00
146	0.122	8	40	30.00
147	0.013	1	30	20.00
148	1.134	76	20	100.00
149	0.686	46	100	30.00
150	0.858	57	30	60.00
151	0.532	35	60	60.00
152	0.480	32	60	50.00
153	0.095	6	50	50.00
154	0.623	42	50	100.00
155	0.297	20	100	30.00
156	1.096	73	30	30.00
157	2.419	161	30	40.00
158	0.334	22	40	40.00
159	0.599	40	40	30.00
160	0.245	16	30	30.00
161	0.182	12	30	20.00
162	0.603	40	20	40.00
163	0.009	1	40	40.00
164	0.197	13	40	20.00
165	0.135	9	20	40.00
166	1.190	79	40	50.00
167	0.983	66	50	50.00
168	0.282	19	50	50.00
169	0.165	11	50	50.00
170	0.151	10	50	50.00
171	0.014	1	50	60.00
172	2.396	160	60	50.00
173	1.704	114	50	40.00

Subcatchment ID	Area (ha)	Flow Length (m)	Imperv. (%)	Curve Number
174	0.016	1	40	40.00
175	0.141	9	40	40.00
176	0.028	2	40	40.00
177	1.182	79	40	50.00
178	0.931	62	50	100.00
180	0.318	21	100	50.00
181	1.780	119	50	50.00
182	1.491	99	50	90.00
183	1.236	82	90	50.00
184	3.945	263	50	80.00
185	1.051	70	80	30.00
186	0.160	11	30	10.00
187	1.140	76	10	50.00
188	0.751	50	50	80.00
189	0.744	50	80	70.00
190	3.335	222	70	70.00
191	0.166	11	70	5.00
192	3.235	216	5	50.00
193	1.583	106	50	100.00
194	0.726	48	100	100.00
195	5.854	390	100	80.00
196	1.262	84	80	95.00
197	2.995	200	95	95.00
201	0.227	15	95	95.00
202	0.215	14	95	40.00
203	0.386	26	40	50.00
204	0.540	36	50	100.00
205	0.172	11	100	40.00
206	0.122	8	40	50.00
207	0.110	7	50	100.00
208	0.112	7	100	100.00
209	0.055	4	100	50.00
210	0.054	4	50	80.00
211	0.054	4	80	98.00
212	0.379	25	98	98.00
213	0.569	38	98	95.00
214	0.542	36	95	80.00
215	1.205	80	80	50.00
216	0.664	44	50	90.00
217	1.250	83	90	95.00
218	2.319	155	95	70.00
219	0.568	38	70	100.00
220	0.014	1	100	40.00
221	0.901	60	40	70.00
222	0.951	63	70	90.00
223	0.975	65	90	60.00
224	0.318	21	60	60.00

Subcatchment ID	Area (ha)	Flow Length (m)	Imperv. (%)	Curve Number
225	0.010	1	60	60.00
226	0.648	43	60	40.00
227	0.347	23	40	40.00
228	6.377	425	40	60.00
229	0.394	26	60	100.00
230	0.634	42	100	60.00
231	0.138	9	60	40.00
232	0.322	21	40	50.00
233	0.332	22	50	50.00
234	0.311	21	50	100.00
235	0.182	12	100	50.00
236	0.909	61	50	40.00
237	0.760	51	40	60.00
238	0.784	52	60	60.00
239	0.177	12	60	60.00
240	1.990	133	60	60.00
241	8.170	545	60	50.00
242	1.351	90	50	98.00
243	0.038	3	98	80.00
244	1.864	124	80	50.00
245	0.049	3	50	80.00
246	0.113	8	80	30.00
247	1.975	132	30	50.00
249	7.333	489	50	20.00
250	3.338	223	20	60.00
253	0.652	43	60	50.00
254	4.307	287	50	50.00
255	2.886	192	50	70.00
256	0.163	11	70	90.00
257	0.706	47	90	50.00
258	0.427	28	50	70.00
259	0.269	18	70	90.00
260	0.502	33	90	40.00
261	0.942	63	40	50.00
262	0.261	17	50	50.00
263	0.149	10	50	30.00
264	0.643	43	30	60.00
265	0.069	5	60	30.00
266	2.549	170	30	20.00
267	0.715	48	20	60.00
268	0.792	53	60	50.00
269	2.498	167	50	40.00
270	2.001	133	40	40.00
271	7.995	533	40	50.00
272	2.338	156	50	40.00
273	2.243	150	40	40.00
274	0.534	36	40	60.00

Subcatchment ID	Area (ha)	Flow Length (m)	Imperv. (%)	Curve Number
275	1.778	119	60	40.00
276	0.682	45	40	60.00
277	0.321	21	60	60.00
278	0.041	3	60	20.00
279	0.013	1	20	60.00
280	0.777	52	60	30.00
281	2.298	153	30	20.00
282	0.025	2	20	40.00
283	0.216	14	40	50.00
284	0.111	7	50	60.00
285	0.236	16	60	40.00
286	0.417	28	40	20.00
287	0.343	23	20	50.00
288	0.481	32	50	70.00
289	0.509	34	70	100.00
290	0.218	15	100	70.00
291	0.235	16	70	50.00
292	11.771	785	50	100.00
293	0.702	47	100	98.00
294	0.347	23	98	90.00
295	0.267	18	90	90.00
296	0.495	33	90	80.00
297	0.716	48	80	80.00
298	0.994	66	80	70.00
299	0.314	21	70	80.00
300	0.358	24	80	80.00
301	0.176	12	80	70.00
302	0.224	15	70	95.00
303	0.115	8	95	70.00
304	0.048	3	70	50.00
305	0.131	9	50	50.00
306	0.033	2	50	20.00
307	0.246	16	20	20.00
308	0.880	59	20	50.00
309	1.023	68	50	20.00
310	0.157	10	20	50.00
311	3.066	204	50	70.00
312	0.258	17	70	50.00
313	0.310	21	50	50.00
314	0.542	36	50	20.00
315	0.750	50	20	10.00
316	3.607	240	10	0.00
317	9.057	604	0	20.00
318	0.336	22	20	60.00
319	0.102	7	60	60.00
320	0.449	30	60	40.00
321	0.468	31	40	60.00

Subcatchment ID	Area (ha)	Flow Length (m)	Imperv. (%)	Curve Number
322	0.405	27	60	70.00
323	0.141	9	70	50.00
324	0.139	9	50	50.00
325	0.675	45	50	50.00
326	2.455	164	50	70.00
327	0.958	64	70	10.00
328	0.468	31	10	50.00
329	3.521	235	50	30.00
330	1.747	116	30	40.00
331	4.803	320	40	40.00
332	0.664	44	40	40.00
333	0.038	3	40	40.00
334	5.329	355	40	40.00
335	2.372	158	40	40.00
336	0.127	8	40	50.00
337	0.101	7	50	50.00
338	0.675	45	50	50.00
339	0.138	9	50	10.00
340	0.543	36	10	20.00
341	1.409	94	20	30.00
342	0.089	6	30	50.00
343	0.743	50	50	40.00
344	5.635	376	40	20.00
345	13.953	930	20	50.00
346	1.553	104	50	60.00
347	1.429	95	60	70.00
348	0.630	42	70	40.00
349	0.281	19	40	60.00
350	2.271	151	60	40.00
351	0.726	48	40	50.00
352	1.043	70	50	50.00
353	7.380	492	50	50.00
354	1.705	114	50	50.00
357	1.289	86	50	30.00
358	1.574	105	30	50.00
359	3.087	206	50	50.00
360	0.485	32	50	50.00
361	0.702	47	50	50.00
362	0.289	19	50	50.00
363	0.330	22	50	70.00
364	2.914	194	70	60.00
365	0.572	38	60	50.00
366	0.229	15	50	60.00
367	0.022	1	60	40.00
368	0.260	17	40	70.00
369	0.088	6	70	30.00
370	0.941	63	30	40.00

Subcatchment ID	Area (ha)	Flow Length (m)	Imperv. (%)	Curve Number
371	0.427	28	40	70.00
372	0.486	32	70	50.00
373	0.284	19	50	30.00
374	0.418	28	30	40.00
375	4.876	325	40	40.00
376	1.932	129	40	20.00
377	0.253	17	20	20.00
378	1.000	67	20	30.00
379	0.523	35	30	98.00
380	4.187	279	98	40.00
381	3.225	215	40	20.00
382	0.098	7	20	40.00
383	0.122	8	40	40.00
384	0.012	1	40	50.00
385	0.590	39	50	30.00
386	1.836	122	30	60.00
387	1.141	76	60	50.00
388	0.955	64	50	40.00
389	5.964	398	40	20.00
390	0.070	5	20	50.00
391	6.055	404	50	50.00
392	1.752	117	50	50.00
393	1.139	76	50	50.00
394	1.905	127	50	80.00
395	0.261	17	80	90.00
396	0.138	9	90	100.00
397	0.951	63	100	80.00
398	0.023	2	80	50.00
399	0.406	27	50	50.00
401	0.512	34	50	40.00
403	1.071	71	40	50.00
406	1.330	89	50	100.00
407	0.901	60	100	60.00
408	0.643	43	60	30.00
409	0.147	10	30	60.00
410	1.535	102	60	50.00
411	0.211	14	50	30.00
412	2.177	145	30	30.00
413	4.031	269	30	60.00
414	0.378	25	60	90.00
415	0.243	16	90	70.00
416	0.025	2	70	60.00
417	0.598	40	60	50.00
418	0.454	30	50	2.00
419	0.422	28	2	60.00
420	0.526	35	60	50.00
421	0.362	24	50	30.00

Subcatchment ID	Area (ha)	Flow Length (m)	Imperv. (%)	Curve Number
422	0.591	39	30	60.00
423	0.258	17	60	50.00
424	0.168	11	50	50.00
425	0.614	41	50	70.00
426	0.017	1	70	50.00
427	1.242	83	50	50.00
428	2.085	139	50	0.00
429	0.256	17	0	30.00
430	0.068	5	30	0.00
431	0.510	34	0	0.00
432	1.630	109	0	50.00
433	4.105	274	50	50.00
434	2.650	177	50	50.00
435	0.781	52	50	50.00
436	0.339	23	50	50.00
437	0.122	8	50	50.00
438	0.365	24	50	40.00
439	0.271	18	40	50.00
440	0.859	57	50	50.00
441	0.551	37	50	40.00
442	0.446	30	40	80.00
443	6.285	419	80	50.00
444	1.266	84	50	40.00
445	0.256	17	40	60.00
446	0.493	33	60	80.00
447	0.228	15	80	40.00
448	0.194	13	40	30.00
449	0.502	33	30	50.00
450	0.009	1	50	40.00
451	0.290	19	40	30.00
452	0.290	19	30	40.00
453	0.722	48	40	40.00
454	1.078	72	40	40.00
455	1.843	123	40	40.00
456	0.924	62	40	40.00
457	1.117	74	40	70.00
458	0.926	62	70	40.00
459	0.711	47	40	50.00
460	0.389	26	50	50.00
461	1.475	98	50	40.00
462	1.030	69	40	30.00
463	0.316	21	30	30.00
464	31.782	2119	30	30.00
465	0.197	13	30	50.00
466	2.549	170	50	100.00
467	0.102	7	100	98.00
468	1.352	90	98	98.00

Subcatchment ID	Area (ha)	Flow Length (m)	Imperv. (%)	Curve Number
469	0.059	4	98	50.00
473	2.180	145	50	80.00
474	0.143	10	80	60.00
475	0.030	2	60	40.00
476	1.730	115	40	50.00
477	1.861	124	50	50.00
478	0.122	8	50	60.00
482	0.970	65	60	50.00
483	1.324	88	50	60.00
484	11.119	741	60	50.00
S1	36.608	2441	25	60.00
S10	0.468	31	30	25.00
S11	0.723	48	40	25.00
S12	2.861	191	30	20.00
S13	15.420	1028	50	20.00
S14	19.048	1270	70	20.00
S15	30.757	2050	30	80.00
S16	10.628	709	40	30.00
S17	16.030	1069	5	40.00
S18	0.563	38	60	30.00
S19	1.297	86	40	25.00
S2	1.283	86	50	50.00
S20	12.435	829	30	70.00
S21	32.716	2181	50	30.00
S22	9.390	626	25	40.00
S23	14.078	939	25	5.00
S24	0.366	24	25	60.00
S25	24.470	1631	25	40.00
S26	7.171	478	25	30.00
S3	8.392	559	60	50.00
S4	5.268	351	25	60.00
S5	1.712	114	25	50.00
S6	0.413	28	20	98.00
S7	4.457	297	20	90.00
S8	2.347	156	20	90.00
S9	0.852	57	80	80.00

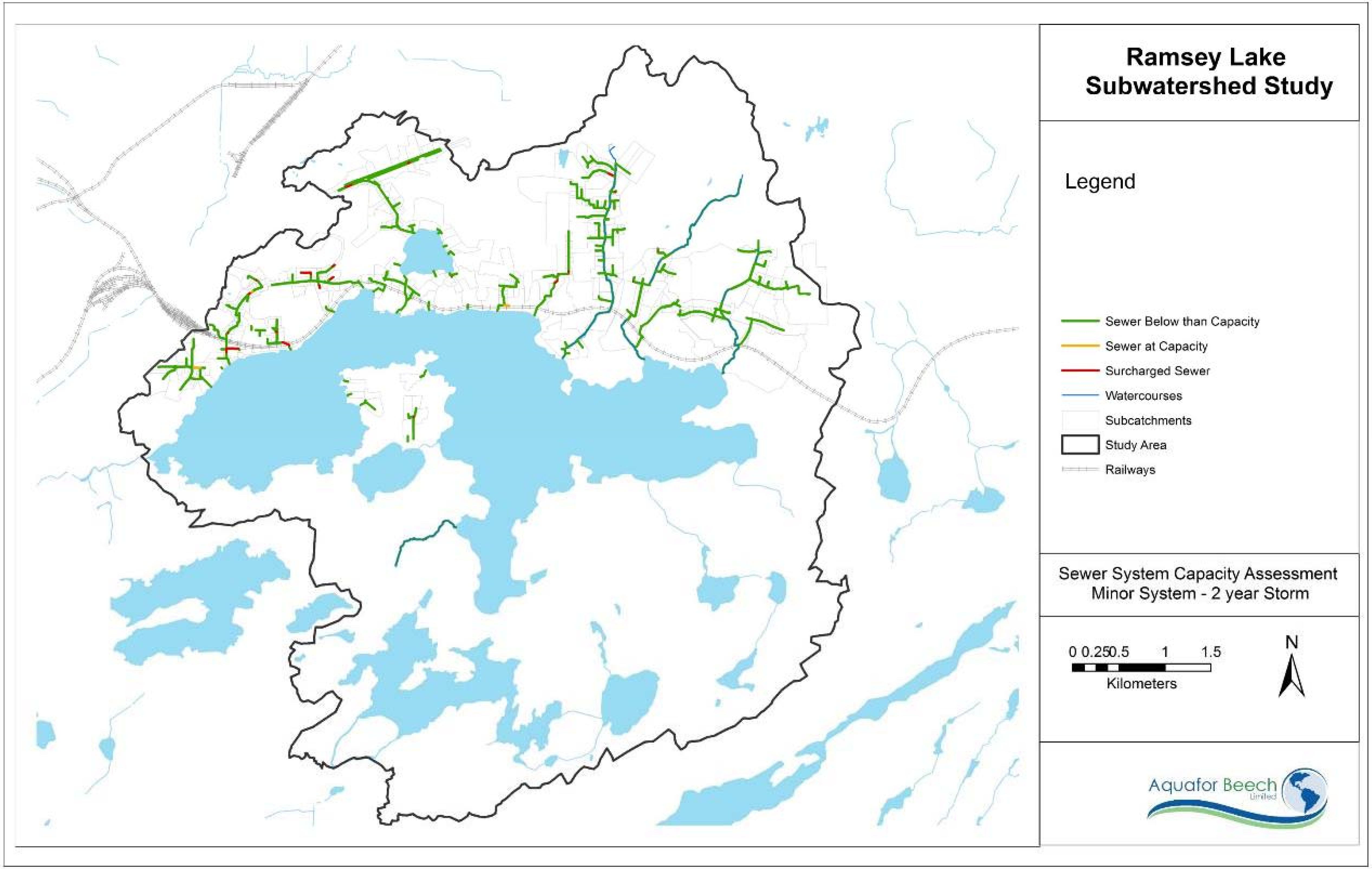


Figure A 2. Minor System Assessment - 2-Yr Design Storm

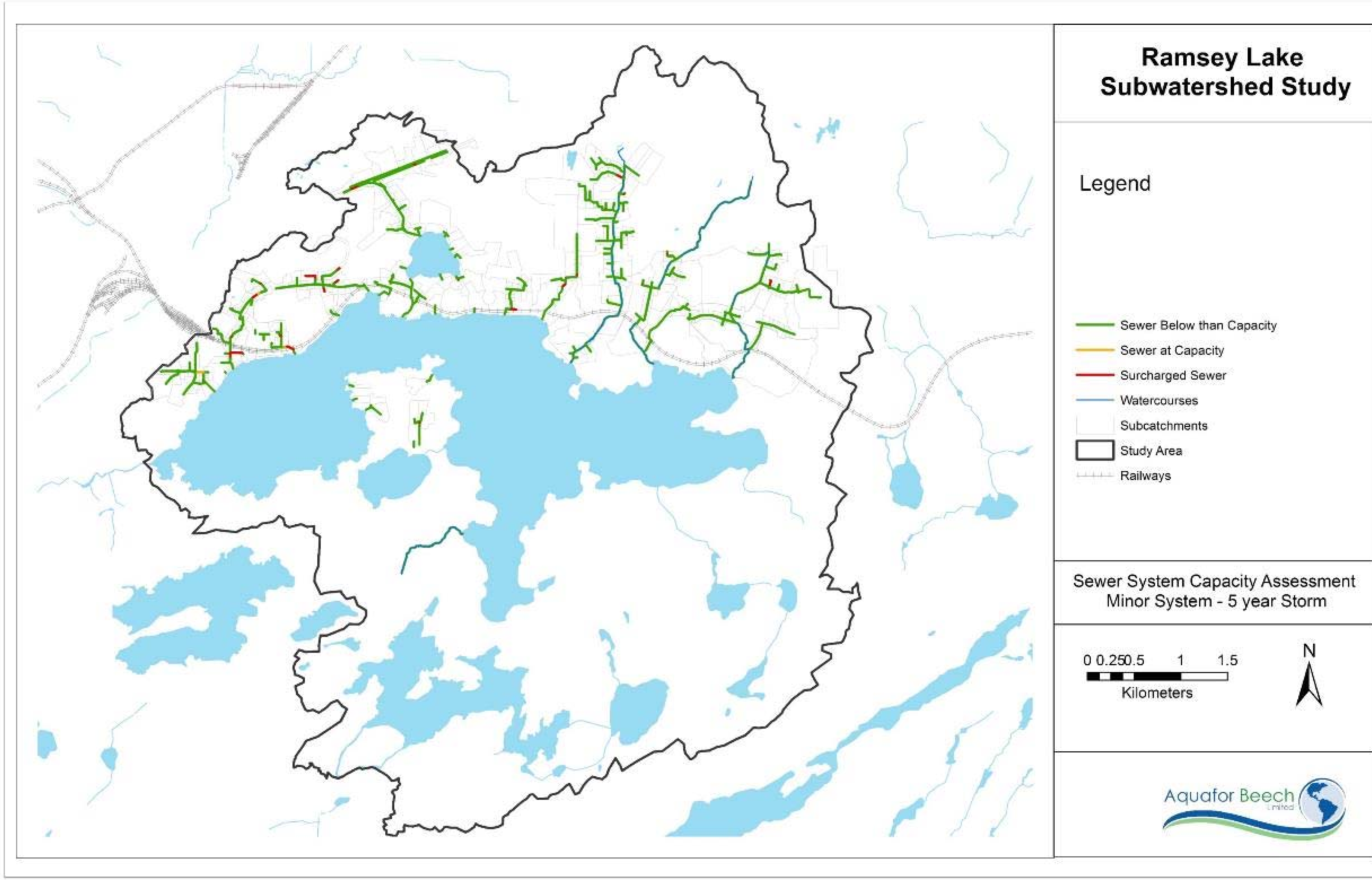


Figure A 3. Minor System Assessment - 5-Yr Design Storm

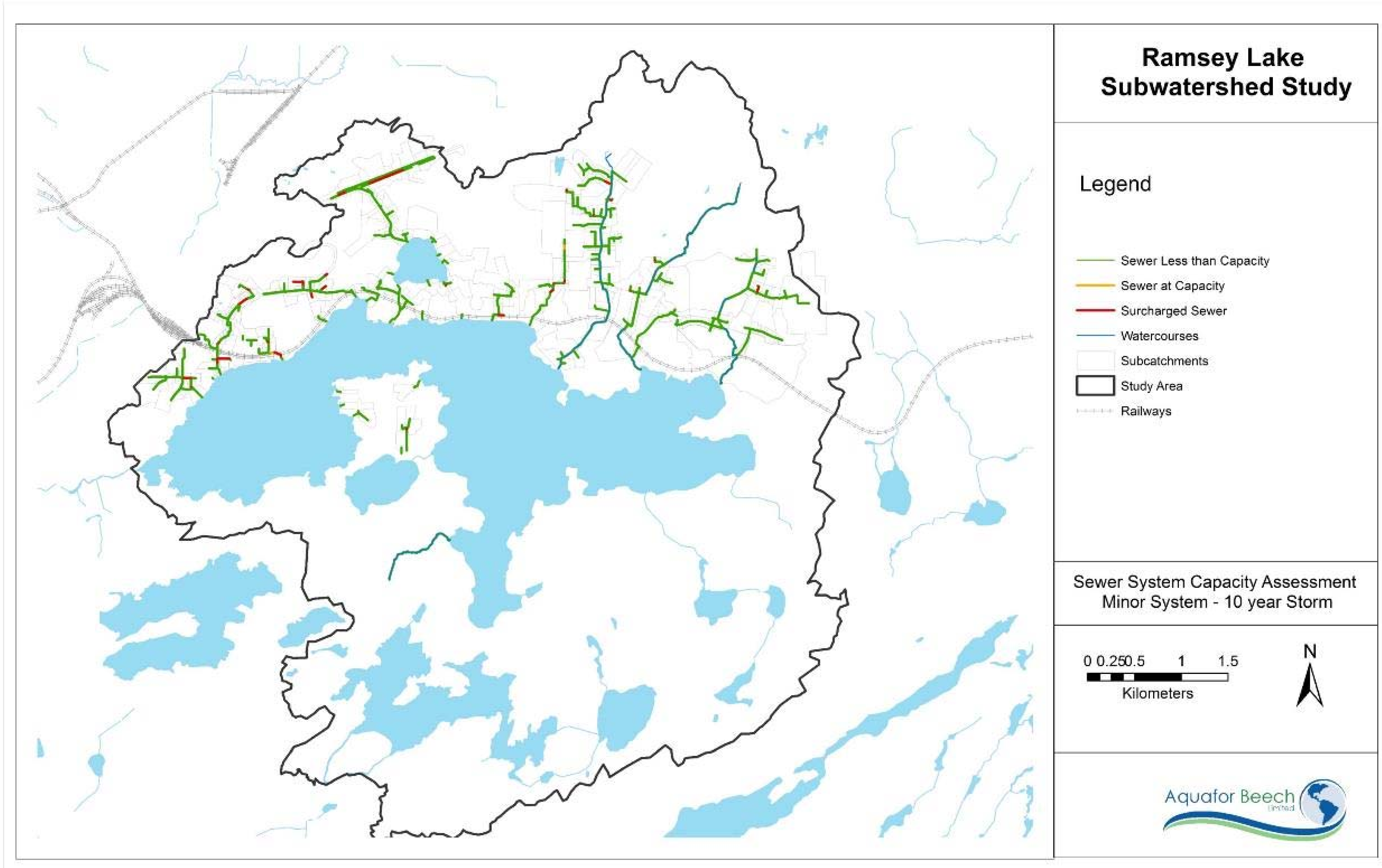


Figure A 4. Minor System Assessment - 10-Yr Design Storm

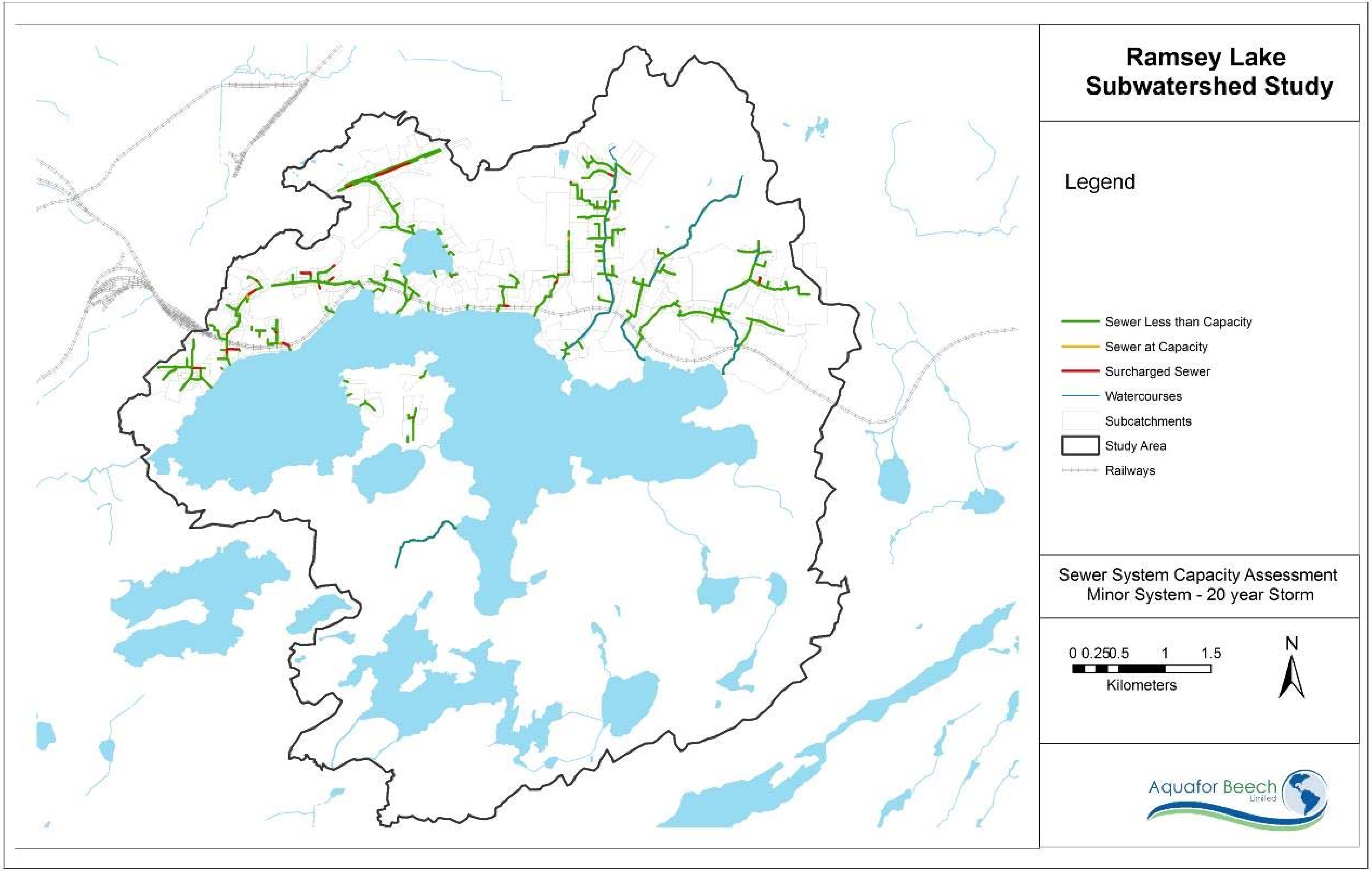


Figure A 5. Minor System Assessment - 20-Yr Design Storm

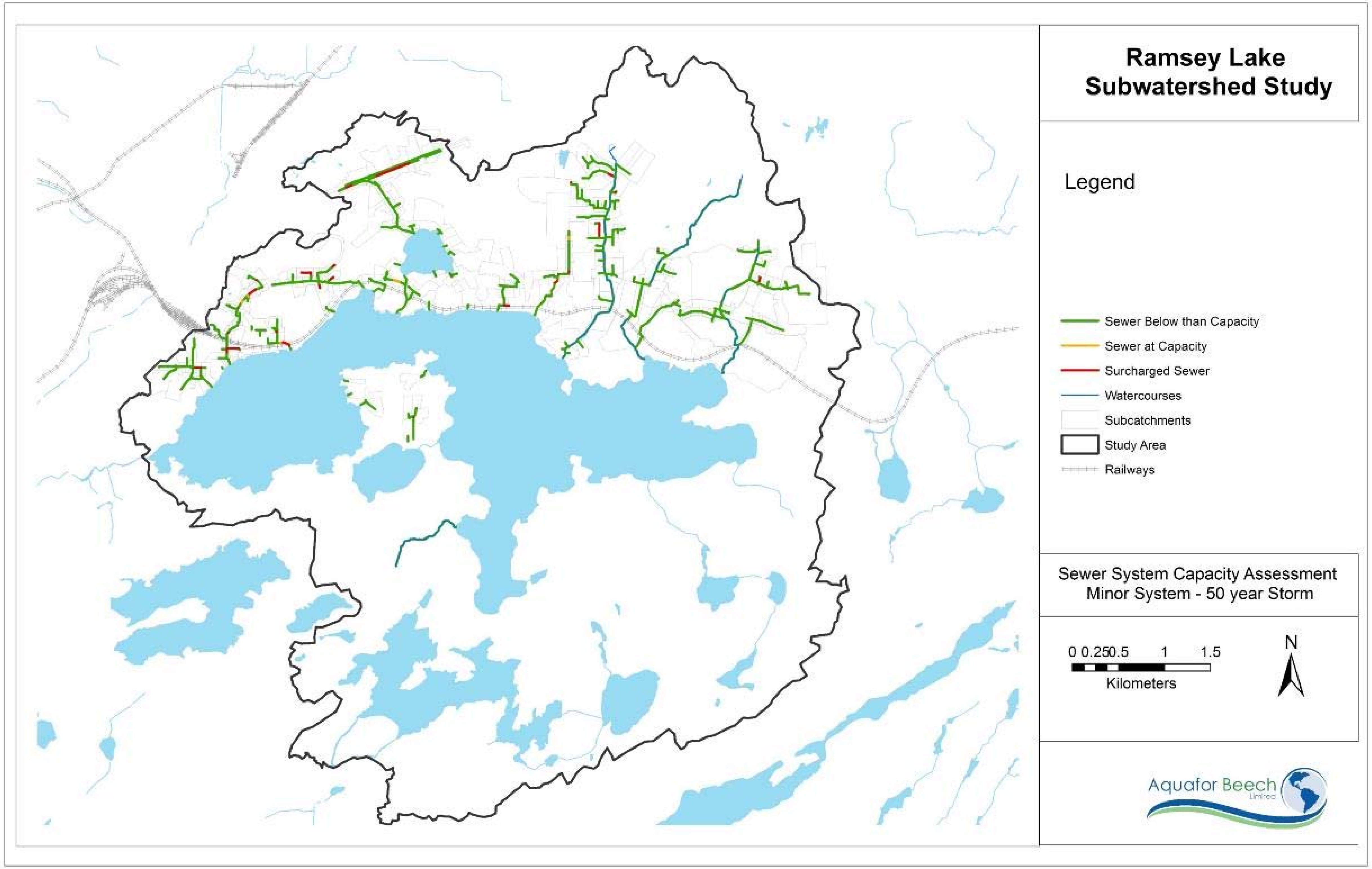


Figure A 6. Minor System Assessment - 50-Yr Design Storm

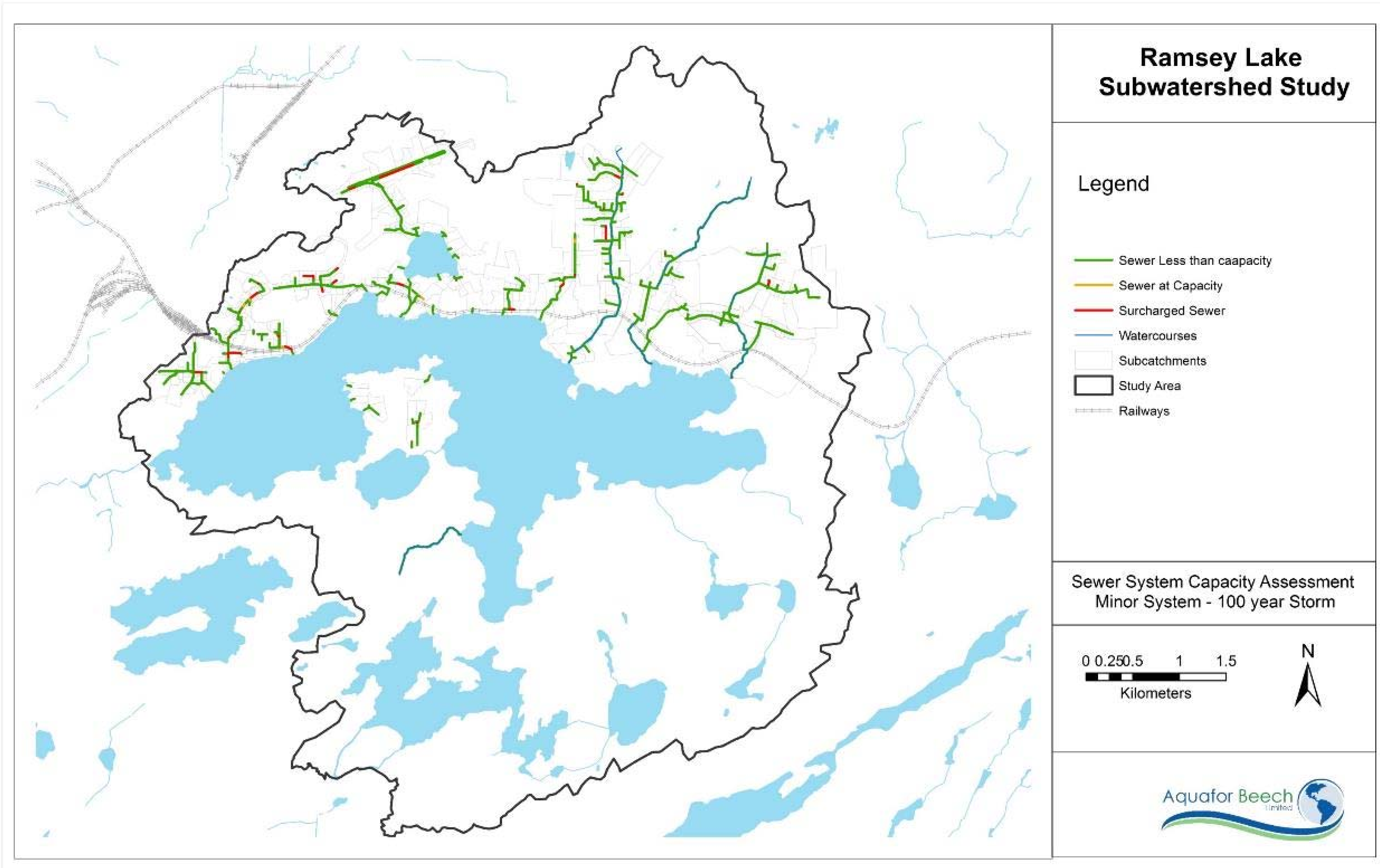


Figure A 7. Minor System Assessment - 100 Year Design Storm

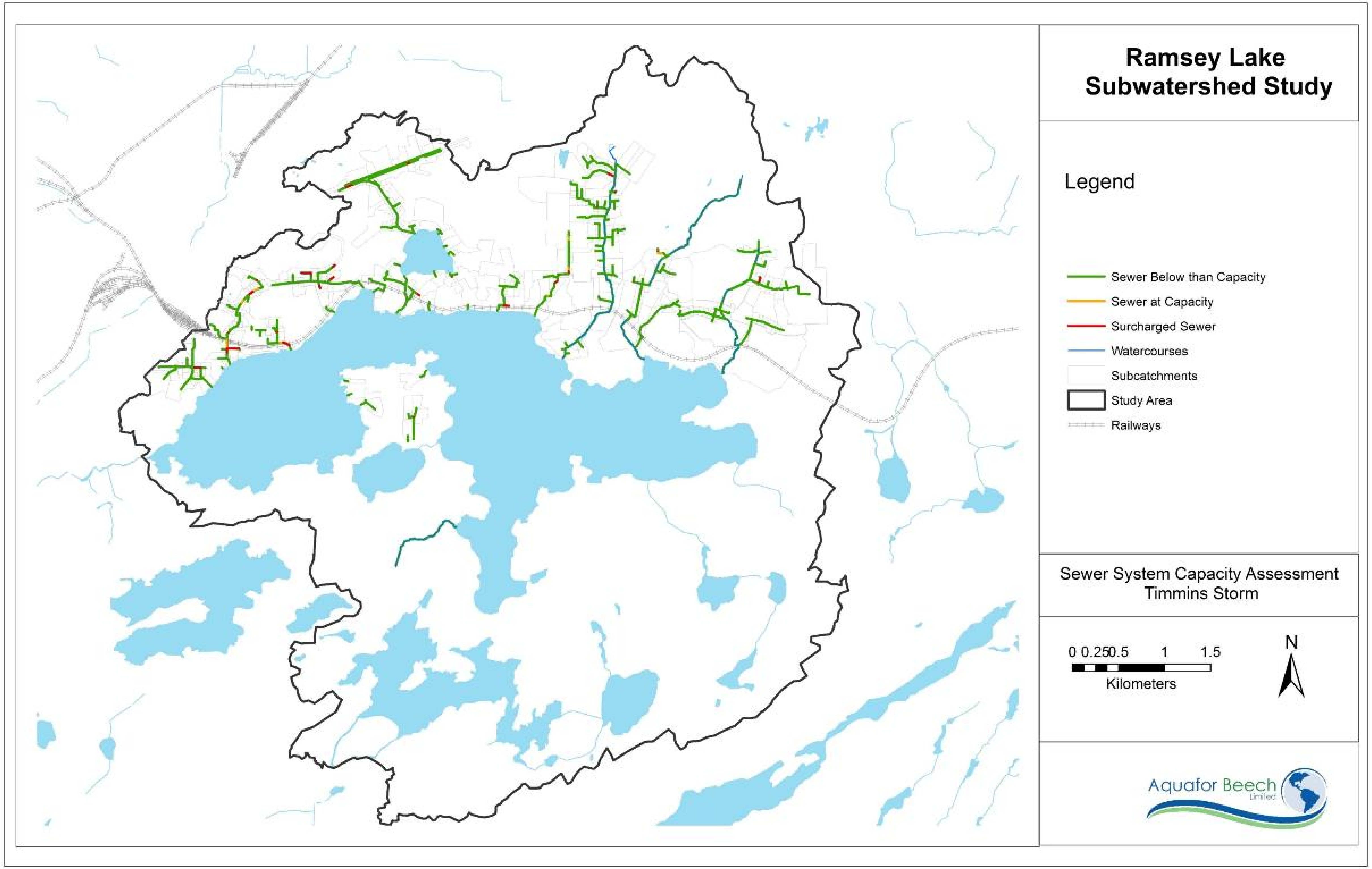


Figure A 8. Minor System Assessment - Regional Design Storm

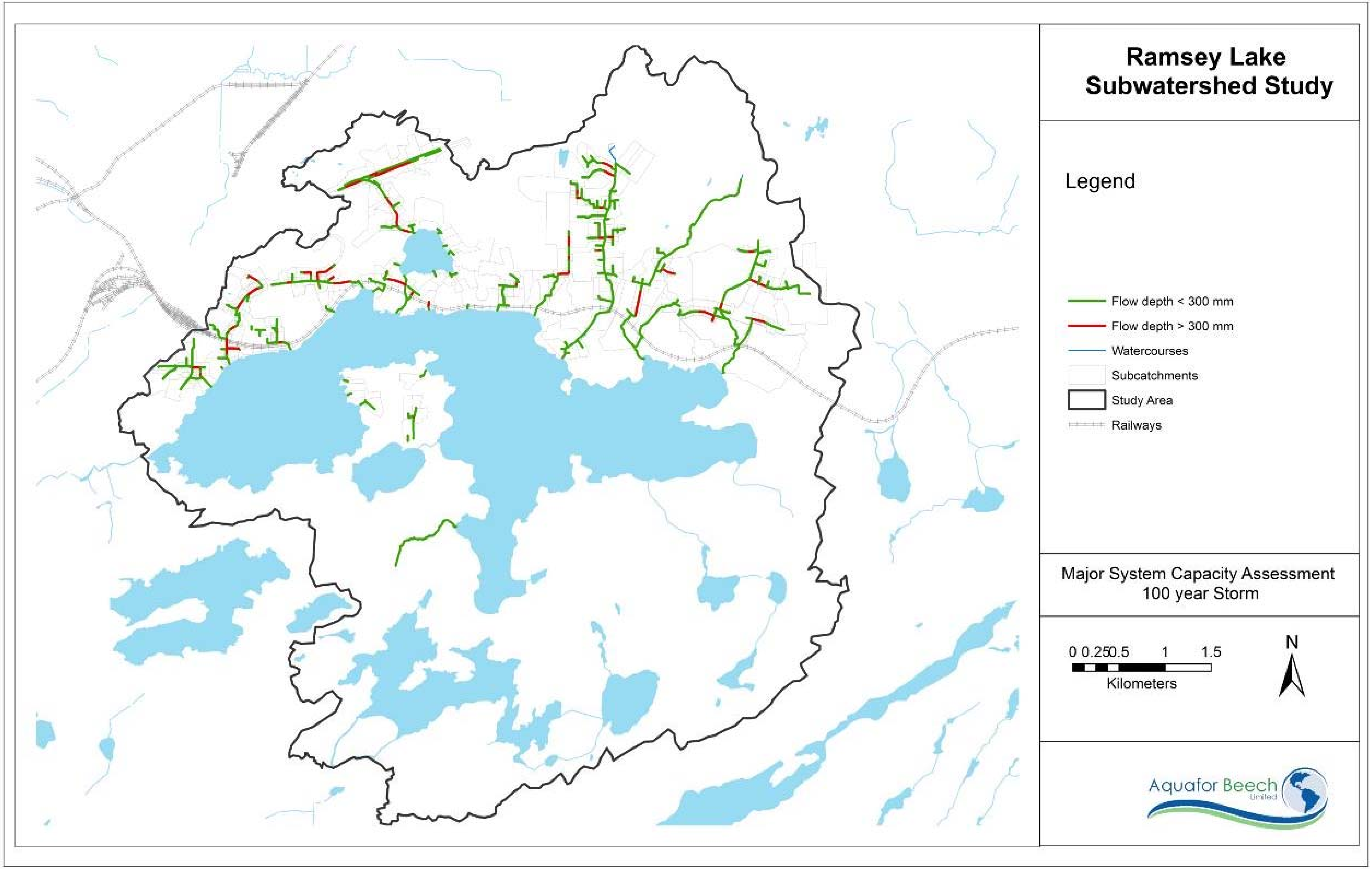


Figure A 9. Major System Assessment (Depth on Road) - 100-Yr Design Storm

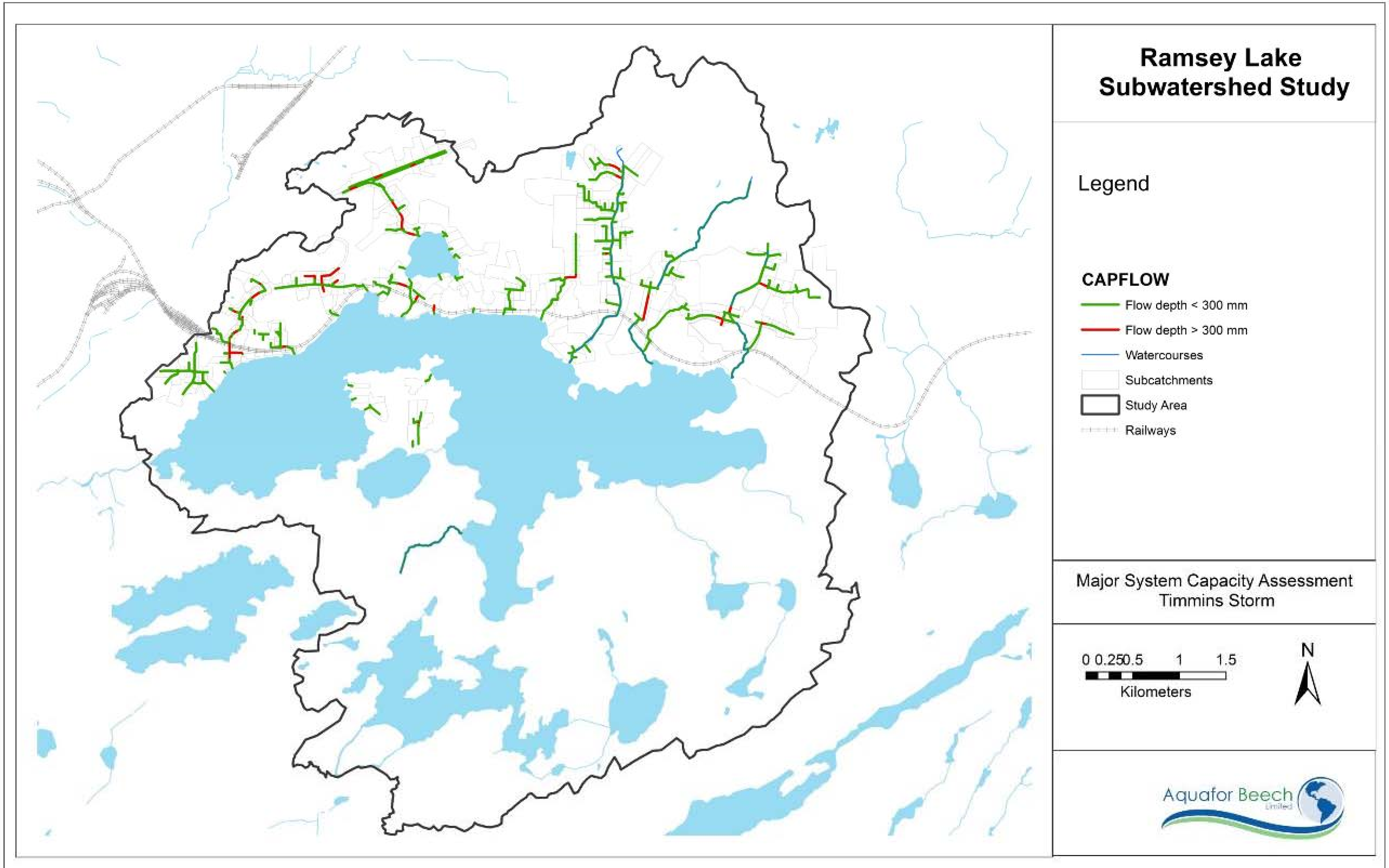
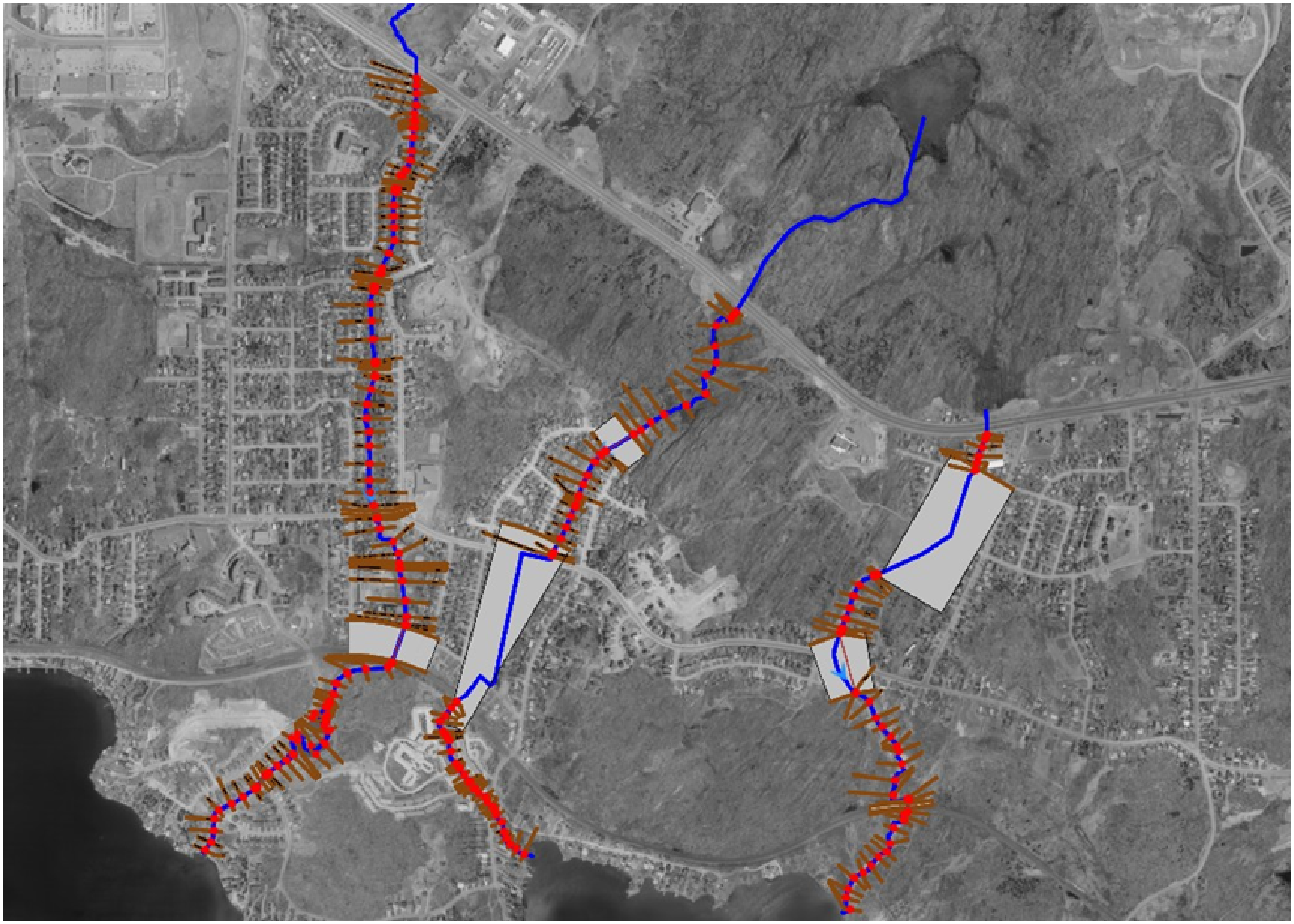


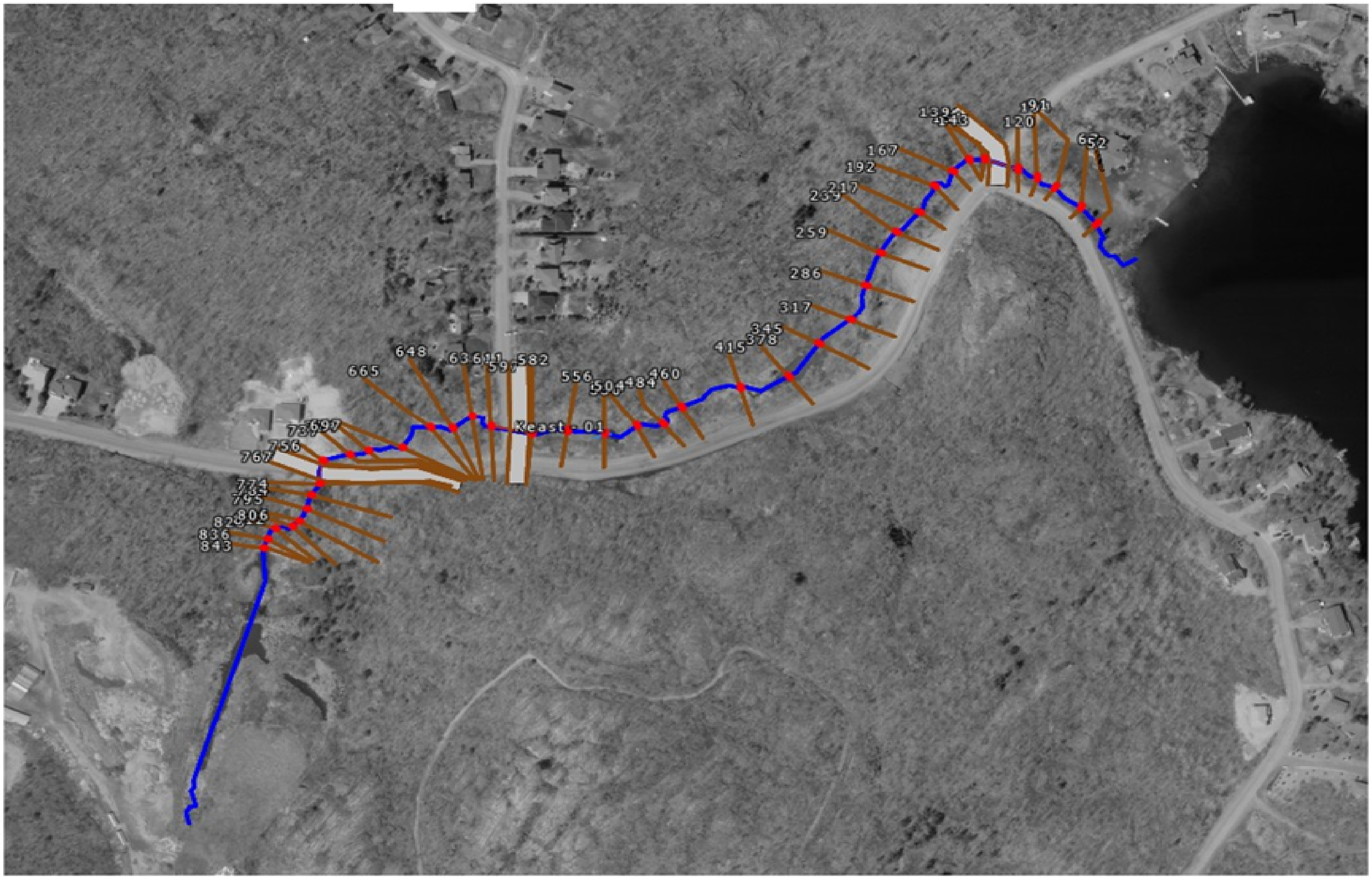
Figure A 10. Major System Assessment - Regional Storm

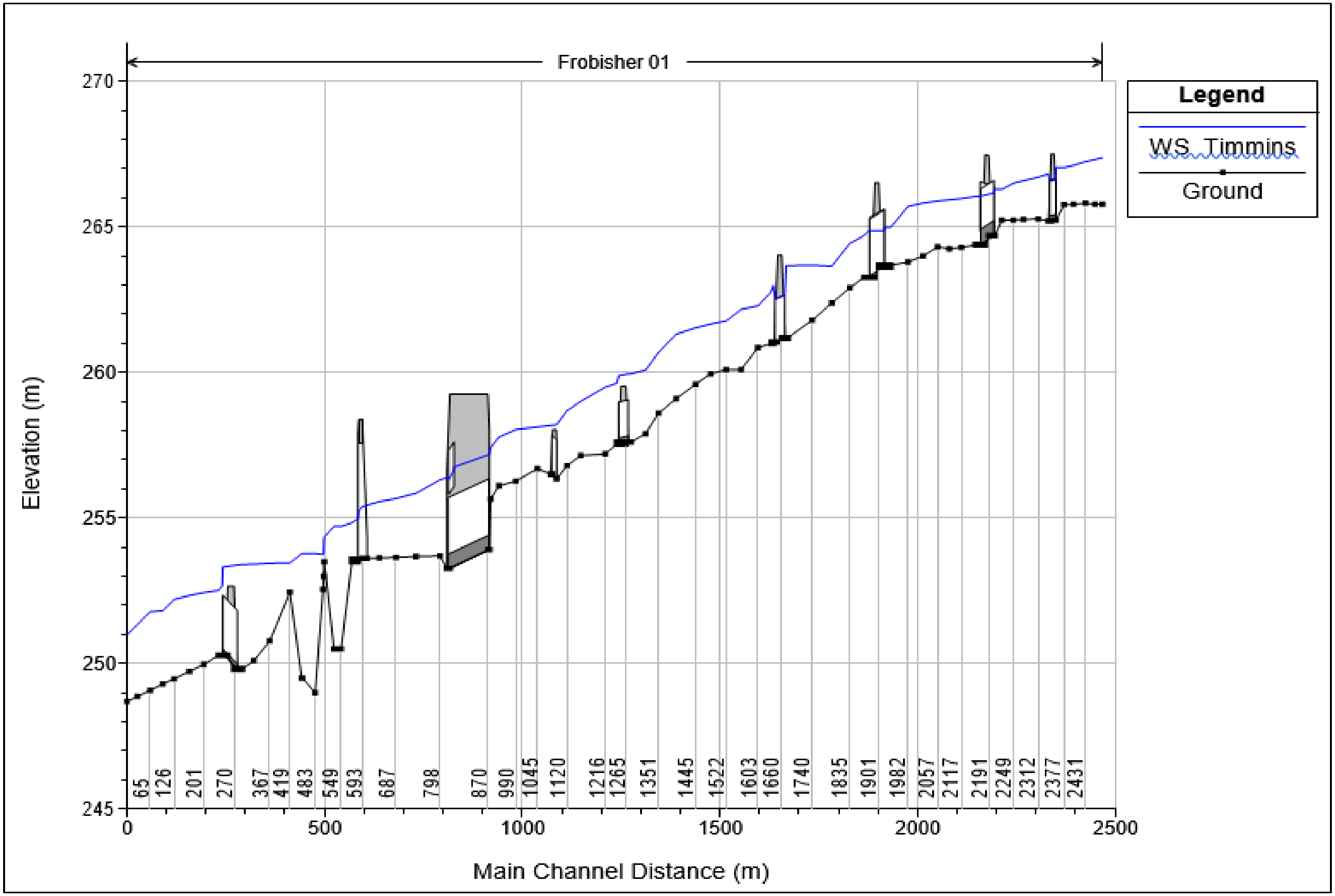
APPENDIX B: Hydraulic Modelling

Cross Section Location within HEC-RAS Model Along Frobisher, Roger & Eugene Creek

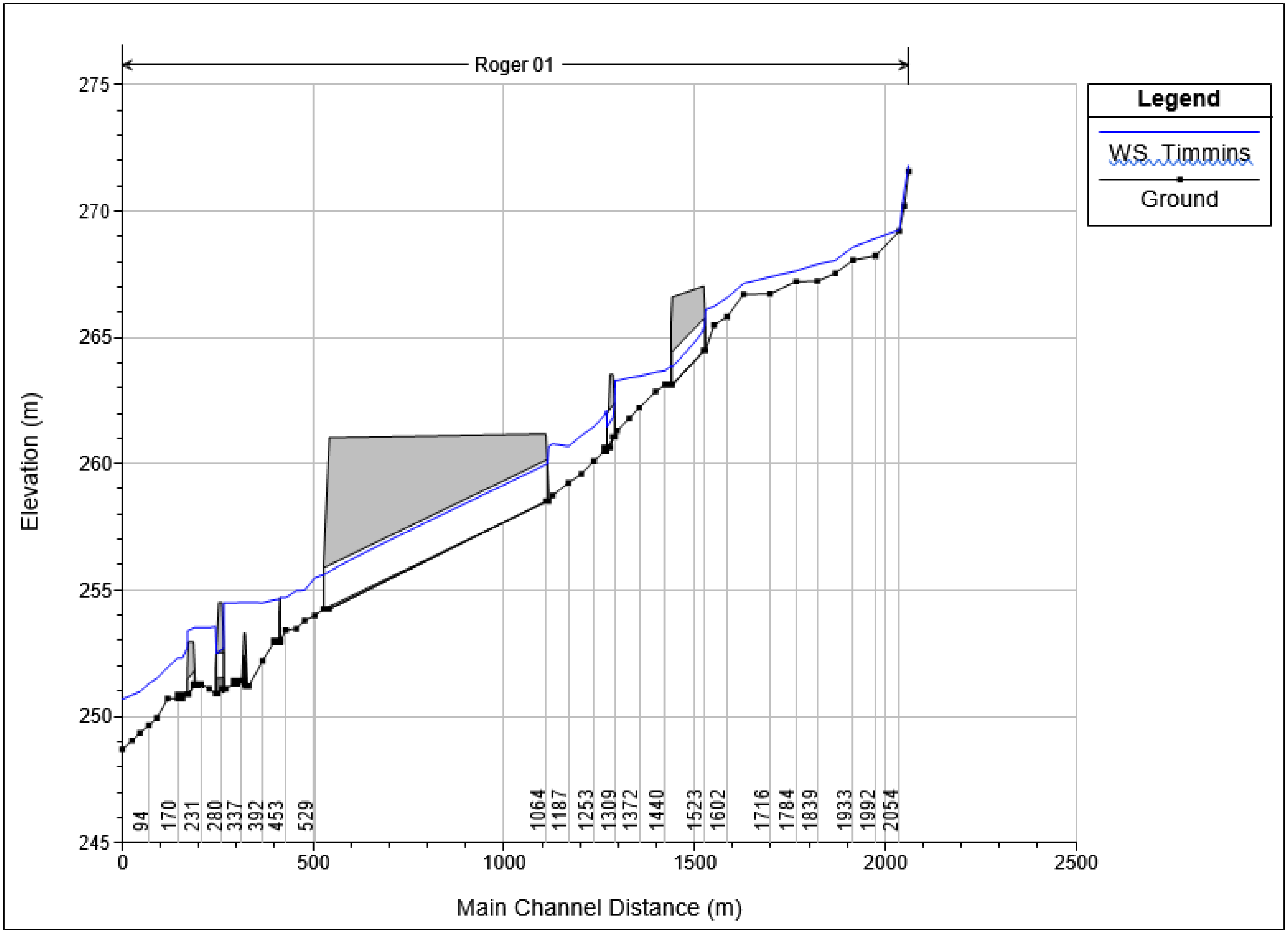


Cross Section Location within HEC-RAS Model Along Keast Creek

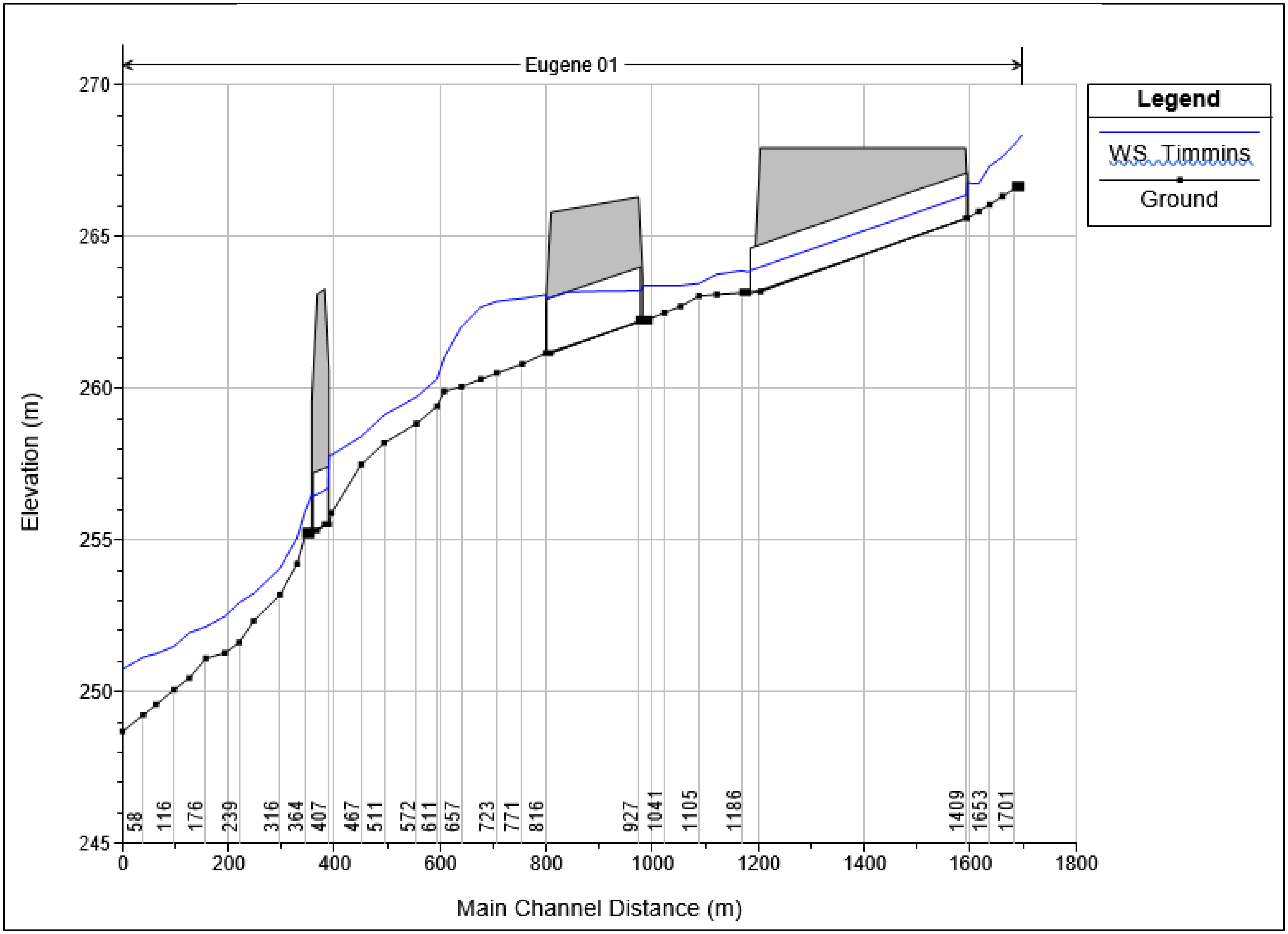




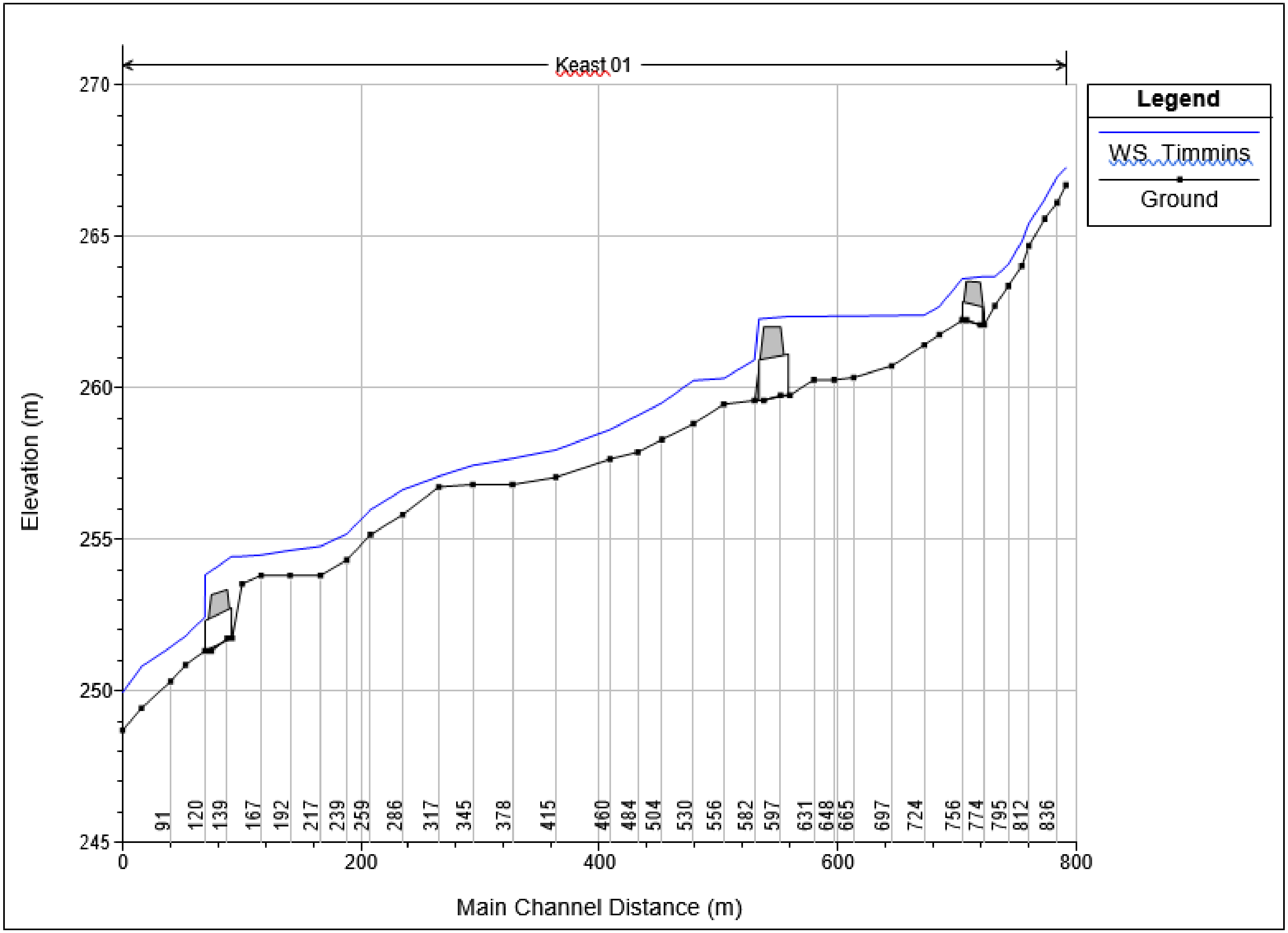
Frobisher 01
Legend
WS Timmins
Ground
Elevation (m)
270
265
260
255
250
245
65
126
201
270
367
419
483
549
593
687
798
870
990
1045
1120
1216
1265
1351
1445
1522
1603
1660
1740
1835
1901
1982
2057
2117
2191
2249
2312
2377
2431
0
500
1000
1500
2000
2500
Main Channel Distance (m)



Roger 01
Legend
WS Timmins
Ground
Elevation (m)
275
270
265
260
255
250
245
0
500
1000
1500
2000
2500
Main Channel Distance (m)
94
170
231
280
337
392
453
529
1064
1187
1253
1309
1372
1440
1523
1602
1716
1784
1839
1933
1992
2054



Eugene 01
Legend
WS Timmins
Ground
Elevation (m)
Main Channel Distance (m)
270
265
260
255
250
245
0
200
400
600
800
1000
1200
1400
1600
1800
58
116
176
239
316
364
407
467
511
572
611
657
723
771
816
927
1041
1105
1186
1409
1653
1701


Keast 01
Legend
WS Timmins
Ground
Elevation (m)
270
265
260
255
250
245
91
120
139
167
192
217
239
259
286
317
345
378
415
460
484
504
530
556
582
597
631
648
665
697
724
756
774
795
812
836
0
200
400
600
800
Main Channel Distance (m)

HEC-RAS Output for 6-Hr Chicago Flood Events and Timmins Design Storm

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
Roger	1	2078	Timmins	3.32	271.57	271.82	271.82	271.88	0.087069	1.74	3.03	22.73	1.29	136.2	112.62	0.1211	0.25
Roger	1	2078	2-yr	0.17	271.57	271.59	271.59	271.62	0.146747	0.61	0.26	6.15	1.28	32.64	61.57	0.1211	0.02
Roger	1	2078	5-yr	0.26	271.57	271.61	271.61	271.64	0.147439	0.82	0.36	6.84	1.37	50.47	75.54	0.1211	0.04
Roger	1	2078	10-yr	0.34	271.57	271.62	271.62	271.65	0.139247	0.93	0.44	7.39	1.38	60.05	81.13	0.1211	0.05
Roger	1	2078	20-yr	0.47	271.57	271.64	271.64	271.67	0.133835	1.07	0.57	8.19	1.4	73.91	91.01	0.1211	0.07
Roger	1	2078	50-yr	0.7	271.57	271.66	271.66	271.7	0.125381	1.24	0.78	9.33	1.4	89.58	102.29	0.1211	0.09
Roger	1	2078	100-yr	0.95	271.57	271.68	271.68	271.73	0.124183	1.37	0.98	10.3	1.43	104.6	115.04	0.1211	0.11
																	0
Roger	1	2067	Timmins	3.32	270.21	270.82	270.82	270.91	0.028928	1.87	3.92	23.23	0.86	115.45	47.19	0.0794	0.61
Roger	1	2067	2-yr	0.17	270.21	270.39	270.39	270.47	0.055849	1.19	0.14	1.01	1.01	69.58	69.58	0.0794	0.18
Roger	1	2067	5-yr	0.26	270.21	270.45	270.45	270.53	0.053286	1.32	0.2	1.13	1	80.06	80.06	0.0794	0.24
Roger	1	2067	10-yr	0.34	270.21	270.48	270.48	270.58	0.052081	1.41	0.24	1.21	1.01	87.29	87.29	0.0794	0.27
Roger	1	2067	20-yr	0.47	270.21	270.56	270.56	270.64	0.029715	1.25	0.48	3.96	0.79	63.96	32.97	0.0794	0.35
Roger	1	2067	50-yr	0.7	270.21	270.63	270.63	270.69	0.024379	1.27	0.85	7.31	0.73	61.77	26.87	0.0794	0.42
Roger	1	2067	100-yr	0.95	270.21	270.66	270.66	270.73	0.027004	1.4	1.11	8.44	0.78	73.69	33.81	0.0794	0.45
																	0
Roger	1	2054	Timmins	3.32	269.21	269.26		269.29	0.03736	0.48	3.97	25.09	0.72	15.94	57.79	0.0157	0.05
Roger	1	2054	2-yr	0.17	269.21	269.04	269.04	269.05	0.229313		0.34	13.28	0		56.83	0.0157	-0.17
Roger	1	2054	5-yr	0.26	269.21	269.04	269.04	269.06	0.197512		0.45	13.43	0		65.36	0.0157	-0.17
Roger	1	2054	10-yr	0.34	269.21	269.05	269.05	269.07	0.185628		0.54	13.54	0		72.51	0.0157	-0.16
Roger	1	2054	20-yr	0.47	269.21	269.06	269.06	269.09	0.170725		0.68	13.72	0		82.85	0.0157	-0.15
Roger	1	2054	50-yr	0.7	269.21	269.08	269.08	269.11	0.158964		0.89	13.99	0		98.83	0.0157	-0.13
Roger	1	2054	100-yr	0.95	269.21	269.09	269.09	269.13	0.147015		1.1	14.25	0		111	0.0157	-0.12
																	0
Roger	1	1992	Timmins	3.32	268.23	268.92		268.93	0.002191	0.62	10.81	31.82	0.25	11.68	7.24	0.0029	0.69
Roger	1	1992	2-yr	0.17	268.23	268.56		268.57	0.002313	0.36	0.98	21.63	0.22	5.13	1.02	0.0029	0.33
Roger	1	1992	5-yr	0.26	268.23	268.59	268.43	268.6	0.002115	0.37	1.65	22.8	0.22	5.24	1.49	0.0029	0.36
Roger	1	1992	10-yr	0.34	268.23	268.61		268.61	0.002148	0.39	2.06	23.41	0.22	5.64	1.84	0.0029	0.38
Roger	1	1992	20-yr	0.47	268.23	268.64		268.65	0.001831	0.38	2.88	24.55	0.21	5.35	2.09	0.0029	0.41
Roger	1	1992	50-yr	0.7	268.23	268.68		268.69	0.001852	0.41	3.86	25.64	0.21	6.03	2.71	0.0029	0.45
Roger	1	1992	100-yr	0.95	268.23	268.72		268.72	0.001924	0.44	4.73	26.42	0.22	6.81	3.35	0.0029	0.49
																	0
Roger	1	1933	Timmins	3.32	268.06	268.59		268.64	0.019828	1.52	4.78	24.84	0.72	76.93	37.07	0.0113	0.53
Roger	1	1933	2-yr	0.17	268.06	268.35	268.22	268.36	0.005564	0.5	0.46	7.79	0.34	10.62	3.11	0.0113	0.29
Roger	1	1933	5-yr	0.26	268.06	268.39	268.26	268.4	0.005349	0.54	0.85	12.26	0.34	11.78	3.56	0.0113	0.33
Roger	1	1933	10-yr	0.34	268.06	268.42	268.3	268.43	0.005121	0.56	1.17	15.11	0.34	12.32	3.85	0.0113	0.36
Roger	1	1933	20-yr	0.47	268.06	268.42	268.38	268.44	0.008754	0.74	1.26	15.73	0.44	21.49	6.8	0.0113	0.36
Roger	1	1933	50-yr	0.7	268.06	268.46	268.42	268.48	0.008301	0.79	1.94	19.06	0.44	23.09	8.17	0.0113	0.4
Roger	1	1933	100-yr	0.95	268.06	268.48	268.44	268.5	0.009041	0.86	2.43	20.38	0.47	27.08	10.46	0.0113	0.42
																	0
Roger	1	1886	Timmins	3.32	267.54	268.06		268.07	0.008138	0.96	10.8	92.14	0.46	30.75	9.33	0.0065	0.52
Roger	1	1886	2-yr	0.17	267.54	267.7	267.7	267.76	0.054853	1.14	0.15	1.15	1	64.62	64.62	0.0065	0.16
Roger	1	1886	5-yr	0.26	267.54	267.74	267.74	267.83	0.052612	1.28	0.21	1.26	1.01	75.72	75.72	0.0065	0.2
Roger	1	1886	10-yr	0.34	267.54	267.78	267.78	267.87	0.0512	1.36	0.25	1.34	1.01	82.91	82.91	0.0065	0.24
Roger	1	1886	20-yr	0.47	267.54	267.86	267.86	267.89	0.017283	0.93	1.09	22.25	0.61	35.9	8.22	0.0065	0.32
Roger	1	1886	50-yr	0.7	267.54	267.88	267.88	267.91	0.019671	1.05	1.6	27.85	0.65	44.26	10.97	0.0065	0.34
Roger	1	1886	100-yr	0.95	267.54	267.9	267.9	267.93	0.017972	1.06	2.29	33.83	0.63	43.89	11.85	0.0065	0.36
																	0
Roger	1	1839	Timmins	3.32	267.23	267.89		267.9	0.0019	0.56	13.81	53.07	0.23	9.59	4.83	0.0004	0.66
Roger	1	1839	2-yr	0.17	267.23	267.58	267.39	267.58	0.000819	0.22	1.83	25.07	0.13	1.95	0.58	0.0004	0.35
Roger	1	1839	5-yr	0.26	267.23	267.63		267.63	0.000618	0.21	2.97	28.76	0.12	1.7	0.62	0.0004	0.4
Roger	1	1839	10-yr	0.34	267.23	267.64		267.64	0.000689	0.23	3.49	30.21	0.13	2	0.78	0.0004	0.41
Roger	1	1839	20-yr	0.47	267.23	267.67		267.67	0.000792	0.26	4.3	32.3	0.14	2.47	1.03	0.0004	0.44
Roger	1	1839	50-yr	0.7	267.23	267.7		267.7	0.000958	0.31	5.43	35.13	0.15	3.26	1.44	0.0004	0.47
Roger	1	1839	100-yr	0.95	267.23	267.73		267.74	0.001066	0.34	6.57	37.82	0.17	3.91	1.81	0.0004	0.5
																	0
Roger	1	1784	Timmins	3.32	267.21	267.64	267.61	267.66	0.018587	1.25	7.21	60.81	0.67	56.29	21.53	0.0071	0.43
Roger	1	1784	2-yr	0.17	267.21	267.37	267.37	267.43	0.05477	1.14	0.15	1.16	1	64.31	64.31	0.0071	0.16
Roger	1	1784	5-yr	0.26	267.21	267.52	267.52	267.54	0.008188	0.64	0.92	49.16	0.42	16.84	1.5	0.0071	0.31
Roger	1	1784	10-yr	0.34	267.21	267.53	267.53	267.55	0.008951	0.68	1.34	50.34	0.44	19.06	2.33	0.0071	0.32
Roger	1	1784	20-yr	0.47	267.21	267.54	267.54	267.56	0.010746	0.77	1.83	51.67	0.48	23.76	3.72	0.0071	0.33
Roger	1	1784	50-yr	0.7	267.21	267.55	267.55	267.57	0.012119	0.85	2.57	53.12	0.52	28.26	5.72	0.0071	0.34
Roger	1	1784	100-yr	0.95	267.21	267.56	267.56	267.58	0.016029	0.99	2.97	53.89	0.6	38.4	8.62	0.0071	0.35
																	0
Roger	1	1716	Timmins	3.32	266.73	267.4		267.41	0.001484	0.5	15.21	55.09	0.21	7.64	4	0.0003	0.67
Roger	1	1716	2-yr	0.17	266.73	267.09		267.1	0.000691	0.21	2.07	29.72	0.12	1.73	0.47	0.0003	0.36
Roger	1	1716	5-yr	0.26	266.73	267.13	266.93	267.13	0.000646	0.22	3.06	32.32	0.12	1.8	0.6	0.0003	0.4
Roger	1	1716	10-yr	0.34	266.73	267.14		267.15	0.000689	0.23	3.65	33.72	0.13	2.02	0.73	0.0003	0.41
Roger	1	1716	20-yr	0.47	266.73	267.17		267.18	0.000709	0.25	4.68	36.24	0.13	2.26	0.89	0.0003	0.44
Roger	1	1716	50-yr	0.7	266.73	267.21		267.21	0.000828	0.29	5.97	39.24	0.14	2.88	1.23	0.0003	0.48
Roger	1	1716	100-yr	0.95	266.73	267.24		267.24	0.000905	0.32	7.25	41.88	0.15	3.39	1.53	0.0003	0.51

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
																	0
Roger	1	1646	Timmins	3.32	266.71	267.14	267.1	267.16	0.017101	1.19	7.04	53.53	0.64	51.76	21.95	0.0203	0.43
Roger	1	1646	2-yr	0.17	266.71	266.87	266.87	266.93	0.055225	1.14	0.15	1.16	1	64.71	64.71	0.0203	0.16
Roger	1	1646	5-yr	0.26	266.71	266.97	266.97	267	0.017461	0.83	0.53	12.46	0.59	30.09	7.15	0.0203	0.26
Roger	1	1646	10-yr	0.34	266.71	266.98	266.98	267.01	0.017823	0.86	0.74	14.02	0.6	32.22	9.14	0.0203	0.27
Roger	1	1646	20-yr	0.47	266.71	267	267	267.03	0.022602	1	0.96	15.41	0.68	42.52	13.56	0.0203	0.29
Roger	1	1646	50-yr	0.7	266.71	267.03	267.03	267.06	0.015832	0.92	2.05	44.25	0.58	34.14	7.18	0.0203	0.32
Roger	1	1646	100-yr	0.95	266.71	267.04	267.04	267.07	0.0188	1.03	2.55	45.31	0.64	42.3	10.31	0.0203	0.33
																	0
Roger	1	1602	Timmins	3.32	265.82	266.57		266.61	0.009472	1.35	6.18	32.55	0.53	53.74	17.49	0.01	0.75
Roger	1	1602	2-yr	0.17	265.82	266.09		266.11	0.008534	0.59	0.3	2.46	0.42	15.26	9.51	0.01	0.27
Roger	1	1602	5-yr	0.26	265.82	266.14	266.03	266.16	0.008841	0.67	0.49	4.11	0.43	18.44	9.71	0.01	0.32
Roger	1	1602	10-yr	0.34	265.82	266.17	266.06	266.2	0.008844	0.72	0.63	5.37	0.44	20.65	9.71	0.01	0.35
Roger	1	1602	20-yr	0.47	265.82	266.22	266.14	266.24	0.008798	0.79	0.9	7.16	0.45	23.73	10.5	0.01	0.4
Roger	1	1602	50-yr	0.7	265.82	266.27	266.2	266.3	0.008364	0.87	1.36	8.8	0.45	26.71	12.37	0.01	0.45
Roger	1	1602	100-yr	0.95	265.82	266.33	266.24	266.35	0.008008	0.92	1.85	10.42	0.45	29.04	13.63	0.01	0.51
																	0
Roger	1	1568	Timmins	3.32	265.48	266.23		266.32	0.007611	1.75	5.04	20.87	0.69	43.93	17.82	0.0445	0.75
Roger	1	1568	2-yr	0.17	265.48	265.65	265.65	265.7	0.017757	0.97	0.24	3.43	0.83	22.42	11.8	0.0445	0.17
Roger	1	1568	5-yr	0.26	265.48	265.69	265.69	265.74	0.018453	1.11	0.35	3.7	0.87	27.59	16.64	0.0445	0.21
Roger	1	1568	10-yr	0.34	265.48	265.71	265.71	265.77	0.01889	1.2	0.43	3.88	0.89	31.22	20.07	0.0445	0.23
Roger	1	1568	20-yr	0.47	265.48	265.74	265.74	265.81	0.019293	1.32	0.57	4.16	0.92	36.4	25.04	0.0445	0.26
Roger	1	1568	50-yr	0.7	265.48	265.79	265.79	265.87	0.020482	1.5	0.76	4.46	0.97	44.82	33.13	0.0445	0.31
Roger	1	1568	100-yr	0.95	265.48	265.83	265.83	265.93	0.021396	1.66	0.94	4.71	1.01	52.42	40.63	0.0445	0.35
																	0
Roger	1	1546	Timmins	3.32	264.48	266.1	265.35	266.18	0.0046	1.31	2.52	1.92	0.37	25.22	25.22	0.0152	1.62
Roger	1	1546	2-yr	0.17	264.48	264.79	264.61	264.8	0.001793	0.44	0.4	1.34	0.26	3.79	3.79	0.0152	0.31
Roger	1	1546	5-yr	0.26	264.48	264.87	264.65	264.88	0.002169	0.53	0.5	1.37	0.28	5.31	5.31	0.0152	0.39
Roger	1	1546	10-yr	0.34	264.48	264.92	264.68	264.94	0.002436	0.59	0.57	1.4	0.3	6.5	6.5	0.0152	0.44
Roger	1	1546	20-yr	0.47	264.48	265	264.73	265.03	0.002833	0.69	0.69	1.43	0.32	8.43	8.43	0.0152	0.52
Roger	1	1546	50-yr	0.7	264.48	265.12	264.8	265.16	0.003373	0.81	0.86	1.49	0.34	11.35	11.35	0.0152	0.64
Roger	1	1546	100-yr	0.95	264.48	265.24	264.87	265.28	0.003817	0.92	1.03	1.54	0.36	14.09	14.09	0.0152	0.76
																	0
Roger	1	1523		Culvert													0
																	0
Roger	1	1456	Timmins	3.32	263.11	263.87		263.93	0.002539	1.03	3.37	6.06	0.4	14.96	12.56	-0.0016	0.76
Roger	1	1456	2-yr	0.17	263.11	263.44		263.44	0.000125	0.14	1.26	4.16	0.08	0.35	0.35	-0.0016	0.33
Roger	1	1456	5-yr	0.26	263.11	263.52		263.52	0.000139	0.16	1.6	4.29	0.09	0.47	0.47	-0.0016	0.41
Roger	1	1456	10-yr	0.34	263.11	263.57		263.58	0.000152	0.18	1.83	4.38	0.09	0.57	0.57	-0.0016	0.46
Roger	1	1456	20-yr	0.47	263.11	263.63		263.63	0.000206	0.23	2.07	4.47	0.11	0.84	0.84	-0.0016	0.52
Roger	1	1456	50-yr	0.7	263.11	263.69		263.7	0.000297	0.3	2.38	4.82	0.13	1.36	1.29	-0.0016	0.58
Roger	1	1456	100-yr	0.95	263.11	263.75		263.76	0.000394	0.36	2.66	5.29	0.15	1.97	1.76	-0.0016	0.64
																	0
Roger	1	1440	Timmins	4.65	263.14	263.69		263.83	0.008892	1.65	2.9	6.39	0.74	41.94	37.57	0.0111	0.55
Roger	1	1440	2-yr	0.94	263.14	263.31	263.3	263.38	0.019989	1.18	0.79	4.9	0.94	30.98	30.98	0.0111	0.17
Roger	1	1440	5-yr	1.41	263.14	263.36	263.35	263.45	0.018343	1.34	1.05	5.02	0.93	36.54	36.54	0.0111	0.22
Roger	1	1440	10-yr	1.78	263.14	263.4	263.39	263.5	0.016806	1.42	1.26	5.12	0.91	39	39	0.0111	0.26
Roger	1	1440	20-yr	2.17	263.14	263.44		263.55	0.015676	1.49	1.46	5.21	0.9	41.22	41.21	0.0111	0.3
Roger	1	1440	50-yr	2.72	263.14	263.49	263.46	263.62	0.013974	1.56	1.74	5.49	0.87	43.16	41.64	0.0111	0.35
Roger	1	1440	100-yr	3.21	263.14	263.54	263.5	263.67	0.012566	1.61	2.01	5.7	0.84	43.89	41.46	0.0111	0.4
																	0
Roger	1	1415	Timmins	4.65	262.86	263.62		263.68	0.002482	1.12	4.63	8.4	0.42	17.04	12.84	0.0147	0.76
Roger	1	1415	2-yr	0.94	262.86	263.11		263.14	0.004721	0.74	1.26	5.27	0.48	10.73	10.73	0.0147	0.25
Roger	1	1415	5-yr	1.41	262.86	263.2		263.23	0.004197	0.83	1.7	5.56	0.47	12.35	12.07	0.0147	0.34
Roger	1	1415	10-yr	1.78	262.86	263.25		263.29	0.003942	0.89	2.02	5.81	0.47	13.48	12.83	0.0147	0.39
Roger	1	1415	20-yr	2.17	262.86	263.31		263.35	0.003686	0.94	2.34	6.15	0.46	14.43	13.13	0.0147	0.45
Roger	1	1415	50-yr	2.72	262.86	263.38		263.43	0.003395	1	2.8	6.66	0.46	15.57	13.38	0.0147	0.52
Roger	1	1415	100-yr	3.21	262.86	263.44		263.49	0.003176	1.05	3.22	7.09	0.45	16.38	13.51	0.0147	0.58
																	0
Roger	1	1372	Timmins	4.65	262.23	263.47		263.55	0.003706	1.65	5.92	10.78	0.5	33.68	19.14	0.0164	1.24
Roger	1	1372	2-yr	0.94	262.23	262.78		262.86	0.009063	1.35	0.92	3.93	0.67	31.13	19.36	0.0164	0.55
Roger	1	1372	5-yr	1.41	262.23	262.9		262.99	0.007309	1.44	1.49	5.3	0.63	32.48	18.99	0.0164	0.67
Roger	1	1372	10-yr	1.78	262.23	262.98		263.07	0.006684	1.51	1.93	6.02	0.61	33.94	19.86	0.0164	0.75
Roger	1	1372	20-yr	2.17	262.23	263.05		263.14	0.006231	1.56	2.37	6.57	0.6	35.25	20.9	0.0164	0.82
Roger	1	1372	50-yr	2.72	262.23	263.14		263.24	0.005815	1.64	2.98	7.26	0.59	37.14	22.24	0.0164	0.91
Roger	1	1372	100-yr	3.21	262.23	263.21		263.31	0.005577	1.7	3.53	7.96	0.59	38.9	23.07	0.0164	0.98
																	0
Roger	1	1346	Timmins	4.65	261.8	263.4		263.46	0.002719	1.33	6.53	9.98	0.37	22.59	15.71	0.0159	1.6
Roger	1	1346	2-yr	0.94	261.8	262.63		262.68	0.004978	1.04	1.05	3.54	0.43	18.11	11.55	0.0159	0.83
Roger	1	1346	5-yr	1.41	261.8	262.76		262.83	0.004874	1.17	1.64	5.22	0.44	21.43	12.77	0.0159	0.96
Roger	1	1346	10-yr	1.78	261.8	262.85		262.92	0.004743	1.24	2.12	6.03	0.44	23.31	14.14	0.0159	1.05
Roger	1	1346	20-yr	2.17	261.8	262.93		263	0.004589	1.3	2.61	6.62	0.44	24.74	15.5	0.0159	1.13

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
Roger	1	1346	50-yr	2.72	261.8	263.02		263.1	0.004419	1.37	3.28	7.28	0.44	26.44	17.21	0.0159	1.22
Roger	1	1346	100-yr	3.21	261.8	263.1		263.18	0.004275	1.41	3.87	7.77	0.44	27.62	18.46	0.0159	1.3
																	0
Roger	1	1315	Timmins	4.65	261.3	263.29		263.36	0.003481	1.44	5.32	7.17	0.39	27.02	21.11	0.0446	1.99
Roger	1	1315	2-yr	0.94	261.3	262.13	262.13	262.34	0.033226	2.02	0.48	1.4	0.97	78.65	68.53	0.0446	0.83
Roger	1	1315	5-yr	1.41	261.3	262.29	262.29	262.51	0.026981	2.11	0.76	2.12	0.92	79.81	64.88	0.0446	0.99
Roger	1	1315	10-yr	1.78	261.3	262.39	262.39	262.61	0.024592	2.17	0.98	2.56	0.9	81.42	66.19	0.0446	1.09
Roger	1	1315	20-yr	2.17	261.3	262.47	262.47	262.7	0.023708	2.25	1.2	2.92	0.89	85.22	69.88	0.0446	1.17
Roger	1	1315	50-yr	2.72	261.3	262.56	262.56	262.81	0.022927	2.35	1.5	3.36	0.89	90.19	75.12	0.0446	1.26
Roger	1	1315	100-yr	3.21	261.3	262.63	262.63	262.89	0.022831	2.45	1.75	3.69	0.9	95.46	80.5	0.0446	1.33
																	0
Roger	1	1309	Timmins	4.65	261.07	263.3	262.15	263.34	0.001687	0.96	6.35	9.04	0.21	12.22	8.72	0.019	2.23
Roger	1	1309	2-yr	0.94	261.07	261.81	261.45	261.86	0.004318	0.95	0.99	1.39	0.36	15.14	15.14	0.019	0.74
Roger	1	1309	5-yr	1.41	261.07	261.99	261.56	262.06	0.005343	1.13	1.25	1.42	0.38	20.83	20.83	0.019	0.92
Roger	1	1309	10-yr	1.78	261.07	262.12	261.64	262.2	0.006008	1.24	1.43	1.44	0.4	24.82	24.82	0.019	1.05
Roger	1	1309	20-yr	2.17	261.07	262.25	261.72	262.34	0.006562	1.34	1.61	1.45	0.41	28.45	28.45	0.019	1.18
Roger	1	1309	50-yr	2.72	261.07	262.42	261.83	262.53	0.007136	1.45	1.87	1.48	0.41	32.7	32.7	0.019	1.35
Roger	1	1309	100-yr	3.21	261.07	262.58	261.91	262.7	0.007398	1.53	2.11	2.23	0.41	35.5	30.48	0.019	1.51
																	0
Roger	1	1298		Culvert													0
																	0
Roger	1	1287	Timmins	4.65	260.64	262.12		262.27	0.007696	1.89	3.57	6.5	0.51	49.59	32.57	0.0229	1.48
Roger	1	1287	2-yr	0.94	260.64	261.31		261.37	0.005951	1.08	0.87	1.41	0.44	19.91	19.91	0.0229	0.67
Roger	1	1287	5-yr	1.41	260.64	261.51		261.58	0.006371	1.22	1.15	1.47	0.44	24.44	24.44	0.0229	0.87
Roger	1	1287	10-yr	1.78	260.64	261.63		261.72	0.00681	1.33	1.35	1.96	0.45	28.38	25.04	0.0229	0.99
Roger	1	1287	20-yr	2.17	260.64	261.73		261.84	0.006827	1.43	1.62	3.09	0.46	31.69	22.7	0.0229	1.09
Roger	1	1287	50-yr	2.72	260.64	261.85		261.97	0.006907	1.56	2.08	4.67	0.47	35.94	22.15	0.0229	1.21
Roger	1	1287	100-yr	3.21	260.64	261.94		262.06	0.007048	1.65	2.5	5.26	0.48	39.43	24.75	0.0229	1.3
																	0
Roger	1	1281	Timmins	4.65	260.5	261.91	261.89	262.18	0.016721	2.42	2.66	5.8	0.73	86.93	58.07	0.0147	1.41
Roger	1	1281	2-yr	0.94	260.5	261.21		261.31	0.011642	1.4	0.67	1.19	0.59	34.81	34.81	0.0147	0.71
Roger	1	1281	5-yr	1.41	260.5	261.39		261.51	0.012174	1.56	0.9	1.32	0.6	41.58	41.58	0.0147	0.89
Roger	1	1281	10-yr	1.78	260.5	261.49		261.64	0.013401	1.71	1.04	1.39	0.63	48.76	48.76	0.0147	0.99
Roger	1	1281	20-yr	2.17	260.5	261.58	261.35	261.75	0.015025	1.87	1.17	2.26	0.67	57.28	45.19	0.0147	1.08
Roger	1	1281	50-yr	2.72	260.5	261.67	261.47	261.88	0.01657	2.05	1.48	3.78	0.7	67.48	44.27	0.0147	1.17
Roger	1	1281	100-yr	3.21	260.5	261.75	261.66	261.97	0.016452	2.15	1.8	4.5	0.71	72.67	46.99	0.0147	1.25
																	0
Roger	1	1253	Timmins	4.65	260.1	261.47	261.46	261.72	0.016439	2.42	2.86	6.15	0.77	86.44	61.06	0.0153	1.37
Roger	1	1253	2-yr	0.94	260.1	260.86		260.97	0.013211	1.46	0.64	1.2	0.64	38.35	38.35	0.0153	0.76
Roger	1	1253	5-yr	1.41	260.1	261.05		261.18	0.012678	1.58	0.9	2.25	0.63	42.94	32.53	0.0153	0.95
Roger	1	1253	10-yr	1.78	260.1	261.16	260.94	261.29	0.01163	1.64	1.27	3.91	0.61	44.29	27.91	0.0153	1.06
Roger	1	1253	20-yr	2.17	260.1	261.26	261.05	261.39	0.010726	1.67	1.68	4.68	0.6	44.49	29.39	0.0153	1.16
Roger	1	1253	50-yr	2.72	260.1	261.33	261.24	261.48	0.011538	1.83	2.03	5.18	0.63	51.9	35.16	0.0153	1.23
Roger	1	1253	100-yr	3.21	260.1	261.36	261.3	261.54	0.013872	2.05	2.18	5.38	0.69	64.46	44	0.0153	1.26
																	0
Roger	1	1221	Timmins	4.65	259.6	261.13	260.99	261.29	0.009745	2.01	3.61	6.85	0.6	57.5	41.6	0.0103	1.53
Roger	1	1221	2-yr	0.94	259.6	260.33	260.21	260.46	0.018012	1.64	0.57	1.14	0.74	49.2	49.2	0.0103	0.73
Roger	1	1221	5-yr	1.41	259.6	260.47	260.37	260.65	0.020541	1.89	0.74	1.28	0.79	63.21	63.21	0.0103	0.87
Roger	1	1221	10-yr	1.78	259.6	260.55	260.47	260.77	0.022612	2.08	0.87	2.24	0.84	74.94	56.8	0.0103	0.95
Roger	1	1221	20-yr	2.17	259.6	260.62	260.61	260.87	0.023729	2.25	1.06	3	0.87	84.78	58.37	0.0103	1.02
Roger	1	1221	50-yr	2.72	259.6	260.75	260.75	260.99	0.019767	2.22	1.53	4.13	0.81	79.82	54.61	0.0103	1.15
Roger	1	1221	100-yr	3.21	259.6	260.87	260.82	261.07	0.015056	2.11	2.07	4.97	0.72	68.78	48.36	0.0103	1.27
																	0
Roger	1	1187	Timmins	4.65	259.25	260.7		260.92	0.011797	2.06	2.26	1.95	0.61	62.63	62.63	0.0118	1.45
Roger	1	1187	2-yr	0.94	259.25	259.69		259.83	0.019063	1.66	0.57	1.4	0.83	50.91	50.91	0.0118	0.44
Roger	1	1187	5-yr	1.41	259.25	259.85		260.01	0.017195	1.79	0.79	1.49	0.78	55.48	55.48	0.0118	0.6
Roger	1	1187	10-yr	1.78	259.25	259.99		260.15	0.014419	1.78	1	1.56	0.71	52.72	52.72	0.0118	0.74
Roger	1	1187	20-yr	2.17	259.25	260.15		260.3	0.011653	1.72	1.26	1.65	0.63	47.64	47.64	0.0118	0.9
Roger	1	1187	50-yr	2.72	259.25	260.38		260.51	0.008939	1.64	1.66	1.78	0.54	41.48	41.48	0.0118	1.13
Roger	1	1187	100-yr	3.21	259.25	260.56		260.69	0.0077	1.61	1.99	1.88	0.5	38.78	38.78	0.0118	1.31
																	0
Roger	1	1145	Timmins	4.65	258.75	260.8		260.81	0.00032	0.58	11.19	11.75	0.14	3.81	2.67	0.0226	2.05
Roger	1	1145	2-yr	0.94	258.75	259.53		259.56	0.002672	0.81	1.15	1.9	0.33	10.67	10.67	0.0226	0.78
Roger	1	1145	5-yr	1.41	258.75	259.8		259.83	0.001367	0.71	2.37	5.46	0.25	7.46	4.86	0.0226	1.05
Roger	1	1145	10-yr	1.78	258.75	259.99		260.01	0.00084	0.64	3.58	7.08	0.2	5.62	3.59	0.0226	1.24
Roger	1	1145	20-yr	2.17	258.75	260.18		260.19	0.000547	0.58	4.99	8.21	0.17	4.32	2.85	0.0226	1.43
Roger	1	1145	50-yr	2.72	258.75	260.43		260.44	0.000341	0.52	7.19	9.59	0.14	3.23	2.21	0.0226	1.68
Roger	1	1145	100-yr	3.21	258.75	260.62		260.63	0.000256	0.49	9.13	10.65	0.12	2.75	1.91	0.0226	1.87
																	0
Roger	1	1135	Timmins	6.41	258.52	260.69	259.68	260.8	0.003841	1.49	4.87	6.66	0.34	29.13	18.47	0.0072	2.17
Roger	1	1135	2-yr	1.68	258.52	259.47	259.01	259.52	0.003815	1.05	1.59	1.83	0.36	17.26	17.26	0.0072	0.95
Roger	1	1135	5-yr	2.56	258.52	259.71	259.16	259.79	0.004533	1.24	2.06	1.91	0.38	23.1	23.1	0.0072	1.19

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
Roger	1	1135	10-yr	3.24	258.52	259.89	259.27	259.98	0.004932	1.36	2.39	1.96	0.39	26.85	26.85	0.0072	1.37
Roger	1	1135	20-yr	3.94	258.52	260.06	259.37	260.17	0.005201	1.44	2.73	2.01	0.4	29.93	29.93	0.0072	1.54
Roger	1	1135	50-yr	4.92	258.52	260.29	259.5	260.41	0.005376	1.53	3.21	2.08	0.39	33	33	0.0072	1.77
Roger	1	1135	100-yr	5.78	258.52	260.48	259.6	260.6	0.005133	1.6	3.75	4	0.39	34.63	26.2	0.0072	1.96
																	0
Roger	1	1064		Culvert													0
																	0
Roger	1	552	Timmins	6.41	254.25	255.61	255.31	255.86	0.010546	2.21	3.28	7.24	0.65	67.77	36.89	0.0119	1.36
Roger	1	552	2-yr	1.68	254.25	255.02		255.08	0.004642	1.14	1.48	2.13	0.44	20.31	20.31	0.0119	0.77
Roger	1	552	5-yr	2.56	254.25	255.17		255.27	0.006233	1.42	1.8	2.21	0.5	30.41	30.41	0.0119	0.92
Roger	1	552	10-yr	3.24	254.25	255.27		255.4	0.007233	1.59	2.04	2.27	0.54	37.59	37.59	0.0119	1.02
Roger	1	552	20-yr	3.94	254.25	255.36		255.52	0.008305	1.76	2.24	2.32	0.57	45.28	45.28	0.0119	1.11
Roger	1	552	50-yr	4.92	254.25	255.47		255.67	0.00976	1.98	2.49	2.38	0.62	56.06	56.06	0.0119	1.22
Roger	1	552	100-yr	5.78	254.25	255.55	255.24	255.78	0.010638	2.14	2.83	6.39	0.65	64.61	35.44	0.0119	1.3
																	0
Roger	1	529	Timmins	6.41	253.98	255.48	255.21	255.62	0.006722	2.03	6.32	12.78	0.57	53.16	30.05	0.0067	1.5
Roger	1	529	2-yr	1.68	253.98	254.88	254.72	254.95	0.006902	1.34	1.75	4.75	0.52	28.66	20.69	0.0067	0.9
Roger	1	529	5-yr	2.56	253.98	255.03	254.85	255.12	0.006848	1.52	2.54	5.97	0.54	34.79	24.53	0.0067	1.05
Roger	1	529	10-yr	3.24	253.98	255.13	254.93	255.23	0.006493	1.61	3.24	6.93	0.53	37.3	25.93	0.0067	1.15
Roger	1	529	20-yr	3.94	253.98	255.22	255	255.33	0.006361	1.7	3.9	7.76	0.54	40.14	27.69	0.0067	1.24
Roger	1	529	50-yr	4.92	253.98	255.34	255.09	255.45	0.006241	1.8	4.84	9	0.54	43.72	29.47	0.0067	1.36
Roger	1	529	100-yr	5.78	253.98	255.43	255.17	255.55	0.006034	1.87	5.75	10.27	0.54	45.83	29.99	0.0067	1.45
																	0
Roger	1	502	Timmins	8.35	253.8	255	255	255.32	0.012577	3.1	5.39	9.22	0.94	117.24	68.74	0.0153	1.2
Roger	1	502	2-yr	2.15	253.8	254.47	254.47	254.65	0.013825	2.09	1.57	5.11	0.88	66.67	39.24	0.0153	0.67
Roger	1	502	5-yr	3.29	253.8	254.61	254.61	254.83	0.012937	2.34	2.37	6.2	0.89	77.76	45.87	0.0153	0.81
Roger	1	502	10-yr	4.19	253.8	254.69	254.69	254.94	0.013153	2.55	2.91	6.81	0.91	88.3	52.28	0.0153	0.89
Roger	1	502	20-yr	5.11	253.8	254.77	254.77	255.04	0.012892	2.69	3.49	7.44	0.92	95.39	56.32	0.0153	0.97
Roger	1	502	50-yr	6.4	253.8	254.87	254.87	255.16	0.01258	2.86	4.29	8.23	0.92	103.83	61.12	0.0153	1.07
Roger	1	502	100-yr	7.52	253.8	254.94	254.94	255.25	0.012813	3.02	4.89	8.79	0.94	113.45	66.63	0.0153	1.14
																	0
Roger	1	481	Timmins	8.35	253.47	254.97		255.01	0.002156	1.13	9.71	13.67	0.32	16.56	13.85	0.0022	1.5
Roger	1	481	2-yr	2.15	253.47	254.48		254.49	0.001605	0.7	4.02	9.28	0.25	7.53	6.13	0.0022	1.01
Roger	1	481	5-yr	3.29	253.47	254.61		254.63	0.001674	0.8	5.37	10.48	0.27	9.23	7.64	0.0022	1.14
Roger	1	481	10-yr	4.19	253.47	254.7		254.73	0.001744	0.86	6.32	11.24	0.28	10.53	8.76	0.0022	1.23
Roger	1	481	20-yr	5.11	253.47	254.78		254.81	0.001748	0.91	7.3	12	0.28	11.45	9.54	0.0022	1.31
Roger	1	481	50-yr	6.4	253.47	254.88		254.91	0.001853	0.99	8.43	12.8	0.29	13.16	11	0.0022	1.41
Roger	1	481	100-yr	7.52	253.47	254.93		254.97	0.002039	1.07	9.18	13.32	0.31	15.17	12.69	0.0022	1.46
																	0
Roger	1	453	Timmins	8.35	253.41	254.7	254.7	254.89	0.010496	2.44	5.5	13.71	0.75	78.14	39.07	0.0291	1.29
Roger	1	453	2-yr	2.15	253.41	254.22	254.22	254.38	0.013766	1.88	1.44	5.12	0.78	56.74	33.44	0.0291	0.81
Roger	1	453	5-yr	3.29	253.41	254.34	254.34	254.52	0.01339	2.09	2.1	6.13	0.79	66.15	40.26	0.0291	0.93
Roger	1	453	10-yr	4.19	253.41	254.42	254.42	254.61	0.012913	2.21	2.61	6.78	0.79	70.88	43.89	0.0291	1.01
Roger	1	453	20-yr	5.11	253.41	254.46	254.46	254.69	0.015026	2.46	2.89	7.16	0.86	86.68	53.79	0.0291	1.05
Roger	1	453	50-yr	6.4	253.41	254.61	254.61	254.79	0.01042	2.29	4.36	12.53	0.74	71.26	33.48	0.0291	1.2
Roger	1	453	100-yr	7.52	253.41	254.67	254.67	254.85	0.010207	2.36	5.09	13.37	0.74	73.84	36.03	0.0291	1.26
																	0
Roger	1	439	Timmins	8.35	253.01	254.71	254.28	254.73	0.000993	0.91	16.57	30.31	0.24	9.86	5.12	0	1.7
Roger	1	439	2-yr	2.15	253.01	254	253.81	254.06	0.004402	1.22	2.26	5.69	0.45	22.41	14.98	0	0.99
Roger	1	439	5-yr	3.29	253.01	254.17	253.93	254.22	0.003527	1.26	3.96	13.65	0.42	22.04	9.44	0	1.16
Roger	1	439	10-yr	4.19	253.01	254.29	254.01	254.33	0.002716	1.19	5.8	17.6	0.37	19.13	8.35	0	1.28
Roger	1	439	20-yr	5.11	253.01	254.38	254.13	254.42	0.002326	1.17	7.6	20.97	0.35	17.86	7.92	0	1.37
Roger	1	439	50-yr	6.4	253.01	254.48	254.21	254.51	0.002052	1.16	9.88	24.33	0.33	17.13	7.85	0	1.47
Roger	1	439	100-yr	7.52	253.01	254.55	254.26	254.58	0.001961	1.18	11.82	28.26	0.33	17.31	7.75	0	1.54
																	0
Roger	1	438		Bridge													0
																	0
Roger	1	436	Timmins	8.35	252.96	254.65		254.68	0.001754	1.17	13.53	30.49	0.31	16.56	7.33	0.0021	1.69
Roger	1	436	2-yr	2.15	252.96	253.93		254.02	0.00692	1.48	1.87	5.55	0.55	33.2	19.7	0.0021	0.97
Roger	1	436	5-yr	3.29	252.96	254.09		254.19	0.006033	1.57	2.91	7.42	0.53	35.21	20.68	0.0021	1.13
Roger	1	436	10-yr	4.19	252.96	254.2		254.29	0.005246	1.58	3.86	10.72	0.5	34.43	17.05	0.0021	1.24
Roger	1	436	20-yr	5.11	252.96	254.3		254.38	0.004679	1.59	5.12	15.93	0.48	33.55	13.9	0.0021	1.34
Roger	1	436	50-yr	6.4	252.96	254.41		254.48	0.003795	1.53	7.29	21.23	0.44	30.06	12.21	0.0021	1.45
Roger	1	436	100-yr	7.52	252.96	254.5		254.56	0.003254	1.48	9.21	24.49	0.41	27.55	11.49	0.0021	1.54
																	0
Roger	1	422	Timmins	8.35	252.93	254.61		254.65	0.001956	1.22	9.95	13.69	0.32	18.15	12.92	0.0248	1.68
Roger	1	422	2-yr	2.15	252.93	253.87		253.92	0.004654	1.17	2.44	6.71	0.44	21.3	14.62	0.0248	0.94
Roger	1	422	5-yr	3.29	252.93	254.05		254.1	0.003589	1.19	3.76	8.21	0.4	20.48	14.45	0.0248	1.12
Roger	1	422	10-yr	4.19	252.93	254.17		254.22	0.003203	1.22	4.79	9.4	0.39	20.67	14.5	0.0248	1.24
Roger	1	422	20-yr	5.11	252.93	254.26		254.31	0.003064	1.27	5.72	10.43	0.39	21.62	15.05	0.0248	1.33
Roger	1	422	50-yr	6.4	252.93	254.37		254.43	0.002918	1.32	6.97	11.61	0.38	22.71	15.79	0.0248	1.44
Roger	1	422	100-yr	7.52	252.93	254.46		254.51	0.002881	1.37	7.96	12.42	0.38	23.93	16.7	0.0248	1.53

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
																	0
Roger	1	392	Timmins	8.35	252.2	254.5		254.57	0.003028	1.48	7.86	10.65	0.35	27.16	18.8	0.0272	2.3
Roger	1	392	2-yr	2.15	252.2	253.23	253.23	253.55	0.034196	2.52	0.86	1.41	0.99	110.29	106.17	0.0272	1.03
Roger	1	392	5-yr	3.29	252.2	253.52	253.52	253.81	0.022694	2.45	1.47	2.79	0.85	95.59	76.28	0.0272	1.32
Roger	1	392	10-yr	4.19	252.2	253.66	253.66	253.95	0.019914	2.51	1.92	3.74	0.81	96.16	70.71	0.0272	1.46
Roger	1	392	20-yr	5.11	252.2	253.78	253.78	254.06	0.017562	2.55	2.41	4.66	0.78	95.06	66.65	0.0272	1.58
Roger	1	392	50-yr	6.4	252.2	253.91	253.91	254.19	0.015974	2.62	3.07	5.63	0.75	96.55	66.41	0.0272	1.71
Roger	1	392	100-yr	7.52	252.2	254.25		254.38	0.005768	1.85	5.49	8.49	0.47	44.69	30.47	0.0272	2.05
																	0
Roger	1	355	Timmins	8.35	251.2	254.52	252.07	254.53	0.000213	0.59	18.31	15.12	0.1	3.51	2.01	-0.0109	3.32
Roger	1	355	2-yr	2.15	251.2	253.37	251.55	253.38	0.000088	0.28	7.89	5.05	0.06	0.94	0.8	-0.0109	2.17
Roger	1	355	5-yr	3.29	251.2	253.57	251.67	253.58	0.000148	0.39	9	6.1	0.08	1.72	1.35	-0.0109	2.37
Roger	1	355	10-yr	4.19	251.2	253.71	251.75	253.72	0.000193	0.46	9.87	6.86	0.09	2.38	1.78	-0.0109	2.51
Roger	1	355	20-yr	5.11	251.2	253.84	251.83	253.85	0.000231	0.53	10.83	7.65	0.1	3.01	2.17	-0.0109	2.64
Roger	1	355	50-yr	6.4	251.2	254.06	251.93	254.07	0.000258	0.59	12.66	9.37	0.11	3.65	2.44	-0.0109	2.86
Roger	1	355	100-yr	7.52	251.2	254.3	252.01	254.32	0.000244	0.6	15.32	12.41	0.11	3.76	2.26	-0.0109	3.1
																	0
Roger	1	344		Culvert													0
																	0
Roger	1	337	Timmins	8.35	251.4	254.51		254.51	0.000109	0.48	23.59	15.66	0.09	2.18	1.38	0.0048	3.11
Roger	1	337	2-yr	2.15	251.4	253.26		253.27	0.000076	0.28	8.67	8.34	0.07	0.9	0.61	0.0048	1.86
Roger	1	337	5-yr	3.29	251.4	253.45		253.45	0.000119	0.38	10.31	9.46	0.09	1.55	1.03	0.0048	2.05
Roger	1	337	10-yr	4.19	251.4	253.6		253.61	0.00014	0.43	11.85	10.39	0.09	1.97	1.28	0.0048	2.2
Roger	1	337	20-yr	5.11	251.4	253.77		253.78	0.000148	0.47	13.68	11.37	0.1	2.25	1.45	0.0048	2.37
Roger	1	337	50-yr	6.4	251.4	254.03		254.04	0.000143	0.49	16.81	12.83	0.1	2.42	1.54	0.0048	2.63
Roger	1	337	100-yr	7.52	251.4	254.29		254.3	0.000124	0.49	20.42	14.33	0.09	2.32	1.48	0.0048	2.89
																	0
Roger	1	316	Timmins	8.35	251.3	254.5		254.51	0.000203	0.56	20.96	14.61	0.11	3.17	2.51	0.0101	3.2
Roger	1	316	2-yr	2.15	251.3	253.25		253.26	0.000339	0.49	6.1	8.61	0.12	2.96	2.02	0.0101	1.95
Roger	1	316	5-yr	3.29	251.3	253.43		253.45	0.000433	0.59	7.76	9.67	0.14	4.21	2.94	0.0101	2.13
Roger	1	316	10-yr	4.19	251.3	253.59		253.6	0.00044	0.63	9.33	10.56	0.15	4.66	3.31	0.0101	2.29
Roger	1	316	20-yr	5.11	251.3	253.76		253.77	0.000408	0.64	11.2	11.46	0.14	4.7	3.41	0.0101	2.46
Roger	1	316	50-yr	6.4	251.3	254.02		254.03	0.000332	0.63	14.36	12.73	0.13	4.31	3.22	0.0101	2.72
Roger	1	316	100-yr	7.52	251.3	254.29		254.3	0.000253	0.59	17.94	13.83	0.12	3.65	2.82	0.0101	2.99
																	0
Roger	1	296	Timmins	8.35	251.1	254.5		254.51	0.000143	0.45	25.11	17.56	0.08	2.11	1.79	0	3.4
Roger	1	296	2-yr	2.15	251.1	253.25		253.25	0.000202	0.37	7.78	9.91	0.09	1.74	1.31	0	2.15
Roger	1	296	5-yr	3.29	251.1	253.43		253.44	0.000271	0.46	9.67	11.1	0.11	2.58	1.98	0	2.33
Roger	1	296	10-yr	4.19	251.1	253.59		253.59	0.000285	0.5	11.47	12.14	0.11	2.92	2.28	0	2.49
Roger	1	296	20-yr	5.11	251.1	253.76		253.76	0.000271	0.51	13.64	13.27	0.11	3.01	2.38	0	2.66
Roger	1	296	50-yr	6.4	251.1	254.02		254.02	0.000226	0.5	17.3	14.77	0.1	2.79	2.28	0	2.92
Roger	1	296	100-yr	7.52	251.1	254.29		254.29	0.000176	0.47	21.5	16.34	0.09	2.41	2.01	0	3.19
																	0
Roger	1	291	Timmins	8.35	251.1	254.5	251.97	254.51	0.000118	0.45	22.28	13.47	0.08	2.01	1.45	0.0094	3.4
Roger	1	291	2-yr	2.15	251.1	253.25	251.49	253.25	0.000056	0.23	10.06	7.01	0.05	0.6	0.52	0.0094	2.15
Roger	1	291	5-yr	3.29	251.1	253.43	251.61	253.44	0.000095	0.31	11.37	7.43	0.07	1.1	0.95	0.0094	2.33
Roger	1	291	10-yr	4.19	251.1	253.59	251.7	253.59	0.00012	0.36	12.54	7.82	0.08	1.47	1.26	0.0094	2.49
Roger	1	291	20-yr	5.11	251.1	253.75	251.77	253.76	0.000137	0.4	13.9	8.27	0.08	1.77	1.52	0.0094	2.65
Roger	1	291	50-yr	6.4	251.1	254.01	251.85	254.02	0.000142	0.44	16.46	10.76	0.09	2.04	1.54	0.0094	2.91
Roger	1	291	100-yr	7.52	251.1	254.28	251.93	254.29	0.00013	0.45	19.54	12.21	0.09	2.07	1.52	0.0094	3.18
																	0
Roger	1	280		Culvert													0
																	0
Roger	1	269	Timmins	8.35	250.9	253.55		253.58	0.000487	0.75	12.11	8.3	0.16	6.16	4.64	-0.0118	2.65
Roger	1	269	2-yr	2.15	250.9	253.19		253.19	0.00006	0.23	9.48	6.12	0.05	0.64	0.55	-0.0118	2.29
Roger	1	269	5-yr	3.29	250.9	253.29		253.29	0.000118	0.34	10.11	6.77	0.07	1.33	1.08	-0.0118	2.39
Roger	1	269	10-yr	4.19	250.9	253.35		253.36	0.000172	0.42	10.55	7.1	0.09	1.99	1.6	-0.0118	2.45
Roger	1	269	20-yr	5.11	250.9	253.41		253.42	0.000233	0.5	10.94	7.39	0.11	2.76	2.18	-0.0118	2.51
Roger	1	269	50-yr	6.4	250.9	253.47		253.48	0.00033	0.6	11.4	7.75	0.13	4.02	3.11	-0.0118	2.57
Roger	1	269	100-yr	7.52	250.9	253.52		253.54	0.000418	0.69	11.83	8.08	0.14	5.22	3.97	-0.0118	2.62
																	0
Roger	1	252	Timmins	8.35	251.1	253.52		253.56	0.001575	1.11	9.88	10.41	0.25	15.06	12.13	-0.0084	2.42
Roger	1	252	2-yr	2.15	251.1	253.18		253.19	0.00029	0.42	6.66	8.64	0.1	2.32	1.77	-0.0084	2.08
Roger	1	252	5-yr	3.29	251.1	253.28		253.29	0.000503	0.58	7.49	9.17	0.14	4.24	3.29	-0.0084	2.18
Roger	1	252	10-yr	4.19	251.1	253.34		253.35	0.000679	0.69	8.04	9.48	0.16	5.92	4.63	-0.0084	2.24
Roger	1	252	20-yr	5.11	251.1	253.39		253.41	0.000868	0.79	8.53	9.74	0.18	7.76	6.12	-0.0084	2.29
Roger	1	252	50-yr	6.4	251.1	253.44		253.47	0.001161	0.93	9.06	10.01	0.21	10.67	8.49	-0.0084	2.34
Roger	1	252	100-yr	7.52	251.1	253.49		253.53	0.001396	1.04	9.56	10.26	0.23	13.14	10.54	-0.0084	2.39
																	0
Roger	1	231	Timmins	8.35	251.28	253.52		253.53	0.000437	0.83	17.22	18.29	0.19	7.08	3.88	0.0036	2.24
Roger	1	231	2-yr	2.15	251.28	253.18		253.18	0.000077	0.31	11.67	14.82	0.08	1.04	0.57	0.0036	1.9
Roger	1	231	5-yr	3.29	251.28	253.27		253.28	0.000135	0.43	13.08	15.79	0.1	1.93	1.05	0.0036	1.99

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
Roger	1	231	10-yr	4.19	251.28	253.33		253.34	0.000184	0.51	14.04	16.42	0.12	2.72	1.48	0.0036	2.05
Roger	1	231	20-yr	5.11	251.28	253.38		253.39	0.000237	0.59	14.87	16.93	0.14	3.59	1.96	0.0036	2.1
Roger	1	231	50-yr	6.4	251.28	253.44		253.45	0.00032	0.7	15.79	17.48	0.16	4.98	2.72	0.0036	2.16
Roger	1	231	100-yr	7.52	251.28	253.49		253.5	0.000386	0.78	16.66	17.98	0.18	6.16	3.37	0.0036	2.21
																	0
Roger	1	216	Timmins	8.35	251.23	253.52	252.45	253.53	0.000327	0.64	21.58	25.2	0.14	4.41	2.64	0.0167	2.29
Roger	1	216	2-yr	2.15	251.23	253.18	252.02	253.18	0.000068	0.26	13.79	20.42	0.06	0.77	0.43	0.0167	1.95
Roger	1	216	5-yr	3.29	251.23	253.27	252.12	253.28	0.000116	0.35	15.77	22.33	0.08	1.38	0.77	0.0167	2.04
Roger	1	216	10-yr	4.19	251.23	253.33	252.19	253.34	0.000154	0.41	17.12	23.31	0.1	1.9	1.07	0.0167	2.1
Roger	1	216	20-yr	5.11	251.23	253.38	252.25	253.39	0.000193	0.47	18.3	23.97	0.11	2.44	1.39	0.0167	2.15
Roger	1	216	50-yr	6.4	251.23	253.44	252.34	253.44	0.000251	0.55	19.58	24.46	0.12	3.25	1.89	0.0167	2.21
Roger	1	216	100-yr	7.52	251.23	253.49	252.4	253.49	0.000294	0.6	20.81	24.92	0.14	3.91	2.31	0.0167	2.26
																	0
Roger	1	211		Culvert													0
																	0
Roger	1	195	Timmins	8.35	250.87	252.73	252.73	252.96	0.015418	2.55	4.98	10.7	0.68	92.03	59.08	0.001	1.86
Roger	1	195	2-yr	2.15	250.87	251.81	251.81	252.16	0.038019	2.62	0.82	1.19	1.01	120.31	120.31	0.001	0.94
Roger	1	195	5-yr	3.29	250.87	252.07	252.07	252.49	0.038279	2.89	1.14	1.36	1.01	139.25	139.25	0.001	1.2
Roger	1	195	10-yr	4.19	250.87	252.41	252.41	252.65	0.01726	2.28	2.31	6.09	0.69	79.98	48.36	0.001	1.54
Roger	1	195	20-yr	5.11	250.87	252.52	252.52	252.74	0.015723	2.31	3.01	7.59	0.67	79.66	48.33	0.001	1.65
Roger	1	195	50-yr	6.4	250.87	252.61	252.61	252.84	0.01571	2.43	3.81	9.06	0.68	85.95	52.88	0.001	1.74
Roger	1	195	100-yr	7.52	250.87	252.69	252.69	252.92	0.014996	2.47	4.58	10.24	0.67	87.08	54.83	0.001	1.82
																	0
Roger	1	183	Timmins	8.35	250.86	252.32		252.38	0.002576	1.59	12.87	18.74	0.44	28.9	16.91	0.0116	1.46
Roger	1	183	2-yr	2.15	250.86	251.71		251.77	0.003889	1.3	3.46	11.13	0.48	23.8	11.52	0.0116	0.85
Roger	1	183	5-yr	3.29	250.86	251.87		251.93	0.003227	1.36	5.43	12.82	0.46	24.16	13.03	0.0116	1.01
Roger	1	183	10-yr	4.19	250.86	251.98		252.03	0.003111	1.43	6.81	14.89	0.46	25.95	13.59	0.0116	1.12
Roger	1	183	20-yr	5.11	250.86	252.07		252.12	0.002935	1.47	8.32	17.02	0.45	26.71	13.73	0.0116	1.21
Roger	1	183	50-yr	6.4	250.86	252.18		252.23	0.00272	1.51	10.26	17.76	0.44	27.28	15.02	0.0116	1.32
Roger	1	183	100-yr	7.52	250.86	252.26		252.32	0.002626	1.56	11.8	18.34	0.44	28.19	16.15	0.0116	1.4
																	0
Roger	1	170	Timmins	8.35	250.71	252.31		252.34	0.001338	1.25	17.09	21.48	0.32	17.12	10.22	0	1.6
Roger	1	170	2-yr	2.15	250.71	251.7		251.72	0.001174	0.83	6.02	14.25	0.28	8.98	4.74	0	0.99
Roger	1	170	5-yr	3.29	250.71	251.87		251.89	0.001212	0.94	8.54	16.84	0.29	10.95	5.9	0	1.16
Roger	1	170	10-yr	4.19	250.71	251.97		251.99	0.001229	1.01	10.34	18.01	0.3	12.17	6.77	0	1.26
Roger	1	170	20-yr	5.11	250.71	252.06		252.08	0.001244	1.07	12.01	18.88	0.3	13.27	7.6	0	1.35
Roger	1	170	50-yr	6.4	250.71	252.17		252.2	0.001279	1.14	14.15	19.99	0.31	14.83	8.69	0	1.46
Roger	1	170	100-yr	7.52	250.71	252.25		252.28	0.001315	1.21	15.88	20.88	0.32	16.19	9.6	0	1.54
																	0
Roger	1	144	Timmins	8.35	250.71	251.96	251.96	252.24	0.014306	3.03	5.71	10.77	0.95	117.15	71.01	0.0266	1.25
Roger	1	144	2-yr	2.15	250.71	251.45	251.45	251.63	0.017353	2.12	1.59	5.28	0.94	72.05	47.85	0.0266	0.74
Roger	1	144	5-yr	3.29	250.71	251.58	251.58	251.79	0.015835	2.36	2.41	6.81	0.93	82.79	51.81	0.0266	0.87
Roger	1	144	10-yr	4.19	250.71	251.67	251.67	251.9	0.015023	2.51	3.06	7.82	0.93	89.18	54.66	0.0266	0.96
Roger	1	144	20-yr	5.11	250.71	251.75	251.75	251.99	0.014638	2.64	3.69	8.69	0.93	95.78	58.02	0.0266	1.04
Roger	1	144	50-yr	6.4	250.71	251.84	251.84	252.1	0.0144	2.81	4.53	9.64	0.94	104.66	63.23	0.0266	1.13
Roger	1	144	100-yr	7.52	250.71	251.91	251.91	252.18	0.014282	2.94	5.23	10.31	0.94	111.75	67.78	0.0266	1.2
																	0
Roger	1	115	Timmins	8.35	249.94	251.5		251.65	0.006961	2.24	7.93	13.86	0.61	62.09	36.73	0.0137	1.56
Roger	1	115	2-yr	2.15	249.94	250.95		251.05	0.006307	1.5	2.22	6.69	0.54	33.25	18.37	0.0137	1.01
Roger	1	115	5-yr	3.29	249.94	251.09		251.21	0.006931	1.75	3.28	8.5	0.58	42.9	23.94	0.0137	1.15
Roger	1	115	10-yr	4.19	249.94	251.19		251.32	0.006771	1.85	4.22	9.87	0.58	46.48	26.19	0.0137	1.25
Roger	1	115	20-yr	5.11	249.94	251.27		251.4	0.006932	1.97	5.05	10.94	0.59	51.24	29.12	0.0137	1.33
Roger	1	115	50-yr	6.4	249.94	251.37		251.51	0.007025	2.1	6.2	12.27	0.61	56.53	32.52	0.0137	1.43
Roger	1	115	100-yr	7.52	249.94	251.45		251.6	0.007	2.19	7.22	13.32	0.61	60	34.9	0.0137	1.51
																	0
Roger	1	94	Timmins	8.35	249.65	251.3		251.48	0.009547	2.34	6.1	10.16	0.63	71.68	49.48	0.0136	1.65
Roger	1	94	2-yr	2.15	249.65	250.85		250.92	0.004836	1.28	2.47	6.23	0.42	24.58	15.64	0.0136	1.2
Roger	1	94	5-yr	3.29	249.65	250.96		251.06	0.006705	1.62	3.16	7	0.51	37.83	25	0.0136	1.31
Roger	1	94	10-yr	4.19	249.65	251.06		251.17	0.006704	1.72	3.92	7.92	0.52	41.58	27.9	0.0136	1.41
Roger	1	94	20-yr	5.11	249.65	251.12		251.25	0.007451	1.89	4.46	8.54	0.55	48.85	32.97	0.0136	1.47
Roger	1	94	50-yr	6.4	249.65	251.18		251.34	0.009139	2.15	4.96	9.1	0.61	62.73	42.5	0.0136	1.53
Roger	1	94	100-yr	7.52	249.65	251.26		251.43	0.00907	2.23	5.71	9.84	0.62	66.2	45.31	0.0136	1.61
																	0
Roger	1	71	Timmins	8.35	249.34	250.98	250.98	251.18	0.018182	2.54	5.56	12.36	0.75	95.54	69.7	0.0138	1.64
Roger	1	71	2-yr	2.15	249.34	250.53	250.31	250.72	0.017688	1.94	1.11	1.38	0.69	63.44	63.44	0.0138	1.19
Roger	1	71	5-yr	3.29	249.34	250.78		250.88	0.009589	1.63	3.3	9.92	0.53	41.73	26.41	0.0138	1.44
Roger	1	71	10-yr	4.19	249.34	250.78	250.78	250.94	0.015662	2.08	3.29	9.92	0.67	68.12	43.05	0.0138	1.44
Roger	1	71	20-yr	5.11	249.34	250.83	250.83	251.01	0.01632	2.2	3.86	10.53	0.69	74.93	49.93	0.0138	1.49
Roger	1	71	50-yr	6.4	249.34	251.04		251.13	0.007802	1.72	6.31	13.12	0.49	43.03	32.17	0.0138	1.7
Roger	1	71	100-yr	7.52	249.34	250.95	250.95	251.14	0.017781	2.47	5.16	11.94	0.73	90.81	65.19	0.0138	1.61
																	0
Roger	1	50	Timmins	8.35	249.05	250.84		250.87	0.003815	1.2	11.83	35.4	0.32	21.02	11.71	0.0137	1.79

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
Roger	1	50	2-yr	2.15	249.05	250.28		250.42	0.010796	1.62	1.33	1.38	0.52	42.5	42.5	0.0137	1.23
Roger	1	50	5-yr	3.29	249.05	250.59	250.13	250.69	0.007973	1.53	3.61	31.74	0.45	36.45	8.28	0.0137	1.54
Roger	1	50	10-yr	4.19	249.05	250.72	250.3	250.75	0.003152	1.03	7.56	33.65	0.29	15.87	6.49	0.0137	1.67
Roger	1	50	20-yr	5.11	249.05	250.85	250.45	250.86	0.001307	0.71	12.21	35.51	0.19	7.26	4.13	0.0137	1.8
Roger	1	50	50-yr	6.4	249.05	251.07		251.08	0.000448	0.46	20.42	37.91	0.11	2.88	2.22	0.0137	2.02
Roger	1	50	100-yr	7.52	249.05	250.82		250.85	0.003581	1.16	11.24	35.22	0.31	19.51	10.5	0.0137	1.77
																	0
Roger	1	25	Timmins	8.35	248.7	250.68	250.68	250.74	0.007327	1.57	14.17	81.9	0.4	36.83	11.99		1.98
Roger	1	25	2-yr	2.15	248.7	249.55	249.55	249.91	0.03999	2.68	0.8	1.11	1	125.65	125.65		0.85
Roger	1	25	5-yr	3.29	248.7	249.8	249.8	250.26	0.042551	3	1.1	1.21	1.01	151.44	151.44		1.1
Roger	1	25	10-yr	4.19	248.7	249.98	249.98	250.49	0.043848	3.19	1.32	1.28	1	167.33	167.33		1.28
Roger	1	25	20-yr	5.11	248.7	250.13	250.13	250.71	0.045013	3.35	1.52	1.34	1.01	181.62	181.62		1.43
Roger	1	25	50-yr	6.4	248.7	250.34	250.34	250.98	0.045894	3.53	1.81	1.43	1	197.46	197.46		1.64
Roger	1	25	100-yr	7.52	248.7	250.67	250.67	250.73	0.007136	1.54	13.1	81.65	0.4	35.57	10.82		1.97
																	0
Keast	1	843	Timmins	4.58	266.7	267.27	267.27	267.71	0.080434	4.21	2.55	12.97	1.99	295.82	152.36	0.0791	0.57
Keast	1	843	2-yr	0.88	266.7	267.14	267.14	267.21	0.016397	1.52	1.27	8.55	0.85	42.97	23.22	0.0791	0.44
Keast	1	843	5-yr	1.29	266.7	267.19	267.19	267.27	0.018141	1.74	1.67	9.28	0.91	54.01	31.11	0.0791	0.49
Keast	1	843	10-yr	1.67	266.7	267.22	267.22	267.32	0.020065	1.93	1.97	9.82	0.97	64.88	38.51	0.0791	0.52
Keast	1	843	20-yr	2.09	266.7	267.25	267.25	267.36	0.020981	2.09	2.32	10.5	1.01	73.65	44.41	0.0791	0.55
Keast	1	843	50-yr	2.76	266.7	267.29	267.29	267.43	0.024839	2.39	2.77	14.86	1.11	94.41	44.63	0.0791	0.59
Keast	1	843	100-yr	3.43	266.7	267.3	267.3	267.49	0.035693	2.9	2.88	15.71	1.33	137.67	63.03	0.0791	0.6
																	0
Keast	1	836	Timmins	4.58	266.11	266.96	266.96	267.14	0.019273	2.72	3.89	10.55	1.03	107.44	67.6	0.0513	0.85
Keast	1	836	2-yr	0.88	266.11	266.61	266.61	266.71	0.017341	1.65	1	5.89	0.88	49.37	27.61	0.0513	0.5
Keast	1	836	5-yr	1.29	266.11	266.68	266.68	266.79	0.016954	1.82	1.43	7.03	0.89	57.09	32.51	0.0513	0.57
Keast	1	836	10-yr	1.67	266.11	266.73	266.73	266.84	0.017096	1.97	1.78	7.62	0.91	64.03	37.79	0.0513	0.62
Keast	1	836	20-yr	2.09	266.11	266.77	266.77	266.9	0.017632	2.12	2.12	8.15	0.94	72.05	43.48	0.0513	0.66
Keast	1	836	50-yr	2.76	266.11	266.83	266.83	266.97	0.0183	2.32	2.62	8.88	0.97	83.26	51.3	0.0513	0.72
Keast	1	836	100-yr	3.43	266.11	266.88	266.88	267.04	0.019041	2.5	3.09	9.53	1.01	94.17	58.61	0.0513	0.77
																	0
Keast	1	825	Timmins	4.58	265.58	266.23	266.23	266.37	0.027355	2.67	4.03	13.35	1.18	114.04	79.3	0.0674	0.65
Keast	1	825	2-yr	0.88	265.58	266	266	266.06	0.018595	1.5	1.32	9.71	0.88	43.53	24.13	0.0674	0.42
Keast	1	825	5-yr	1.29	265.58	266.04	266.04	266.11	0.020246	1.71	1.73	10.66	0.94	53.98	31.58	0.0674	0.46
Keast	1	825	10-yr	1.67	265.58	266.07	266.07	266.15	0.021259	1.86	2.09	11.22	0.98	62.11	37.92	0.0674	0.49
Keast	1	825	20-yr	2.09	265.58	266.1	266.1	266.19	0.022474	2.01	2.42	11.71	1.02	70.95	44.67	0.0674	0.52
Keast	1	825	50-yr	2.76	265.58	266.14	266.14	266.25	0.025135	2.26	2.86	12.27	1.09	86.63	56.27	0.0674	0.56
Keast	1	825	100-yr	3.43	265.58	266.17	266.17	266.3	0.025951	2.42	3.32	12.74	1.13	97.06	65.01	0.0674	0.59
																	0
Keast	1	812	Timmins	4.58	264.69	265.44	265.44	265.6	0.021761	2.64	4.05	12.58	1.07	105.95	67.08	0.1108	0.75
Keast	1	812	2-yr	0.88	264.69	265.16	265.16	265.24	0.016837	1.54	1.16	7.3	0.85	44.39	25.3	0.1108	0.47
Keast	1	812	5-yr	1.29	264.69	265.21	265.21	265.3	0.019512	1.81	1.51	8.32	0.94	58.35	33.62	0.1108	0.52
Keast	1	812	10-yr	1.67	264.69	265.25	265.25	265.35	0.01852	1.9	1.92	9.35	0.93	62.22	36.29	0.1108	0.56
Keast	1	812	20-yr	2.09	264.69	265.28	265.28	265.4	0.020057	2.08	2.24	10.07	0.98	72.62	42.65	0.1108	0.59
Keast	1	812	50-yr	2.76	264.69	265.34	265.34	265.46	0.020298	2.25	2.79	11.06	1.01	81.82	49.01	0.1108	0.65
Keast	1	812	100-yr	3.43	264.69	265.38	265.38	265.51	0.020155	2.38	3.33	11.75	1.02	88.69	54.61	0.1108	0.69
																	0
Keast	1	806	Timmins	4.58	264.03	264.84	264.84	265	0.018317	2.67	4.2	12.57	1.02	103.14	58.71	0.0584	0.81
Keast	1	806	2-yr	0.88	264.03	264.51	264.51	264.6	0.015471	1.6	1.09	6.55	0.84	46	24.29	0.0584	0.48
Keast	1	806	5-yr	1.29	264.03	264.57	264.57	264.67	0.016245	1.81	1.49	7.48	0.88	55.9	30.81	0.0584	0.54
Keast	1	806	10-yr	1.67	264.03	264.61	264.61	264.73	0.017155	1.98	1.83	8.18	0.92	64.93	36.47	0.0584	0.58
Keast	1	806	20-yr	2.09	264.03	264.65	264.65	264.78	0.01701	2.1	2.23	9.01	0.93	70.73	40.04	0.0584	0.62
Keast	1	806	50-yr	2.76	264.03	264.71	264.71	264.85	0.0174	2.29	2.79	10.18	0.96	80.64	45.63	0.0584	0.68
Keast	1	806	100-yr	3.43	264.03	264.76	264.76	264.91	0.018079	2.46	3.31	11.15	0.99	90.87	51.37	0.0584	0.73
																	0
Keast	1	795	Timmins	4.58	263.37	264.08	264.08	264.22	0.021431	2.6	4.48	15.49	1.07	102.7	59.82	0.0582	0.71
Keast	1	795	2-yr	0.88	263.37	263.84	263.84	263.9	0.01335	1.45	1.4	10.14	0.78	38.12	17.63	0.0582	0.47
Keast	1	795	5-yr	1.29	263.37	263.88	263.88	263.96	0.015697	1.69	1.82	11.04	0.86	49.86	24.85	0.0582	0.51
Keast	1	795	10-yr	1.67	263.37	263.91	263.91	264	0.015928	1.81	2.25	11.85	0.88	55.38	29.04	0.0582	0.54
Keast	1	795	20-yr	2.09	263.37	263.95	263.95	264.04	0.01672	1.94	2.65	12.57	0.91	62.53	33.89	0.0582	0.58
Keast	1	795	50-yr	2.76	263.37	263.99	263.99	264.09	0.018124	2.14	3.2	13.49	0.96	73.94	41.38	0.0582	0.62
Keast	1	795	100-yr	3.43	263.37	264.03	264.03	264.14	0.019048	2.31	3.73	14.35	1	83.58	47.73	0.0582	0.66
																	0
Keast	1	784	Timmins	4.58	262.71	263.68		263.68	0.000981	0.7	15.93	29.73	0.24	6.59	5.1	0.0676	0.97
Keast	1	784	2-yr	0.88	262.71	263.54		263.54	0.00008	0.18	12.13	27.27	0.07	0.45	0.34	0.0676	0.83
Keast	1	784	5-yr	1.29	262.71	263.59		263.6	0.000125	0.23	13.53	28.2	0.08	0.76	0.58	0.0676	0.88
Keast	1	784	10-yr	1.67	262.71	263.78		263.78	0.000079	0.21	19.1	31.84	0.07	0.59	0.46	0.0676	1.07
Keast	1	784	20-yr	2.09	262.71	263.62		263.62	0.000288	0.36	14.16	28.61	0.13	1.8	1.38	0.0676	0.91
Keast	1	784	50-yr	2.76	262.71	263.64		263.64	0.000431	0.45	14.89	29.08	0.16	2.78	2.14	0.0676	0.93
Keast	1	784	100-yr	3.43	262.71	263.65		263.65	0.000636	0.55	15.14	29.24	0.19	4.14	3.19	0.0676	0.94
																	0
Keast	1	774	Timmins	4.58	262.09	263.68	263.18	263.68	0.0003	0.34	35.69	85.33	0.09	1.66	1.21	-0.0085	1.59

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
Keast	1	774	2-yr	0.88	262.09	263.54	262.65	263.54	0.000023	0.09	25.76	66.21	0.02	0.12	0.09	-0.0085	1.45
Keast	1	774	5-yr	1.29	262.09	263.59	262.8	263.59	0.000037	0.11	29.24	71.95	0.03	0.19	0.14	-0.0085	1.5
Keast	1	774	10-yr	1.67	262.09	263.78	262.92	263.78	0.000021	0.09	45.13	94.02	0.02	0.13	0.1	-0.0085	1.69
Keast	1	774	20-yr	2.09	262.09	263.62	263.11	263.62	0.000086	0.18	30.85	74.97	0.05	0.45	0.34	-0.0085	1.53
Keast	1	774	50-yr	2.76	262.09	263.64	263.15	263.64	0.000132	0.22	32.8	80.32	0.06	0.71	0.52	-0.0085	1.55
Keast	1	774	100-yr	3.43	262.09	263.65	263.16	263.65	0.000196	0.27	33.47	81.57	0.07	1.06	0.77	-0.0085	1.56
																	0
Keast	1	767		Culvert													0
																	0
Keast	1	756	Timmins	7.26	262.24	263.61	263.61	263.67	0.005466	1.09	6.59	64.26	0.36	19.85	5.33	0.0252	1.37
Keast	1	756	2-yr	1.44	262.24	263.04	263.04	263.35	0.041471	2.44	0.59	0.98	1.01	110.4	110.4	0.0252	0.8
Keast	1	756	5-yr	2.1	262.24	263.23	263.23	263.59	0.042255	2.67	0.79	1.1	1.01	126.87	126.87	0.0252	0.99
Keast	1	756	10-yr	2.68	262.24	263.37	263.37	263.78	0.04252	2.82	0.95	1.19	1.01	138.13	138.13	0.0252	1.13
Keast	1	756	20-yr	3.32	262.24	263.57	263.57	263.6	0.004035	0.93	4.43	62.92	0.31	14.43	2.7	0.0252	1.33
Keast	1	756	50-yr	4.29	262.24	263.59	263.59	263.62	0.003969	0.92	5.26	63.46	0.31	14.28	3.13	0.0252	1.35
Keast	1	756	100-yr	5.26	262.24	263.58	263.58	263.64	0.006641	1.19	5.08	63.35	0.4	23.87	5.07	0.0252	1.34
																	0
Keast	1	737	Timmins	7.26	261.76	262.69	262.69	262.81	0.021489	2.24	5.49	19.93	0.79	140.54	57.11	0.0268	0.93
Keast	1	737	2-yr	1.44	261.76	262.31	262.31	262.41	0.031378	1.76	1.29	6.71	0.86	108.01	57.06	0.0268	0.55
Keast	1	737	5-yr	2.1	261.76	262.37	262.37	262.48	0.030273	1.91	1.8	8.05	0.86	120.82	64.17	0.0268	0.61
Keast	1	737	10-yr	2.68	261.76	262.42	262.42	262.54	0.030884	2.04	2.17	8.89	0.89	134.27	71.89	0.0268	0.66
Keast	1	737	20-yr	3.32	261.76	262.46	262.46	262.59	0.029987	2.12	2.58	9.5	0.88	141.09	77.79	0.0268	0.7
Keast	1	737	50-yr	4.29	261.76	262.51	262.51	262.65	0.030901	2.28	3.09	10.05	0.91	158.07	90.48	0.0268	0.75
Keast	1	737	100-yr	5.26	261.76	262.56	262.56	262.71	0.031382	2.4	3.56	10.51	0.93	172.07	101.34	0.0268	0.8
																	0
Keast	1	724	Timmins	7.26	261.42	262.41		262.46	0.007726	1.41	8.33	17.54	0.48	54.37	35.36	0.0252	0.99
Keast	1	724	2-yr	1.44	261.42	261.92	261.92	261.99	0.029136	1.59	1.57	9.96	0.81	90.76	44.15	0.0252	0.5
Keast	1	724	5-yr	2.1	261.42	261.96	261.96	262.05	0.032929	1.81	2	10.63	0.88	113.43	59.36	0.0252	0.54
Keast	1	724	10-yr	2.68	261.42	262	262	262.09	0.033482	1.92	2.38	11.16	0.9	124.7	68.42	0.0252	0.58
Keast	1	724	20-yr	3.32	261.42	262.02	262.02	262.13	0.036702	2.09	2.68	11.58	0.95	144.68	81.72	0.0252	0.6
Keast	1	724	50-yr	4.29	261.42	262.12		262.2	0.021522	1.81	3.93	13.18	0.75	102.23	61.71	0.0252	0.7
Keast	1	724	100-yr	5.26	261.42	262.26		262.31	0.010809	1.47	5.86	15.35	0.55	63.07	39.73	0.0252	0.84
																	0
Keast	1	697	Timmins	7.26	260.73	262.39		262.4	0.000755	0.64	19.42	24.45	0.16	9.27	5.78	0.0119	1.66
Keast	1	697	2-yr	1.44	260.73	261.33		261.37	0.011492	1.15	1.94	8.61	0.53	44.11	24.69	0.0119	0.6
Keast	1	697	5-yr	2.1	260.73	261.41		261.45	0.010815	1.23	2.69	9.98	0.53	48.39	27.79	0.0119	0.68
Keast	1	697	10-yr	2.68	260.73	261.49		261.53	0.008572	1.2	3.55	11.15	0.48	43.96	26.11	0.0119	0.76
Keast	1	697	20-yr	3.32	260.73	261.66		261.69	0.003887	0.95	5.65	13.47	0.34	25.21	15.62	0.0119	0.93
Keast	1	697	50-yr	4.29	260.73	262.12		262.13	0.000673	0.53	13.5	20.27	0.15	6.83	4.31	0.0119	1.39
Keast	1	697	100-yr	5.26	260.73	262.24		262.25	0.000642	0.55	16.1	22.11	0.15	7.14	4.5	0.0119	1.51
																	0
Keast	1	665	Timmins	7.26	260.35	262.37		262.38	0.000451	0.6	26.51	30.03	0.14	7.49	3.85	0.0048	2.02
Keast	1	665	2-yr	1.44	260.35	261		261.06	0.008499	1.18	1.9	6.88	0.49	42.81	22.04	0.0048	0.65
Keast	1	665	5-yr	2.1	260.35	261.16		261.21	0.005795	1.14	3.21	9.61	0.42	36.98	18.36	0.0048	0.81
Keast	1	665	10-yr	2.68	260.35	261.35		261.38	0.003016	0.96	5.31	12.74	0.31	24.03	11.99	0.0048	1
Keast	1	665	20-yr	3.32	260.35	261.6		261.62	0.001311	0.74	9.04	16.75	0.22	13.24	6.78	0.0048	1.25
Keast	1	665	50-yr	4.29	260.35	262.11		262.11	0.000326	0.47	19.45	24.35	0.11	4.69	2.51	0.0048	1.76
Keast	1	665	100-yr	5.26	260.35	262.23		262.24	0.000343	0.5	22.57	26.69	0.12	5.29	2.8	0.0048	1.88
																	0
Keast	1	648	Timmins	7.26	260.27	262.36		262.37	0.000475	0.63	29.08	41.04	0.14	8.06	3.26	0	2.09
Keast	1	648	2-yr	1.44	260.27	260.93		260.95	0.003973	0.81	2.94	8.65	0.33	19.89	12.77	0	0.66
Keast	1	648	5-yr	2.1	260.27	261.12		261.14	0.002443	0.76	4.71	10.25	0.27	16.08	10.64	0	0.85
Keast	1	648	10-yr	2.68	260.27	261.33		261.34	0.001413	0.67	7.01	12.13	0.22	11.72	7.74	0	1.06
Keast	1	648	20-yr	3.32	260.27	261.59		261.6	0.000747	0.57	10.5	14.48	0.16	7.84	5.15	0	1.32
Keast	1	648	50-yr	4.29	260.27	262.1		262.11	0.000357	0.5	19.96	29.19	0.12	5.28	2.35	0	1.83
Keast	1	648	100-yr	5.26	260.27	262.22		262.23	0.000377	0.53	23.85	34.66	0.12	5.96	2.51	0	1.95
																	0
Keast	1	631	Timmins	7.26	260.27	262.36		262.36	0.000218	0.62	36.54	44	0.14	3.77	1.75	0.025	2.09
Keast	1	631	2-yr	1.44	260.27	260.83		260.88	0.005175	1.19	2.39	9.14	0.53	22.34	12.92	0.025	0.56
Keast	1	631	5-yr	2.1	260.27	261.08		261.1	0.001725	0.9	5.11	12.26	0.33	11.17	6.88	0.025	0.81
Keast	1	631	10-yr	2.68	260.27	261.31		261.32	0.000856	0.75	8.11	14.45	0.24	7.18	4.6	0.025	1.04
Keast	1	631	20-yr	3.32	260.27	261.58		261.59	0.000445	0.64	12.45	17.74	0.18	4.77	3	0.025	1.31
Keast	1	631	50-yr	4.29	260.27	262.1		262.1	0.000162	0.49	26.1	36.53	0.12	2.45	1.12	0.025	1.83
Keast	1	631	100-yr	5.26	260.27	262.22		262.23	0.000169	0.52	30.78	40.11	0.12	2.74	1.26	0.025	1.95
																	0
Keast	1	611	Timmins	7.26	259.76	262.36	260.95	262.36	0.000183	0.46	39.38	43.64	0.09	2.33	1.56	0.0061	2.6
Keast	1	611	2-yr	1.44	259.76	260.79	260.28	260.81	0.001663	0.71	3.56	10.6	0.24	7.75	4.81	0.0061	1.03
Keast	1	611	5-yr	2.1	259.76	261.07	260.42	261.08	0.000788	0.58	6.8	13.15	0.17	4.75	3.58	0.0061	1.31
Keast	1	611	10-yr	2.68	259.76	261.3	260.67	261.31	0.000488	0.52	10.12	15.67	0.14	3.53	2.81	0.0061	1.54
Keast	1	611	20-yr	3.32	259.76	261.57	260.73	261.58	0.000296	0.45	14.94	19.57	0.11	2.56	2.05	0.0061	1.81
Keast	1	611	50-yr	4.29	259.76	262.1	260.8	262.1	0.000127	0.36	29.18	35.52	0.08	1.44	0.98	0.0061	2.34
Keast	1	611	100-yr	5.26	259.76	262.22	260.85	262.22	0.000137	0.38	33.73	39.2	0.08	1.65	1.11	0.0061	2.46

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
																	0
Keast	1	597		Culvert													0
																	0
Keast	1	582	Timmins	7.26	259.58	260.93	260.93	261.16	0.012971	2.34	5.16	12.89	0.68	77.43	44.05	0.0047	1.35
Keast	1	582	2-yr	1.44	259.58	260.22		260.31	0.008204	1.34	1.07	1.79	0.55	30.13	30.13	0.0047	0.64
Keast	1	582	5-yr	2.1	259.58	260.34		260.48	0.010521	1.63	1.29	1.83	0.62	42.83	42.83	0.0047	0.76
Keast	1	582	10-yr	2.68	259.58	260.43	260.24	260.61	0.012356	1.85	1.45	1.87	0.67	53.65	53.65	0.0047	0.85
Keast	1	582	20-yr	3.32	259.58	260.52	260.33	260.73	0.01421	2.05	1.62	1.9	0.71	65.15	65.15	0.0047	0.94
Keast	1	582	50-yr	4.29	259.58	260.63	260.47	260.91	0.017005	2.34	1.9	6.1	0.77	82.86	40.3	0.0047	1.05
Keast	1	582	100-yr	5.26	259.58	260.81	260.81	261.02	0.01242	2.15	3.65	11.65	0.65	67.44	32.63	0.0047	1.23
																	0
Keast	1	556	Timmins	7.26	259.46	260.32		260.45	0.019329	2.15	5.46	11.41	0.77	128.9	87.32	0.0251	0.86
Keast	1	556	2-yr	1.44	259.46	259.8	259.8	259.9	0.041497	1.69	1.19	5.57	0.98	108.73	82.69	0.0251	0.34
Keast	1	556	5-yr	2.1	259.46	259.86	259.86	259.99	0.041758	1.89	1.58	6.14	1	128.42	99.95	0.0251	0.4
Keast	1	556	10-yr	2.68	259.46	259.91	259.91	260.06	0.041408	2.01	1.9	6.59	1.01	141.42	111.52	0.0251	0.45
Keast	1	556	20-yr	3.32	259.46	259.96	259.96	260.12	0.041889	2.15	2.23	7	1.03	155.9	124.12	0.0251	0.5
Keast	1	556	50-yr	4.29	259.46	260.03	260.03	260.21	0.041798	2.34	2.69	7.76	1.05	177.01	135.55	0.0251	0.57
Keast	1	556	100-yr	5.26	259.46	260.09	260.09	260.29	0.040514	2.48	3.18	8.47	1.05	191.83	142.29	0.0251	0.63
																	0
Keast	1	530	Timmins	7.26	258.82	260.25		260.28	0.002081	1.06	11.61	12.93	0.29	25.65	17.52	0.0196	1.43
Keast	1	530	2-yr	1.44	258.82	259.34		259.38	0.00799	1.04	2.03	7.21	0.47	34.52	21.28	0.0196	0.52
Keast	1	530	5-yr	2.1	258.82	259.46		259.5	0.006554	1.09	3.01	8.68	0.44	35.34	21.54	0.0196	0.64
Keast	1	530	10-yr	2.68	258.82	259.56		259.6	0.005517	1.1	3.89	9.36	0.42	34.48	21.74	0.0196	0.74
Keast	1	530	20-yr	3.32	258.82	259.66		259.7	0.004614	1.1	4.88	9.89	0.39	32.98	21.52	0.0196	0.84
Keast	1	530	50-yr	4.29	258.82	259.81		259.85	0.003625	1.09	6.44	10.67	0.35	30.75	20.63	0.0196	0.99
Keast	1	530	100-yr	5.26	258.82	259.96		259.99	0.002942	1.08	8.08	11.44	0.33	28.77	19.54	0.0196	1.14
																	0
Keast	1	504	Timmins	7.26	258.3	259.51	259.51	260.07	0.064102	3.32	2.18	1.94	1	334.3	334.3	0.0206	1.21
Keast	1	504	2-yr	1.44	258.3	258.71	258.71	258.92	0.05392	2.01	0.72	1.77	1.01	150.48	150.48	0.0206	0.41
Keast	1	504	5-yr	2.1	258.3	258.83	258.83	259.09	0.054708	2.26	0.93	1.8	1.01	180.65	180.65	0.0206	0.53
Keast	1	504	10-yr	2.68	258.3	258.93	258.93	259.23	0.055869	2.45	1.1	1.82	1.01	204.15	204.15	0.0206	0.63
Keast	1	504	20-yr	3.32	258.3	259.02	259.02	259.37	0.057082	2.62	1.27	1.84	1	226.82	226.82	0.0206	0.72
Keast	1	504	50-yr	4.29	258.3	259.16	259.16	259.56	0.058913	2.83	1.52	1.86	1	257.52	257.52	0.0206	0.86
Keast	1	504	100-yr	5.26	258.3	259.28	259.28	259.74	0.061052	3.02	1.74	1.89	1.01	286.33	286.33	0.0206	0.98
																	0
Keast	1	484	Timmins	7.26	257.88	259.09		259.15	0.005352	1.4	7.87	10.21	0.42	48.92	38.02	0.01	1.21
Keast	1	484	2-yr	1.44	257.88	258.44		258.47	0.005938	0.85	2.4	6.7	0.39	23.97	19.66	0.01	0.56
Keast	1	484	5-yr	2.1	257.88	258.56		258.59	0.005442	0.92	3.22	7.25	0.38	26.29	22.27	0.01	0.68
Keast	1	484	10-yr	2.68	257.88	258.65		258.68	0.005254	0.99	3.87	7.79	0.38	29.06	24.06	0.01	0.77
Keast	1	484	20-yr	3.32	257.88	258.73		258.77	0.005077	1.05	4.55	8.31	0.38	31.6	25.67	0.01	0.85
Keast	1	484	50-yr	4.29	257.88	258.84		258.88	0.00512	1.15	5.46	8.92	0.39	36.27	28.93	0.01	0.96
Keast	1	484	100-yr	5.26	257.88	258.93		258.98	0.005165	1.24	6.31	9.4	0.4	40.5	31.97	0.01	1.05
																	0
Keast	1	460	Timmins	7.26	257.65	258.62	258.62	258.9	0.023953	2.71	4.06	7.71	0.9	192.83	115.99	0.0131	0.97
Keast	1	460	2-yr	1.44	257.65	258.14	258.07	258.24	0.018315	1.46	1.17	4.06	0.69	71.21	47.97	0.0131	0.49
Keast	1	460	5-yr	2.1	257.65	258.21	258.17	258.35	0.021628	1.76	1.5	4.73	0.77	98.02	62.71	0.0131	0.56
Keast	1	460	10-yr	2.68	257.65	258.27	258.25	258.44	0.024215	1.98	1.76	5.15	0.83	120.69	75.83	0.0131	0.62
Keast	1	460	20-yr	3.32	257.65	258.31	258.31	258.52	0.026936	2.2	2.01	5.49	0.89	145.32	90.59	0.0131	0.66
Keast	1	460	50-yr	4.29	257.65	258.41	258.41	258.64	0.025632	2.36	2.55	6.2	0.89	158.66	96.98	0.0131	0.76
Keast	1	460	100-yr	5.26	257.65	258.48	258.48	258.73	0.025177	2.5	3.05	6.77	0.89	172.54	104.28	0.0131	0.83
																	0
Keast	1	415	Timmins	7.26	257.05	257.95		258.03	0.009323	1.66	8.04	16.52	0.56	72.9	43.7	0.0066	0.9
Keast	1	415	2-yr	1.44	257.05	257.49		257.54	0.012367	1.17	1.92	8.93	0.57	46.2	25.42	0.0066	0.44
Keast	1	415	5-yr	2.1	257.05	257.58		257.63	0.011361	1.26	2.76	10.97	0.57	50.93	27.41	0.0066	0.53
Keast	1	415	10-yr	2.68	257.05	257.64		257.7	0.010797	1.33	3.47	12.19	0.56	54.24	29.51	0.0066	0.59
Keast	1	415	20-yr	3.32	257.05	257.7		257.75	0.01039	1.39	4.19	13.11	0.56	57.46	31.96	0.0066	0.65
Keast	1	415	50-yr	4.29	257.05	257.77		257.83	0.009987	1.47	5.22	14.16	0.56	61.9	35.44	0.0066	0.72
Keast	1	415	100-yr	5.26	257.05	257.84		257.9	0.009737	1.54	6.18	15.05	0.56	66.02	38.53	0.0066	0.79
																	0
Keast	1	378	Timmins	7.26	256.81	257.66		257.73	0.007113	1.41	6.95	12.02	0.49	53.39	39.07	0	0.85
Keast	1	378	2-yr	1.44	256.81	257.31		257.33	0.003185	0.66	3.05	10.17	0.3	13.89	9.12	0	0.5
Keast	1	378	5-yr	2.1	256.81	257.37		257.39	0.003883	0.79	3.68	10.5	0.34	19.07	13	0	0.56
Keast	1	378	10-yr	2.68	256.81	257.42		257.44	0.004437	0.88	4.15	10.75	0.37	23.56	16.35	0	0.61
Keast	1	378	20-yr	3.32	256.81	257.46		257.49	0.004904	0.98	4.64	11	0.39	28	19.71	0	0.65
Keast	1	378	50-yr	4.29	256.81	257.52		257.56	0.005536	1.1	5.3	11.31	0.42	34.53	24.7	0	0.71
Keast	1	378	100-yr	5.26	256.81	257.57		257.62	0.006099	1.21	5.89	11.56	0.45	40.85	29.53	0	0.76
																	0
Keast	1	345	Timmins	7.26	256.81	257.45		257.49	0.006917	1.15	9.07	22	0.46	38.76	27.61	0.0028	0.64
Keast	1	345	2-yr	1.44	256.81	257.16	257.11	257.18	0.007144	0.77	3.07	19	0.42	21.45	11.18	0.0028	0.35
Keast	1	345	5-yr	2.1	256.81	257.22		257.23	0.00634	0.8	4.12	19.7	0.41	22.12	12.86	0.0028	0.41
Keast	1	345	10-yr	2.68	256.81	257.26		257.28	0.005632	0.81	5.04	20.25	0.39	21.98	13.61	0.0028	0.45
Keast	1	345	20-yr	3.32	256.81	257.3		257.32	0.005707	0.86	5.78	20.65	0.4	24.12	15.5	0.0028	0.49

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
Keast	1	345	50-yr	4.29	256.81	257.35		257.37	0.005886	0.93	6.78	21.08	0.41	27.38	18.34	0.0028	0.54
Keast	1	345	100-yr	5.26	256.81	257.39		257.41	0.006111	1	7.65	21.44	0.43	30.67	21.13	0.0028	0.58
																	0
Keast	1	317	Timmins	7.26	256.73	257.08	257.04	257.16	0.022179	1.34	6.52	29.01	0.74	65.41	48.26	0.0301	0.35
Keast	1	317	2-yr	1.44	256.73	256.78		256.83	0.024636	0.42	1.53	8.04	0.6	11.99	45.33	0.0301	0.05
Keast	1	317	5-yr	2.1	256.73	256.83		256.89	0.027886	0.68	1.94	8.64	0.7	25.17	60.22	0.0301	0.1
Keast	1	317	10-yr	2.68	256.73	256.91		256.96	0.031023	1	2.69	13.83	0.79	45.73	58.06	0.0301	0.18
Keast	1	317	20-yr	3.32	256.73	256.94		256.99	0.030739	1.09	3.13	14.56	0.8	52.24	63.56	0.0301	0.21
Keast	1	317	50-yr	4.29	256.73	256.98		257.05	0.028837	1.19	3.74	14.7	0.79	58.36	70.41	0.0301	0.25
Keast	1	317	100-yr	5.26	256.73	257.02	256.96	257.09	0.026889	1.27	4.6	28.38	0.78	63.39	42.19	0.0301	0.29
																	0
Keast	1	286	Timmins	7.26	255.82	256.64		256.71	0.010505	1.67	7.28	13.14	0.59	75.49	55.43	0.0243	0.82
Keast	1	286	2-yr	1.44	255.82	256.2	256.16	256.25	0.015415	1.19	2.01	10.47	0.63	50.25	28.46	0.0243	0.38
Keast	1	286	5-yr	2.1	255.82	256.27	256.21	256.32	0.013537	1.26	2.79	11	0.61	52.94	33.01	0.0243	0.45
Keast	1	286	10-yr	2.68	255.82	256.33	256.24	256.38	0.012945	1.33	3.39	11.38	0.61	56.76	36.96	0.0243	0.51
Keast	1	286	20-yr	3.32	255.82	256.38		256.44	0.012366	1.39	4.01	11.77	0.6	60.14	40.35	0.0243	0.56
Keast	1	286	50-yr	4.29	255.82	256.45		256.51	0.011848	1.48	4.88	12.34	0.6	65.33	44.89	0.0243	0.63
Keast	1	286	100-yr	5.26	255.82	256.52		256.58	0.01138	1.56	5.71	12.76	0.6	69.45	48.73	0.0243	0.7
																	0
Keast	1	259	Timmins	7.26	255.16	255.98	255.98	256.23	0.031899	2.73	3.95	8.02	0.99	208.66	145.8	0.042	0.82
Keast	1	259	2-yr	1.44	255.16	255.56	255.56	255.67	0.03007	1.61	1.19	5.29	0.85	93.37	62.97	0.042	0.4
Keast	1	259	5-yr	2.1	255.16	255.63	255.63	255.77	0.033028	1.86	1.54	5.67	0.91	118.19	82.89	0.042	0.47
Keast	1	259	10-yr	2.68	255.16	255.68	255.68	255.84	0.032828	2	1.85	6.13	0.93	132.28	91.92	0.042	0.52
Keast	1	259	20-yr	3.32	255.16	255.73	255.73	255.91	0.032598	2.14	2.18	6.52	0.94	145.71	100.98	0.042	0.57
Keast	1	259	50-yr	4.29	255.16	255.8	255.8	256	0.032341	2.32	2.65	6.98	0.96	163.78	113.87	0.042	0.64
Keast	1	259	100-yr	5.26	255.16	255.86	255.86	256.08	0.032224	2.47	3.09	7.36	0.97	180.14	125.72	0.042	0.7
																	0
Keast	1	239	Timmins	7.26	254.32	255.18	255.18	255.46	0.032392	2.78	3.79	7.36	0.99	215.37	153.55	0.0231	0.86
Keast	1	239	2-yr	1.44	254.32	254.72	254.72	254.85	0.03508	1.72	1.08	4.42	0.92	106.97	78.46	0.0231	0.4
Keast	1	239	5-yr	2.1	254.32	254.8	254.8	254.95	0.035159	1.91	1.45	4.85	0.94	125.49	95.83	0.0231	0.48
Keast	1	239	10-yr	2.68	254.32	254.86	254.86	255.03	0.035966	2.06	1.73	5.13	0.96	141.25	110.72	0.0231	0.54
Keast	1	239	20-yr	3.32	254.32	254.91	254.91	255.1	0.035895	2.21	2.02	5.54	0.97	157.12	119.79	0.0231	0.59
Keast	1	239	50-yr	4.29	254.32	254.99	254.99	255.21	0.034635	2.39	2.48	6.09	0.98	174.22	129.33	0.0231	0.67
Keast	1	239	100-yr	5.26	254.32	255.06	255.06	255.3	0.033569	2.53	2.93	6.57	0.98	188.57	137.34	0.0231	0.74
																	0
Keast	1	217	Timmins	7.26	253.81	254.78		254.85	0.007974	1.62	7.47	12.03	0.53	67.82	47.04	0	0.97
Keast	1	217	2-yr	1.44	253.81	254.37		254.39	0.003745	0.76	3.03	9.49	0.33	18.1	11.41	0	0.56
Keast	1	217	5-yr	2.1	253.81	254.44		254.47	0.004482	0.91	3.75	10.04	0.37	24.63	16	0	0.63
Keast	1	217	10-yr	2.68	253.81	254.5		254.53	0.004999	1.02	4.31	10.39	0.4	29.94	19.8	0	0.69
Keast	1	217	20-yr	3.32	253.81	254.54		254.58	0.005649	1.13	4.82	10.67	0.43	36.23	24.31	0	0.73
Keast	1	217	50-yr	4.29	253.81	254.61		254.66	0.006383	1.28	5.55	11.06	0.46	44.77	30.47	0	0.8
Keast	1	217	100-yr	5.26	253.81	254.67		254.73	0.006992	1.4	6.22	11.41	0.49	52.78	36.24	0	0.86
																	0
Keast	1	192	Timmins	7.26	253.81	254.64		254.68	0.005189	1.19	10.85	19.9	0.42	37.98	27.32	0	0.83
Keast	1	192	2-yr	1.44	253.81	254.3		254.3	0.002563	0.58	4.5	16.14	0.27	10.76	6.9	0	0.49
Keast	1	192	5-yr	2.1	253.81	254.36		254.37	0.003058	0.68	5.52	16.96	0.3	14.53	9.62	0	0.55
Keast	1	192	10-yr	2.68	253.81	254.4		254.42	0.003388	0.76	6.33	17.56	0.32	17.52	11.8	0	0.59
Keast	1	192	20-yr	3.32	253.81	254.44		254.45	0.004033	0.86	6.92	17.97	0.35	22.04	15	0	0.63
Keast	1	192	50-yr	4.29	253.81	254.49		254.51	0.004577	0.97	7.92	18.59	0.38	27.25	18.83	0	0.68
Keast	1	192	100-yr	5.26	253.81	254.54		254.57	0.004874	1.05	8.91	19.05	0.4	31.32	22.01	0	0.73
																	0
Keast	1	167	Timmins	7.26	253.81	254.49		254.52	0.007639	1.25	10.18	22.02	0.49	45.4	34.12	0.0168	0.68
Keast	1	167	2-yr	1.44	253.81	254.11	254.11	254.16	0.026529	1.31	2.22	19.44	0.79	66.65	29.33	0.0168	0.3
Keast	1	167	5-yr	2.1	253.81	254.14	254.14	254.2	0.028206	1.46	2.87	19.68	0.83	79.24	39.8	0.0168	0.33
Keast	1	167	10-yr	2.68	253.81	254.16	254.16	254.23	0.03092	1.6	3.3	19.85	0.88	92.95	49.83	0.0168	0.35
Keast	1	167	20-yr	3.32	253.81	254.22		254.27	0.019179	1.4	4.5	20.26	0.71	67.89	41.22	0.0168	0.41
Keast	1	167	50-yr	4.29	253.81	254.3		254.34	0.012359	1.28	6.17	20.84	0.59	52.77	35.43	0.0168	0.49
Keast	1	167	100-yr	5.26	253.81	254.37		254.41	0.009565	1.23	7.68	21.32	0.53	46.95	33.31	0.0168	0.56
																	0
Keast	1	151	Timmins	7.26	253.54	254.44		254.46	0.002194	0.8	15.85	29.57	0.27	16.92	11.34	0.2134	0.9
Keast	1	151	2-yr	1.44	253.54	253.9		253.91	0.002854	0.48	3.9	11.58	0.26	8.43	9.16	0.2134	0.36
Keast	1	151	5-yr	2.1	253.54	254.02		254.03	0.002335	0.53	5.54	17.13	0.25	9.4	7.25	0.2134	0.48
Keast	1	151	10-yr	2.68	253.54	254.09		254.1	0.002395	0.59	6.77	20.15	0.26	11.02	7.74	0.2134	0.55
Keast	1	151	20-yr	3.32	253.54	254.17		254.18	0.002161	0.62	8.49	22.99	0.25	11.45	7.69	0.2134	0.63
Keast	1	151	50-yr	4.29	253.54	254.25		254.26	0.002164	0.67	10.5	25.21	0.26	13.04	8.69	0.2134	0.71
Keast	1	151	100-yr	5.26	253.54	254.33		254.34	0.002147	0.72	12.45	27.49	0.26	14.33	9.38	0.2134	0.79
																	0
Keast	1	143	Timmins	7.26	251.74	254.44	253.05	254.45	0.000389	0.72	21.87	23.05	0.14	5.53	3.33	0.0183	2.7
Keast	1	143	2-yr	1.44	251.74	253.9	252.16	253.91	0.000048	0.22	12.3	13.83	0.05	0.54	0.37	0.0183	2.16
Keast	1	143	5-yr	2.1	251.74	254.03	252.28	254.03	0.000077	0.29	14.06	15.27	0.06	0.92	0.62	0.0183	2.29
Keast	1	143	10-yr	2.68	251.74	254.09	252.38	254.09	0.00011	0.35	15.09	16.52	0.07	1.36	0.88	0.0183	2.35
Keast	1	143	20-yr	3.32	251.74	254.17	252.47	254.17	0.000142	0.41	16.44	17.74	0.08	1.81	1.16	0.0183	2.43

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
Keast	1	143	50-yr	4.29	251.74	254.25	252.6	254.26	0.0002	0.49	17.93	19.13	0.1	2.64	1.67	0.0183	2.51
Keast	1	143	100-yr	5.26	251.74	254.32	252.77	254.33	0.000259	0.57	19.37	20.55	0.12	3.51	2.18	0.0183	2.58
																	0
Keast	1	139		Culvert													0
																	0
Keast	1	120	Timmins	7.26	251.33	252.44	252.44	252.91	0.023312	3.04	2.39	2.56	1.01	133.05	133.05	0.0285	1.11
Keast	1	120	2-yr	1.44	251.33	251.73	251.73	251.92	0.023347	1.92	0.75	2.02	1.01	66.75	66.75	0.0285	0.4
Keast	1	120	5-yr	2.1	251.33	251.84	251.84	252.07	0.023082	2.15	0.98	2.1	1.01	78.8	78.8	0.0285	0.51
Keast	1	120	10-yr	2.68	251.33	251.92	251.92	252.2	0.023018	2.31	1.16	2.17	1.01	87.68	87.68	0.0285	0.59
Keast	1	120	20-yr	3.32	251.33	252.01	252.01	252.32	0.022851	2.45	1.36	2.24	1	95.57	95.57	0.0285	0.68
Keast	1	120	50-yr	4.29	251.33	252.13	252.13	252.49	0.023026	2.64	1.63	2.33	1.01	107.01	107.01	0.0285	0.8
Keast	1	120	100-yr	5.26	251.33	252.24	252.24	252.64	0.023129	2.79	1.89	2.41	1.01	116.63	116.63	0.0285	0.91
																	0
Keast	1	104	Timmins	7.26	250.86	251.81	251.81	251.97	0.012368	2.2	6.88	20.38	0.81	69.73	39.35	0.0438	0.95
Keast	1	104	2-yr	1.44	250.86	251.3	251.3	251.48	0.021872	1.91	0.75	2.06	1.01	65.02	65.02	0.0438	0.44
Keast	1	104	5-yr	2.1	250.86	251.41	251.41	251.64	0.021271	2.11	1	2.23	1.01	74.94	74.94	0.0438	0.55
Keast	1	104	10-yr	2.68	250.86	251.49	251.49	251.76	0.021965	2.28	1.18	2.36	1.03	85.21	85.21	0.0438	0.63
Keast	1	104	20-yr	3.32	250.86	251.66	251.66	251.77	0.008606	1.64	3.87	19.13	0.66	41.14	16.41	0.0438	0.8
Keast	1	104	50-yr	4.29	250.86	251.71	251.71	251.83	0.009514	1.79	4.8	19.53	0.7	48.13	22.08	0.0438	0.85
Keast	1	104	100-yr	5.26	250.86	251.75	251.75	251.88	0.010244	1.92	5.63	19.88	0.73	54.24	27.38	0.0438	0.89
																	0
Keast	1	91	Timmins	7.26	250.31	251.45	251.45	251.6	0.009277	2.06	7.83	25.88	0.7	59.01	26.6	0.0362	1.14
Keast	1	91	2-yr	1.44	250.31	250.79	250.79	250.98	0.022348	1.95	0.74	1.91	1	67.83	67.83	0.0362	0.48
Keast	1	91	5-yr	2.1	250.31	250.91	250.91	251.14	0.021855	2.15	0.98	2.1	1.01	77.97	77.97	0.0362	0.6
Keast	1	91	10-yr	2.68	250.31	251	251	251.27	0.021789	2.3	1.17	2.23	1.01	85.88	85.88	0.0362	0.69
Keast	1	91	20-yr	3.32	250.31	251.19	251.19	251.36	0.010903	1.9	2.59	12.87	0.74	54.36	20.31	0.0362	0.88
Keast	1	91	50-yr	4.29	250.31	251.28	251.28	251.44	0.009973	1.94	4.01	17.75	0.72	54.68	21.13	0.0362	0.97
Keast	1	91	100-yr	5.26	250.31	251.35	251.35	251.5	0.009344	1.96	5.45	21.68	0.7	54.74	22.15	0.0362	1.04
																	0
Keast	1	67	Timmins	7.26	249.43	250.8	250.8	251.07	0.012416	2.42	4.11	9.66	0.76	80.64	44.83	0.046	1.37
Keast	1	67	2-yr	1.44	249.43	249.91	249.91	250.11	0.023883	2.01	0.72	1.76	1.01	71.95	71.95	0.046	0.48
Keast	1	67	5-yr	2.1	249.43	250.03	250.03	250.28	0.023621	2.23	0.94	1.89	1.01	83.63	83.63	0.046	0.6
Keast	1	67	10-yr	2.68	249.43	250.13	250.13	250.41	0.023459	2.37	1.13	1.99	1.01	91.88	91.88	0.046	0.7
Keast	1	67	20-yr	3.32	249.43	250.22	250.22	250.54	0.023368	2.51	1.32	2.1	1.01	99.65	99.65	0.046	0.79
Keast	1	67	50-yr	4.29	249.43	250.35	250.35	250.72	0.023248	2.67	1.61	2.23	1.01	109.58	109.58	0.046	0.92
Keast	1	67	100-yr	5.26	249.43	250.47	250.47	250.87	0.023148	2.81	1.87	2.36	1.01	117.96	117.96	0.046	1.04
																	0
Keast	1	52	Timmins	7.26	248.7	249.94	249.94	250.46	0.026364	3.17	2.29	2.26	1.01	146.17	146.17		1.24
Keast	1	52	2-yr	1.44	248.7	249.5	249.15	249.56	0.004212	1.06	1.35	1.96	0.41	17.95	17.95		0.8
Keast	1	52	5-yr	2.1	248.7	249.5	249.28	249.62	0.008973	1.55	1.35	1.96	0.6	38.25	38.25		0.8
Keast	1	52	10-yr	2.68	248.7	249.5	249.37	249.7	0.014661	1.99	1.35	1.96	0.76	62.5	62.5		0.8
Keast	1	52	20-yr	3.32	248.7	249.5	249.47	249.81	0.022463	2.46	1.35	1.96	0.94	95.75	95.75		0.8
Keast	1	52	50-yr	4.29	248.7	249.6	249.6	249.99	0.025569	2.75	1.56	2.03	1	117.4	117.4		0.9
Keast	1	52	100-yr	5.26	248.7	249.72	249.72	250.16	0.025912	2.91	1.81	2.11	1.01	128.17	128.17		1.02
																	0
Frobisher	1	2474	Timmins	10.57	265.78	267.38		267.41	0.001934	0.98	14.87	17.54	0.25	22.27	14.76	0	1.6
Frobisher	1	2474	2-yr	4.06	265.78	266.82		266.85	0.001937	0.75	7.08	10.65	0.24	15.01	11.21	0	1.04
Frobisher	1	2474	5-yr	5.97	265.78	267.01		267.04	0.002093	0.85	9.25	12.89	0.25	18.53	13.18	0	1.23
Frobisher	1	2474	10-yr	7.41	265.78	267.13		267.16	0.002104	0.91	10.91	14.49	0.25	20.48	14.05	0	1.35
Frobisher	1	2474	20-yr	8.93	265.78	267.25		267.29	0.002036	0.95	12.78	16.02	0.25	21.61	14.52	0	1.47
Frobisher	1	2474	50-yr	10.95	265.78	267.41		267.44	0.001904	0.98	15.38	17.88	0.25	22.31	14.76	0	1.63
Frobisher	1	2474	100-yr	12.66	265.78	267.54		267.57	0.001666	0.97	19.73	55.23	0.23	21.13	5.65	0	1.76
																	0
Frobisher	1	2455	Timmins	10.57	265.78	267.31		267.37	0.00273	1.2	14.12	20.66	0.31	32.74	17.28	-0.0017	1.53
Frobisher	1	2455	2-yr	4.06	265.78	266.77		266.8	0.002552	0.86	6.05	10.34	0.28	19.76	13.22	-0.0017	0.99
Frobisher	1	2455	5-yr	5.97	265.78	266.95		266.99	0.002854	1.02	8.08	12.92	0.3	26.03	16.07	-0.0017	1.17
Frobisher	1	2455	10-yr	7.41	265.78	267.07		267.11	0.002942	1.1	9.72	14.91	0.31	29.54	17.43	-0.0017	1.29
Frobisher	1	2455	20-yr	8.93	265.78	267.19		267.24	0.00289	1.16	11.69	17.41	0.31	31.77	17.8	-0.0017	1.41
Frobisher	1	2455	50-yr	10.95	265.78	267.34		267.4	0.002672	1.2	14.75	21.42	0.31	32.66	17.06	-0.0017	1.56
Frobisher	1	2455	100-yr	12.66	265.78	267.49		267.53	0.002271	1.17	18.11	36.45	0.29	30.29	10.7	-0.0017	1.71
																	0
Frobisher	1	2431	Timmins	10.57	265.82	267.24		267.29	0.003437	1.23	13.16	19.37	0.33	36.37	21.37	0.0013	1.42
Frobisher	1	2431	2-yr	4.06	265.82	266.71		266.74	0.003046	0.86	6.03	9.45	0.29	20.61	16.89	0.0013	0.89
Frobisher	1	2431	5-yr	5.97	265.82	266.87		266.91	0.003531	1.02	7.73	11.13	0.32	27.72	21.46	0.0013	1.05
Frobisher	1	2431	10-yr	7.41	265.82	266.99		267.04	0.003632	1.11	9.12	13.02	0.33	31.63	22.58	0.0013	1.17
Frobisher	1	2431	20-yr	8.93	265.82	267.11		267.16	0.003649	1.19	10.85	15.93	0.34	35.05	22.44	0.0013	1.29
Frobisher	1	2431	50-yr	10.95	265.82	267.27		267.33	0.003352	1.24	13.79	20.29	0.33	36.26	20.91	0.0013	1.45
Frobisher	1	2431	100-yr	12.66	265.82	267.43		267.47	0.002778	1.2	17.25	24.28	0.3	33.24	18.29	0.0013	1.61
																	0
Frobisher	1	2401	Timmins	10.57	265.78	267.12		267.18	0.003993	1.34	11.79	18	0.37	42.72	24.23	0.0008	1.34
Frobisher	1	2401	2-yr	4.06	265.78	266.55		266.61	0.006025	1.14	4.44	9.28	0.41	37.21	25.64	0.0008	0.77
Frobisher	1	2401	5-yr	5.97	265.78	266.69		266.77	0.006613	1.34	5.88	11	0.45	48.37	31.83	0.0008	0.91

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
Frobisher	1	2401	10-yr	7.41	265.78	266.81		266.89	0.006184	1.4	7.27	12.53	0.44	51.11	32.61	0.0008	1.03
Frobisher	1	2401	20-yr	8.93	265.78	266.95		267.03	0.005244	1.41	9.15	14.36	0.41	49.21	30.6	0.0008	1.17
Frobisher	1	2401	50-yr	10.95	265.78	267.16		267.22	0.003728	1.32	12.52	19.31	0.36	41.07	22.47	0.0008	1.38
Frobisher	1	2401	100-yr	12.66	265.78	267.35		267.39	0.002582	1.2	16.9	26.93	0.31	32.37	15.29	0.0008	1.57
																	0
Frobisher	1	2377	Timmins	10.57	265.76	267.05		267.09	0.002984	1.17	13.44	15.56	0.33	32.42	23.86	0.0257	1.29
Frobisher	1	2377	2-yr	4.06	265.76	266.31		266.39	0.014395	1.45	3.69	10.52	0.63	66.21	46.47	0.0257	0.55
Frobisher	1	2377	5-yr	5.97	265.76	266.53		266.6	0.007568	1.32	6.27	12.18	0.48	49.19	35.93	0.0257	0.77
Frobisher	1	2377	10-yr	7.41	265.76	266.69		266.75	0.005534	1.28	8.25	13.19	0.42	43.26	31.96	0.0257	0.93
Frobisher	1	2377	20-yr	8.93	265.76	266.86		266.91	0.004022	1.22	10.63	14.32	0.37	37.32	27.62	0.0257	1.1
Frobisher	1	2377	50-yr	10.95	265.76	267.09		267.14	0.002802	1.16	14.12	15.86	0.32	31.47	23.11	0.0257	1.33
Frobisher	1	2377	100-yr	12.66	265.76	267.3		267.34	0.002109	1.11	17.5	17.27	0.28	27.33	19.83	0.0257	1.54
																	0
Frobisher	1	2357	Timmins	10.57	265.24	267.04	265.87	267.06	0.000619	0.64	17.85	15.91	0.16	8.84	6.29	0.0017	1.8
Frobisher	1	2357	2-yr	4.06	265.24	266.32	265.61	266.33	0.000701	0.47	8.65	9.26	0.16	5.74	5.74	0.0017	1.08
Frobisher	1	2357	5-yr	5.97	265.24	266.53	265.7	266.55	0.000783	0.56	10.82	11.21	0.17	7.68	6.7	0.0017	1.29
Frobisher	1	2357	10-yr	7.41	265.24	266.68	265.75	266.7	0.000771	0.6	12.68	13.11	0.17	8.59	6.69	0.0017	1.44
Frobisher	1	2357	20-yr	8.93	265.24	266.85	265.81	266.87	0.000702	0.63	15.03	14.19	0.17	8.88	6.69	0.0017	1.61
Frobisher	1	2357	50-yr	10.95	265.24	267.09	265.88	267.11	0.000601	0.64	18.55	16.46	0.16	8.8	6.14	0.0017	1.85
Frobisher	1	2357	100-yr	12.66	265.24	267.29	265.94	267.31	0.000508	0.64	22.23	19.18	0.15	8.36	5.39	0.0017	2.05
																	0
Frobisher	1	2350		Culvert													0
																	0
Frobisher	1	2337	Timmins	10.57	265.21	266.82		266.84	0.000736	0.65	17.42	14.44	0.17	9.39	7.85	-0.003	1.61
Frobisher	1	2337	2-yr	4.06	265.21	266.28		266.29	0.000538	0.43	10.09	12.74	0.14	4.69	3.88	-0.003	1.07
Frobisher	1	2337	5-yr	5.97	265.21	266.46		266.48	0.000621	0.51	12.47	13.32	0.15	6.3	5.24	-0.003	1.25
Frobisher	1	2337	10-yr	7.41	265.21	266.58		266.6	0.000671	0.56	14.09	13.7	0.16	7.41	6.18	-0.003	1.37
Frobisher	1	2337	20-yr	8.93	265.21	266.7		266.72	0.000709	0.61	15.72	14.07	0.16	8.44	7.04	-0.003	1.49
Frobisher	1	2337	50-yr	10.95	265.21	266.85		266.87	0.000743	0.66	17.79	14.53	0.17	9.61	8.03	-0.003	1.64
Frobisher	1	2337	100-yr	12.66	265.21	266.96		266.98	0.000761	0.69	19.51	14.97	0.17	10.48	8.73	-0.003	1.75
																	0
Frobisher	1	2312	Timmins	10.57	265.28	266.71		266.79	0.004174	1.34	10.11	10.16	0.36	43.1	35	0.0005	1.43
Frobisher	1	2312	2-yr	4.06	265.28	266.22		266.26	0.002831	0.86	5.76	7.99	0.28	20.19	17.21	0.0005	0.94
Frobisher	1	2312	5-yr	5.97	265.28	266.39		266.44	0.003445	1.04	7.12	8.51	0.31	28	24.07	0.0005	1.11
Frobisher	1	2312	10-yr	7.41	265.28	266.5		266.55	0.003812	1.15	8.06	8.88	0.33	33.44	28.75	0.0005	1.22
Frobisher	1	2312	20-yr	8.93	265.28	266.6		266.67	0.004037	1.25	9.04	9.49	0.35	38.5	32.15	0.0005	1.32
Frobisher	1	2312	50-yr	10.95	265.28	266.74		266.81	0.004202	1.36	10.36	10.32	0.36	44.11	35.58	0.0005	1.46
Frobisher	1	2312	100-yr	12.66	265.28	266.85		266.93	0.004258	1.43	11.52	11.03	0.37	48.03	37.75	0.0005	1.57
																	0
Frobisher	1	2275	Timmins	10.57	265.26	266.58		266.63	0.003492	1.19	12.73	15.36	0.33	34.81	26.06	0.0008	1.32
Frobisher	1	2275	2-yr	4.06	265.26	266.13		266.15	0.002691	0.8	6.77	10.96	0.27	17.8	14.69	0.0008	0.87
Frobisher	1	2275	5-yr	5.97	265.26	266.27		266.31	0.00321	0.96	8.46	12.19	0.3	24.48	19.75	0.0008	1.01
Frobisher	1	2275	10-yr	7.41	265.26	266.37		266.41	0.003446	1.06	9.71	13.15	0.32	28.83	22.67	0.0008	1.11
Frobisher	1	2275	20-yr	8.93	265.26	266.47		266.52	0.003516	1.13	11.12	14.16	0.33	32.14	24.72	0.0008	1.21
Frobisher	1	2275	50-yr	10.95	265.26	266.61		266.66	0.003506	1.21	13.1	15.71	0.33	35.58	26.35	0.0008	1.35
Frobisher	1	2275	100-yr	12.66	265.26	266.72		266.77	0.003405	1.26	14.96	17.54	0.33	37.43	26.39	0.0008	1.46
																	0
Frobisher	1	2249	Timmins	10.57	265.24	266.5		266.54	0.003569	1.12	13.01	14.49	0.32	31.77	28.21	0.0003	1.26
Frobisher	1	2249	2-yr	4.06	265.24	266.06		266.08	0.00293	0.8	6.99	12.59	0.28	18.35	14.63	0.0003	0.82
Frobisher	1	2249	5-yr	5.97	265.24	266.19		266.22	0.003429	0.95	8.73	13.17	0.31	24.39	20.29	0.0003	0.95
Frobisher	1	2249	10-yr	7.41	265.24	266.28		266.32	0.003653	1.03	9.98	13.57	0.32	28.04	23.88	0.0003	1.04
Frobisher	1	2249	20-yr	8.93	265.24	266.39		266.43	0.003669	1.08	11.4	14.01	0.32	30.36	26.42	0.0003	1.15
Frobisher	1	2249	50-yr	10.95	265.24	266.52		266.57	0.00356	1.13	13.35	14.61	0.32	32.17	28.63	0.0003	1.28
Frobisher	1	2249	100-yr	12.66	265.24	266.64		266.69	0.003354	1.16	15.1	15.36	0.31	33.07	29.11	0.0003	1.4
																	0
Frobisher	1	2220	Timmins	10.57	265.23	266.3		266.39	0.00725	1.62	9.35	13.07	0.5	65.85	47.86	0.0295	1.07
Frobisher	1	2220	2-yr	4.06	265.23	265.71	265.71	265.87	0.028309	1.87	2.71	9.27	0.87	115.25	76.01	0.0295	0.48
Frobisher	1	2220	5-yr	5.97	265.23	265.86		266.01	0.019369	1.87	4.24	10.47	0.75	104.45	72.28	0.0295	0.63
Frobisher	1	2220	10-yr	7.41	265.23	266.01		266.13	0.012688	1.74	5.86	11.41	0.63	84.36	60.04	0.0295	0.78
Frobisher	1	2220	20-yr	8.93	265.23	266.15		266.26	0.00935	1.67	7.53	12.25	0.55	73.41	52.99	0.0295	0.92
Frobisher	1	2220	50-yr	10.95	265.23	266.32		266.42	0.007028	1.62	9.71	13.22	0.49	65.45	47.61	0.0295	1.09
Frobisher	1	2220	100-yr	12.66	265.23	266.47		266.55	0.005696	1.58	11.65	13.95	0.45	59.99	43.87	0.0295	1.24
																	0
Frobisher	1	2202	Timmins	10.57	264.7	266.3	265.43	266.33	0.001228	0.8	15.21	16.02	0.22	14.58	10.58	0.0079	1.6
Frobisher	1	2202	2-yr	4.06	264.7	265.71	265.14	265.72	0.001369	0.58	7.14	10.53	0.21	9.22	8.21	0.0079	1.01
Frobisher	1	2202	5-yr	5.97	264.7	265.88	265.26	265.91	0.001446	0.68	9.21	12.63	0.22	11.98	9.45	0.0079	1.18
Frobisher	1	2202	10-yr	7.41	264.7	266.02	265.32	266.04	0.001399	0.73	11.01	14.15	0.22	13.23	9.83	0.0079	1.32
Frobisher	1	2202	20-yr	8.93	264.7	266.15	265.38	266.18	0.001319	0.77	12.99	15.08	0.22	14.04	10.29	0.0079	1.45
Frobisher	1	2202	50-yr	10.95	264.7	266.32	265.45	266.35	0.001225	0.81	15.64	16.19	0.22	14.83	10.74	0.0079	1.62
Frobisher	1	2202	100-yr	12.66	264.7	266.47	265.51	266.5	0.001137	0.83	18.01	17.14	0.21	15.19	10.87	0.0079	1.77
																	0
Frobisher	1	2191		Culvert													0

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
																	0
Frobisher	1	2164	Timmins	10.57	264.4	266.06		266.09	0.001878	0.89	13.36	15.09	0.26	19.15	14.83	0.0018	1.66
Frobisher	1	2164	2-yr	4.06	264.4	265.47		265.49	0.00271	0.71	5.71	8.95	0.28	15.02	15.02	0.0018	1.07
Frobisher	1	2164	5-yr	5.97	264.4	265.68		265.71	0.002269	0.77	8.08	13.1	0.27	16.27	12.49	0.0018	1.28
Frobisher	1	2164	10-yr	7.41	264.4	265.81		265.85	0.00208	0.81	9.9	13.67	0.26	17.08	13.4	0.0018	1.41
Frobisher	1	2164	20-yr	8.93	264.4	265.94		265.97	0.001966	0.85	11.62	14.31	0.26	18.07	14.21	0.0018	1.54
Frobisher	1	2164	50-yr	10.95	264.4	266.07		266.11	0.001919	0.91	13.6	15.19	0.26	19.83	15.33	0.0018	1.67
Frobisher	1	2164	100-yr	12.66	264.4	266.17		266.22	0.001903	0.95	15.19	15.77	0.27	21.32	16.37	0.0018	1.77
																	0
Frobisher	1	2153	Timmins	10.57	264.38	266.05		266.07	0.000723	0.69	19.81	15.27	0.17	10.32	8.33	0.0022	1.67
Frobisher	1	2153	2-yr	4.06	264.38	265.46		265.47	0.000534	0.44	11.38	13.42	0.14	4.93	4.07	0.0022	1.08
Frobisher	1	2153	5-yr	5.97	264.38	265.68		265.69	0.00059	0.53	14.31	14.05	0.15	6.52	5.37	0.0022	1.3
Frobisher	1	2153	10-yr	7.41	264.38	265.81		265.82	0.00063	0.58	16.24	14.45	0.16	7.69	6.31	0.0022	1.43
Frobisher	1	2153	20-yr	8.93	264.38	265.93		265.95	0.000674	0.63	18.04	14.81	0.16	8.94	7.3	0.0022	1.55
Frobisher	1	2153	50-yr	10.95	264.38	266.07		266.09	0.000749	0.71	20.06	15.31	0.17	10.79	8.71	0.0022	1.69
Frobisher	1	2153	100-yr	12.66	264.38	266.17		266.19	0.000806	0.76	21.63	15.6	0.18	12.31	9.9	0.0022	1.79
																	0
Frobisher	1	2117	Timmins	10.57	264.3	265.98		266.03	0.001736	0.94	12.26	10.8	0.23	20.28	15.36	0.0016	1.68
Frobisher	1	2117	2-yr	4.06	264.3	265.43		265.44	0.000973	0.55	7.33	6.5	0.17	7.99	7.99	0.0016	1.13
Frobisher	1	2117	5-yr	5.97	264.3	265.63		265.65	0.001261	0.69	8.85	8.7	0.19	11.8	9.71	0.0016	1.33
Frobisher	1	2117	10-yr	7.41	264.3	265.76		265.79	0.001438	0.77	9.98	9.13	0.2	14.55	11.87	0.0016	1.46
Frobisher	1	2117	20-yr	8.93	264.3	265.87		265.91	0.001589	0.86	11.1	10.23	0.22	17.35	13.34	0.0016	1.57
Frobisher	1	2117	50-yr	10.95	264.3	266		266.04	0.001812	0.96	12.4	10.87	0.24	21.32	16.12	0.0016	1.7
Frobisher	1	2117	100-yr	12.66	264.3	266.09		266.14	0.001988	1.04	13.43	11.37	0.25	24.68	18.45	0.0016	1.79
																	0
Frobisher	1	2087	Timmins	10.57	264.25	265.93		265.97	0.001789	0.93	12.51	11.24	0.23	20.25	15.41	-0.0023	1.68
Frobisher	1	2087	2-yr	4.06	264.25	265.4		265.41	0.000919	0.54	7.47	6.5	0.16	7.65	7.65	-0.0023	1.15
Frobisher	1	2087	5-yr	5.97	264.25	265.59		265.62	0.001236	0.68	8.93	9.98	0.19	11.59	8.59	-0.0023	1.34
Frobisher	1	2087	10-yr	7.41	264.25	265.71		265.74	0.001423	0.77	10.18	10.44	0.2	14.37	10.76	-0.0023	1.46
Frobisher	1	2087	20-yr	8.93	264.25	265.82		265.86	0.001606	0.85	11.35	10.85	0.22	17.23	13.01	-0.0023	1.57
Frobisher	1	2087	50-yr	10.95	264.25	265.94		265.98	0.001879	0.96	12.63	11.28	0.24	21.37	16.27	-0.0023	1.69
Frobisher	1	2087	100-yr	12.66	264.25	266.03		266.08	0.002103	1.04	13.62	11.6	0.25	24.92	19.08	-0.0023	1.78
																	0
Frobisher	1	2057	Timmins	10.57	264.32	265.89		265.92	0.00135	0.86	14.69	12.48	0.22	16.72	13.55	0.0088	1.57
Frobisher	1	2057	2-yr	4.06	264.32	265.38		265.39	0.000792	0.52	9.01	10.18	0.16	6.83	6.02	0.0088	1.06
Frobisher	1	2057	5-yr	5.97	264.32	265.56		265.58	0.000983	0.63	10.96	10.62	0.18	9.75	8.59	0.0088	1.24
Frobisher	1	2057	10-yr	7.41	264.32	265.68		265.7	0.00111	0.71	12.24	11.02	0.19	11.92	10.39	0.0088	1.36
Frobisher	1	2057	20-yr	8.93	264.32	265.79		265.82	0.001229	0.78	13.45	11.77	0.21	14.23	11.92	0.0088	1.47
Frobisher	1	2057	50-yr	10.95	264.32	265.9		265.93	0.001421	0.88	14.79	12.54	0.22	17.7	14.31	0.0088	1.58
Frobisher	1	2057	100-yr	12.66	264.32	265.98		266.02	0.001589	0.97	15.84	13.24	0.24	20.81	16.32	0.0088	1.66
																	0
Frobisher	1	2021	Timmins	10.57	264	265.83		265.87	0.001789	1	13.83	15.02	0.25	22.42	14.68	0.0052	1.83
Frobisher	1	2021	2-yr	4.06	264	265.34		265.35	0.001129	0.62	7.87	9.94	0.19	9.89	7.68	0.0052	1.34
Frobisher	1	2021	5-yr	5.97	264	265.51		265.54	0.001394	0.76	9.76	11.39	0.21	14.11	10.38	0.0052	1.51
Frobisher	1	2021	10-yr	7.41	264	265.63		265.66	0.00153	0.84	11.1	12.43	0.23	16.82	11.97	0.0052	1.63
Frobisher	1	2021	20-yr	8.93	264	265.73		265.76	0.001664	0.92	12.43	13.71	0.24	19.6	13.33	0.0052	1.73
Frobisher	1	2021	50-yr	10.95	264	265.83		265.87	0.001899	1.03	13.89	15.08	0.26	23.85	15.59	0.0052	1.83
Frobisher	1	2021	100-yr	12.66	264	265.9		265.95	0.002087	1.11	15.07	16.19	0.27	27.43	17.41	0.0052	1.9
																	0
Frobisher	1	1982	Timmins	10.57	263.8	265.7		265.75	0.005748	1.35	12.34	15.75	0.31	47.53	39.76	0.0023	1.9
Frobisher	1	1982	2-yr	4.06	263.8	265.25		265.28	0.004137	0.96	6.43	10.71	0.25	26.05	21.1	0.0023	1.45
Frobisher	1	1982	5-yr	5.97	263.8	265.41		265.45	0.004743	1.1	8.29	12.21	0.28	33.21	27.72	0.0023	1.61
Frobisher	1	1982	10-yr	7.41	263.8	265.52		265.56	0.005072	1.19	9.65	13.37	0.29	37.84	31.78	0.0023	1.72
Frobisher	1	1982	20-yr	8.93	263.8	265.61		265.66	0.005424	1.27	10.96	14.53	0.3	42.7	35.85	0.0023	1.81
Frobisher	1	1982	50-yr	10.95	263.8	265.7		265.75	0.006278	1.41	12.25	15.66	0.33	51.74	43.3	0.0023	1.9
Frobisher	1	1982	100-yr	12.66	263.8	265.76		265.82	0.006699	1.49	13.3	16.8	0.34	57.11	47.08	0.0023	1.96
																	0
Frobisher	1	1939	Timmins	10.57	263.7	265	264.99	265.21	0.040757	2.72	6.05	11.92	0.76	220.89	176.39	0.0044	1.3
Frobisher	1	1939	2-yr	4.06	263.7	264.76	264.76	264.89	0.02872	1.99	3.3	10.66	0.62	126.53	75.31	0.0044	1.06
Frobisher	1	1939	5-yr	5.97	263.7	264.84	264.84	265	0.033393	2.26	4.24	11.13	0.67	159.19	108.21	0.0044	1.14
Frobisher	1	1939	10-yr	7.41	263.7	264.89	264.89	265.07	0.03778	2.47	4.78	11.38	0.72	187.66	135.14	0.0044	1.19
Frobisher	1	1939	20-yr	8.93	263.7	264.94	264.94	265.14	0.039456	2.6	5.41	11.66	0.74	204.94	156.03	0.0044	1.24
Frobisher	1	1939	50-yr	10.95	263.7	265.09		265.24	0.027193	2.33	7.17	12.36	0.63	157.9	134.83	0.0044	1.39
Frobisher	1	1939	100-yr	12.66	263.7	265.23		265.36	0.01929	2.09	8.98	13.04	0.54	123.45	113.8	0.0044	1.53
																	0
Frobisher	1	1923	Timmins	10.57	263.63	264.99	264.26	265.04	0.003003	1.01	10.51	8.8	0.29	25.86	25.86	0.0093	1.36
Frobisher	1	1923	2-yr	4.06	263.63	264.39	263.98	264.42	0.003231	0.76	5.37	7.8	0.29	17.18	17.18	0.0093	0.76
Frobisher	1	1923	5-yr	5.97	263.63	264.58	264.07	264.62	0.003474	0.86	6.93	8.53	0.31	21.27	21.27	0.0093	0.95
Frobisher	1	1923	10-yr	7.41	263.63	264.76	264.13	264.8	0.002856	0.87	8.49	8.65	0.28	20.7	20.7	0.0093	1.13
Frobisher	1	1923	20-yr	8.93	263.63	264.91	264.2	264.95	0.002649	0.91	9.81	8.75	0.27	21.6	21.6	0.0093	1.28
Frobisher	1	1923	50-yr	10.95	263.63	265.06	264.28	265.11	0.002696	0.98	11.15	8.85	0.28	24.31	24.31	0.0093	1.43
Frobisher	1	1923	100-yr	12.66	263.63	265.19	264.34	265.24	0.002696	1.03	12.27	8.93	0.28	26.18	26.18	0.0093	1.56

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
																	0
Frobisher	1	1901		Culvert													0
																	0
Frobisher	1	1884	Timmins	13.84	263.27	264.87		264.91	0.001882	0.96	16.66	13.78	0.26	21.58	19.3	0	1.6
Frobisher	1	1884	2-yr	5.09	263.27	264.28		264.3	0.001604	0.64	8.97	12.44	0.22	11.29	10.03	0	1.01
Frobisher	1	1884	5-yr	7.39	263.27	264.48		264.5	0.001652	0.74	11.43	12.8	0.23	14.01	12.66	0	1.21
Frobisher	1	1884	10-yr	10.25	263.27	264.67		264.7	0.001758	0.84	13.97	13.17	0.24	17.37	15.85	0	1.4
Frobisher	1	1884	20-yr	12.82	263.27	264.82		264.86	0.001844	0.93	15.94	13.61	0.25	20.37	18.33	0	1.55
Frobisher	1	1884	50-yr	15.77	263.27	264.95		265	0.002018	1.03	17.76	14.02	0.27	24.44	21.67	0	1.68
Frobisher	1	1884	100-yr	18.23	263.27	265.06		265.11	0.002117	1.11	19.27	14.37	0.28	27.45	24.07	0	1.79
																	0
Frobisher	1	1871	Timmins	13.84	263.27	264.71		264.84	0.007804	1.99	10.82	12.35	0.53	91.19	62.46	0.0099	1.44
Frobisher	1	1871	2-yr	5.09	263.27	264.16		264.24	0.008412	1.49	4.85	9.02	0.51	60.35	41.07	0.0099	0.89
Frobisher	1	1871	5-yr	7.39	263.27	264.34		264.44	0.007871	1.64	6.65	10.17	0.5	68.4	46.87	0.0099	1.07
Frobisher	1	1871	10-yr	10.25	263.27	264.53		264.64	0.007727	1.8	8.62	11.28	0.51	78.64	53.87	0.0099	1.26
Frobisher	1	1871	20-yr	12.82	263.27	264.66		264.79	0.007749	1.93	10.23	12.08	0.52	87.51	59.95	0.0099	1.39
Frobisher	1	1871	50-yr	15.77	263.27	264.77		264.92	0.008494	2.13	11.58	12.69	0.55	103.41	70.8	0.0099	1.5
Frobisher	1	1871	100-yr	18.23	263.27	264.87		265.03	0.008717	2.25	12.82	13.24	0.57	112.88	77.13	0.0099	1.6
																	0
Frobisher	1	1835	Timmins	13.84	262.91	264.44		264.55	0.007682	1.86	11.83	16.17	0.48	82.51	51.04	0.0115	1.53
Frobisher	1	1835	2-yr	5.09	262.91	263.9		263.96	0.006574	1.29	5.33	8.71	0.41	45.59	34.65	0.0115	0.99
Frobisher	1	1835	5-yr	7.39	262.91	264.09		264.17	0.006732	1.47	7.19	10.79	0.43	55.7	39.43	0.0115	1.18
Frobisher	1	1835	10-yr	10.25	262.91	264.26		264.36	0.007235	1.67	9.26	13.03	0.46	68.73	45.93	0.0115	1.35
Frobisher	1	1835	20-yr	12.82	262.91	264.39		264.5	0.007554	1.81	11.12	15.35	0.47	78.73	49.51	0.0115	1.48
Frobisher	1	1835	50-yr	15.77	262.91	264.41		264.57	0.011033	2.2	11.3	15.56	0.57	115.9	72.56	0.0115	1.5
Frobisher	1	1835	100-yr	18.23	262.91	264.48		264.66	0.011638	2.34	12.58	16.96	0.59	128.67	78.61	0.0115	1.57
																	0
Frobisher	1	1790	Timmins	13.84	262.39	263.66	263.66	263.98	0.022361	2.89	7.52	14.47	0.82	208.12	106.17	0.0118	1.27
Frobisher	1	1790	2-yr	5.09	262.39	263.1	263.1	263.37	0.033957	2.4	2.44	5.05	0.91	175.48	134.88	0.0118	0.71
Frobisher	1	1790	5-yr	7.39	262.39	263.28	263.28	263.59	0.029468	2.62	3.56	7.14	0.89	192.24	126.11	0.0118	0.89
Frobisher	1	1790	10-yr	10.25	262.39	263.48	263.48	263.79	0.024668	2.73	5.25	10.27	0.84	196.24	112.37	0.0118	1.09
Frobisher	1	1790	20-yr	12.82	262.39	263.61	263.61	263.93	0.022807	2.85	6.88	13.37	0.82	204.57	106.7	0.0118	1.22
Frobisher	1	1790	50-yr	15.77	262.39	263.99		264.13	0.008341	2.06	13.97	23.19	0.52	98	47.06	0.0118	1.6
Frobisher	1	1790	100-yr	18.23	262.39	264.22		264.31	0.004926	1.73	19.7	26.12	0.41	66.19	34.92	0.0118	1.83
																	0
Frobisher	1	1740	Timmins	13.84	261.8	263.7		263.74	0.000747	1	25.81	28.85	0.23	10.67	6.19	0.0099	1.9
Frobisher	1	1740	2-yr	5.09	261.8	262.49		262.6	0.005962	1.47	3.47	5	0.56	31.74	31.74	0.0099	0.69
Frobisher	1	1740	5-yr	7.39	261.8	262.76		262.88	0.00415	1.5	5.56	11.02	0.49	30.04	18.02	0.0099	0.96
Frobisher	1	1740	10-yr	10.25	261.8	263.15		263.23	0.002068	1.33	11.65	20.59	0.37	20.96	10.66	0.0099	1.35
Frobisher	1	1740	20-yr	12.82	261.8	263.54		263.58	0.000997	1.09	21.23	27.66	0.26	13.03	7.09	0.0099	1.74
Frobisher	1	1740	50-yr	15.77	261.8	264.01		264.04	0.000464	0.87	35.12	31.12	0.19	7.71	4.86	0.0099	2.21
Frobisher	1	1740	100-yr	18.23	261.8	264.22		264.24	0.000404	0.87	41.74	32.68	0.18	7.34	4.79	0.0099	2.42
																	0
Frobisher	1	1679	Timmins	13.84	261.2	263.68		263.7	0.000375	0.79	31.7	28.74	0.16	6.24	3.73	0.005	2.48
Frobisher	1	1679	2-yr	5.09	261.2	262.42		262.46	0.000998	0.82	6.75	8.04	0.24	8.43	6.49	0.005	1.22
Frobisher	1	1679	5-yr	7.39	261.2	262.7		262.74	0.001043	0.94	9.41	12.75	0.25	10.52	6.38	0.005	1.5
Frobisher	1	1679	10-yr	10.25	261.2	263.11		263.14	0.000732	0.92	16.87	22.6	0.21	9.39	4.85	0.005	1.91
Frobisher	1	1679	20-yr	12.82	261.2	263.51		263.54	0.000453	0.83	27.06	27.27	0.17	7.04	4.04	0.005	2.31
Frobisher	1	1679	50-yr	15.77	261.2	263.99		264.01	0.000267	0.72	41.17	31.18	0.14	5.03	3.2	0.005	2.79
Frobisher	1	1679	100-yr	18.23	261.2	264.2		264.22	0.000254	0.74	47.91	33.66	0.14	5.12	3.28	0.005	3
																	0
Frobisher	1	1674	Timmins	13.84	261.17	263.67	262.09	263.7	0.000388	0.81	29.81	26.54	0.16	6.6	3.92	0.0038	2.5
Frobisher	1	1674	2-yr	5.09	261.17	262.42	261.64	262.45	0.000946	0.8	6.8	7.87	0.23	8.12	6.3	0.0038	1.25
Frobisher	1	1674	5-yr	7.39	261.17	262.69	261.78	262.74	0.000983	0.93	9.45	12.33	0.24	10.18	6.25	0.0038	1.52
Frobisher	1	1674	10-yr	10.25	261.17	263.1	261.92	263.14	0.000714	0.93	16.27	20.3	0.21	9.37	5.04	0.0038	1.93
Frobisher	1	1674	20-yr	12.82	261.17	263.51	262.05	263.54	0.000463	0.85	25.52	25.06	0.18	7.36	4.23	0.0038	2.34
Frobisher	1	1674	50-yr	15.77	261.17	263.99	262.19	264.01	0.000283	0.75	38.66	29.31	0.14	5.42	3.37	0.0038	2.82
Frobisher	1	1674	100-yr	18.23	261.17	264.2	262.3	264.22	0.000266	0.76	45.01	31.9	0.14	5.48	3.41	0.0038	3.03
																	0
Frobisher	1	1660		Culvert													0
																	0
Frobisher	1	1641	Timmins	13.84	261.05	263		263.12	0.002527	1.66	10.09	10.34	0.38	30.83	19.9	0.0096	1.95
Frobisher	1	1641	2-yr	5.09	261.05	262.33		262.38	0.001712	1.05	5.2	5.53	0.3	14.08	11.79	0.0096	1.28
Frobisher	1	1641	5-yr	7.39	261.05	262.54		262.62	0.002083	1.26	6.45	6.12	0.33	19.36	16.03	0.0096	1.49
Frobisher	1	1641	10-yr	10.25	261.05	262.76		262.86	0.002354	1.46	7.94	7.78	0.36	25.06	18.4	0.0096	1.71
Frobisher	1	1641	20-yr	12.82	261.05	262.94		263.05	0.002469	1.61	9.46	9.48	0.38	29.12	19.59	0.0096	1.89
Frobisher	1	1641	50-yr	15.77	261.05	263.1		263.24	0.002645	1.76	11.22	11.73	0.4	34.01	20.83	0.0096	2.05
Frobisher	1	1641	100-yr	18.23	261.05	263.24		263.38	0.002656	1.84	12.92	13.51	0.4	36.46	21.34	0.0096	2.19
																	0
Frobisher	1	1636	Timmins	13.84	261	262.77	262.46	263.05	0.008309	2.57	8.17	11.23	0.62	79.74	49.42	0.0045	1.77
Frobisher	1	1636	2-yr	5.09	261	262.25	261.75	262.35	0.004525	1.5	4.14	5.41	0.43	30.51	24.42	0.0045	1.25
Frobisher	1	1636	5-yr	7.39	261	262.43	262.01	262.58	0.00559	1.82	5.25	6.8	0.49	43.18	32.1	0.0045	1.43

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
Frobisher	1	1636	10-yr	10.25	261	262.61	262.23	262.81	0.006596	2.14	6.6	8.21	0.54	57.38	40.97	0.0045	1.61
Frobisher	1	1636	20-yr	12.82	261	262.73	262.4	262.99	0.007794	2.45	7.73	10.3	0.59	73.08	47.14	0.0045	1.73
Frobisher	1	1636	50-yr	15.77	261	262.83	262.59	263.16	0.009403	2.79	8.85	12.33	0.66	93.17	56	0.0045	1.83
Frobisher	1	1636	100-yr	18.23	261	262.96	262.62	263.3	0.009346	2.91	10.6	15.35	0.66	98.99	55.16	0.0045	1.96
																	0
Frobisher	1	1603	Timmins	13.84	260.85	262.29	262.29	262.67	0.013612	3.02	5.99	8.64	0.8	115.18	76.4	0.0176	1.44
Frobisher	1	1603	2-yr	5.09	260.85	261.6	261.59	261.98	0.024334	2.7	1.89	2.5	0.99	112.31	112.31	0.0176	0.75
Frobisher	1	1603	5-yr	7.39	260.85	261.9	261.9	262.23	0.015413	2.62	3.23	5.87	0.81	95.79	64.2	0.0176	1.05
Frobisher	1	1603	10-yr	10.25	260.85	262.1	262.1	262.45	0.013925	2.79	4.54	7.31	0.8	102.87	68.15	0.0176	1.25
Frobisher	1	1603	20-yr	12.82	260.85	262.24	262.24	262.61	0.013712	2.96	5.58	8.28	0.8	112.09	74.31	0.0176	1.39
Frobisher	1	1603	50-yr	15.77	260.85	262.38	262.38	262.77	0.012895	3.07	6.89	9.45	0.79	116.65	77.07	0.0176	1.53
Frobisher	1	1603	100-yr	18.23	260.85	262.45	262.44	262.89	0.014	3.3	7.56	10.04	0.83	132.32	87.14	0.0176	1.6
																	0
Frobisher	1	1560	Timmins	13.84	260.1	262.17		262.29	0.00377	1.72	10.36	11.74	0.38	35.97	26.01	0	2.07
Frobisher	1	1560	2-yr	5.09	260.1	261.55		261.62	0.002777	1.21	4.92	6.68	0.32	19.69	14.49	0	1.45
Frobisher	1	1560	5-yr	7.39	260.1	261.77		261.85	0.003179	1.38	6.47	7.88	0.34	24.8	18.89	0	1.67
Frobisher	1	1560	10-yr	10.25	260.1	261.97		262.07	0.003478	1.54	8.24	9.5	0.36	29.94	22.6	0	1.87
Frobisher	1	1560	20-yr	12.82	260.1	262.12		262.23	0.003652	1.67	9.75	10.88	0.37	33.94	25.23	0	2.02
Frobisher	1	1560	50-yr	15.77	260.1	262.27		262.39	0.003976	1.82	11.53	13.48	0.39	39.63	27.27	0	2.17
Frobisher	1	1560	100-yr	18.23	260.1	262.37		262.5	0.004166	1.92	13	15.37	0.41	43.49	28.87	0	2.27
																	0
Frobisher	1	1522	Timmins	13.84	260.1	261.77	261.68	262.05	0.009988	2.62	8.75	16.06	0.65	86.14	46.65	0.0038	1.67
Frobisher	1	1522	2-yr	5.09	260.1	261.37		261.48	0.00464	1.5	4.23	7.58	0.42	30.8	19.66	0.0038	1.27
Frobisher	1	1522	5-yr	7.39	260.1	261.52		261.68	0.00627	1.86	5.48	10.04	0.5	45.88	27.36	0.0038	1.42
Frobisher	1	1522	10-yr	10.25	260.1	261.65	261.4	261.86	0.008078	2.24	6.95	12.92	0.57	64.47	36.17	0.0038	1.55
Frobisher	1	1522	20-yr	12.82	260.1	261.74	261.59	262	0.009475	2.52	8.25	15.18	0.63	80.14	43.8	0.0038	1.64
Frobisher	1	1522	50-yr	15.77	260.1	261.83	261.78	262.14	0.010813	2.79	9.74	17.68	0.68	96.52	51.62	0.0038	1.73
Frobisher	1	1522	100-yr	18.23	260.1	261.9	261.9	262.24	0.011577	2.97	11.06	19.61	0.71	107.56	57.18	0.0038	1.8
																	0
Frobisher	1	1483	Timmins	13.84	259.95	261.66		261.75	0.004249	1.64	11.89	18.64	0.4	34.38	23.17	0.0092	1.71
Frobisher	1	1483	2-yr	5.09	259.95	261.22		261.3	0.004138	1.37	4.92	13.25	0.39	26.09	12.72	0.0092	1.27
Frobisher	1	1483	5-yr	7.39	259.95	261.37		261.45	0.004344	1.48	6.99	14.85	0.4	29.67	17.04	0.0092	1.42
Frobisher	1	1483	10-yr	10.25	259.95	261.51		261.6	0.004337	1.56	9.27	16.55	0.4	32.03	20.46	0.0092	1.56
Frobisher	1	1483	20-yr	12.82	259.95	261.62		261.71	0.00426	1.62	11.18	18.1	0.4	33.68	22.41	0.0092	1.67
Frobisher	1	1483	50-yr	15.77	259.95	261.73		261.82	0.004231	1.68	13.21	19.62	0.4	35.6	24.5	0.0092	1.78
Frobisher	1	1483	100-yr	18.23	259.95	261.81		261.91	0.004211	1.72	14.82	20.69	0.4	37.02	26.08	0.0092	1.86
																	0
Frobisher	1	1445	Timmins	13.84	259.6	261.53		261.59	0.003721	1.35	13.39	21.48	0.31	24.99	20.7	0.0102	1.93
Frobisher	1	1445	2-yr	5.09	259.6	261.11		261.15	0.003381	1.1	6.17	12.43	0.28	17.74	14.1	0.0102	1.51
Frobisher	1	1445	5-yr	7.39	259.6	261.24		261.29	0.003842	1.23	7.93	15.25	0.31	21.86	17.24	0.0102	1.64
Frobisher	1	1445	10-yr	10.25	259.6	261.38		261.43	0.003919	1.31	10.29	18.4	0.31	24.21	19.28	0.0102	1.78
Frobisher	1	1445	20-yr	12.82	259.6	261.49		261.55	0.003773	1.34	12.53	20.81	0.31	24.81	20.22	0.0102	1.89
Frobisher	1	1445	50-yr	15.77	259.6	261.6		261.67	0.003627	1.37	14.98	22.64	0.31	25.27	21.5	0.0102	2
Frobisher	1	1445	100-yr	18.23	259.6	261.69		261.75	0.003536	1.39	16.91	23.96	0.31	25.66	22.46	0.0102	2.09
																	0
Frobisher	1	1396	Timmins	13.84	259.1	261.32		261.39	0.004603	1.41	12.51	18.94	0.3	28.02	25.77	0.0112	2.22
Frobisher	1	1396	2-yr	5.09	259.1	260.77		260.88	0.009849	1.71	4.25	11.91	0.42	45.17	27.72	0.0112	1.67
Frobisher	1	1396	5-yr	7.39	259.1	260.98		261.05	0.00625	1.47	6.89	14.11	0.34	32.14	24.79	0.0112	1.88
Frobisher	1	1396	10-yr	10.25	259.1	261.14		261.21	0.005387	1.44	9.33	16.05	0.32	30.11	25.95	0.0112	2.04
Frobisher	1	1396	20-yr	12.82	259.1	261.28		261.34	0.004729	1.41	11.68	18.23	0.31	28.2	25.55	0.0112	2.18
Frobisher	1	1396	50-yr	15.77	259.1	261.4		261.47	0.004418	1.41	14.05	20.23	0.3	27.84	26.22	0.0112	2.3
Frobisher	1	1396	100-yr	18.23	259.1	261.49		261.56	0.004281	1.43	15.91	21.75	0.29	28.01	26.98	0.0112	2.39
																	0
Frobisher	1	1351	Timmins	13.84	258.6	260.69	260.65	261	0.018401	2.95	6.14	9.19	0.65	119.84	90.55	0.0212	2.09
Frobisher	1	1351	2-yr	5.09	258.6	260.35	260.18	260.47	0.008386	1.77	3.63	6.15	0.43	45.68	32.76	0.0212	1.75
Frobisher	1	1351	5-yr	7.39	258.6	260.38	260.34	260.61	0.015677	2.44	3.81	6.32	0.59	86.85	63.11	0.0212	1.78
Frobisher	1	1351	10-yr	10.25	258.6	260.53	260.49	260.8	0.01649	2.65	4.86	7.24	0.61	99.35	76.65	0.0212	1.93
Frobisher	1	1351	20-yr	12.82	258.6	260.64	260.58	260.95	0.018453	2.91	5.71	8.55	0.65	117.34	89.08	0.0212	2.04
Frobisher	1	1351	50-yr	15.77	258.6	260.76	260.74	261.09	0.018935	3.06	6.84	10.12	0.66	127.57	96.24	0.0212	2.16
Frobisher	1	1351	100-yr	18.23	258.6	260.85	260.85	261.18	0.019044	3.15	7.75	11.17	0.67	133.39	101.49	0.0212	2.25
																	0
Frobisher	1	1319	Timmins	13.84	257.9	260.08	260.08	260.35	0.020354	2.7	6.56	11.82	0.58	107.44	85.69	0.0079	2.18
Frobisher	1	1319	2-yr	5.09	257.9	259.19	259.19	259.85	0.055896	3.58	1.42	1.1	1.01	211.48	211.48	0.0079	1.29
Frobisher	1	1319	5-yr	7.39	257.9	259.86	259.86	260.06	0.016853	2.29	4.22	9.38	0.52	79.97	54.55	0.0079	1.96
Frobisher	1	1319	10-yr	10.25	257.9	259.97	259.97	260.2	0.019119	2.52	5.28	10.55	0.56	95.62	70.79	0.0079	2.07
Frobisher	1	1319	20-yr	12.82	257.9	260.06	260.06	260.31	0.019141	2.6	6.32	11.59	0.56	100.1	78.9	0.0079	2.16
Frobisher	1	1319	50-yr	15.77	257.9	260.14	260.14	260.42	0.020959	2.78	7.2	12.4	0.59	113.32	93.25	0.0079	2.24
Frobisher	1	1319	100-yr	18.23	257.9	260.21	260.21	260.5	0.020287	2.8	8.18	13.18	0.59	113.45	97.71	0.0079	2.31
																	0
Frobisher	1	1282	Timmins	13.84	257.61	259.95	258.69	260.03	0.001561	1.33	11.82	8.62	0.28	19.52	15.01	0.0022	2.34
Frobisher	1	1282	2-yr	5.09	257.61	259.39	258.17	259.41	0.000561	0.7	7.74	6.05	0.17	5.74	4.79	0.0022	1.78
Frobisher	1	1282	5-yr	7.39	257.61	259.58	258.32	259.62	0.000829	0.89	8.98	6.74	0.2	9.16	7.46	0.0022	1.97

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
Frobisher	1	1282	10-yr	10.25	257.61	259.78	258.5	259.84	0.001134	1.09	10.42	7.76	0.24	13.44	10.52	0.0022	2.17
Frobisher	1	1282	20-yr	12.82	257.61	259.91	258.64	259.99	0.001432	1.26	11.47	8.42	0.27	17.69	13.65	0.0022	2.3
Frobisher	1	1282	50-yr	15.77	257.61	260.03	258.79	260.13	0.00177	1.44	12.52	8.77	0.3	22.68	17.64	0.0022	2.42
Frobisher	1	1282	100-yr	18.23	257.61	260.13	258.93	260.24	0.001982	1.56	13.41	9.01	0.32	26.36	20.52	0.0022	2.52
																	0
Frobisher	1	1265		Culvert													0
																	0
Frobisher	1	1246	Timmins	14.98	257.53	259.64		259.69	0.00176	1.11	18.76	22.86	0.25	26.24	13.02	0.0113	2.11
Frobisher	1	1246	2-yr	5.96	257.53	259.32		259.34	0.000564	0.56	13.23	15.02	0.14	7.11	4.31	0.0113	1.79
Frobisher	1	1246	5-yr	7.75	257.53	259.44		259.46	0.000721	0.66	15.04	16.5	0.16	9.7	5.75	0.0113	1.91
Frobisher	1	1246	10-yr	11.42	257.53	259.56		259.59	0.001183	0.89	17.11	18.35	0.2	16.95	9.75	0.0113	2.03
Frobisher	1	1246	20-yr	14.59	257.53	259.63		259.68	0.0017	1.09	18.53	22.12	0.24	25.23	12.81	0.0113	2.1
Frobisher	1	1246	50-yr	17.17	257.53	259.67		259.74	0.00217	1.25	19.59	25.38	0.28	32.91	15.22	0.0113	2.14
Frobisher	1	1246	100-yr	20.34	257.53	259.72		259.81	0.002803	1.44	20.84	29.7	0.31	43.44	18.07	0.0113	2.19
																	0
Frobisher	1	1216	Timmins	14.98	257.2	259.5		259.57	0.012035	1.72	13.35	42.19	0.36	81.83	35.1	0.0008	2.3
Frobisher	1	1216	2-yr	5.96	257.2	259.17		259.27	0.013193	1.63	4.78	11.31	0.37	77.08	44.24	0.0008	1.97
Frobisher	1	1216	5-yr	7.75	257.2	259.28	259.06	259.38	0.013688	1.72	6.6	21.83	0.38	84.45	36.12	0.0008	2.08
Frobisher	1	1216	10-yr	11.42	257.2	259.39	259.34	259.49	0.014977	1.86	9.37	31.68	0.4	96.97	40.01	0.0008	2.19
Frobisher	1	1216	20-yr	14.59	257.2	259.47		259.56	0.013683	1.82	12.15	38.17	0.39	91.81	39.86	0.0008	2.27
Frobisher	1	1216	50-yr	17.17	257.2	259.53		259.61	0.011949	1.73	15.14	59.68	0.36	82.54	28.39	0.0008	2.33
Frobisher	1	1216	100-yr	20.34	257.2	259.57		259.65	0.012068	1.76	17.58	61.88	0.36	84.79	32.08	0.0008	2.37
																	0
Frobisher	1	1154	Timmins	14.98	257.15	259.01		259.04	0.005956	1.15	19.78	70.17	0.27	37.66	16.02	0.0103	1.86
Frobisher	1	1154	2-yr	5.96	257.15	258.78		258.8	0.004264	0.89	9.44	32.9	0.22	23.64	11.33	0.0103	1.63
Frobisher	1	1154	5-yr	7.75	257.15	258.82		258.85	0.005203	1	10.95	36.94	0.25	29.61	14.37	0.0103	1.67
Frobisher	1	1154	10-yr	11.42	257.15	258.94		258.97	0.004738	1	16.05	49.59	0.24	28.87	14.47	0.0103	1.79
Frobisher	1	1154	20-yr	14.59	257.15	258.99		259.02	0.005459	1.1	18.55	54.83	0.26	34.15	17.49	0.0103	1.84
Frobisher	1	1154	50-yr	17.17	257.15	259.04		259.07	0.006051	1.17	22.36	80.72	0.27	38.94	16.04	0.0103	1.89
Frobisher	1	1154	100-yr	20.34	257.15	259.07		259.11	0.00613	1.2	25.05	81.78	0.28	40.14	17.98	0.0103	1.92
																	0
Frobisher	1	1120	Timmins	14.98	256.8	258.69	258.69	258.78	0.009431	2.23	18.04	76.77	0.52	58.41	20.97	0.0176	1.89
Frobisher	1	1120	2-yr	5.96	256.8	258.37	258.21	258.55	0.013081	2.32	4.82	10.73	0.59	67.19	48.14	0.0176	1.57
Frobisher	1	1120	5-yr	7.75	256.8	258.63	258.48	258.68	0.004698	1.54	13.38	63.5	0.36	28.09	9.33	0.0176	1.83
Frobisher	1	1120	10-yr	11.42	256.8	258.64	258.64	258.74	0.00962	2.21	13.8	65.07	0.52	57.73	19.25	0.0176	1.84
Frobisher	1	1120	20-yr	14.59	256.8	258.69	258.69	258.78	0.009288	2.21	17.77	76.43	0.51	57.42	20.44	0.0176	1.89
Frobisher	1	1120	50-yr	17.17	256.8	258.71	258.71	258.81	0.010269	2.35	19.44	78.53	0.54	64.2	24.05	0.0176	1.91
Frobisher	1	1120	100-yr	20.34	256.8	258.74	258.74	258.84	0.01063	2.41	21.86	80.48	0.55	67.52	27.3	0.0176	1.94
																	0
Frobisher	1	1094	Timmins	14.98	256.34	258.2	258.2	258.28	0.007105	1.83	18.39	85.65	0.47	46.17	14.47	-0.0104	1.86
Frobisher	1	1094	2-yr	5.96	256.34	257.82	257.55	258.14	0.017511	2.53	2.36	1.89	0.72	93.87	93.87	-0.0104	1.48
Frobisher	1	1094	5-yr	7.75	256.34	257.76	257.76	258.37	0.033228	3.44	2.25	1.87	1	174.88	174.88	-0.0104	1.42
Frobisher	1	1094	10-yr	11.42	256.34	258.17	258.17	258.24	0.006476	1.72	15.32	85.03	0.44	41.11	11.07	-0.0104	1.83
Frobisher	1	1094	20-yr	14.59	256.34	258.2	258.2	258.28	0.006676	1.77	18.46	85.67	0.45	43.4	13.64	-0.0104	1.86
Frobisher	1	1094	50-yr	17.17	256.34	258.25	258.22	258.31	0.005452	1.64	22.51	86.47	0.41	36.5	13.45	-0.0104	1.91
Frobisher	1	1094	100-yr	20.34	256.34	258.28	258.24	258.34	0.005796	1.71	24.87	86.92	0.42	39.45	15.71	-0.0104	1.94
																	0
Frobisher	1	1089		Culvert													0
																	0
Frobisher	1	1079	Timmins	14.98	256.51	258.18		258.25	0.002987	1.61	25.11	115.57	0.45	30.74	6.31	-0.0055	1.67
Frobisher	1	1079	2-yr	5.96	256.51	257.95		258.05	0.003057	1.43	5.5	10.99	0.44	25.93	13.79	-0.0055	1.44
Frobisher	1	1079	5-yr	7.75	256.51	258.01	257.68	258.15	0.004248	1.75	6.22	33.61	0.52	37.84	7.5	-0.0055	1.5
Frobisher	1	1079	10-yr	11.42	256.51	258.11	257.93	258.22	0.003893	1.77	16.35	111.56	0.51	37.73	5.55	-0.0055	1.6
Frobisher	1	1079	20-yr	14.59	256.51	258.18		258.25	0.003033	1.62	24.33	115.21	0.45	31.05	6.23	-0.0055	1.67
Frobisher	1	1079	50-yr	17.17	256.51	258.22		258.28	0.002785	1.58	29.22	118.06	0.43	29.41	6.7	-0.0055	1.71
Frobisher	1	1079	100-yr	20.34	256.51	258.27		258.32	0.002584	1.56	34.69	121.33	0.42	28.21	7.19	-0.0055	1.76
																	0
Frobisher	1	1045	Timmins	14.98	256.69	258.13		258.16	0.001712	1.22	32.54	119.26	0.35	17.63	4.56	0.0076	1.44
Frobisher	1	1045	2-yr	5.96	256.69	257.88		257.94	0.002491	1.26	10.24	55.47	0.41	20.38	4.46	0.0076	1.19
Frobisher	1	1045	5-yr	7.75	256.69	257.95		258	0.002399	1.3	14.38	68.07	0.41	20.98	4.92	0.0076	1.26
Frobisher	1	1045	10-yr	11.42	256.69	258.05		258.09	0.002087	1.29	23.17	111.76	0.38	20.07	4.22	0.0076	1.36
Frobisher	1	1045	20-yr	14.59	256.69	258.12		258.15	0.001721	1.22	31.75	118.65	0.35	17.63	4.49	0.0076	1.43
Frobisher	1	1045	50-yr	17.17	256.69	258.16		258.19	0.001682	1.23	36.71	122.47	0.35	17.81	4.92	0.0076	1.47
Frobisher	1	1045	100-yr	20.34	256.69	258.21		258.24	0.001655	1.25	42.33	126.84	0.35	18.16	5.39	0.0076	1.52
																	0
Frobisher	1	990	Timmins	14.98	256.27	258.04		258.07	0.001603	1.18	34.71	119.68	0.3	16.54	4.52	0.0037	1.77
Frobisher	1	990	2-yr	5.96	256.27	257.79		257.82	0.001572	1.04	14.13	58.32	0.29	13.53	3.67	0.0037	1.52
Frobisher	1	990	5-yr	7.75	256.27	257.85		257.88	0.001554	1.07	18.44	68.64	0.29	14.08	4.03	0.0037	1.58
Frobisher	1	990	10-yr	11.42	256.27	257.96		257.99	0.001498	1.1	26.66	84.95	0.29	14.65	4.55	0.0037	1.69
Frobisher	1	990	20-yr	14.59	256.27	258.04		258.06	0.00162	1.19	33.83	118.73	0.31	16.64	4.48	0.0037	1.77
Frobisher	1	990	50-yr	17.17	256.27	258.08		258.1	0.001559	1.19	39.17	124.43	0.3	16.47	4.77	0.0037	1.81
Frobisher	1	990	100-yr	20.34	256.27	258.13		258.15	0.001536	1.2	45.08	130.93	0.3	16.71	5.14	0.0037	1.86

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
																	0
Frobisher	1	948	Timmins	14.98	256.11	257.78	257.78	257.93	0.00755	2.32	13.78	45.8	0.64	67.07	21.17	0.0213	1.67
Frobisher	1	948	2-yr	5.96	256.11	257.35	257.35	257.64	0.015389	2.55	3.25	7.18	0.86	92.07	58.98	0.0213	1.24
Frobisher	1	948	5-yr	7.75	256.11	257.62	257.62	257.75	0.006395	1.96	7.83	30.94	0.58	49.79	15.12	0.0213	1.51
Frobisher	1	948	10-yr	11.42	256.11	257.71	257.71	257.85	0.007148	2.18	10.89	35.72	0.62	60.12	20.25	0.0213	1.6
Frobisher	1	948	20-yr	14.59	256.11	257.78	257.78	257.92	0.007462	2.3	13.51	44.94	0.64	66	20.9	0.0213	1.67
Frobisher	1	948	50-yr	17.17	256.11	257.82	257.82	257.96	0.007727	2.39	15.57	51.17	0.65	70.54	21.94	0.0213	1.71
Frobisher	1	948	100-yr	20.34	256.11	257.87	257.87	258.01	0.007621	2.44	18.46	58.16	0.65	72.25	22.58	0.0213	1.76
																	0
Frobisher	1	926	Timmins	14.98	255.66	257.43	257.43	257.71	0.005315	2.86	10.57	18.19	0.74	50.7	27.56	0.6557	1.77
Frobisher	1	926	2-yr	5.96	255.66	256.81	256.81	257.19	0.010082	2.79	2.5	4.77	0.93	57.27	40.2	0.6557	1.15
Frobisher	1	926	5-yr	7.75	255.66	257.02	257.02	257.39	0.007775	2.82	3.82	8.23	0.85	54.4	30.14	0.6557	1.36
Frobisher	1	926	10-yr	11.42	255.66	257.33	257.33	257.58	0.004714	2.57	8.71	17.98	0.69	41.96	20.48	0.6557	1.67
Frobisher	1	926	20-yr	14.59	255.66	257.42	257.42	257.7	0.005227	2.83	10.4	18.17	0.73	49.57	26.72	0.6557	1.76
Frobisher	1	926	50-yr	17.17	255.66	257.55	257.55	257.78	0.00431	2.71	13.62	35.52	0.67	44.4	15.33	0.6557	1.89
Frobisher	1	926	100-yr	20.34	255.66	257.7	257.64	257.87	0.00319	2.47	19.6	46.14	0.59	35.79	12.57	0.6557	2.04
																	0
Frobisher	1	924	Timmins	14.98	253.92	257.2	255.02	257.25	0.000136	1.06	17.66	15.92	0.19	1.72	0.98	0.0061	3.28
Frobisher	1	924	2-yr	5.96	253.92	256.12	254.52	256.15	0.000065	0.65	9.24	6.74	0.14	0.69	0.53	0.0061	2.2
Frobisher	1	924	5-yr	7.75	253.92	256.42	254.63	256.45	0.000078	0.74	11.23	6.81	0.15	0.87	0.7	0.0061	2.5
Frobisher	1	924	10-yr	11.42	253.92	256.82	254.84	256.86	0.000111	0.93	13.97	6.91	0.18	1.33	1.09	0.0061	2.9
Frobisher	1	924	20-yr	14.59	253.92	257.15	255	257.2	0.000136	1.05	16.91	14.26	0.19	1.7	1.01	0.0061	3.23
Frobisher	1	924	50-yr	17.17	253.92	257.43	255.13	257.49	0.000136	1.1	21.42	15.93	0.19	1.8	1.16	0.0061	3.51
Frobisher	1	924	100-yr	20.34	253.92	257.76	255.27	257.81	0.000118	1.09	36.21	69.72	0.18	1.71	0.53	0.0061	3.84
																	0
Frobisher	1	870		Culvert													0
																	0
Frobisher	1	816	Timmins	17.64	253.26	256.39		256.44	0.001037	1.14	21	22.02	0.22	14.05	8.3	-0.0245	3.13
Frobisher	1	816	2-yr	7.3	253.26	255.87		255.9	0.000722	0.83	11.11	16.72	0.18	7.9	3.89	-0.0245	2.61
Frobisher	1	816	5-yr	9.53	253.26	256.08		256.11	0.000679	0.85	14.67	17.91	0.18	8.12	4.53	-0.0245	2.82
Frobisher	1	816	10-yr	13.49	253.26	256.24		256.28	0.000896	1.02	17.77	20.22	0.2	11.45	6.53	-0.0245	2.98
Frobisher	1	816	20-yr	16.9	253.26	256.37		256.41	0.001023	1.13	20.37	21.69	0.22	13.71	8.05	-0.0245	3.11
Frobisher	1	816	50-yr	20.57	253.26	256.49		256.54	0.001111	1.21	23.2	23.24	0.23	15.59	9.38	-0.0245	3.23
Frobisher	1	816	100-yr	24	253.26	256.59		256.65	0.001206	1.29	25.77	30.01	0.24	17.53	9.03	-0.0245	3.33
																	0
Frobisher	1	798	Timmins	17.64	253.7	256.32		256.41	0.002077	1.53	17.26	19.21	0.35	25.86	16.53	0.0003	2.62
Frobisher	1	798	2-yr	7.3	253.7	255.81		255.87	0.001979	1.21	8.31	15.71	0.33	18.13	9.15	0.0003	2.11
Frobisher	1	798	5-yr	9.53	253.7	256.03	255.25	256.08	0.001501	1.16	11.96	17.3	0.29	15.88	9.13	0.0003	2.33
Frobisher	1	798	10-yr	13.49	253.7	256.18		256.25	0.001852	1.37	14.61	18.31	0.33	21.37	13.05	0.0003	2.48
Frobisher	1	798	20-yr	16.9	253.7	256.29		256.38	0.002064	1.51	16.73	19.04	0.35	25.33	16.06	0.0003	2.59
Frobisher	1	798	50-yr	20.57	253.7	256.41		256.51	0.002202	1.62	19	19.76	0.36	28.68	18.79	0.0003	2.71
Frobisher	1	798	100-yr	24	253.7	256.5		256.61	0.002344	1.72	20.86	20.53	0.38	31.92	21.17	0.0003	2.8
																	0
Frobisher	1	738	Timmins	17.64	253.68	255.85	255.85	256.13	0.008545	2.58	9.91	18.95	0.68	80.88	39.75	0.0006	2.17
Frobisher	1	738	2-yr	7.3	253.68	255.03	255.03	255.48	0.021724	2.96	2.47	2.81	1.01	125.53	125.53	0.0006	1.35
Frobisher	1	738	5-yr	9.53	253.68	255.23	255.23	255.73	0.021025	3.12	3.05	3.1	1	134.65	134.65	0.0006	1.55
Frobisher	1	738	10-yr	13.49	253.68	255.74	255.74	255.99	0.008205	2.39	7.77	17.86	0.65	71.57	31.62	0.0006	2.06
Frobisher	1	738	20-yr	16.9	253.68	255.84	255.84	256.1	0.008215	2.52	9.7	18.85	0.66	77.17	37.59	0.0006	2.16
Frobisher	1	738	50-yr	20.57	253.68	255.92	255.92	256.21	0.008951	2.72	11.14	19.55	0.7	88.4	45.5	0.0006	2.24
Frobisher	1	738	100-yr	24	253.68	255.99	255.99	256.3	0.009204	2.84	12.58	20.2	0.71	95.16	51.23	0.0006	2.31
																	0
Frobisher	1	687	Timmins	17.64	253.65	255.67		255.72	0.000801	1.11	20.62	18.36	0.27	12.63	8.5	0.0005	2.02
Frobisher	1	687	2-yr	7.3	253.65	255.08		255.11	0.000829	0.85	10.67	15.3	0.26	8.51	5.5	0.0005	1.43
Frobisher	1	687	5-yr	9.53	253.65	255.22		255.26	0.000847	0.93	12.88	16.01	0.27	9.82	6.47	0.0005	1.57
Frobisher	1	687	10-yr	13.49	253.65	255.46		255.5	0.000821	1.03	16.8	17.24	0.27	11.32	7.58	0.0005	1.81
Frobisher	1	687	20-yr	16.9	253.65	255.64		255.69	0.000801	1.1	19.98	18.19	0.27	12.38	8.32	0.0005	1.99
Frobisher	1	687	50-yr	20.57	253.65	255.79		255.84	0.000827	1.18	22.8	18.99	0.28	13.95	9.38	0.0005	2.14
Frobisher	1	687	100-yr	24	253.65	255.86		255.93	0.000952	1.3	24.25	19.42	0.3	16.72	11.22	0.0005	2.21
																	0
Frobisher	1	645	Timmins	17.64	253.63	255.56		255.67	0.002004	1.57	16.72	17.35	0.42	26.77	18.29	0.0003	1.93
Frobisher	1	645	2-yr	7.3	253.63	254.98		255.05	0.002491	1.24	7.81	13.33	0.43	19.86	13.84	0.0003	1.35
Frobisher	1	645	5-yr	9.53	253.63	255.12		255.2	0.002446	1.36	9.67	14.2	0.43	22.54	15.78	0.0003	1.49
Frobisher	1	645	10-yr	13.49	253.63	255.35		255.44	0.002178	1.47	13.19	15.72	0.42	24.79	17.29	0.0003	1.72
Frobisher	1	645	20-yr	16.9	253.63	255.53		255.63	0.002021	1.55	16.13	17.07	0.42	26.35	18.08	0.0003	1.9
Frobisher	1	645	50-yr	20.57	253.63	255.68		255.79	0.002031	1.66	18.7	18.42	0.42	29.2	19.54	0.0003	2.05
Frobisher	1	645	100-yr	24	253.63	255.73		255.86	0.002434	1.86	19.64	19.01	0.47	36.12	23.83	0.0003	2.1
																	0
Frobisher	1	615	Timmins	17.64	253.62	255.45	254.98	255.59	0.002562	1.78	12.12	12.76	0.47	34.26	22.76	0	1.83
Frobisher	1	615	2-yr	7.3	253.62	254.88	254.52	254.97	0.002828	1.34	5.87	9.25	0.46	22.96	16.81	0	1.26
Frobisher	1	615	5-yr	9.53	253.62	255	254.65	255.11	0.003002	1.51	7.05	10.04	0.48	27.76	19.73	0	1.38
Frobisher	1	615	10-yr	13.49	253.62	255.24	254.82	255.36	0.002744	1.66	9.56	11.42	0.48	31.31	21.47	0	1.62
Frobisher	1	615	20-yr	16.9	253.62	255.41	254.95	255.56	0.002573	1.75	11.7	12.55	0.47	33.61	22.43	0	1.79

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
Frobisher	1	615	50-yr	20.57	253.62	255.54	255.08	255.71	0.002706	1.91	13.39	13.39	0.49	38.62	25.32	0	1.92
Frobisher	1	615	100-yr	24	253.62	255.53	255.18	255.76	0.003803	2.25	13.23	13.31	0.58	53.85	35.35	0	1.91
																	0
Frobisher	1	593		Bridge													0
																	0
Frobisher	1	591	Timmins	17.64	253.59	254.97	254.97	255.42	0.012499	2.98	6.17	8.16	0.96	110.67	86.29	0.0057	1.38
Frobisher	1	591	2-yr	7.3	253.59	254.72	254.49	254.86	0.005931	1.68	4.34	6.32	0.63	38.89	37.02	0.0057	1.13
Frobisher	1	591	5-yr	9.53	253.59	254.74		254.97	0.009149	2.13	4.48	6.46	0.79	61.81	57.68	0.0057	1.15
Frobisher	1	591	10-yr	13.49	253.59	254.82	254.8	255.2	0.013071	2.72	5.01	7	0.96	97.67	85.16	0.0057	1.23
Frobisher	1	591	20-yr	16.9	253.59	254.94	254.94	255.38	0.012679	2.95	5.95	7.94	0.97	109.07	86.65	0.0057	1.35
Frobisher	1	591	50-yr	20.57	253.59	255.18	255.18	255.56	0.008512	2.79	8.78	21.08	0.82	91.08	33.72	0.0057	1.59
Frobisher	1	591	100-yr	24	253.59	255.3	255.3	255.67	0.007507	2.81	11.59	22.67	0.78	89.02	36.51	0.0057	1.71
																	0
Frobisher	1	576	Timmins	17.64	253.5	254.84	254.84	255.07	0.008107	2.39	11.11	24.23	0.78	71.04	35.71	0.111	1.34
Frobisher	1	576	2-yr	7.3	253.5	254.39	254.39	254.68	0.016153	2.38	3.07	5.42	1.01	83.85	83.85	0.111	0.89
Frobisher	1	576	5-yr	9.53	253.5	254.62	254.62	254.82	0.008278	2.03	5.99	22.08	0.75	55.85	21.58	0.111	1.12
Frobisher	1	576	10-yr	13.49	253.5	254.74	254.74	254.96	0.008042	2.21	8.76	23.32	0.76	63.22	29.03	0.111	1.24
Frobisher	1	576	20-yr	16.9	253.5	254.83	254.83	255.05	0.008065	2.35	10.73	24.08	0.77	69.51	34.51	0.111	1.33
Frobisher	1	576	50-yr	20.57	253.5	254.9	254.9	255.15	0.008307	2.51	12.51	24.68	0.8	77.15	40.44	0.111	1.4
Frobisher	1	576	100-yr	24	253.5	254.96	254.96	255.23	0.008636	2.66	13.96	25.06	0.82	84.79	46.18	0.111	1.46
																	0
Frobisher	1	549	Timmins	17.64	250.5	254.72		254.72	0.000004	0.13	138.31	34.75	0.02	0.13	0.13	0	4.22
Frobisher	1	549	2-yr	7.3	250.5	254.23		254.23	0.000001	0.06	122.14	32.93	0.01	0.03	0.03	0	3.73
Frobisher	1	549	5-yr	9.53	250.5	254.36		254.36	0.000002	0.08	126.31	32.94	0.01	0.05	0.05	0	3.86
Frobisher	1	549	10-yr	13.49	250.5	254.55		254.55	0.000003	0.1	132.49	32.96	0.02	0.08	0.08	0	4.05
Frobisher	1	549	20-yr	16.9	250.5	254.69		254.69	0.000004	0.12	137.3	34.63	0.02	0.12	0.12	0	4.19
Frobisher	1	549	50-yr	20.57	250.5	254.83		254.83	0.000005	0.15	142.08	35.17	0.02	0.17	0.16	0	4.33
Frobisher	1	549	100-yr	24	250.5	254.85		254.85	0.000007	0.17	142.93	35.26	0.03	0.22	0.21	0	4.35
																	0
Frobisher	1	530	Timmins	17.64	250.5	254.72		254.72	0.000003	0.11	164.79	47.05	0.02	0.09	0.08	-0.1217	4.22
Frobisher	1	530	2-yr	7.3	250.5	254.23		254.23	0.000001	0.05	143.93	39.59	0.01	0.02	0.02	-0.1217	3.73
Frobisher	1	530	5-yr	9.53	250.5	254.36		254.36	0.000001	0.06	148.95	40.48	0.01	0.03	0.03	-0.1217	3.86
Frobisher	1	530	10-yr	13.49	250.5	254.55		254.55	0.000002	0.09	156.95	44.2	0.01	0.06	0.05	-0.1217	4.05
Frobisher	1	530	20-yr	16.9	250.5	254.69		254.69	0.000002	0.1	163.42	46.71	0.02	0.09	0.07	-0.1217	4.19
Frobisher	1	530	50-yr	20.57	250.5	254.83		254.83	0.000003	0.12	169.93	48.19	0.02	0.12	0.1	-0.1217	4.33
Frobisher	1	530	100-yr	24	250.5	254.85		254.85	0.000004	0.14	171.09	48.43	0.02	0.16	0.13	-0.1217	4.35
																	0
Frobisher	1	506	Timmins	17.64	253.5	254.35	254.35	254.69	0.013396	2.59	7.08	11.88	0.98	90.93	75.72	0.3651	0.85
Frobisher	1	506	2-yr	7.3	253.5	253.99	253.99	254.21	0.016798	2.08	3.5	8	1	69.5	69.5	0.3651	0.49
Frobisher	1	506	5-yr	9.53	253.5	254.09	254.09	254.34	0.016176	2.18	4.36	9.25	1	73.9	72.22	0.3651	0.59
Frobisher	1	506	10-yr	13.49	253.5	254.23	254.23	254.52	0.01466	2.4	5.72	10.72	0.99	82.82	74.11	0.3651	0.73
Frobisher	1	506	20-yr	16.9	253.5	254.33	254.33	254.66	0.013536	2.55	6.84	11.69	0.98	89.36	75.19	0.3651	0.83
Frobisher	1	506	50-yr	20.57	253.5	254.43	254.43	254.79	0.012392	2.68	8.17	15.3	0.96	93.98	63.2	0.3651	0.93
Frobisher	1	506	100-yr	24	253.5	254.66	254.66	254.83	0.005174	2.04	19.73	65.33	0.64	50.28	15.22	0.3651	1.16
																	0
Frobisher	1	504	Timmins	17.64	253	253.83	253.83	254.17	0.012322	2.61	7.3	12.85	0.93	90.42	65.48	0.2738	0.83
Frobisher	1	504	2-yr	7.3	253	253.45	253.45	253.67	0.017231	2.07	3.52	8.07	1	69.52	69.52	0.2738	0.45
Frobisher	1	504	5-yr	9.53	253	253.54	253.54	253.8	0.016589	2.26	4.22	8.19	1.01	78.3	78.3	0.2738	0.54
Frobisher	1	504	10-yr	13.49	253	253.69	253.69	254	0.014002	2.46	5.65	11.02	0.96	85.11	66.77	0.2738	0.69
Frobisher	1	504	20-yr	16.9	253	253.81	253.81	254.14	0.012567	2.59	7.01	12.55	0.94	89.55	65.56	0.2738	0.81
Frobisher	1	504	50-yr	20.57	253	253.91	253.91	254.28	0.011596	2.71	8.45	13.94	0.92	94.17	65.88	0.2738	0.91
Frobisher	1	504	100-yr	24	253	254.01	254.01	254.39	0.010809	2.8	9.84	15.06	0.9	97.25	66.35	0.2738	1.01
																	0
Frobisher	1	503	Timmins	17.64	252.54	253.75		253.8	0.001575	1.25	28.74	85.36	0.37	17.78	5.19	0.1791	1.21
Frobisher	1	503	2-yr	7.3	252.54	253	253	253.17	0.015144	1.92	4.34	13.56	0.96	60.15	47.36	0.1791	0.46
Frobisher	1	503	5-yr	9.53	252.54	253.07	253.07	253.27	0.014441	2.09	5.34	14.51	0.97	67.41	51.88	0.1791	0.53
Frobisher	1	503	10-yr	13.49	252.54	253.29		253.45	0.007347	1.92	8.78	17.21	0.73	49.85	36.56	0.1791	0.75
Frobisher	1	503	20-yr	16.9	252.54	253.49		253.61	0.004237	1.73	13.64	29.26	0.58	37.17	19.24	0.1791	0.95
Frobisher	1	503	50-yr	20.57	252.54	253.49	253.37	253.67	0.006306	2.1	13.6	29.19	0.71	55.25	28.63	0.1791	0.95
Frobisher	1	503	100-yr	24	252.54	253.45	253.45	253.73	0.01009	2.59	12.61	27.33	0.89	84.95	45.39	0.1791	0.91
																	0
Frobisher	1	483	Timmins	17.64	249	253.78		253.78	0.000002	0.1	234.51	116.98	0.02	0.08	0.04	-0.0155	4.78
Frobisher	1	483	2-yr	7.3	249	253.07		253.07	0.000001	0.05	176.46	57.25	0.01	0.02	0.02	-0.0155	4.07
Frobisher	1	483	5-yr	9.53	249	253.17		253.17	0.000001	0.06	182.63	59.22	0.01	0.03	0.03	-0.0155	4.17
Frobisher	1	483	10-yr	13.49	249	253.4		253.4	0.000002	0.09	196.47	65.17	0.01	0.06	0.04	-0.0155	4.4
Frobisher	1	483	20-yr	16.9	249	253.57		253.57	0.000003	0.11	210.92	107.8	0.02	0.09	0.04	-0.0155	4.57
Frobisher	1	483	50-yr	20.57	249	253.61		253.61	0.000004	0.13	215.27	109.52	0.02	0.13	0.06	-0.0155	4.61
Frobisher	1	483	100-yr	24	249	253.64		253.64	0.000005	0.15	218.04	110.63	0.02	0.17	0.08	-0.0155	4.64
																	0
Frobisher	1	451	Timmins	17.64	249.5	253.78		253.78	0.000017	0.25	100.54	127.3	0.04	0.53	0.13	0	4.28
Frobisher	1	451	2-yr	7.3	249.5	253.07		253.07	0.000006	0.14	54.91	20.63	0.02	0.16	0.13	0	3.57
Frobisher	1	451	5-yr	9.53	249.5	253.17		253.17	0.00001	0.17	57.19	22.75	0.03	0.26	0.2	0	3.67

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
Frobisher	1	451	10-yr	13.49	249.5	253.4		253.4	0.000016	0.23	63.08	31.17	0.04	0.44	0.27	0	3.9
Frobisher	1	451	20-yr	16.9	249.5	253.57		253.57	0.000021	0.27	74.33	121.97	0.04	0.61	0.12	0	4.07
Frobisher	1	451	50-yr	20.57	249.5	253.61		253.61	0.00003	0.32	79.05	122.79	0.05	0.87	0.18	0	4.11
Frobisher	1	451	100-yr	24	249.5	253.63		253.64	0.000039	0.37	81.93	123.29	0.06	1.16	0.24	0	4.13
																	0
Frobisher	1	448	Timmins	17.64	249.5	253.78		253.78	0.000016	0.24	102.03	126.17	0.04	0.48	0.12	-0.0992	4.28
Frobisher	1	448	2-yr	7.3	249.5	253.07		253.07	0.000006	0.13	58.03	20.8	0.02	0.14	0.12	-0.0992	3.57
Frobisher	1	448	5-yr	9.53	249.5	253.17		253.17	0.000009	0.16	60.3	22.54	0.03	0.23	0.18	-0.0992	3.67
Frobisher	1	448	10-yr	13.49	249.5	253.4		253.4	0.000014	0.22	65.84	27.19	0.03	0.39	0.28	-0.0992	3.9
Frobisher	1	448	20-yr	16.9	249.5	253.57		253.57	0.000019	0.26	75.98	120.98	0.04	0.55	0.11	-0.0992	4.07
Frobisher	1	448	50-yr	20.57	249.5	253.61		253.61	0.000027	0.31	80.67	122.05	0.05	0.79	0.17	-0.0992	4.11
Frobisher	1	448	100-yr	24	249.5	253.63		253.64	0.000036	0.36	83.56	122.69	0.06	1.05	0.23	-0.0992	4.13
																	0
Frobisher	1	419	Timmins	33.65	252.45	253.46	253.43	253.75	0.01205	3.12	17.71	27.62	1	117.24	75.45	0.0327	1.01
Frobisher	1	419	2-yr	8.25	252.45	252.88	252.88	253.05	0.018895	2.19	5.34	16.31	1.08	77.32	60.43	0.0327	0.43
Frobisher	1	419	5-yr	10.97	252.45	252.96	252.96	253.15	0.017963	2.39	6.6	17.17	1.09	86.77	67.46	0.0327	0.51
Frobisher	1	419	10-yr	17.68	252.45	253.12	253.12	253.37	0.016666	2.77	9.57	20.28	1.1	106.49	76.81	0.0327	0.67
Frobisher	1	419	20-yr	24.25	252.45	253.25	253.25	253.54	0.015482	3.02	12.44	22.83	1.09	119.08	82.33	0.0327	0.8
Frobisher	1	419	50-yr	25.85	252.45	253.27	253.27	253.58	0.015777	3.11	12.96	23.3	1.1	124.86	85.66	0.0327	0.82
Frobisher	1	419	100-yr	26.88	252.45	253.29	253.29	253.6	0.015814	3.16	13.34	23.65	1.11	127.66	87.09	0.0327	0.84
																	0
Frobisher	1	367	Timmins	33.65	250.77	253.45		253.52	0.001443	1.72	36.15	34.48	0.36	28.18	14.53	0.0168	2.68
Frobisher	1	367	2-yr	8.25	250.77	252.29		252.37	0.002636	1.45	8.38	14.24	0.44	25.28	14.64	0.0168	1.52
Frobisher	1	367	5-yr	10.97	250.77	252.74		252.78	0.000975	1.1	16.72	22.38	0.28	13.13	6.95	0.0168	1.97
Frobisher	1	367	10-yr	17.68	250.77	253.08		253.12	0.000969	1.25	24.94	27.15	0.29	15.83	8.52	0.0168	2.31
Frobisher	1	367	20-yr	24.25	250.77	253.26		253.31	0.001152	1.45	30.08	29.91	0.32	20.62	11.11	0.0168	2.49
Frobisher	1	367	50-yr	25.85	250.77	253.3		253.35	0.001195	1.49	31.2	30.51	0.33	21.76	11.72	0.0168	2.53
Frobisher	1	367	100-yr	26.88	250.77	253.31		253.37	0.001242	1.53	31.72	30.88	0.33	22.79	12.23	0.0168	2.54
																	0
Frobisher	1	328	Timmins	33.65	250.1	253.42		253.47	0.000815	1.54	45.2	38.29	0.29	20.83	9.18	0.0103	3.32
Frobisher	1	328	2-yr	8.25	250.1	252.29		252.31	0.000518	0.89	14.85	15.35	0.21	8.17	4.66	0.0103	2.19
Frobisher	1	328	5-yr	10.97	250.1	252.73		252.75	0.000352	0.85	23.5	23.26	0.18	6.91	3.36	0.0103	2.63
Frobisher	1	328	10-yr	17.68	250.1	253.06		253.09	0.000499	1.11	32.37	33.23	0.22	11.21	4.63	0.0103	2.96
Frobisher	1	328	20-yr	24.25	250.1	253.23		253.28	0.000629	1.3	38.39	35.76	0.25	15.06	6.44	0.0103	3.13
Frobisher	1	328	50-yr	25.85	250.1	253.27		253.31	0.000659	1.34	39.69	36.24	0.26	15.99	6.88	0.0103	3.17
Frobisher	1	328	100-yr	26.88	250.1	253.28		253.33	0.000687	1.38	40.27	36.44	0.26	16.78	7.25	0.0103	3.18
																	0
Frobisher	1	299	Timmins	33.65	249.8	253.4		253.45	0.000613	1.38	45.02	33.54	0.25	16.36	7.6	-0.0023	3.6
Frobisher	1	299	2-yr	8.25	249.8	252.27		252.3	0.00048	0.91	15.16	16.83	0.2	8.23	4.01	-0.0023	2.47
Frobisher	1	299	5-yr	10.97	249.8	252.73		252.74	0.000274	0.79	24.79	25.6	0.16	5.75	2.5	-0.0023	2.93
Frobisher	1	299	10-yr	17.68	249.8	253.05		253.08	0.000341	0.95	34.02	29.33	0.18	8.09	3.71	-0.0023	3.25
Frobisher	1	299	20-yr	24.25	249.8	253.22		253.26	0.00045	1.14	39.1	31.36	0.21	11.33	5.25	-0.0023	3.42
Frobisher	1	299	50-yr	25.85	249.8	253.26		253.29	0.000476	1.18	40.24	32.74	0.22	12.14	5.48	-0.0023	3.46
Frobisher	1	299	100-yr	26.88	249.8	253.27		253.31	0.0005	1.21	40.75	32.82	0.22	12.79	5.79	-0.0023	3.47
																	0
Frobisher	1	286	Timmins	33.65	249.83	253.38	252.37	253.44	0.000994	1.37	39.61	33.8	0.24	18.22	10.36	-0.0114	3.55
Frobisher	1	286	2-yr	8.25	249.83	252.25	250.79	252.29	0.000776	0.91	11.62	14.47	0.2	9.25	5.09	-0.0114	2.42
Frobisher	1	286	5-yr	10.97	249.83	252.71	250.98	252.74	0.00048	0.81	19.84	23.2	0.16	6.97	3.56	-0.0114	2.88
Frobisher	1	286	10-yr	17.68	249.83	253.04	251.39	253.07	0.000603	0.99	28.56	30.39	0.19	9.87	5.05	-0.0114	3.21
Frobisher	1	286	20-yr	24.25	249.83	253.21	251.73	253.25	0.000764	1.15	33.81	31.81	0.21	13.24	7.22	-0.0114	3.38
Frobisher	1	286	50-yr	25.85	249.83	253.24	252.08	253.29	0.000802	1.19	34.92	32.18	0.22	14.05	7.74	-0.0114	3.41
Frobisher	1	286	100-yr	26.88	249.83	253.26	252.13	253.3	0.000838	1.22	35.4	32.35	0.22	14.76	8.16	-0.0114	3.43
																	0
Frobisher	1	270		Culvert													0
																	0
Frobisher	1	249	Timmins	33.65	250.28	252.67		252.87	0.003462	2.7	21.85	16.41	0.57	68.93	42.65	0	2.39
Frobisher	1	249	2-yr	8.25	250.28	251.71		251.77	0.001922	1.4	9.16	10.59	0.39	22.25	15.35	0	1.43
Frobisher	1	249	5-yr	10.97	250.28	251.9		251.98	0.00195	1.54	11.32	11.61	0.4	25.86	17.54	0	1.62
Frobisher	1	249	10-yr	17.68	250.28	252.22		252.33	0.002317	1.91	15.31	13.34	0.45	37.16	24.53	0	1.94
Frobisher	1	249	20-yr	24.25	250.28	252.45		252.59	0.002664	2.21	18.51	14.53	0.49	48.03	31.27	0	2.17
Frobisher	1	249	50-yr	25.85	250.28	252.49		252.64	0.002786	2.29	19.13	14.82	0.5	51.24	33.16	0	2.21
Frobisher	1	249	100-yr	26.88	250.28	252.52		252.67	0.002865	2.35	19.52	15.01	0.51	53.35	34.36	0	2.24
																	0
Frobisher	1	238	Timmins	33.65	250.28	252.51		252.8	0.006272	3.34	18.07	17.92	0.72	110.1	58.83	0.0083	2.23
Frobisher	1	238	2-yr	8.25	250.28	251.62		251.73	0.003924	1.87	6.97	9	0.52	40.98	27.48	0.0083	1.34
Frobisher	1	238	5-yr	10.97	250.28	251.81		251.94	0.003827	2.02	8.8	10.05	0.53	45.83	30.36	0.0083	1.53
Frobisher	1	238	10-yr	17.68	250.28	252.09		252.28	0.004921	2.56	11.82	12.18	0.61	69.73	43.64	0.0083	1.81
Frobisher	1	238	20-yr	24.25	250.28	252.29		252.53	0.005692	2.96	14.47	14.4	0.67	89.75	52.69	0.0083	2.01
Frobisher	1	238	50-yr	25.85	250.28	252.33		252.58	0.005802	3.03	15.09	14.95	0.68	93.42	54	0.0083	2.05
Frobisher	1	238	100-yr	26.88	250.28	252.36		252.61	0.00587	3.07	15.48	15.31	0.69	95.74	54.79	0.0083	2.08
																	0
Frobisher	1	201	Timmins	33.65	249.97	252.43		252.55	0.00327	2.22	26.78	27.59	0.46	50.82	29.71	0.0063	2.46

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
Frobisher	1	201	2-yr	8.25	249.97	251.55		251.6	0.002061	1.3	10.32	13.4	0.34	20.32	14.31	0.0063	1.58
Frobisher	1	201	5-yr	10.97	249.97	251.75		251.8	0.001937	1.37	13.19	14.99	0.33	21.61	15.46	0.0063	1.78
Frobisher	1	201	10-yr	17.68	249.97	252.02		252.09	0.002549	1.73	17.56	18.2	0.39	32.77	22.55	0.0063	2.05
Frobisher	1	201	20-yr	24.25	249.97	252.21		252.31	0.002913	1.97	21.42	21.27	0.42	41.13	27.11	0.0063	2.24
Frobisher	1	201	50-yr	25.85	249.97	252.25		252.35	0.002978	2.01	22.33	22.37	0.43	42.84	27.54	0.0063	2.28
Frobisher	1	201	100-yr	26.88	249.97	252.28		252.38	0.00302	2.04	22.91	23.06	0.43	43.94	27.85	0.0063	2.31
																	0
Frobisher	1	165	Timmins	33.65	249.74	252.34		252.43	0.002963	1.98	28.61	30.18	0.4	41.68	26.08	0.0067	2.6
Frobisher	1	165	2-yr	8.25	249.74	251.46		251.51	0.002537	1.38	9.5	12.77	0.34	23.31	16.48	0.0067	1.72
Frobisher	1	165	5-yr	10.97	249.74	251.66		251.72	0.002356	1.44	12.49	16.27	0.34	24.38	16.16	0.0067	1.92
Frobisher	1	165	10-yr	17.68	249.74	251.91		251.99	0.002987	1.76	17.14	21.68	0.39	34.95	21.56	0.0067	2.17
Frobisher	1	165	20-yr	24.25	249.74	252.11		252.2	0.003012	1.87	22.09	27.5	0.39	38.6	22.39	0.0067	2.37
Frobisher	1	165	50-yr	25.85	249.74	252.15		252.24	0.002996	1.89	23.27	28.05	0.39	39.09	23.02	0.0067	2.41
Frobisher	1	165	100-yr	26.88	249.74	252.18		252.27	0.002987	1.9	24.02	28.39	0.39	39.42	23.42	0.0067	2.44
																	0
Frobisher	1	126	Timmins	33.65	249.48	252.21		252.31	0.003359	1.96	26.9	31.89	0.38	42.31	26.01	0.0063	2.73
Frobisher	1	126	2-yr	8.25	249.48	251.35		251.41	0.002705	1.35	9.27	12.65	0.32	23.09	16.7	0.0063	1.87
Frobisher	1	126	5-yr	10.97	249.48	251.58		251.63	0.002253	1.34	12.49	16.04	0.3	21.65	15.21	0.0063	2.1
Frobisher	1	126	10-yr	17.68	249.48	251.8		251.88	0.002909	1.63	16.52	20.43	0.35	31	20.89	0.0063	2.32
Frobisher	1	126	20-yr	24.25	249.48	251.99		252.08	0.003132	1.79	20.85	24.77	0.37	36.24	23.8	0.0063	2.51
Frobisher	1	126	50-yr	25.85	249.48	252.03		252.12	0.00318	1.82	21.87	25.81	0.37	37.39	24.39	0.0063	2.55
Frobisher	1	126	100-yr	26.88	249.48	252.06		252.15	0.003207	1.84	22.53	26.47	0.37	38.1	24.75	0.0063	2.58
																	0
Frobisher	1	98	Timmins	33.65	249.3	251.81	251.77	252.12	0.012074	3.26	15.98	20.65	0.67	125.38	81.76	0.0068	2.51
Frobisher	1	98	2-yr	8.25	249.3	251.19		251.3	0.005068	1.73	6.89	10.29	0.41	39.12	27.01	0.0068	1.89
Frobisher	1	98	5-yr	10.97	249.3	251.45		251.54	0.004145	1.71	9.85	13.31	0.38	36.51	25.43	0.0068	2.15
Frobisher	1	98	10-yr	17.68	249.3	251.53		251.73	0.0085	2.52	10.97	14.39	0.55	77.83	54.32	0.0068	2.23
Frobisher	1	98	20-yr	24.25	249.3	251.67		251.92	0.01006	2.86	13.16	17.42	0.6	98.14	65.29	0.0068	2.37
Frobisher	1	98	50-yr	25.85	249.3	251.7		251.95	0.010415	2.93	13.66	18.15	0.62	102.86	67.68	0.0068	2.4
Frobisher	1	98	100-yr	26.88	249.3	251.71		251.98	0.010636	2.98	13.99	18.59	0.62	105.84	69.25	0.0068	2.41
																	0
Frobisher	1	65	Timmins	33.65	249.08	251.77		251.85	0.003758	1.78	31.04	51.68	0.35	37.88	20.98	0.0065	2.69
Frobisher	1	65	2-yr	8.25	249.08	251.14		251.18	0.002314	1.16	11.43	18.45	0.26	17.58	12.22	0.0065	2.06
Frobisher	1	65	5-yr	10.97	249.08	251.42		251.45	0.001522	1.03	17.33	23.81	0.22	13.23	9.72	0.0065	2.34
Frobisher	1	65	10-yr	17.68	249.08	251.46		251.53	0.00335	1.55	18.38	24.96	0.33	29.69	21.74	0.0065	2.38
Frobisher	1	65	20-yr	24.25	249.08	251.6		251.68	0.003732	1.7	23.01	40.18	0.35	35.12	19.58	0.0065	2.52
Frobisher	1	65	50-yr	25.85	249.08	251.63		251.71	0.003782	1.72	24.27	42.47	0.35	36.03	19.87	0.0065	2.55
Frobisher	1	65	100-yr	26.88	249.08	251.65		251.73	0.003804	1.74	25.11	44.29	0.35	36.53	19.88	0.0065	2.57
																	0
Frobisher	1	33	Timmins	33.65	248.87	251.35	251.35	251.62	0.013614	3.01	16.37	24.51	0.62	114.32	77.84	0.0064	2.48
Frobisher	1	33	2-yr	8.25	248.87	251.02	250.29	251.08	0.003516	1.38	8.78	17.78	0.31	25.34	14.47	0.0064	2.15
Frobisher	1	33	5-yr	10.97	248.87	251.37	250.87	251.4	0.001317	0.94	16.92	24.51	0.19	11.16	7.77	0.0064	2.5
Frobisher	1	33	10-yr	17.68	248.87	251.08	251.08	251.32	0.012855	2.69	9.9	20.21	0.59	95.33	53.42	0.0064	2.21
Frobisher	1	33	20-yr	24.25	248.87	251.24	251.24	251.46	0.011872	2.72	13.54	24.51	0.58	94.83	56.61	0.0064	2.37
Frobisher	1	33	50-yr	25.85	248.87	251.26	251.26	251.49	0.012017	2.75	14.14	24.51	0.58	97.03	59.74	0.0064	2.39
Frobisher	1	33	100-yr	26.88	248.87	251.27	251.27	251.51	0.012169	2.78	14.49	24.51	0.59	98.87	61.92	0.0064	2.4
																	0
Frobisher	1	7	Timmins	33.65	248.7	250.98	250.98	251.16	0.013725	2.7	20.74	45.45	0.59	97.57	57		2.28
Frobisher	1	7	2-yr	8.25	248.7	250.13	250.13	250.8	0.038643	3.64	2.27	1.69	1	197.4	197.4		1.43
Frobisher	1	7	5-yr	10.97	248.7	250.41	250.41	251.22	0.042173	3.98	2.75	1.72	1.01	231.25	231.25		1.71
Frobisher	1	7	10-yr	17.68	248.7	250.83	250.83	250.96	0.010252	2.22	14.13	41.58	0.5	67.75	31.55		2.13
Frobisher	1	7	20-yr	24.25	248.7	250.9	250.9	251.05	0.011661	2.43	17.25	43.69	0.54	79.89	41.85		2.2
Frobisher	1	7	50-yr	25.85	248.7	250.91	250.91	251.07	0.012472	2.52	17.66	43.99	0.56	85.83	45.53		2.21
Frobisher	1	7	100-yr	26.88	248.7	250.91	250.91	251.09	0.013769	2.64	17.52	43.89	0.59	94.61	49.97		2.21
																	0
Eugene	1	1715	Timmins	2.24	266.73	268.34		268.37	0.002609	0.89	3.31	8.28	0.26	12.19	8.09	0.0109	1.61
Eugene	1	1715	2-yr	0.26	266.73	267.29		267.3	0.00305	0.61	0.43	0.94	0.29	7.25	7.25	0.0109	0.56
Eugene	1	1715	5-yr	0.42	266.73	267.44		267.47	0.003459	0.72	0.58	1.04	0.3	9.46	9.46	0.0109	0.71
Eugene	1	1715	10-yr	0.54	266.73	267.55		267.58	0.00372	0.78	0.69	1.1	0.31	10.95	10.95	0.0109	0.82
Eugene	1	1715	20-yr	0.65	266.73	267.62		267.66	0.00392	0.83	0.78	1.14	0.32	12.13	12.13	0.0109	0.89
Eugene	1	1715	50-yr	0.79	266.73	267.72		267.76	0.004169	0.89	0.89	1.2	0.33	13.65	13.65	0.0109	0.99
Eugene	1	1715	100-yr	1.01	266.73	267.85		267.89	0.004494	0.96	1.05	1.28	0.34	15.75	15.75	0.0109	1.12
																	0
Eugene	1	1701	Timmins	2.24	266.58	268.06	267.85	268.27	0.023176	2.06	1.13	2.81	0.71	74	52.99	0.0107	1.48
Eugene	1	1701	2-yr	0.26	266.58	267.13	267.02	267.21	0.022591	1.24	0.21	0.59	0.66	34.42	34.42	0.0107	0.55
Eugene	1	1701	5-yr	0.42	266.58	267.26	267.14	267.36	0.025034	1.44	0.29	0.68	0.7	43.93	43.93	0.0107	0.68
Eugene	1	1701	10-yr	0.54	266.58	267.34	267.22	267.46	0.025834	1.54	0.35	0.75	0.72	49.18	49.18	0.0107	0.76
Eugene	1	1701	20-yr	0.65	266.58	267.4	267.28	267.54	0.026187	1.61	0.4	0.79	0.72	52.84	52.84	0.0107	0.82
Eugene	1	1701	50-yr	0.79	266.58	267.49	267.35	267.63	0.026357	1.69	0.47	0.85	0.73	56.97	56.97	0.0107	0.91
Eugene	1	1701	100-yr	1.01	266.58	267.59	267.45	267.76	0.026233	1.79	0.57	0.94	0.73	61.76	61.76	0.0107	1.01
																	0
Eugene	1	1678	Timmins	2.24	266.33	267.64		267.81	0.016072	1.86	1.2	1.28	0.61	57.91	57.91	0.0113	1.31

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
Eugene	1	1678	2-yr	0.26	266.33	266.67		266.74	0.017787	1.19	0.22	0.75	0.7	30.45	30.45	0.0113	0.34
Eugene	1	1678	5-yr	0.42	266.33	266.79		266.88	0.016981	1.31	0.32	0.82	0.67	34.88	34.88	0.0113	0.46
Eugene	1	1678	10-yr	0.54	266.33	266.88		266.98	0.016645	1.38	0.39	0.86	0.66	37.52	37.52	0.0113	0.55
Eugene	1	1678	20-yr	0.65	266.33	266.95		267.05	0.016457	1.43	0.45	0.9	0.65	39.48	39.48	0.0113	0.62
Eugene	1	1678	50-yr	0.79	266.33	267.03		267.15	0.016289	1.49	0.53	0.95	0.64	41.91	41.91	0.0113	0.7
Eugene	1	1678	100-yr	1.01	266.33	267.15		267.27	0.016124	1.57	0.64	1.01	0.63	45.03	45.03	0.0113	0.82
																	0
Eugene	1	1653	Timmins	2.24	266.05	267.33	266.93	267.47	0.011557	1.66	1.35	1.36	0.53	45.19	45.19	0.0106	1.28
Eugene	1	1653	2-yr	0.26	266.05	266.42	266.28	266.46	0.007411	0.85	0.31	0.92	0.47	14.85	14.85	0.0106	0.37
Eugene	1	1653	5-yr	0.42	266.05	266.54	266.36	266.59	0.007994	0.99	0.42	0.98	0.48	18.92	18.92	0.0106	0.49
Eugene	1	1653	10-yr	0.54	266.05	266.62	266.41	266.68	0.008375	1.07	0.5	1.02	0.49	21.57	21.57	0.0106	0.57
Eugene	1	1653	20-yr	0.65	266.05	266.69	266.46	266.75	0.008664	1.13	0.57	1.05	0.49	23.62	23.62	0.0106	0.64
Eugene	1	1653	50-yr	0.79	266.05	266.77	266.51	266.84	0.009042	1.21	0.66	1.09	0.5	26.25	26.25	0.0106	0.72
Eugene	1	1653	100-yr	1.01	266.05	266.88	266.59	266.96	0.009455	1.3	0.78	1.14	0.5	29.58	29.58	0.0106	0.83
																	0
Eugene	1	1633	Timmins	2.24	265.84	266.75	266.73	267.08	0.034254	2.56	0.88	1.21	0.96	113.07	113.07	0.0111	0.91
Eugene	1	1633	2-yr	0.26	265.84	266.07	266.07	266.18	0.032109	1.45	0.18	0.84	1	47.61	47.61	0.0111	0.23
Eugene	1	1633	5-yr	0.42	265.84	266.15	266.15	266.3	0.032997	1.68	0.25	0.88	1.01	59.43	59.43	0.0111	0.31
Eugene	1	1633	10-yr	0.54	265.84	266.21	266.21	266.38	0.033459	1.81	0.3	0.91	1.01	66.63	66.63	0.0111	0.37
Eugene	1	1633	20-yr	0.65	265.84	266.25	266.25	266.44	0.033833	1.9	0.34	0.94	1.01	72.05	72.05	0.0111	0.41
Eugene	1	1633	50-yr	0.79	265.84	266.31	266.31	266.52	0.034071	2	0.4	0.97	1	78.29	78.29	0.0111	0.47
Eugene	1	1633	100-yr	1.01	265.84	266.39	266.39	266.62	0.034981	2.15	0.47	1.01	1.01	87.54	87.54	0.0111	0.55
																	0
Eugene	1	1612	Timmins	2.24	265.6	266.77	266.22	266.83	0.003398	1.1	2.04	2.17	0.36	17.79	17.79	0.0058	1.17
Eugene	1	1612	2-yr	0.26	265.6	265.98	265.76	265.99	0.001628	0.47	0.56	1.6	0.25	4.16	4.16	0.0058	0.38
Eugene	1	1612	5-yr	0.42	265.6	266.08	265.81	266.1	0.001995	0.58	0.72	1.67	0.28	6	6	0.0058	0.48
Eugene	1	1612	10-yr	0.54	265.6	266.15	265.85	266.17	0.002219	0.65	0.83	1.72	0.3	7.28	7.28	0.0058	0.55
Eugene	1	1612	20-yr	0.65	265.6	266.2	265.88	266.23	0.002382	0.7	0.92	1.76	0.31	8.29	8.29	0.0058	0.6
Eugene	1	1612	50-yr	0.79	265.6	266.27	265.92	266.3	0.002575	0.76	1.04	1.8	0.32	9.58	9.58	0.0058	0.67
Eugene	1	1612	100-yr	1.01	265.6	266.36	265.98	266.39	0.002808	0.84	1.21	1.87	0.33	11.31	11.31	0.0058	0.76
																	0
Eugene	1	1409		Culvert													0
																	0
Eugene	1	1198	Timmins	2.24	263.2	263.84	263.84	264.12	0.015644	2.35	0.95	1.71	1.01	55.54	55.54	0.0042	0.64
Eugene	1	1198	2-yr	0.26	263.2	263.37	263.36	263.44	0.014005	1.16	0.22	1.4	0.93	18.81	18.81	0.0042	0.17
Eugene	1	1198	5-yr	0.42	263.2	263.42	263.42	263.52	0.015015	1.4	0.3	1.43	0.98	25.17	25.17	0.0042	0.22
Eugene	1	1198	10-yr	0.54	263.2	263.46	263.46	263.58	0.015211	1.53	0.35	1.46	0.99	28.83	28.83	0.0042	0.26
Eugene	1	1198	20-yr	0.65	263.2	263.49	263.49	263.62	0.014997	1.61	0.4	1.48	0.99	31.07	31.07	0.0042	0.29
Eugene	1	1198	50-yr	0.79	263.2	263.53	263.53	263.68	0.015361	1.73	0.46	1.5	1	34.83	34.83	0.0042	0.33
Eugene	1	1198	100-yr	1.01	263.2	263.58	263.58	263.76	0.015374	1.86	0.54	1.54	1	39	39	0.0042	0.38
																	0
Eugene	1	1186	Timmins	2.24	263.15	263.88		263.92	0.001223	0.86	2.62	4	0.34	6.45	6.45	0.0011	0.73
Eugene	1	1186	2-yr	0.26	263.15	263.37		263.38	0.000822	0.36	0.73	3.4	0.25	1.6	1.6	0.0011	0.22
Eugene	1	1186	5-yr	0.42	263.15	263.44		263.45	0.000915	0.44	0.95	3.48	0.27	2.23	2.23	0.0011	0.29
Eugene	1	1186	10-yr	0.54	263.15	263.48		263.49	0.000943	0.49	1.11	3.53	0.28	2.61	2.61	0.0011	0.33
Eugene	1	1186	20-yr	0.65	263.15	263.52		263.53	0.000972	0.53	1.23	3.57	0.29	2.93	2.93	0.0011	0.37
Eugene	1	1186	50-yr	0.79	263.15	263.56		263.58	0.001008	0.57	1.39	3.62	0.29	3.34	3.34	0.0011	0.41
Eugene	1	1186	100-yr	1.01	263.15	263.62		263.64	0.001059	0.63	1.61	3.69	0.31	3.93	3.93	0.0011	0.47
																	0
Eugene	1	1139	Timmins	2.24	263.1	263.76		263.83	0.002674	1.16	1.93	3.42	0.49	12.34	12.34	0.0015	0.66
Eugene	1	1139	2-yr	0.26	263.1	263.32		263.33	0.001487	0.47	0.56	2.76	0.33	2.74	2.74	0.0015	0.22
Eugene	1	1139	5-yr	0.42	263.1	263.37		263.38	0.001917	0.6	0.7	2.83	0.39	4.23	4.23	0.0015	0.27
Eugene	1	1139	10-yr	0.54	263.1	263.4		263.43	0.002029	0.67	0.81	2.89	0.4	5.03	5.03	0.0015	0.3
Eugene	1	1139	20-yr	0.65	263.1	263.43		263.46	0.002112	0.72	0.9	2.94	0.41	5.67	5.67	0.0015	0.33
Eugene	1	1139	50-yr	0.79	263.1	263.47		263.5	0.00221	0.78	1.01	2.99	0.43	6.5	6.5	0.0015	0.37
Eugene	1	1139	100-yr	1.01	263.1	263.53		263.56	0.002351	0.86	1.17	3.07	0.45	7.69	7.69	0.0015	0.43
																	0
Eugene	1	1105	Timmins	2.24	263.05	263.47	263.47	263.65	0.011707	1.91	1.17	3.21	1.01	37.69	37.69	0.0098	0.42
Eugene	1	1105	2-yr	0.26	263.05	263.15	263.15	263.2	0.016058	0.99	0.26	2.63	1	15.28	15.28	0.0098	0.1
Eugene	1	1105	5-yr	0.42	263.05	263.22	263.19	263.27	0.007437	0.92	0.45	2.76	0.73	11.34	11.34	0.0098	0.17
Eugene	1	1105	10-yr	0.54	263.05	263.25	263.22	263.3	0.007723	1.02	0.53	2.81	0.75	13.38	13.38	0.0098	0.2
Eugene	1	1105	20-yr	0.65	263.05	263.27	263.24	263.33	0.007933	1.1	0.59	2.85	0.77	14.99	14.99	0.0098	0.22
Eugene	1	1105	50-yr	0.79	263.05	263.3	263.26	263.37	0.008268	1.2	0.66	2.9	0.8	17.2	17.2	0.0098	0.25
Eugene	1	1105	100-yr	1.01	263.05	263.33	263.3	263.42	0.008491	1.31	0.77	2.96	0.82	19.91	19.91	0.0098	0.28
																	0
Eugene	1	1071	Timmins	2.24	262.71	263.39		263.44	0.001606	0.99	2.55	5.43	0.41	8.52	6.89	0.007	0.68
Eugene	1	1071	2-yr	0.26	262.71	262.85	262.81	262.87	0.005412	0.69	0.38	2.89	0.61	6.74	6.74	0.007	0.14
Eugene	1	1071	5-yr	0.42	262.71	262.85	262.85	262.91	0.014802	1.12	0.37	2.89	1	18.1	18.1	0.007	0.14
Eugene	1	1071	10-yr	0.54	262.71	262.87	262.87	262.95	0.014245	1.22	0.44	2.95	1	20.23	20.23	0.007	0.16
Eugene	1	1071	20-yr	0.65	262.71	262.89	262.89	262.98	0.013887	1.29	0.5	2.99	1.01	21.85	21.85	0.007	0.18
Eugene	1	1071	50-yr	0.79	262.71	262.92	262.92	263.01	0.013288	1.37	0.58	3.06	1	23.58	23.58	0.007	0.21
Eugene	1	1071	100-yr	1.01	262.71	262.95	262.95	263.06	0.012795	1.47	0.69	3.14	1	26.07	26.07	0.007	0.24

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
																	0
Eugene	1	1041	Timmins	2.24	262.5	263.39		263.41	0.000361	0.55	4.12	5.58	0.2	2.45	2.27	0.0071	0.89
Eugene	1	1041	2-yr	0.26	262.5	262.58	262.58	262.61	0.015576	0.83	0.31	4.03	0.95	11.68	11.68	0.0071	0.08
Eugene	1	1041	5-yr	0.42	262.5	262.68		262.7	0.0025	0.57	0.74	4.18	0.43	4.15	4.15	0.0071	0.18
Eugene	1	1041	10-yr	0.54	262.5	262.75		262.76	0.00152	0.53	1.02	4.27	0.35	3.34	3.34	0.0071	0.25
Eugene	1	1041	20-yr	0.65	262.5	262.8		262.81	0.001172	0.52	1.23	4.34	0.31	3.05	3.05	0.0071	0.3
Eugene	1	1041	50-yr	0.79	262.5	262.86		262.88	0.000923	0.52	1.52	4.44	0.28	2.85	2.85	0.0071	0.36
Eugene	1	1041	100-yr	1.01	262.5	262.95		262.97	0.000736	0.53	1.92	4.56	0.26	2.75	2.75	0.0071	0.45
																	0
Eugene	1	1012	Timmins	2.24	262.3	263.39		263.4	0.000192	0.45	5.17	6.14	0.15	1.54	1.36	0.0068	1.09
Eugene	1	1012	2-yr	0.26	262.3	262.58		262.58	0.000265	0.24	1.11	4.21	0.15	0.64	0.64	0.0068	0.28
Eugene	1	1012	5-yr	0.42	262.3	262.68		262.68	0.000246	0.27	1.53	4.35	0.15	0.78	0.78	0.0068	0.38
Eugene	1	1012	10-yr	0.54	262.3	262.74		262.75	0.000241	0.3	1.82	4.44	0.15	0.88	0.88	0.0068	0.44
Eugene	1	1012	20-yr	0.65	262.3	262.79		262.8	0.000239	0.32	2.05	4.51	0.15	0.96	0.96	0.0068	0.49
Eugene	1	1012	50-yr	0.79	262.3	262.86		262.86	0.000239	0.34	2.35	4.6	0.15	1.06	1.06	0.0068	0.56
Eugene	1	1012	100-yr	1.01	262.3	262.95		262.95	0.00024	0.37	2.76	4.73	0.15	1.2	1.2	0.0068	0.65
																	0
Eugene	1	999	Timmins	2.24	262.21	263.39	262.57	263.4	0.000187	0.46	5.31	6.35	0.15	1.59	1.34	0.0058	1.18
Eugene	1	999	2-yr	0.26	262.21	262.57	262.3	262.58	0.000151	0.21	1.27	3.78	0.11	0.45	0.45	0.0058	0.36
Eugene	1	999	5-yr	0.42	262.21	262.67	262.33	262.68	0.000173	0.25	1.65	3.95	0.13	0.64	0.64	0.0058	0.46
Eugene	1	999	10-yr	0.54	262.21	262.74	262.35	262.74	0.000186	0.28	1.91	4.07	0.13	0.76	0.76	0.0058	0.53
Eugene	1	999	20-yr	0.65	262.21	262.79	262.37	262.79	0.000192	0.3	2.12	4.26	0.14	0.86	0.84	0.0058	0.58
Eugene	1	999	50-yr	0.79	262.21	262.85	262.39	262.86	0.000198	0.33	2.41	4.49	0.14	0.98	0.93	0.0058	0.64
Eugene	1	999	100-yr	1.01	262.21	262.94	262.42	262.95	0.000206	0.36	2.82	4.82	0.14	1.15	1.05	0.0058	0.73
																	0
Eugene	1	927		Culvert													0
																	0
Eugene	1	816	Timmins	9.34	261.16	263.09		263.2	0.003755	1.71	7.94	9.82	0.41	35.41	24.65	0.0079	1.93
Eugene	1	816	2-yr	0.68	261.16	261.75		261.77	0.002216	0.68	0.99	1.88	0.3	7.84	7.84	0.0079	0.59
Eugene	1	816	5-yr	1.33	261.16	262.01		262.05	0.002743	0.89	1.5	2.04	0.33	12.24	12.24	0.0079	0.85
Eugene	1	816	10-yr	1.91	261.16	262.16		262.22	0.003378	1.05	1.82	2.14	0.36	16.65	16.65	0.0079	1
Eugene	1	816	20-yr	2.58	261.16	262.3		262.37	0.004081	1.21	2.12	2.48	0.4	21.73	20.4	0.0079	1.14
Eugene	1	816	50-yr	3.65	261.16	262.47		262.57	0.004557	1.4	2.94	5.47	0.42	27.68	17.98	0.0079	1.31
Eugene	1	816	100-yr	4.69	261.16	262.61		262.72	0.004547	1.51	3.83	7.32	0.43	31.06	18.62	0.0079	1.45
																	0
Eugene	1	771	Timmins	9.34	260.8	262.97		263.02	0.002748	1.22	10.32	9.8	0.28	33.93	24.71	0.0063	2.17
Eugene	1	771	2-yr	0.68	260.8	261.61		261.64	0.003976	0.69	1.07	2.98	0.27	15.64	10.72	0.0063	0.81
Eugene	1	771	5-yr	1.33	260.8	261.87		261.9	0.003373	0.79	2.08	4.76	0.27	18.69	11.98	0.0063	1.07
Eugene	1	771	10-yr	1.91	260.8	262.02		262.05	0.003319	0.87	2.84	5.64	0.27	21.39	13.85	0.0063	1.22
Eugene	1	771	20-yr	2.58	260.8	262.15		262.19	0.003266	0.94	3.63	6.32	0.28	23.72	15.71	0.0063	1.35
Eugene	1	771	50-yr	3.65	260.8	262.33		262.37	0.003144	1.01	4.82	7.14	0.28	26.29	17.94	0.0063	1.53
Eugene	1	771	100-yr	4.69	260.8	262.48		262.51	0.00306	1.07	5.91	7.78	0.28	28.35	19.71	0.0063	1.68
																	0
Eugene	1	723	Timmins	9.34	260.5	262.87		262.9	0.001994	0.95	12.89	13.01	0.21	21.3	16.98	0.0066	2.37
Eugene	1	723	2-yr	0.68	260.5	261.42		261.44	0.004208	0.67	1.01	1.43	0.25	15.31	15.31	0.0066	0.92
Eugene	1	723	5-yr	1.33	260.5	261.67		261.7	0.005241	0.88	1.78	4.78	0.29	24.19	14.68	0.0066	1.17
Eugene	1	723	10-yr	1.91	260.5	261.83		261.87	0.004394	0.9	2.7	6.14	0.27	24.01	15.25	0.0066	1.33
Eugene	1	723	20-yr	2.58	260.5	261.99		262.02	0.003764	0.91	3.72	7.3	0.26	23.42	15.53	0.0066	1.49
Eugene	1	723	50-yr	3.65	260.5	262.18		262.21	0.003137	0.91	5.31	8.78	0.24	22.64	15.74	0.0066	1.68
Eugene	1	723	100-yr	4.69	260.5	262.34		262.37	0.00277	0.92	6.79	9.9	0.23	22.2	15.98	0.0066	1.84
																	0
Eugene	1	693	Timmins	9.34	260.3	262.68		262.8	0.0051	1.77	8.62	7.19	0.38	68.77	47.21	0.0069	2.38
Eugene	1	693	2-yr	0.68	260.3	261.37		261.38	0.001166	0.46	1.77	3.29	0.16	6.35	4.6	0.0069	1.07
Eugene	1	693	5-yr	1.33	260.3	261.59		261.61	0.00186	0.68	2.57	3.93	0.2	12.64	9.04	0.0069	1.29
Eugene	1	693	10-yr	1.91	260.3	261.75		261.77	0.002248	0.81	3.23	4.39	0.23	17.44	12.38	0.0069	1.45
Eugene	1	693	20-yr	2.58	260.3	261.88		261.92	0.002663	0.95	3.86	4.79	0.25	22.91	16.17	0.0069	1.58
Eugene	1	693	50-yr	3.65	260.3	262.06		262.11	0.003232	1.13	4.76	5.3	0.29	31.32	21.99	0.0069	1.76
Eugene	1	693	100-yr	4.69	260.3	262.2		262.27	0.003704	1.28	5.54	5.71	0.31	39.12	27.35	0.0069	1.9
																	0
Eugene	1	657	Timmins	9.34	260.05	262.03	262	262.37	0.04132	2.83	3.74	5.18	0.8	234.94	210.49	0.0047	1.98
Eugene	1	657	2-yr	0.68	260.05	261.25		261.28	0.008947	0.84	0.83	2.05	0.33	25.91	20.35	0.0047	1.2
Eugene	1	657	5-yr	1.33	260.05	261.37		261.45	0.018357	1.3	1.12	2.74	0.48	59.87	46.62	0.0047	1.32
Eugene	1	657	10-yr	1.91	260.05	261.49		261.58	0.019579	1.44	1.49	3.17	0.51	71.22	58.96	0.0047	1.44
Eugene	1	657	20-yr	2.58	260.05	261.59		261.7	0.021875	1.61	1.81	3.49	0.55	85.86	74.07	0.0047	1.54
Eugene	1	657	50-yr	3.65	260.05	261.71		261.85	0.024682	1.81	2.26	3.87	0.59	105.78	95.73	0.0047	1.66
Eugene	1	657	100-yr	4.69	260.05	261.8	261.67	261.97	0.026619	1.99	2.65	4.26	0.62	124.03	112.11	0.0047	1.75
																	0
Eugene	1	624	Timmins	9.34	259.9	261.02	261.02	261.15	0.031598	2.07	6.16	25.97	0.78	138.06	70.93	0.0352	1.12
Eugene	1	624	2-yr	0.68	259.9	260.47	260.47	260.65	0.066635	1.89	0.36	1.02	1.02	144.17	144.17	0.0352	0.57
Eugene	1	624	5-yr	1.33	259.9	260.66	260.66	260.73	0.027221	1.45	1.36	8.29	0.68	77.84	40.12	0.0352	0.76
Eugene	1	624	10-yr	1.91	259.9	260.7	260.7	260.79	0.03202	1.64	1.72	8.95	0.74	97.22	55.58	0.0352	0.8
Eugene	1	624	20-yr	2.58	259.9	260.75	260.75	260.84	0.032805	1.73	2.15	9.82	0.76	105.78	65.13	0.0352	0.85

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
Eugene	1	624	50-yr	3.65	259.9	260.8	260.8	260.91	0.034428	1.85	2.73	11.36	0.79	118.68	75.57	0.0352	0.9
Eugene	1	624	100-yr	4.69	259.9	260.84	260.84	260.96	0.036056	1.95	3.25	12.7	0.81	130.56	84.81	0.0352	0.94
																	0
Eugene	1	611	Timmins	9.34	259.41	260.31		260.47	0.024023	2.31	5.75	12.68	0.84	152.03	103.77	0.0149	0.9
Eugene	1	611	2-yr	0.68	259.41	259.81	259.79	259.85	0.02156	1.15	0.84	6.13	0.68	51.65	27.66	0.0149	0.4
Eugene	1	611	5-yr	1.33	259.41	259.89	259.87	259.95	0.023442	1.35	1.39	7.25	0.73	67.46	42.33	0.0149	0.48
Eugene	1	611	10-yr	1.91	259.41	259.96		260.02	0.019731	1.4	1.95	8.53	0.69	67.72	42.69	0.0149	0.55
Eugene	1	611	20-yr	2.58	259.41	260.02		260.09	0.019404	1.51	2.46	9.43	0.7	75.64	47.98	0.0149	0.61
Eugene	1	611	50-yr	3.65	259.41	260.09		260.17	0.019217	1.65	3.19	10.43	0.71	86.49	55.82	0.0149	0.68
Eugene	1	611	100-yr	4.69	259.41	260.14		260.24	0.020038	1.79	3.75	10.98	0.74	98.95	65.2	0.0149	0.73
																	0
Eugene	1	572	Timmins	9.34	258.84	259.71		259.78	0.012931	1.69	8.99	30.09	0.62	81.13	37.52	0.0103	0.87
Eugene	1	572	2-yr	0.68	258.84	259.27	259.23	259.3	0.010315	0.85	1.22	8.86	0.48	27.34	13.53	0.0103	0.43
Eugene	1	572	5-yr	1.33	258.84	259.36		259.39	0.009743	0.96	2.1	10.77	0.48	32.62	18.12	0.0103	0.52
Eugene	1	572	10-yr	1.91	258.84	259.4		259.44	0.011842	1.14	2.57	11.79	0.54	43.77	24.71	0.0103	0.56
Eugene	1	572	20-yr	2.58	258.84	259.45		259.5	0.012216	1.24	3.21	13.93	0.56	50.28	27.08	0.0103	0.61
Eugene	1	572	50-yr	3.65	258.84	259.52		259.57	0.012813	1.37	4.19	17.9	0.59	59.37	28.96	0.0103	0.68
Eugene	1	572	100-yr	4.69	258.84	259.56		259.62	0.012894	1.45	5.11	21.37	0.6	64.71	29.82	0.0103	0.72
																	0
Eugene	1	511	Timmins	9.34	258.21	259.13		259.18	0.007587	1.37	11.16	31.9	0.48	52.15	25.79	0.0163	0.92
Eugene	1	511	2-yr	0.68	258.21	258.63	258.6	258.66	0.010471	0.86	1.22	9.22	0.49	27.77	13.17	0.0163	0.42
Eugene	1	511	5-yr	1.33	258.21	258.71		258.74	0.011578	1.04	2.02	11.9	0.53	38.04	18.81	0.0163	0.5
Eugene	1	511	10-yr	1.91	258.21	258.78		258.81	0.008992	1.03	3	14.69	0.48	35.14	17.69	0.0163	0.57
Eugene	1	511	20-yr	2.58	258.21	258.83		258.86	0.008861	1.09	3.74	16.62	0.48	38.14	19.25	0.0163	0.62
Eugene	1	511	50-yr	3.65	258.21	258.89	258.79	258.93	0.00848	1.15	4.95	19.63	0.48	41.24	20.68	0.0163	0.68
Eugene	1	511	100-yr	4.69	258.21	258.95	258.83	258.99	0.008312	1.21	6.09	22.49	0.49	44.2	21.8	0.0163	0.74
																	0
Eugene	1	467	Timmins	9.34	257.5	258.42	258.42	258.57	0.031521	2.46	6.37	20.83	0.88	178.65	91.88	0.0289	0.92
Eugene	1	467	2-yr	0.68	257.5	258.03	257.88	258.09	0.015904	1.12	0.61	6.61	0.56	45.85	13.32	0.0289	0.53
Eugene	1	467	5-yr	1.33	257.5	258.15	258.13	258.2	0.013082	1.2	1.8	12.75	0.53	48.56	17.35	0.0289	0.65
Eugene	1	467	10-yr	1.91	257.5	258.17	258.17	258.25	0.019548	1.51	2.1	13.41	0.65	75.8	28.87	0.0289	0.67
Eugene	1	467	20-yr	2.58	257.5	258.21	258.21	258.3	0.02027	1.61	2.7	14.61	0.67	84.73	35.33	0.0289	0.71
Eugene	1	467	50-yr	3.65	257.5	258.26	258.26	258.36	0.022848	1.8	3.43	15.98	0.72	103.32	46.44	0.0289	0.76
Eugene	1	467	100-yr	4.69	257.5	258.3	258.3	258.4	0.024306	1.94	4.1	17.14	0.75	116.92	55.17	0.0289	0.8
																	0
Eugene	1	412	Timmins	9.34	255.9	257.82		257.82	0.000305	0.32	34.52	39.13	0.08	2.64	2.54	0.0687	1.92
Eugene	1	412	2-yr	0.68	255.9	256.34	256.34	256.52	0.063645	1.88	0.36	1.02	1.01	141.65	141.65	0.0687	0.44
Eugene	1	412	5-yr	1.33	255.9	256.55	256.55	256.81	0.06401	2.22	0.6	1.21	1.01	182.61	182.61	0.0687	0.65
Eugene	1	412	10-yr	1.91	255.9	256.83	256.83	256.88	0.01461	1.24	2.77	21.94	0.48	52.36	17.17	0.0687	0.93
Eugene	1	412	20-yr	2.58	255.9	256.86	256.86	256.91	0.016568	1.34	3.42	22.31	0.52	61.23	23.59	0.0687	0.96
Eugene	1	412	50-yr	3.65	255.9	256.88	256.88	256.96	0.023667	1.63	3.92	22.6	0.62	89.48	38.16	0.0687	0.98
Eugene	1	412	100-yr	4.69	255.9	256.91	256.91	256.99	0.026604	1.76	4.55	23.07	0.66	103.36	48.84	0.0687	1.01
																	0
Eugene	1	407	Timmins	9.34	255.52	257.8	256.67	257.82	0.000652	0.78	19	23.62	0.17	8.69	4.69	0.0064	2.28
Eugene	1	407	2-yr	0.68	255.52	255.82	255.72	255.86	0.009861	0.96	0.7	2.4	0.57	23.36	23.36	0.0064	0.3
Eugene	1	407	5-yr	1.33	255.52	255.99	255.84	256.06	0.009189	1.18	1.13	2.46	0.56	31.13	31.13	0.0064	0.47
Eugene	1	407	10-yr	1.91	255.52	256.13	255.92	256.21	0.008898	1.31	1.46	2.5	0.55	36.09	36.09	0.0064	0.61
Eugene	1	407	20-yr	2.58	255.52	256.27	256.01	256.37	0.008673	1.42	1.82	2.55	0.54	40.46	40.46	0.0064	0.75
Eugene	1	407	50-yr	3.65	255.52	256.48	256.14	256.6	0.008387	1.55	2.36	2.62	0.52	45.7	45.7	0.0064	0.96
Eugene	1	407	100-yr	4.69	255.52	256.67	256.25	256.8	0.007363	1.64	2.9	3.02	0.5	48.12	43.37	0.0064	1.15
																	0
Eugene	1	393		Culvert													0
																	0
Eugene	1	376	Timmins	11.53	255.31	256.51	256.51	256.94	0.014881	3.2	5.17	7.23	0.94	128.46	91.01	0.0119	1.2
Eugene	1	376	2-yr	0.73	255.31	255.66		255.7	0.005081	0.88	0.9	3.58	0.49	14.1	11.16	0.0119	0.35
Eugene	1	376	5-yr	1.54	255.31	255.76		255.85	0.009282	1.38	1.27	3.84	0.67	32.32	26.29	0.0119	0.45
Eugene	1	376	10-yr	2.29	255.31	255.82		255.97	0.012759	1.75	1.53	4.01	0.79	50.13	41.23	0.0119	0.51
Eugene	1	376	20-yr	3.15	255.31	255.88	255.87	256.1	0.01669	2.13	1.76	4.16	0.91	71.7	59.38	0.0119	0.57
Eugene	1	376	50-yr	4.53	255.31	256	256	256.28	0.018012	2.45	2.27	4.46	0.96	90.48	75.73	0.0119	0.69
Eugene	1	376	100-yr	5.86	255.31	256.11	256.11	256.43	0.017976	2.67	2.77	4.83	0.97	102.52	84.81	0.0119	0.8
																	0
Eugene	1	364	Timmins	11.53	255.16	255.95	255.95	256.17	0.028069	3.06	6.37	14.64	1.24	140.57	116.58	0.0636	0.79
Eugene	1	364	2-yr	0.73	255.16	255.56	255.56	255.6	0.011671	1.18	1.24	11.76	0.71	26.94	11.85	0.0636	0.4
Eugene	1	364	5-yr	1.54	255.16	255.61	255.61	255.68	0.017833	1.58	1.88	12.08	0.89	46.65	26.63	0.0636	0.45
Eugene	1	364	10-yr	2.29	255.16	255.65	255.65	255.73	0.021116	1.81	2.36	12.32	0.98	59.85	38.75	0.0636	0.49
Eugene	1	364	20-yr	3.15	255.16	255.69	255.69	255.79	0.023404	2	2.84	12.56	1.04	71.22	50.59	0.0636	0.53
Eugene	1	364	50-yr	4.53	255.16	255.74	255.74	255.86	0.02641	2.25	3.49	12.86	1.12	87.59	68.44	0.0636	0.58
Eugene	1	364	100-yr	5.86	255.16	255.79	255.79	255.93	0.027103	2.45	4.1	13.28	1.16	100.15	79.92	0.0636	0.63
																	0
Eugene	1	349	Timmins	11.53	254.22	255.07	255.07	255.24	0.017932	2.94	8.72	23.08	1.07	118.15	65.56	0.0309	0.85
Eugene	1	349	2-yr	0.73	254.22	254.61	254.61	254.67	0.010146	1.2	1.03	8.9	0.69	26.93	11.23	0.0309	0.39
Eugene	1	349	5-yr	1.54	254.22	254.69	254.69	254.77	0.013312	1.6	1.77	10.04	0.82	44.22	22.5	0.0309	0.47

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
Eugene	1	349	10-yr	2.29	254.22	254.8	254.8	254.88	0.009463	1.61	3.22	18.17	0.72	40.77	16.21	0.0309	0.58
Eugene	1	349	20-yr	3.15	254.22	254.77	254.77	254.93	0.021286	2.31	2.71	13.77	1.07	85.9	40.29	0.0309	0.55
Eugene	1	349	50-yr	4.53	254.22	254.89	254.89	254.99	0.012687	2.07	4.92	19.74	0.86	64.39	30.59	0.0309	0.67
Eugene	1	349	100-yr	5.86	254.22	254.93	254.93	255.05	0.014183	2.29	5.75	20.48	0.92	76.92	38.48	0.0309	0.71
																	0
Eugene	1	316	Timmins	11.53	253.2	254.07	254.07	254.27	0.031143	2.66	6.48	15.73	0.97	199.83	123.02	0.0176	0.87
Eugene	1	316	2-yr	0.73	253.2	253.61	253.6	253.67	0.019729	1.15	0.91	6.86	0.66	50.99	24.67	0.0176	0.41
Eugene	1	316	5-yr	1.54	253.2	253.69	253.69	253.77	0.026393	1.55	1.54	9.48	0.8	84.92	40.91	0.0176	0.49
Eugene	1	316	10-yr	2.29	253.2	253.75	253.75	253.84	0.025282	1.66	2.13	10.7	0.8	93.63	48.16	0.0176	0.55
Eugene	1	316	20-yr	3.15	253.2	253.79	253.79	253.89	0.027603	1.85	2.6	11.41	0.85	112.02	60.2	0.0176	0.59
Eugene	1	316	50-yr	4.53	253.2	253.85	253.85	253.98	0.030637	2.09	3.27	12.36	0.91	138.68	77.59	0.0176	0.65
Eugene	1	316	100-yr	5.86	253.2	253.9	253.9	254.04	0.03035	2.22	3.97	13.28	0.92	151.19	86.89	0.0176	0.7
																	0
Eugene	1	266	Timmins	11.53	252.33	253.24		253.32	0.012277	1.55	9.72	21.07	0.59	70.43	54.62	0.0258	0.91
Eugene	1	266	2-yr	0.73	252.33	252.71	252.68	252.74	0.017684	1	1.14	8.7	0.61	39.76	22.28	0.0258	0.38
Eugene	1	266	5-yr	1.54	252.33	252.83		252.86	0.010802	0.93	2.48	12.55	0.5	31.81	20.51	0.0258	0.5
Eugene	1	266	10-yr	2.29	252.33	252.91		252.93	0.009574	0.95	3.53	14.97	0.48	31.97	21.76	0.0258	0.58
Eugene	1	266	20-yr	3.15	252.33	252.98		253.01	0.008364	0.95	4.69	17.11	0.45	30.89	22.08	0.0258	0.65
Eugene	1	266	50-yr	4.53	252.33	253.02		253.06	0.011046	1.14	5.41	17.78	0.53	43.51	32.41	0.0258	0.69
Eugene	1	266	100-yr	5.86	252.33	253.09		253.13	0.010188	1.19	6.57	18.82	0.52	45.39	34.3	0.0258	0.76
																	0
Eugene	1	239	Timmins	11.53	251.62	252.95		253.04	0.008544	1.97	11.14	22.1	0.56	91.93	40.56	0.0129	1.33
Eugene	1	239	2-yr	0.73	251.62	252.02	251.99	252.12	0.027895	1.45	0.54	2	0.81	78.18	61.2	0.0129	0.4
Eugene	1	239	5-yr	1.54	251.62	252.18	252.15	252.37	0.030335	1.98	0.87	2.26	0.9	127.75	86.75	0.0129	0.56
Eugene	1	239	10-yr	2.29	251.62	252.36	252.36	252.54	0.020869	2.02	1.51	5.24	0.79	119.35	50.82	0.0129	0.74
Eugene	1	239	20-yr	3.15	251.62	252.47	252.47	252.66	0.019167	2.14	2.2	7.45	0.77	127.42	49.72	0.0129	0.85
Eugene	1	239	50-yr	4.53	251.62	252.62	252.62	252.74	0.011877	1.9	4.63	17.97	0.63	94.89	28.65	0.0129	1
Eugene	1	239	100-yr	5.86	251.62	252.67	252.67	252.8	0.013386	2.09	5.51	18.64	0.67	112.46	37.09	0.0129	1.05
																	0
Eugene	1	212	Timmins	11.53	251.28	252.49	252.49	252.7	0.019479	2.77	6.94	17.45	0.83	189.33	74.27	0.0049	1.21
Eugene	1	212	2-yr	0.73	251.28	251.85		251.87	0.004212	0.74	1.27	4.52	0.34	17.83	10.88	0.0049	0.57
Eugene	1	212	5-yr	1.54	251.28	251.99		252.03	0.005911	1.04	1.99	5.63	0.42	32.23	19.37	0.0049	0.71
Eugene	1	212	10-yr	2.29	251.28	252.08		252.14	0.006919	1.24	2.57	6.41	0.46	43.42	25.8	0.0049	0.8
Eugene	1	212	20-yr	3.15	251.28	252.17		252.24	0.008249	1.45	3.13	7.53	0.51	57.55	32.13	0.0049	0.89
Eugene	1	212	50-yr	4.53	251.28	252.24	252.08	252.35	0.011089	1.78	3.77	8.96	0.6	84.71	43.92	0.0049	0.96
Eugene	1	212	100-yr	5.86	251.28	252.3	252.18	252.43	0.013275	2.04	4.34	10.32	0.67	108.12	52.79	0.0049	1.02
																	0
Eugene	1	176	Timmins	11.53	251.1	252.14		252.2	0.007975	1.55	11.76	24.17	0.51	63.19	37.49	0.0209	1.04
Eugene	1	176	2-yr	0.73	251.1	251.52	251.52	251.58	0.020208	1.2	0.85	9.57	0.68	54.46	17.06	0.0209	0.42
Eugene	1	176	5-yr	1.54	251.1	251.6	251.6	251.66	0.020341	1.41	1.79	12.58	0.71	68.97	27.74	0.0209	0.5
Eugene	1	176	10-yr	2.29	251.1	251.65	251.65	251.72	0.022176	1.58	2.39	13.63	0.75	83.82	37.42	0.0209	0.55
Eugene	1	176	20-yr	3.15	251.1	251.7	251.68	251.77	0.021758	1.67	3.09	14.75	0.76	91.15	43.77	0.0209	0.6
Eugene	1	176	50-yr	4.53	251.1	251.79		251.86	0.016077	1.61	4.55	16.85	0.67	79.91	41.87	0.0209	0.69
Eugene	1	176	100-yr	5.86	251.1	251.86		251.93	0.013417	1.6	5.89	18.38	0.62	75.26	41.46	0.0209	0.76
																	0
Eugene	1	145	Timmins	11.53	250.45	251.94		252	0.004954	1.57	11.59	17.44	0.43	57.41	31.4	0.0133	1.49
Eugene	1	145	2-yr	0.73	250.45	251		251.02	0.004669	0.7	1.23	3.66	0.34	16.7	14.26	0.0133	0.55
Eugene	1	145	5-yr	1.54	250.45	251.17		251.2	0.005876	0.98	1.99	5.85	0.41	29.36	18.57	0.0133	0.72
Eugene	1	145	10-yr	2.29	250.45	251.28		251.33	0.00619	1.13	2.78	8.15	0.43	36.93	19.88	0.0133	0.83
Eugene	1	145	20-yr	3.15	250.45	251.38		251.43	0.006225	1.24	3.71	10.27	0.44	42.5	21.28	0.0133	0.93
Eugene	1	145	50-yr	4.53	250.45	251.51		251.57	0.005894	1.33	5.22	12.57	0.44	46.8	23.25	0.0133	1.06
Eugene	1	145	100-yr	5.86	250.45	251.62		251.67	0.005505	1.38	6.57	13.68	0.43	48.56	25.15	0.0133	1.17
																	0
Eugene	1	116	Timmins	11.53	250.07	251.5	251.43	251.71	0.027165	2.56	6.29	15.36	0.79	182.64	102.82	0.0143	1.43
Eugene	1	116	2-yr	0.73	250.07	250.74		250.8	0.015963	1.12	0.84	4.44	0.53	46.06	25.82	0.0143	0.67
Eugene	1	116	5-yr	1.54	250.07	250.92		250.97	0.012285	1.15	1.7	5.21	0.48	44.8	34.22	0.0143	0.85
Eugene	1	116	10-yr	2.29	250.07	250.99		251.06	0.015774	1.37	2.08	5.54	0.55	62.09	50.68	0.0143	0.92
Eugene	1	116	20-yr	3.15	250.07	251.07		251.16	0.01708	1.5	2.54	5.92	0.58	72.75	62.84	0.0143	1
Eugene	1	116	50-yr	4.53	250.07	251.17		251.28	0.020063	1.72	3.13	6.43	0.64	93.14	83.81	0.0143	1.1
Eugene	1	116	100-yr	5.86	250.07	251.25		251.39	0.021624	1.92	3.69	7.38	0.67	111.5	94.23	0.0143	1.18
																	0
Eugene	1	82	Timmins	11.53	249.58	251.26		251.3	0.005542	1.25	13.14	21.46	0.33	41.95	31.2	0.0139	1.68
Eugene	1	82	2-yr	0.73	249.58	250.27		250.32	0.01217	1.03	0.71	1.3	0.44	37.88	37.88	0.0139	0.69
Eugene	1	82	5-yr	1.54	249.58	250.66		250.69	0.005422	0.87	2.67	13.08	0.3	24.28	9.86	0.0139	1.08
Eugene	1	82	10-yr	2.29	249.58	250.79		250.81	0.003779	0.8	4.47	15.22	0.26	19.42	9.99	0.0139	1.21
Eugene	1	82	20-yr	3.15	249.58	250.86		250.88	0.004164	0.88	5.53	16.24	0.27	22.87	12.82	0.0139	1.28
Eugene	1	82	50-yr	4.53	249.58	250.98		251.01	0.003652	0.89	7.68	18.21	0.26	22.45	14.05	0.0139	1.4
Eugene	1	82	100-yr	5.86	249.58	251.14		251.16	0.002521	0.8	10.72	20.47	0.22	17.56	12.12	0.0139	1.56
																	0
Eugene	1	58	Timmins	11.53	249.24	251.14		251.17	0.004607	1.06	14.44	24.48	0.27	31.13	24.57	0.0139	1.9
Eugene	1	58	2-yr	0.73	249.24	249.96		250.02	0.012763	1.04	0.71	1.18	0.43	38.86	38.86	0.0139	0.72
Eugene	1	58	5-yr	1.54	249.24	250.44		250.51	0.010813	1.15	1.34	1.45	0.38	43.41	43.41	0.0139	1.2

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
Eugene	1	58	10-yr	2.29	249.24	250.64		250.68	0.007562	1.05	3.44	19.45	0.32	35.01	11.91	0.0139	1.4
Eugene	1	58	20-yr	3.15	249.24	250.74	250.27	250.77	0.00507	0.92	5.51	20.54	0.27	25.71	12.16	0.0139	1.5
Eugene	1	58	50-yr	4.53	249.24	250.91		250.93	0.002664	0.73	9.16	22.23	0.2	15.44	9.86	0.0139	1.67
Eugene	1	58	100-yr	5.86	249.24	251.1		251.11	0.001459	0.59	13.48	24.11	0.15	9.61	7.37	0.0139	1.86
																	0
Eugene	1	19	Timmins	11.53	248.7	250.75	250.75	250.84	0.020061	1.87	10.94	43.29	0.47	105.42	46.48		2.05
Eugene	1	19	2-yr	0.73	248.7	249.5	249.13	249.55	0.011298	0.98	0.75	1.09	0.38	34.47	34.47		0.8
Eugene	1	19	5-yr	1.54	248.7	249.5	249.39	249.71	0.049877	2.05	0.75	1.09	0.79	152.16	152.16		0.8
Eugene	1	19	10-yr	2.29	248.7	249.58	249.58	249.96	0.08243	2.72	0.84	1.13	1.01	263.92	263.92		0.88
Eugene	1	19	20-yr	3.15	248.7	249.77	249.77	250.22	0.086347	2.96	1.06	1.2	1.01	303.26	303.26		1.07
Eugene	1	19	50-yr	4.53	248.7	250.03	250.03	250.57	0.090498	3.25	1.39	1.3	1.01	352.74	352.74		1.33
Eugene	1	19	100-yr	5.86	248.7	250.26	250.26	250.87	0.092543	3.46	1.7	1.39	1	388.6	388.6		1.56

HEC-RAS Output for 24-Hr SCS Flood Events and Timmins Design Storrm

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
1	2078	Timmins	3.32	271.57	271.82	271.82	271.88	0.087069	1.74	3.03	22.73	1.29	136.2	112.62	0.1211	0.25
1	2078	2-yr	0.12	271.57	271.58	271.58	271.6	0.148334	0.41	0.2	5.52	1.17	18.12	51.81	0.1211	0.01
1	2078	5-yr	0.39	271.57	271.63	271.63	271.66	0.137931	0.99	0.49	7.69	1.39	65.79	85.4	0.1211	0.06
1	2078	10-yr	0.6	271.57	271.65	271.65	271.69	0.12868	1.17	0.69	8.84	1.4	83.16	97.52	0.1211	0.08
1	2078	20-yr	0.8	271.57	271.67	271.67	271.72	0.125674	1.3	0.86	9.73	1.42	96.56	108.38	0.1211	0.1
1	2078	50-yr	1.37	271.57	271.71	271.71	271.77	0.116959	1.52	1.32	11.93	1.42	119.58	125.78	0.1211	0.14
1	2078	100-yr	1.84	271.57	271.74	271.74	271.81	0.109535	1.62	1.7	13.6	1.4	129.76	132.36	0.1211	0.17
																0
1	2067	Timmins	3.32	270.21	270.82	270.82	270.91	0.028928	1.87	3.92	23.23	0.86	115.45	47.19	0.0794	0.61
1	2067	2-yr	0.12	270.21	270.36	270.36	270.42	0.058266	1.09	0.11	0.92	1	61.02	61.02	0.0794	0.15
1	2067	5-yr	0.39	270.21	270.53	270.53	270.61	0.032637	1.23	0.36	3.64	0.81	63.85	29.58	0.0794	0.32
1	2067	10-yr	0.6	270.21	270.6	270.6	270.67	0.025758	1.25	0.69	6.46	0.75	61.57	25.85	0.0794	0.39
1	2067	20-yr	0.8	270.21	270.64	270.64	270.71	0.027191	1.36	0.93	7.67	0.78	70.56	31.21	0.0794	0.43
1	2067	50-yr	1.37	270.21	270.72	270.72	270.78	0.023623	1.43	1.86	15.93	0.74	73.73	26.5	0.0794	0.51
1	2067	100-yr	1.84	270.21	270.76	270.76	270.82	0.023039	1.51	2.53	18.61	0.75	79.28	30.18	0.0794	0.55
																0
1	2054	Timmins	3.32	269.21	269.26		269.29	0.03736	0.48	3.97	25.09	0.72	15.94	57.79	0.0157	0.05
1	2054	2-yr	0.12	269.21	269.03	269.03	269.04	0.134512		0.31	13.25	0		31.29	0.0157	-0.18
1	2054	5-yr	0.39	269.21	269.05	269.05	269.08	0.181709		0.59	13.61	0		77.12	0.0157	-0.16
1	2054	10-yr	0.6	269.21	269.07	269.07	269.1	0.16265		0.8	13.87	0		91.58	0.0157	-0.14
1	2054	20-yr	0.8	269.21	269.08	269.08	269.12	0.153146		0.98	14.1	0		103.87	0.0157	-0.13
1	2054	50-yr	1.37	269.21	269.13		269.16	0.092121		1.59	14.84	0		96.95	0.0157	-0.08
1	2054	100-yr	1.84	269.21	269.16		269.2	0.069568		2.1	15.41	0		92.97	0.0157	-0.05
																0
1	1992	Timmins	3.32	268.23	268.92		268.93	0.002191	0.62	10.81	31.82	0.25	11.68	7.24	0.0029	0.69
1	1992	2-yr	0.12	268.23	268.53		268.54	0.002632	0.35	0.34	1.5	0.23	5.13	5.13	0.0029	0.3
1	1992	5-yr	0.39	268.23	268.63		268.63	0.001831	0.37	2.46	23.98	0.21	5.07	1.82	0.0029	0.4
1	1992	10-yr	0.6	268.23	268.67		268.67	0.001793	0.39	3.47	25.23	0.21	5.6	2.39	0.0029	0.44
1	1992	20-yr	0.8	268.23	268.7		268.7	0.001878	0.43	4.23	25.97	0.22	6.34	2.97	0.0029	0.47
1	1992	50-yr	1.37	268.23	268.76		268.77	0.002051	0.49	5.96	27.56	0.23	8.06	4.31	0.0029	0.53
1	1992	100-yr	1.84	268.23	268.81		268.81	0.002056	0.53	7.31	28.78	0.24	8.93	5.08	0.0029	0.58
																0
1	1933	Timmins	3.32	268.06	268.59		268.64	0.019828	1.52	4.78	24.84	0.72	76.93	37.07	0.0113	0.53
1	1933	2-yr	0.12	268.06	268.31	268.19	268.32	0.005456	0.45	0.26	1.36	0.33	9.12	9.12	0.0113	0.25
1	1933	5-yr	0.39	268.06	268.4	268.37	268.42	0.009058	0.72	0.98	13.6	0.45	20.76	6.32	0.0113	0.34
1	1933	10-yr	0.6	268.06	268.44	268.4	268.46	0.009386	0.8	1.56	17.67	0.46	24.48	8.04	0.0113	0.38
1	1933	20-yr	0.8	268.06	268.47	268.43	268.49	0.008971	0.83	2.11	19.67	0.46	25.65	9.34	0.0113	0.41
1	1933	50-yr	1.37	268.06	268.53	268.47	268.55	0.00841	0.9	3.35	22.32	0.46	28.3	12.27	0.0113	0.47
1	1933	100-yr	1.84	268.06	268.55	268.5	268.57	0.010721	1.05	3.85	23.33	0.52	38.05	17.17	0.0113	0.49
																0
1	1886	Timmins	3.32	267.54	268.06		268.07	0.008138	0.96	10.8	92.14	0.46	30.75	9.33	0.0065	0.52
1	1886	2-yr	0.12	267.54	267.67	267.67	267.72	0.058213	1.03	0.12	1.07	1.01	56.65	56.65	0.0065	0.13
1	1886	5-yr	0.39	267.54	267.85	267.85	267.88	0.015745	0.87	0.9	19.91	0.57	31.52	6.87	0.0065	0.31
1	1886	10-yr	0.6	267.54	267.87	267.87	267.9	0.016176	0.94	1.49	26.79	0.59	35.85	8.74	0.0065	0.33
1	1886	20-yr	0.8	267.54	267.89	267.89	267.92	0.017662	1.03	1.95	31.04	0.62	41.54	10.79	0.0065	0.35
1	1886	50-yr	1.37	267.54	267.92	267.92	267.95	0.021947	1.22	2.91	36.32	0.71	56.94	17.17	0.0065	0.38
1	1886	100-yr	1.84	267.54	267.95		267.98	0.015743	1.11	4.31	41.45	0.61	45.69	15.98	0.0065	0.41
																0
1	1839	Timmins	3.32	267.23	267.89		267.9	0.0019	0.56	13.81	53.07	0.23	9.59	4.83	0.0004	0.66
1	1839	2-yr	0.12	267.23	267.56		267.56	0.000936	0.22	1.17	22.14	0.14	2.01	0.48	0.0004	0.33
1	1839	5-yr	0.39	267.23	267.65		267.65	0.000726	0.24	3.8	31.02	0.13	2.16	0.87	0.0004	0.42
1	1839	10-yr	0.6	267.23	267.69		267.69	0.000867	0.28	4.98	33.99	0.15	2.86	1.24	0.0004	0.46
1	1839	20-yr	0.8	267.23	267.72		267.72	0.000994	0.32	5.93	36.37	0.16	3.5	1.58	0.0004	0.49
1	1839	50-yr	1.37	267.23	267.78		267.78	0.00122	0.39	8.22	41.41	0.18	4.91	2.36	0.0004	0.55
1	1839	100-yr	1.84	267.23	267.81		267.82	0.001379	0.43	9.82	44.45	0.19	5.99	2.97	0.0004	0.58
																0
1	1784	Timmins	3.32	267.21	267.64	267.61	267.66	0.018587	1.25	7.21	60.81	0.67	56.29	21.53	0.0071	0.43
1	1784	2-yr	0.12	267.21	267.33	267.33	267.39	0.05812	1.03	0.12	1.08	1.01	56.33	56.33	0.0071	0.12
1	1784	5-yr	0.39	267.21	267.53	267.53	267.55	0.009563	0.71	1.54	50.88	0.45	20.68	2.83	0.0071	0.32
1	1784	10-yr	0.6	267.21	267.55	267.55	267.57	0.012906	0.85	2.13	52.27	0.53	29.18	5.14	0.0071	0.34
1	1784	20-yr	0.8	267.21	267.56	267.56	267.58	0.01451	0.93	2.67	53.32	0.57	34.08	7.1	0.0071	0.35
1	1784	50-yr	1.37	267.21	267.57	267.57	267.6	0.019571	1.13	3.68	55.2	0.66	49.07	12.74	0.0071	0.36
1	1784	100-yr	1.84	267.21	267.59	267.59	267.62	0.023331	1.26	4.32	56.29	0.73	60.8	17.49	0.0071	0.38
																0
1	1716	Timmins	3.32	266.73	267.4		267.41	0.001484	0.5	15.21	55.09	0.21	7.64	4	0.0003	0.67
1	1716	2-yr	0.12	266.73	267.07		267.07	0.000799	0.21	1.3	27.4	0.13	1.82	0.37	0.0003	0.34
1	1716	5-yr	0.39	266.73	267.16		267.16	0.000697	0.24	4.03	34.65	0.13	2.11	0.79	0.0003	0.43
1	1716	10-yr	0.6	266.73	267.19		267.2	0.000767	0.27	5.44	38.03	0.14	2.58	1.07	0.0003	0.46
1	1716	20-yr	0.8	266.73	267.22		267.22	0.000854	0.3	6.53	40.42	0.15	3.07	1.35	0.0003	0.49
1	1716	50-yr	1.37	266.73	267.28		267.28	0.001012	0.36	9.1	45.41	0.16	4.16	1.98	0.0003	0.55
1	1716	100-yr	1.84	266.73	267.32		267.32	0.001122	0.4	10.91	48.6	0.18	4.99	2.46	0.0003	0.59
																0
1	1646	Timmins	3.32	266.71	267.14	267.1	267.16	0.017101	1.19	7.04	53.53	0.64	51.76	21.95	0.0203	0.43
1	1646	2-yr	0.12	266.71	266.83	266.83	266.89	0.057985	1.03	0.12	1.08	1	56.23	56.23	0.0203	0.12
1	1646	5-yr	0.39	266.71	266.99	266.99	267.02	0.018632	0.9	0.85	14.73	0.62	34.38	10.39	0.0203	0.28
1	1646	10-yr	0.6	266.71	267.02	267.02	267.05	0.016234	0.91	1.67	38.78	0.59	33.75	6.82	0.0203	0.31
1	1646	20-yr	0.8	266.71	267.04	267.04	267.06	0.018878	1.01	2.16	44.47	0.64	41.07	8.93	0.0203	0.33
1	1646	50-yr	1.37	266.71	267.06	267.06	267.09	0.023972	1.2	3.14	46.58	0.73	56.62	15.8	0.0203	0.35
1	1646	100-yr	1.84	266.71	267.07	267.07	267.1	0.027453	1.32	3.79	47.83	0.79	68.05	21.24	0.0203	0.36
																0

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
1	1602	Timmins	3.32	265.82	266.57		266.61	0.009472	1.35	6.18	32.55	0.53	53.74	17.49	0.01	0.75
1	1602	2-yr	0.12	265.82	266.06		266.07	0.006436	0.48	0.25	1.32	0.36	10.43	10.43	0.01	0.24
1	1602	5-yr	0.39	265.82	266.19	266.09	266.22	0.008748	0.75	0.73	6.26	0.44	21.71	9.61	0.01	0.37
1	1602	10-yr	0.6	265.82	266.25	266.17	266.28	0.008468	0.83	1.16	8.09	0.45	25.3	11.56	0.01	0.43
1	1602	20-yr	0.8	265.82	266.3	266.21	266.32	0.008247	0.89	1.56	9.47	0.45	27.85	12.99	0.01	0.48
1	1602	50-yr	1.37	265.82	266.39	266.29	266.42	0.00762	0.99	2.63	12.7	0.45	31.99	15.17	0.01	0.57
1	1602	100-yr	1.84	265.82	266.46	266.34	266.49	0.006868	1.02	3.54	14.7	0.44	32.73	15.96	0.01	0.64
																0
1	1568	Timmins	3.32	265.48	266.23		266.32	0.007611	1.75	5.04	20.87	0.69	43.93	17.82	0.0445	0.75
1	1568	2-yr	0.12	265.48	265.61	265.61	265.67	0.027522	1.01	0.12	1.13	1	26.45	26.45	0.0445	0.13
1	1568	5-yr	0.39	265.48	265.72	265.72	265.78	0.019334	1.25	0.48	3.98	0.91	33.59	22.18	0.0445	0.24
1	1568	10-yr	0.6	265.48	265.77	265.77	265.85	0.020114	1.43	0.67	4.33	0.95	41.38	29.74	0.0445	0.29
1	1568	20-yr	0.8	265.48	265.8	265.8	265.89	0.020751	1.57	0.84	4.57	0.98	47.81	36.12	0.0445	0.32
1	1568	50-yr	1.37	265.48	265.89	265.89	266	0.021662	1.83	1.24	5.1	1.03	61.18	49.7	0.0445	0.41
1	1568	100-yr	1.84	265.48	265.94	265.94	266.08	0.023436	2.07	1.5	5.71	1.09	74.69	58.26	0.0445	0.46
																0
1	1546	Timmins	3.32	264.48	266.1	265.35	266.18	0.0046	1.31	2.52	1.92	0.37	25.22	25.22	0.0152	1.62
1	1546	2-yr	0.12	264.48	264.74	264.58	264.75	0.001519	0.37	0.33	1.32	0.23	2.8	2.8	0.0152	0.26
1	1546	5-yr	0.39	264.48	264.95	264.7	264.97	0.002588	0.63	0.62	1.41	0.3	7.21	7.21	0.0152	0.47
1	1546	10-yr	0.6	264.48	265.07	264.77	265.1	0.003145	0.76	0.79	1.46	0.33	10.07	10.07	0.0152	0.59
1	1546	20-yr	0.8	264.48	265.17	264.83	265.21	0.003567	0.86	0.94	1.51	0.35	12.51	12.51	0.0152	0.69
1	1546	50-yr	1.37	264.48	265.4	264.97	265.46	0.004334	1.05	1.3	1.61	0.38	17.83	17.83	0.0152	0.92
1	1546	100-yr	1.84	264.48	265.58	265.08	265.65	0.004625	1.16	1.59	1.69	0.38	20.85	20.85	0.0152	1.1
																0
1	1523		Culvert													0
																0
1	1456	Timmins	3.32	263.11	263.87		263.93	0.002539	1.03	3.37	6.06	0.4	14.96	12.56	-0.0016	0.76
1	1456	2-yr	0.12	263.11	263.34		263.34	0.000203	0.14	0.85	3.99	0.1	0.4	0.4	-0.0016	0.23
1	1456	5-yr	0.39	263.11	263.58		263.58	0.000186	0.21	1.87	4.39	0.1	0.71	0.71	-0.0016	0.47
1	1456	10-yr	0.6	263.11	263.66		263.66	0.000274	0.27	2.2	4.52	0.12	1.17	1.17	-0.0016	0.55
1	1456	20-yr	0.8	263.11	263.73		263.73	0.000317	0.32	2.55	5.12	0.14	1.53	1.4	-0.0016	0.62
1	1456	50-yr	1.37	263.11	263.82		263.83	0.000565	0.46	3.04	5.77	0.19	3.1	2.65	-0.0016	0.71
1	1456	100-yr	1.84	263.11	263.88		263.9	0.00076	0.56	3.4	6.08	0.22	4.5	3.78	-0.0016	0.77
																0
1	1440	Timmins	4.65	263.14	263.69		263.83	0.008892	1.65	2.9	6.39	0.74	41.94	37.57	0.0111	0.55
1	1440	2-yr	0.44	263.14	263.24	263.24	263.29	0.026201	0.96	0.46	4.73	0.99	24.37	24.37	0.0111	0.1
1	1440	5-yr	1.84	263.14	263.41	263.39	263.51	0.016611	1.43	1.29	5.13	0.91	39.31	39.31	0.0111	0.27
1	1440	10-yr	2.39	263.14	263.46	263.44	263.58	0.014974	1.52	1.57	5.32	0.89	42.18	41.59	0.0111	0.32
1	1440	20-yr	3.02	263.14	263.52	263.49	263.65	0.013096	1.59	1.9	5.62	0.85	43.7	41.6	0.0111	0.38
1	1440	50-yr	3.86	263.14	263.6		263.74	0.011136	1.66	2.37	5.98	0.81	44.59	41.18	0.0111	0.46
1	1440	100-yr	4.49	263.14	263.67		263.81	0.00964	1.67	2.76	6.26	0.77	43.59	39.54	0.0111	0.53
																0
1	1415	Timmins	4.65	262.86	263.62		263.68	0.002482	1.12	4.63	8.4	0.42	17.04	12.84	0.0147	0.76
1	1415	2-yr	0.44	262.86	263.02		263.04	0.004726	0.56	0.78	5.05	0.45	7.03	7.03	0.0147	0.16
1	1415	5-yr	1.84	262.86	263.26		263.3	0.003903	0.9	2.06	5.85	0.47	13.61	12.91	0.0147	0.4
1	1415	10-yr	2.39	262.86	263.33		263.38	0.00356	0.97	2.52	6.36	0.46	14.92	13.24	0.0147	0.47
1	1415	20-yr	3.02	262.86	263.41		263.47	0.003253	1.03	3.05	6.93	0.45	16.07	13.45	0.0147	0.55
1	1415	50-yr	3.86	262.86	263.51		263.57	0.003	1.11	3.75	7.61	0.45	17.53	13.89	0.0147	0.65
1	1415	100-yr	4.49	262.86	263.59		263.65	0.002691	1.14	4.37	8.18	0.43	17.7	13.52	0.0147	0.73
																0
1	1372	Timmins	4.65	262.23	263.47		263.55	0.003706	1.65	5.92	10.78	0.5	33.68	19.14	0.0164	1.24
1	1372	2-yr	0.44	262.23	262.56	262.55	262.66	0.020385	1.41	0.32	1.7	0.92	40.48	33.03	0.0164	0.33
1	1372	5-yr	1.84	262.23	262.99		263.08	0.006612	1.51	1.99	6.1	0.61	34.14	20.02	0.0164	0.76
1	1372	10-yr	2.39	262.23	263.09		263.18	0.006031	1.59	2.62	6.86	0.6	35.98	21.46	0.0164	0.86
1	1372	20-yr	3.02	262.23	263.18		263.28	0.005664	1.68	3.32	7.69	0.59	38.25	22.77	0.0164	0.95
1	1372	50-yr	3.86	262.23	263.29		263.4	0.005519	1.79	4.19	8.76	0.6	42.09	24.67	0.0164	1.06
1	1372	100-yr	4.49	262.23	263.41		263.51	0.004381	1.73	5.32	10.09	0.54	37.74	21.68	0.0164	1.18
																0
1	1346	Timmins	4.65	261.8	263.4		263.46	0.002719	1.33	6.53	9.98	0.37	22.59	15.71	0.0159	1.6
1	1346	2-yr	0.44	261.8	262.38		262.41	0.0048	0.84	0.52	1.25	0.41	12.92	12.92	0.0159	0.58
1	1346	5-yr	1.84	261.8	262.86		262.93	0.00472	1.25	2.19	6.12	0.44	23.54	14.36	0.0159	1.06
1	1346	10-yr	2.39	261.8	262.97		263.04	0.004513	1.33	2.89	6.92	0.44	25.47	16.2	0.0159	1.17
1	1346	20-yr	3.02	261.8	263.07		263.15	0.004325	1.4	3.65	7.58	0.44	27.17	18	0.0159	1.27
1	1346	50-yr	3.86	261.8	263.18		263.26	0.004418	1.51	4.49	8.26	0.45	30.65	20.93	0.0159	1.38
1	1346	100-yr	4.49	261.8	263.33		263.4	0.003292	1.41	5.83	9.39	0.4	25.89	17.96	0.0159	1.53
																0
1	1315	Timmins	4.65	261.3	263.29		263.36	0.003481	1.44	5.32	7.17	0.39	27.02	21.11	0.0446	1.99
1	1315	2-yr	0.44	261.3	261.91	261.91	262.07	0.040918	1.76	0.25	0.8	1.01	67.63	67.63	0.0446	0.61
1	1315	5-yr	1.84	261.3	262.4	262.4	262.63	0.024399	2.18	1.02	2.62	0.89	81.87	66.57	0.0446	1.1
1	1315	10-yr	2.39	261.3	262.51	262.51	262.75	0.023407	2.3	1.32	3.1	0.9	87.49	72.24	0.0446	1.21
1	1315	20-yr	3.02	261.3	262.61	262.61	262.86	0.02306	2.42	1.65	3.55	0.9	94.15	79.04	0.0446	1.31
1	1315	50-yr	3.86	261.3	262.78	262.7	263	0.016609	2.32	2.35	4.56	0.79	81.5	66.03	0.0446	1.48
1	1315	100-yr	4.49	261.3	263.19		263.27	0.004533	1.56	4.61	6.59	0.44	32.55	25.64	0.0446	1.89
																0
1	1309	Timmins	4.65	261.07	263.3	262.15	263.34	0.001687	0.96	6.35	9.04	0.21	12.22	8.72	0.019	2.23
1	1309	2-yr	0.44	261.07	261.57	261.3	261.59	0.002806	0.66	0.66	1.36	0.3	7.95	7.95	0.019	0.5
1	1309	5-yr	1.84	261.07	262.14	261.65	262.22	0.006096	1.26	1.46	1.44	0.4	25.38	25.38	0.019	1.07
1	1309	10-yr	2.39	261.07	262.32	261.76	262.42	0.006825	1.39	1.72	1.46	0.41	30.3	30.3	0.019	1.25
1	1309	20-yr	3.02	261.07	262.52	261.88	262.63	0.007348	1.5	2.01	1.49	0.41	34.58	34.58	0.019	1.45
1	1309	50-yr	3.86	261.07	262.82	262.02	262.92	0.00541	1.45	3.05	4.93	0.36	30.32	20.75	0.019	1.75
1	1309	100-yr	4.49	261.07	263.2	262.12	263.24	0.00217	1.05	5.47	7.99	0.24	14.97	10.63	0.019	2.13

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
																0
1	1298		Culvert													0
																0
1	1287	Timmins	4.65	260.64	262.12		262.27	0.007696	1.89	3.57	6.5	0.51	49.59	32.57	0.0229	1.48
1	1287	2-yr	0.44	260.64	261.03		261.07	0.006375	0.9	0.49	1.32	0.47	15.39	15.39	0.0229	0.39
1	1287	5-yr	1.84	260.64	261.64		261.73	0.006843	1.35	1.38	2.06	0.45	28.91	25	0.0229	1
1	1287	10-yr	2.39	260.64	261.79		261.9	0.006808	1.48	1.8	3.78	0.46	33.33	22.01	0.0229	1.15
1	1287	20-yr	3.02	260.64	261.91		262.03	0.00697	1.61	2.35	5.05	0.48	38.02	23.7	0.0229	1.27
1	1287	50-yr	3.86	260.64	262.03		262.17	0.007349	1.77	3.01	5.88	0.5	44.21	28.38	0.0229	1.39
1	1287	100-yr	4.49	260.64	262.11		262.26	0.007432	1.85	3.51	6.44	0.5	47.54	31.14	0.0229	1.47
																0
1	1281	Timmins	4.65	260.5	261.91	261.89	262.18	0.016721	2.42	2.66	5.8	0.73	86.93	58.07	0.0147	1.41
1	1281	2-yr	0.44	260.5	260.94		261.01	0.011486	1.15	0.38	1.01	0.6	26.04	26.04	0.0147	0.44
1	1281	5-yr	1.84	260.5	261.51		261.66	0.013575	1.73	1.06	1.4	0.63	49.8	49.8	0.0147	1.01
1	1281	10-yr	2.39	260.5	261.62	261.4	261.81	0.015924	1.95	1.28	3.45	0.68	62.04	39.65	0.0147	1.12
1	1281	20-yr	3.02	260.5	261.72	261.53	261.94	0.01674	2.12	1.66	4.23	0.71	71.51	46.25	0.0147	1.22
1	1281	50-yr	3.86	260.5	261.83	261.79	262.07	0.016263	2.27	2.22	5.21	0.71	78.45	51.3	0.0147	1.33
1	1281	100-yr	4.49	260.5	261.89	261.87	262.16	0.017599	2.44	2.5	5.59	0.75	89.15	59.11	0.0147	1.39
																0
1	1253	Timmins	4.65	260.1	261.47	261.46	261.72	0.016439	2.42	2.86	6.15	0.77	86.44	61.06	0.0153	1.37
1	1253	2-yr	0.44	260.1	260.59		260.67	0.013444	1.23	0.36	0.96	0.64	29.71	29.71	0.0153	0.49
1	1253	5-yr	1.84	260.1	261.17	260.95	261.31	0.011601	1.65	1.32	4.02	0.61	44.72	28.29	0.0153	1.07
1	1253	10-yr	2.39	260.1	261.29	261.16	261.43	0.010808	1.72	1.85	4.93	0.6	46.6	31.26	0.0153	1.19
1	1253	20-yr	3.02	260.1	261.36	261.28	261.52	0.012388	1.93	2.17	5.37	0.65	57.45	39.2	0.0153	1.26
1	1253	50-yr	3.86	260.1	261.4	261.38	261.62	0.016282	2.29	2.42	5.66	0.75	79.23	54.82	0.0153	1.3
1	1253	100-yr	4.49	260.1	261.5	261.44	261.7	0.013533	2.23	3.03	6.33	0.7	73.08	51.96	0.0153	1.4
																0
1	1221	Timmins	4.65	259.6	261.13	260.99	261.29	0.009745	2.01	3.61	6.85	0.6	57.5	41.6	0.0103	1.53
1	1221	2-yr	0.44	259.6	260.09	260	260.18	0.016975	1.34	0.33	0.91	0.71	35.82	35.82	0.0103	0.49
1	1221	5-yr	1.84	259.6	260.57	260.48	260.79	0.022374	2.1	0.91	2.4	0.83	75.36	55.55	0.0103	0.97
1	1221	10-yr	2.39	259.6	260.67	260.67	260.92	0.022364	2.26	1.23	3.51	0.85	84.13	56.65	0.0103	1.07
1	1221	20-yr	3.02	259.6	260.82	260.79	261.04	0.017692	2.19	1.81	4.46	0.77	75.71	54.07	0.0103	1.22
1	1221	50-yr	3.86	259.6	261.31		261.37	0.003288	1.29	4.96	7.89	0.36	22.54	17.02	0.0103	1.71
1	1221	100-yr	4.49	259.6	261.42		261.48	0.003028	1.31	5.85	8.52	0.35	22.48	17.29	0.0103	1.82
																0
1	1187	Timmins	4.65	259.25	260.7		260.92	0.011797	2.06	2.26	1.95	0.61	62.63	62.63	0.0118	1.45
1	1187	2-yr	0.44	259.25	259.53		259.61	0.016156	1.25	0.35	1.32	0.77	31.84	31.84	0.0118	0.28
1	1187	5-yr	1.84	259.25	260		260.16	0.014629	1.8	1.02	1.57	0.71	53.96	53.96	0.0118	0.75
1	1187	10-yr	2.39	259.25	260.21		260.37	0.011423	1.75	1.37	1.69	0.62	48.55	48.55	0.0118	0.96
1	1187	20-yr	3.02	259.25	260.45		260.6	0.009038	1.69	1.79	1.82	0.54	43.39	43.39	0.0118	1.2
1	1187	50-yr	3.86	259.25	261.23		261.28	0.002044	1.08	4.56	6.62	0.27	15.3	10.09	0.0118	1.98
1	1187	100-yr	4.49	259.25	261.33		261.39	0.002087	1.14	5.31	7.33	0.27	16.64	11.08	0.0118	2.08
																0
1	1145	Timmins	4.65	258.75	260.8		260.81	0.00032	0.58	11.19	11.75	0.14	3.81	2.67	0.0226	2.05
1	1145	2-yr	0.44	258.75	259.11		259.16	0.007406	0.95	0.46	1.46	0.54	17.58	17.58	0.0226	0.36
1	1145	5-yr	1.84	258.75	260.01		260.03	0.000833	0.65	3.68	7.17	0.2	5.66	3.62	0.0226	1.26
1	1145	10-yr	2.39	258.75	260.25		260.26	0.000496	0.57	5.61	8.61	0.16	4.14	2.77	0.0226	1.5
1	1145	20-yr	3.02	258.75	260.51		260.52	0.000321	0.52	7.98	10.05	0.13	3.21	2.21	0.0226	1.76
1	1145	50-yr	3.86	258.75	261.25		261.26	0.000075	0.33	17.19	14.92	0.07	1.11	0.77	0.0226	2.5
1	1145	100-yr	4.49	258.75	261.36		261.37	0.00008	0.35	18.87	15.77	0.07	1.25	0.86	0.0226	2.61
																0
1	1135	Timmins	6.41	258.52	260.69	259.68	260.8	0.003841	1.49	4.87	6.66	0.34	29.13	18.47	0.0072	2.17
1	1135	2-yr	0.63	258.52	259.09	258.78	259.12	0.002344	0.68	0.93	1.72	0.29	7.92	7.92	0.0072	0.57
1	1135	5-yr	3.3	258.52	259.9	259.28	260	0.004958	1.36	2.42	1.96	0.39	27.12	27.12	0.0072	1.38
1	1135	10-yr	4.23	258.52	260.13	259.41	260.24	0.005275	1.47	2.87	2.03	0.4	30.98	30.98	0.0072	1.61
1	1135	20-yr	5.29	258.52	260.37	259.54	260.49	0.005432	1.57	3.38	2.83	0.4	34.33	30.16	0.0072	1.85
1	1135	50-yr	6.77	258.52	261.23	259.72	261.25	0.000914	0.86	13.25	40.88	0.17	8.87	2.68	0.0072	2.71
1	1135	100-yr	7.93	258.52	261.34	259.85	261.36	0.000705	0.78	18.77	49.5	0.15	7.17	2.46	0.0072	2.82
																0
1	1064		Culvert													0
																0
1	552	Timmins	6.41	254.25	255.61	255.31	255.86	0.010546	2.21	3.28	7.24	0.65	67.77	36.89	0.0119	1.36
1	552	2-yr	0.63	254.25	254.73		254.75	0.002822	0.72	0.88	1.97	0.34	9.01	9.01	0.0119	0.48
1	552	5-yr	3.3	254.25	255.28		255.41	0.007229	1.6	2.06	2.27	0.54	37.81	37.81	0.0119	1.03
1	552	10-yr	4.23	254.25	255.4		255.57	0.008629	1.82	2.33	2.34	0.58	47.97	47.97	0.0119	1.15
1	552	20-yr	5.29	254.25	255.51	255.18	255.72	0.010145	2.04	2.59	2.4	0.63	59.42	59.42	0.0119	1.26
1	552	50-yr	6.77	254.25	255.66	255.34	255.91	0.009923	2.21	3.66	7.77	0.63	66.47	36.54	0.0119	1.41
1	552	100-yr	7.93	254.25	255.75	255.46	256.01	0.010286	2.35	4.34	8.67	0.65	73.57	41.11	0.0119	1.5
																0
1	529	Timmins	6.41	253.98	255.48	255.21	255.62	0.006722	2.03	6.32	12.78	0.57	53.16	30.05	0.0067	1.5
1	529	2-yr	0.63	253.98	254.59	254.42	254.64	0.007604	1.04	0.62	3.17	0.53	20.02	12	0.0067	0.61
1	529	5-yr	3.3	253.98	255.15	254.93	255.25	0.006196	1.59	3.36	7.08	0.52	36.26	25.16	0.0067	1.17
1	529	10-yr	4.23	253.98	255.27	255.03	255.37	0.006064	1.71	4.26	8.24	0.53	39.96	27.29	0.0067	1.29
1	529	20-yr	5.29	253.98	255.39	255.13	255.5	0.005822	1.8	5.36	9.63	0.53	42.77	28.58	0.0067	1.41
1	529	50-yr	6.77	253.98	255.54	255.24	255.68	0.006362	2.03	7.16	16	0.56	52.62	26.11	0.0067	1.56
1	529	100-yr	7.93	253.98	255.66	255.33	255.78	0.005364	1.98	9.36	20.03	0.52	48.31	23.29	0.0067	1.68
																0
1	502	Timmins	8.35	253.8	255	255	255.32	0.012577	3.1	5.39	9.22	0.94	117.24	68.74	0.0153	1.2
1	502	2-yr	0.79	253.8	254.23	254.21	254.34	0.014569	1.51	0.61	2.92	0.83	41.39	27.49	0.0153	0.43
1	502	5-yr	4.35	253.8	254.71	254.71	254.95	0.013109	2.57	3.01	6.92	0.91	89.61	53.04	0.0153	0.91
1	502	10-yr	5.6	253.8	254.81	254.81	255.08	0.012703	2.75	3.81	7.76	0.92	98.42	58.06	0.0153	1.01

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
1	502	20-yr	7.03	253.8	254.92	254.92	255.21	0.012583	2.94	4.65	8.57	0.93	108.49	63.8	0.0153	1.12
1	502	50-yr	9.12	253.8	255.04	255.04	255.37	0.012757	3.2	5.78	9.54	0.95	123.39	72.31	0.0153	1.24
1	502	100-yr	10.8	253.8	255.14	255.14	255.49	0.012424	3.33	6.76	10.3	0.95	130.44	76.27	0.0153	1.34
																0
1	481	Timmins	8.35	253.47	254.97		255.01	0.002156	1.13	9.71	13.67	0.32	16.56	13.85	0.0022	1.5
1	481	2-yr	0.79	253.47	254.2		254.22	0.002121	0.63	1.76	7.57	0.28	6.93	4.34	0.0022	0.73
1	481	5-yr	4.35	253.47	254.71		254.74	0.001751	0.87	6.48	11.36	0.28	10.73	8.93	0.0022	1.24
1	481	10-yr	5.6	253.47	254.83		254.86	0.001742	0.93	7.82	12.37	0.28	11.86	9.9	0.0022	1.36
1	481	20-yr	7.03	253.47	254.91		254.94	0.001965	1.04	8.85	13.1	0.3	14.33	11.98	0.0022	1.44
1	481	50-yr	9.12	253.47	255		255.05	0.002288	1.18	10.15	13.96	0.33	18.01	15.06	0.0022	1.53
1	481	100-yr	10.8	253.47	255.09		255.14	0.00237	1.25	11.37	14.72	0.34	19.87	16.61	0.0022	1.62
																0
1	453	Timmins	8.35	253.41	254.7	254.7	254.89	0.010496	2.44	5.5	13.71	0.75	78.14	39.07	0.0291	1.29
1	453	2-yr	0.79	253.41	253.9	253.9	254.06	0.027245	1.78	0.45	1.41	1.01	61.88	61.88	0.0291	0.49
1	453	5-yr	4.35	253.41	254.43	254.43	254.62	0.013033	2.23	2.68	6.87	0.8	72.48	44.94	0.0291	1.02
1	453	10-yr	5.6	253.41	254.48	254.48	254.73	0.016106	2.59	3.03	7.34	0.9	95.09	59.07	0.0291	1.07
1	453	20-yr	7.03	253.41	254.65	254.65	254.83	0.010068	2.31	4.83	13.11	0.73	71.43	34.32	0.0291	1.24
1	453	50-yr	9.12	253.41	254.74	254.73	254.92	0.010059	2.44	6.03	14.11	0.74	77.56	39.9	0.0291	1.33
1	453	100-yr	10.8	253.41	254.94		255.04	0.004906	1.91	9.17	16.34	0.53	44.9	25.68	0.0291	1.53
																0
1	439	Timmins	8.35	253.01	254.71	254.28	254.73	0.000993	0.91	16.57	30.31	0.24	9.86	5.12	0	1.7
1	439	2-yr	0.79	253.01	253.71	253.5	253.76	0.00467	0.94	0.96	3.63	0.43	15.22	10.15	0	0.7
1	439	5-yr	4.35	253.01	254.3	254.05	254.35	0.002628	1.19	6.13	18.25	0.37	18.83	8.23	0	1.29
1	439	10-yr	5.6	253.01	254.42	254.16	254.46	0.002221	1.17	8.47	22.4	0.34	17.65	7.9	0	1.41
1	439	20-yr	7.03	253.01	254.51	254.24	254.55	0.00225	1.24	10.63	27.93	0.35	19.22	8.1	0	1.5
1	439	50-yr	9.12	253.01	254.83	254.31	254.84	0.000684	0.79	20.26	32.13	0.2	7.34	4.06	0	1.82
1	439	100-yr	10.8	253.01	254.99	254.38	255	0.000489	0.71	25.49	33.46	0.17	5.77	3.49	0	1.98
																0
1	438		Bridge													0
																0
1	436	Timmins	8.35	252.96	254.65		254.68	0.001754	1.17	13.53	30.49	0.31	16.56	7.33	0.0021	1.69
1	436	2-yr	0.79	252.96	253.69		253.74	0.004763	0.96	0.88	2.74	0.43	15.8	11.66	0.0021	0.73
1	436	5-yr	4.35	252.96	254.22		254.31	0.005159	1.59	4.05	11.68	0.5	34.41	16.24	0.0021	1.26
1	436	10-yr	5.6	252.96	254.34		254.42	0.004329	1.57	5.92	18.29	0.47	32.36	13.06	0.0021	1.38
1	436	20-yr	7.03	252.96	254.44		254.51	0.003837	1.56	7.96	22.31	0.44	31.16	12.85	0.0021	1.48
1	436	50-yr	9.12	252.96	254.77		254.79	0.00108	0.97	17.27	31.6	0.24	11.04	5.55	0.0021	1.81
1	436	100-yr	10.8	252.96	254.95		254.96	0.000652	0.81	23.01	32.42	0.19	7.42	4.33	0.0021	1.99
																0
1	422	Timmins	8.35	252.93	254.61		254.65	0.001956	1.22	9.95	13.69	0.32	18.15	12.92	0.0248	1.68
1	422	2-yr	0.79	252.93	253.54	253.42	253.62	0.011653	1.29	0.64	4.38	0.66	30.86	14.44	0.0248	0.61
1	422	5-yr	4.35	252.93	254.18		254.23	0.003177	1.23	4.95	9.58	0.39	20.85	14.6	0.0248	1.25
1	422	10-yr	5.6	252.93	254.31		254.36	0.002992	1.29	6.22	10.91	0.38	22	15.31	0.0248	1.38
1	422	20-yr	7.03	252.93	254.4		254.46	0.003163	1.4	7.28	11.87	0.4	25.15	17.5	0.0248	1.47
1	422	50-yr	9.12	252.93	254.73		254.77	0.001509	1.13	11.66	14.5	0.29	15.18	11.05	0.0248	1.8
1	422	100-yr	10.8	252.93	254.91		254.94	0.001184	1.08	14.41	15.74	0.26	13.28	9.89	0.0248	1.98
																0
1	392	Timmins	8.35	252.2	254.5		254.57	0.003028	1.48	7.86	10.65	0.35	27.16	18.8	0.0272	2.3
1	392	2-yr	0.79	252.2	252.81	252.81	253.02	0.036899	2.05	0.39	0.92	1.01	82.39	82.39	0.0272	0.61
1	392	5-yr	4.35	252.2	253.68	253.68	253.97	0.019276	2.51	2.01	3.93	0.8	95.35	69.15	0.0272	1.48
1	392	10-yr	5.6	252.2	253.83	253.83	254.11	0.0168	2.57	2.67	5.06	0.77	95.35	66.13	0.0272	1.63
1	392	20-yr	7.03	252.2	254.13		254.29	0.008049	2.07	4.49	7.37	0.55	57.36	39.17	0.0272	1.93
1	392	50-yr	9.12	252.2	254.65		254.71	0.002233	1.34	9.55	11.73	0.31	21.68	15.44	0.0272	2.45
1	392	100-yr	10.8	252.2	254.85		254.9	0.001739	1.26	12.01	13.03	0.27	18.6	13.76	0.0272	2.65
																0
1	355	Timmins	8.35	251.2	254.52	252.07	254.53	0.000213	0.59	18.31	15.12	0.1	3.51	2.01	-0.0109	3.32
1	355	2-yr	0.79	251.2	252.52	251.38	252.53	0.000057	0.18	4.44	3.48	0.05	0.42	0.42	-0.0109	1.32
1	355	5-yr	4.35	251.2	253.73	251.77	253.74	0.0002	0.47	10.02	6.98	0.1	2.49	1.85	-0.0109	2.53
1	355	10-yr	5.6	251.2	253.91	251.87	253.93	0.000247	0.55	11.42	8.17	0.11	3.32	2.33	-0.0109	2.71
1	355	20-yr	7.03	251.2	254.2	251.98	254.22	0.00025	0.6	14.13	11.04	0.11	3.72	2.33	-0.0109	3
1	355	50-yr	9.12	251.2	254.66	252.12	254.68	0.000201	0.59	20.55	16.34	0.1	3.46	1.99	-0.0109	3.46
1	355	100-yr	10.8	251.2	254.86	252.23	254.87	0.000205	0.62	23.87	17.85	0.1	3.73	2.19	-0.0109	3.66
																0
1	344		Culvert													0
																0
1	337	Timmins	8.35	251.4	254.51		254.51	0.000109	0.48	23.59	15.66	0.09	2.18	1.38	0.0048	3.11
1	337	2-yr	0.79	251.4	252.51		252.51	0.000071	0.19	4.12	3.96	0.06	0.5	0.5	0.0048	1.11
1	337	5-yr	4.35	251.4	253.63		253.64	0.000142	0.44	12.15	10.56	0.09	2.02	1.31	0.0048	2.23
1	337	10-yr	5.6	251.4	253.86		253.87	0.000148	0.48	14.79	11.92	0.1	2.35	1.51	0.0048	2.46
1	337	20-yr	7.03	251.4	254.19		254.2	0.00013	0.49	18.92	13.71	0.09	2.34	1.49	0.0048	2.79
1	337	50-yr	9.12	251.4	254.66		254.67	0.000102	0.48	26.15	16.71	0.09	2.15	1.35	0.0048	3.26
1	337	100-yr	10.8	251.4	254.86		254.87	0.000107	0.51	29.52	18.01	0.09	2.39	1.5	0.0048	3.46
																0
1	316	Timmins	8.35	251.3	254.5		254.51	0.000203	0.56	20.96	14.61	0.11	3.17	2.51	0.0101	3.2
1	316	2-yr	0.79	251.3	252.48		252.5	0.001248	0.6	1.5	3.24	0.21	5.56	4.14	0.0101	1.18
1	316	5-yr	4.35	251.3	253.62		253.63	0.000436	0.63	9.64	10.71	0.15	4.68	3.34	0.0101	2.32
1	316	10-yr	5.6	251.3	253.86		253.87	0.000382	0.64	12.33	11.97	0.14	4.61	3.38	0.0101	2.56
1	316	20-yr	7.03	251.3	254.18		254.19	0.000278	0.6	16.47	13.4	0.12	3.86	2.94	0.0101	2.88
1	316	50-yr	9.12	251.3	254.66		254.67	0.000181	0.54	23.33	15.19	0.1	2.99	2.39	0.0101	3.36
1	316	100-yr	10.8	251.3	254.85		254.86	0.000182	0.57	26.35	15.93	0.1	3.2	2.59	0.0101	3.55
																0
1	296	Timmins	8.35	251.1	254.5		254.51	0.000143	0.45	25.11	17.56	0.08	2.11	1.79	0	3.4

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
1	296	2-yr	0.79	251.1	252.47		252.48	0.000642	0.45	2.08	4.59	0.14	3.12	2.13	0	1.37
1	296	5-yr	4.35	251.1	253.61		253.62	0.000284	0.5	11.83	12.33	0.11	2.95	2.31	0	2.51
1	296	10-yr	5.6	251.1	253.85		253.86	0.000256	0.51	14.94	13.82	0.11	2.96	2.37	0	2.75
1	296	20-yr	7.03	251.1	254.18		254.19	0.000192	0.48	19.76	15.71	0.09	2.53	2.09	0	3.08
1	296	50-yr	9.12	251.1	254.66		254.66	0.000129	0.44	27.97	18.48	0.08	1.99	1.7	0	3.56
1	296	100-yr	10.8	251.1	254.85		254.86	0.000129	0.46	31.68	19.6	0.08	2.12	1.83	0	3.75
																0
1	291	Timmins	8.35	251.1	254.5	251.97	254.51	0.000118	0.45	22.28	13.47	0.08	2.01	1.45	0.0094	3.4
1	291	2-yr	0.79	251.1	252.48	251.31	252.48	0.00004	0.15	5.38	4.62	0.04	0.29	0.29	0.0094	1.38
1	291	5-yr	4.35	251.1	253.61	251.71	253.62	0.000123	0.37	12.77	7.9	0.08	1.52	1.31	0.0094	2.51
1	291	10-yr	5.6	251.1	253.85	251.8	253.86	0.000142	0.42	14.76	9.89	0.09	1.9	1.47	0.0094	2.75
1	291	20-yr	7.03	251.1	254.18	251.89	254.18	0.000134	0.44	18.26	11.61	0.09	2.04	1.52	0.0094	3.08
1	291	50-yr	9.12	251.1	254.65	252.02	254.66	0.000112	0.45	24.47	14.24	0.08	2.01	1.45	0.0094	3.55
1	291	100-yr	10.8	251.1	254.85	252.11	254.86	0.000121	0.49	27.42	16.31	0.08	2.3	1.57	0.0094	3.75
																0
1	280		Culvert													0
																0
1	269	Timmins	8.35	250.9	253.55		253.58	0.000487	0.75	12.11	8.3	0.16	6.16	4.64	-0.0118	2.65
1	269	2-yr	0.79	250.9	252.47		252.47	0.000033	0.14	5.8	4.51	0.04	0.25	0.24	-0.0118	1.57
1	269	5-yr	4.35	250.9	253.36		253.37	0.000182	0.43	10.63	7.15	0.09	2.11	1.69	-0.0118	2.46
1	269	10-yr	5.6	250.9	253.43		253.44	0.000269	0.54	11.13	7.54	0.11	3.23	2.52	-0.0118	2.53
1	269	20-yr	7.03	250.9	253.51		253.53	0.000372	0.64	11.74	8.02	0.14	4.62	3.53	-0.0118	2.61
1	269	50-yr	9.12	250.9	253.58		253.62	0.000553	0.8	12.37	8.51	0.17	7.09	5.3	-0.0118	2.68
1	269	100-yr	10.8	250.9	253.65		253.69	0.000702	0.92	12.9	8.96	0.19	9.23	6.76	-0.0118	2.75
																0
1	252	Timmins	8.35	251.1	253.52		253.56	0.001575	1.11	9.88	10.41	0.25	15.06	12.13	-0.0084	2.42
1	252	2-yr	0.79	251.1	252.45		252.46	0.000753	0.48	1.92	4.21	0.15	3.49	2.38	-0.0084	1.35
1	252	5-yr	4.35	251.1	253.35		253.36	0.00071	0.71	8.14	9.54	0.16	6.21	4.87	-0.0084	2.25
1	252	10-yr	5.6	251.1	253.41		253.43	0.000978	0.85	8.74	9.86	0.19	8.84	7	-0.0084	2.31
1	252	20-yr	7.03	251.1	253.48		253.52	0.001246	0.98	9.49	10.22	0.22	11.69	9.37	-0.0084	2.38
1	252	50-yr	9.12	251.1	253.55		253.6	0.001744	1.18	10.17	10.54	0.26	16.9	13.67	-0.0084	2.45
1	252	100-yr	10.8	251.1	253.6		253.66	0.002108	1.32	10.76	10.79	0.29	20.96	17.1	-0.0084	2.5
																0
1	231	Timmins	8.35	251.28	253.52		253.53	0.000437	0.83	17.22	18.29	0.19	7.08	3.88	0.0036	2.24
1	231	2-yr	0.79	251.28	252.45		252.45	0.00019	0.34	3.49	7.48	0.11	1.46	0.81	0.0036	1.17
1	231	5-yr	4.35	251.28	253.34		253.35	0.000193	0.52	14.2	16.52	0.12	2.86	1.56	0.0036	2.06
1	231	10-yr	5.6	251.28	253.41		253.42	0.000268	0.63	15.24	17.17	0.15	4.11	2.24	0.0036	2.13
1	231	20-yr	7.03	251.28	253.48		253.49	0.000344	0.73	16.53	17.91	0.17	5.48	3	0.0036	2.2
1	231	50-yr	9.12	251.28	253.55		253.56	0.000484	0.89	17.73	18.55	0.2	7.96	4.37	0.0036	2.27
1	231	100-yr	10.8	251.28	253.6		253.62	0.000586	0.99	18.76	19.01	0.22	9.88	5.45	0.0036	2.32
																0
1	216	Timmins	8.35	251.23	253.52	252.45	253.53	0.000327	0.64	21.58	25.2	0.14	4.41	2.64	0.0167	2.29
1	216	2-yr	0.79	251.23	252.45	251.74	252.45	0.000152	0.26	4.07	8.01	0.09	0.97	0.68	0.0167	1.22
1	216	5-yr	4.35	251.23	253.34	252.2	253.35	0.000161	0.42	17.35	23.45	0.1	1.99	1.12	0.0167	2.11
1	216	10-yr	5.6	251.23	253.41	252.29	253.41	0.000215	0.5	18.82	24.17	0.12	2.74	1.58	0.0167	2.18
1	216	20-yr	7.03	251.23	253.48	252.38	253.49	0.000263	0.57	20.63	24.85	0.13	3.49	2.06	0.0167	2.25
1	216	50-yr	9.12	251.23	253.54	252.49	253.56	0.000358	0.67	22.28	25.45	0.15	4.89	2.95	0.0167	2.31
1	216	100-yr	10.8	251.23	253.6	252.58	253.61	0.000422	0.75	23.7	25.95	0.16	5.94	3.64	0.0167	2.37
																0
1	211		Culvert													0
																0
1	195	Timmins	8.35	250.87	252.73	252.73	252.96	0.015418	2.55	4.98	10.7	0.68	92.03	59.08	0.001	1.86
1	195	2-yr	0.79	250.87	251.48		251.63	0.022418	1.71	0.46	0.97	0.79	55.35	55.35	0.001	0.61
1	195	5-yr	4.35	250.87	252.44	252.44	252.67	0.016527	2.26	2.46	6.45	0.68	78.3	47.26	0.001	1.57
1	195	10-yr	5.6	250.87	252.56	252.56	252.78	0.015541	2.35	3.34	8.21	0.67	81.45	49.74	0.001	1.69
1	195	20-yr	7.03	250.87	252.66	252.66	252.89	0.0151	2.44	4.28	9.89	0.67	85.8	53.19	0.001	1.79
1	195	50-yr	9.12	250.87	252.77	252.77	253	0.015125	2.57	5.45	11.21	0.68	93.03	60.97	0.001	1.9
1	195	100-yr	10.8	250.87	252.83	252.83	253.09	0.01661	2.77	6.08	11.86	0.72	106.02	71.22	0.001	1.96
																0
1	183	Timmins	8.35	250.86	252.32		252.38	0.002576	1.59	12.87	18.74	0.44	28.9	16.91	0.0116	1.46
1	183	2-yr	0.79	250.86	251.41		251.47	0.005596	1.1	0.99	4.8	0.53	20.38	10.64	0.0116	0.55
1	183	5-yr	4.35	250.86	251.99		252.05	0.00313	1.45	7.06	15.99	0.46	26.52	13.22	0.0116	1.13
1	183	10-yr	5.6	250.86	252.11		252.17	0.002826	1.48	9.1	17.31	0.44	26.78	14.21	0.0116	1.25
1	183	20-yr	7.03	250.86	252.23		252.28	0.002655	1.54	11.16	18.1	0.44	27.72	15.64	0.0116	1.37
1	183	50-yr	9.12	250.86	252.37		252.43	0.00254	1.62	13.85	19.08	0.44	29.59	17.61	0.0116	1.51
1	183	100-yr	10.8	250.86	252.48		252.54	0.002493	1.68	15.85	19.8	0.44	31.17	19.04	0.0116	1.62
																0
1	170	Timmins	8.35	250.71	252.31		252.34	0.001338	1.25	17.09	21.48	0.32	17.12	10.22	0	1.6
1	170	2-yr	0.79	250.71	251.41		251.42	0.001088	0.61	2.5	9.06	0.25	5.59	2.85	0	0.7
1	170	5-yr	4.35	250.71	251.98		252.01	0.001231	1.02	10.64	18.17	0.3	12.36	6.91	0	1.27
1	170	10-yr	5.6	250.71	252.1		252.13	0.001254	1.1	12.87	19.33	0.31	13.85	8.01	0	1.39
1	170	20-yr	7.03	250.71	252.22		252.25	0.001297	1.18	15.15	20.51	0.32	15.59	9.2	0	1.51
1	170	50-yr	9.12	250.71	252.36		252.4	0.001358	1.29	18.21	22.03	0.33	17.97	10.77	0	1.65
1	170	100-yr	10.8	250.71	252.46		252.5	0.001411	1.37	20.52	23.37	0.34	19.89	11.9	0	1.75
																0
1	144	Timmins	8.35	250.71	251.96	251.96	252.24	0.014306	3.03	5.71	10.77	0.95	117.15	71.01	0.0266	1.25
1	144	2-yr	0.79	250.71	251.21	251.21	251.34	0.018567	1.66	0.61	2.94	0.91	50.59	34.41	0.0266	0.5
1	144	5-yr	4.35	250.71	251.69	251.69	251.91	0.014912	2.53	3.18	7.98	0.92	90.21	55.14	0.0266	0.98
1	144	10-yr	5.6	250.71	251.78	251.78	252.03	0.014668	2.72	4	9.08	0.94	100.06	60.37	0.0266	1.07
1	144	20-yr	7.03	250.71	251.88	251.88	252.14	0.014518	2.9	4.9	10	0.95	109.88	66.52	0.0266	1.17
1	144	50-yr	9.12	250.71	252	252	252.29	0.014336	3.11	6.16	11.23	0.96	122.05	73.74	0.0266	1.29

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
1	144	100-yr	10.8	250.71	252.08	252.08	252.39	0.014496	3.28	7.09	12.14	0.98	132.6	79.54	0.0266	1.37
																0
1	115	Timmins	8.35	249.94	251.5		251.65	0.006961	2.24	7.93	13.86	0.61	62.09	36.73	0.0137	1.56
1	115	2-yr	0.79	249.94	250.54		250.63	0.011544	1.35	0.59	1.9	0.66	32.92	26.37	0.0137	0.6
1	115	5-yr	4.35	249.94	251.21		251.33	0.006795	1.87	4.36	10.06	0.58	47.3	26.7	0.0137	1.27
1	115	10-yr	5.6	249.94	251.31		251.45	0.007041	2.03	5.47	11.45	0.6	53.8	30.71	0.0137	1.37
1	115	20-yr	7.03	249.94	251.42		251.56	0.006998	2.15	6.78	12.9	0.61	58.47	33.84	0.0137	1.48
1	115	50-yr	9.12	249.94	251.55		251.7	0.006916	2.28	8.59	14.25	0.62	63.82	38.46	0.0137	1.61
1	115	100-yr	10.8	249.94	251.64		251.8	0.006871	2.37	9.93	15.01	0.62	67.58	42.04	0.0137	1.7
																0
1	94	Timmins	8.35	249.65	251.3		251.48	0.009547	2.34	6.1	10.16	0.63	71.68	49.48	0.0136	1.65
1	94	2-yr	0.79	249.65	250.35		250.42	0.007922	1.17	0.68	1.29	0.51	24.09	24.09	0.0136	0.7
1	94	5-yr	4.35	249.65	251.07		251.18	0.006829	1.75	4.02	8.03	0.52	42.81	28.75	0.0136	1.42
1	94	10-yr	5.6	249.65	251.15		251.29	0.00797	1.98	4.69	8.8	0.57	53.41	36.13	0.0136	1.5
1	94	20-yr	7.03	249.65	251.25		251.4	0.008386	2.13	5.58	9.73	0.59	60.58	41.35	0.0136	1.6
1	94	50-yr	9.12	249.65	251.33		251.52	0.009954	2.43	6.45	10.43	0.65	76.6	53.27	0.0136	1.68
1	94	100-yr	10.8	249.65	251.4		251.61	0.010743	2.6	7.18	10.93	0.68	86.63	61.3	0.0136	1.75
																0
1	71	Timmins	8.35	249.34	250.98	250.98	251.18	0.018182	2.54	5.56	12.36	0.75	95.54	69.7	0.0138	1.64
1	71	2-yr	0.79	249.34	249.98		250.13	0.023101	1.72	0.46	0.97	0.79	56.5	56.5	0.0138	0.64
1	71	5-yr	4.35	249.34	250.79	250.79	250.95	0.015842	2.1	3.39	10.01	0.68	69.5	44.44	0.0138	1.45
1	71	10-yr	5.6	249.34	250.86	250.86	251.04	0.016026	2.23	4.21	10.92	0.69	75.93	51.88	0.0138	1.52
1	71	20-yr	7.03	249.34	251.17		251.23	0.005007	1.47	8.08	14.84	0.4	30.44	23.7	0.0138	1.83
1	71	50-yr	9.12	249.34	251.01	251.01	251.22	0.018584	2.61	5.92	12.73	0.76	100.02	73.94	0.0138	1.67
1	71	100-yr	10.8	249.34	251.07	251.07	251.29	0.019435	2.75	6.65	13.46	0.78	109.42	82.64	0.0138	1.73
																0
1	50	Timmins	8.35	249.05	250.84		250.87	0.003815	1.2	11.83	35.4	0.32	21.02	11.71	0.0137	1.79
1	50	2-yr	0.79	249.05	249.69		249.78	0.01126	1.32	0.6	1.09	0.57	31.61	31.61	0.0137	0.64
1	50	5-yr	4.35	249.05	250.74	250.32	250.76	0.002708	0.96	8.28	33.98	0.27	13.86	6.05	0.0137	1.69
1	50	10-yr	5.6	249.05	250.93		250.94	0.000836	0.59	15.17	36.4	0.15	4.91	3.2	0.0137	1.88
1	50	20-yr	7.03	249.05	251.19		251.19	0.000298	0.39	24.9	39.18	0.09	2.04	1.74	0.0137	2.14
1	50	50-yr	9.12	249.05	250.86		250.9	0.003853	1.22	12.55	35.62	0.32	21.53	12.47	0.0137	1.81
1	50	100-yr	10.8	249.05	250.89		250.93	0.004265	1.3	13.62	35.94	0.34	24.32	14.85	0.0137	1.84
																0
1	25	Timmins	8.35	248.7	250.68	250.68	250.74	0.007327	1.57	14.17	81.9	0.4	36.83	11.99		1.98
1	25	2-yr	0.79	248.7	249.5	249.15	249.56	0.006491	1.06	0.75	1.1	0.41	19.81	19.81		0.8
1	25	5-yr	4.35	248.7	250	250	250.53	0.044162	3.22	1.35	1.29	1.01	170.23	170.23		1.3
1	25	10-yr	5.6	248.7	250.21	250.21	250.81	0.045572	3.43	1.63	1.38	1.01	188.68	188.68		1.51
1	25	20-yr	7.03	248.7	250.43	250.43	251.1	0.046824	3.63	1.94	1.46	1.01	206.65	206.65		1.73
1	25	50-yr	9.12	248.7	250.68	250.68	250.75	0.008453	1.68	14.38	81.95	0.43	42.56	14.03		1.98
1	25	100-yr	10.8	248.7	250.7	250.7	250.77	0.009368	1.79	15.85	82.29	0.46	47.71	17.06		2
																0
1	843	Timmins	4.58	266.7	267.27	267.27	267.71	0.080434	4.21	2.55	12.97	1.99	295.82	152.36	0.0791	0.57
1	843	2-yr	0.84	266.7	267.13	267.13	267.21	0.016961	1.52	1.2	8.4	0.86	43.29	23.04	0.0791	0.43
1	843	5-yr	1.93	266.7	267.26	267.26	267.35	0.017543	1.91	2.34	10.55	0.92	61.84	37.29	0.0791	0.56
1	843	10-yr	2.68	266.7	267.27	267.27	267.42	0.028454	2.49	2.51	12.56	1.18	103.87	54.71	0.0791	0.57
1	843	20-yr	3.58	266.7	267.28	267.28	267.53	0.047238	3.25	2.6	13.43	1.52	175.16	88.14	0.0791	0.58
1	843	50-yr	4.98	266.7	267.28	267.28	267.78	0.093777	4.56	2.58	13.17	2.14	346.08	176.48	0.0791	0.58
1	843	100-yr	6.21	266.7	267.28	267.28	268.04	0.140481	5.61	2.62	13.59	2.63	522.34	260.88	0.0791	0.58
																0
1	836	Timmins	4.58	266.11	266.96	266.96	267.14	0.019273	2.72	3.89	10.55	1.03	107.44	67.6	0.0513	0.85
1	836	2-yr	0.84	266.11	266.61	266.61	266.7	0.01697	1.61	0.96	5.78	0.86	47.45	26.51	0.0513	0.5
1	836	5-yr	1.93	266.11	266.75	266.75	266.88	0.018151	2.09	1.96	7.91	0.94	71.31	42.64	0.0513	0.64
1	836	10-yr	2.68	266.11	266.82	266.82	266.97	0.019001	2.33	2.52	8.73	0.99	84.7	52.02	0.0513	0.71
1	836	20-yr	3.58	266.11	266.89	266.89	267.05	0.019417	2.55	3.17	9.64	1.02	97.4	60.72	0.0513	0.78
1	836	50-yr	4.98	266.11	266.98	266.98	267.17	0.019388	2.79	4.16	10.87	1.04	111.89	70.56	0.0513	0.87
1	836	100-yr	6.21	266.11	267.05	267.05	267.25	0.019814	2.99	4.92	11.72	1.07	124.85	79.2	0.0513	0.94
																0
1	825	Timmins	4.58	265.58	266.23	266.23	266.37	0.027355	2.67	4.03	13.35	1.18	114.04	79.3	0.0674	0.65
1	825	2-yr	0.84	265.58	265.99	265.99	266.05	0.018486	1.48	1.26	9.56	0.88	42.47	23.38	0.0674	0.41
1	825	5-yr	1.93	265.58	266.09	266.09	266.18	0.021491	1.94	2.32	11.56	0.99	66.32	41.41	0.0674	0.51
1	825	10-yr	2.68	265.58	266.13	266.13	266.24	0.025003	2.23	2.8	12.21	1.09	85.24	55.13	0.0674	0.55
1	825	20-yr	3.58	265.58	266.18	266.18	266.31	0.026004	2.45	3.43	12.84	1.13	98.95	66.7	0.0674	0.6
1	825	50-yr	4.98	265.58	266.25	266.25	266.39	0.026647	2.71	4.32	13.58	1.17	115.74	81.49	0.0674	0.67
1	825	100-yr	6.21	265.58	266.29	266.29	266.46	0.028297	2.95	4.95	14.06	1.22	133.21	95.82	0.0674	0.71
																0
1	812	Timmins	4.58	264.69	265.44	265.44	265.6	0.021761	2.64	4.05	12.58	1.07	105.95	67.08	0.1108	0.75
1	812	2-yr	0.84	264.69	265.15	265.15	265.23	0.01731	1.54	1.09	7.09	0.86	44.41	25.26	0.1108	0.46
1	812	5-yr	1.93	264.69	265.27	265.27	265.38	0.020122	2.04	2.09	9.75	0.98	70.49	41.28	0.1108	0.58
1	812	10-yr	2.68	264.69	265.34	265.34	265.45	0.019434	2.2	2.77	11.03	0.98	78.09	46.73	0.1108	0.65
1	812	20-yr	3.58	264.69	265.39	265.39	265.53	0.020346	2.41	3.43	11.87	1.02	90.92	56.26	0.1108	0.7
1	812	50-yr	4.98	264.69	265.46	265.46	265.62	0.022551	2.74	4.26	12.81	1.1	112.83	71.91	0.1108	0.77
1	812	100-yr	6.21	264.69	265.52	265.52	265.69	0.022197	2.89	5.09	13.69	1.11	121.94	79.07	0.1108	0.83
																0
1	806	Timmins	4.58	264.03	264.84	264.84	265	0.018317	2.67	4.2	12.57	1.02	103.14	58.71	0.0584	0.81
1	806	2-yr	0.84	264.03	264.5	264.5	264.59	0.014977	1.56	1.05	6.46	0.83	43.88	23.06	0.0584	0.47
1	806	5-yr	1.93	264.03	264.64	264.64	264.76	0.016203	2.02	2.12	8.8	0.91	65.86	37.24	0.0584	0.61
1	806	10-yr	2.68	264.03	264.7	264.7	264.84	0.018011	2.3	2.68	9.96	0.98	81.88	46.34	0.0584	0.67
1	806	20-yr	3.58	264.03	264.77	264.77	264.93	0.018028	2.49	3.44	11.38	1	92.27	52.19	0.0584	0.74
1	806	50-yr	4.98	264.03	264.87	264.87	265.03	0.017782	2.7	4.57	13.08	1.01	104.18	59.54	0.0584	0.84
1	806	100-yr	6.21	264.03	264.93	264.93	265.11	0.018333	2.9	5.4	14.12	1.04	116.44	67.31	0.0584	0.9

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
																0
1	795	Timmins	4.58	263.37	264.08	264.08	264.22	0.021431	2.6	4.48	15.49	1.07	102.7	59.82	0.0582	0.71
1	795	2-yr	0.84	263.37	263.83	263.83	263.9	0.013234	1.43	1.34	10	0.77	37.16	16.96	0.0582	0.46
1	795	5-yr	1.93	263.37	263.93	263.93	264.02	0.016679	1.9	2.48	12.28	0.9	60.61	32.45	0.0582	0.56
1	795	10-yr	2.68	263.37	263.98	263.98	264.09	0.018067	2.13	3.13	13.37	0.96	72.93	40.67	0.0582	0.61
1	795	20-yr	3.58	263.37	264.04	264.04	264.15	0.019357	2.35	3.84	14.52	1.01	86.08	49.32	0.0582	0.67
1	795	50-yr	4.98	263.37	264.1	264.1	264.24	0.020995	2.63	4.83	15.99	1.07	104.37	61.23	0.0582	0.73
1	795	100-yr	6.21	263.37	264.15	264.15	264.3	0.022323	2.85	5.61	17.06	1.11	119.42	70.92	0.0582	0.78
																0
1	784	Timmins	4.58	262.71	263.68		263.68	0.000981	0.7	15.93	29.73	0.24	6.59	5.1	0.0676	0.97
1	784	2-yr	0.84	262.71	263.53		263.53	0.000079	0.17	11.72	26.98	0.07	0.44	0.33	0.0676	0.82
1	784	5-yr	1.93	262.71	263.88		263.88	0.00007	0.21	22.27	36.05	0.07	0.58	0.42	0.0676	1.17
1	784	10-yr	2.68	262.71	263.64		263.65	0.0004	0.43	14.98	29.14	0.15	2.58	1.99	0.0676	0.93
1	784	20-yr	3.58	262.71	263.65		263.66	0.000687	0.57	15.19	29.27	0.2	4.48	3.46	0.0676	0.94
1	784	50-yr	4.98	262.71	263.68		263.69	0.001153	0.75	15.98	29.76	0.26	7.76	6	0.0676	0.97
1	784	100-yr	6.21	262.71	263.71		263.72	0.001496	0.88	17.01	30.42	0.3	10.48	8.11	0.0676	1
																0
1	774	Timmins	4.58	262.09	263.68	263.18	263.68	0.0003	0.34	35.69	85.33	0.09	1.66	1.21	-0.0085	1.59
1	774	2-yr	0.84	262.09	263.53	262.63	263.53	0.000023	0.09	24.77	64.56	0.02	0.11	0.08	-0.0085	1.44
1	774	5-yr	1.93	262.09	263.88	263.11	263.88	0.000017	0.09	54.26	97.31	0.02	0.1	0.09	-0.0085	1.79
1	774	10-yr	2.68	262.09	263.64	263.14	263.64	0.000123	0.21	33.04	80.78	0.06	0.66	0.48	-0.0085	1.55
1	774	20-yr	3.58	262.09	263.65	263.16	263.65	0.000211	0.28	33.6	81.82	0.08	1.15	0.84	-0.0085	1.56
1	774	50-yr	4.98	262.09	263.68	263.19	263.68	0.000353	0.37	35.81	85.49	0.1	1.95	1.42	-0.0085	1.59
1	774	100-yr	6.21	262.09	263.71	263.22	263.71	0.000447	0.42	38.84	89.43	0.11	2.54	1.87	-0.0085	1.62
																0
1	767		Culvert													0
																0
1	756	Timmins	7.26	262.24	263.61	263.61	263.67	0.005466	1.09	6.59	64.26	0.36	19.85	5.33	0.0252	1.37
1	756	2-yr	1	262.24	262.89	262.89	263.15	0.040687	2.24	0.45	0.89	1.01	96.41	96.41	0.0252	0.65
1	756	5-yr	3.01	262.24	263.44	263.44	263.88	0.043164	2.91	1.04	1.23	1.01	145.23	145.23	0.0252	1.2
1	756	10-yr	4.11	262.24	263.57	263.57	263.62	0.007205	1.24	4.2	62.76	0.41	25.73	4.59	0.0252	1.33
1	756	20-yr	5.46	262.24	263.59	263.59	263.64	0.006404	1.17	5.26	63.46	0.39	23.04	5.05	0.0252	1.35
1	756	50-yr	7.6	262.24	263.61	263.61	263.67	0.00562	1.11	6.72	64.34	0.36	20.43	5.58	0.0252	1.37
1	756	100-yr	9.45	262.24	263.63	263.63	263.7	0.004624	1.01	8.14	65.02	0.33	16.98	5.5	0.0252	1.39
																0
1	737	Timmins	7.26	261.76	262.69	262.69	262.81	0.021489	2.24	5.49	19.93	0.79	140.54	57.11	0.0268	0.93
1	737	2-yr	1	261.76	262.25	262.25	262.34	0.030063	1.58	0.97	5.81	0.82	91.03	47.15	0.0268	0.49
1	737	5-yr	3.01	261.76	262.44	262.44	262.56	0.029672	2.07	2.41	9.28	0.87	135.27	73.5	0.0268	0.68
1	737	10-yr	4.11	261.76	262.5	262.5	262.64	0.03213	2.29	2.94	9.9	0.92	160.73	91.12	0.0268	0.74
1	737	20-yr	5.46	261.76	262.57	262.57	262.72	0.031357	2.42	3.65	10.58	0.93	174.15	103.18	0.0268	0.81
1	737	50-yr	7.6	261.76	262.69	262.69	262.82	0.023258	2.33	5.52	20.04	0.82	152.4	61.83	0.0268	0.93
1	737	100-yr	9.45	261.76	262.75	262.75	262.88	0.02438	2.49	6.71	30.52	0.85	169.93	51.92	0.0268	0.99
																0
1	724	Timmins	7.26	261.42	262.41		262.46	0.007726	1.41	8.33	17.54	0.48	54.37	35.36	0.0252	0.99
1	724	2-yr	1	261.42	261.89	261.89	261.94	0.024581	1.38	1.27	9.43	0.74	70.4	31.73	0.0252	0.47
1	724	5-yr	3.01	261.42	262.01	262.01	262.11	0.035637	2.02	2.53	11.36	0.93	136.55	76.07	0.0252	0.59
1	724	10-yr	4.11	261.42	262.07	262.06	262.18	0.033914	2.13	3.23	12.31	0.93	146.04	85.38	0.0252	0.65
1	724	20-yr	5.46	261.42	262.28		262.33	0.010142	1.45	6.15	15.66	0.54	60.74	38.4	0.0252	0.86
1	724	50-yr	7.6	261.42	262.43		262.48	0.007527	1.41	8.68	17.81	0.48	54.18	35.38	0.0252	1.01
1	724	100-yr	9.45	261.42	262.53		262.58	0.006709	1.43	10.62	22.99	0.46	53.91	29.97	0.0252	1.11
																0
1	697	Timmins	7.26	260.73	262.39		262.4	0.000755	0.64	19.42	24.45	0.16	9.27	5.78	0.0119	1.66
1	697	2-yr	1	260.73	261.26		261.3	0.013867	1.13	1.35	7.32	0.56	44.95	24.21	0.0119	0.53
1	697	5-yr	3.01	260.73	261.57		261.6	0.006112	1.09	4.42	12.19	0.41	34.97	21.2	0.0119	0.84
1	697	10-yr	4.11	260.73	262.08		262.08	0.000734	0.54	12.64	19.74	0.16	7.2	4.52	0.0119	1.35
1	697	20-yr	5.46	260.73	262.26		262.27	0.000646	0.56	16.51	22.39	0.15	7.29	4.59	0.0119	1.53
1	697	50-yr	7.6	260.73	262.41		262.42	0.00078	0.65	19.89	24.81	0.17	9.7	6.03	0.0119	1.68
1	697	100-yr	9.45	260.73	262.5		262.52	0.000947	0.75	22.46	28.16	0.19	12.51	7.29	0.0119	1.77
																0
1	665	Timmins	7.26	260.35	262.37		262.38	0.000451	0.6	26.51	30.03	0.14	7.49	3.85	0.0048	2.02
1	665	2-yr	1	260.35	260.93		260.97	0.007858	1.04	1.4	5.73	0.46	34.4	18	0.0048	0.58
1	665	5-yr	3.01	260.35	261.47		261.49	0.002008	0.85	6.98	14.77	0.26	18.07	9.09	0.0048	1.12
1	665	10-yr	4.11	260.35	262.06		262.07	0.000343	0.47	18.39	23.63	0.12	4.81	2.57	0.0048	1.71
1	665	20-yr	5.46	260.35	262.25		262.25	0.000351	0.51	23.05	27.11	0.12	5.47	2.88	0.0048	1.9
1	665	50-yr	7.6	260.35	262.39		262.4	0.000472	0.62	27.07	30.52	0.14	7.9	4.04	0.0048	2.04
1	665	100-yr	9.45	260.35	262.48		262.49	0.00058	0.71	30.06	33.36	0.16	10.18	5.05	0.0048	2.13
																0
1	648	Timmins	7.26	260.27	262.36		262.37	0.000475	0.63	29.08	41.04	0.14	8.06	3.26	0	2.09
1	648	2-yr	1	260.27	260.86		260.88	0.003459	0.69	2.34	7.96	0.3	15.24	9.62	0	0.59
1	648	5-yr	3.01	260.27	261.46		261.46	0.001027	0.62	8.64	13.28	0.19	9.62	6.34	0	1.19
1	648	10-yr	4.11	260.27	262.06		262.06	0.000371	0.5	18.7	27.32	0.12	5.34	2.44	0	1.79
1	648	20-yr	5.46	260.27	262.24		262.25	0.000385	0.54	24.49	35.5	0.13	6.14	2.56	0	1.97
1	648	50-yr	7.6	260.27	262.38		262.39	0.000493	0.64	29.83	41.86	0.14	8.44	3.4	0	2.11
1	648	100-yr	9.45	260.27	262.47		262.48	0.000578	0.72	33.91	46.21	0.16	10.33	4.11	0	2.2
																0
1	631	Timmins	7.26	260.27	262.36		262.36	0.000218	0.62	36.54	44	0.14	3.77	1.75	0.025	2.09
1	631	2-yr	1	260.27	260.67	260.67	260.76	0.014434	1.54	1.1	6.8	0.84	42.53	22.06	0.025	0.4
1	631	5-yr	3.01	260.27	261.44		261.45	0.00061	0.69	10.14	15.9	0.21	5.81	3.73	0.025	1.17
1	631	10-yr	4.11	260.27	262.05		262.06	0.000168	0.49	24.51	34.78	0.12	2.48	1.15	0.025	1.78
1	631	20-yr	5.46	260.27	262.24		262.24	0.000173	0.53	31.5	40.62	0.12	2.82	1.3	0.025	1.97
1	631	50-yr	7.6	260.27	262.38		262.38	0.000227	0.63	37.33	44.53	0.14	3.97	1.85	0.025	2.11

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
1	631	100-yr	9.45	260.27	262.47		262.47	0.000274	0.72	41.53	47.2	0.16	5.01	2.34	0.025	2.2
																0
1	611	Timmins	7.26	259.76	262.36	260.95	262.36	0.000183	0.46	39.38	43.64	0.09	2.33	1.56	0.0061	2.6
1	611	2-yr	1	259.76	260.58	260.17	260.62	0.00323	0.87	1.46	8.63	0.33	12.43	4.66	0.0061	0.82
1	611	5-yr	3.01	259.76	261.43	260.71	261.44	0.000379	0.48	12.37	17.42	0.12	3.01	2.42	0.0061	1.67
1	611	10-yr	4.11	259.76	262.05	260.79	262.05	0.000131	0.36	27.63	34.14	0.08	1.46	0.99	0.0061	2.29
1	611	20-yr	5.46	259.76	262.24	260.86	262.24	0.000141	0.39	34.44	39.77	0.08	1.7	1.15	0.0061	2.48
1	611	50-yr	7.6	259.76	262.37	260.96	262.38	0.000192	0.47	40.16	44.21	0.1	2.45	1.65	0.0061	2.61
1	611	100-yr	9.45	259.76	262.46	261.04	262.47	0.000236	0.54	44.31	47.02	0.11	3.13	2.1	0.0061	2.7
																0
1	597		Culvert													0
																0
1	582	Timmins	7.26	259.58	260.93	260.93	261.16	0.012971	2.34	5.16	12.89	0.68	77.43	44.05	0.0047	1.35
1	582	2-yr	1	259.58	260.12		260.19	0.006486	1.12	0.9	1.75	0.5	21.48	21.48	0.0047	0.54
1	582	5-yr	3.01	259.58	260.48	260.28	260.67	0.013358	1.96	1.54	1.88	0.69	59.73	59.73	0.0047	0.9
1	582	10-yr	4.11	259.58	260.61	260.44	260.88	0.016441	2.28	1.8	4.02	0.76	79.36	50.65	0.0047	1.03
1	582	20-yr	5.46	259.58	260.83	260.83	261.03	0.012125	2.14	3.88	11.78	0.65	66.71	33.57	0.0047	1.25
1	582	50-yr	7.6	259.58	260.95	260.95	261.18	0.012925	2.36	5.42	13.1	0.68	78.42	45.43	0.0047	1.37
1	582	100-yr	9.45	259.58	261.02	261.02	261.28	0.014895	2.62	6.35	14.47	0.73	95.38	56.18	0.0047	1.44
																0
1	556	Timmins	7.26	259.46	260.32		260.45	0.019329	2.15	5.46	11.41	0.77	128.9	87.32	0.0251	0.86
1	556	2-yr	1	259.46	259.74	259.74	259.83	0.04163	1.52	0.9	5.06	0.96	93.03	69.39	0.0251	0.28
1	556	5-yr	3.01	259.46	259.94	259.94	260.09	0.04114	2.08	2.08	6.82	1.01	147.63	117.02	0.0251	0.48
1	556	10-yr	4.11	259.46	260.01	260.01	260.19	0.042313	2.31	2.59	7.6	1.05	174.61	134.76	0.0251	0.55
1	556	20-yr	5.46	259.46	260.1	260.1	260.3	0.040173	2.5	3.28	8.61	1.05	194.09	143.19	0.0251	0.64
1	556	50-yr	7.6	259.46	260.36		260.49	0.016892	2.08	5.98	12.02	0.73	118.95	79.46	0.0251	0.9
1	556	100-yr	9.45	259.46	260.6		260.68	0.00852	1.75	9.17	14.41	0.54	77.07	51.41	0.0251	1.14
																0
1	530	Timmins	7.26	258.82	260.25		260.28	0.002081	1.06	11.61	12.93	0.29	25.65	17.52	0.0196	1.43
1	530	2-yr	1	258.82	259.25	259.14	259.29	0.009107	0.97	1.43	6.08	0.49	32.12	20.17	0.0196	0.43
1	530	5-yr	3.01	258.82	259.61		259.65	0.005021	1.1	4.4	9.64	0.4	33.72	21.68	0.0196	0.79
1	530	10-yr	4.11	258.82	259.78		259.82	0.003787	1.09	6.13	10.52	0.36	31.16	20.83	0.0196	0.96
1	530	20-yr	5.46	258.82	259.99		260.02	0.002832	1.08	8.41	11.58	0.32	28.41	19.33	0.0196	1.17
1	530	50-yr	7.6	258.82	260.3		260.33	0.001979	1.06	12.24	13.18	0.28	25.22	17.22	0.0196	1.48
1	530	100-yr	9.45	258.82	260.55		260.58	0.001552	1.04	15.72	14.47	0.26	23.21	15.76	0.0196	1.73
																0
1	504	Timmins	7.26	258.3	259.51	259.51	260.07	0.064102	3.32	2.18	1.94	1	334.3	334.3	0.0206	1.21
1	504	2-yr	1	258.3	258.63	258.63	258.79	0.052921	1.78	0.56	1.75	1	124.85	124.85	0.0206	0.33
1	504	5-yr	3.01	258.3	258.98	258.98	259.31	0.056523	2.54	1.19	1.83	1.01	216.23	216.23	0.0206	0.68
1	504	10-yr	4.11	258.3	259.13	259.13	259.53	0.058538	2.79	1.47	1.86	1	251.81	251.81	0.0206	0.83
1	504	20-yr	5.46	258.3	259.3	259.3	259.77	0.061446	3.06	1.79	1.9	1.01	291.66	291.66	0.0206	1
1	504	50-yr	7.6	258.3	259.54	259.54	260.12	0.06466	3.37	2.25	1.95	1	342.03	342.03	0.0206	1.24
1	504	100-yr	9.45	258.3	259.73	259.73	260.39	0.067804	3.6	2.62	1.99	1	382.73	382.73	0.0206	1.43
																0
1	484	Timmins	7.26	257.88	259.09		259.15	0.005352	1.4	7.87	10.21	0.42	48.92	38.02	0.01	1.21
1	484	2-yr	1	257.88	258.35		258.37	0.006446	0.8	1.79	6.32	0.4	22.32	17	0.01	0.47
1	484	5-yr	3.01	257.88	258.69		258.73	0.005157	1.02	4.23	8.07	0.38	30.41	24.91	0.01	0.81
1	484	10-yr	4.11	257.88	258.82		258.86	0.005112	1.13	5.29	8.81	0.39	35.41	28.33	0.01	0.94
1	484	20-yr	5.46	257.88	258.95		259	0.005191	1.26	6.47	9.48	0.41	41.39	32.64	0.01	1.07
1	484	50-yr	7.6	257.88	259.11		259.18	0.005398	1.42	8.11	10.34	0.42	50.38	39.03	0.01	1.23
1	484	100-yr	9.45	257.88	259.24		259.31	0.005531	1.54	9.44	11.02	0.44	57.24	43.66	0.01	1.36
																0
1	460	Timmins	7.26	257.65	258.62	258.62	258.9	0.023953	2.71	4.06	7.71	0.9	192.83	115.99	0.0131	0.97
1	460	2-yr	1	257.65	258.08		258.15	0.015524	1.22	0.93	3.49	0.62	51.98	37.42	0.0131	0.43
1	460	5-yr	3.01	257.65	258.29	258.28	258.48	0.025659	2.1	1.89	5.33	0.86	133.5	83.56	0.0131	0.64
1	460	10-yr	4.11	257.65	258.39	258.39	258.62	0.025763	2.33	2.45	6.08	0.89	155.89	95.51	0.0131	0.74
1	460	20-yr	5.46	257.65	258.5	258.5	258.75	0.024758	2.51	3.17	6.91	0.89	173.28	104.37	0.0131	0.85
1	460	50-yr	7.6	257.65	258.65	258.65	258.93	0.023623	2.74	4.24	7.85	0.89	194.8	117.28	0.0131	1
1	460	100-yr	9.45	257.65	258.74	258.74	259.05	0.023864	2.94	5.03	8.38	0.91	216.73	131.5	0.0131	1.09
																0
1	415	Timmins	7.26	257.05	257.95		258.03	0.009323	1.66	8.04	16.52	0.56	72.9	43.7	0.0066	0.9
1	415	2-yr	1	257.05	257.42		257.47	0.013835	1.09	1.34	7.39	0.59	42.92	23.8	0.0066	0.37
1	415	5-yr	3.01	257.05	257.67		257.73	0.010571	1.36	3.85	12.71	0.56	55.96	30.77	0.0066	0.62
1	415	10-yr	4.11	257.05	257.76		257.82	0.010051	1.46	5.03	13.97	0.56	61.08	34.82	0.0066	0.71
1	415	20-yr	5.46	257.05	257.85		257.92	0.009698	1.56	6.37	15.2	0.56	66.79	39.11	0.0066	0.8
1	415	50-yr	7.6	257.05	257.97		258.04	0.009271	1.68	8.34	16.71	0.56	73.95	44.54	0.0066	0.92
1	415	100-yr	9.45	257.05	258.06		258.14	0.009039	1.77	9.89	17.66	0.57	79.34	48.75	0.0066	1.01
																0
1	378	Timmins	7.26	256.81	257.66		257.73	0.007113	1.41	6.95	12.02	0.49	53.39	39.07	0	0.85
1	378	2-yr	1	256.81	257.26		257.27	0.002585	0.55	2.56	9.89	0.27	10.15	6.39	0	0.45
1	378	5-yr	3.01	256.81	257.44		257.47	0.004683	0.93	4.41	10.88	0.38	25.86	18.09	0	0.63
1	378	10-yr	4.11	256.81	257.51		257.55	0.005422	1.08	5.18	11.25	0.42	33.29	23.75	0	0.7
1	378	20-yr	5.46	256.81	257.58		257.63	0.006204	1.23	6	11.61	0.45	42.08	30.47	0	0.77
1	378	50-yr	7.6	256.81	257.68		257.74	0.007271	1.44	7.12	12.08	0.5	55.47	40.66	0	0.87
1	378	100-yr	9.45	256.81	257.75		257.83	0.00805	1.6	7.98	12.43	0.53	66.47	49	0	0.94
																0
1	345	Timmins	7.26	256.81	257.45		257.49	0.006917	1.15	9.07	22	0.46	38.76	27.61	0.0028	0.64
1	345	2-yr	1	256.81	257.12	257.08	257.14	0.007834	0.74	2.31	18.47	0.43	20.69	9.51	0.0028	0.31
1	345	5-yr	3.01	256.81	257.28		257.3	0.005659	0.84	5.44	20.48	0.4	23.06	14.57	0.0028	0.47
1	345	10-yr	4.11	256.81	257.34		257.36	0.005874	0.92	6.58	21	0.41	26.84	17.85	0.0028	0.53
1	345	20-yr	5.46	256.81	257.39		257.42	0.006159	1.01	7.81	21.5	0.43	31.33	21.68	0.0028	0.58

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
1	345	50-yr	7.6	256.81	257.46		257.5	0.007067	1.17	9.28	22.09	0.47	40.2	28.76	0.0028	0.65
1	345	100-yr	9.45	256.81	257.51		257.55	0.008007	1.3	10.28	22.48	0.5	48.76	35.44	0.0028	0.7
																0
1	317	Timmins	7.26	256.73	257.08	257.04	257.16	0.022179	1.34	6.52	29.01	0.74	65.41	48.26	0.0301	0.35
1	317	2-yr	1	256.73	256.73		256.77	0.023846	0.09	1.16	7.49	0.4	1.1	35.99	0.0301	0
1	317	5-yr	3.01	256.73	256.92		256.98	0.030649	1.05	2.94	14.39	0.79	49.06	60.26	0.0301	0.19
1	317	10-yr	4.11	256.73	256.97		257.04	0.029164	1.17	3.63	14.67	0.79	57.28	69.18	0.0301	0.24
1	317	20-yr	5.46	256.73	257.02	256.97	257.1	0.026494	1.28	4.79	28.45	0.78	64.03	43.2	0.0301	0.29
1	317	50-yr	7.6	256.73	257.09		257.17	0.021464	1.34	6.83	29.11	0.73	65.35	48.77	0.0301	0.36
1	317	100-yr	9.45	256.73	257.16		257.23	0.01723	1.34	8.65	29.7	0.67	61.91	48.6	0.0301	0.43
																0
1	286	Timmins	7.26	255.82	256.64		256.71	0.010505	1.67	7.28	13.14	0.59	75.49	55.43	0.0243	0.82
1	286	2-yr	1	255.82	256.15	256.12	256.19	0.015797	1.09	1.5	9.83	0.62	44.31	23.09	0.0243	0.33
1	286	5-yr	3.01	255.82	256.35	256.26	256.41	0.012693	1.37	3.7	11.58	0.61	58.79	38.93	0.0243	0.53
1	286	10-yr	4.11	255.82	256.44		256.5	0.011953	1.47	4.72	12.24	0.6	64.46	44.12	0.0243	0.62
1	286	20-yr	5.46	255.82	256.53		256.6	0.011281	1.57	5.87	12.81	0.6	70.1	49.43	0.0243	0.71
1	286	50-yr	7.6	255.82	256.66		256.73	0.010395	1.68	7.53	13.19	0.59	76.48	56.46	0.0243	0.84
1	286	100-yr	9.45	255.82	256.76		256.84	0.009926	1.77	8.85	13.49	0.59	81.79	61.72	0.0243	0.94
																0
1	259	Timmins	7.26	255.16	255.98	255.98	256.23	0.031899	2.73	3.95	8.02	0.99	208.66	145.8	0.042	0.82
1	259	2-yr	1	255.16	255.5	255.5	255.6	0.03161	1.49	0.86	4.79	0.86	83.85	52.8	0.042	0.34
1	259	5-yr	3.01	255.16	255.71	255.71	255.87	0.032313	2.07	2.03	6.35	0.93	138.13	95.8	0.042	0.55
1	259	10-yr	4.11	255.16	255.79	255.79	255.98	0.032371	2.28	2.56	6.91	0.95	160.44	111.4	0.042	0.63
1	259	20-yr	5.46	255.16	255.88	255.88	256.1	0.032147	2.49	3.18	7.43	0.97	182.94	127.72	0.042	0.72
1	259	50-yr	7.6	255.16	255.99	255.99	256.26	0.031778	2.76	4.1	8.13	0.99	212.69	148.54	0.042	0.83
1	259	100-yr	9.45	255.16	256.08	256.08	256.37	0.031527	2.96	4.85	8.65	1.01	234.84	163.59	0.042	0.92
																0
1	239	Timmins	7.26	254.32	255.18	255.18	255.46	0.032392	2.78	3.79	7.36	0.99	215.37	153.55	0.0231	0.86
1	239	2-yr	1	254.32	254.66	254.66	254.76	0.03463	1.54	0.81	4.03	0.89	90.65	64.05	0.0231	0.34
1	239	5-yr	3.01	254.32	254.88	254.88	255.07	0.03698	2.16	1.86	5.33	0.98	152.82	118.06	0.0231	0.56
1	239	10-yr	4.11	254.32	254.98	254.98	255.19	0.034961	2.36	2.39	5.99	0.98	171.55	127.88	0.0231	0.66
1	239	20-yr	5.46	254.32	255.07	255.07	255.31	0.033446	2.55	3.01	6.65	0.98	191.45	139.03	0.0231	0.75
1	239	50-yr	7.6	254.32	255.21	255.21	255.48	0.031867	2.8	3.95	7.47	0.99	217.58	154.97	0.0231	0.89
1	239	100-yr	9.45	254.32	255.3	255.3	255.61	0.031192	2.99	4.7	7.95	1	238.12	169.42	0.0231	0.98
																0
1	217	Timmins	7.26	253.81	254.78		254.85	0.007974	1.62	7.47	12.03	0.53	67.82	47.04	0	0.97
1	217	2-yr	1	253.81	254.31		254.32	0.003115	0.64	2.46	8.92	0.3	13.35	8.22	0	0.5
1	217	5-yr	3.01	253.81	254.52		254.56	0.005342	1.08	4.58	10.53	0.41	33.2	22.14	0	0.71
1	217	10-yr	4.11	253.81	254.6		254.64	0.006251	1.25	5.41	10.99	0.45	43.16	29.32	0	0.79
1	217	20-yr	5.46	253.81	254.68		254.74	0.007097	1.43	6.34	11.47	0.49	54.28	37.33	0	0.87
1	217	50-yr	7.6	253.81	254.79		254.87	0.008154	1.66	7.66	12.12	0.54	70.49	48.93	0	0.98
1	217	100-yr	9.45	253.81	254.88		254.97	0.008809	1.83	8.7	12.58	0.57	82.83	57.85	0	1.07
																0
1	192	Timmins	7.26	253.81	254.64		254.68	0.005189	1.19	10.85	19.9	0.42	37.98	27.32	0	0.83
1	192	2-yr	1	253.81	254.25		254.25	0.002156	0.49	3.71	15.5	0.24	8.09	4.98	0	0.44
1	192	5-yr	3.01	253.81	254.42		254.44	0.003725	0.81	6.64	17.78	0.34	19.85	13.44	0	0.61
1	192	10-yr	4.11	253.81	254.48		254.5	0.004488	0.95	7.73	18.48	0.37	26.31	18.13	0	0.67
1	192	20-yr	5.46	253.81	254.55		254.58	0.004911	1.07	9.1	19.14	0.4	32.01	22.56	0	0.74
1	192	50-yr	7.6	253.81	254.66		254.69	0.005301	1.21	11.12	20.01	0.42	39.43	28.43	0	0.85
1	192	100-yr	9.45	253.81	254.74		254.78	0.005411	1.3	12.82	20.74	0.44	44.3	32.28	0	0.93
																0
1	167	Timmins	7.26	253.81	254.49		254.52	0.007639	1.25	10.18	22.02	0.49	45.4	34.12	0.0168	0.68
1	167	2-yr	1	253.81	254.08	254.08	254.13	0.022991	1.15	1.76	19.27	0.73	52.91	20.36	0.0168	0.27
1	167	5-yr	3.01	253.81	254.19		254.24	0.024728	1.51	3.86	20.05	0.8	80.56	46.14	0.0168	0.38
1	167	10-yr	4.11	253.81	254.29		254.33	0.013042	1.29	5.89	20.74	0.6	54.09	35.83	0.0168	0.48
1	167	20-yr	5.46	253.81	254.39		254.42	0.009219	1.23	7.95	21.41	0.52	46.32	33.13	0.0168	0.58
1	167	50-yr	7.6	253.81	254.5		254.53	0.007919	1.29	10.37	22.07	0.5	47.65	35.93	0.0168	0.69
1	167	100-yr	9.45	253.81	254.59		254.63	0.006862	1.31	12.5	22.51	0.48	47.16	36.74	0.0168	0.78
																0
1	151	Timmins	7.26	253.54	254.44		254.46	0.002194	0.8	15.85	29.57	0.27	16.92	11.34	0.2134	0.9
1	151	2-yr	1	253.54	253.81		253.81	0.003514	0.43	2.9	10.05	0.28	7.57	9.62	0.2134	0.27
1	151	5-yr	3.01	253.54	254.14		254.15	0.002164	0.6	7.81	22.02	0.25	10.89	7.39	0.2134	0.6
1	151	10-yr	4.11	253.54	254.24		254.25	0.002152	0.66	10.15	24.97	0.26	12.7	8.43	0.2134	0.7
1	151	20-yr	5.46	253.54	254.34		254.35	0.002147	0.73	12.82	27.91	0.26	14.58	9.51	0.2134	0.8
1	151	50-yr	7.6	253.54	254.45		254.47	0.002339	0.83	16.01	29.65	0.28	18.16	12.19	0.2134	0.91
1	151	100-yr	9.45	253.54	254.55		254.57	0.002273	0.88	19.04	30.97	0.28	19.63	13.48	0.2134	1.01
																0
1	143	Timmins	7.26	251.74	254.44	253.05	254.45	0.000389	0.72	21.87	23.05	0.14	5.53	3.33	0.0183	2.7
1	143	2-yr	1	251.74	253.81	252.07	253.81	0.000029	0.16	11.04	12.78	0.04	0.31	0.21	0.0183	2.07
1	143	5-yr	3.01	251.74	254.14	252.43	254.14	0.000125	0.38	15.91	17.28	0.08	1.57	1.01	0.0183	2.4
1	143	10-yr	4.11	251.74	254.24	252.58	254.24	0.000188	0.48	17.68	18.84	0.1	2.46	1.56	0.0183	2.5
1	143	20-yr	5.46	251.74	254.34	252.8	254.35	0.00027	0.59	19.64	20.82	0.12	3.69	2.28	0.0183	2.6
1	143	50-yr	7.6	251.74	254.44	253.08	254.46	0.000422	0.75	21.98	23.16	0.15	6.01	3.61	0.0183	2.7
1	143	100-yr	9.45	251.74	254.54	253.23	254.56	0.000535	0.87	24.27	25.13	0.17	7.89	4.69	0.0183	2.8
																0
1	139		Culvert													0
																0
1	120	Timmins	7.26	251.33	252.44	252.44	252.91	0.023312	3.04	2.39	2.56	1.01	133.05	133.05	0.0285	1.11
1	120	2-yr	1	251.33	251.64	251.64	251.79	0.023823	1.72	0.58	1.95	1.01	56.93	56.93	0.0285	0.31
1	120	5-yr	3.01	251.33	251.97	251.97	252.26	0.022996	2.39	1.26	2.2	1.01	92.12	92.12	0.0285	0.64
1	120	10-yr	4.11	251.33	252.11	252.11	252.46	0.023051	2.6	1.58	2.31	1.01	105.16	105.16	0.0285	0.78

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
1	120	20-yr	5.46	251.33	252.26	252.26	252.67	0.02316	2.82	1.94	2.43	1.01	118.43	118.43	0.0285	0.93
1	120	50-yr	7.6	251.33	252.47	252.47	252.96	0.023335	3.08	2.47	2.59	1.01	135.5	135.5	0.0285	1.14
1	120	100-yr	9.45	251.33	252.86	252.86	253.14	0.011045	2.45	5.56	15.15	0.7	79.94	35.19	0.0285	1.53
																0
1	104	Timmins	7.26	250.86	251.81	251.81	251.97	0.012368	2.2	6.88	20.38	0.81	69.73	39.35	0.0438	0.95
1	104	2-yr	1	250.86	251.21	251.21	251.36	0.022548	1.73	0.58	1.92	1	56.57	56.57	0.0438	0.35
1	104	5-yr	3.01	250.86	251.64	251.64	251.75	0.008605	1.61	3.45	18.95	0.66	40.05	14.78	0.0438	0.78
1	104	10-yr	4.11	250.86	251.7	251.7	251.82	0.009421	1.77	4.62	19.45	0.7	47.15	21.1	0.0438	0.84
1	104	20-yr	5.46	250.86	251.76	251.76	251.89	0.010418	1.94	5.78	19.94	0.74	55.58	28.46	0.0438	0.9
1	104	50-yr	7.6	250.86	251.83	251.83	251.98	0.01213	2.2	7.21	20.51	0.8	69.45	40.18	0.0438	0.97
1	104	100-yr	9.45	250.86	251.88	251.88	252.05	0.01337	2.38	8.29	20.93	0.85	80.29	49.85	0.0438	1.02
																0
1	91	Timmins	7.26	250.31	251.45	251.45	251.6	0.009277	2.06	7.83	25.88	0.7	59.01	26.6	0.0362	1.14
1	91	2-yr	1	250.31	250.7	250.7	250.86	0.022847	1.78	0.56	1.76	1	59.07	59.07	0.0362	0.39
1	91	5-yr	3.01	250.31	251.12	251.12	251.32	0.01329	2	1.89	9.28	0.81	61.64	24.57	0.0362	0.81
1	91	10-yr	4.11	250.31	251.26	251.26	251.43	0.010139	1.93	3.73	16.87	0.72	54.72	20.98	0.0362	0.95
1	91	20-yr	5.46	250.31	251.36	251.36	251.51	0.009531	1.99	5.62	22.08	0.71	56.23	22.9	0.0362	1.05
1	91	50-yr	7.6	250.31	251.46	251.46	251.61	0.009385	2.09	8.14	26.1	0.71	60.25	27.74	0.0362	1.15
1	91	100-yr	9.45	250.31	251.51	251.51	251.67	0.010474	2.26	9.47	26.85	0.75	69.83	35	0.0362	1.2
																0
1	67	Timmins	7.26	249.43	250.8	250.8	251.07	0.012416	2.42	4.11	9.66	0.76	80.64	44.83	0.046	1.37
1	67	2-yr	1	249.43	249.81	249.81	249.98	0.024291	1.82	0.55	1.65	1.01	62.2	62.2	0.046	0.38
1	67	5-yr	3.01	249.43	250.18	250.18	250.48	0.023442	2.45	1.23	2.05	1.01	96.14	96.14	0.046	0.75
1	67	10-yr	4.11	249.43	250.33	250.33	250.68	0.023277	2.64	1.55	2.21	1.01	107.84	107.84	0.046	0.9
1	67	20-yr	5.46	249.43	250.49	250.49	250.9	0.022941	2.83	1.93	2.38	1	118.68	118.68	0.046	1.06
1	67	50-yr	7.6	249.43	250.83	250.83	251.1	0.012214	2.43	4.37	10.07	0.75	80.73	45.16	0.046	1.4
1	67	100-yr	9.45	249.43	250.95	250.95	251.21	0.01162	2.49	5.69	12.04	0.74	82.77	47.57	0.046	1.52
																0
1	52	Timmins	7.26	248.7	249.94	249.94	250.46	0.026364	3.17	2.29	2.26	1.01	146.17	146.17		1.24
1	52	2-yr	1	248.7	249.5	249.06	249.53	0.002045	0.74	1.35	1.96	0.28	8.72	8.72		0.8
1	52	5-yr	3.01	248.7	249.5	249.42	249.75	0.018477	2.23	1.35	1.96	0.86	78.76	78.76		0.8
1	52	10-yr	4.11	248.7	249.58	249.58	249.96	0.02565	2.73	1.51	2.01	1.01	115.71	115.71		0.88
1	52	20-yr	5.46	248.7	249.75	249.75	250.19	0.026011	2.94	1.85	2.12	1.01	130.29	130.29		1.05
1	52	50-yr	7.6	248.7	249.98	249.98	250.5	0.026417	3.21	2.37	2.28	1.01	148.82	148.82		1.28
1	52	100-yr	9.45	248.7	250.16	250.16	250.74	0.02646	3.38	2.8	2.41	1	160.94	160.94		1.46
																0
1	2474	Timmins	10.57	265.78	267.38		267.41	0.001934	0.98	14.87	17.54	0.25	22.27	14.76	0	1.6
1	2474	2-yr	1.59	265.78	266.48		266.49	0.001302	0.49	3.9	8.19	0.19	7.23	5.42	0	0.7
1	2474	5-yr	7.11	265.78	267.11		267.14	0.002107	0.9	10.55	14.16	0.25	20.13	13.9	0	1.33
1	2474	10-yr	8.91	265.78	267.25		267.29	0.002037	0.95	12.75	16.01	0.25	21.6	14.51	0	1.47
1	2474	20-yr	10.91	265.78	267.4		267.44	0.001907	0.98	15.34	17.85	0.25	22.31	14.76	0	1.62
1	2474	50-yr	13.78	265.78	267.62		267.65	0.001394	0.91	24.39	57.79	0.21	18.51	5.54	0	1.84
1	2474	100-yr	16.24	265.78	267.77		267.79	0.001013	0.82	33.73	70.98	0.19	14.51	4.49	0	1.99
																0
1	2455	Timmins	10.57	265.78	267.31		267.37	0.00273	1.2	14.12	20.66	0.31	32.74	17.28	-0.0017	1.53
1	2455	2-yr	1.59	265.78	266.45		266.46	0.001654	0.54	3.37	6.91	0.21	8.84	6.95	-0.0017	0.67
1	2455	5-yr	7.11	265.78	267.04		267.09	0.002936	1.09	9.36	14.5	0.31	28.92	17.2	-0.0017	1.26
1	2455	10-yr	8.91	265.78	267.19		267.24	0.002891	1.16	11.67	17.38	0.31	31.76	17.8	-0.0017	1.41
1	2455	20-yr	10.91	265.78	267.34		267.39	0.002678	1.2	14.69	21.36	0.31	32.68	17.09	-0.0017	1.56
1	2455	50-yr	13.78	265.78	267.59		267.62	0.001568	1.01	28.32	112.21	0.24	22.18	3.83	-0.0017	1.81
1	2455	100-yr	16.24	265.78	267.76		267.77	0.000734	0.73	48.38	126.6	0.17	11.34	2.71	-0.0017	1.98
																0
1	2431	Timmins	10.57	265.82	267.24		267.29	0.003437	1.23	13.16	19.37	0.33	36.37	21.37	0.0013	1.42
1	2431	2-yr	1.59	265.82	266.41		266.42	0.002049	0.56	3.46	7.85	0.23	9.75	7.97	0.0013	0.59
1	2431	5-yr	7.11	265.82	266.96		267.01	0.00363	1.1	8.81	12.62	0.33	30.95	22.43	0.0013	1.14
1	2431	10-yr	8.91	265.82	267.11		267.16	0.00365	1.19	10.83	15.89	0.34	35.02	22.45	0.0013	1.29
1	2431	20-yr	10.91	265.82	267.27		267.32	0.00336	1.24	13.73	20.21	0.33	36.28	20.95	0.0013	1.45
1	2431	50-yr	13.78	265.82	267.54		267.58	0.002187	1.12	21.82	69.64	0.27	28	6.57	0.0013	1.72
1	2431	100-yr	16.24	265.82	267.73		267.75	0.001141	0.87	36.72	86.1	0.2	16.22	4.64	0.0013	1.91
																0
1	2401	Timmins	10.57	265.78	267.12		267.18	0.003993	1.34	11.79	18	0.37	42.72	24.23	0.0008	1.34
1	2401	2-yr	1.59	265.78	266.32		266.34	0.003538	0.7	2.57	6.85	0.3	15.58	11.66	0.0008	0.54
1	2401	5-yr	7.11	265.78	266.79		266.87	0.006326	1.4	6.95	12.19	0.44	50.96	32.7	0.0008	1.01
1	2401	10-yr	8.91	265.78	266.95		267.03	0.005256	1.41	9.13	14.34	0.42	49.25	30.63	0.0008	1.17
1	2401	20-yr	10.91	265.78	267.15		267.22	0.00375	1.32	12.45	19.18	0.36	41.21	22.64	0.0008	1.37
1	2401	50-yr	13.78	265.78	267.48		267.51	0.001956	1.1	20.74	31.97	0.27	26.55	12.04	0.0008	1.7
1	2401	100-yr	16.24	265.78	267.7		267.72	0.00089	0.8	40.23	99.5	0.19	13.68	3.47	0.0008	1.92
																0
1	2377	Timmins	10.57	265.76	267.05		267.09	0.002984	1.17	13.44	15.56	0.33	32.42	23.86	0.0257	1.29
1	2377	2-yr	1.59	265.76	266.03	266.03	266.14	0.034156	1.43	1.19	8.39	0.88	80.95	44.9	0.0257	0.27
1	2377	5-yr	7.11	265.76	266.65		266.71	0.005915	1.29	7.8	12.97	0.44	44.55	32.87	0.0257	0.89
1	2377	10-yr	8.91	265.76	266.86		266.91	0.004036	1.22	10.6	14.3	0.37	37.38	27.66	0.0257	1.1
1	2377	20-yr	10.91	265.76	267.09		267.13	0.002817	1.16	14.06	15.83	0.32	31.56	23.17	0.0257	1.33
1	2377	50-yr	13.78	265.76	267.43		267.47	0.00176	1.07	19.99	19.58	0.26	24.83	16.75	0.0257	1.67
1	2377	100-yr	16.24	265.76	267.65		267.69	0.001417	1.04	25.13	28.9	0.24	22.64	11.66	0.0257	1.89
																0
1	2357	Timmins	10.57	265.24	267.04	265.87	267.06	0.000619	0.64	17.85	15.91	0.16	8.84	6.29	0.0017	1.8
1	2357	2-yr	1.59	265.24	265.96	265.47	265.96	0.000466	0.3	5.37	8.79	0.12	2.59	2.59	0.0017	0.72
1	2357	5-yr	7.11	265.24	266.65	265.74	266.67	0.00078	0.6	12.25	12.76	0.17	8.46	6.7	0.0017	1.41
1	2357	10-yr	8.91	265.24	266.85	265.81	266.87	0.000703	0.63	15	14.17	0.17	8.87	6.69	0.0017	1.61
1	2357	20-yr	10.91	265.24	267.08	265.88	267.1	0.000602	0.64	18.49	16.41	0.16	8.81	6.15	0.0017	1.84

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
1	2357	50-yr	13.78	265.24	267.43	265.98	267.45	0.000449	0.63	24.98	20.79	0.14	7.92	4.95	0.0017	2.19
1	2357	100-yr	16.24	265.24	267.65	266.05	267.67	0.000418	0.65	30.23	28.11	0.14	8.18	4.19	0.0017	2.41
																0
1	2350		Culvert													0
																0
1	2337	Timmins	10.57	265.21	266.82		266.84	0.000736	0.65	17.42	14.44	0.17	9.39	7.85	-0.003	1.61
1	2337	2-yr	1.59	265.21	265.94		265.94	0.000389	0.28	5.93	11.51	0.11	2.31	1.87	-0.003	0.73
1	2337	5-yr	7.11	265.21	266.56		266.57	0.000662	0.55	13.76	13.63	0.16	7.19	5.99	-0.003	1.35
1	2337	10-yr	8.91	265.21	266.7		266.72	0.000708	0.61	15.7	14.07	0.16	8.42	7.03	-0.003	1.49
1	2337	20-yr	10.91	265.21	266.84		266.86	0.000742	0.65	17.76	14.52	0.17	9.59	8.02	-0.003	1.63
1	2337	50-yr	13.78	265.21	267.04		267.06	0.000768	0.72	20.61	15.39	0.17	11.04	9.06	-0.003	1.83
1	2337	100-yr	16.24	265.21	267.21		267.23	0.000744	0.75	23.35	16.81	0.17	11.75	9.16	-0.003	2
																0
1	2312	Timmins	10.57	265.28	266.71		266.79	0.004174	1.34	10.11	10.16	0.36	43.1	35	0.0005	1.43
1	2312	2-yr	1.59	265.28	265.91		265.92	0.001821	0.55	3.39	6.95	0.22	9.21	7.68	0.0005	0.63
1	2312	5-yr	7.11	265.28	266.48		266.53	0.003752	1.12	7.87	8.77	0.33	32.34	27.95	0.0005	1.2
1	2312	10-yr	8.91	265.28	266.6		266.67	0.004035	1.25	9.02	9.48	0.35	38.44	32.11	0.0005	1.32
1	2312	20-yr	10.91	265.28	266.74		266.81	0.004201	1.36	10.34	10.3	0.36	44.04	35.54	0.0005	1.46
1	2312	50-yr	13.78	265.28	266.92		267	0.004271	1.48	12.29	11.5	0.37	50.29	38.91	0.0005	1.64
1	2312	100-yr	16.24	265.28	267.09		267.18	0.004009	1.53	14.35	12.65	0.36	52.11	39.08	0.0005	1.81
																0
1	2275	Timmins	10.57	265.26	266.58		266.63	0.003492	1.19	12.73	15.36	0.33	34.81	26.06	0.0008	1.32
1	2275	2-yr	1.59	265.26	265.84		265.85	0.001908	0.53	3.84	9.6	0.22	8.96	6.85	0.0008	0.58
1	2275	5-yr	7.11	265.26	266.35		266.39	0.003412	1.04	9.44	12.95	0.32	28.02	22.14	0.0008	1.09
1	2275	10-yr	8.91	265.26	266.47		266.52	0.003515	1.13	11.1	14.15	0.33	32.11	24.7	0.0008	1.21
1	2275	20-yr	10.91	265.26	266.61		266.66	0.003507	1.21	13.06	15.68	0.33	35.53	26.34	0.0008	1.35
1	2275	50-yr	13.78	265.26	266.8		266.85	0.003167	1.26	16.35	18.85	0.32	36.63	25.06	0.0008	1.54
1	2275	100-yr	16.24	265.26	266.99		267.04	0.002444	1.2	20.66	25.28	0.29	31.91	18.53	0.0008	1.73
																0
1	2249	Timmins	10.57	265.24	266.5		266.54	0.003569	1.12	13.01	14.49	0.32	31.77	28.21	0.0003	1.26
1	2249	2-yr	1.59	265.24	265.79	265.49	265.8	0.00227	0.56	3.81	11.1	0.24	10.07	7.08	0.0003	0.55
1	2249	5-yr	7.11	265.24	266.26		266.3	0.003628	1.01	9.71	13.48	0.32	27.41	23.23	0.0003	1.02
1	2249	10-yr	8.91	265.24	266.39		266.43	0.00367	1.08	11.38	14.01	0.32	30.33	26.39	0.0003	1.15
1	2249	20-yr	10.91	265.24	266.52		266.56	0.003564	1.13	13.32	14.6	0.32	32.15	28.63	0.0003	1.28
1	2249	50-yr	13.78	265.24	266.72		266.77	0.003175	1.17	16.36	15.88	0.31	33.1	28.92	0.0003	1.48
1	2249	100-yr	16.24	265.24	266.93		266.98	0.002631	1.17	19.88	18	0.29	31.32	25.93	0.0003	1.69
																0
1	2220	Timmins	10.57	265.23	266.3		266.39	0.00725	1.62	9.35	13.07	0.5	65.85	47.86	0.0295	1.07
1	2220	2-yr	1.59	265.23	265.48	265.48	265.61	0.045898	1.58	1.01	4	1	100.55	100.55	0.0295	0.25
1	2220	5-yr	7.11	265.23	265.98		266.1	0.013678	1.76	5.52	11.24	0.65	87.47	61.92	0.0295	0.75
1	2220	10-yr	8.91	265.23	266.15		266.26	0.009381	1.67	7.5	12.24	0.56	73.52	53.06	0.0295	0.92
1	2220	20-yr	10.91	265.23	266.32		266.42	0.007063	1.62	9.67	13.2	0.5	65.59	47.71	0.0295	1.09
1	2220	50-yr	13.78	265.23	266.56		266.65	0.00497	1.56	13.03	14.44	0.43	56.46	41.32	0.0295	1.33
1	2220	100-yr	16.24	265.23	266.81		266.88	0.003464	1.46	16.79	15.76	0.37	46.73	33.99	0.0295	1.58
																0
1	2202	Timmins	10.57	264.7	266.3	265.43	266.33	0.001228	0.8	15.21	16.02	0.22	14.58	10.58	0.0079	1.6
1	2202	2-yr	1.59	264.7	265.42	264.96	265.43	0.000851	0.35	4.51	8.73	0.16	3.9	3.9	0.0079	0.72
1	2202	5-yr	7.11	264.7	265.99	265.31	266.02	0.001412	0.72	10.61	13.86	0.22	13.01	9.76	0.0079	1.29
1	2202	10-yr	8.91	264.7	266.15	265.38	266.18	0.001321	0.77	12.97	15.07	0.22	14.03	10.29	0.0079	1.45
1	2202	20-yr	10.91	264.7	266.32	265.45	266.35	0.001227	0.81	15.59	16.17	0.22	14.83	10.74	0.0079	1.62
1	2202	50-yr	13.78	264.7	266.56	265.54	266.6	0.001071	0.84	19.71	17.92	0.21	15.2	10.73	0.0079	1.86
1	2202	100-yr	16.24	264.7	266.81	265.62	266.84	0.000865	0.83	24.45	20.03	0.19	14.17	9.67	0.0079	2.11
																0
1	2191		Culvert													0
																0
1	2164	Timmins	10.57	264.4	266.06		266.09	0.001878	0.89	13.36	15.09	0.26	19.15	14.83	0.0018	1.66
1	2164	2-yr	1.59	264.4	265.06		265.08	0.004648	0.66	2.39	6.35	0.35	15.49	15.49	0.0018	0.66
1	2164	5-yr	7.11	264.4	265.79		265.82	0.002109	0.8	9.54	13.57	0.26	16.89	13.2	0.0018	1.39
1	2164	10-yr	8.91	264.4	265.94		265.97	0.001968	0.85	11.6	14.3	0.26	18.06	14.2	0.0018	1.54
1	2164	20-yr	10.91	264.4	266.07		266.11	0.001922	0.91	13.57	15.17	0.26	19.82	15.33	0.0018	1.67
1	2164	50-yr	13.78	264.4	266.24		266.28	0.001891	0.98	16.21	16.14	0.27	22.22	16.97	0.0018	1.84
1	2164	100-yr	16.24	264.4	266.37		266.42	0.001872	1.04	18.38	16.93	0.27	24.09	18.19	0.0018	1.97
																0
1	2153	Timmins	10.57	264.38	266.05		266.07	0.000723	0.69	19.81	15.27	0.17	10.32	8.33	0.0022	1.67
1	2153	2-yr	1.59	264.38	265.06		265.06	0.000473	0.31	6.23	11.91	0.12	2.74	2.24	0.0022	0.68
1	2153	5-yr	7.11	264.38	265.78		265.8	0.000621	0.57	15.85	14.37	0.15	7.44	6.11	0.0022	1.4
1	2153	10-yr	8.91	264.38	265.93		265.95	0.000674	0.63	18.01	14.81	0.16	8.92	7.29	0.0022	1.55
1	2153	20-yr	10.91	264.38	266.07		266.09	0.000749	0.71	20.02	15.3	0.17	10.77	8.69	0.0022	1.69
1	2153	50-yr	13.78	264.38	266.23		266.26	0.000839	0.8	22.64	15.78	0.19	13.27	10.64	0.0022	1.85
1	2153	100-yr	16.24	264.38	266.37		266.39	0.000905	0.87	24.73	16.15	0.2	15.33	12.22	0.0022	1.99
																0
1	2117	Timmins	10.57	264.3	265.98		266.03	0.001736	0.94	12.26	10.8	0.23	20.28	15.36	0.0016	1.68
1	2117	2-yr	1.59	264.3	265.04		265.04	0.000545	0.33	4.78	6.5	0.12	3.21	3.21	0.0016	0.74
1	2117	5-yr	7.11	264.3	265.73		265.76	0.001402	0.76	9.75	9.01	0.2	13.97	11.46	0.0016	1.43
1	2117	10-yr	8.91	264.3	265.87		265.91	0.001587	0.86	11.09	10.22	0.22	17.32	13.32	0.0016	1.57
1	2117	20-yr	10.91	264.3	265.99		266.04	0.00181	0.96	12.38	10.86	0.24	21.28	16.09	0.0016	1.69
1	2117	50-yr	13.78	264.3	266.15		266.2	0.002089	1.09	14.1	11.68	0.26	26.78	19.89	0.0016	1.85
1	2117	100-yr	16.24	264.3	266.27		266.33	0.002287	1.19	15.54	12.31	0.27	31.22	22.92	0.0016	1.97
																0
1	2087	Timmins	10.57	264.25	265.93		265.97	0.001789	0.93	12.51	11.24	0.23	20.25	15.41	-0.0023	1.68
1	2087	2-yr	1.59	264.25	265.02		265.03	0.000473	0.32	5.01	6.5	0.12	2.89	2.89	-0.0023	0.77

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
1	2087	5-yr	7.11	264.25	265.69		265.72	0.001384	0.75	9.93	10.35	0.2	13.78	10.3	-0.0023	1.44
1	2087	10-yr	8.91	264.25	265.82		265.86	0.001604	0.85	11.33	10.84	0.22	17.19	12.98	-0.0023	1.57
1	2087	20-yr	10.91	264.25	265.94		265.98	0.001877	0.96	12.6	11.27	0.23	21.33	16.23	-0.0023	1.69
1	2087	50-yr	13.78	264.25	266.08		266.14	0.002234	1.09	14.26	11.81	0.26	27.14	20.84	-0.0023	1.83
1	2087	100-yr	16.24	264.25	266.19		266.26	0.002463	1.19	15.64	12.65	0.27	31.76	23.81	-0.0023	1.94
																0
1	2057	Timmins	10.57	264.32	265.89		265.92	0.00135	0.86	14.69	12.48	0.22	16.72	13.55	0.0088	1.57
1	2057	2-yr	1.59	264.32	265.01		265.01	0.000531	0.33	5.4	9.32	0.13	3.12	2.72	0.0088	0.69
1	2057	5-yr	7.11	264.32	265.66		265.68	0.001085	0.69	11.98	10.87	0.19	11.46	10.07	0.0088	1.34
1	2057	10-yr	8.91	264.32	265.79		265.81	0.001227	0.78	13.44	11.76	0.21	14.21	11.9	0.0088	1.47
1	2057	20-yr	10.91	264.32	265.9		265.93	0.001421	0.88	14.76	12.52	0.22	17.66	14.29	0.0088	1.58
1	2057	50-yr	13.78	264.32	266.03		266.08	0.001691	1.02	16.54	13.76	0.25	22.83	17.52	0.0088	1.71
1	2057	100-yr	16.24	264.32	266.14		266.19	0.001887	1.12	18.08	14.82	0.27	27.08	19.98	0.0088	1.82
																0
1	2021	Timmins	10.57	264	265.83		265.87	0.001789	1	13.83	15.02	0.25	22.42	14.68	0.0052	1.83
1	2021	2-yr	1.59	264	264.98		264.99	0.000662	0.38	4.67	8.22	0.14	4.2	3.27	0.0052	0.98
1	2021	5-yr	7.11	264	265.6		265.63	0.001501	0.83	10.83	12.19	0.22	16.24	11.66	0.0052	1.6
1	2021	10-yr	8.91	264	265.73		265.76	0.001662	0.92	12.42	13.7	0.24	19.57	13.31	0.0052	1.73
1	2021	20-yr	10.91	264	265.83		265.87	0.001899	1.03	13.86	15.04	0.26	23.83	15.59	0.0052	1.83
1	2021	50-yr	13.78	264	265.95		266.01	0.002185	1.16	15.87	16.92	0.28	29.54	18.42	0.0052	1.95
1	2021	100-yr	16.24	264	266.06		266.12	0.002352	1.25	17.69	18.71	0.29	33.67	20.15	0.0052	2.06
																0
1	1982	Timmins	10.57	263.8	265.7		265.75	0.005748	1.35	12.34	15.75	0.31	47.53	39.76	0.0023	1.9
1	1982	2-yr	1.59	263.8	264.92	264.36	264.94	0.003105	0.7	3.36	7.98	0.21	15.14	10.7	0.0023	1.12
1	1982	5-yr	7.11	263.8	265.5		265.54	0.004993	1.17	9.37	13.14	0.29	36.81	30.91	0.0023	1.7
1	1982	10-yr	8.91	263.8	265.61		265.66	0.00542	1.27	10.95	14.51	0.3	42.64	35.8	0.0023	1.81
1	1982	20-yr	10.91	263.8	265.7		265.75	0.00629	1.41	12.21	15.63	0.33	51.77	43.33	0.0023	1.9
1	1982	50-yr	13.78	263.8	265.81		265.87	0.006786	1.52	14.09	17.8	0.34	59.19	47.91	0.0023	2.01
1	1982	100-yr	16.24	263.8	265.91		265.97	0.006622	1.56	16.05	20.42	0.34	60.72	46.95	0.0023	2.11
																0
1	1939	Timmins	10.57	263.7	265	264.99	265.21	0.040757	2.72	6.05	11.92	0.76	220.89	176.39	0.0044	1.3
1	1939	2-yr	1.59	263.7	264.26	264.26	264.54	0.072505	2.36	0.67	1.2	1.01	206.09	206.09	0.0044	0.56
1	1939	5-yr	7.11	263.7	264.88	264.88	265.06	0.037369	2.44	4.65	11.32	0.72	183.81	130.67	0.0044	1.18
1	1939	10-yr	8.91	263.7	264.94	264.94	265.14	0.039429	2.6	5.4	11.66	0.74	204.7	155.75	0.0044	1.24
1	1939	20-yr	10.91	263.7	265.09		265.24	0.026718	2.31	7.2	12.38	0.62	155.42	132.93	0.0044	1.39
1	1939	50-yr	13.78	263.7	265.32		265.43	0.016269	1.99	10.12	13.47	0.5	109.99	104.93	0.0044	1.62
1	1939	100-yr	16.24	263.7	265.5		265.59	0.012196	1.85	12.57	14.3	0.44	91.42	92.21	0.0044	1.8
																0
1	1923	Timmins	10.57	263.63	264.99	264.26	265.04	0.003003	1.01	10.51	8.8	0.29	25.86	25.86	0.0093	1.36
1	1923	2-yr	1.59	263.63	264.12	263.82	264.13	0.002082	0.48	3.32	7.4	0.23	7.75	7.75	0.0093	0.49
1	1923	5-yr	7.11	263.63	264.74	264.12	264.78	0.002798	0.86	8.31	8.64	0.28	19.95	19.95	0.0093	1.11
1	1923	10-yr	8.91	263.63	264.92	264.2	264.96	0.002587	0.9	9.88	8.76	0.27	21.2	21.2	0.0093	1.29
1	1923	20-yr	10.91	263.63	265.07	264.27	265.11	0.002664	0.98	11.17	8.85	0.28	24.06	24.06	0.0093	1.44
1	1923	50-yr	13.78	263.63	265.27	264.38	265.33	0.002687	1.06	12.99	8.99	0.28	27.26	27.26	0.0093	1.64
1	1923	100-yr	16.24	263.63	265.44	264.46	265.5	0.002655	1.12	14.53	9.33	0.28	29.42	28.86	0.0093	1.81
																0
1	1901		Culvert													0
																0
1	1884	Timmins	13.84	263.27	264.87		264.91	0.001882	0.96	16.66	13.78	0.26	21.58	19.3	0	1.6
1	1884	2-yr	1.98	263.27	263.91		263.92	0.001351	0.46	4.69	10.07	0.19	6.51	5.56	0	0.64
1	1884	5-yr	9.99	263.27	264.66		264.69	0.001748	0.83	13.76	13.14	0.24	17.07	15.57	0	1.39
1	1884	10-yr	12.99	263.27	264.83		264.87	0.001848	0.94	16.07	13.64	0.25	20.56	18.48	0	1.56
1	1884	20-yr	15.85	263.27	264.96		265	0.002021	1.04	17.81	14.04	0.27	24.53	21.75	0	1.69
1	1884	50-yr	19.98	263.27	265.12		265.18	0.002208	1.16	20.22	14.59	0.29	29.8	25.95	0	1.85
1	1884	100-yr	23.51	263.27	265.25		265.32	0.002361	1.26	22.09	14.99	0.3	34.26	29.47	0	1.98
																0
1	1871	Timmins	13.84	263.27	264.71		264.84	0.007804	1.99	10.82	12.35	0.53	91.19	62.46	0.0099	1.44
1	1871	2-yr	1.98	263.27	263.8		263.87	0.010687	1.19	2.06	6.49	0.52	46.03	30.4	0.0099	0.53
1	1871	5-yr	9.99	263.27	264.51		264.62	0.007729	1.79	8.45	11.19	0.51	77.73	53.26	0.0099	1.24
1	1871	10-yr	12.99	263.27	264.67		264.8	0.007744	1.94	10.34	12.13	0.52	88.01	60.29	0.0099	1.4
1	1871	20-yr	15.85	263.27	264.78		264.93	0.008497	2.13	11.62	12.71	0.55	103.69	70.99	0.0099	1.51
1	1871	50-yr	19.98	263.27	264.92		265.1	0.009062	2.34	13.55	13.55	0.58	121.36	82.89	0.0099	1.65
1	1871	100-yr	23.51	263.27	265.03		265.23	0.009615	2.52	15.03	14.21	0.61	137.04	93.05	0.0099	1.76
																0
1	1835	Timmins	13.84	262.91	264.44		264.55	0.007682	1.86	11.83	16.17	0.48	82.51	51.04	0.0115	1.53
1	1835	2-yr	1.98	262.91	263.45		263.5	0.009182	1.08	2.26	5.69	0.47	37.85	31.18	0.0115	0.54
1	1835	5-yr	9.99	262.91	264.25		264.34	0.007195	1.65	9.08	12.84	0.46	67.65	45.39	0.0115	1.34
1	1835	10-yr	12.99	262.91	264.4		264.51	0.007542	1.82	11.26	15.51	0.47	79.1	49.57	0.0115	1.49
1	1835	20-yr	15.85	262.91	264.41		264.57	0.011121	2.21	11.31	15.57	0.58	116.88	73.15	0.0115	1.5
1	1835	50-yr	19.98	262.91	264.54		264.73	0.01156	2.39	13.6	17.65	0.6	132.6	81.29	0.0115	1.63
1	1835	100-yr	23.51	262.91	264.65		264.84	0.011538	2.49	15.55	19.11	0.6	140.99	86.02	0.0115	1.74
																0
1	1790	Timmins	13.84	262.39	263.66	263.66	263.98	0.022361	2.89	7.52	14.47	0.82	208.12	106.17	0.0118	1.27
1	1790	2-yr	1.98	262.39	262.93	262.77	263.01	0.012961	1.28	1.69	4.15	0.55	53.35	43.23	0.0118	0.54
1	1790	5-yr	9.99	262.39	263.46	263.46	263.77	0.024884	2.72	5.11	10.03	0.84	195.33	112.56	0.0118	1.07
1	1790	10-yr	12.99	262.39	263.62	263.62	263.94	0.022973	2.86	6.95	13.48	0.82	206.91	107.66	0.0118	1.23
1	1790	20-yr	15.85	262.39	264.01		264.14	0.00792	2.02	14.36	23.46	0.51	94.01	45.43	0.0118	1.62
1	1790	50-yr	19.98	262.39	264.3		264.38	0.004584	1.72	21.8	26.82	0.4	64.26	35.04	0.0118	1.91
1	1790	100-yr	23.51	262.39	264.42		264.51	0.004394	1.75	25.13	27.86	0.39	65.52	37.29	0.0118	2.03
																0
1	1740	Timmins	13.84	261.8	263.7		263.74	0.000747	1	25.81	28.85	0.23	10.67	6.19	0.0099	1.9

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
1	1740	2-yr	1.98	261.8	262.05	262.05	262.18	0.021839	1.58	1.25	5	1	48.83	48.83	0.0099	0.25
1	1740	5-yr	9.99	261.8	263.11		263.2	0.002194	1.35	10.98	19.82	0.37	21.68	11.04	0.0099	1.31
1	1740	10-yr	12.99	261.8	263.56		263.61	0.000949	1.08	21.97	27.86	0.26	12.59	6.93	0.0099	1.76
1	1740	20-yr	15.85	261.8	264.02		264.05	0.000454	0.87	35.56	31.22	0.19	7.6	4.8	0.0099	2.22
1	1740	50-yr	19.98	261.8	264.29		264.32	0.000421	0.9	44.2	33.33	0.18	7.9	5.19	0.0099	2.49
1	1740	100-yr	23.51	261.8	264.41		264.44	0.000473	0.99	48.08	34.33	0.19	9.27	6.16	0.0099	2.61
																0
1	1679	Timmins	13.84	261.2	263.68		263.7	0.000375	0.79	31.7	28.74	0.16	6.24	3.73	0.005	2.48
1	1679	2-yr	1.98	261.2	261.82		261.84	0.001245	0.63	3.12	5	0.26	6.09	6.09	0.005	0.62
1	1679	5-yr	9.99	261.2	263.07		263.11	0.000758	0.93	16.09	22.06	0.22	9.54	4.89	0.005	1.87
1	1679	10-yr	12.99	261.2	263.54		263.57	0.000439	0.82	27.8	27.51	0.17	6.91	3.99	0.005	2.34
1	1679	20-yr	15.85	261.2	264.01		264.03	0.000264	0.72	41.62	31.29	0.14	4.98	3.18	0.005	2.81
1	1679	50-yr	19.98	261.2	264.28		264.3	0.000272	0.77	50.41	34.61	0.14	5.62	3.61	0.005	3.08
1	1679	100-yr	23.51	261.2	264.39		264.41	0.000317	0.86	54.37	36.2	0.15	6.8	4.35	0.005	3.19
																0
1	1674	Timmins	13.84	261.17	263.67	262.09	263.7	0.000388	0.81	29.81	26.54	0.16	6.6	3.92	0.0038	2.5
1	1674	2-yr	1.98	261.17	261.82	261.42	261.84	0.001123	0.61	3.22	5	0.24	5.64	5.64	0.0038	0.65
1	1674	5-yr	9.99	261.17	263.07	261.91	263.11	0.000736	0.93	15.57	19.84	0.22	9.48	5.07	0.0038	1.9
1	1674	10-yr	12.99	261.17	263.53	262.05	263.56	0.00045	0.84	26.21	25.3	0.17	7.23	4.18	0.0038	2.36
1	1674	20-yr	15.85	261.17	264	262.19	264.02	0.000279	0.75	39.08	29.44	0.14	5.38	3.35	0.0038	2.83
1	1674	50-yr	19.98	261.17	264.27	262.38	264.29	0.000284	0.8	47.39	33.2	0.15	5.99	3.7	0.0038	3.1
1	1674	100-yr	23.51	261.17	264.38	262.53	264.41	0.000325	0.88	51.24	35.68	0.16	7.11	4.27	0.0038	3.21
																0
1	1660		Culvert													0
																0
1	1641	Timmins	13.84	261.05	263		263.12	0.002527	1.66	10.09	10.34	0.38	30.83	19.9	0.0096	1.95
1	1641	2-yr	1.98	261.05	261.77		261.8	0.001769	0.78	2.54	3.65	0.3	9.03	9.03	0.0096	0.72
1	1641	5-yr	9.99	261.05	262.74		262.84	0.002322	1.45	7.82	7.65	0.36	24.5	18.13	0.0096	1.69
1	1641	10-yr	12.99	261.05	262.95		263.06	0.002481	1.62	9.56	9.62	0.38	29.42	19.65	0.0096	1.9
1	1641	20-yr	15.85	261.05	263.11		263.24	0.002647	1.76	11.28	11.79	0.4	34.11	20.85	0.0096	2.06
1	1641	50-yr	19.98	261.05	263.29		263.45	0.002837	1.94	13.7	14.3	0.42	39.97	23	0.0096	2.24
1	1641	100-yr	23.51	261.05	263.39		263.58	0.003171	2.11	15.22	15.65	0.44	46.73	26.38	0.0096	2.34
																0
1	1636	Timmins	13.84	261	262.77	262.46	263.05	0.008309	2.57	8.17	11.23	0.62	79.74	49.42	0.0045	1.77
1	1636	2-yr	1.98	261	261.71	261.4	261.78	0.004304	1.11	1.78	2.5	0.42	19.18	19.18	0.0045	0.71
1	1636	5-yr	9.99	261	262.6	262.21	262.79	0.006459	2.11	6.51	8.13	0.53	55.79	39.91	0.0045	1.6
1	1636	10-yr	12.99	261	262.74	262.41	263	0.007887	2.47	7.8	10.46	0.6	74.24	47.54	0.0045	1.74
1	1636	20-yr	15.85	261	262.83	262.59	263.16	0.009443	2.8	8.88	12.39	0.66	93.7	56.22	0.0045	1.83
1	1636	50-yr	19.98	261	263.08	262.65	263.38	0.008001	2.81	12.68	16.93	0.62	90.25	51.76	0.0045	2.08
1	1636	100-yr	23.51	261	263.18	263.1	263.51	0.008496	2.98	14.41	17.73	0.64	100.44	59.89	0.0045	2.18
																0
1	1603	Timmins	13.84	260.85	262.29	262.29	262.67	0.013612	3.02	5.99	8.64	0.8	115.18	76.4	0.0176	1.44
1	1603	2-yr	1.98	260.85	261.25	261.25	261.45	0.023911	1.99	0.99	2.5	1.01	70.76	70.76	0.0176	0.4
1	1603	5-yr	9.99	260.85	262.08	262.08	262.44	0.014203	2.79	4.4	7.18	0.8	103.3	68.42	0.0176	1.23
1	1603	10-yr	12.99	260.85	262.25	262.25	262.62	0.013682	2.97	5.65	8.34	0.8	112.53	74.61	0.0176	1.4
1	1603	20-yr	15.85	260.85	262.39	262.39	262.78	0.012883	3.08	6.93	9.48	0.79	116.82	77.18	0.0176	1.54
1	1603	50-yr	19.98	260.85	262.5	262.47	262.98	0.014807	3.46	8.07	10.75	0.86	144.24	92.73	0.0176	1.65
1	1603	100-yr	23.51	260.85	262.69	262.69	263.13	0.012622	3.44	10.46	14.48	0.81	137.1	78.99	0.0176	1.84
																0
1	1560	Timmins	13.84	260.1	262.17		262.29	0.00377	1.72	10.36	11.74	0.38	35.97	26.01	0	2.07
1	1560	2-yr	1.98	260.1	261.05		261.08	0.001953	0.84	2.37	2.5	0.27	10.31	10.31	0	0.95
1	1560	5-yr	9.99	260.1	261.96		262.05	0.00346	1.53	8.08	9.35	0.36	29.52	22.34	0	1.86
1	1560	10-yr	12.99	260.1	262.13		262.24	0.003666	1.67	9.85	10.98	0.38	34.22	25.39	0	2.03
1	1560	20-yr	15.85	260.1	262.27		262.39	0.003984	1.83	11.57	13.54	0.4	39.77	27.33	0	2.17
1	1560	50-yr	19.98	260.1	262.42		262.56	0.004446	2.01	13.78	16.3	0.42	47.41	31.06	0	2.32
1	1560	100-yr	23.51	260.1	262.51		262.67	0.004834	2.16	15.42	17.98	0.44	53.68	34.75	0	2.41
																0
1	1522	Timmins	13.84	260.1	261.77	261.68	262.05	0.009988	2.62	8.75	16.06	0.65	86.14	46.65	0.0038	1.67
1	1522	2-yr	1.98	260.1	260.95		261	0.002615	0.93	2.13	2.5	0.32	12.99	12.99	0.0038	0.85
1	1522	5-yr	9.99	260.1	261.64	261.38	261.85	0.007921	2.21	6.82	12.66	0.57	62.81	35.41	0.0038	1.54
1	1522	10-yr	12.99	260.1	261.74	261.6	262.01	0.00956	2.54	8.33	15.32	0.63	81.13	44.3	0.0038	1.64
1	1522	20-yr	15.85	260.1	261.83	261.79	262.14	0.010844	2.8	9.78	17.74	0.68	96.93	51.83	0.0038	1.73
1	1522	50-yr	19.98	260.1	261.98	261.98	262.3	0.010771	2.94	12.71	21.57	0.69	104.53	56.12	0.0038	1.88
1	1522	100-yr	23.51	260.1	262.08	262.08	262.4	0.010755	3.05	14.95	23.3	0.69	109.9	61.43	0.0038	1.98
																0
1	1483	Timmins	13.84	259.95	261.66		261.75	0.004249	1.64	11.89	18.64	0.4	34.38	23.17	0.0092	1.71
1	1483	2-yr	1.98	259.95	260.86		260.9	0.002152	0.87	2.28	2.5	0.29	11.14	11.14	0.0092	0.91
1	1483	5-yr	9.99	259.95	261.5		261.59	0.004345	1.55	9.07	16.39	0.4	31.85	20.24	0.0092	1.55
1	1483	10-yr	12.99	259.95	261.63		261.72	0.00426	1.62	11.3	18.19	0.4	33.81	22.55	0.0092	1.68
1	1483	20-yr	15.85	259.95	261.73		261.83	0.00423	1.68	13.26	19.66	0.4	35.65	24.55	0.0092	1.78
1	1483	50-yr	19.98	259.95	261.86		261.96	0.004197	1.75	15.93	21.39	0.4	37.95	27.14	0.0092	1.91
1	1483	100-yr	23.51	259.95	261.96		262.06	0.004198	1.81	18.05	22.65	0.41	39.87	29.2	0.0092	2.01
																0
1	1445	Timmins	13.84	259.6	261.53		261.59	0.003721	1.35	13.39	21.48	0.31	24.99	20.7	0.0102	1.93
1	1445	2-yr	1.98	259.6	260.72		260.77	0.005934	1.19	2.26	7.68	0.36	23.03	13.57	0.0102	1.12
1	1445	5-yr	9.99	259.6	261.36		261.42	0.003927	1.31	10.07	18.13	0.31	24.1	19.16	0.0102	1.76
1	1445	10-yr	12.99	259.6	261.5		261.56	0.003767	1.35	12.68	20.92	0.31	24.86	20.31	0.0102	1.9
1	1445	20-yr	15.85	259.6	261.6		261.67	0.003623	1.37	15.04	22.69	0.31	25.28	21.53	0.0102	2
1	1445	50-yr	19.98	259.6	261.74		261.81	0.003489	1.4	18.25	24.85	0.31	25.98	23.12	0.0102	2.14
1	1445	100-yr	23.51	259.6	261.84		261.91	0.003423	1.43	20.77	26.24	0.31	26.67	24.55	0.0102	2.24
																0

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
1	1396	Timmins	13.84	259.1	261.32		261.39	0.004603	1.41	12.51	18.94	0.3	28.02	25.77	0.0112	2.22
1	1396	2-yr	1.98	259.1	260.25		260.38	0.011088	1.56	1.27	1.1	0.46	40.5	40.5	0.0112	1.15
1	1396	5-yr	9.99	259.1	261.13		261.19	0.005455	1.44	9.11	15.83	0.32	30.28	25.95	0.0112	2.03
1	1396	10-yr	12.99	259.1	261.28		261.35	0.004719	1.41	11.81	18.34	0.3	28.23	25.63	0.0112	2.18
1	1396	20-yr	15.85	259.1	261.4		261.47	0.004412	1.41	14.12	20.28	0.3	27.84	26.24	0.0112	2.3
1	1396	50-yr	19.98	259.1	261.55		261.62	0.004213	1.44	17.18	22.73	0.29	28.23	27.57	0.0112	2.45
1	1396	100-yr	23.51	259.1	261.65		261.73	0.004083	1.46	19.62	24.23	0.29	28.52	28.82	0.0112	2.55
																0
1	1351	Timmins	13.84	258.6	260.69	260.65	261	0.018401	2.95	6.14	9.19	0.65	119.84	90.55	0.0212	2.09
1	1351	2-yr	1.98	258.6	259.48		259.69	0.021963	2.05	0.96	1.1	0.7	72.74	72.74	0.0212	0.88
1	1351	5-yr	9.99	258.6	260.52	260.47	260.78	0.016415	2.63	4.77	7.11	0.61	98.2	75.73	0.0212	1.92
1	1351	10-yr	12.99	258.6	260.65	260.59	260.96	0.018264	2.9	5.81	8.7	0.65	116.8	88.55	0.0212	2.05
1	1351	20-yr	15.85	258.6	260.76	260.75	261.09	0.018946	3.06	6.87	10.16	0.67	127.82	96.43	0.0212	2.16
1	1351	50-yr	19.98	258.6	260.9	260.9	261.24	0.019141	3.21	8.36	11.74	0.68	137.21	105.64	0.0212	2.3
1	1351	100-yr	23.51	258.6	260.99	260.99	261.36	0.019288	3.31	9.52	12.75	0.68	143.99	113.42	0.0212	2.39
																0
1	1319	Timmins	13.84	257.9	260.08	260.08	260.35	0.020354	2.7	6.56	11.82	0.58	107.44	85.69	0.0079	2.18
1	1319	2-yr	1.98	257.9	258.88		259.05	0.016386	1.83	1.08	1.1	0.59	56.7	56.7	0.0079	0.98
1	1319	5-yr	9.99	257.9	259.96	259.96	260.19	0.018975	2.51	5.18	10.45	0.56	94.5	69.52	0.0079	2.06
1	1319	10-yr	12.99	257.9	260.06	260.06	260.32	0.019701	2.64	6.31	11.58	0.57	103	81.16	0.0079	2.16
1	1319	20-yr	15.85	257.9	260.14	260.14	260.42	0.020995	2.79	7.22	12.42	0.59	113.61	93.62	0.0079	2.24
1	1319	50-yr	19.98	257.9	260.25	260.24	260.55	0.020657	2.86	8.74	13.75	0.59	117.62	102.8	0.0079	2.35
1	1319	100-yr	23.51	257.9	260.44		260.67	0.014374	2.51	11.52	16.41	0.5	88.23	81.47	0.0079	2.54
																0
1	1282	Timmins	13.84	257.61	259.95	258.69	260.03	0.001561	1.33	11.82	8.62	0.28	19.52	15.01	0.0022	2.34
1	1282	2-yr	1.98	257.61	258.97	257.91	258.98	0.000203	0.36	5.5	4.8	0.1	1.69	1.52	0.0022	1.36
1	1282	5-yr	9.99	257.61	259.77	258.48	259.83	0.001097	1.07	10.34	7.71	0.24	12.96	10.17	0.0022	2.16
1	1282	10-yr	12.99	257.61	259.92	258.65	260	0.00144	1.27	11.58	8.48	0.27	17.86	13.76	0.0022	2.31
1	1282	20-yr	15.85	257.61	260.04	258.8	260.13	0.001775	1.44	12.57	8.77	0.3	22.76	17.73	0.0022	2.43
1	1282	50-yr	19.98	257.61	260.2	259.02	260.32	0.00212	1.64	14.02	9.24	0.33	28.96	22.4	0.0022	2.59
1	1282	100-yr	23.51	257.61	260.33	259.2	260.47	0.002366	1.79	15.22	9.68	0.35	33.95	25.98	0.0022	2.72
																0
1	1265		Culvert													0
																0
1	1246	Timmins	14.98	257.53	259.64		259.69	0.00176	1.11	18.76	22.86	0.25	26.24	13.02	0.0113	2.11
1	1246	2-yr	2.31	257.53	258.97		258.97	0.000216	0.3	8.65	10.81	0.08	2.16	1.44	0.0113	1.44
1	1246	5-yr	11.31	257.53	259.55		259.59	0.001166	0.88	17.05	18.28	0.2	16.68	9.62	0.0113	2.02
1	1246	10-yr	15.04	257.53	259.64		259.69	0.00177	1.11	18.8	22.97	0.25	26.42	13.06	0.0113	2.11
1	1246	20-yr	17.39	257.53	259.68		259.74	0.002214	1.26	19.67	25.61	0.28	33.63	15.47	0.0113	2.15
1	1246	50-yr	22.42	257.53	259.75		259.85	0.003203	1.55	21.77	32.62	0.34	50.33	19.75	0.0113	2.22
1	1246	100-yr	27.12	257.53	259.81		259.94	0.004076	1.78	24	38.72	0.38	65.91	23.56	0.0113	2.28
																0
1	1216	Timmins	14.98	257.2	259.5		259.57	0.012035	1.72	13.35	42.19	0.36	81.83	35.1	0.0008	2.3
1	1216	2-yr	2.31	257.2	258.89		258.94	0.006814	1.06	2.63	5.7	0.26	34.18	21.08	0.0008	1.69
1	1216	5-yr	11.31	257.2	259.38	259.33	259.48	0.015006	1.86	9.27	31.41	0.4	97.02	39.98	0.0008	2.18
1	1216	10-yr	15.04	257.2	259.5		259.58	0.01193	1.71	13.48	42.61	0.36	81.22	34.79	0.0008	2.3
1	1216	20-yr	17.39	257.2	259.53		259.61	0.011996	1.74	15.3	59.82	0.36	82.96	28.74	0.0008	2.33
1	1216	50-yr	22.42	257.2	259.59		259.67	0.012739	1.82	18.65	62.92	0.38	90.16	35.32	0.0008	2.39
1	1216	100-yr	27.12	257.2	259.63		259.72	0.013289	1.88	21.37	65.55	0.38	95.72	40.51	0.0008	2.43
																0
1	1154	Timmins	14.98	257.15	259.01		259.04	0.005956	1.15	19.78	70.17	0.27	37.66	16.02	0.0103	1.86
1	1154	2-yr	2.31	257.15	258.37		258.42	0.0103	1.15	2.39	7.28	0.33	42.81	26.26	0.0103	1.22
1	1154	5-yr	11.31	257.15	258.94		258.96	0.004725	1	15.93	49.33	0.24	28.75	14.4	0.0103	1.79
1	1154	10-yr	15.04	257.15	259.01		259.04	0.005994	1.16	19.9	71.67	0.27	37.93	15.89	0.0103	1.86
1	1154	20-yr	17.39	257.15	259.04		259.08	0.006032	1.17	22.59	80.81	0.27	38.87	16.14	0.0103	1.89
1	1154	50-yr	22.42	257.15	259.1		259.14	0.005743	1.17	27.39	82.68	0.27	38.16	18.21	0.0103	1.95
1	1154	100-yr	27.12	257.15	259.15		259.19	0.005475	1.16	31.65	84.31	0.26	37.33	19.67	0.0103	2
																0
1	1120	Timmins	14.98	256.8	258.69	258.69	258.78	0.009431	2.23	18.04	76.77	0.52	58.41	20.97	0.0176	1.89
1	1120	2-yr	2.31	256.8	258		258.1	0.008309	1.55	2.18	5.06	0.45	32.7	24.95	0.0176	1.2
1	1120	5-yr	11.31	256.8	258.63	258.63	258.73	0.009592	2.2	13.66	64.48	0.52	57.5	19.18	0.0176	1.83
1	1120	10-yr	15.04	256.8	258.7	258.7	258.78	0.009451	2.24	18.09	76.83	0.52	58.55	21.05	0.0176	1.9
1	1120	20-yr	17.39	256.8	258.71	258.71	258.81	0.010359	2.36	19.57	78.7	0.54	64.82	24.37	0.0176	1.91
1	1120	50-yr	22.42	256.8	258.75	258.75	258.85	0.012139	2.58	22.37	80.71	0.59	77.35	31.81	0.0176	1.95
1	1120	100-yr	27.12	256.8	258.77	258.77	258.9	0.015058	2.89	23.79	81.38	0.66	96.81	41.58	0.0176	1.97
																0
1	1094	Timmins	14.98	256.34	258.2	258.2	258.28	0.007105	1.83	18.39	85.65	0.47	46.17	14.47	-0.0104	1.86
1	1094	2-yr	2.31	256.34	257.95	257	257.99	0.002017	0.88	2.61	1.95	0.24	11.28	11.28	-0.0104	1.61
1	1094	5-yr	11.31	256.34	258.17	258.17	258.24	0.005882	1.64	15.81	85.13	0.42	37.49	10.36	-0.0104	1.83
1	1094	10-yr	15.04	256.34	258.21	258.21	258.28	0.007076	1.83	18.48	85.67	0.46	46.01	14.47	-0.0104	1.87
1	1094	20-yr	17.39	256.34	258.23	258.22	258.3	0.00692	1.83	20.82	86.14	0.46	45.76	15.85	-0.0104	1.89
1	1094	50-yr	22.42	256.34	258.32	258.26	258.37	0.004933	1.6	28.16	87.58	0.39	34.34	15.01	-0.0104	1.98
1	1094	100-yr	27.12	256.34	258.51	258.28	258.53	0.001771	1.03	45.46	108.07	0.24	13.7	7.06	-0.0104	2.17
																0
1	1089		Culvert													0
																0
1	1079	Timmins	14.98	256.51	258.18		258.25	0.002987	1.61	25.11	115.57	0.45	30.74	6.31	-0.0055	1.67
1	1079	2-yr	2.31	256.51	257.63		257.67	0.001557	0.84	2.97	5.97	0.3	9.81	6.64	-0.0055	1.12
1	1079	5-yr	11.31	256.51	258.1	257.93	258.22	0.003927	1.77	16.04	111.42	0.51	37.97	5.5	-0.0055	1.59
1	1079	10-yr	15.04	256.51	258.19		258.26	0.00298	1.61	25.24	115.62	0.45	30.69	6.33	-0.0055	1.68
1	1079	20-yr	17.39	256.51	258.22		258.28	0.002766	1.58	29.63	118.31	0.43	29.29	6.74	-0.0055	1.71

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
1	1079	50-yr	22.42	256.51	258.29		258.34	0.002484	1.55	38.06	123.29	0.41	27.65	7.46	-0.0055	1.78
1	1079	100-yr	27.12	256.51	258.51		258.53	0.000901	1.02	67.24	168.38	0.25	11.54	3.51	-0.0055	2
																0
1	1045	Timmins	14.98	256.69	258.13		258.16	0.001712	1.22	32.54	119.26	0.35	17.63	4.56	0.0076	1.44
1	1045	2-yr	2.31	256.69	257.54		257.59	0.003067	1.05	2.25	4.65	0.42	16.21	12.94	0.0076	0.85
1	1045	5-yr	11.31	256.69	258.05		258.09	0.002099	1.29	22.86	111.49	0.39	20.13	4.2	0.0076	1.36
1	1045	10-yr	15.04	256.69	258.13		258.16	0.001711	1.22	32.67	119.36	0.35	17.63	4.57	0.0076	1.44
1	1045	20-yr	17.39	256.69	258.17		258.2	0.001678	1.23	37.14	122.79	0.35	17.82	4.95	0.0076	1.48
1	1045	50-yr	22.42	256.69	258.24		258.27	0.001637	1.26	45.87	129.55	0.35	18.34	5.66	0.0076	1.55
1	1045	100-yr	27.12	256.69	258.49		258.5	0.000486	0.77	81.25	159.71	0.2	6.48	2.41	0.0076	1.8
																0
1	990	Timmins	14.98	256.27	258.04		258.07	0.001603	1.18	34.71	119.68	0.3	16.54	4.52	0.0037	1.77
1	990	2-yr	2.31	256.27	257.38		257.43	0.002808	1.07	2.92	7.96	0.37	16.44	8.89	0.0037	1.11
1	990	5-yr	11.31	256.27	257.96		257.98	0.001499	1.1	26.41	84.5	0.29	14.62	4.53	0.0037	1.69
1	990	10-yr	15.04	256.27	258.04		258.07	0.001601	1.18	34.85	119.83	0.3	16.53	4.52	0.0037	1.77
1	990	20-yr	17.39	256.27	258.08		258.11	0.001552	1.18	39.65	124.92	0.3	16.44	4.79	0.0037	1.81
1	990	50-yr	22.42	256.27	258.15		258.18	0.001509	1.2	48.92	134.51	0.3	16.7	5.34	0.0037	1.88
1	990	100-yr	27.12	256.27	258.47		258.48	0.000325	0.63	96.24	159.83	0.14	4.28	1.9	0.0037	2.2
																0
1	948	Timmins	14.98	256.11	257.78	257.78	257.93	0.00755	2.32	13.78	45.8	0.64	67.07	21.17	0.0213	1.67
1	948	2-yr	2.31	256.11	256.9	256.9	257.15	0.023592	2.19	1.08	3.02	0.96	81.69	61.8	0.0213	0.79
1	948	5-yr	11.31	256.11	257.71	257.71	257.85	0.007134	2.18	10.79	35.46	0.62	59.88	20.18	0.0213	1.6
1	948	10-yr	15.04	256.11	257.78	257.78	257.93	0.007556	2.33	13.84	45.96	0.64	67.19	21.2	0.0213	1.67
1	948	20-yr	17.39	256.11	257.82	257.82	257.97	0.00778	2.41	15.72	51.57	0.65	71.18	22.12	0.0213	1.71
1	948	50-yr	22.42	256.11	258		258.07	0.004115	1.9	26.43	68.33	0.49	42.47	14.78	0.0213	1.89
1	948	100-yr	27.12	256.11	258.45		258.46	0.000475	0.76	91.14	192.07	0.17	6.34	2.12	0.0213	2.34
																0
1	926	Timmins	14.98	255.66	257.43	257.43	257.71	0.005315	2.86	10.57	18.19	0.74	50.7	27.56	0.6557	1.77
1	926	2-yr	2.31	255.66	256.34	256.34	256.6	0.012552	2.23	1.03	2.06	1.01	43.32	43.32	0.6557	0.68
1	926	5-yr	11.31	255.66	257.32	257.32	257.57	0.004705	2.57	8.63	17.97	0.68	41.75	20.27	0.6557	1.66
1	926	10-yr	15.04	255.66	257.43	257.43	257.72	0.00531	2.86	10.61	18.19	0.74	50.73	27.64	0.6557	1.77
1	926	20-yr	17.39	255.66	257.56	257.56	257.79	0.004312	2.72	13.84	35.73	0.67	44.58	15.49	0.6557	1.9
1	926	50-yr	22.42	255.66	257.97		258.02	0.001174	1.64	36.59	83	0.36	15.13	4.82	0.6557	2.31
1	926	100-yr	27.12	255.66	258.45		258.45	0.000137	0.65	138.56	228	0.13	2.18	0.8	0.6557	2.79
																0
1	924	Timmins	14.98	253.92	257.2	255.02	257.25	0.000136	1.06	17.66	15.92	0.19	1.72	0.98	0.0061	3.28
1	924	2-yr	2.31	253.92	255.27	254.24	255.28	0.000037	0.41	5.58	4.15	0.11	0.3	0.3	0.0061	1.35
1	924	5-yr	11.31	253.92	256.81	254.83	256.85	0.00011	0.92	13.9	6.91	0.17	1.31	1.08	0.0061	2.89
1	924	10-yr	15.04	253.92	257.2	255.03	257.26	0.000137	1.06	17.74	15.92	0.19	1.73	0.99	0.0061	3.28
1	924	20-yr	17.39	253.92	257.46	255.14	257.51	0.000135	1.1	21.82	15.93	0.19	1.8	1.18	0.0061	3.54
1	924	50-yr	22.42	253.92	257.98	255.37	258.02	0.000095	1.01	53.46	84.22	0.16	1.46	0.52	0.0061	4.06
1	924	100-yr	27.12	253.92	258.43	255.56	258.45	0.000049	0.78	140.66	227.67	0.12	0.84	0.28	0.0061	4.51
																0
1	870		Culvert													0
																0
1	816	Timmins	17.64	253.26	256.39		256.44	0.001037	1.14	21	22.02	0.22	14.05	8.3	-0.0245	3.13
1	816	2-yr	2.77	253.26	255.17		255.18	0.000425	0.53	5.24	3.3	0.13	3.54	3.54	-0.0245	1.91
1	816	5-yr	13.45	253.26	256.24		256.28	0.000891	1.02	17.76	20.22	0.2	11.38	6.5	-0.0245	2.98
1	816	10-yr	17.71	253.26	256.39		256.44	0.001044	1.14	21	22.02	0.22	14.14	8.36	-0.0245	3.13
1	816	20-yr	20.96	253.26	256.5		256.56	0.001123	1.22	23.48	23.43	0.23	15.82	9.52	-0.0245	3.24
1	816	50-yr	27.16	253.26	256.67		256.73	0.001296	1.36	28.89	52.81	0.25	19.33	6.49	-0.0245	3.41
1	816	100-yr	32.02	253.26	256.78		256.84	0.001347	1.42	35.88	75.59	0.26	20.82	5.97	-0.0245	3.52
																0
1	798	Timmins	17.64	253.7	256.32		256.41	0.002077	1.53	17.26	19.21	0.35	25.86	16.53	0.0003	2.62
1	798	2-yr	2.77	253.7	255.1		255.16	0.002696	1.06	2.61	2.89	0.36	16.01	16.01	0.0003	1.4
1	798	5-yr	13.45	253.7	256.18		256.25	0.001839	1.37	14.61	18.31	0.33	21.23	12.97	0.0003	2.48
1	798	10-yr	17.71	253.7	256.32		256.41	0.002095	1.53	17.25	19.21	0.35	26.07	16.67	0.0003	2.62
1	798	20-yr	20.96	253.7	256.42		256.52	0.002221	1.63	19.22	19.81	0.37	29.08	19.11	0.0003	2.72
1	798	50-yr	27.16	253.7	256.59		256.69	0.002384	1.78	24.38	59.51	0.38	33.73	9.24	0.0003	2.89
1	798	100-yr	32.02	253.7	256.72		256.8	0.002178	1.77	36.11	122.27	0.37	32.69	6.2	0.0003	3.02
																0
1	738	Timmins	17.64	253.68	255.85	255.85	256.13	0.008545	2.58	9.91	18.95	0.68	80.88	39.75	0.0006	2.17
1	738	2-yr	2.77	253.68	254.67		254.83	0.010866	1.8	1.54	2.28	0.7	49.99	49.99	0.0006	0.99
1	738	5-yr	13.45	253.68	255.73	255.73	255.99	0.00832	2.41	7.69	17.82	0.66	72.33	31.8	0.0006	2.05
1	738	10-yr	17.71	253.68	255.86	255.86	256.13	0.008398	2.56	10.02	19	0.67	79.81	39.41	0.0006	2.18
1	738	20-yr	20.96	253.68	255.93	255.93	256.22	0.008967	2.73	11.32	19.63	0.7	89.08	46.13	0.0006	2.25
1	738	50-yr	27.16	253.68	256.06	256.06	256.37	0.009092	2.9	14.02	20.76	0.71	98.09	54.97	0.0006	2.38
1	738	100-yr	32.02	253.68	256.14	256.14	256.48	0.009721	3.09	15.58	21.23	0.74	109.5	63.91	0.0006	2.46
																0
1	687	Timmins	17.64	253.65	255.67		255.72	0.000801	1.11	20.62	18.36	0.27	12.63	8.5	0.0005	2.02
1	687	2-yr	2.77	253.65	254.66		254.68	0.000923	0.65	4.75	12.15	0.25	5.84	3.44	0.0005	1.01
1	687	5-yr	13.45	253.65	255.46		255.5	0.000822	1.03	16.76	17.23	0.27	11.3	7.57	0.0005	1.81
1	687	10-yr	17.71	253.65	255.68		255.72	0.000801	1.11	20.68	18.38	0.27	12.65	8.51	0.0005	2.03
1	687	20-yr	20.96	253.65	255.81		255.86	0.000825	1.19	23.14	19.09	0.28	14.05	9.44	0.0005	2.16
1	687	50-yr	27.16	253.65	255.97		256.04	0.00097	1.36	26.39	20.09	0.31	18.02	12.02	0.0005	2.32
1	687	100-yr	32.02	253.65	256.13		256.21	0.000975	1.44	29.74	23.73	0.31	19.51	11.58	0.0005	2.48
																0
1	645	Timmins	17.64	253.63	255.56		255.67	0.002004	1.57	16.72	17.35	0.42	26.77	18.29	0.0003	1.93
1	645	2-yr	2.77	253.63	254.56		254.61	0.003182	1	2.89	9.18	0.44	15.3	9.48	0.0003	0.93
1	645	5-yr	13.45	253.63	255.35		255.44	0.002181	1.47	13.15	15.71	0.42	24.78	17.29	0.0003	1.72
1	645	10-yr	17.71	253.63	255.57		255.67	0.002002	1.57	16.78	17.37	0.42	26.8	18.3	0.0003	1.94

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
1	645	20-yr	20.96	253.63	255.69		255.8	0.002011	1.67	19.05	18.63	0.42	29.25	19.48	0.0003	2.06
1	645	50-yr	27.16	253.63	255.83		255.98	0.002408	1.93	21.72	20.33	0.47	38.08	24.41	0.0003	2.2
1	645	100-yr	32.02	253.63	255.98		256.14	0.002368	2.02	24.95	22.3	0.47	40.75	25.18	0.0003	2.35
																0
1	615	Timmins	17.64	253.62	255.45	254.98	255.59	0.002562	1.78	12.12	12.76	0.47	34.26	22.76	0	1.83
1	615	2-yr	2.77	253.62	254.46	254.18	254.51	0.003153	0.99	2.8	5.45	0.44	14.99	14.99	0	0.84
1	615	5-yr	13.45	253.62	255.23	254.82	255.36	0.002748	1.65	9.53	11.41	0.48	31.29	21.47	0	1.61
1	615	10-yr	17.71	253.62	255.45	254.98	255.6	0.00256	1.78	12.16	12.78	0.47	34.31	22.78	0	1.83
1	615	20-yr	20.96	253.62	255.56	255.09	255.73	0.00268	1.92	13.65	13.51	0.49	38.72	25.32	0	1.94
1	615	50-yr	27.16	253.62	255.62	255.27	255.87	0.003885	2.36	14.47	13.9	0.59	58.29	37.83	0	2
1	615	100-yr	32.02	253.62	255.75	255.4	256.03	0.003976	2.52	16.34	14.75	0.61	64.46	41.22	0	2.13
																0
1	593		Bridge													0
																0
1	591	Timmins	17.64	253.59	254.97	254.97	255.42	0.012499	2.98	6.17	8.16	0.96	110.67	86.29	0.0057	1.38
1	591	2-yr	2.77	253.59	254.32	254.14	254.4	0.005563	1.25	2.21	4.56	0.58	24.65	24.65	0.0057	0.73
1	591	5-yr	13.45	253.59	254.82	254.8	255.19	0.013023	2.72	5.01	7	0.96	97.24	84.82	0.0057	1.23
1	591	10-yr	17.71	253.59	254.97	254.97	255.42	0.012492	2.99	6.19	8.18	0.96	110.86	86.31	0.0057	1.38
1	591	20-yr	20.96	253.59	255.19	255.19	255.57	0.008295	2.79	9.18	21.4	0.81	90.16	33.84	0.0057	1.6
1	591	50-yr	27.16	253.59	255.38	255.38	255.77	0.00739	2.9	13.43	23.15	0.79	92.99	40.72	0.0057	1.79
1	591	100-yr	32.02	253.59	255.48	255.48	255.89	0.0075	3.06	15.78	23.76	0.8	101.2	47.3	0.0057	1.89
																0
1	576	Timmins	17.64	253.5	254.84	254.84	255.07	0.008107	2.39	11.11	24.23	0.78	71.04	35.71	0.111	1.34
1	576	2-yr	2.77	253.5	254.04	254.04	254.23	0.018345	1.93	1.44	3.87	1.01	63.16	63.16	0.111	0.54
1	576	5-yr	13.45	253.5	254.74	254.74	254.96	0.00802	2.21	8.75	23.31	0.76	63.01	28.92	0.111	1.24
1	576	10-yr	17.71	253.5	254.84	254.84	255.08	0.008114	2.39	11.14	24.24	0.78	71.2	35.82	0.111	1.34
1	576	20-yr	20.96	253.5	254.91	254.91	255.16	0.008339	2.53	12.69	24.73	0.8	77.99	41.08	0.111	1.41
1	576	50-yr	27.16	253.5	255	255	255.29	0.009055	2.8	15.11	25.34	0.84	92.67	51.81	0.111	1.5
1	576	100-yr	32.02	253.5	255.08	255.08	255.39	0.009176	2.94	17.06	25.77	0.86	100.34	58.27	0.111	1.58
																0
1	549	Timmins	17.64	250.5	254.72		254.72	0.000004	0.13	138.31	34.75	0.02	0.13	0.13	0	4.22
1	549	2-yr	2.77	250.5	253.9		253.9	0	0.02	111.16	32.89	0	0.01	0.01	0	3.4
1	549	5-yr	13.45	250.5	254.55		254.55	0.000003	0.1	132.43	32.96	0.02	0.08	0.08	0	4.05
1	549	10-yr	17.71	250.5	254.72		254.72	0.000004	0.13	138.4	34.76	0.02	0.13	0.13	0	4.22
1	549	20-yr	20.96	250.5	254.84		254.84	0.000005	0.15	142.57	35.22	0.02	0.17	0.16	0	4.34
1	549	50-yr	27.16	250.5	254.9		254.9	0.000008	0.19	144.51	35.44	0.03	0.28	0.27	0	4.4
1	549	100-yr	32.02	250.5	254.96		254.96	0.000011	0.22	146.69	35.69	0.03	0.38	0.36	0	4.46
																0
1	530	Timmins	17.64	250.5	254.72		254.72	0.000003	0.11	164.79	47.05	0.02	0.09	0.08	-0.1217	4.22
1	530	2-yr	2.77	250.5	253.9		253.9	0	0.02	130.75	39.4	0	0	0	-0.1217	3.4
1	530	5-yr	13.45	250.5	254.55		254.55	0.000002	0.09	156.87	44.19	0.01	0.06	0.05	-0.1217	4.05
1	530	10-yr	17.71	250.5	254.72		254.72	0.000003	0.11	164.9	47.08	0.02	0.09	0.08	-0.1217	4.22
1	530	20-yr	20.96	250.5	254.84		254.84	0.000003	0.12	170.61	48.33	0.02	0.12	0.1	-0.1217	4.34
1	530	50-yr	27.16	250.5	254.9		254.9	0.000005	0.16	173.27	48.89	0.02	0.2	0.17	-0.1217	4.4
1	530	100-yr	32.02	250.5	254.96		254.96	0.000007	0.19	176.29	49.53	0.03	0.26	0.22	-0.1217	4.46
																0
1	506	Timmins	17.64	253.5	254.35	254.35	254.69	0.013396	2.59	7.08	11.88	0.98	90.93	75.72	0.3651	0.85
1	506	2-yr	2.77	253.5	253.76	253.76	253.89	0.019934	1.56	1.77	7.21	1	47.08	47.08	0.3651	0.26
1	506	5-yr	13.45	253.5	254.23	254.23	254.52	0.014678	2.39	5.7	10.71	0.99	82.75	74.11	0.3651	0.73
1	506	10-yr	17.71	253.5	254.35	254.35	254.69	0.013371	2.59	7.1	11.9	0.97	91.01	75.71	0.3651	0.85
1	506	20-yr	20.96	253.5	254.44	254.44	254.81	0.012275	2.69	8.34	15.99	0.95	94.36	61.2	0.3651	0.94
1	506	50-yr	27.16	253.5	254.69	254.69	254.88	0.00546	2.14	21.93	65.91	0.66	54.79	17.69	0.3651	1.19
1	506	100-yr	32.02	253.5	254.74	254.74	254.94	0.005683	2.26	25.36	66.85	0.68	59.81	21	0.3651	1.24
																0
1	504	Timmins	17.64	253	253.83	253.83	254.17	0.012322	2.61	7.3	12.85	0.93	90.42	65.48	0.2738	0.83
1	504	2-yr	2.77	253	253.24	253.24	253.36	0.020307	1.52	1.83	7.77	1	45.31	45.31	0.2738	0.24
1	504	5-yr	13.45	253	253.69	253.69	254	0.01401	2.46	5.64	11	0.96	85	66.76	0.2738	0.69
1	504	10-yr	17.71	253	253.83	253.83	254.17	0.012312	2.62	7.32	12.87	0.93	90.56	65.52	0.2738	0.83
1	504	20-yr	20.96	253	253.92	253.92	254.29	0.011521	2.73	8.6	14.08	0.92	94.71	66.01	0.2738	0.92
1	504	50-yr	27.16	253	254.08	254.08	254.49	0.010756	2.93	10.89	15.76	0.91	103.49	69.88	0.2738	1.08
1	504	100-yr	32.02	253	254.21	254.21	254.63	0.009713	3	13.17	20.92	0.88	104.85	58.03	0.2738	1.21
																0
1	503	Timmins	17.64	252.54	253.75		253.8	0.001575	1.25	28.74	85.36	0.37	17.78	5.19	0.1791	1.21
1	503	2-yr	2.77	252.54	252.81	252.81	252.91	0.019893	1.45	2.03	10.59	1	41.97	37.38	0.1791	0.27
1	503	5-yr	13.45	252.54	253.18	253.18	253.42	0.013296	2.31	7.06	16.02	0.96	76.75	57.2	0.1791	0.64
1	503	10-yr	17.71	252.54	253.47		253.61	0.00516	1.87	12.98	27.99	0.64	44.12	23.32	0.1791	0.93
1	503	20-yr	20.96	252.54	253.38	253.38	253.66	0.010681	2.52	10.86	24.27	0.91	82.81	46.61	0.1791	0.84
1	503	50-yr	27.16	252.54	253.48	253.48	253.81	0.011287	2.8	13.44	28.87	0.95	98.27	51.19	0.1791	0.94
1	503	100-yr	32.02	252.54	253.57	253.57	253.92	0.01111	2.96	16.51	44.07	0.96	106.08	40.62	0.1791	1.03
																0
1	483	Timmins	17.64	249	253.78		253.78	0.000002	0.1	234.51	116.98	0.02	0.08	0.04	-0.0155	4.78
1	483	2-yr	2.77	249	252.8		252.8	0	0.02	161.86	53.3	0	0	0	-0.0155	3.8
1	483	5-yr	13.45	249	253.31		253.31	0.000002	0.09	190.89	62.07	0.01	0.06	0.05	-0.0155	4.31
1	483	10-yr	17.71	249	253.57		253.57	0.000003	0.11	210.19	107.51	0.02	0.1	0.05	-0.0155	4.57
1	483	20-yr	20.96	249	253.57		253.58	0.000004	0.13	210.97	107.82	0.02	0.14	0.07	-0.0155	4.57
1	483	50-yr	27.16	249	253.71		253.71	0.000006	0.17	225.47	113.54	0.02	0.21	0.1	-0.0155	4.71
1	483	100-yr	32.02	249	253.81		253.81	0.000007	0.19	237.47	118.08	0.03	0.27	0.13	-0.0155	4.81
																0
1	451	Timmins	17.64	249.5	253.78		253.78	0.000017	0.25	100.54	127.3	0.04	0.53	0.13	0	4.28
1	451	2-yr	2.77	249.5	252.8		252.8	0.000001	0.06	49.82	18.16	0.01	0.03	0.03	0	3.3
1	451	5-yr	13.45	249.5	253.31		253.31	0.000017	0.23	60.52	27.19	0.04	0.46	0.31	0	3.81

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
1	451	10-yr	17.71	249.5	253.56		253.57	0.000023	0.28	73.45	121.82	0.05	0.67	0.13	0	4.06
1	451	20-yr	20.96	249.5	253.57		253.57	0.000032	0.34	74.14	121.93	0.05	0.94	0.18	0	4.07
1	451	50-yr	27.16	249.5	253.7		253.71	0.000046	0.41	90.02	124.85	0.06	1.38	0.31	0	4.2
1	451	100-yr	32.02	249.5	253.8		253.81	0.000055	0.45	102.91	127.76	0.07	1.69	0.42	0	4.3
																0
1	448	Timmins	17.64	249.5	253.78		253.78	0.000016	0.24	102.03	126.17	0.04	0.48	0.12	-0.0992	4.28
1	448	2-yr	2.77	249.5	252.8		252.8	0.000001	0.05	52.88	18.27	0.01	0.02	0.02	-0.0992	3.3
1	448	5-yr	13.45	249.5	253.31		253.31	0.000015	0.22	63.54	25.21	0.04	0.42	0.31	-0.0992	3.81
1	448	10-yr	17.71	249.5	253.56		253.57	0.000021	0.27	75.11	120.78	0.04	0.61	0.12	-0.0992	4.06
1	448	20-yr	20.96	249.5	253.57		253.57	0.00003	0.32	75.81	120.94	0.05	0.85	0.17	-0.0992	4.07
1	448	50-yr	27.16	249.5	253.7		253.71	0.000042	0.39	91.61	124.29	0.06	1.26	0.29	-0.0992	4.2
1	448	100-yr	32.02	249.5	253.8		253.81	0.000051	0.43	104.41	126.59	0.07	1.56	0.39	-0.0992	4.3
																0
1	419	Timmins	33.65	252.45	253.46	253.43	253.75	0.01205	3.12	17.71	27.62	1	117.24	75.45	0.0327	1.01
1	419	2-yr	2.98	252.45	252.7	252.7	252.79	0.020293	1.56	2.61	14.2	1.02	47.44	36.45	0.0327	0.25
1	419	5-yr	14.82	252.45	253.05	253.05	253.28	0.01773	2.65	8.22	18.87	1.11	101.33	75.46	0.0327	0.6
1	419	10-yr	23.97	252.45	253.24	253.24	253.54	0.015519	3.01	12.32	22.72	1.09	118.57	82.12	0.0327	0.79
1	419	20-yr	24.25	252.45	253.25	253.25	253.54	0.015474	3.02	12.44	22.83	1.09	119.03	82.3	0.0327	0.8
1	419	50-yr	29.76	252.45	253.36	253.34	253.67	0.014052	3.15	15.16	25.68	1.06	123.61	81	0.0327	0.91
1	419	100-yr	34.86	252.45	253.49	253.45	253.78	0.011395	3.1	18.58	28.08	0.98	114.33	73.59	0.0327	1.04
																0
1	367	Timmins	33.65	250.77	253.45		253.52	0.001443	1.72	36.15	34.48	0.36	28.18	14.53	0.0168	2.68
1	367	2-yr	2.98	250.77	251.67	251.67	251.82	0.012758	1.83	1.93	6.75	0.84	53.49	33.68	0.0168	0.9
1	367	5-yr	14.82	250.77	252.98		253.01	0.000889	1.15	22.23	25.36	0.27	13.74	7.45	0.0168	2.21
1	367	10-yr	23.97	250.77	253.25		253.3	0.001159	1.45	29.75	29.79	0.32	20.63	11.1	0.0168	2.48
1	367	20-yr	24.25	250.77	253.26		253.31	0.001156	1.45	30.04	29.89	0.32	20.67	11.14	0.0168	2.49
1	367	50-yr	29.76	250.77	253.37		253.44	0.001328	1.61	33.63	32.32	0.35	25.07	13.26	0.0168	2.6
1	367	100-yr	34.86	250.77	253.47		253.55	0.001481	1.75	36.97	35.5	0.37	29.22	14.82	0.0168	2.7
																0
1	328	Timmins	33.65	250.1	253.42		253.47	0.000815	1.54	45.2	38.29	0.29	20.83	9.18	0.0103	3.32
1	328	2-yr	2.98	250.1	251.42		251.44	0.000749	0.7	5.65	7.77	0.23	6.16	4.96	0.0103	1.32
1	328	5-yr	14.82	250.1	252.96		252.99	0.000413	0.98	29.3	28.72	0.2	8.91	4	0.0103	2.86
1	328	10-yr	23.97	250.1	253.22		253.26	0.00063	1.3	37.99	35.61	0.25	15.03	6.41	0.0103	3.12
1	328	20-yr	24.25	250.1	253.23		253.27	0.00063	1.3	38.34	35.74	0.25	15.1	6.45	0.0103	3.13
1	328	50-yr	29.76	250.1	253.34		253.4	0.000742	1.45	42.43	37.21	0.27	18.49	8.07	0.0103	3.24
1	328	100-yr	34.86	250.1	253.44		253.5	0.000834	1.57	46.1	38.64	0.29	21.49	9.5	0.0103	3.34
																0
1	299	Timmins	33.65	249.8	253.4		253.45	0.000613	1.38	45.02	33.54	0.25	16.36	7.6	-0.0023	3.6
1	299	2-yr	2.98	249.8	251.4		251.42	0.000601	0.7	5.52	7.36	0.21	5.88	4.01	-0.0023	1.6
1	299	5-yr	14.82	249.8	252.95		252.97	0.000297	0.87	31.13	28.98	0.17	6.81	3.01	-0.0023	3.15
1	299	10-yr	23.97	249.8	253.21		253.25	0.000449	1.13	38.76	30.4	0.21	11.28	5.36	-0.0023	3.41
1	299	20-yr	24.25	249.8	253.22		253.26	0.000451	1.14	39.06	31.24	0.21	11.35	5.28	-0.0023	3.42
1	299	50-yr	29.76	249.8	253.33		253.37	0.000548	1.28	42.64	33.08	0.23	14.3	6.57	-0.0023	3.53
1	299	100-yr	34.86	249.8	253.43		253.48	0.00063	1.41	45.78	33.69	0.25	16.95	7.91	-0.0023	3.63
																0
1	286	Timmins	33.65	249.83	253.38	252.37	253.44	0.000994	1.37	39.61	33.8	0.24	18.22	10.36	-0.0114	3.55
1	286	2-yr	2.98	249.83	251.39	250.33	251.41	0.000585	0.61	4.89	3.64	0.17	4.75	4.75	-0.0114	1.56
1	286	5-yr	14.82	249.83	252.94	251.23	252.97	0.000528	0.9	25.67	28.43	0.17	8.35	4.23	-0.0114	3.11
1	286	10-yr	23.97	249.83	253.19	251.71	253.24	0.000766	1.15	33.45	31.68	0.21	13.23	7.19	-0.0114	3.36
1	286	20-yr	24.25	249.83	253.2	251.73	253.25	0.000767	1.16	33.76	31.79	0.21	13.28	7.24	-0.0114	3.37
1	286	50-yr	29.76	249.83	253.31	252.25	253.36	0.000906	1.29	37.25	32.99	0.23	16.24	9.1	-0.0114	3.48
1	286	100-yr	34.86	249.83	253.41	252.4	253.47	0.001017	1.39	40.38	34.05	0.25	18.77	10.73	-0.0114	3.58
																0
1	270		Culvert													0
																0
1	249	Timmins	33.65	250.28	252.67		252.87	0.003462	2.7	21.85	16.41	0.57	68.93	42.65	0	2.39
1	249	2-yr	2.98	250.28	251.18		251.22	0.001944	1.01	4.25	8.06	0.36	13.6	9.52	0	0.9
1	249	5-yr	14.82	250.28	252.09		252.18	0.002222	1.78	13.57	12.63	0.43	33.07	22.04	0	1.81
1	249	10-yr	23.97	250.28	252.44		252.58	0.002644	2.2	18.4	14.49	0.49	47.49	30.94	0	2.16
1	249	20-yr	24.25	250.28	252.45		252.59	0.002664	2.21	18.51	14.53	0.49	48.03	31.27	0	2.17
1	249	50-yr	29.76	250.28	252.59		252.76	0.003115	2.5	20.55	15.63	0.54	59.84	37.84	0	2.31
1	249	100-yr	34.86	250.28	252.69		252.9	0.003569	2.76	22.24	16.64	0.58	71.78	44.15	0	2.41
																0
1	238	Timmins	33.65	250.28	252.51		252.8	0.006272	3.34	18.07	17.92	0.72	110.1	58.83	0.0083	2.23
1	238	2-yr	2.98	250.28	251.11		251.18	0.004373	1.41	3.04	6.33	0.51	27.71	18.93	0.0083	0.83
1	238	5-yr	14.82	250.28	251.97		252.14	0.00454	2.35	10.48	11.09	0.58	60.16	39.01	0.0083	1.69
1	238	10-yr	23.97	250.28	252.28		252.52	0.005668	2.95	14.37	14.3	0.67	89.05	52.41	0.0083	2
1	238	20-yr	24.25	250.28	252.29		252.53	0.005692	2.96	14.47	14.4	0.67	89.75	52.68	0.0083	2.01
1	238	50-yr	29.76	250.28	252.43		252.69	0.00605	3.19	16.58	16.42	0.7	102.03	56.6	0.0083	2.15
1	238	100-yr	34.86	250.28	252.54		252.83	0.00635	3.38	18.53	18.4	0.72	112.75	59.53	0.0083	2.26
																0
1	201	Timmins	33.65	249.97	252.43		252.55	0.00327	2.22	26.78	27.59	0.46	50.82	29.71	0.0063	2.46
1	201	2-yr	2.98	249.97	251.01		251.05	0.002306	1.03	4.38	8.98	0.33	14.73	9.88	0.0063	1.04
1	201	5-yr	14.82	249.97	251.9		251.97	0.002376	1.6	15.57	16.73	0.37	28.79	20.17	0.0063	1.93
1	201	10-yr	23.97	249.97	252.21		252.3	0.002902	1.96	21.27	21.09	0.42	40.84	27.03	0.0063	2.24
1	201	20-yr	24.25	249.97	252.21		252.31	0.002913	1.97	21.42	21.27	0.42	41.13	27.11	0.0063	2.24
1	201	50-yr	29.76	249.97	252.35		252.46	0.003135	2.12	24.55	24.93	0.44	47	28.76	0.0063	2.38
1	201	100-yr	34.86	249.97	252.46		252.58	0.003308	2.25	27.49	28.57	0.46	51.94	29.83	0.0063	2.49
																0
1	165	Timmins	33.65	249.74	252.34		252.43	0.002963	1.98	28.61	30.18	0.4	41.68	26.08	0.0067	2.6
1	165	2-yr	2.98	249.74	250.89		250.95	0.003209	1.17	3.63	8.13	0.36	19.44	11.93	0.0067	1.15

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
1	165	5-yr	14.82	249.74	251.8		251.87	0.002916	1.67	14.82	19.18	0.38	32.29	20.39	0.0067	2.06
1	165	10-yr	23.97	249.74	252.1		252.19	0.003015	1.87	21.88	27.39	0.39	38.51	22.28	0.0067	2.36
1	165	20-yr	24.25	249.74	252.11		252.2	0.003012	1.87	22.08	27.5	0.39	38.6	22.39	0.0067	2.37
1	165	50-yr	29.76	249.74	252.25		252.34	0.002971	1.94	26.03	29.22	0.39	40.36	24.55	0.0067	2.51
1	165	100-yr	34.86	249.74	252.36		252.46	0.002965	1.99	29.38	30.45	0.4	42.11	26.57	0.0067	2.62
																0
1	126	Timmins	33.65	249.48	252.21		252.31	0.003359	1.96	26.9	31.89	0.38	42.31	26.01	0.0063	2.73
1	126	2-yr	2.98	249.48	250.73		250.8	0.004272	1.28	3.03	7.67	0.38	23.78	13.26	0.0063	1.25
1	126	5-yr	14.82	249.48	251.69		251.76	0.002906	1.57	14.33	18.27	0.34	29.41	20.03	0.0063	2.21
1	126	10-yr	23.97	249.48	251.98		252.07	0.003124	1.78	20.67	24.59	0.36	36.03	23.69	0.0063	2.5
1	126	20-yr	24.25	249.48	251.99		252.08	0.003133	1.79	20.85	24.77	0.37	36.24	23.8	0.0063	2.51
1	126	50-yr	29.76	249.48	252.12		252.22	0.003278	1.89	24.36	28.41	0.38	39.97	25.61	0.0063	2.64
1	126	100-yr	34.86	249.48	252.23		252.33	0.003374	1.97	27.71	32.96	0.38	42.91	26.1	0.0063	2.75
																0
1	98	Timmins	33.65	249.3	251.81	251.77	252.12	0.012074	3.26	15.98	20.65	0.67	125.38	81.76	0.0068	2.51
1	98	2-yr	2.98	249.3	250.53		250.65	0.006883	1.5	1.99	4.04	0.45	33.9	21.49	0.0068	1.23
1	98	5-yr	14.82	249.3	251.44		251.62	0.007698	2.33	9.77	13.23	0.52	67.61	47.1	0.0068	2.14
1	98	10-yr	23.97	249.3	251.66		251.91	0.009985	2.84	13.08	17.3	0.6	97.2	64.8	0.0068	2.36
1	98	20-yr	24.25	249.3	251.67		251.92	0.010053	2.85	13.17	17.43	0.6	98.08	65.24	0.0068	2.37
1	98	50-yr	29.76	249.3	251.76	251.71	252.04	0.011258	3.1	14.86	19.73	0.64	114.23	73.88	0.0068	2.46
1	98	100-yr	34.86	249.3	251.83	251.8	252.15	0.012323	3.31	16.31	20.88	0.68	128.81	84.33	0.0068	2.53
																0
1	65	Timmins	33.65	249.08	251.77		251.85	0.003758	1.78	31.04	51.68	0.35	37.88	20.98	0.0065	2.69
1	65	2-yr	2.98	249.08	250.3		250.42	0.007223	1.52	1.96	1.71	0.45	35.12	35.12	0.0065	1.22
1	65	5-yr	14.82	249.08	251.37		251.43	0.003295	1.49	16.17	22.52	0.32	28.01	20.64	0.0065	2.29
1	65	10-yr	23.97	249.08	251.6		251.67	0.003713	1.69	22.82	39.91	0.35	34.87	19.44	0.0065	2.52
1	65	20-yr	24.25	249.08	251.6		251.68	0.003727	1.7	23.02	40.2	0.35	35.07	19.56	0.0065	2.52
1	65	50-yr	29.76	249.08	251.7		251.78	0.003816	1.77	27.58	48.09	0.35	37.44	20.27	0.0065	2.62
1	65	100-yr	34.86	249.08	251.8		251.87	0.003732	1.79	32.12	52.72	0.35	37.92	21.16	0.0065	2.72
																0
1	33	Timmins	33.65	248.87	251.35	251.35	251.62	0.013614	3.01	16.37	24.51	0.62	114.32	77.84	0.0064	2.48
1	33	2-yr	2.98	248.87	250.03		250.17	0.008427	1.61	1.85	1.68	0.49	39.81	39.81	0.0064	1.16
1	33	5-yr	14.82	248.87	251	250.98	251.23	0.011988	2.54	8.54	17.33	0.57	85.82	49.09	0.0064	2.13
1	33	10-yr	23.97	248.87	251.23	251.23	251.46	0.011868	2.71	13.43	24.51	0.58	94.6	56.13	0.0064	2.36
1	33	20-yr	24.25	248.87	251.24	251.24	251.46	0.011871	2.72	13.54	24.51	0.58	94.82	56.61	0.0064	2.37
1	33	50-yr	29.76	248.87	251.31	251.31	251.56	0.012702	2.87	15.37	24.51	0.6	104.82	68.37	0.0064	2.44
1	33	100-yr	34.86	248.87	251.36	251.36	251.64	0.013909	3.05	16.66	24.51	0.63	117.38	80.85	0.0064	2.49
																0
1	7	Timmins	33.65	248.7	250.98	250.98	251.16	0.013725	2.7	20.74	45.45	0.59	97.57	57		2.28
1	7	2-yr	2.98	248.7	249.5	249.43	249.8	0.024139	2.41	1.24	1.6	0.87	94.56	94.56		0.8
1	7	5-yr	14.82	248.7	250.79	250.79	250.92	0.00931	2.09	12.71	40.66	0.48	60.46	26.31		2.09
1	7	10-yr	23.97	248.7	250.89	250.89	251.05	0.012634	2.52	16.57	43.19	0.56	85.9	44.01		2.19
1	7	20-yr	24.25	248.7	250.89	250.89	251.05	0.012685	2.52	16.69	43.28	0.56	86.37	44.44		2.19
1	7	50-yr	29.76	248.7	250.93	250.93	251.12	0.014342	2.72	18.64	44.56	0.6	99.74	54.59		2.23
1	7	100-yr	34.86	248.7	250.98	250.98	251.17	0.014889	2.81	20.66	45.42	0.61	105.76	61.64		2.28
																0
1	1715	Timmins	2.24	266.73	268.34		268.37	0.002609	0.89	3.31	8.28	0.26	12.19	8.09	0.0109	1.61
1	1715	2-yr	0.08	266.73	267.01		267.02	0.002597	0.43	0.19	0.77	0.28	4.1	4.1	0.0109	0.28
1	1715	5-yr	0.58	266.73	267.58		267.61	0.003804	0.8	0.73	1.12	0.32	11.44	11.44	0.0109	0.85
1	1715	10-yr	0.74	266.73	267.69		267.73	0.004089	0.87	0.85	1.18	0.33	13.16	13.16	0.0109	0.96
1	1715	20-yr	1.03	266.73	267.85		267.9	0.004513	0.97	1.06	1.28	0.34	15.88	15.88	0.0109	1.12
1	1715	50-yr	1.51	266.73	268.08		268.14	0.004985	1.09	1.48	5.79	0.36	19.52	9.28	0.0109	1.35
1	1715	100-yr	1.92	266.73	268.24		268.28	0.003473	0.97	2.54	7.33	0.3	14.98	9.11	0.0109	1.51
																0
1	1701	Timmins	2.24	266.58	268.06	267.85	268.27	0.023176	2.06	1.13	2.81	0.71	74	52.99	0.0107	1.48
1	1701	2-yr	0.08	266.58	266.91	266.81	266.94	0.015156	0.82	0.1	0.43	0.54	16.73	16.73	0.0107	0.33
1	1701	5-yr	0.58	266.58	267.37	267.25	267.49	0.026006	1.57	0.37	0.77	0.72	50.76	50.76	0.0107	0.79
1	1701	10-yr	0.74	266.58	267.46	267.33	267.6	0.026332	1.67	0.45	0.83	0.73	55.69	55.69	0.0107	0.88
1	1701	20-yr	1.03	266.58	267.6	267.46	267.77	0.026214	1.79	0.57	0.94	0.73	62.01	62.01	0.0107	1.02
1	1701	50-yr	1.51	266.58	267.81	267.64	268	0.025309	1.94	0.78	1.09	0.73	68.96	68.96	0.0107	1.23
1	1701	100-yr	1.92	266.58	267.96		268.16	0.024411	2.02	0.95	1.2	0.72	72.75	72.75	0.0107	1.38
																0
1	1678	Timmins	2.24	266.33	267.64		267.81	0.016072	1.86	1.2	1.28	0.61	57.91	57.91	0.0113	1.31
1	1678	2-yr	0.08	266.33	266.48		266.52	0.02215	0.93	0.09	0.64	0.8	22.13	22.13	0.0113	0.15
1	1678	5-yr	0.58	266.33	266.91		267.01	0.016562	1.4	0.42	0.88	0.65	38.36	38.36	0.0113	0.58
1	1678	10-yr	0.74	266.33	267		267.11	0.016335	1.48	0.5	0.93	0.64	41.12	41.12	0.0113	0.67
1	1678	20-yr	1.03	266.33	267.16		267.28	0.016117	1.57	0.65	1.01	0.63	45.22	45.22	0.0113	0.83
1	1678	50-yr	1.51	266.33	267.38		267.52	0.015983	1.71	0.89	1.13	0.62	50.89	50.89	0.0113	1.05
1	1678	100-yr	1.92	266.33	267.53		267.7	0.015974	1.79	1.07	1.22	0.61	54.87	54.87	0.0113	1.2
																0
1	1653	Timmins	2.24	266.05	267.33	266.93	267.47	0.011557	1.66	1.35	1.36	0.53	45.19	45.19	0.0106	1.28
1	1653	2-yr	0.08	266.05	266.23	266.16	266.25	0.00629	0.57	0.14	0.83	0.44	7.88	7.88	0.0106	0.18
1	1653	5-yr	0.58	266.05	266.65	266.43	266.71	0.008508	1.1	0.53	1.03	0.49	22.46	22.46	0.0106	0.6
1	1653	10-yr	0.74	266.05	266.74	266.49	266.81	0.008907	1.18	0.63	1.08	0.49	25.36	25.36	0.0106	0.69
1	1653	20-yr	1.03	266.05	266.88	266.59	266.97	0.009484	1.3	0.79	1.15	0.5	29.79	29.79	0.0106	0.83
1	1653	50-yr	1.51	266.05	267.09	266.74	267.2	0.010328	1.47	1.03	1.25	0.51	36.32	36.32	0.0106	1.04
1	1653	100-yr	1.92	266.05	267.23	266.85	267.36	0.010946	1.58	1.22	1.32	0.52	41.14	41.14	0.0106	1.18
																0
1	1633	Timmins	2.24	265.84	266.75	266.73	267.08	0.034254	2.56	0.88	1.21	0.96	113.07	113.07	0.0111	0.91
1	1633	2-yr	0.08	265.84	265.95	265.95	266	0.033328	1.02	0.08	0.77	1	28.17	28.17	0.0111	0.11
1	1633	5-yr	0.58	265.84	266.23	266.23	266.4	0.033476	1.84	0.32	0.92	1	68.69	68.69	0.0111	0.39

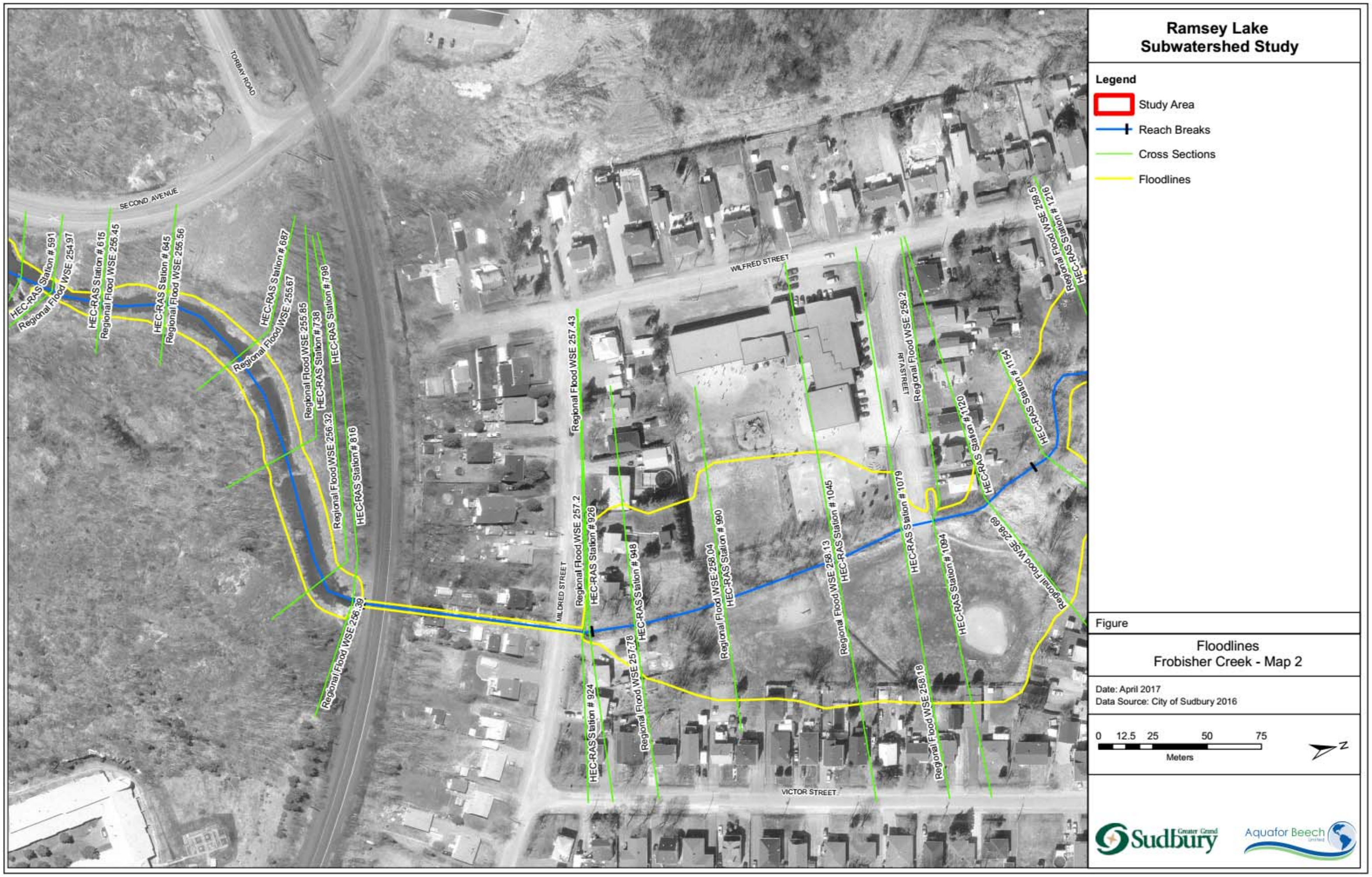
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
1	1633	10-yr	0.74	265.84	266.29	266.29	266.49	0.034151	1.97	0.38	0.96	1.01	76.58	76.58	0.0111	0.45
1	1633	20-yr	1.03	265.84	266.39	266.39	266.63	0.035014	2.16	0.48	1.01	1.01	88.04	88.04	0.0111	0.55
1	1633	50-yr	1.51	265.84	266.54	266.54	266.83	0.036159	2.39	0.63	1.1	1.01	103.67	103.67	0.0111	0.7
1	1633	100-yr	1.92	265.84	266.65	266.65	266.98	0.036467	2.53	0.76	1.16	1	113.2	113.2	0.0111	0.81
																0
1	1612	Timmins	2.24	265.6	266.77	266.22	266.83	0.003398	1.1	2.04	2.17	0.36	17.79	17.79	0.0058	1.17
1	1612	2-yr	0.08	265.6	265.81	265.67	265.82	0.000982	0.27	0.3	1.48	0.19	1.62	1.62	0.0058	0.21
1	1612	5-yr	0.58	265.6	266.17	265.86	266.19	0.002289	0.67	0.87	1.73	0.3	7.7	7.7	0.0058	0.57
1	1612	10-yr	0.74	265.6	266.25	265.91	266.27	0.002515	0.74	1	1.79	0.32	9.16	9.16	0.0058	0.65
1	1612	20-yr	1.03	265.6	266.36	265.98	266.4	0.002821	0.84	1.22	1.87	0.33	11.42	11.42	0.0058	0.76
1	1612	50-yr	1.51	265.6	266.54	266.09	266.59	0.003162	0.97	1.56	2	0.35	14.53	14.53	0.0058	0.94
1	1612	100-yr	1.92	265.6	266.67	266.17	266.73	0.003325	1.05	1.83	2.1	0.36	16.53	16.53	0.0058	1.07
																0
1	1409		Culvert													0
																0
1	1198	Timmins	2.24	263.2	263.84	263.84	264.12	0.015644	2.35	0.95	1.71	1.01	55.54	55.54	0.0042	0.64
1	1198	2-yr	0.08	263.2	263.27	263.27	263.31	0.019086	0.85	0.1	1.34	1	12.56	12.56	0.0042	0.07
1	1198	5-yr	0.58	263.2	263.47	263.47	263.6	0.015398	1.57	0.37	1.47	1	30.2	30.2	0.0042	0.27
1	1198	10-yr	0.74	263.2	263.51	263.51	263.66	0.015534	1.7	0.44	1.5	1.01	34.1	34.1	0.0042	0.31
1	1198	20-yr	1.03	263.2	263.59	263.59	263.77	0.015345	1.87	0.55	1.54	1	39.19	39.19	0.0042	0.39
1	1198	50-yr	1.51	263.2	263.7	263.7	263.92	0.015483	2.1	0.72	1.61	1.01	46.82	46.82	0.0042	0.5
1	1198	100-yr	1.92	263.2	263.78	263.78	264.04	0.015563	2.25	0.85	1.67	1.01	51.96	51.96	0.0042	0.58
																0
1	1186	Timmins	2.24	263.15	263.88		263.92	0.001223	0.86	2.62	4	0.34	6.45	6.45	0.0011	0.73
1	1186	2-yr	0.08	263.15	263.26		263.26	0.000799	0.23	0.35	3.27	0.22	0.82	0.82	0.0011	0.11
1	1186	5-yr	0.58	263.15	263.5		263.51	0.000955	0.5	1.16	3.55	0.28	2.74	2.74	0.0011	0.35
1	1186	10-yr	0.74	263.15	263.55		263.56	0.000997	0.56	1.34	3.61	0.29	3.21	3.21	0.0011	0.4
1	1186	20-yr	1.03	263.15	263.62		263.64	0.001061	0.63	1.62	3.7	0.31	3.96	3.96	0.0011	0.47
1	1186	50-yr	1.51	263.15	263.74		263.77	0.001117	0.73	2.07	3.84	0.32	4.99	4.99	0.0011	0.59
1	1186	100-yr	1.92	263.15	263.82		263.86	0.00118	0.81	2.38	3.93	0.33	5.84	5.84	0.0011	0.67
																0
1	1139	Timmins	2.24	263.1	263.76		263.83	0.002674	1.16	1.93	3.42	0.49	12.34	12.34	0.0015	0.66
1	1139	2-yr	0.08	263.1	263.22		263.22	0.001098	0.28	0.29	2.61	0.26	1.16	1.16	0.0015	0.12
1	1139	5-yr	0.58	263.1	263.42		263.44	0.002062	0.69	0.85	2.91	0.41	5.29	5.29	0.0015	0.32
1	1139	10-yr	0.74	263.1	263.46		263.49	0.002179	0.76	0.98	2.97	0.42	6.23	6.23	0.0015	0.36
1	1139	20-yr	1.03	263.1	263.53		263.57	0.002358	0.87	1.18	3.07	0.45	7.76	7.76	0.0015	0.43
1	1139	50-yr	1.51	263.1	263.64		263.69	0.002414	0.99	1.53	3.24	0.46	9.52	9.52	0.0015	0.54
1	1139	100-yr	1.92	263.1	263.71		263.77	0.002575	1.09	1.76	3.34	0.48	11.18	11.18	0.0015	0.61
																0
1	1105	Timmins	2.24	263.05	263.47	263.47	263.65	0.011707	1.91	1.17	3.21	1.01	37.69	37.69	0.0098	0.42
1	1105	2-yr	0.08	263.05	263.1	263.1	263.12	0.020094	0.68	0.12	2.53	1	9.22	9.22	0.0098	0.05
1	1105	5-yr	0.58	263.05	263.26	263.23	263.32	0.007868	1.06	0.55	2.83	0.77	14.12	14.12	0.0098	0.21
1	1105	10-yr	0.74	263.05	263.29	263.25	263.36	0.008163	1.17	0.64	2.88	0.79	16.48	16.48	0.0098	0.24
1	1105	20-yr	1.03	263.05	263.34	263.3	263.43	0.008517	1.32	0.78	2.97	0.83	20.1	20.1	0.0098	0.29
1	1105	50-yr	1.51	263.05	263.37	263.37	263.52	0.012269	1.7	0.89	3.04	1	32.16	32.16	0.0098	0.32
1	1105	100-yr	1.92	263.05	263.43	263.43	263.6	0.011802	1.82	1.06	3.14	1	35.18	35.18	0.0098	0.38
																0
1	1071	Timmins	2.24	262.71	263.39		263.44	0.001606	0.99	2.55	5.43	0.41	8.52	6.89	0.007	0.68
1	1071	2-yr	0.08	262.71	262.79	262.76	262.79	0.004023	0.41	0.2	2.74	0.48	2.84	2.84	0.007	0.08
1	1071	5-yr	0.58	262.71	262.88	262.88	262.96	0.013963	1.25	0.47	2.97	1	20.78	20.78	0.007	0.17
1	1071	10-yr	0.74	262.71	262.91	262.91	263	0.013476	1.34	0.55	3.04	1	23.03	23.03	0.007	0.2
1	1071	20-yr	1.03	262.71	262.95	262.95	263.06	0.012767	1.48	0.7	3.14	1	26.21	26.21	0.007	0.24
1	1071	50-yr	1.51	262.71	263.11		263.19	0.004812	1.24	1.25	3.92	0.66	15.75	14.11	0.007	0.4
1	1071	100-yr	1.92	262.71	263.27		263.33	0.002416	1.07	1.93	4.78	0.49	10.72	8.92	0.007	0.56
																0
1	1041	Timmins	2.24	262.5	263.39		263.41	0.000361	0.55	4.12	5.58	0.2	2.45	2.27	0.0071	0.89
1	1041	2-yr	0.08	262.5	262.54	262.54	262.55	0.02227	0.59	0.14	3.97	1	7.6	7.6	0.0071	0.04
1	1041	5-yr	0.58	262.5	262.77		262.78	0.001349	0.53	1.11	4.3	0.33	3.2	3.2	0.0071	0.27
1	1041	10-yr	0.74	262.5	262.84		262.86	0.00099	0.52	1.43	4.41	0.29	2.9	2.9	0.0071	0.34
1	1041	20-yr	1.03	262.5	262.96		262.97	0.000728	0.53	1.94	4.57	0.26	2.74	2.74	0.0071	0.46
1	1041	50-yr	1.51	262.5	263.12		263.13	0.000591	0.56	2.69	4.8	0.24	2.86	2.86	0.0071	0.62
1	1041	100-yr	1.92	262.5	263.27		263.29	0.000442	0.56	3.46	5.21	0.21	2.62	2.51	0.0071	0.77
																0
1	1012	Timmins	2.24	262.3	263.39		263.4	0.000192	0.45	5.17	6.14	0.15	1.54	1.36	0.0068	1.09
1	1012	2-yr	0.08	262.3	262.41		262.41	0.000523	0.19	0.43	3.98	0.18	0.54	0.54	0.0068	0.11
1	1012	5-yr	0.58	262.3	262.76		262.77	0.00024	0.3	1.92	4.47	0.15	0.91	0.91	0.0068	0.46
1	1012	10-yr	0.74	262.3	262.84		262.84	0.000239	0.33	2.25	4.57	0.15	1.03	1.03	0.0068	0.54
1	1012	20-yr	1.03	262.3	262.95		262.96	0.00024	0.37	2.79	4.74	0.15	1.21	1.21	0.0068	0.65
1	1012	50-yr	1.51	262.3	263.11		263.12	0.000245	0.42	3.58	5.22	0.16	1.51	1.43	0.0068	0.81
1	1012	100-yr	1.92	262.3	263.27		263.28	0.000214	0.44	4.44	5.78	0.15	1.55	1.39	0.0068	0.97
																0
1	999	Timmins	2.24	262.21	263.39	262.57	263.4	0.000187	0.46	5.31	6.35	0.15	1.59	1.34	0.0058	1.18
1	999	2-yr	0.08	262.21	262.41	262.25	262.41	0.000107	0.12	0.67	3.5	0.09	0.19	0.19	0.0058	0.2
1	999	5-yr	0.58	262.21	262.76	262.36	262.76	0.000188	0.29	2	4.15	0.13	0.8	0.79	0.0058	0.55
1	999	10-yr	0.74	262.21	262.83	262.38	262.84	0.000196	0.32	2.32	4.42	0.14	0.94	0.9	0.0058	0.62
1	999	20-yr	1.03	262.21	262.95	262.42	262.96	0.000206	0.37	2.85	4.84	0.15	1.16	1.05	0.0058	0.74
1	999	50-yr	1.51	262.21	263.11	262.49	263.12	0.000224	0.43	3.67	5.4	0.16	1.51	1.32	0.0058	0.9
1	999	100-yr	1.92	262.21	263.26	262.53	263.28	0.000204	0.45	4.55	5.94	0.15	1.58	1.35	0.0058	1.05
																0
1	927		Culvert													0
																0

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
1	816	Timmins	9.34	261.16	263.09		263.2	0.003755	1.71	7.94	9.82	0.41	35.41	24.65	0.0079	1.93
1	816	2-yr	0.35	261.16	261.51		261.53	0.002801	0.61	0.57	1.73	0.34	7	7	0.0079	0.35
1	816	5-yr	2.44	261.16	262.27		262.34	0.003943	1.18	2.06	2.21	0.39	20.66	20.66	0.0079	1.11
1	816	10-yr	3.44	261.16	262.44		262.53	0.00453	1.37	2.78	5.06	0.42	26.78	17.94	0.0079	1.28
1	816	20-yr	4.62	261.16	262.6		262.71	0.004555	1.51	3.77	7.24	0.43	30.9	18.51	0.0079	1.44
1	816	50-yr	6.47	261.16	262.81		262.92	0.004252	1.62	5.43	8.41	0.43	33.72	21.89	0.0079	1.65
1	816	100-yr	8.12	261.16	262.97		263.09	0.003974	1.68	6.86	9.25	0.42	35.04	23.79	0.0079	1.81
																0
1	771	Timmins	9.34	260.8	262.97		263.02	0.002748	1.22	10.32	9.8	0.28	33.93	24.71	0.0063	2.17
1	771	2-yr	0.35	260.8	261.35		261.37	0.00499	0.61	0.57	1.32	0.3	14	14	0.0063	0.55
1	771	5-yr	2.44	260.8	262.13		262.16	0.003287	0.92	3.46	6.18	0.28	23.32	15.38	0.0063	1.33
1	771	10-yr	3.44	260.8	262.3		262.33	0.003164	1	4.6	7	0.28	25.85	17.56	0.0063	1.5
1	771	20-yr	4.62	260.8	262.47		262.51	0.003065	1.06	5.84	7.74	0.28	28.22	19.6	0.0063	1.67
1	771	50-yr	6.47	260.8	262.69		262.73	0.002955	1.14	7.65	8.72	0.28	31.23	22.12	0.0063	1.89
1	771	100-yr	8.12	260.8	262.86		262.9	0.002851	1.2	9.18	9.37	0.28	33.11	23.85	0.0063	2.06
																0
1	723	Timmins	9.34	260.5	262.87		262.9	0.001994	0.95	12.89	13.01	0.21	21.3	16.98	0.0066	2.37
1	723	2-yr	0.35	260.5	261.15		261.17	0.003497	0.53	0.65	1.24	0.23	10.41	10.41	0.0066	0.65
1	723	5-yr	2.44	260.5	261.95		261.99	0.003887	0.91	3.5	7.07	0.26	23.59	15.51	0.0066	1.45
1	723	10-yr	3.44	260.5	262.15		262.18	0.003231	0.91	5.01	8.52	0.25	22.76	15.7	0.0066	1.65
1	723	20-yr	4.62	260.5	262.33		262.36	0.00279	0.92	6.69	9.83	0.23	22.22	15.96	0.0066	1.83
1	723	50-yr	6.47	260.5	262.57		262.6	0.002379	0.93	9.19	11.29	0.22	21.77	16.48	0.0066	2.07
1	723	100-yr	8.12	260.5	262.75		262.78	0.00215	0.94	11.3	12.31	0.21	21.61	16.91	0.0066	2.25
																0
1	693	Timmins	9.34	260.3	262.68		262.8	0.0051	1.77	8.62	7.19	0.38	68.77	47.21	0.0069	2.38
1	693	2-yr	0.35	260.3	261.1		261.11	0.0012	0.37	1	2.5	0.15	4.58	3.4	0.0069	0.8
1	693	5-yr	2.44	260.3	261.86		261.89	0.002581	0.92	3.73	4.71	0.25	21.76	15.38	0.0069	1.56
1	693	10-yr	3.44	260.3	262.03		262.08	0.003132	1.1	4.59	5.21	0.28	29.75	20.9	0.0069	1.73
1	693	20-yr	4.62	260.3	262.2		262.26	0.003674	1.27	5.49	5.69	0.31	38.61	27	0.0069	1.9
1	693	50-yr	6.47	260.3	262.41		262.5	0.004377	1.5	6.76	6.31	0.34	51.64	35.88	0.0069	2.11
1	693	100-yr	8.12	260.3	262.57		262.67	0.004885	1.67	7.81	6.82	0.37	62.42	43.03	0.0069	2.27
																0
1	657	Timmins	9.34	260.05	262.03	262	262.37	0.04132	2.83	3.74	5.18	0.8	234.94	210.49	0.0047	1.98
1	657	2-yr	0.35	260.05	260.99		261.01	0.007702	0.67	0.52	0.99	0.29	17.82	17.82	0.0047	0.94
1	657	5-yr	2.44	260.05	261.57		261.68	0.021591	1.58	1.74	3.42	0.54	83.43	71.36	0.0047	1.52
1	657	10-yr	3.44	260.05	261.69		261.82	0.024216	1.77	2.18	3.8	0.58	102.26	91.88	0.0047	1.64
1	657	20-yr	4.62	260.05	261.8	261.67	261.97	0.02655	1.98	2.62	4.23	0.62	122.99	111.29	0.0047	1.75
1	657	50-yr	6.47	260.05	261.93	261.81	262.15	0.029574	2.26	3.23	4.82	0.67	154.63	137.93	0.0047	1.88
1	657	100-yr	8.12	260.05	262.01	261.93	262.28	0.033677	2.53	3.63	5.11	0.72	188.48	168.76	0.0047	1.96
																0
1	624	Timmins	9.34	259.9	261.02	261.02	261.15	0.031598	2.07	6.16	25.97	0.78	138.06	70.93	0.0352	1.12
1	624	2-yr	0.35	259.9	260.31	260.31	260.45	0.069296	1.63	0.21	0.8	1.01	117.3	117.3	0.0352	0.41
1	624	5-yr	2.44	259.9	260.74	260.74	260.83	0.032006	1.69	2.08	9.65	0.75	102.28	62.53	0.0352	0.84
1	624	10-yr	3.44	259.9	260.79	260.79	260.9	0.034069	1.83	2.62	11.08	0.78	116.15	73.6	0.0352	0.89
1	624	20-yr	4.62	259.9	260.84	260.84	260.96	0.035853	1.95	3.22	12.63	0.81	129.49	84.03	0.0352	0.94
1	624	50-yr	6.47	259.9	260.9	260.9	261.05	0.038303	2.1	4.08	14.45	0.84	148	100.1	0.0352	1
1	624	100-yr	8.12	259.9	260.96	260.96	261.11	0.037008	2.15	4.97	16.49	0.84	151.32	103.67	0.0352	1.06
																0
1	611	Timmins	9.34	259.41	260.31		260.47	0.024023	2.31	5.75	12.68	0.84	152.03	103.77	0.0149	0.9
1	611	2-yr	0.35	259.41	259.73	259.73	259.78	0.024245	1.06	0.42	5.02	0.7	46.97	19.04	0.0149	0.32
1	611	5-yr	2.44	259.41	260		260.07	0.019528	1.49	2.35	9.24	0.7	74.24	47.06	0.0149	0.59
1	611	10-yr	3.44	259.41	260.08		260.16	0.019174	1.62	3.06	10.3	0.71	84.38	54.16	0.0149	0.67
1	611	20-yr	4.62	259.41	260.14		260.23	0.019992	1.78	3.72	10.94	0.74	98.18	64.61	0.0149	0.73
1	611	50-yr	6.47	259.41	260.22		260.34	0.021664	2.01	4.59	11.72	0.78	120.14	80.75	0.0149	0.81
1	611	100-yr	8.12	259.41	260.27		260.41	0.023043	2.19	5.28	12.31	0.82	138.69	94.18	0.0149	0.86
																0
1	572	Timmins	9.34	258.84	259.71		259.78	0.012931	1.69	8.99	30.09	0.62	81.13	37.52	0.0103	0.87
1	572	2-yr	0.35	258.84	259.22	259.11	259.23	0.007917	0.68	0.76	7.91	0.41	18.37	7.28	0.0103	0.38
1	572	5-yr	2.44	258.84	259.44		259.49	0.012086	1.22	3.08	13.42	0.56	48.77	26.64	0.0103	0.6
1	572	10-yr	3.44	258.84	259.51		259.56	0.012716	1.35	4.02	16.99	0.58	57.88	29.01	0.0103	0.67
1	572	20-yr	4.62	258.84	259.56		259.61	0.012881	1.45	5.05	21.2	0.6	64.35	29.69	0.0103	0.72
1	572	50-yr	6.47	258.84	259.63		259.69	0.012875	1.56	6.65	25.11	0.61	71.66	33.03	0.0103	0.79
1	572	100-yr	8.12	258.84	259.68		259.74	0.012906	1.64	8.01	27.98	0.61	77.33	35.84	0.0103	0.84
																0
1	511	Timmins	9.34	258.21	259.13		259.18	0.007587	1.37	11.16	31.9	0.48	52.15	25.79	0.0163	0.92
1	511	2-yr	0.35	258.21	258.55	258.47	258.58	0.014971	0.88	0.54	7.37	0.56	31.67	10.4	0.0163	0.34
1	511	5-yr	2.44	258.21	258.82	258.72	258.85	0.008941	1.08	3.58	16.2	0.48	37.73	19.04	0.0163	0.61
1	511	10-yr	3.44	258.21	258.88	258.78	258.92	0.008561	1.14	4.72	19.05	0.48	40.77	20.48	0.0163	0.67
1	511	20-yr	4.62	258.21	258.94	258.83	258.98	0.008335	1.21	6.01	22.3	0.49	44.08	21.77	0.0163	0.73
1	511	50-yr	6.47	258.21	259.03		259.07	0.008051	1.29	8.03	26.67	0.49	48.13	23.53	0.0163	0.82
1	511	100-yr	8.12	258.21	259.09		259.13	0.007786	1.34	9.82	29.64	0.49	50.69	25.06	0.0163	0.88
																0
1	467	Timmins	9.34	257.5	258.42	258.42	258.57	0.031521	2.46	6.37	20.83	0.88	178.65	91.88	0.0289	0.92
1	467	2-yr	0.35	257.5	257.86		257.91	0.016124	0.94	0.37	1.27	0.55	35.51	35.51	0.0289	0.36
1	467	5-yr	2.44	257.5	258.21	258.21	258.29	0.019935	1.59	2.59	14.39	0.67	82.24	33.8	0.0289	0.71
1	467	10-yr	3.44	257.5	258.25	258.25	258.34	0.022319	1.77	3.3	15.75	0.71	99.65	44.3	0.0289	0.75
1	467	20-yr	4.62	257.5	258.3	258.29	258.4	0.024137	1.93	4.06	17.07	0.75	115.74	54.48	0.0289	0.8
1	467	50-yr	6.47	257.5	258.36	258.36	258.48	0.02702	2.15	5.06	18.61	0.81	140.35	69.89	0.0289	0.86
1	467	100-yr	8.12	257.5	258.4	258.4	258.53	0.029533	2.33	5.84	19.88	0.85	161.96	82.69	0.0289	0.9
																0
1	412	Timmins	9.34	255.9	257.82		257.82	0.000305	0.32	34.52	39.13	0.08	2.64	2.54	0.0687	1.92

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
1	412	2-yr	0.35	255.9	256.19	256.19	256.32	0.06344	1.58	0.22	0.89	1.01	108.77	108.77	0.0687	0.29
1	412	5-yr	2.44	255.9	256.84	256.84	256.91	0.018895	1.42	3.07	22.11	0.55	68.72	24.42	0.0687	0.94
1	412	10-yr	3.44	255.9	256.87	256.87	256.95	0.023138	1.6	3.78	22.52	0.61	86.93	36.09	0.0687	0.97
1	412	20-yr	4.62	255.9	256.91	256.91	256.99	0.026781	1.76	4.49	23.02	0.66	103.78	48.59	0.0687	1.01
1	412	50-yr	6.47	255.9	257.15		257.17	0.004168	0.84	11.37	30.51	0.27	21.45	14.6	0.0687	1.25
1	412	100-yr	8.12	255.9	257.47		257.47	0.000959	0.49	21.53	34.92	0.14	6.52	5.58	0.0687	1.57
																0
1	407	Timmins	9.34	255.52	257.8	256.67	257.82	0.000652	0.78	19	23.62	0.17	8.69	4.69	0.0064	2.28
1	407	2-yr	0.35	255.52	255.7	255.65	255.74	0.011546	0.8	0.44	2.36	0.59	18.42	18.42	0.0064	0.18
1	407	5-yr	2.44	255.52	256.24	255.99	256.34	0.008717	1.4	1.74	2.54	0.54	39.61	39.61	0.0064	0.72
1	407	10-yr	3.44	255.52	256.44	256.12	256.56	0.008438	1.53	2.26	2.61	0.52	44.83	44.83	0.0064	0.92
1	407	20-yr	4.62	255.52	256.65	256.25	256.79	0.007433	1.63	2.86	2.99	0.5	48.03	43.58	0.0064	1.13
1	407	50-yr	6.47	255.52	256.99	256.42	257.13	0.005766	1.72	3.98	3.77	0.46	48.71	38.64	0.0064	1.47
1	407	100-yr	8.12	255.52	257.41	256.57	257.46	0.001903	1.18	10.85	18.68	0.28	20.93	9.69	0.0064	1.89
																0
1	393		Culvert													0
																0
1	376	Timmins	11.53	255.31	256.51	256.51	256.94	0.014881	3.2	5.17	7.23	0.94	128.46	91.01	0.0119	1.2
1	376	2-yr	0.45	255.31	255.61		255.63	0.003185	0.64	0.75	3.47	0.38	7.77	6.02	0.0119	0.3
1	376	5-yr	2.96	255.31	255.87	255.85	256.07	0.015835	2.05	1.72	4.13	0.89	66.89	55.31	0.0119	0.56
1	376	10-yr	4.28	255.31	255.98	255.98	256.25	0.017933	2.41	2.17	4.41	0.96	87.79	73.37	0.0119	0.67
1	376	20-yr	5.74	255.31	256.1	256.1	256.42	0.018019	2.65	2.73	4.78	0.97	101.53	84.51	0.0119	0.79
1	376	50-yr	8.25	255.31	256.29	256.29	256.67	0.016324	2.93	3.76	5.94	0.96	115.18	86.95	0.0119	0.98
1	376	100-yr	10.46	255.31	256.44	256.44	256.86	0.015227	3.12	4.72	6.83	0.95	124.16	89.45	0.0119	1.13
																0
1	364	Timmins	11.53	255.16	255.95	255.95	256.17	0.028069	3.06	6.37	14.64	1.24	140.57	116.58	0.0636	0.79
1	364	2-yr	0.45	255.16	255.53	255.53	255.56	0.009357	1	0.89	11.57	0.63	19.92	6.91	0.0636	0.37
1	364	5-yr	2.96	255.16	255.68	255.68	255.78	0.022935	1.96	2.74	12.51	1.03	68.82	48.07	0.0636	0.52
1	364	10-yr	4.28	255.16	255.73	255.73	255.85	0.025543	2.2	3.4	12.81	1.1	83.7	64.67	0.0636	0.57
1	364	20-yr	5.74	255.16	255.78	255.78	255.92	0.0271	2.44	4.05	13.25	1.16	99.23	79.05	0.0636	0.62
1	364	50-yr	8.25	255.16	255.86	255.86	256.04	0.028196	2.76	5.08	13.9	1.21	120.62	98.41	0.0636	0.7
1	364	100-yr	10.46	255.16	255.93	255.93	256.13	0.027304	2.94	6.02	14.45	1.22	131.45	108.67	0.0636	0.77
																0
1	349	Timmins	11.53	254.22	255.07	255.07	255.24	0.017932	2.94	8.72	23.08	1.07	118.15	65.56	0.0309	0.85
1	349	2-yr	0.45	254.22	254.55	254.55	254.61	0.011184	1.11	0.56	7.58	0.7	24.34	7.9	0.0309	0.33
1	349	5-yr	2.96	254.22	254.77	254.77	254.91	0.019843	2.21	2.64	13.22	1.03	79.22	38.11	0.0309	0.55
1	349	10-yr	4.28	254.22	254.88	254.88	254.98	0.012429	2.03	4.75	19.59	0.85	62.15	29.15	0.0309	0.66
1	349	20-yr	5.74	254.22	254.93	254.93	255.05	0.014035	2.27	5.68	20.42	0.91	75.72	37.74	0.0309	0.71
1	349	50-yr	8.25	254.22	255	255	255.14	0.015764	2.58	7.14	21.75	0.98	94.38	50.06	0.0309	0.78
1	349	100-yr	10.46	254.22	255.05	255.05	255.21	0.016895	2.8	8.3	22.72	1.03	108.64	59.69	0.0309	0.83
																0
1	316	Timmins	11.53	253.2	254.07	254.07	254.27	0.031143	2.66	6.48	15.73	0.97	199.83	123.02	0.0176	0.87
1	316	2-yr	0.45	253.2	253.56	253.55	253.61	0.019079	1.04	0.58	5.53	0.64	42.99	18.68	0.0176	0.36
1	316	5-yr	2.96	253.2	253.78	253.78	253.88	0.027449	1.82	2.49	11.25	0.84	109.21	58.18	0.0176	0.58
1	316	10-yr	4.28	253.2	253.84	253.84	253.96	0.029917	2.04	3.16	12.21	0.89	133.27	74.17	0.0176	0.64
1	316	20-yr	5.74	253.2	253.9	253.9	254.04	0.030253	2.2	3.91	13.21	0.91	149.65	85.85	0.0176	0.7
1	316	50-yr	8.25	253.2	253.98	253.98	254.15	0.03139	2.45	5.05	14.54	0.95	176.72	104.48	0.0176	0.78
1	316	100-yr	10.46	253.2	254.05	254.04	254.23	0.030648	2.58	6.07	15.46	0.96	189.94	115.4	0.0176	0.85
																0
1	266	Timmins	11.53	252.33	253.24		253.32	0.012277	1.55	9.72	21.07	0.59	70.43	54.62	0.0258	0.91
1	266	2-yr	0.45	252.33	252.66	252.64	252.69	0.01803	0.92	0.77	7.24	0.61	35.6	18.35	0.0258	0.33
1	266	5-yr	2.96	252.33	252.93		252.97	0.012515	1.12	3.89	15.83	0.55	43.25	29.64	0.0258	0.6
1	266	10-yr	4.28	252.33	253.01		253.05	0.011127	1.13	5.21	17.56	0.53	42.78	31.8	0.0258	0.68
1	266	20-yr	5.74	252.33	253.08		253.12	0.010244	1.19	6.47	18.73	0.52	45.2	34.12	0.0258	0.75
1	266	50-yr	8.25	252.33	253.15		253.21	0.01204	1.4	7.8	19.84	0.57	59.91	45.67	0.0258	0.82
1	266	100-yr	10.46	252.33	253.21		253.28	0.012401	1.51	9.07	20.71	0.59	67.99	52.37	0.0258	0.88
																0
1	239	Timmins	11.53	251.62	252.95		253.04	0.008544	1.97	11.14	22.1	0.56	91.93	40.56	0.0129	1.33
1	239	2-yr	0.45	251.62	251.93	251.9	252.01	0.034263	1.29	0.36	2	0.85	69.03	53.65	0.0129	0.31
1	239	5-yr	2.96	251.62	252.55	252.55	252.65	0.010152	1.66	3.3	16.35	0.57	74.39	19.07	0.0129	0.93
1	239	10-yr	4.28	251.62	252.61	252.61	252.73	0.011693	1.87	4.43	17.81	0.62	92.29	27.21	0.0129	0.99
1	239	20-yr	5.74	251.62	252.67	252.67	252.8	0.013267	2.07	5.44	18.58	0.67	111	36.37	0.0129	1.05
1	239	50-yr	8.25	251.62	252.81	252.74	252.91	0.009845	1.95	8.21	20.47	0.59	94.34	37.11	0.0129	1.19
1	239	100-yr	10.46	251.62	252.91	252.8	253	0.008685	1.94	10.31	21.7	0.56	90.62	38.83	0.0129	1.29
																0
1	212	Timmins	11.53	251.28	252.49	252.49	252.7	0.019479	2.77	6.94	17.45	0.83	189.33	74.27	0.0049	1.21
1	212	2-yr	0.45	251.28	251.77		251.79	0.003265	0.59	0.96	3.96	0.29	11.83	7.29	0.0049	0.49
1	212	5-yr	2.96	251.28	252.16		252.22	0.007725	1.39	3.05	7.36	0.49	53.19	30	0.0049	0.88
1	212	10-yr	4.28	251.28	252.23		252.33	0.010677	1.73	3.66	8.71	0.59	80.4	42.2	0.0049	0.95
1	212	20-yr	5.74	251.28	252.3	252.16	252.43	0.013075	2.01	4.29	10.2	0.66	105.97	52.01	0.0049	1.02
1	212	50-yr	8.25	251.28	252.38	252.33	252.56	0.017085	2.44	5.28	13.86	0.77	151.01	62.07	0.0049	1.1
1	212	100-yr	10.46	251.28	252.45	252.45	252.66	0.019295	2.7	6.33	16.82	0.82	181.66	69.59	0.0049	1.17
																0
1	176	Timmins	11.53	251.1	252.14		252.2	0.007975	1.55	11.76	24.17	0.51	63.19	37.49	0.0209	1.04
1	176	2-yr	0.45	251.1	251.42	251.42	251.51	0.033424	1.29	0.39	3.22	0.83	68.35	37.34	0.0209	0.32
1	176	5-yr	2.96	251.1	251.68	251.68	251.76	0.023899	1.71	2.84	14.37	0.79	96.72	45.42	0.0209	0.58
1	176	10-yr	4.28	251.1	251.77		251.84	0.0167	1.62	4.3	16.52	0.68	80.9	41.91	0.0209	0.67
1	176	20-yr	5.74	251.1	251.86		251.92	0.013621	1.6	5.77	18.24	0.63	75.64	41.53	0.0209	0.76
1	176	50-yr	8.25	251.1	251.99		252.05	0.010404	1.57	8.33	21.03	0.57	69.2	39.8	0.0209	0.89
1	176	100-yr	10.46	251.1	252.09		252.15	0.008592	1.55	10.66	23.27	0.52	64.72	38.02	0.0209	0.99
																0

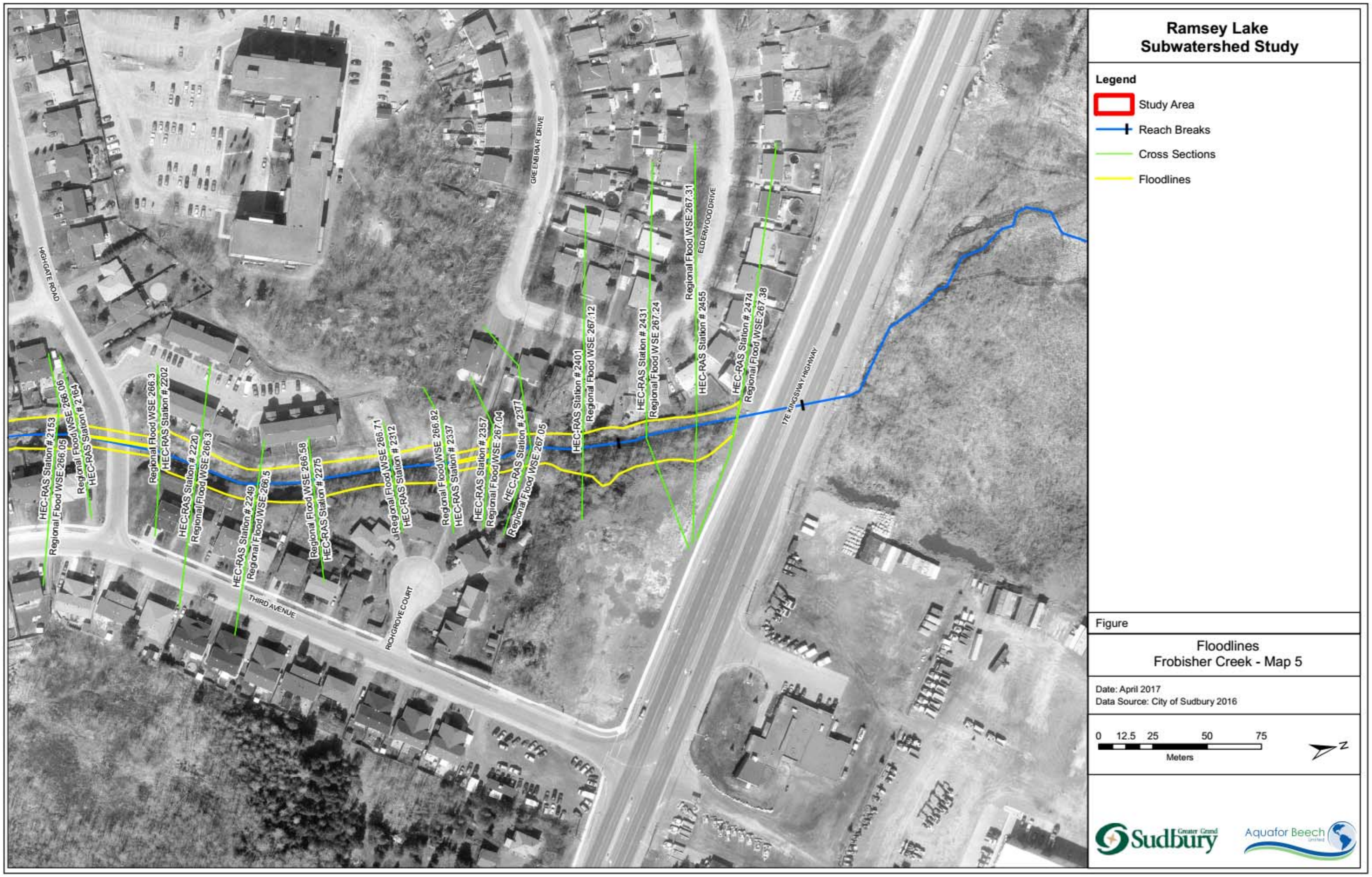
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear Total	Invert Slope	Depth
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)		(N/m2)	(N/m2)		(m)
1	145	Timmins	11.53	250.45	251.94		252	0.004954	1.57	11.59	17.44	0.43	57.41	31.4	0.0133	1.49
1	145	2-yr	0.45	250.45	250.91		250.92	0.004189	0.59	0.91	3.2	0.32	12.62	10.81	0.0133	0.46
1	145	5-yr	2.96	250.45	251.36		251.41	0.006234	1.22	3.51	9.83	0.44	41.48	21.01	0.0133	0.91
1	145	10-yr	4.28	250.45	251.49		251.55	0.005979	1.32	4.96	12.34	0.44	46.39	22.81	0.0133	1.04
1	145	20-yr	5.74	250.45	251.61		251.66	0.005537	1.38	6.45	13.59	0.44	48.43	25.01	0.0133	1.16
1	145	50-yr	8.25	250.45	251.77		251.83	0.00507	1.46	8.84	15.38	0.43	51.5	27.74	0.0133	1.32
1	145	100-yr	10.46	250.45	251.89		251.95	0.004957	1.54	10.74	16.82	0.43	55.35	30.18	0.0133	1.44
																0
1	116	Timmins	11.53	250.07	251.5	251.43	251.71	0.027165	2.56	6.29	15.36	0.79	182.64	102.82	0.0143	1.43
1	116	2-yr	0.45	250.07	250.63		250.69	0.020996	1.12	0.41	2.37	0.59	49.43	28.8	0.0143	0.56
1	116	5-yr	2.96	250.07	251.06		251.14	0.016766	1.47	2.45	5.85	0.57	70.36	60.17	0.0143	0.99
1	116	10-yr	4.28	250.07	251.15		251.26	0.01953	1.68	3.03	6.33	0.63	89.24	80.29	0.0143	1.08
1	116	20-yr	5.74	250.07	251.24		251.38	0.021641	1.9	3.63	7.25	0.67	110.42	94.11	0.0143	1.17
1	116	50-yr	8.25	250.07	251.37	251.25	251.54	0.024783	2.24	4.67	9.5	0.74	145.99	108.64	0.0143	1.3
1	116	100-yr	10.46	250.07	251.46	251.37	251.66	0.026619	2.47	5.71	13.06	0.78	172.06	106.42	0.0143	1.39
																0
1	82	Timmins	11.53	249.58	251.26		251.3	0.005542	1.25	13.14	21.46	0.33	41.95	31.2	0.0139	1.68
1	82	2-yr	0.45	249.58	250.08		250.13	0.012801	0.93	0.49	1.16	0.46	33.06	33.06	0.0139	0.5
1	82	5-yr	2.96	249.58	250.84		250.87	0.004114	0.86	5.29	16.01	0.27	22.29	12.3	0.0139	1.26
1	82	10-yr	4.28	249.58	250.96		250.98	0.003839	0.89	7.22	17.81	0.27	23.08	14.18	0.0139	1.38
1	82	20-yr	5.74	249.58	251.12		251.14	0.002639	0.81	10.38	20.3	0.23	18.15	12.38	0.0139	1.54
1	82	50-yr	8.25	249.58	251.14		251.18	0.004911	1.12	10.79	20.5	0.31	34.29	23.72	0.0139	1.56
1	82	100-yr	10.46	249.58	251.22		251.26	0.005357	1.21	12.4	21.17	0.33	39.59	28.85	0.0139	1.64
																0
1	58	Timmins	11.53	249.24	251.14		251.17	0.004607	1.06	14.44	24.48	0.27	31.13	24.57	0.0139	1.9
1	58	2-yr	0.45	249.24	249.76		249.8	0.01378	0.95	0.48	1.07	0.45	34.85	34.85	0.0139	0.52
1	58	5-yr	2.96	249.24	250.72		250.75	0.005504	0.94	5.07	20.32	0.28	27.4	12.27	0.0139	1.48
1	58	10-yr	4.28	249.24	250.88		250.9	0.003001	0.76	8.43	21.91	0.21	16.97	10.37	0.0139	1.64
1	58	20-yr	5.74	249.24	251.08		251.09	0.001547	0.6	13.02	23.92	0.15	10.07	7.6	0.0139	1.84
1	58	50-yr	8.25	249.24	251.04		251.07	0.003951	0.94	12.11	23.52	0.25	25.07	18.35	0.0139	1.8
1	58	100-yr	10.46	249.24	251.11		251.14	0.00442	1.02	13.71	24.2	0.26	29.3	22.62	0.0139	1.87
																0
1	19	Timmins	11.53	248.7	250.75	250.75	250.84	0.020061	1.87	10.94	43.29	0.47	105.42	46.48		2.05
1	19	2-yr	0.45	248.7	249.5	249.02	249.52	0.004365	0.61	0.75	1.09	0.23	13.32	13.32		0.8
1	19	5-yr	2.96	248.7	249.73	249.73	250.17	0.085547	2.92	1.02	1.19	1.01	295.22	295.22		1.03
1	19	10-yr	4.28	248.7	249.99	249.99	250.51	0.089805	3.21	1.33	1.29	1.01	344.49	344.49		1.29
1	19	20-yr	5.74	248.7	250.24	250.24	250.84	0.092287	3.44	1.67	1.39	1	385.29	385.29		1.54
1	19	50-yr	8.25	248.7	250.71	250.71	250.78	0.01669	1.67	9.02	42.12	0.43	85.26	32.7		2.01
1	19	100-yr	10.46	248.7	250.74	250.74	250.82	0.018888	1.8	10.39	42.95	0.46	98.47	41.85		2.04


Ramsey Lake
Subwatershed Study
Legend
Study Area
Reach Breaks
Cross Sections
Floodlines
Figure
Floodlines
Frobisher Creek - Map1
Date: April 2017
Data Source: City of Sudbury 2016
0 12.5 25 50 75
Meters
SECOND AVENUE
KORMAK STREET
TORBAY ROAD
GREENWOOD DRIVE
BAYCREST ROAD
UNNAMED PRIVATE ROAD
HEC-RAS Station # 7
Regional Flood WSE 250.98
HEC-RAS Station # 33
Regional Flood WSE 251.35
Regional Flood WSE 251.77
HEC-RAS Station # 65
Regional Flood WSE 251.81
HEC-RAS Station # 98
HEC-RAS Station # 126
Regional Flood WSE 252.21
HEC-RAS Station # 165
Regional Flood WSE 252.34
HEC-RAS Station # 201
Regional Flood WSE 252.43
HEC-RAS Station # 238
HEC-RAS Station # 249
Regional Flood WSE 252.67
HEC-RAS Station # 286
HEC-RAS Station # 299
Regional Flood WSE 253.4
HEC-RAS Station # 328
Regional Flood WSE 253.42
HEC-RAS Station # 367
Regional Flood WSE 253.45
HEC-RAS Station # 419
Regional Flood WSE 253.46
HEC-RAS Station # 451
Regional Flood WSE 253.78
HEC-RAS Station # 448
Regional Flood WSE 253.78
HEC-RAS Station # 483
Regional Flood WSE 253.78
HEC-RAS Station # 503
Regional Flood WSE 253.75
HEC-RAS Station # 504
HEC-RAS Station # 506
Regional Flood WSE 254.35
HEC-RAS Station # 530
HEC-RAS Station # 549
HEC-RAS Station # 576
HEC-RAS Station # 591
Sudbury
Aquafor Beech


Ramsey Lake
Subwatershed Study
Legend
Study Area
Reach Breaks
Cross Sections
Floodlines
Figure
Floodlines
Frobisher Creek - Map 2
Date: April 2017
Data Source: City of Sudbury 2016
0 12.5 25 50 75
Meters
N
Greater Grand Sudbury
Aquafor Beech
SECOND AVENUE
TORBAY ROAD
WILFRED STREET
MILDRED STREET
RITA STREET
VICTOR STREET
HEC-RAS Station # 591
Regional Flood WSE 254.97
HEC-RAS Station # 615
Regional Flood WSE 255.45
HEC-RAS Station # 645
Regional Flood WSE 255.56
HEC-RAS Station # 687
Regional Flood WSE 255.67
Regional Flood WSE 255.85
HEC-RAS Station # 739
HEC-RAS Station # 798
Regional Flood WSE 256.32
HEC-RAS Station # 816
Regional Flood WSE 256.39
Regional Flood WSE 257.43
Regional Flood WSE 257.2
HEC-RAS Station # 926
HEC-RAS Station # 924
HEC-RAS Station # 948
Regional Flood WSE 257.78
Regional Flood WSE 258.04
HEC-RAS Station # 990
Regional Flood WSE 258.13
HEC-RAS Station # 1045
Regional Flood WSE 258.2
HEC-RAS Station # 1079
Regional Flood WSE 258.18
HEC-RAS Station # 1094
HEC-RAS Station # 1120
Regional Flood WSE 258.69
HEC-RAS Station # 1154
Regional Flood WSE 259.5
HEC-RAS Station # 1216

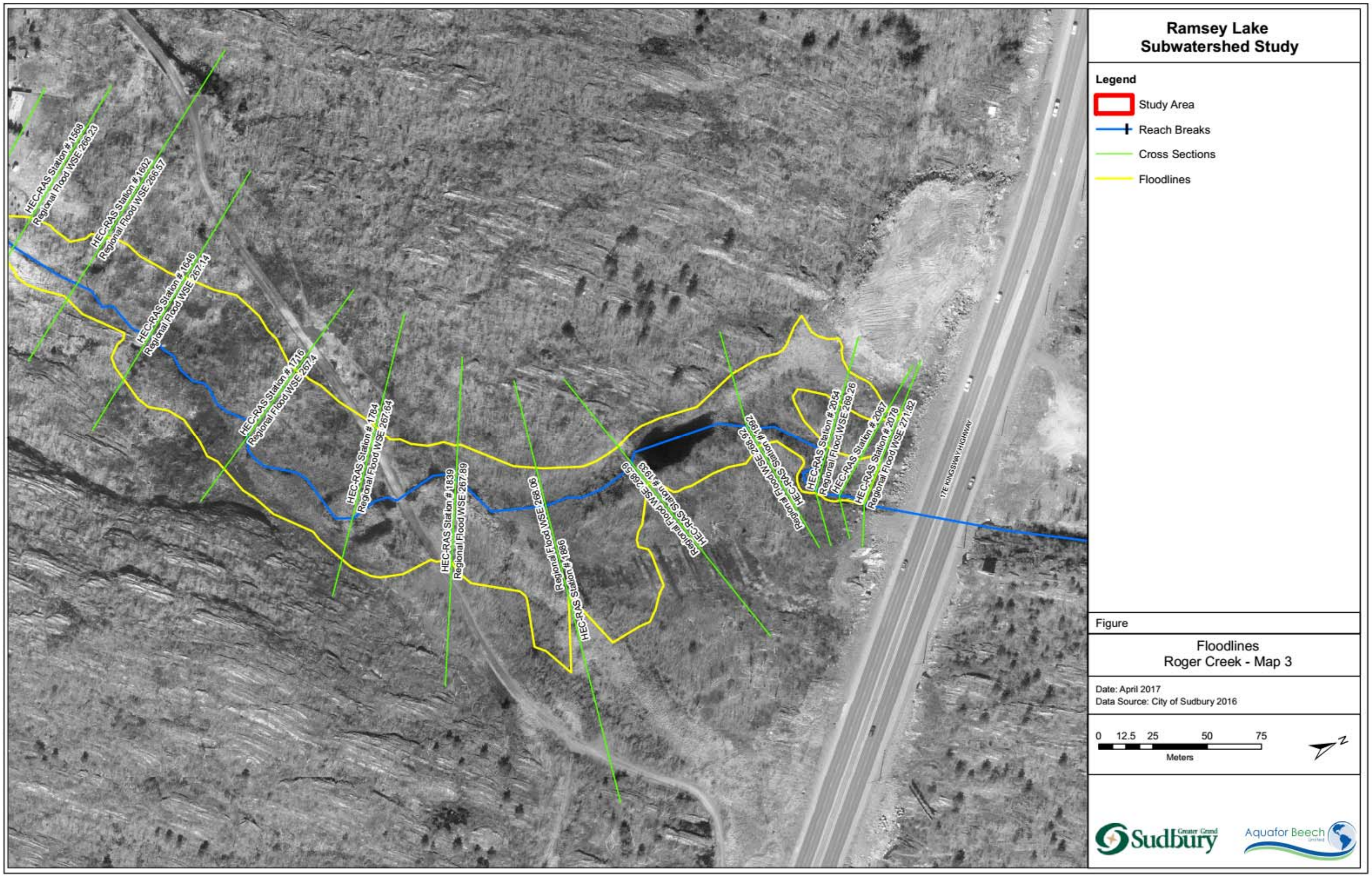

Ramsey Lake Subwatershed Study
Legend
Study Area
Reach Breaks
Cross Sections
Floodlines
Figure
Floodlines
Frobisher Creek - Map 3
Date: April 2017
Data Source: City of Sudbury 2016
0 12.5 25 50 75
Meters
THIRD AVENUE
WILTSHIRE STREET
CAMANOR COURT
RANDOLPH STREET
RICHARD STREET
BANCROFT DRIVE
WILFRED STREET
GARLAND CRESCENT
HEBERT STREET
Sudbury
Aquafor Beech


Ramsey Lake
Subwatershed Study
Legend
Study Area
Reach Breaks
Cross Sections
Floodlines
Figure
Floodlines
Frobisher Creek - Map 4
Date: April 2017
Data Source: City of Sudbury 2016
0 12.5 25 50 75
Meters
N
Sudbury
Aquafor Beech
ADAMS STREET
MARGARET STREET
GARLAND CRESCENT
KENWOOD STREET
PLUMTREE CRESCENT
HIGHGATE ROAD
THIRD AVENUE
EAGLESTONE COURT
HEC-RAS Station # 1674
HEC-RAS Station # 1679
Regional Flood WSE 263.7
HEC-RAS Station # 1740
Regional Flood WSE 263.66
HEC-RAS Station # 1790
Regional Flood WSE 264.44
HEC-RAS Station # 1835
HEC-RAS Station # 1871
Regional Flood WSE 264.71
Regional Flood WSE 264.87
HEC-RAS Station # 1884
Regional Flood WSE 264.99
HEC-RAS Station # 1923
HEC-RAS Station # 1939
Regional Flood WSE 265
HEC-RAS Station # 1982
Regional Flood WSE 265.7
Regional Flood WSE 265.83
HEC-RAS Station # 2021
Regional Flood WSE 265.89
HEC-RAS Station # 2057
Regional Flood WSE 265.93
HEC-RAS Station # 2087
Regional Flood WSE 265.98
HEC-RAS Station # 2117
HEC-RAS Station # 2153
Regional Flood WSE 266.05
Regional Flood WSE 266.06
HEC-RAS Station # 2164

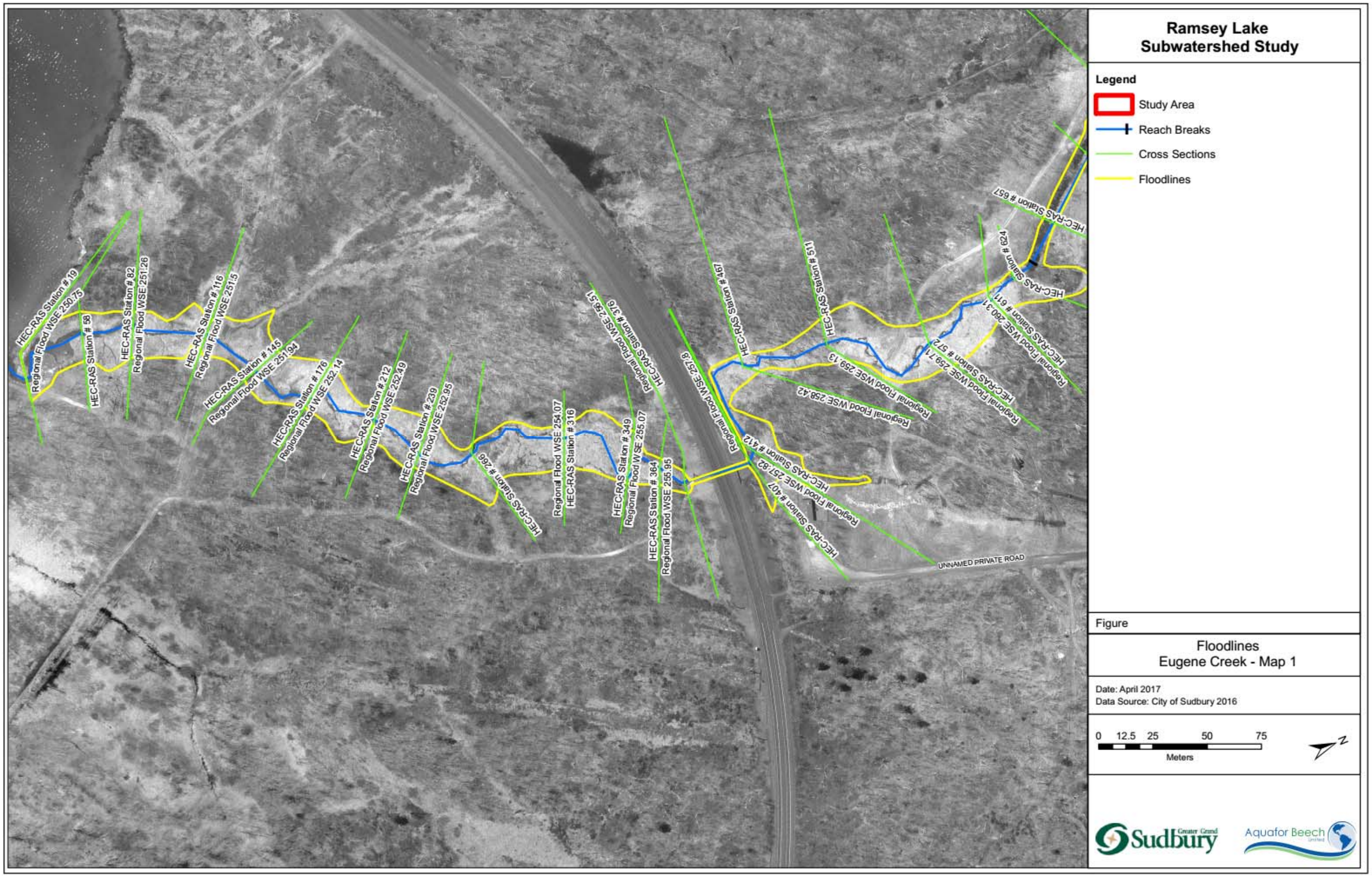

Ramsey Lake
Subwatershed Study
Legend
Study Area
Reach Breaks
Cross Sections
Floodlines
THIRD AVENUE
Figure
Floodlines
Frobisher Creek - Map 5
Date: April 2017
Data Source: City of Sudbury 2016
0 12.5 25 50 75
Meters
N
Sudbury
Aquafor Beech

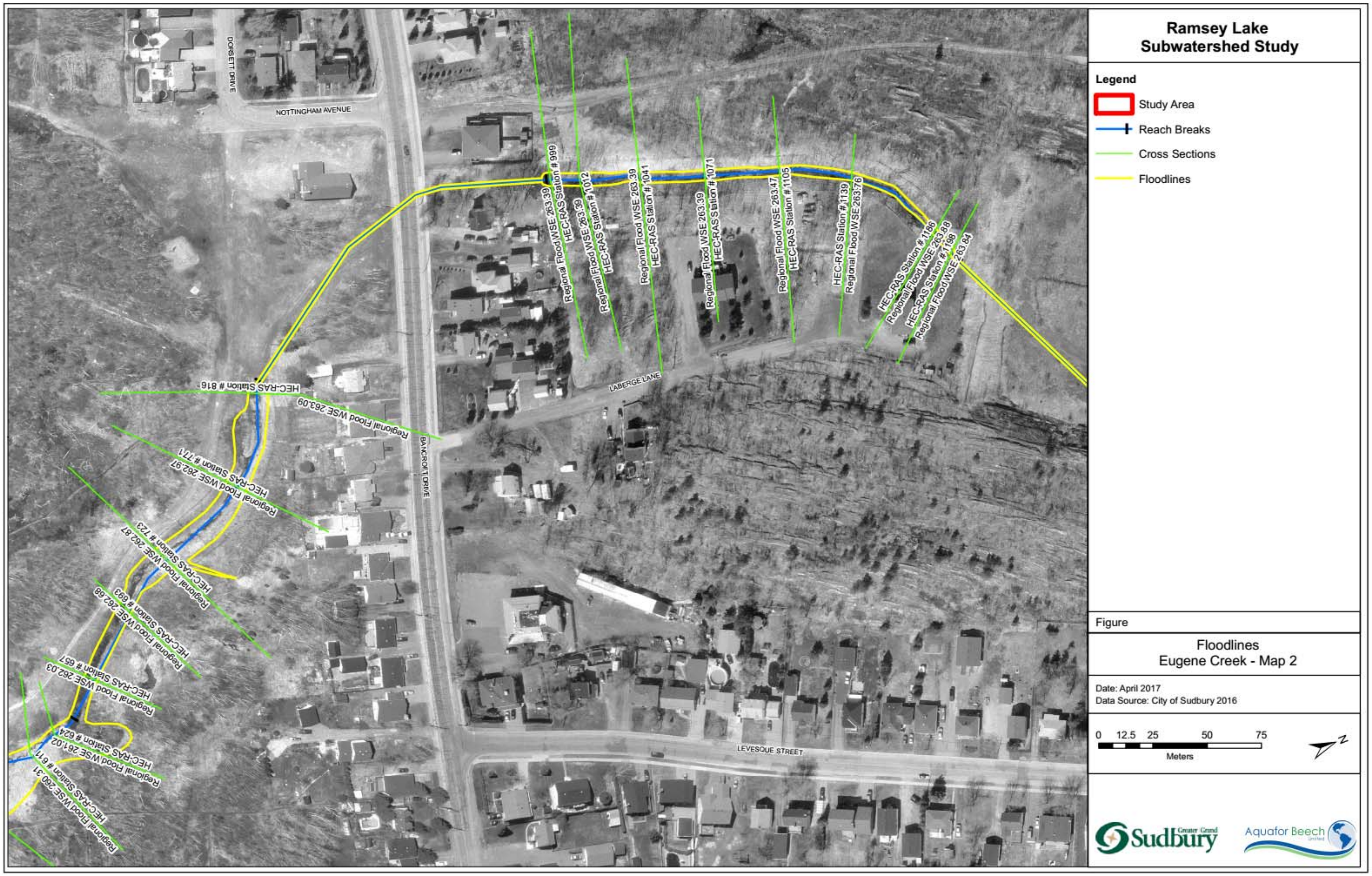

Ramsey Lake Subwatershed Study
Legend
Study Area
Reach Breaks
Cross Sections
Floodlines
Figure
Floodlines
Roger Creek - Map 1
Date: April 2017
Data Source: City of Sudbury 2016
0 12.5 25 50 75
Meters
Sudbury
Aquafor Beech


Ramsey Lake
Subwatershed Study
Legend
Study Area
Reach Breaks
Cross Sections
Floodlines
Figure
Floodlines
Roger Creek - Map 2
Date: April 2017
Data Source: City of Sudbury 2016
0 12.5 25 50 75
Meters
AUTUMNWOOD CRESCENT
CHERRYWOOD CRESCENT
HEATHERGLEN PLACE
REDWOOD DRIVE
FOURTH AVENUE
LAURELCREST AVENUE
BANCROFT DRIVE
HEC-RAS Station # 1135
Regional Flood WSE 260.69
HEC-RAS Station # 1145
Regional Flood WSE 260.8
HEC-RAS Station # 1187
Regional Flood WSE 260.7
HEC-RAS Station # 1221
Regional Flood WSE 261.13
HEC-RAS Station # 1253
Regional Flood WSE 261.47
HEC-RAS Station # 1281
HEC-RAS Station # 1287
Regional Flood WSE 262.12
HEC-RAS Station # 1309
Regional Flood WSE 263.3
HEC-RAS Station # 1315
Regional Flood WSE 263.29
Regional Flood WSE 263.4
HEC-RAS Station # 1346
HEC-RAS Station # 1372
Regional Flood WSE 263.47
HEC-RAS Station # 1415
Regional Flood WSE 263.62
HEC-RAS Station # 1440
Regional Flood WSE 263.69
HEC-RAS Station # 1456
Regional Flood WSE 263.87
HEC-RAS Station # 1546
Regional Flood WSE 266.1
HEC-RAS Station # 1568
Regional Flood WSE 266.23
HEC-RAS Station # 1602
Regional Flood WSE 266.57
HEC-RAS Station # 1646



Ramsey Lake
Subwatershed Study
Legend
Study Area
Reach Breaks
Cross Sections
Floodlines
Figure
Floodlines
Roger Creek - Map 3
Date: April 2017
Data Source: City of Sudbury 2016
0 12.5 25 50 75
Meters
N
HEC-RAS Station # 1568
Regional Flood WSE 266.23
HEC-RAS Station # 1602
Regional Flood WSE 266.57
HEC-RAS Station # 1646
Regional Flood WSE 267.14
HEC-RAS Station # 1716
Regional Flood WSE 267.4
HEC-RAS Station # 1784
Regional Flood WSE 267.64
HEC-RAS Station # 1839
Regional Flood WSE 267.89
THE KINGSWAY HIGHWAY
Sudbury
Aquafor Beech


Ramsey Lake
Subwatershed Study
Legend
Study Area
Reach Breaks
Cross Sections
Floodlines
UNNAMED PRIVATE ROAD
Figure
Floodlines
Eugene Creek - Map 1
Date: April 2017
Data Source: City of Sudbury 2016
0 12.5 25 50 75
Meters
Sudbury
Aquafor Beech


Ramsey Lake
Subwatershed Study
Legend
Study Area
Reach Breaks
Cross Sections
Floodlines
Figure
Floodlines
Eugene Creek - Map 2
Date: April 2017
Data Source: City of Sudbury 2016
0 12.5 25 50 75
Meters
N
Sudbury
Aquafor Beech
DORSETT DRIVE
NOTTINGHAM AVENUE
BANCROFT DRIVE
LABERGE LANE
LEVESQUE STREET
HEC-RAS Station # 999
Regional Flood WSE 263.39
HEC-RAS Station # 1012
Regional Flood WSE 263.39
HEC-RAS Station # 1041
Regional Flood WSE 263.39
HEC-RAS Station # 1071
Regional Flood WSE 263.39
HEC-RAS Station # 1105
Regional Flood WSE 263.47
HEC-RAS Station # 1139
Regional Flood WSE 263.76
HEC-RAS Station # 1186
Regional Flood WSE 263.88
HEC-RAS Station # 816
Regional Flood WSE 263.09
HEC-RAS Station # 771
Regional Flood WSE 262.97
HEC-RAS Station # 723
Regional Flood WSE 262.87
HEC-RAS Station # 693
Regional Flood WSE 262.68
HEC-RAS Station # 657
Regional Flood WSE 262.03
HEC-RAS Station # 624
Regional Flood WSE 261.02


Ramsey Lake Subwatershed Study
Legend
Study Area
Reach Breaks
Cross Sections
Floodlines
Figure
Floodlines
Eugene Creek - Map 3
Date: April 2017
Data Source: City of Sudbury 2016
0 12.5 25 50 75
Meters
CLAIRMONT STREET
EUGENE STREET
LEVESQUE STREET
RHEAL STREET
RAYMOND STREET
KINGSWAY HIGHWAY
Regional Flood WSE 266.77
HEC-RAS Station # 1612
Regional Flood WSE 266.75
HEC-RAS Station # 1633
Regional Flood WSE 267.33
HEC-RAS Station # 1653
HEC-RAS Station # 1678
Regional Flood WSE 268.06
HEC-RAS Station # 1701
Regional Flood WSE 268.34
HEC-RAS Station # 1715
Sudbury
Aquafor Beech


Ramsey Lake
Subwatershed Study
Legend
Study Area
Reach Breaks
Cross Sections
Floodlines
Figure
Floodlines
Keast Creek - Map 1
Date: April 2017
Data Source: City of Sudbury 2016
0 12.5 25 50 75
Meters
N
Sudbury
Aquafor Beech


SOUTH BAY ROAD
ARLINGTON BOULEVARD
Ramsey Lake Subwatershed Study
Legend
Study Area
Reach Breaks
Cross Sections
Floodlines
Figure
Floodlines
Keast Creek - Map 2
Date: April 2017
Data Source: City of Sudbury 2016
0 12.5 25 50 75
Meters
N
Greater Sudbury
Aquafor Beech

Manning Reference Material from City of Greater Sudbury Official Plan Background Report

Table 6-4: Manning Roughness Coefficient
(MTO – Drainage Management Manual, 1997)

	Manning Roughness Coefficients
I. Sewers	0.011 – 0.013
A. Concrete pipe storm sewers	0.012 – 0.014
B. Verified clay pipe	0.009 – 0.011
C. Steel pipe (smooth)	
D. Monolithic concrete:	0.015 – 0.017
1. Wood forms, rough	0.012 – 0.014
2. Wood forms, smooth	0.012 – 0.013
3. Steel forms	
E. Cemented rubble masonry walls:	
1. Concrete floor and top	0.017 – 0.022
2. Natural floor	0.019 – 0.025
F. Laminated treated wood	0.015 – 0.017
G. Smooth walled polyethylene pipe	0.011 – 0.013
Corrugated interior polyethylene pipe (tentative)	0.024
H. Corrugated steel pipe or pipe arch	
68 x 13 mm corrugation (riveted, annular)	
Unpaved	0.024
25% paved	0.021
100% paved	0.012
68 x 13 mm helical	
Unpaved: 600 to 1525 mm Φ range:	0.016 – 0.024
25% paved: 600 to 1525 mm Φ range:	0.015 – 0.021
100% paved: all sizes	0.012
68 x 25 mm riveted (annular)	
Unpaved	0.027
25% paved	0.023
100 % paved	0.012
76 x 25 mm helical	
Unpaved: 900 to 1980 mm dia.:	0.021 – 0.027
25% paved: 900 to 1980 mm dia.:	0.019 – 0.023
100% paved: all sizes	0.012
152 x 51 mm corrugation (annular)	
Unpaved 1550 – 4500 mm dia., or 1900 to 5050 mm span	0.030 – 0.033
25% paved	0.026

Table 6-4 (Continued)

	Manning Roughness Coefficients
II. Road Gutters	
A. Concrete gutter, trowelled finish	0.012
B. Asphalt pavement:	
1. Smooth texture	0.013
2. Rough texture	0.016
C. Concrete gutter with asphalt pavement:	
1. Smooth	0.013
2. Rough	0.015
D. Concrete pavement:	
1. Float finish	0.014
2. Broom finish	0.016
E. Brick	0.016
For gutters with small slope where sediment may accumulate, increase values by 0.002.	
III. Lined Open Channels	
A. Concrete, with surfaces as indicated:	
1. Formed, no finish	0.013 – 0.017
2. Trowel finish	0.012 – 0.014
3. Float finish	0.013 – 0.015
4. Float finish, some gravel on bottom	0.015 – 0.017
5. Gunite, good section	0.016 – 0.019
6. Gunite, wavy section	0.018 – 0.022
B. Concrete bottom float-finished, sides as indicated:	
1. Dressed stone in mortar	0.015 – 0.017
2. Random stone in mortar	0.017 – 0.020
3. Cement rubble masonry	0.020 – 0.030
4. Dry rubble (riprap)	0.020 – 0.030
C. Gravel bottom, sides as indicated	
1. Formed concrete	0.017 – 0.020
2. Random stone mortar	0.020 – 0.023
3. Dry rubble (riprap)	0.023 – 0.033
D. Asphalt	
1. Smooth	0.013
2. Rough	0.016
E. Wood, planed, clean	0.011 – 0.013
F. 1. Good section	0.017 – 0.020
2. Irregular section	0.022 – 0.027
G. Riprap	0.035 – 0.040
H. Rock cut	0.025 – 0.045
IV. Unlined Open Channels	
A. Earth, uniform section:	
1. Clean, recently completed	0.016 – 0.018
2. Clean, after weathering	0.018 – 0.020
3. With short grass, few weeds	0.022 – 0.027
4. In gravelly, soil, uniform section, clean	0.022 – 0.025

Table 6-4 (Continued)

	Manning Roughness Coefficients
B. Earth, fairly uniform section:	
1. No vegetation	0.022 – 0.025
2. Grass, some weeds	0.030 – 0.035
3. Dense weeds in deep channels	0.030 – 0.035
4. Sides clean, gravel bottom	0.025 – 0.030
5. Sides clean, cobble bottom	0.030 – 0.040
C. Dragline excavated or dredged:	
1. No vegetation	0.028 – 0.033
2. Light brush on banks	0.035 – 0.050
D. Rock:	
1. Based on design section	0.035
2. Based on actual mean section:	
a. Smooth and uniform	0.035 – 0.040
b. Jagged and irregular	0.040 – 0.045
E. Channels not maintained, vegetation uncut:	
1. Dense weeds, high as flow depth	0.08 – 0.12
2. Clean bottom, brush on sides	0.05 – 0.08
3. Clean bottom, brush on sides, high stage	0.07 – 0.11
4. Dense brush, high stage	0.10 – 0.14

V. Grassed Channels and Swales[2]

Depth of flow:	Up to 0.2 m	0.2 – 0.5 m
Velocity	0.6 m/s 1.8 m/s	0.6 m/s 1.8 m/s
A. Kentucky bluegrass:		
1. Mowed to 0.05 m	0.07 – 0.045	0.050 – 0.035
2. Length 0.1 to 0.15 m	0.090 – 0.060	0.060 – 0.040
B. Good stand, any grass		
1. Length 0.30 m	0.180 – 0.090	0.120 – 0.070
2. Length 0.60 m	0.300 – 0.190	0.200 – 0.100
C. Fair stand, any grass:		
1. Length 0.30 m	0.140 – 0.080	0.100 – 0.060
2. Length 0.60 m	0.250 – 0.130	0.170 – 0.090

VI. Natural Watercourses

A. Minor stream (surface width at flood stage < 30 m).	
1. Fairly regular section:	
a. Some grass and weeds, little or no brush	0.030 – 0.035
b. Dense growth of weeds, depth of flow materially greater than weed height	0.035 – 0.050
c. Some weeds, light brush on banks	0.035 – 0.050
d. Some weeds, heavy brush on banks	0.050 – 0.070
e. Some weeds, dense willows on banks	0.060 – 0.080
f. For trees within channel with branches submerged at high stage, add 0.01 to 0.02 to above values	
2. Irregular section with pools, slight channel meander; channels (a) to (e) above, add 0.01 to 0.02	

Table 6-4 (Continued)

	Manning Roughness Coefficients
3. Mountain streams, no vegetation in channel, banks usually steep,	
trees and brush along banks submerged at high stage:	0.040 – 0.050
a. Bottom of gravel, cobbles and few boulders	0.050 – 0.070
b. Bottom of cobbles with large boulders	
B. Flood plains (adjacent to natural streams):	
1. Pasture, no brush:	0.030 – 0.035
a. Short grass	0.035 – 0.050
b. High grass	
2. Cultivated areas:	0.030 – 0.040
a. No crop	0.035 – 0.045
b. Mature row crops	0.040 – 0.050
c. Mature field crops	0.050 – 0.070
3. Heavy weeds, scattered	
4. Light brush and trees:	0.050 – 0.060
a. Winter	0.060 – 0.080
b. Summer	
5. Medium to dense vegetation:	0.070 – 0.110
a. Winter	0.010 – 0.160
b. Summer	0.150 – 0.200
6. Dense willows, summer, not bent over by current	
7. Cleared land with tree stumps, 250 – 370 hectare:	0.040 – 0.050
a. No sprouts	0.060 – 0.080
b. With heavy growth of sprouts	
8. Heavy stand of timber, a few down trees, little undergrowth:	0.100 – 0.120
a. Flood depth below branches	0.120 – 0.160
b. Flood depth reaches branches (n increases with depth)	
C. Major stream (surface width at flood stage > 30 m): Roughness coefficient is usually less than for minor streams of similar description on account of less effective resistance offered by irregular banks or vegetation on banks. Roughness values may be somewhat reduced. Follow general recommendations if possible. The roughness value for larger streams of mostly regular section, with no boulders or brush, may be in the range.	0.028 – 0.033

Sources: American Iron and Steel Institute (1980); Herr, L.A. et al, (1965)
Sears, J.K. (1969)
Bradley, J.N. (1978)

APPENDIX C: Erosion Inventory Methodology & Bridge and Culvert Summary Sheets

Erosion Assessment
Maintenance Inventory Definitions and Scoring

Maintenance Code		MAINTENANCE ISSUE	Method Of Assessment	SITE / INDIVIDUAL SCORES							REACH SCORE
				0	1	2	3	4	5	Y/N	
EXTERNAL INFLUENCES	E1	**Visible chemical sheen on water:**	If YES then contact City immediately, investigate and determine if spill response is required. Provide note for any visible sheen that may be organic along with a photo.							Y/N	Y/N
	E2	**Transient activity:**	Evidence of unauthorized permanent or semi-permanent human occupancy near or along the banks of the watercourse (i.e. things such as man-made shelters, and human possessions)							Y/N	Y/N
	E3	**Unintended structures within 3 metres of the bank:**	Inspector must be able to measure a 3m distance from both sides of the bank of the stream to answer this question. Note: this does not include engineered, intentional structures like bridges and culverts What is the possible cause? (1) Is the resident encroaching? (action: who to speak to the resident), (2) Is the watercourse changing/degrading? (action: immediate S/R for repair or follow up investigation and or capital works defined), (3) Is the property line adjacent to the bank intended or originally designed to be this close? (no action required)							Y/N	Y/N
MAINTENANCE DEFECTS	M1	**Signage general condition:**	Look for any signs that identify the stormwater facility and assess their condition.	Asset Not Required/ Doesn't Exist	Pristine with or without minor defects	Defect that has not begun to deteriorate	Moderate defect that will continue to deteriorate	Severe defect that will continue to deteriorate	Asset Required & Missing or Requires Immediate Attention		N/A
	M2	**Permanent Wildlife - Rodents/ Beavers:**	Evaluation of whole tream or reach, take photos to support scoring:		No evidence of activity	Suspect activity, no residence found	Animal sighting, no residence found	Active animal(s)/ residence(s) found	Facility is overrun/ infested		N/A
	M3	**Floating debris and obstructions:**	The intent is that the inspector remove debris at the time of the inspection without having to physically enter the stream. If debris is removed, assign score of 1, if it cannot be removed at time of inspection, assign score between 2 and 5 based on the percentage of space being occupied by the debris at the specific location/cross section. Take photos and notes to support scoring.		There was no debris or obstructions or all debris and obstructions were removed by the inspector	There is a small amount of debris on the stream reach surface and/or a minor obstruction.	There is a medium amount of debris and/or obstructions.	There are significant debris and/or significant obstructions.	The stream reach is fully obstructed or fully covered with debris.		Average
	M4	**Overhanging Obstructions:**	Identify individual overhanging object locations		There are no overhanging objects.	There are overhanging objects but there is more than 5m of clearance above the water surface.	There are overhanging objects between 2m and 5m above the water surface.	There are overhanging objects below 2m above the water surface.	Overhanging objects touch the water surface.		Average
	M5	**Sunken Debris:**	Inspector should try to remove as much of the debris as possible within the cross-section being inspected.		There was no debris or obstructions or all debris and obstructions were removed by the inspector	There is a small amount of debris in the stream reach surface and/or a minor obstruction.	There is a medium amount of debris and/or obstructions.	There are significant debris and/or significant obstructions.	The stream reach is fully obstructed or fully covered with debris		Minimum

Erosion Assessment
Maintenance Inventory Definitions and Scoring

	Maintenance Code	MAINTENANCE ISSUE	Method Of Assessment	SITE / INDIVIDUAL SCORES 0	1	2	3	4	5	Y/N	REACH SCORE
CAPITAL DEFECTS	C1	**Aquatic vegetation (submergent and/or emergent):**	There is a requirement for aquatic vegetation in every stream reach. Too much or too little and the stream reach is operating below design. Note the scoring for this is not by increasing %		from 21% to 40%	from 41% up to 60%	from 0 up to 20%	from 61% up to 80%	from 81% up to 100%		N/A
	C2	***Bank (earthen) erosion:**	Erosion site is defined as any site that has the potential to continue to erode and have a negative impact on the bank environment. Inspect the stream reach area and identify erosion sites which usually exhibit one or a combination of the follow characteristics, although they are not limiting; exposed till, exposed roots, undercutting, and missing vegetation.	Asset Not Required/ Doesn't Exist	Pristine with or without minor defects	Defect that has not begun to deteriorate	Moderate defect that will continue to deteriorate	Severe defect that will continue to deteriorate	Asset Required & Missing or Requires Immediate Attention		Average
	C3	**Constructed riffle:**	Identify if there are any constructed riffles and inspect their condition. Riffles should span the full width of the stream and aerate the water as it passes over the section.	Asset Not Required/ Doesn't Exist	Pristine with or without minor defects	Defect that has not begun to deteriorate	Moderate defect that will continue to deteriorate	Severe defect that will continue to deteriorate	Asset Required & Missing or Requires Immediate Attention		N/A
	C4	**Constructed municipal access:**	Walk the full length of the access route to assess its state. Take photos, document observations and score the access route according to the following criteria:		Access to the stream by vehicle is possible.	Access to the stream by truck could be possible with minor improvements.	Access to the stream is by foot and is easy and well defined.	Access to the stream is by foot with difficulty.	There is no visible access to the stream, bushwhacking and/or travelling a long distance is required		N/A
	C5	**Access road(s) general condition:**	Walk the full length of the access route (from street to end of access) and evaluate the condition of the access. 1- great condition and a 5 - an access that has deep erosion/potholes that prohibits truck travel. Score= 0 only if there is NO access road	No Access Road Exists	Pristine with or without minor defects	Defect that has not begun to deteriorate	Moderate defect that will continue to deteriorate	Severe defect that will continue to deteriorate	Asset Required & Missing or Requires Immediate Attention		N/A
	C6	**Bank vegetation missing (riparian cover):**	The bank should be 100% vegetated so score is based on **% missing**	Asset does not exist	from 0% up to 20%	from 21% up to 40%	from 41% up to 60%	from 61% up to 80%	from 81% up to 100%		N/A
	C7	**Stream structures/velocity breaks:**	Identify any designed stream structures or velocity breaks	Asset Not Required/ Doesn't Exist	Pristine with or without minor defects	Defect that has not begun to deteriorate	Moderate defect that will continue to deteriorate	Severe defect that will continue to deteriorate	Asset Required & Missing or Requires Immediate Attention		N/A
	C8	**Excessive sediment accumulation:**	Walk around the stream reach and identify locations of excessive sediment accumulation. If scoring "yes", the stream reach is no longer functioning as designed, there is a more structured evaluation of sediment required outside of this inspection.							Y/N	Y/N
	C9	***Any unintended permanent structures:**	Are there any unintended permanent structures within the stream reach? Items that are unintended include manholes, pipes, debris etc.		There are no unintended permanent structures near the stream reach.	There are no unintended permanent structures in the stream reach but there are some very close that may be threatened by rising water levels.	There are partially submerged objects in the stream reach.	There is at one submerged unintended object in the stream reach.	There are several manholes, pipes or other structures that should not be within the stream reach. Further inspection is required		Average

HYDRAULIC STRUCTURE INVENTORY SHEET
Ramsey Lake Sub-Watershed Study
STRUCTURE: F01
Greenwood Drive, south of 2nd Ave. S.

Watershed and Location Information		Structure Configuration and Dimensions	
Tributary Name:	Frobisher Creek	Structure Type:	Culvert
Date Surveyed:	October 24 2016	Barrel Shape:	Elliptical
Crew:	CM & LB	Number of Cells:	1
Current Flow Information		Material:	CSP
Flow Present (Yes/No):	Yes	Open footing (Yes/No):	No
		End Treatment (U/S):	Mitered
		End Treatment (D/S):	Mitered
		Height (m):	2
Key Map:		Width (m):	3
		Diameter (m):	-
		Length (m):	36.37
		U/S Invert Elevation (m):	249.83
		D/S Invert Elevation (m):	250.67
		Top of Road Elevation (m):	252.87
		Average Slope (%):	-2.33%

Site Photographs and Additional Field Notes

NOTES:


Upstream Inlet


Upstream Channel

NOTES:


Downstream Outlet


Downstream Channel

HYDRAULIC STRUCTURE INVENTORY SHEET
Ramsey Lake Sub-Watershed Study
STRUCTURE: F03
Private Road to Finlandia Village, east of 2nd Ave. S.

Watershed and Location Information		**Structure Configuration and Dimensions**	
Tributary Name:	Frobisher Creek	Structure Type:	Bridge
Date Surveyed:	October 24 2016	Barrel Shape:	-
Crew:	CM & LB	Number of Cells:	1
Current Flow Information		Material:	Concrete
Flow Present (Yes/No):	Yes	Open footing (Yes/No):	Yes
		End Treatment (U/S):	No Abutments - In Bedrock
		End Treatment (D/S):	No Abutments - In Bedrock
		Height (m):	4
Key Map:		Width (m):	14.5
		Diameter (m):	-
		Length (m):	-
		U/S Invert Elevation (m):	-
		D/S Invert Elevation (m):	-
		Top of Road Elevation (m):	258.70
		Average Slope (%):	-

Site Photographs and Additional Field Notes

NOTES:

Upstream Inlet

Upstream Channel

NOTES:

NA

Downstream Outlet

Downstream Channel

HYDRAULIC STRUCTURE INVENTORY SHEET
Ramsey Lake Sub-Watershed Study
STRUCTURE: F05
Storm sewer from Wilfred Street to CN Train Tracks

Watershed and Location Information		**Structure Configuration and Dimensions**	
Tributary Name:	Frobisher Creek	Structure Type:	Culvert
Date Surveyed:	October 24 2016	Barrel Shape:	Circular
Crew:	CM & LB	Number of Cells:	1
Current Flow Information		Material:	CSP
Flow Present (Yes/No):	Yes	Open footing (Yes/No):	No
		End Treatment (U/S):	Other
		End Treatment (D/S):	Headwall
		Height (m):	-
Key Map:		Width (m):	-
		Diameter (m):	2.44
		Length (m):	103.01
		U/S Invert Elevation (m):	253.92
		D/S Invert Elevation (m):	253.77
		Top of Road Elevation (m):	Approx. 259.50 m at tracks
		Average Slope (%):	0.15%

Site Photographs and Additional Field Notes

NOTES:


Upstream Inlet


Upstream Channel

NOTES:


Downstream Outlet


Downstream Channel

HYDRAULIC STRUCTURE INVENTORY SHEET
Ramsey Lake Sub-Watershed Study
STRUCTURE: F06
Rita Street at Grace Playground

Watershed and Location Information		**Structure Configuration and Dimensions**	
Tributary Name:	Frobisher Creek	Structure Type:	Culvert
Date Surveyed:	October 24 2016	Barrel Shape:	Circular
Crew:	CM & LB	Number of Cells:	1
Current Flow Information		Material:	PVC
Flow Present (Yes/No):	Yes	Open footing (Yes/No):	No
		End Treatment (U/S):	Projecting
		End Treatment (D/S):	Projecting
		Height (m):	-
Key Map:		Width (m):	-
		Diameter (m):	1.34
		Length (m):	12.25
		U/S Invert Elevation (m):	256.34
		D/S Invert Elevation (m):	256.51
		Top of Road Elevation (m):	258.03
		Average Slope (%):	-1.33%

Site Photographs and Additional Field Notes

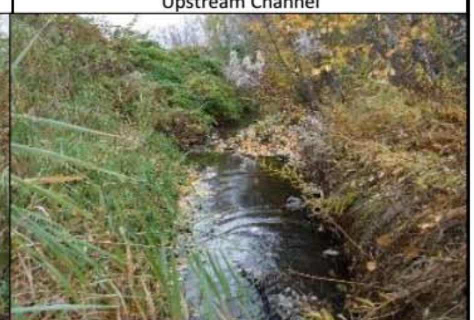
NOTES:

Upstream Inlet

Upstream Channel

NOTES:

Downstream Outlet



Downstream Channel

HYDRAULIC STRUCTURE INVENTORY SHEET

Ramsey Lake Sub-Watershed Study

STRUCTURE: F07

Bancroft Drive, west of 3rd Ave.

Watershed and Location Information		Structure Configuration and Dimensions	
Tributary Name:	Frobisher Creek	Structure Type:	Culvert
Date Surveyed:	October 24 2016	Barrel Shape:	Box
Crew:	CM & LB	Number of Cells:	1
Current Flow Information		Material:	Concrete
Flow Present (Yes/No):	Yes	Open footing (Yes/No):	Yes
		End Treatment (U/S):	Wingwall
		End Treatment (D/S):	Wingwall
		Height (m):	1.45
Key Map:		Width (m):	3.7
		Diameter (m):	-
		Length (m):	24.48
		U/S Invert Elevation (m):	257.61
		D/S Invert Elevation (m):	257.95
		Top of Road Elevation (m):	260.15
		Average Slope (%):	-1.36%

Site Photographs and Additional Field Notes

NOTES:

Upstream Inlet

Upstream Channel

NOTES:

Downstream Outlet

Downstream Channel

HYDRAULIC STRUCTURE INVENTORY SHEET
Ramsey Lake Sub-Watershed Study
STRUCTURE: F08
Hebert Street, west of 3rd Ave.

Watershed and Location Information		**Structure Configuration and Dimensions**	
Tributary Name:	Frobisher Creek	Structure Type:	Culvert
Date Surveyed:	October 24 2016	Barrel Shape:	Box
Crew:	CM & LB	Number of Cells:	1
Current Flow Information		Material:	Concrete
Flow Present (Yes/No):	Yes	Open footing (Yes/No):	Yes
		End Treatment (U/S):	Projecting
		End Treatment (D/S):	Projecting
		Height (m):	1.48
Key Map:		Width (m):	3
		Diameter (m):	-
		Length (m):	25.50
		U/S Invert Elevation (m):	261.17
		D/S Invert Elevation (m):	261.05
		Top of Road Elevation (m):	264.03
		Average Slope (%):	0.48%

Site Photographs and Additional Field Notes

NOTES:

Upstream Inlet

Upstream Channel

NOTES:

Downstream Outlet

Downstream Channel

HYDRAULIC STRUCTURE INVENTORY SHEET
Ramsey Lake Sub-Watershed Study
STRUCTURE: F09
Kenwood Street, west of 3rd Ave.

Watershed and Location Information		**Structure Configuration and Dimensions**	
Tributary Name:	Frobisher Creek	Structure Type:	Culvert
Date Surveyed:	October 24 2016	Barrel Shape:	Elliptical
Crew:	CM & LB	Number of Cells:	2
Current Flow Information		Material:	CSP
Flow Present (Yes/No):	Yes	Open footing (Yes/No):	No
		End Treatment (U/S):	Mitered
		End Treatment (D/S):	Mitered
		Height (m):	1.96
Key Map:		Width (m):	3.7
		Diameter (m):	-
		Length (m):	36.40
		U/S Invert Elevation (m):	263.64
		D/S Invert Elevation (m):	263.32
		Top of Road Elevation (m):	266.70
		Average Slope (%):	0.82%

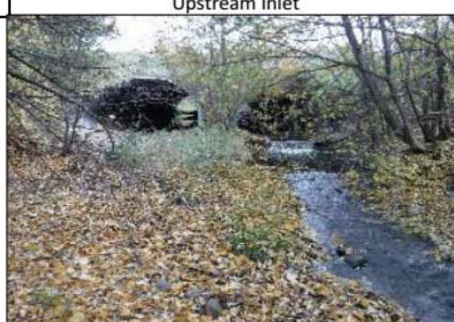
Site Photographs and Additional Field Notes

NOTES:

Upstream Inlet

Upstream Channel

NOTES:



Downstream Outlet

Downstream Channel

HYDRAULIC STRUCTURE INVENTORY SHEET
Ramsey Lake Sub-Watershed Study
STRUCTURE: F10
Highgate Road, west of 3rd Ave.

Watershed and Location Information		**Structure Configuration and Dimensions**	
Tributary Name:	Frobisher Creek	Structure Type:	Culvert
Date Surveyed:	October 24 2016	Barrel Shape:	Elliptical
Crew:	CM & LB	Number of Cells:	2
Current Flow Information		Material:	CSP
Flow Present (Yes/No):	Yes	Open footing (Yes/No):	No
		End Treatment (U/S):	Mitered
		End Treatment (D/S):	Mitered
		Height (m):	1.82
Key Map:		Width (m):	3.4
		Diameter (m):	-
		Length (m):	33.07
		U/S Invert Elevation (m):	264.61
		D/S Invert Elevation (m):	264.85
		Top of Road Elevation (m):	267.49
		Average Slope (%):	-1.61%

Site Photographs and Additional Field Notes

NOTES:

Upstream Inlet

Upstream Channel

NOTES:

Downstream Outlet

Downstream Channel

HYDRAULIC STRUCTURE INVENTORY SHEET
Ramsey Lake Sub-Watershed Study
STRUCTURE: F11
Trail connecting Glenbriar Drive to Richgrove Court

Watershed and Location Information		Structure Configuration and Dimensions	
Tributary Name:	Frobisher Creek	Structure Type:	Culvert
Date Surveyed:	October 24 2016	Barrel Shape:	Elliptical
Crew:	CM & LB	Number of Cells:	2
Current Flow Information		Material:	CSP
Flow Present (Yes/No):	Yes	Open footing (Yes/No):	No
		End Treatment (U/S):	Mitered
		End Treatment (D/S):	Mitered
		Height (m):	1.4
Key Map:		Width (m):	3.4
		Diameter (m):	-
		Length (m):	15.91
		U/S Invert Elevation (m):	264.91
		D/S Invert Elevation (m):	265.28
		Top of Road Elevation (m):	267.50
		Average Slope (%):	-1.33%

Site Photographs and Additional Field Notes

NOTES:

Upstream Inlet

Upstream Channel

NOTES:

Downstream Outlet

Downstream Channel

HYDRAULIC STRUCTURE INVENTORY SHEET
Ramsey Lake Sub-Watershed Study
STRUCTURE: F12
Regional Road 55 (Kingsway), west of 3rd Ave.

Watershed and Location Information		**Structure Configuration and Dimensions**	
Tributary Name:	Frobisher Creek	Structure Type:	Culvert
Date Surveyed:	October 24 2016	Barrel Shape:	Circular
Crew:	CM & LB	Number of Cells:	1
Current Flow Information		Material:	Concrete
Flow Present (Yes/No):	Yes	Open footing (Yes/No):	No
		End Treatment (U/S):	Projecting
		End Treatment (D/S):	Projecting
		Height (m):	-
Key Map:		Width (m):	-
		Diameter (m):	1.90
		Length (m):	45.82
		U/S Invert Elevation (m):	265.95
		D/S Invert Elevation (m):	265.64
		Top of Road Elevation (m):	268.72
		Average Slope (%):	0.68%

Site Photographs and Additional Field Notes

NOTES:


Upstream Inlet


Upstream Channel

NOTES:


Downstream Outlet


Downstream Channel

HYDRAULIC STRUCTURE INVENTORY SHEET
Ramsey Lake Sub-Watershed Study
STRUCTURE: R01
4th Avenue south of intersection with Navando Road

Watershed and Location Information		**Structure Configuration and Dimensions**	
Tributary Name:	Frobisher Creek	Structure Type:	Culvert
Date Surveyed:	October 24 2016	Barrel Shape:	Circular
Crew:	CM & LB	Number of Cells:	1
Current Flow Information		Material:	Concrete
Flow Present (Yes/No):	Yes	Open footing (Yes/No):	No
		End Treatment (U/S):	Projecting
		End Treatment (D/S):	Projecting
		Height (m):	-
Key Map:		Width (m):	-
		Diameter (m):	0.60
		Length (m):	18.67
		U/S Invert Elevation (m):	251.23
		D/S Invert Elevation (m):	250.87
		Top of Road Elevation (m):	253.11
		Average Slope (%):	1.89%

Site Photographs and Additional Field Notes

NOTES:

Upstream Inlet

Upstream Channel

NOTES:

Downstream Outlet

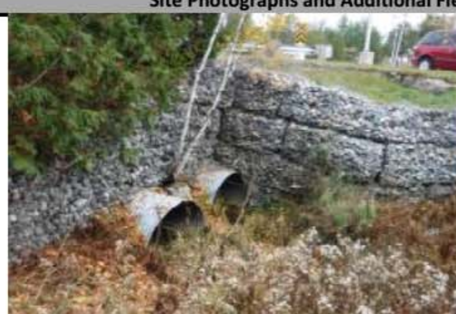
Downstream Channel

HYDRAULIC STRUCTURE INVENTORY SHEET
Ramsey Lake Sub-Watershed Study
STRUCTURE: R02
Finlandia Hill Drive

Watershed and Location Information		Structure Configuration and Dimensions	
Tributary Name:	Frobisher Creek	Structure Type:	Culvert
Date Surveyed:	October 24 2016	Barrel Shape:	Circular
Crew:	CM & LB	Number of Cells:	2
Current Flow Information		Material:	CSP
Flow Present (Yes/No):	Yes	Open footing (Yes/No):	No
		End Treatment (U/S):	Projecting
		End Treatment (D/S):	Projecting
		Height (m):	-
Key Map:		Width (m):	-
		Diameter (m):	1.60
		Length (m):	18.23
		U/S Invert Elevation (m):	251.36
		D/S Invert Elevation (m):	251.35
		Top of Road Elevation (m):	255.02
		Average Slope (%):	0.71%

Site Photographs and Additional Field Notes

NOTES:



Upstream Inlet

Upstream Channel

NOTES:

Downstream Outlet

Downstream Channel

HYDRAULIC STRUCTURE INVENTORY SHEET
Ramsey Lake Sub-Watershed Study
STRUCTURE: R02.5
Walking path in Finlandia Retirement Community

Watershed and Location Information		Structure Configuration and Dimensions	
Tributary Name:	Frobisher Creek	Structure Type:	Culvert
Date Surveyed:	October 24 2016	Barrel Shape:	Circular
Crew:	CM & LB	Number of Cells:	3
Current Flow Information		Material:	Concrete
Flow Present (Yes/No):	Yes	Open footing (Yes/No):	No
		End Treatment (U/S):	Headwall
		End Treatment (D/S):	Headwall
		Height (m):	-
Key Map:		Width (m):	-
		Diameter (m):	0.90
		Length (m):	3.15
		U/S Invert Elevation (m):	-1.65
		D/S Invert Elevation (m):	251.42
		Top of Road Elevation (m):	253.23
		Average Slope (%):	-7.89%

Site Photographs and Additional Field Notes

NOTES:

Upstream Inlet

Upstream Channel

NOTES:

Downstream Outlet

Downstream Channel

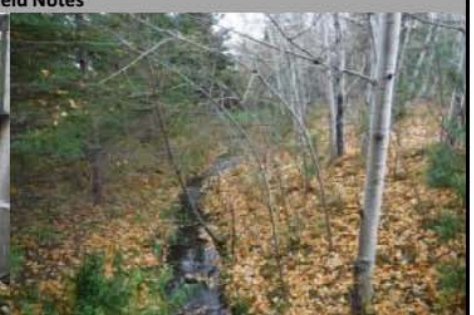
HYDRAULIC STRUCTURE INVENTORY SHEET
Ramsey Lake Sub-Watershed Study
STRUCTURE: R03
Pedestrian Bridge within Finlandia Retirement Community

Watershed and Location Information		**Structure Configuration and Dimensions**	
Tributary Name:	Frobisher Creek	Structure Type:	Bridge
Date Surveyed:	October 24 2016	Barrel Shape:	0
Crew:	CM & LB	Number of Cells:	1
Current Flow Information		Material:	Concrete
Flow Present (Yes/No):	Yes	Open footing (Yes/No):	Yes
		End Treatment (U/S):	None
		End Treatment (D/S):	None
		Height (m):	1.6
Key Map:		Width (m):	25
		Diameter (m):	-
		Length (m):	-
		U/S Invert Elevation (m):	-
		D/S Invert Elevation (m):	-
		Top of Road Elevation (m):	254.70
		Average Slope (%):	-

Site Photographs and Additional Field Notes

NOTES:

Upstream Inlet



Upstream Channel

NOTES:

Perspective of Bridge

Downstream Channel

HYDRAULIC STRUCTURE INVENTORY SHEET
Ramsey Lake Sub-Watershed Study
STRUCTURE: R05
Storm Sewer from Bancroft Road to CN Tracks

Watershed and Location Information		**Structure Configuration and Dimensions**	
Tributary Name:	Frobisher Creek	Structure Type:	Culvert
Date Surveyed:	October 24 2016	Barrel Shape:	Circular inlet & Box outlet
Crew:	CM & LB	Number of Cells:	1
Current Flow Information		Material:	CSP
Flow Present (Yes/No):	Yes	Open footing (Yes/No):	No
		End Treatment (U/S):	Other
		End Treatment (D/S):	Wingwall
		Height (m):	2.1 (outlet)
Key Map:		Width (m):	1.8 (outlet)
		Diameter (m):	1.5 (inlet)
		Length (m):	579.02
		U/S Invert Elevation (m):	258.52
		D/S Invert Elevation (m):	254.25
		Top of Road Elevation (m):	Approx. 261.2m at upstream end
		Average Slope (%):	0.74%

Site Photographs and Additional Field Notes

NOTES:

Upstream Inlet

Upstream Channel

NOTES:

Downstream Outlet

Downstream Channel

HYDRAULIC STRUCTURE INVENTORY SHEET
Ramsey Lake Sub-Watershed Study
STRUCTURE: R06
Trail connecting Cherrywood Crescent and Autumwood Crescent

Watershed and Location Information		**Structure Configuration and Dimensions**	
Tributary Name:	Frobisher Creek	Structure Type:	Culvert
Date Surveyed:	October 24 2016	Barrel Shape:	Circular
Crew:	CM & LB	Number of Cells:	1
Current Flow Information		Material:	Concrete
Flow Present (Yes/No):	Yes	Open footing (Yes/No):	No
		End Treatment (U/S):	Headwall
		End Treatment (D/S):	Headwall
		Height (m):	-
Key Map:		Width (m):	-
		Diameter (m):	1.35
		Length (m):	19.91
		U/S Invert Elevation (m):	261.07
		D/S Invert Elevation (m):	260.64
		Top of Road Elevation (m):	263.73
		Average Slope (%):	2.17%

Site Photographs and Additional Field Notes

NOTES:

Upstream Inlet

Upstream Channel

NOTES:

Downstream Outlet

Downstream Channel

HYDRAULIC STRUCTURE INVENTORY SHEET
Ramsey Lake Sub-Watershed Study
STRUCTURE: R08
Autumwood Crescent southwest of intersection with Redwood Drive

Watershed and Location Information		Structure Configuration and Dimensions	
Tributary Name:	Frobisher Creek	Structure Type:	Culvert
Date Surveyed:	October 24 2016	Barrel Shape:	Circular
Crew:	CM & LB	Number of Cells:	1
Current Flow Information		Material:	Concrete
Flow Present (Yes/No):	Yes	Open footing (Yes/No):	No
		End Treatment (U/S):	Wingwall
		End Treatment (D/S):	Wingwall
		Height (m):	-
Key Map:		Width (m):	-
		Diameter (m):	1.30
		Length (m):	86.26
		U/S Invert Elevation (m):	264.48
		D/S Invert Elevation (m):	263.12
		Top of Road Elevation (m):	266.81
		Average Slope (%):	1.58%

Site Photographs and Additional Field Notes

NOTES:

Upstream Inlet

Upstream Channel

NOTES:

Downstream Outlet

Downstream Channel

HYDRAULIC STRUCTURE INVENTORY SHEET Ramsey Lake Sub-Watershed Study STRUCTURE: E01 CN Tracks			
Watershed and Location Information		**Structure Configuration and Dimensions**	
Tributary Name:	Frobisher Creek	Structure Type:	Culvert
Date Surveyed:	October 24 2016	Barrel Shape:	Arch
Crew:	CM & LB	Number of Cells:	1
Current Flow Information		Material:	Concrete
Flow Present (Yes/No):	Yes	Open footing (Yes/No):	No
		End Treatment (U/S):	Wingwall
		End Treatment (D/S):	Wingwall
		Height (m):	1.9
Key Map:		Width (m):	2.15
		Diameter (m):	-
		Length (m):	28.72
		U/S Invert Elevation (m):	255.52
		D/S Invert Elevation (m):	255.31
		Top of Road Elevation (m):	263.10
		Average Slope (%):	0.72%

Site Photographs and Additional Field Notes

NOTES:

Upstream Inlet

Upstream Channel

NOTES:

Downstream Outlet

Downstream Channel

HYDRAULIC STRUCTURE INVENTORY SHEET
Ramsey Lake Sub-Watershed Study
STRUCTURE: E03
Storm Sewer from north of Bancroft Drive to south of Dorsett Drive

Watershed and Location Information		**Structure Configuration and Dimensions**	
Tributary Name:	Frobisher Creek	Structure Type:	Culvert
Date Surveyed:	October 24 2016	Barrel Shape:	Circular
Crew:	CM & LB	Number of Cells:	1
Current Flow Information		Material:	Concrete
Flow Present (Yes/No):	Yes	Open footing (Yes/No):	No
		End Treatment (U/S):	Wingwall
		End Treatment (D/S):	Wingwall
		Height (m):	-
Key Map:		Width (m):	-
		Diameter (m):	1.80
		Length (m):	175.25
		U/S Invert Elevation (m):	262.21
		D/S Invert Elevation (m):	261.16
		Top of Road Elevation (m):	266.00
		Average Slope (%):	0.60%

Site Photographs and Additional Field Notes

NOTES:

Upstream Inlet

Upstream Channel

NOTES:

Downstream Outlet

Downstream Channel

HYDRAULIC STRUCTURE INVENTORY SHEET
Ramsey Lake Sub-Watershed Study
STRUCTURE: K01
Keast Drive north of intersection with South Bay Road

Watershed and Location Information		**Structure Configuration and Dimensions**	
Tributary Name:	Frobisher Creek	Structure Type:	Culvert
Date Surveyed:	October 24 2016	Barrel Shape:	Circular
Crew:	CM & LB	Number of Cells:	1
Current Flow Information		Material:	Concrete
Flow Present (Yes/No):	Yes	Open footing (Yes/No):	No
		End Treatment (U/S):	Projecting
		End Treatment (D/S):	Projecting
		Height (m):	-
Key Map:		Width (m):	-
		Diameter (m):	1.00
		Length (m):	22.31
		U/S Invert Elevation (m):	251.74
		D/S Invert Elevation (m):	251.33
		Top of Road Elevation (m):	255.63
		Average Slope (%):	1.86%

Site Photographs and Additional Field Notes

NOTES:

Upstream Inlet

Upstream Channel

NOTES:

Downstream Outlet

Downstream Channel

HYDRAULIC STRUCTURE INVENTORY SHEET
Ramsey Lake Sub-Watershed Study
STRUCTURE: K02
Arlington Bulevard north of intersection with South Bay Road

Watershed and Location Information		Structure Configuration and Dimensions	
Tributary Name:	Frobisher Creek	Structure Type:	Culvert
Date Surveyed:	October 24 2016	Barrel Shape:	Circular
Crew:	CM & LB	Number of Cells:	1
Current Flow Information		Material:	Concrete
Flow Present (Yes/No):	Yes	Open footing (Yes/No):	No
		End Treatment (U/S):	Projecting
		End Treatment (D/S):	Projecting
		Height (m):	-
Key Map:		Width (m):	-
		Diameter (m):	1.35
		Length (m):	24.88
		U/S Invert Elevation (m):	259.76
		D/S Invert Elevation (m):	259.58
		Top of Road Elevation (m):	262.20
		Average Slope (%):	0.73%

Site Photographs and Additional Field Notes

NOTES:

Upstream Inlet

Upstream Channel

NOTES:

NA

Downstream Outlet

Downstream Channel

HYDRAULIC STRUCTURE INVENTORY SHEET
Ramsey Lake Sub-Watershed Study
STRUCTURE: K03
South Bay Road west of intersection with Arlington Bulevard

Watershed and Location Information		**Structure Configuration and Dimensions**	
Tributary Name:	Frobisher Creek	Structure Type:	Culvert
Date Surveyed:	October 24 2016	Barrel Shape:	Circular
Crew:	CM & LB	Number of Cells:	1
Current Flow Information		Material:	CSP
Flow Present (Yes/No):	Yes	Open footing (Yes/No):	No
		End Treatment (U/S):	Projecting
		End Treatment (D/S):	Projecting
		Height (m):	-
Key Map:		Width (m):	-
		Diameter (m):	0.60
		Length (m):	16.91
		U/S Invert Elevation (m):	262.09
		D/S Invert Elevation (m):	262.24
		Top of Road Elevation (m):	264.03
		Average Slope (%):	-0.91%

Site Photographs and Additional Field Notes

NOTES:


Upstream Inlet


Upstream Channel

NOTES:


Downstream Outlet


Downstream Channel

APPENDIX D: Flood Line Mapping

Ramsey Lake Subwatershed Study

Legend

- Study Area
- Reach Breaks
- Cross Sections
- Floodlines

Figure

Floodlines
Frobisher Creek - Map1

Date: April 2017
Data Source: City of Sudbury 2016

0 12.5 25 50 75
Meters

N

Greater Grand Sudbury

Aquafor Beech Limited

Ramsey Lake Subwatershed Study

Legend

- Study Area
- Reach Breaks
- Cross Sections
- Floodlines

Figure

Floodlines
Frobisher Creek - Map 2

Date: April 2017
Data Source: City of Sudbury 2016

0 12.5 25 50 75
Meters

N

Greater Sudbury

Aquafor Beech Limited

Ramsey Lake
Subwatershed Study

Legend

- Study Area
- Reach Breaks
- Cross Sections
- Floodlines

Figure

Floodlines
Frobisher Creek - Map 3

Date: April 2017
Data Source: City of Sudbury 2016

0 12.5 25 50 75
Meters

N

Greater Sudbury | Aquafor Beech Limited

Ramsey Lake Subwatershed Study

Legend

- Study Area
- Reach Breaks
- Cross Sections
- Floodlines

Figure

Floodlines
Frobisher Creek - Map 4

Date: April 2017
Data Source: City of Sudbury 2016

0 12.5 25 50 75
Meters

N

Greater Grand Sudbury

Aquafor Beech Limited

Ramsey Lake Subwatershed Study

Legend

- Study Area
- Reach Breaks
- Cross Sections
- Floodlines

Figure

Floodlines
Frobisher Creek - Map 5

Date: April 2017
Data Source: City of Sudbury 2016

0 12.5 25 50 75
Meters

N

Greater Grand Sudbury

Aquafor Beech Limited

Ramsey Lake Subwatershed Study

Legend

- Study Area
- Reach Breaks
- Cross Sections
- Floodlines

Figure

Floodlines
Roger Creek - Map 1

Date: April 2017
Data Source: City of Sudbury 2016

0 12.5 25 50 75
Meters

N

Greater Grand Sudbury

Aquafor Beech Limited

Ramsey Lake Subwatershed Study

Legend

- Study Area
- Reach Breaks
- Cross Sections
- Floodlines

Figure

Floodlines
Roger Creek - Map 2

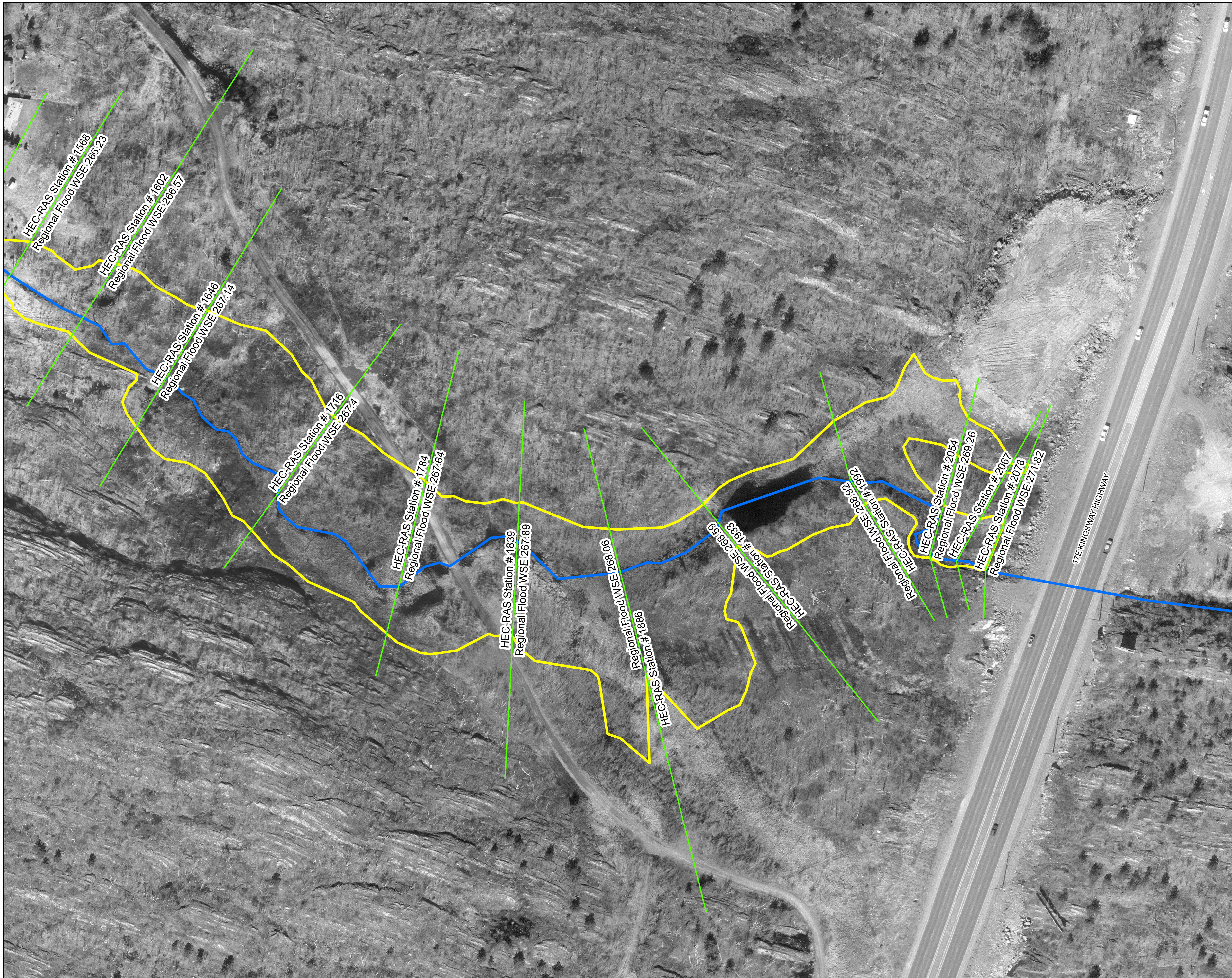
Date: April 2017
Data Source: City of Sudbury 2016

0 12.5 25 50 75
Meters

N

Greater Sudbury

Aquafor Beech Limited



Ramsey Lake Subwatershed Study

Legend

- Study Area
- Reach Breaks
- Cross Sections
- Floodlines

Figure

Floodlines
Roger Creek - Map 3

Date: April 2017
Data Source: City of Sudbury 2016

0 12.5 25 50 75
Meters

Greater Grand Sudbury

Aquafor Beech Limited

Ramsey Lake Subwatershed Study

Legend

- Study Area
- Reach Breaks
- Cross Sections
- Floodlines

Figure

Floodlines
Eugene Creek - Map 1

Date: April 2017
Data Source: City of Sudbury 2016

0 12.5 25 50 75
Meters

Ramsey Lake Subwatershed Study

Legend

- Study Area
- Reach Breaks
- Cross Sections
- Floodlines

Figure

Floodlines
Eugene Creek - Map 2

Date: April 2017
Data Source: City of Sudbury 2016

0 12.5 25 50 75
Meters

Greater Sudbury

Aquafor Beech Limited

Ramsey Lake Subwatershed Study

Legend

- Study Area
- Reach Breaks
- Cross Sections
- Floodlines

Figure

Floodlines
Eugene Creek - Map 3

Date: April 2017
Data Source: City of Sudbury 2016

0 12.5 25 50 75
Meters

Greater Grand Sudbury

Aquafor Beech Limited

Ramsey Lake
Subwatershed Study

Legend

- Study Area
- Reach Breaks
- Cross Sections
- Floodlines

Figure

Floodlines
Keast Creek - Map 1

Date: April 2017
Data Source: City of Sudbury 2016

0 12.5 25 50 75
Meters

N

Greater Sudbury

Aquafor Beech Limited

Ramsey Lake Subwatershed Study

Legend

- Study Area
- Reach Breaks
- Cross Sections
- Floodlines

Figure

Floodlines
Keast Creek - Map 2

Date: April 2017
Data Source: City of Sudbury 2016

0 12.5 25 50 75
Meters

N

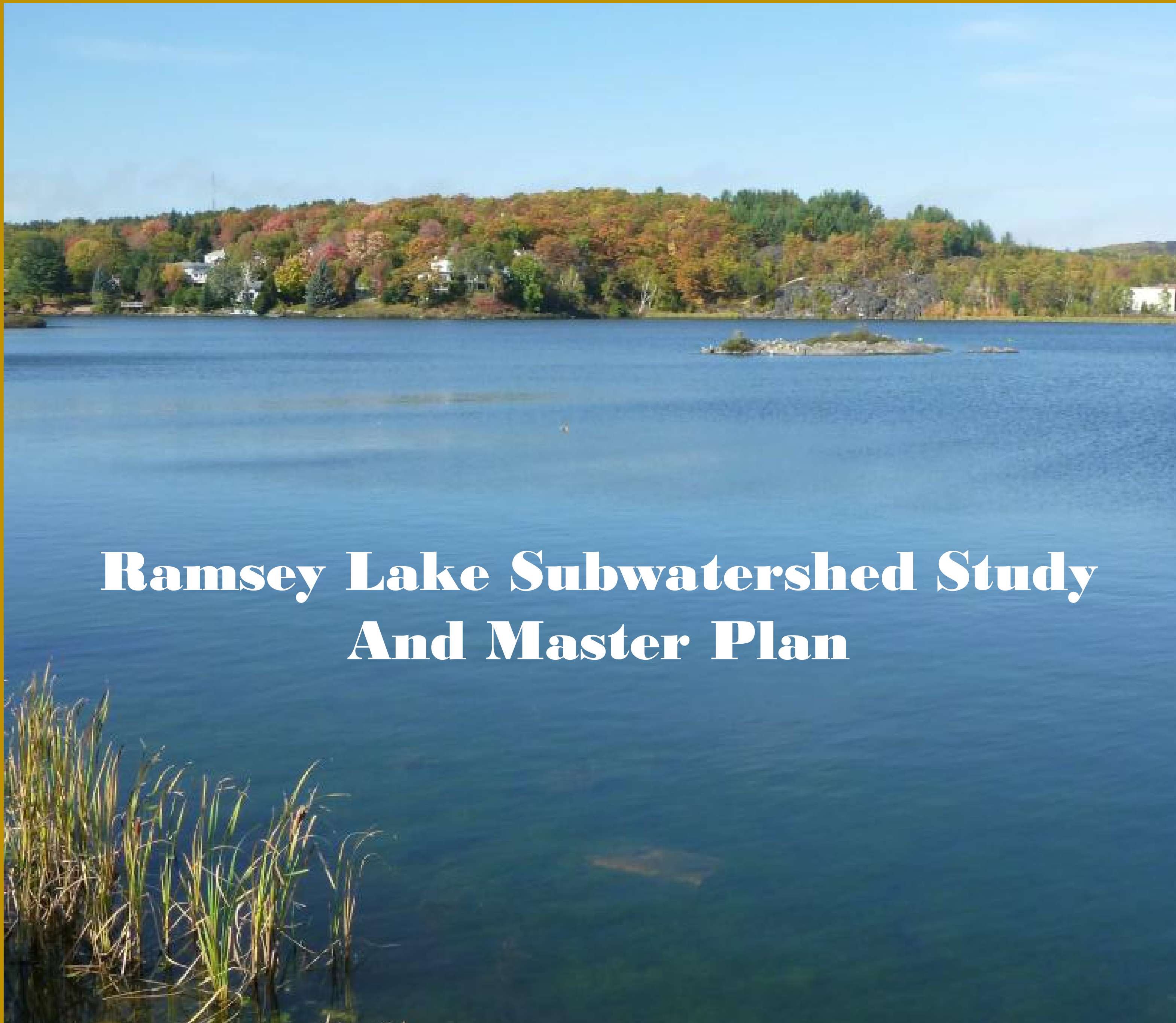
Greater Sudbury

Aquafor Beech Limited

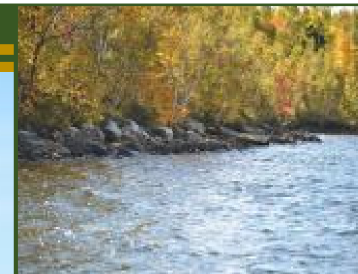
APPENDIX E: Public Consultation

Public Information Centre #1

(December 8, 2016)



Ramsey Lake Subwatershed Study And Master Plan



Public Information Centre #1

December 8th, 2016

Objective of Public Information Centre #1

Tonight's Public Information Centre (PIC) will:

- Introduce the study area
- Provide an overview of the Subwatershed Study purpose and objectives
- Review the Subwatershed Study process
- Provide an opportunity for the public to review the work completed to date as well as upcoming work
- Allow the public to provide input to the study, and to discuss questions and issues with staff

Study Purpose and Objectives

Study Purpose

- Develop a Subwatershed Management Plan to protect, maintain and enhance surface water, groundwater, and natural resources of Ramsey Lake and its tributaries through environmentally sound policy and management actions

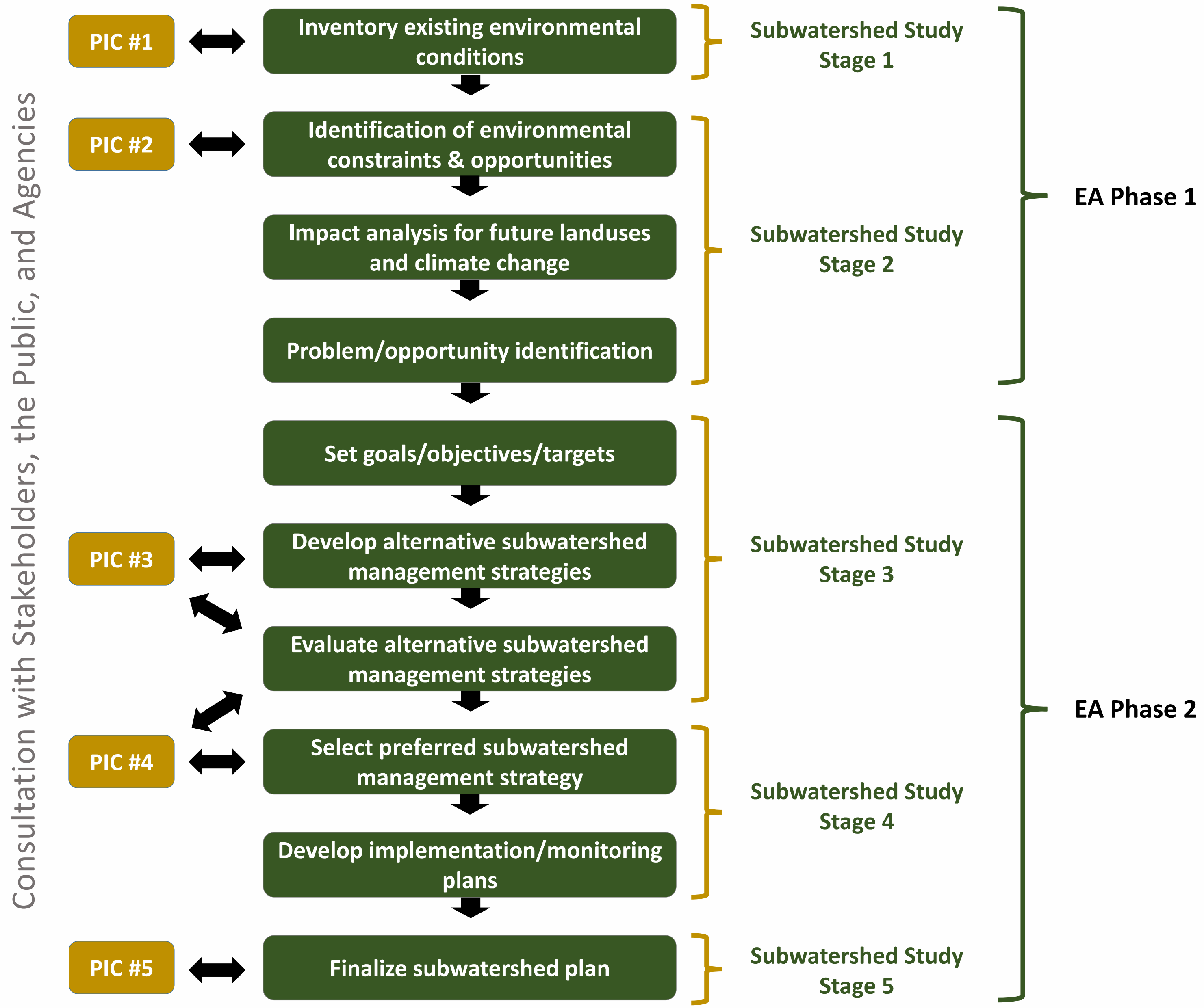
Plan Objectives

- Protect and restore existing natural resources
- Protect and enhance water quality
- Protect and enhance groundwater resources
- Develop strategies to minimize flood risks, erosion, and other impacts on natural systems due to future urban development and climate change

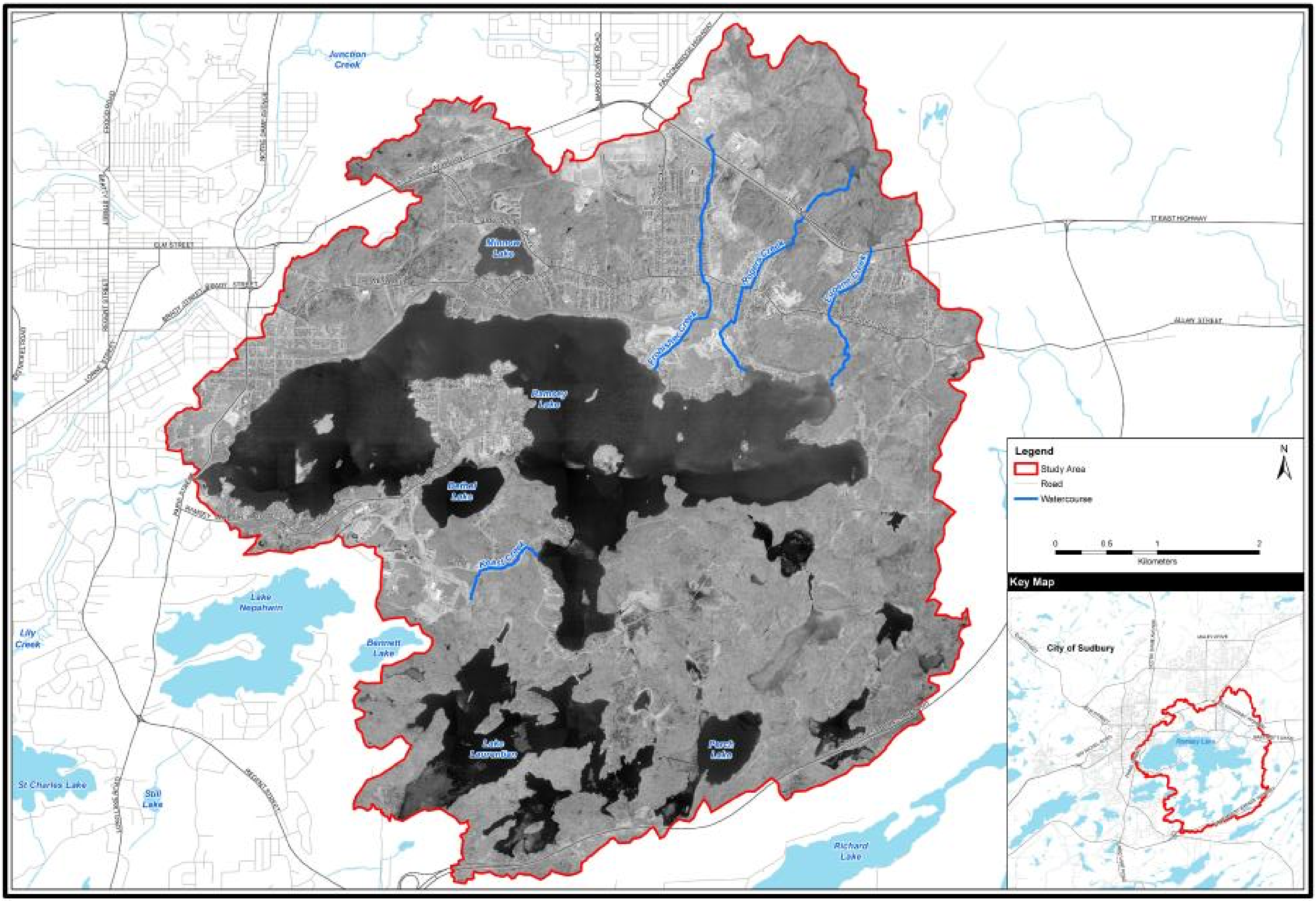
Subwatershed Study/Environmental Assessment Process

We are here

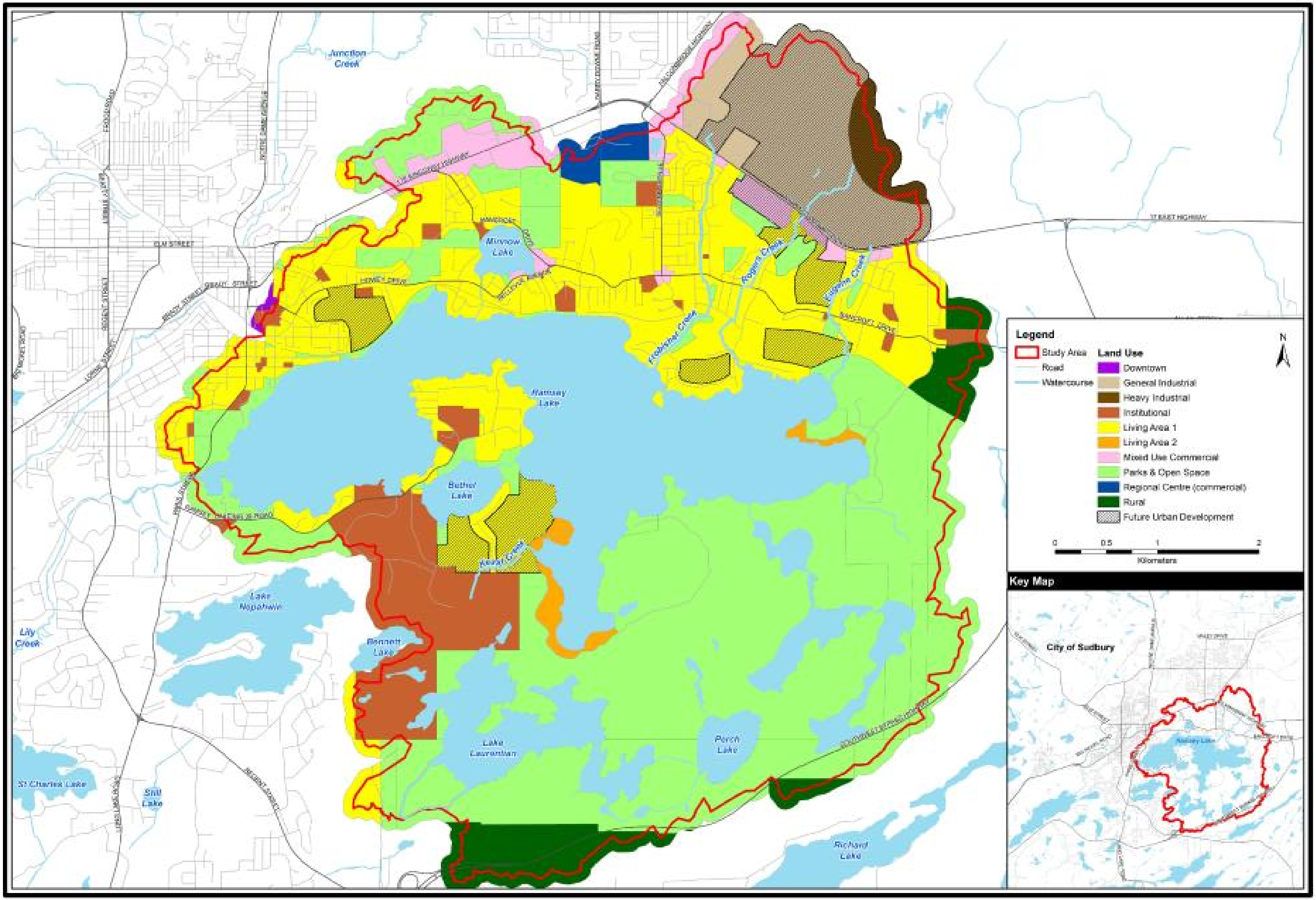
The Subwatershed Study is being conducted as a Master Plan and is intended to satisfy Phases 1 and 2 of the Municipal Engineers Association (MEA) Municipal Class Environmental Assessment Act (Class EA) process. This will involve a process of problem/opportunity identification, evaluation of alternative solutions, and selection of a preferred solution. Stakeholder consultation is an important part of the EA process and a key component of the study.



Study Area


Junction Creek
Minnow Lake
Ramsey Lake
Bethel Lake
Lake Nepahwin
Bennett Lake
Lily Creek
Lake Laurentian
Perch Lake
St Charles Lake
Still Lake
Richard Lake
ELM STREET
Legend
Study Area
Road
Watercourse
0
0.5
1
2
Kilometers
Key Map
City of Sudbury

Landuses


Legend
Study Area
Road
Watercourse
Land Use
Downtown
General Industrial
Heavy Industrial
Institutional
Living Area 1
Living Area 2
Mixed Use Commercial
Parks & Open Space
Regional Centre (commercial)
Rural
Future Urban Development
N
0
0.5
1
2
Kilometers
Key Map
City of Sudbury
Junction Creek
Minnow Lake
Ramsey Lake
Bethel Lake
Lake Nepahwin
Bennett Lake
Lake Laurentian
Perch Lake
Richard Lake
Lily Creek
St Charles Lake
Still Lake
ELM STREET

Water Quality

Objectives

- Identify sources of pollution and water quality trends
- Identify approaches to address water quality issues and improve water quality

Study Tasks:

✓ Review historical water quality data and data collected on biological indicators of water quality (complete)

✓ Assess existing water quality conditions (complete).

✓ Identify known/potential point/non-point sources of pollution (to be completed)

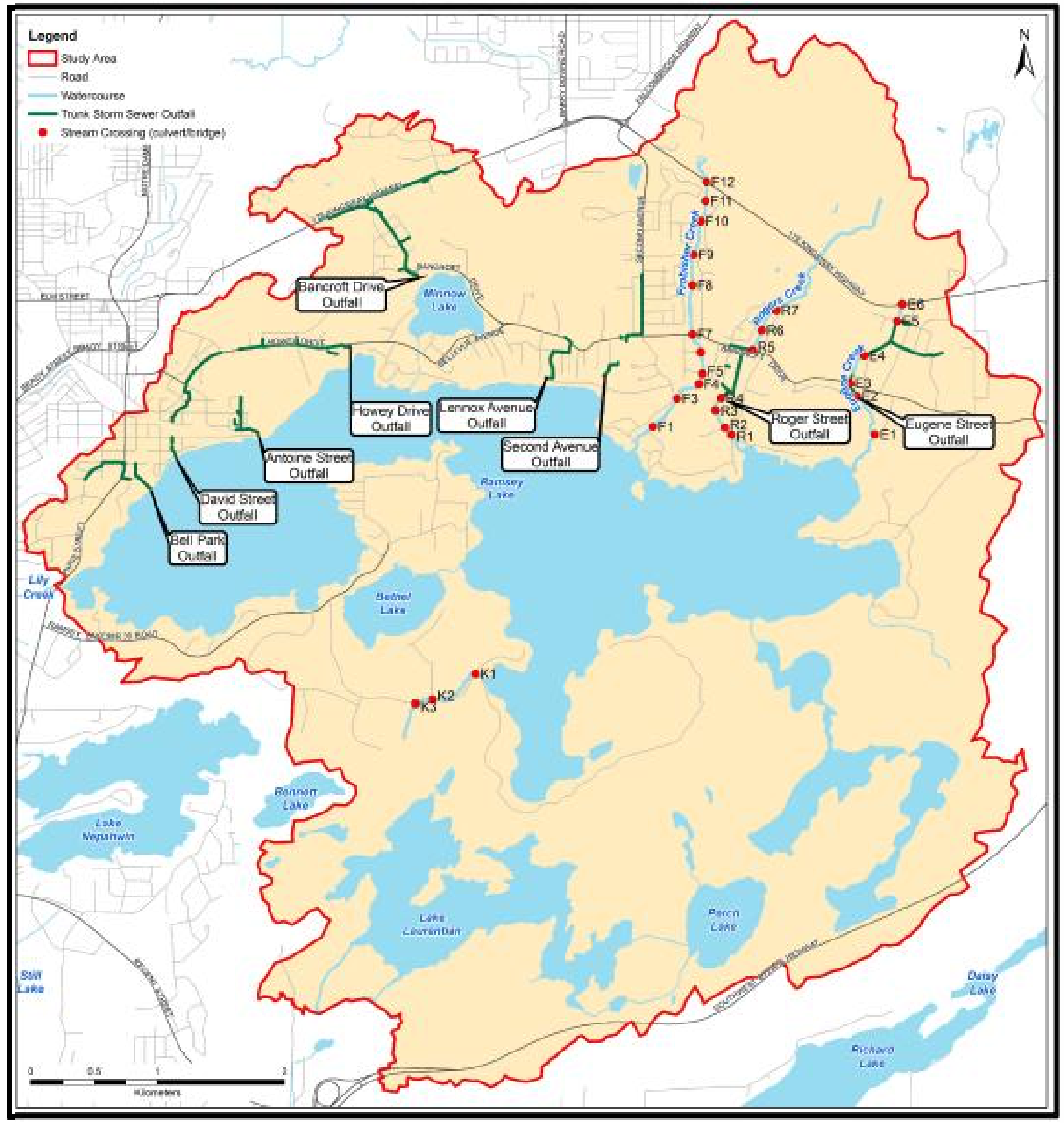
Hydrology / Hydraulics / Flooding

Objectives

- Identify flood hazards
- Identify capacity constraints

Study Tasks:

- ✓ Bridge/culvert surveys (complete)
- ✓ Hydrologic/hydraulic modelling (in progress)
- ✓ Map flood hazard lands (to be completed)
- ✓ Sensitivity analysis for potential climate change (to be completed)
- ✓ Identify stormwater management requirements for new developments (to be completed)



Erosion and Stream Morphology

Objectives

- Stream characterization
- Identify erosion issues

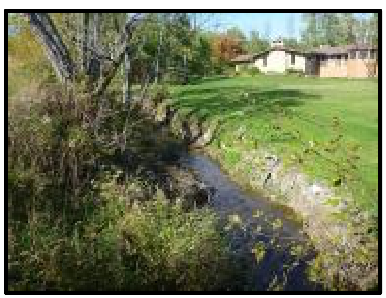
Study Tasks:

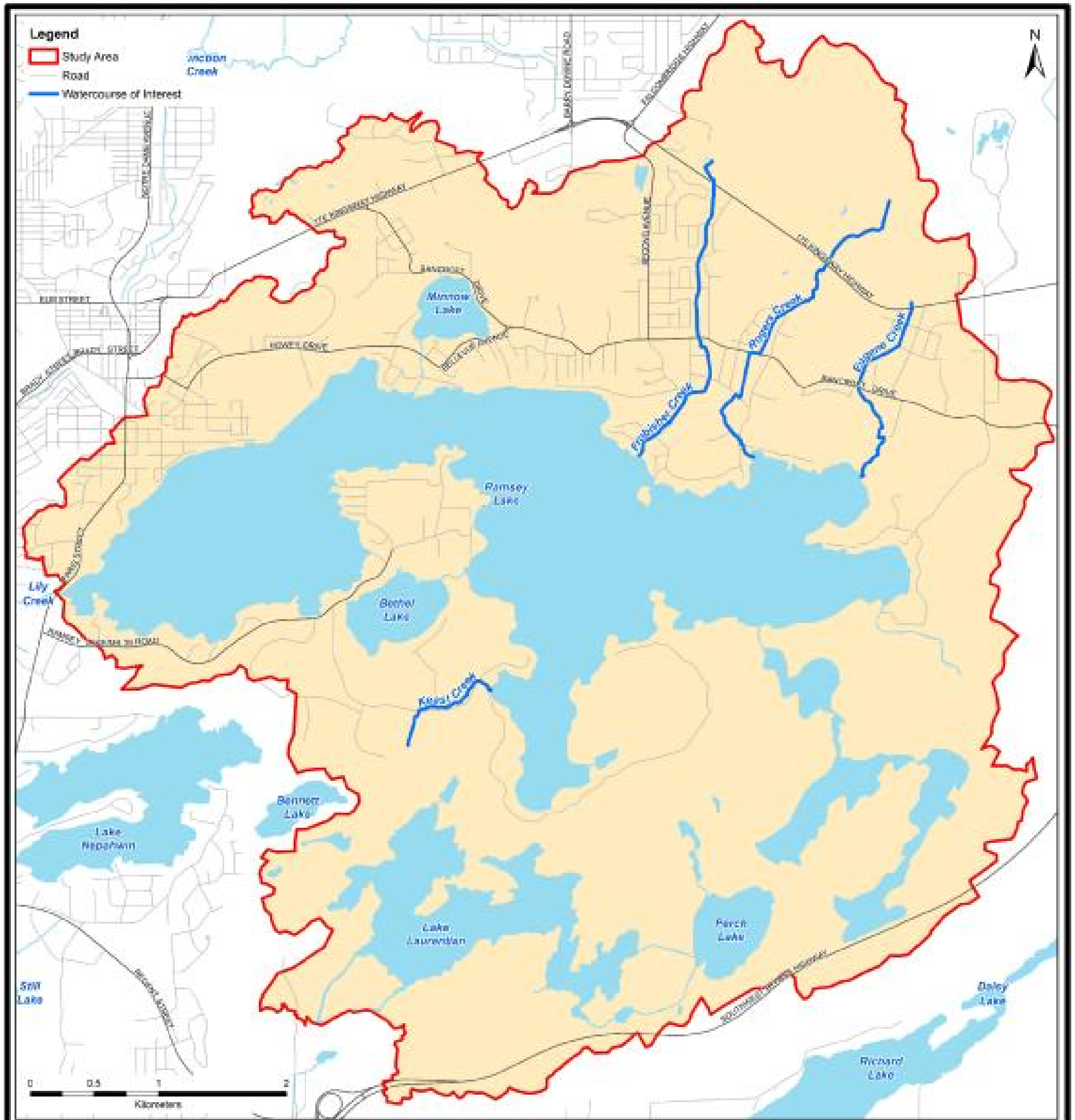
✓ Field Investigations and stream measurements (complete)

✓ Identify erosion sites and geomorphologic hazards

✓ Identify stream restoration opportunities (to be completed)

✓ Identify erosion control requirements for new developments (to be completed)

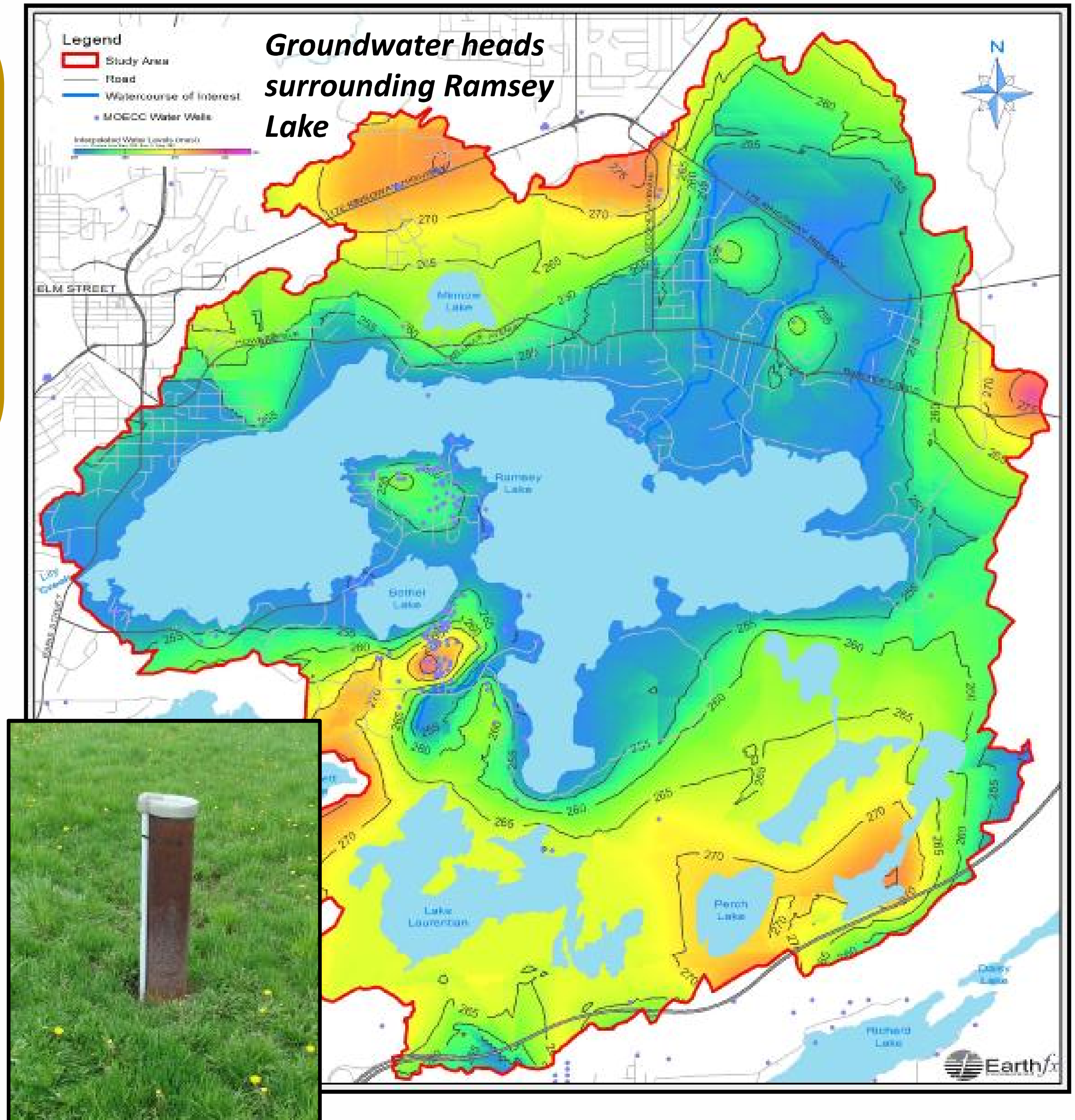




Hydrogeology

Objectives

- **Characterize hydrogeologic conditions and identify system components that may be sensitive to future land use changes**
- **Identify opportunities for mitigating negative long-term impacts to groundwater resources**



Study Tasks:

- ✓ Compilation and review of existing information and datasets related to regional geologic and hydrogeologic conditions (completed)
- ✓ Groundwater resource assessment (to be completed)
- ✓ Provide mitigation and management strategies for maintaining groundwater system integrity (to be completed)
- ✓ Long-term groundwater monitoring programme recommendations (to be completed)

Aquatic Resources

Objectives

- Identify aquatic features/habitats that are sensitive or of high importance to aquatic communities
- Identify need for additional assessment and monitoring of aquatic resources
- Identify opportunities to preserve, enhance, or restore aquatic habitats

Image from huntfishmanitoba.ca

Illustration by Virgil Beck

Study Tasks:

✓ Review existing information related to aquatic biota (fish, invertebrates) and their habitats (complete)

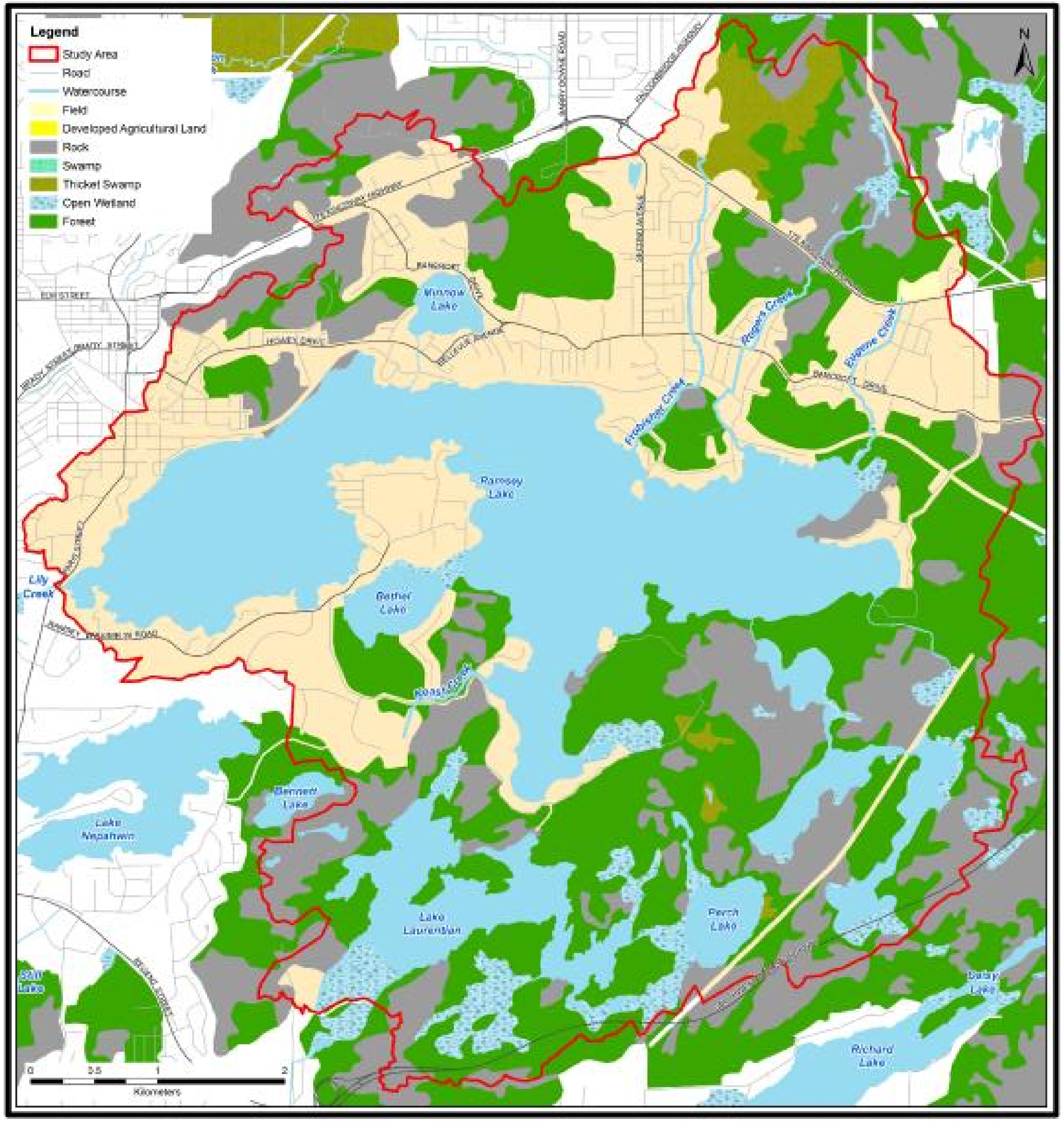
✓ Describe aquatic habitat conditions in lake and tributaries (complete)

Image from huntfishmanitoba.ca

Terrestrial Resources

Objectives

- Identify and assess the sensitivity of terrestrial features and functions to inform the natural heritage system protection areas as well as habitat enhancement, restoration, and management opportunities. The project team will focus on areas which may be potentially impacted by proposed mitigation areas and activities



Study Tasks:

- ✓ Consolidation of existing information (complete)
- ✓ Natural heritage assessment (ongoing)
- ✓ Gap analysis (to be completed)
- ✓ Adaptive management plan (to be completed)
- ✓ Identification and classification of natural heritage constraints (to be completed)
- ✓ Restoration/enhancement and protection measures (to be completed)
- ✓ Implementation and monitoring recommendations (to be completed)

How You Can Help

We look forward to working through the Ramsey Lake Sub-Watershed study with residents and stakeholders. If you wish to participate, please complete our sign-in sheet at the entrance and we will send you updates on study progress and opportunities to participate.

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- Complete our feedback survey on paper (available at the registration desk), or online at: http://www.greatersudbury.ca/living/lakes-facts/watershed-study-2016/
- Contact the study project managers at any time:

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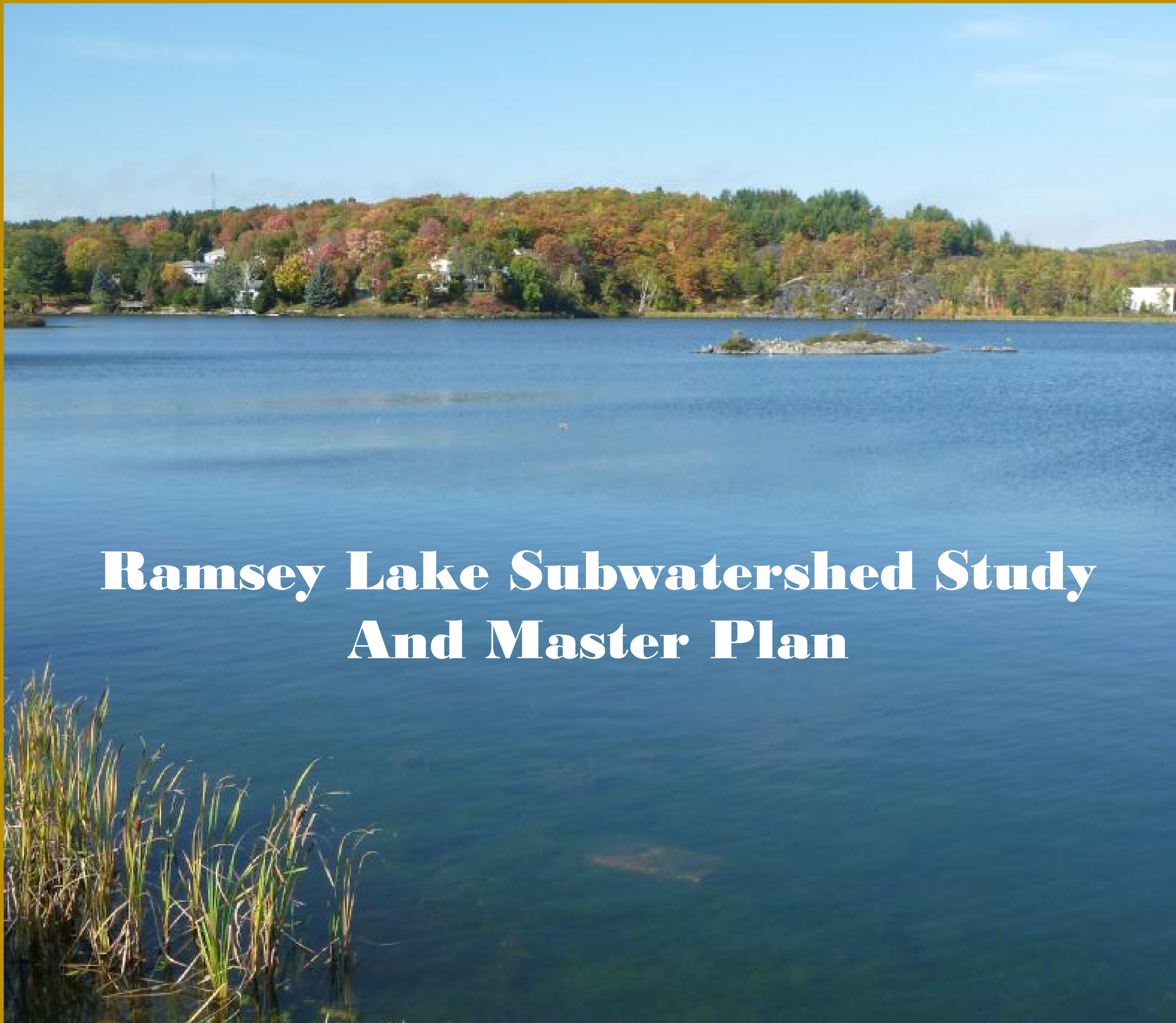
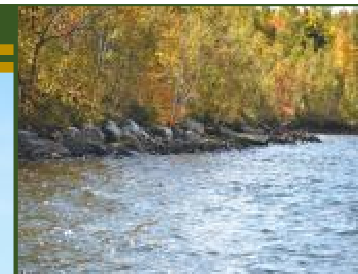
Public Information Centre #2

(May 18, 2017)

Ramsey Lake Subwatershed Study And Master Plan





Public Information Centre #2

May 18, 2017

Objective of Public Information Centre #2

Tonight's Public Information Centre (PIC) will:

- Introduce the study area
- Provide an overview of the Subwatershed Study purpose and objectives
- Review the Subwatershed Study process
- Provide an opportunity for the public to review the work completed to date as well as upcoming work
- Allow the public to provide input to the study, and to discuss questions and issues with staff

Subwatershed Study/Environmental Assessment Process

We are here → PIC #2

Consultation with Stakeholders, the Public, and Agencies

EA Phase 1

- **Subwatershed Study Stage 1**
  - PIC #1 ↔ Inventory existing environmental conditions
- **Subwatershed Study Stage 2**
  - PIC #2 ↔ Identification of environmental constraints & opportunities
  - Impact analysis for future land uses and climate change
  - Problem/opportunity identification

EA Phase 2

- **Subwatershed Study Stage 3**
  - Set goals/objectives/targets
  - PIC #3 ↔ Develop alternative subwatershed management strategies
  - Evaluate alternative subwatershed management strategies
- **Subwatershed Study Stage 4**
  - PIC #4 ↔ Select preferred subwatershed management strategy
  - Develop implementation/monitoring plans
- **Subwatershed Study Stage 5**
  - PIC #5 ↔ Finalize subwatershed plan

The Subwatershed Study is being conducted as a Master Plan and is intended to satisfy Phases 1 and 2 of the Municipal Engineers Association (MEA) Municipal Class Environmental Assessment Act (Class EA) process. This will involve a process of problem/opportunity identification, evaluation of alternative solutions, and selection of a preferred solution. Stakeholder consultation is an important part of the EA process and a key component of the study.

Erosion and Stream Morphology

Objectives

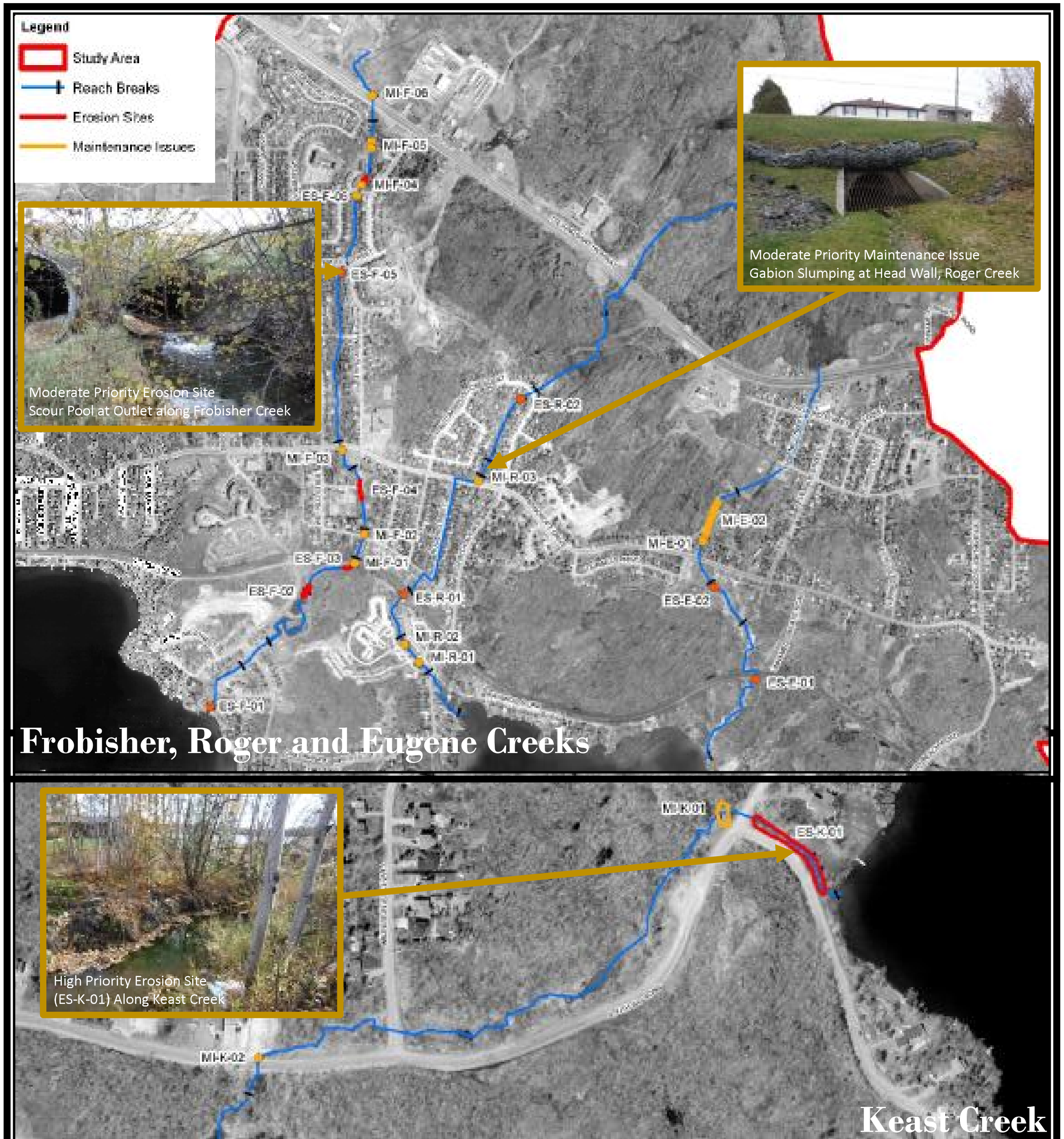
- Stream characterization
- Identify erosion issues

Study Tasks:

- ✓ Identified erosion sites and maintenance issues along water courses
- ✓ Identified stream restoration opportunities

Key Findings

- 11 Erosion Sites were identified
  - Only one High Priority erosion site was identified at the <u>downstream extent of Keast Creek</u> (shown on map)
- 13 Maintenance Issues were identified
  - Two high priority sites
  - Most issues are associated with culvert inlets (i.e., scour, sediment/vegetation accumulation)



Hydrology

Objectives

- Define flows at four tributaries and overall watershed

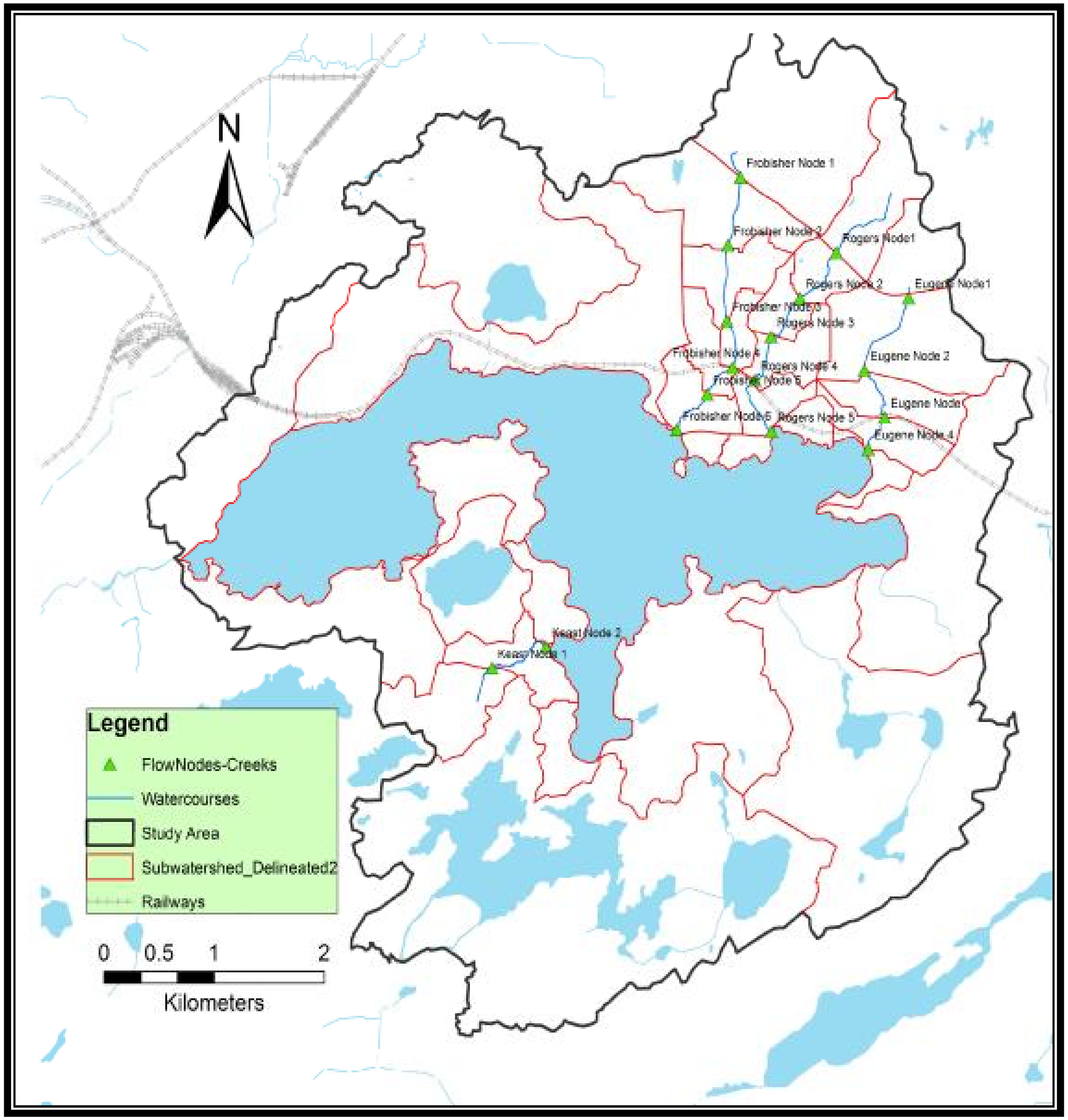
Study Tasks:

- ✓ Hydrologic model (PCSWMM) set up
- ✓ Determined the flow rates at key locations along the creek using the hydrologic model
- ✓ Flow rates were used to establish the flood hazard maps

Key Findings

- Flow rates were determined at key locations along the creeks

Flow Nodes	2-year	5-year	10-year	20-year	50-year	100-year	Timmins
FrobisherNode1	1.19	1.72	2.13	2.56	3.15	3.67	6.057
FrobisherNode2	4.06	5.97	7.42	8.93	10.95	12.66	10.57
FrobisherNode3	5.09	7.39	10.25	12.82	15.77	18.23	13.84
FrobisherNode4	5.96	7.75	11.42	14.59	17.17	20.34	14.98
FrobisherNode5	7.30	9.53	13.49	16.90	20.57	24.00	17.64
FrobisherNode6	8.25	10.97	17.68	24.25	25.85	26.88	33.65
RogersNode1	0.18	0.28	0.38	0.50	0.71	0.96	3.27
RogersNode2	0.17	0.26	0.34	0.47	0.70	0.95	3.32
RogersNode3	0.94	1.41	1.78	2.17	2.72	3.21	4.65
RogersNode4	1.68	2.56	3.24	3.94	4.92	5.78	6.41
RogersNode5	2.15	3.29	4.20	5.11	6.40	7.52	8.35
EugeneNode1	0.35	0.51	0.65	0.80	1.02	1.24	2.25
EugeneNode2	0.26	0.42	0.54	0.65	0.79	1.01	2.24
EugeneNode3	0.68	1.33	1.91	2.58	3.65	5.46	9.34
EugeneNode4	0.73	1.54	2.29	3.15	4.53	8.65	11.53
Keast1	0.88	1.29	1.67	2.09	2.76	3.43	4.58
Keast2	1.44	2.10	2.68	3.32	4.29	5.27	7.26



Hydraulics - Flooding

Objectives

- Identify limits of Regional flood

Study Tasks:

✓ Bridges/culverts surveyed

✓ Hydrologic/hydraulic model developed

✓ Mapped flood hazard lands

Key Findings

Frobisher Creek:

- A total of 13 buildings are within the flood limits
- Under the Regional flood conditions three roads (Bancroft Road, Rita Street and Greenwood Drive) are overtopped.

Roger Creek:

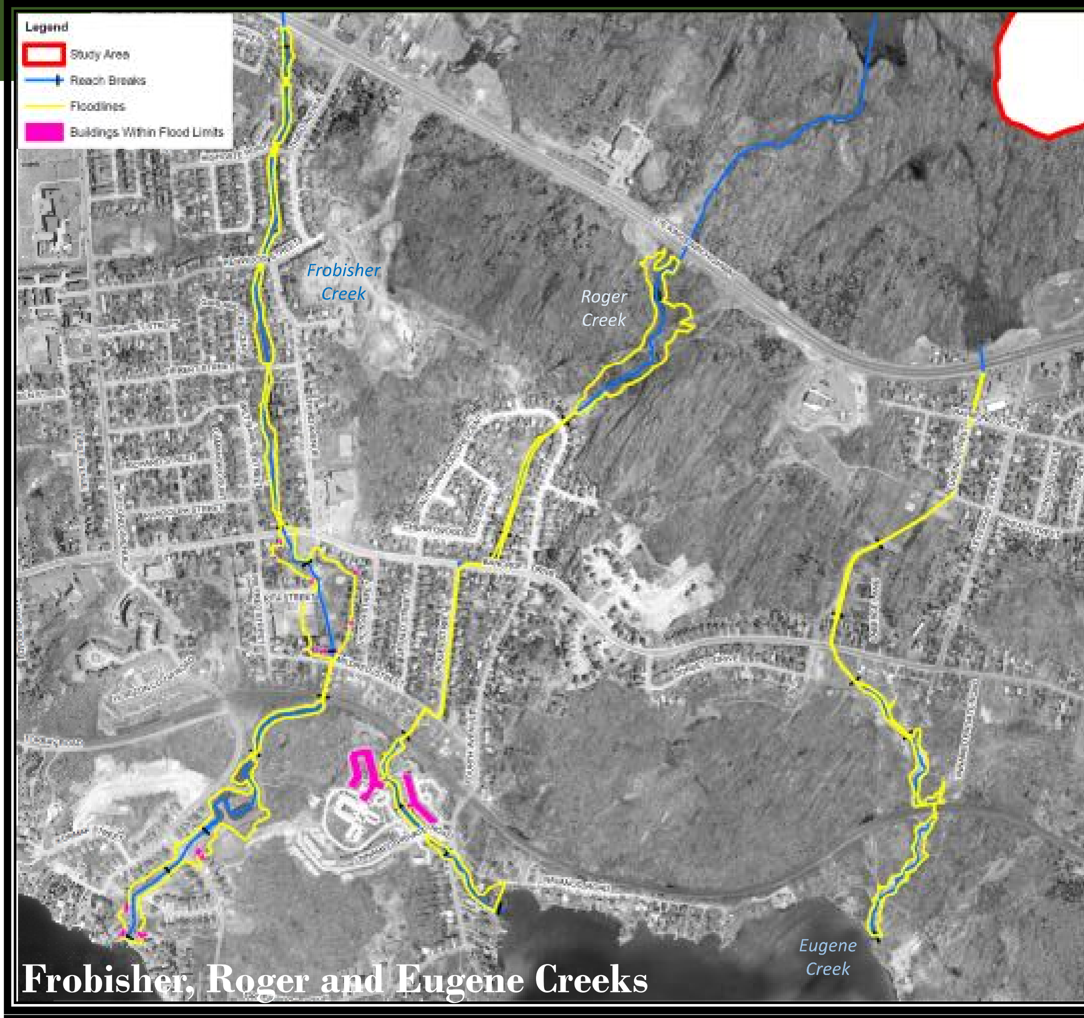
- Only two (2) buildings are within the flood limits, both within the Finlandia Retirement Community
- Under the Regional flood conditions 1 road (4th Avenue) is overtopped and 1 culvert and 1 bridge within the Finlandia Retirement Community are also overtopped

Eugene Creek:

- No buildings are within the flood limits and no roads are overtopped
- The Bancroft Road culvert is close to capacity under the Regional conditions, but is not overtopped

Keast Creek

- No buildings are within the flood limits
- Under the Regional flood conditions all three roads (South Bay Road, Arlington Boulevard and Keast Road) are overtopped.
- Some spilling is anticipated along South Bay Road and Keast Road.



Hydrogeology: Objectives and Data Compilation

Overall Objectives

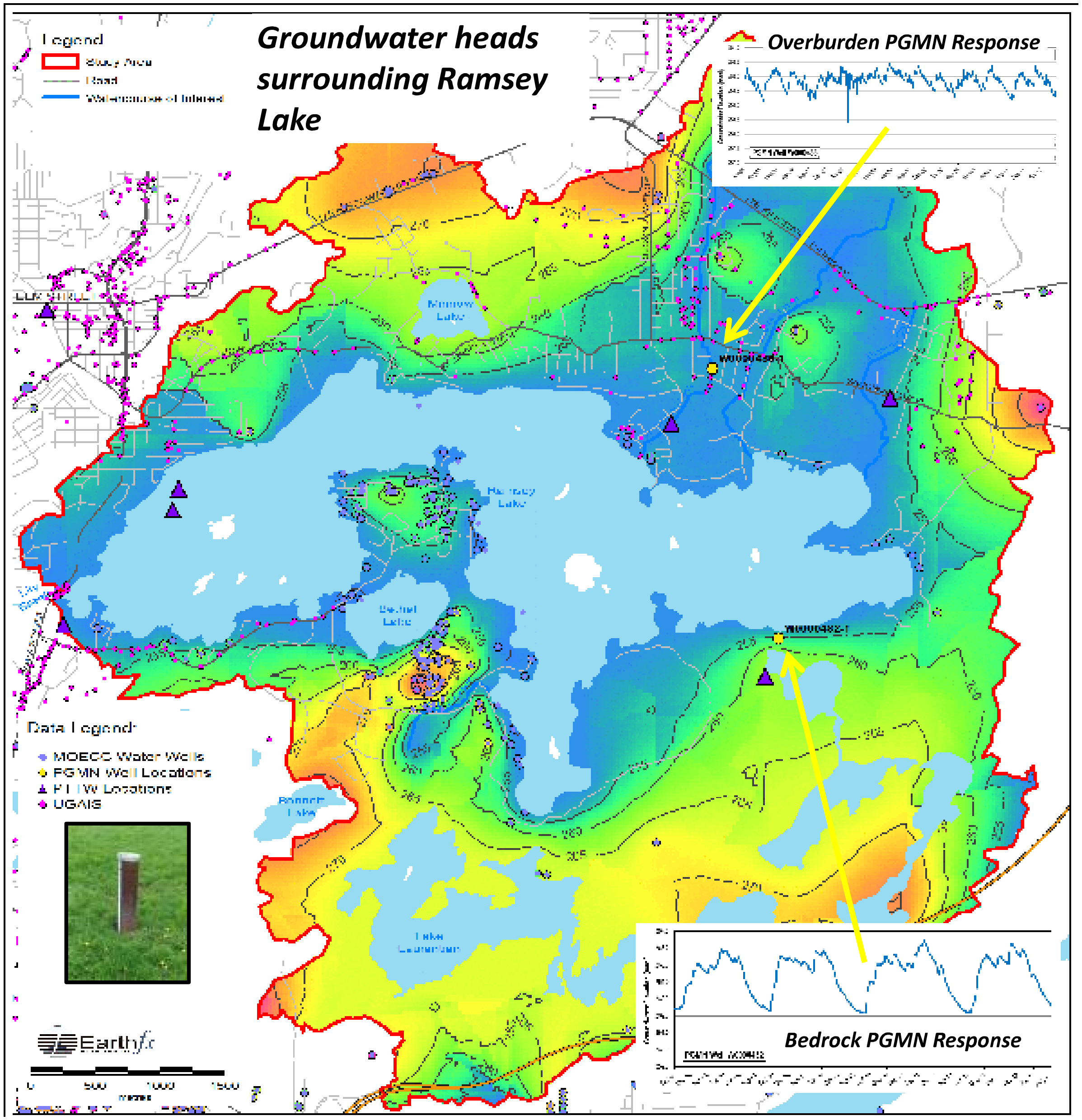
- Characterize hydrogeologic conditions and identify system components that may be sensitive to future land use changes
- Identify opportunities for mitigating negative long-term impacts to groundwater resources

Study Task 1:

✓ Compilation and review of existing information and datasets related to regional geologic and hydrogeologic conditions

Key Findings

- Compiled water well records, permits, geologic and Source Water Protection mapping
- Supplemented water well data with 4000 Urban Geotechnical boreholes (UGAIS)
- Well coverage, even with UGAIS boreholes, is very sparse
- Provincial GW Monitoring Network (PGMN) wells show a more prominent summer recession in bedrock than overburden



Hydrogeology: Resource Assessment

Objectives

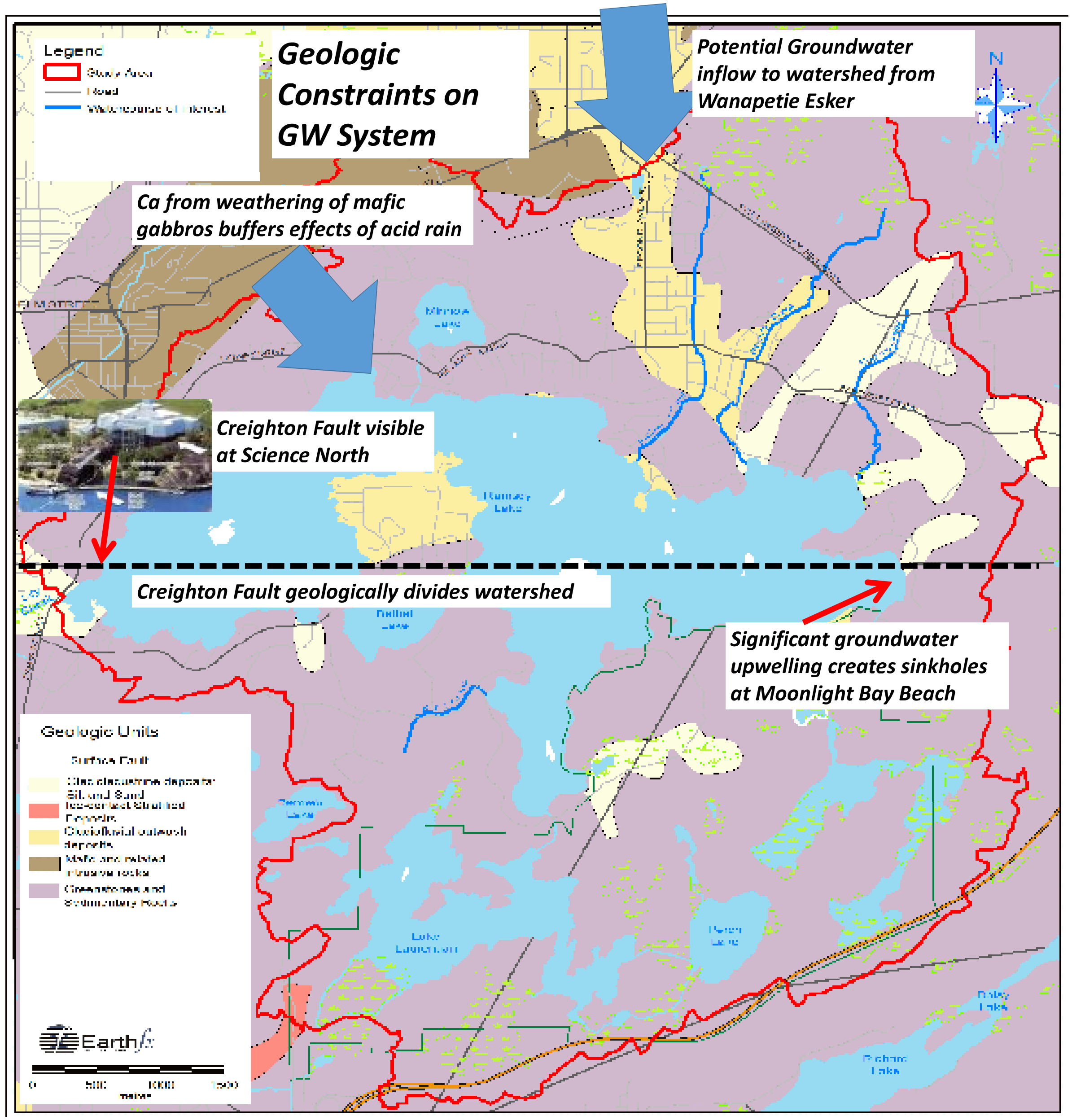
- Characterize hydrogeologic conditions

Study Tasks:

✓ Groundwater resource assessment

Key Findings

- Weathering of mafic gabbros in northwestern portion of the study area is thought to have buffered effects of acid rain – may be influencing water quality in the lake
- The Creighton Fault, extending from Science North to Moonlight Bay, illustrates how faulting and fracturing creates localized but highly irregular groundwater flow conditions. Surrounding local topography can generate potentially significant artesian upwelling conditions through the fractured bedrock.
- The surficial sand and gravel deposits in the northeast of the watershed may be connected into the regional groundwater flow system and, potentially, the Wanapetie Esker. Lateral groundwater inflows likely support the wetlands and headwaters of Frobisher, Rogers and Eugene Creek.



Hydrogeology: Mitigation, Management and Monitoring

Management / Monitoring

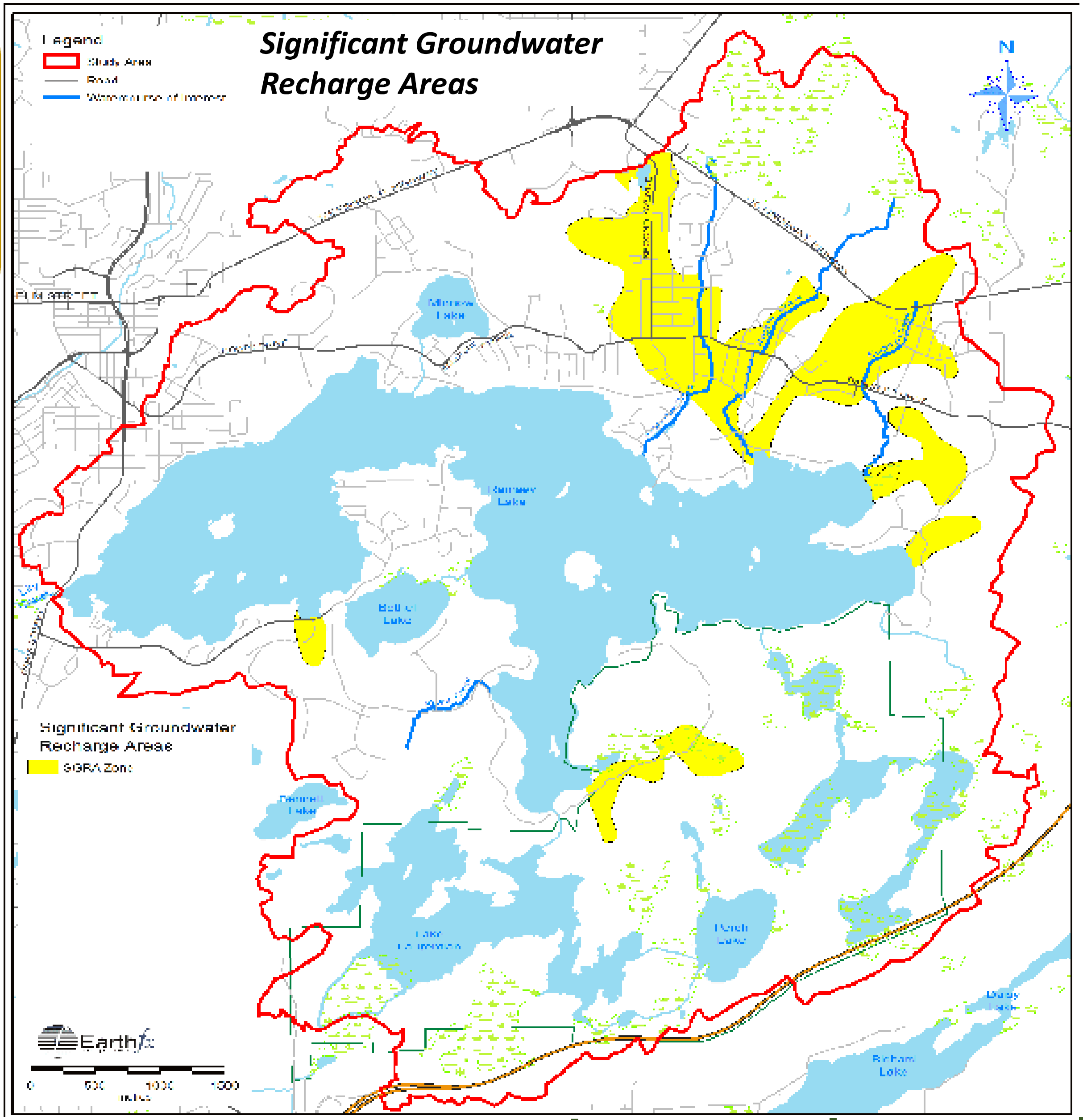
- Identify opportunities for mitigating negative long-term impacts to groundwater resources
- Identify Monitoring Locations

Study Tasks:

- ✓ Mitigation and management strategies
- ✓ Long-term GW monitoring program

Key Findings

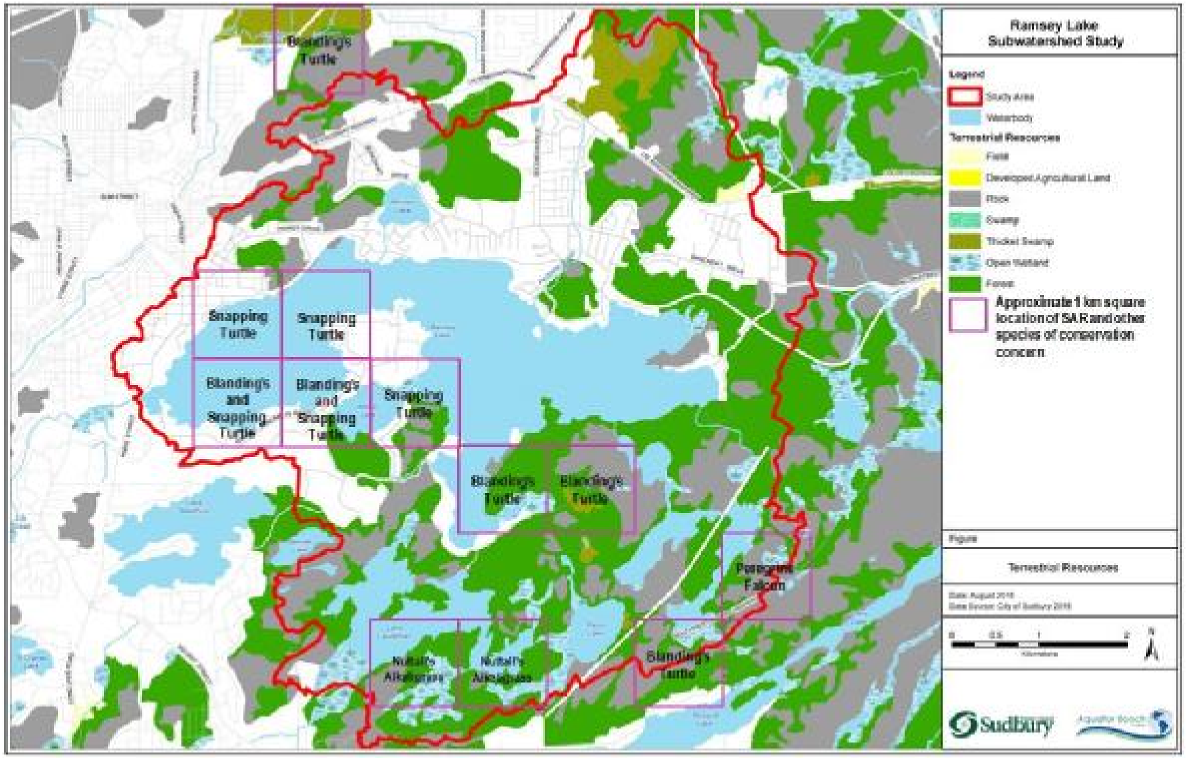
- SWP map of Significant Groundwater Recharge Areas (SGRA) identifies sensitive local shallow overburden aquifers
- Local topographic depressions also potentially important to support fracture flow systems
- Further investigation of water quality patterns related to mafic gabbro weathering
- Recommend monitoring wells in north east of watershed to better characterize potential groundwater inflow from the north for future study



Terrestrial Resources

Objectives

- Identify and assess the sensitivity of terrestrial features and functions to inform the natural heritage system protection areas as well as habitat enhancement, restoration, and management opportunities. The project team will focus on areas which may be potentially impacted by proposed mitigation areas and activities



Study Tasks:

- ✓ Consolidation of existing information
- ✓ Natural heritage assessment
- ✓ Gap analysis
- ✓ Adaptive management plan
- ✓ Identification and classification of natural heritage constraints
- ✓ Restoration/enhancement and protection measures
- ✓ Implementation and monitoring recommendations

Key Findings:

- Vegetation communities include Birch Transition Community, Birch – Maple Community, Red Oak Community, and Poplar Lowland Community
- Sub-watershed supports a diverse arrangement of wildlife including songbirds, waterfowl, small and large mammals, fish, reptiles and amphibians, and insects
- Species at Risk include reptiles, birds, butterflies, and plants
- Fire, logging, mining, and urban development has caused widespread erosion on the thin soils, resulting in exposed rock
- Regreening Program has increased vegetative cover within watershed

Water Quality (Ramsey Lake)

Objectives

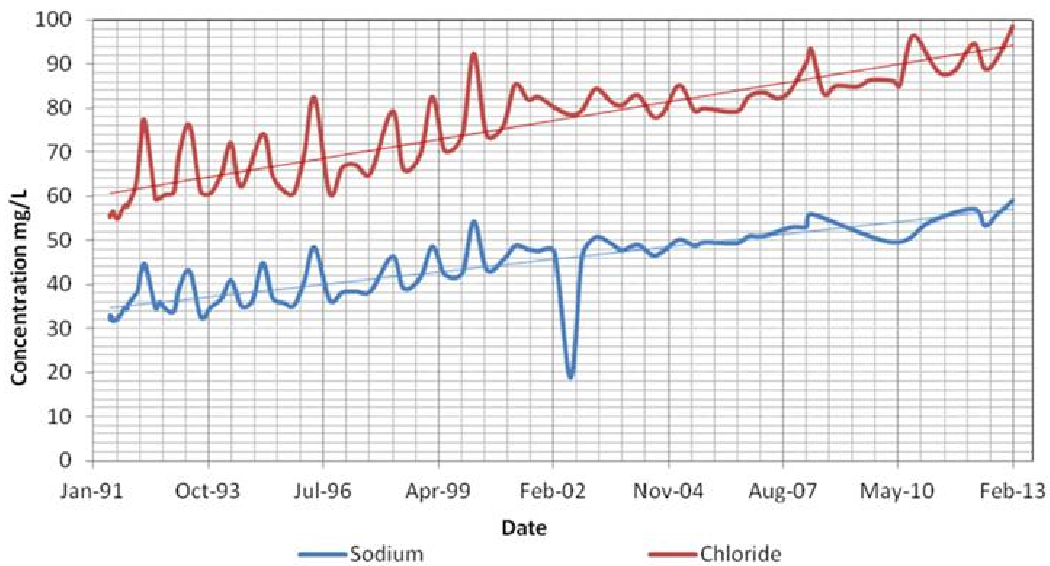
- Identify sources of pollution and water quality trends

Study Tasks:

- ✓ Synthesized water and aquatic sediment data sets
- ✓ Identified long term trends in pollutants

Key Findings

- Sodium and chloride concentrations in Ramsey Lake have increased since 1991
    - Sodium concentrations have been > 50 mg/L since 2013. The Ontario Drinking Water Standard for sodium is 200 mg/L
    - The water quality guideline for chloride, for the protection of aquatic life, is 120 mg/L



Sodium and Chloride Concentrations in Ramsey Lake (1991-2013).

Water Quality (Ramsey Lake)

Objectives

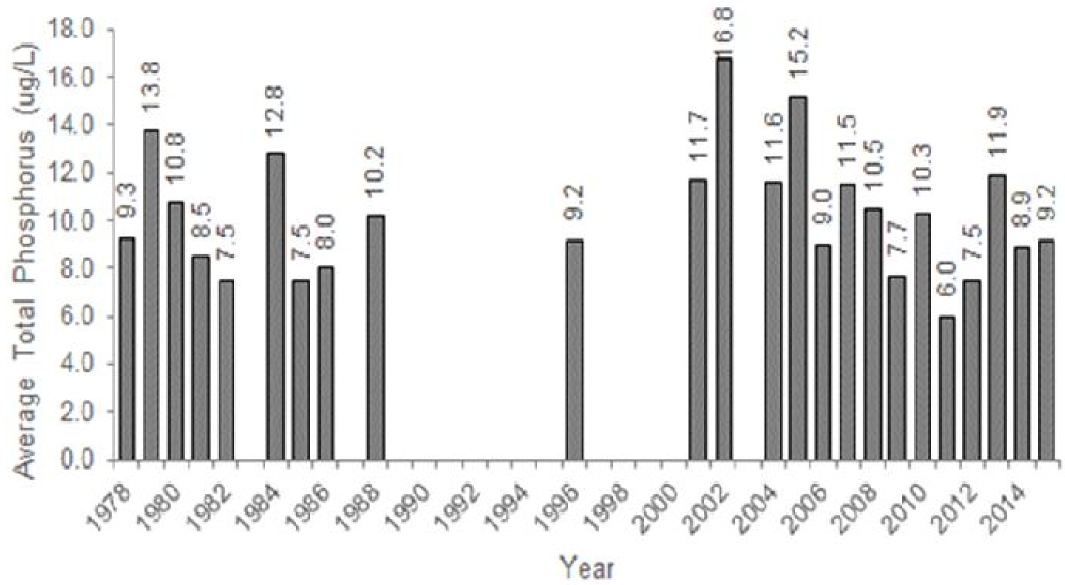
- **Identify sources of pollution and water quality trends**

Study Tasks:

- ✓ Synthesized water and aquatic sediment data sets
- ✓ Identified long term trends in pollutants

Key Findings

- **Phosphorus concentrations have varied since the 1970's between about 10 and 17 µg/L. The lake is currently classifies as meso-eutrophic or moderately nutrient enriched**
  - **Runoff from urban land uses has resulted in an increase in phosphorus concentrations**
  - **Large weed beds throughout Ramsey Lake are one result of higher-than-natural phosphorus loads**



Total Phosphorus Concentrations in Ramsey Lake (1978-2014).

Water Quality (Ramsey Lake)

Objectives

- **Identify sources of pollution and water quality trends**

Study Tasks:

✓ Synthesized water and aquatic sediment data sets

✓ Identified long term trends in pollutants

Key Findings

- **Blooms of cyanobacteria were reported from the lake in 2008, 2010, 2011 and 2012**
  - **Nuisance algal blooms are directly related to surface water runoff**
- **Eurasian water milfoil, an invasive aquatic plant is present in Ramsey Lake**

Aquatic Plant Growth; Ramsey Lake

Water Quality (Ramsey Lake)

Objectives

- Identify sources of pollution and water quality trends

Study Tasks:

- ✓ Synthesized water and aquatic sediment data sets
- ✓ Identified long term trends in pollutants

Key Findings

- Metals concentrations in Ramsey Lake have been elevated from natural levels as a result of exposure to past emissions from local smelter operations
- Metals, including copper and nickel have decreased in response to a reduction in emissions of metal particulates from smelters

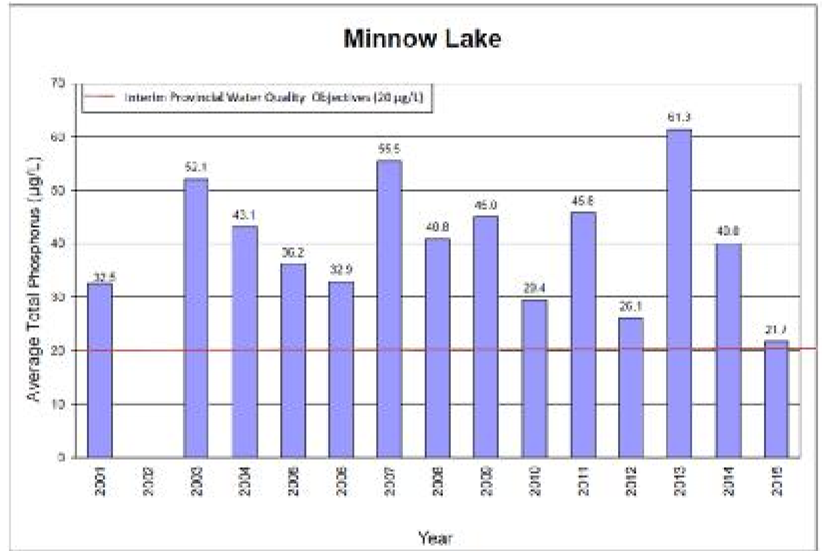
Water Quality (Minnow and Bethel Lakes)

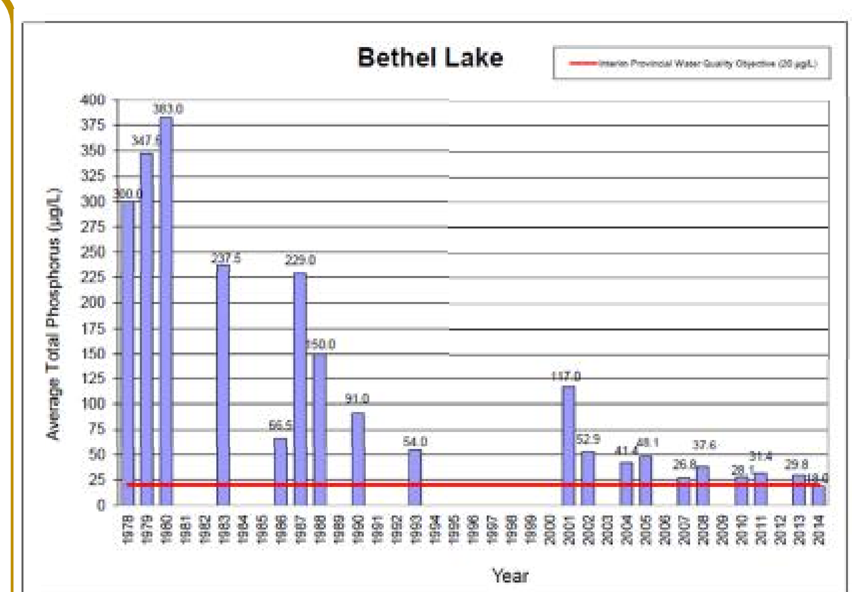
Objectives

- **Identify sources of pollution and water quality trends**

Study Tasks:

- ✓ Synthesized water and aquatic sediment data sets
- ✓ Identified long term trends in pollutants





Key Findings

- **The largest impact on water quality in these lakes is from surface runoff from the catchment.**
- **Phosphorus concentrations in Minnow Lake are high.**
- **Phosphorus concentrations have declined in Bethel lake since the 1980's but remain near the PWQO for phosphorus.**
- **Chloride levels in Minnow Lake are high. Chloride levels in 2010 varied between 110 and 169 mg/L, frequently exceeding the guideline of 120 mg/L.**
- **Chloride in Bethel Lake in 2010 varied between 33 and 56 mg/L; below the CCME long-term guideline for the protection of aquatic life.**

Water Quality and Aquatic Biota (Inflowing Creeks)

Objectives

- Identify sources of pollution and water quality trends
- Identify aquatic features/habitats that are of high importance to aquatic communities

Key Findings

- Very little water quality and biological information has been collected on the small creeks that drain urban areas. These creeks have been physically altered and channels are constrained by existing development.
- Urban effects have likely influenced water quality and aquatic biota communities.
- Total phosphorus, chloride and metal concentrations in Frobisher Creek are high.
- The benthic invertebrate community of Frobisher Creek consists primarily of pollution tolerant species, reflecting poor water quality.

Aquatic Biota (Ramsey Lake)

Objectives

- Identify aquatic features/habitats that are of high importance to aquatic communities

Study Tasks:

- ✓ Review existing information related to biota (fish, invertebrates) and their habitats
- ✓ Describe habitat conditions in Ramsey Lake and its tributaries

Key Findings

- Development along the shoreline of the lake is extensive, including more than 800 private dwellings as well as public spaces.
- Much of the habitat provided by natural shoreline features has been altered.
- Aquatic vegetation growth is dense in shallow waters near heavily urbanized areas.

Altered and natural Shoreline; Ramsey Lake.

Aquatic Biota (Ramsey Lake)

Objectives

- **Identify aquatic features/habitats that are of high importance to aquatic communities**

Study Tasks:

✓ Review existing information related to biota (fish, invertebrates) and their habitats

✓ Describe habitat conditions in Ramsey Lake and its tributaries

Key Findings

- **Aquatic invertebrates in Ramsey Lake are comprised of the species and numbers typical of area lakes and suggest good water quality in nearshore habitats.**
- **Walleye successfully reproduce in Ramsey Lake. Abundance (population size) is low and exploitation is high.**
- **Mercury levels in fish are below the maximum level of mercury considered harmful to human consumers.**

Aquatic Biota (Minnow and Bethel Lakes)

Objectives

- Identify aquatic features/habitats that are of high importance to aquatic communities

Study Tasks:

✓ Review existing information related to biota (fish, invertebrates) and their habitats.

Key Findings

- There is extensive aquatic vegetation growth in the southern portion of the Lake which, in addition to shoreline vegetation, provides important spawning and nursery habitats to fish.
- Eurasian water milfoil, an invasive aquatic plant, has proliferated in Minnow Lake.
- The current status of resident fish populations in these lakes is unknown.
- The benthic invertebrate community of Bethel Lake consists primarily of pollution tolerant species, reflecting poor water quality.

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APPENDIX F: List of Roads with Rural and Urban Cross Sections

List of all Roads within the Ramsey Lake Subwatershed - Classified as Rural and Urban

Roads with Urban Cross Sections	CSG Road Classification	Approximate Length (m)
17E KINGSWAY HIGHWAY	Major Road	5040
ADAMS STREET	Local Road	264
ADMIRAL DRIVE	Local Road	102
ANNIE STREET	Local Road	403
ARLINGTON BOULEVARD	Local Road	297
ATHLETIC BUILDING ROAD	Lane	568
AUTUMNWOOD CRESCENT	Local Road	927
AVALON ROAD	Local Road	218
BANCROFT DRIVE	Major Road	7358
BARRY STREET	Local Road	254
BAYCREST ROAD	Local Road	225
BAYVIEW LANE	Local Road	221
BEATON AVENUE	Local Road	281
BEDFORD COURT	Local Road	171
BELL PARK ROAD	Lane	369
BELLEVUE AVENUE	Major Road	637
BELMONT DRIVE	Local Road	234
BETHUNE AVENUE	Local Road	94
BIRKDALE VILLAGE ROAD	Lane	283
BIRMINGHAM DRIVE	Local Road	74
BLANCHARD AVENUE	Local Road	108
BOLAND AVENUE	Local Road	928
CAMANOR COURT	Local Road	145
CAMELOT DRIVE	Local Road	700
CARMICHAEL VILLAGE ROAD	Lane	221
CARTIER AVENUE	Local Road	466
CHERRYWOOD CRESCENT	Local Road	429
CHRISTAKOS STREET	Local Road	127
CIVIC MEMORIAL CEMETARY ROAD	Lane	862
CLAIRMONT STREET	Local Road	116
CLEARVIEW AVENUE	Local Road	157
DALE STREET	Local Road	213
DARBY STREET	Local Road	194
DAVID STREET	Local Road	690
DEVON ROAD	Local Road	164
DIXON ROAD	Local Road	292
DONALD STREET	Local Road	464
DORSETT DRIVE	Local Road	408
DOWNING STREET	Local Road	166
DUBE ROAD	Local Road	740
DUNDAS STREET	Local Road	91
EAGLESTONE COURT	Local Road	106
EDMUND STREET	Local Road	336
ELDERWOOD DRIVE	Local Road	370
ELGIN STREET	Local Road	454
ELIZABETH STREET	Local Road	680
ELLIOT AVENUE	Local Road	168
ESTELLE STREET	Local Road	443
EUGENE STREET	Local Road	180
FACER STREET	Local Road	111
FERNDALE AVENUE	Local Road	432
FIRST AVENUE	Local Road	538
FOURTH AVENUE	Local Road	906
FRANKLIN AVENUE	Local Road	88
FROBISHER STREET	Local Road	628
GAGNE STREET	Local Road	108
GARLAND CRESCENT	Local Road	387
GENEVA STREET	Local Road	93
GENNINGS STREET	Local Road	230
GERALD STREET	Local Road	309
GILL STREET	Local Road	99
GLEN AVENUE	Local Road	106
GLENDALE AVENUE	Local Road	105
GLOUCESTER COURT	Local Road	119
GREENBRIAR DRIVE	Local Road	617
GREENWOOD DRIVE	Local Road	1007
HARGREAVES AVENUE	Local Road	203
HARRY CRESCENT	Local Road	497
HEATHERGLEN PLACE	Local Road	52
HEBERT STREET	Local Road	464
HIGHGATE ROAD	Local Road	296

Roads with Rural Cross Sections	CSG Road Classification	Approximate Length (m)
17E KINGSWAY HIGHWAY	Major Road	3260
ADAMS STREET	Local Road	264
ARLINGTON BOULEVARD	Local Road	297
ATHLETIC BUILDING ROAD	Lane	568
AVALON ROAD	Local Road	218
BANCROFT DRIVE	Major Road	4725
BARRY STREET	Local Road	254
BAYCREST ROAD	Local Road	100
BAYVIEW LANE	Local Road	221
BEDFORD COURT	Local Road	171
BELL PARK ROAD	Lane	369
BELMONT DRIVE	Local Road	234
BETHUNE AVENUE	Local Road	94
BLANCHARD AVENUE	Local Road	108
CARTIER AVENUE	Local Road	85
CLAIRMONT STREET	Local Road	116
DALE STREET	Local Road	213
DARBY STREET	Local Road	194
DIXON ROAD	Local Road	67
DONALD STREET	Local Road	464
DOWNING STREET	Local Road	166
DUBE ROAD	Local Road	740
DUNDAS STREET	Local Road	91
ELLIOT AVENUE	Local Road	168
ESTELLE STREET	Local Road	443
EUGENE STREET	Local Road	180
FERNDALE AVENUE	Local Road	432
FIRST AVENUE	Local Road	538
FOURTH AVENUE	Local Road	906
FRANKLIN AVENUE	Local Road	88
FROBISHER STREET	Local Road	628
GAGNE STREET	Local Road	108
GENNINGS STREET	Local Road	230
GERALD STREET	Local Road	309
GLENDALE AVENUE	Local Road	105
GREENWOOD DRIVE	Local Road	736
HARGREAVES AVENUE	Local Road	203
HARRY CRESCENT	Local Road	497
HILLSBORO AVENUE	Local Road	322
HILLSIDE AVENUE	Local Road	230
HINES STREET	Local Road	101
HOWEY DRIVE	Major Road	1067
JANET STREET	Local Road	76
JOHN STREET	Local Road	342
KEAST DRIVE	Local Road	525
KEEN STREET	Local Road	125
KIRKWOOD DRIVE	Local Road	1239
LABERGE LANE	Lane	221
LAKE POINT COURT	Local Road	709
LAKESHORE DRIVE	Local Road	172
LAKEWOOD DRIVE	Local Road	407
LENOX AVENUE	Local Road	217
LONSDALE AVENUE	Local Road	854
LOURDES STREET	Local Road	259
MANOR ROAD	Local Road	249
MARGARET STREET	Local Road	197
MCKINNON STREET	Local Road	277
MILDRED STREET	Local Road	545
MOONLIGHT AVENUE	Local Road	677
MOONLIGHT BEACH ROAD	Local Road	1272
NAVANOD ROAD	Local Road	629
NEELON AVENUE	Local Road	161
NELSON STREET	Local Road	126
NORTH SHORE DRIVE	Local Road	632
PARKDALE AVENUE	Local Road	263
PICARD STREET	Local Road	144
PORTAGE AVENUE	Local Road	353
RALPH STREET	Local Road	169
RAMSEY LAKE/MR 39 ROAD	Local Road	3250
RANDOLPH STREET	Local Road	241
RAYMOND STREET	Local Road	488

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Roads with Urban Cross Sections	CSG Road Classification	Approximate Length (m)
HILLSBORO AVENUE	Local Road	322
HILLSIDE AVENUE	Local Road	342
HINES STREET	Local Road	101
HOMES OF PROSPERITY & EQUALITY F	Lane	125
HORIZON CO-OP ROAD	Lane	233
HOWEY DRIVE	Major Road	2129
JANET STREET	Local Road	168
JEANNE D'ARC AVENUE	Local Road	257
JOHN STREET	Local Road	919
KEAST DRIVE	Local Road	525
KEEN STREET	Local Road	125
KENWOOD STREET	Local Road	565
KIRKWOOD DRIVE	Local Road	1239
KORMAK STREET	Local Road	262
LABERGE LANE	Lane	221
LAKE POINT COURT	Local Road	709
LAKESHORE DRIVE	Local Road	172
LAKEVIEW DRIVE	Local Road	79
LAKEWOOD DRIVE	Local Road	407
LAMBTON COURT	Local Road	144
LANCASTER DRIVE	Local Road	252
LAURELCREST AVENUE	Local Road	127
LENOX AVENUE	Local Road	217
LEVESQUE STREET	Local Road	770
LONSDALE AVENUE	Local Road	1126
LOURDES STREET	Local Road	511
MANITOU ROAD	Lane	350
MANOR ROAD	Local Road	249
MARCUS DRIVE	Local Road	314
MARGARET STREET	Local Road	197
MARION STREET	Local Road	307
MARSHALL LANE	Local Road	126
MCKINNON STREET	Local Road	277
MCNAUGHTON STREET	Local Road	546
MCNAUGHTON TERRACE	Local Road	367
MERRYGALE DRIVE	Local Road	166
MILDRED STREET	Local Road	545
MOONEY STREET	Local Road	225
MOONLIGHT AVENUE	Local Road	677
MOONLIGHT BEACH ROAD	Local Road	1272
MORRIS STREET	Local Road	683
NAVANOD ROAD	Local Road	629
NEELON AVENUE	Local Road	226
NELSON STREET	Local Road	226
NORTH SHORE DRIVE	Local Road	632
NOTTINGHAM AVENUE	Local Road	95
PALACE PLACE ROAD	Lane	277
PARIS STREET	Major Road	2187
PARKDALE AVENUE	Local Road	263
PICARD STREET	Local Road	144
PLUMTREE CRESCENT	Local Road	386
PORTAGE AVENUE	Local Road	353
RALPH STREET	Local Road	182
RAMSEY LAKE/MR 39 ROAD	Local Road	3343
RAMSEY ROAD	Local Road	378
RANDOLPH STREET	Local Road	324
RAYMOND STREET	Local Road	488
REDWOOD DRIVE	Local Road	37
RHEAL STREET	Local Road	348
RICHARD STREET	Local Road	243
RICHGROVE COURT	Local Road	38
RIDGEMOUNT AVENUE	Local Road	511
RIPPLE ROAD	Local Road	185
RITA STREET	Local Road	125
RODERICK AVENUE	Local Road	228
ROGER STREET	Local Road	363
SABLE STREET	Local Road	178
SAMSON AVENUE	Local Road	241
SCARLETT ROAD	Local Road	205
SEAFORTH LANE	Lane	183
SECOND AVENUE	Local Road	2897

Roads with Rural Cross Sections	CSG Road Classification	Approximate Length (m)
RHEAL STREET	Local Road	348
RICHARD STREET	Local Road	243
RIDGEMOUNT AVENUE	Local Road	511
RITA STREET	Local Road	125
ROGER STREET	Local Road	363
SABLE STREET	Local Road	178
SAMSON AVENUE	Local Road	171
SECOND AVENUE	Local Road	2131
SEGUIN STREET	Local Road	126
SHAPPERT AVENUE	Local Road	355
SILVERMAN STREET	Local Road	179
SOUTH BAY ROAD	Local Road	3925
SOUTHWEST BYPASS HIGHWAY	Highway	10628
SOUTHWEST BY-PASS HIGHWAY	Highway	665
ST DENIS STREET	Local Road	219
SUNDAY STREET	Local Road	141
TORBAY ROAD	Local Road	406
UNIVERSITY ROAD	Lane	1767
UNNAMED LANES LANE	Lane	81
UNNAMED PRIVATE ROAD	Lane	7639
VICTOR STREET	Local Road	280
WATERVIEW ROAD	Lane	402
WILFRED STREET	Local Road	342
WILTSHIRE STREET	Local Road	539
WOODLAWN ROAD	Local Road	170
WORTHINGTON CRESCENT	Local Road	192
YOLLIE STREET	Local Road	181

List of all Roads within the Ramsey Lake Subwatershed - Classified as Rural and Urban

Roads with Urban Cross Sections	CSG Road Classification	Approximate Length (m)
SEGUIN STREET	Local Road	126
SHAPPERT AVENUE	Local Road	355
SILPAA STREET	Local Road	122
SILVERMAN STREET	Local Road	179
SMITH STREET	Local Road	73
SOMERSET STREET	Local Road	427
SOUTH BAY ROAD	Local Road	3925
SOUTHWEST BYPASS HIGHWAY	Highway	10628
SOUTHWEST BY-PASS HIGHWAY	Highway	665
ST ANTOINE STREET	Local Road	131
ST DENIS STREET	Local Road	219
ST RAPHAEL STREET	Local Road	431
SUNDAY STREET	Local Road	141
TARNEAUD STREET	Local Road	251
THIRD AVENUE	Local Road	1129
TORBAY ROAD	Local Road	967
UNIVERSITY ROAD	Lane	1767
UNNAMED LANES LANE	Lane	137
UNNAMED PRIVATE ROAD	Lane	11915
VAN HORNE STREET	Local Road	756
VICTOR STREET	Local Road	280
WATERVIEW ROAD	Lane	468
WELLER STREET	Local Road	505
WESSEX STREET	Local Road	112
WILFRED STREET	Local Road	342
WILTSHIRE STREET	Local Road	539
WINDSOR CRESCENT	Local Road	470
WOODLAND STREET	Local Road	110
WOODLAWN ROAD	Local Road	170
WOODS STREET	Local Road	53
WORTHINGTON CRESCENT	Local Road	192
YOLLIE STREET	Local Road	250
YORK STREET	Local Road	567

Roads with Rural Cross Sections	CSG Road Classification	Approximate Length (m)

APPENDIX G: Detailed Evaluation for SWM Facilities

Criteria	Description of Criteria	Measures for Assigning Scores
Natural Environment		
Potential Surface Flooding Benefit	Ability to reduce surface flooding associated with private properties and roads	Scores are assigned as follows: 4 - significant reduction in surface flooding risks 2 - potential reduction to surface flooding risks 0 - no change in surface flooding risk
Potential Erosion Control Benefit	Potential to reduce erosional forces in receiving stream based on existing condition of stream and ability to provide required erosion control volume	Scores are assigned as follows: 4 - high potential to reduce erosional forces 2 - moderate potential to reduce erosional forces 0 - limited to no potential to reduce erosional forces
Potential Aquatic Habitat Benefit	Potential to improve aquatic habitats or systems, including possible impacts on aquatic life, features and functions	Scores are assigned as follows: 4 - significant improvement to aquatic habitat or systems 2 - moderate improvement to aquatic habitat or systems 0 - no impact to aquatic habitat or systems
Potential Water Quality Benefit	Potential to improve water quality based on existing water quality conditions in stream and ability to provide required water quality control	Scores are assigned as follows: 4 - high potential that the proposed treatment will improve the water quality 2 - moderate potential that the treatment will improve the water quality 0 - limited to no potential that the treatment will improve the water quality
Potential Hydrologic Flow Benefit	Ability to reduce the peak flow rate and total flow in the downstream receiving water system	Scores are assigned as follows: 4 – significant potential to reduce the peak flow and total flow downstream 2 – moderate potential to reduce the peak flow and total flow downstream 0 – limited or no potential to reduce the peak flow and total flow downstream
Potential Terrestrial Habitat Benefit	Potential to improve terrestrial habitats based on the existing conditions of the terrestrial ecology	Scores are assigned as follows: 4 - high potential to impact existing terrestrial habitat 2 - moderate potential to impact existing terrestrial habitat 0 - limited to no potential to impact existing terrestrial habitat
Socio-Cultural Impacts		
Impact to Aesthetics / Recreation	Potential for retrofit facility to be an asset to the community by integrating facility into activities such as walking, jogging, hiking	Scores are assigned as follows: 4 - high potential to integrate facility into existing activities 2 - moderate potential to integrate facility into existing activities 0 - limited to no potential to integrate facility into existing activities
Compatibility with Adjacent Land Uses	There are potential impacts associated with construction of facilities, particularly with respect to land uses such as residential, old age homes and schools. Access / egress also	Scores are assigned as follows: 4 - no impacts associated with construction and access / egress for operation / maintenance 2 - minor impacts associated with construction and access will be limited 0 - sensitive land uses are located adjacent to proposed facility and access / egress will be limited
Compatibility with Land Ownership	There are potential impacts associated with ownership of the land which could restrict access for construction and maintenance	Scores are assigned as follows: 4 - City owned lands or have easement 2 - most lands are owned by City, but some easrments may be required 0 – lands are privately owned
Community Impact -Disruption to Community During Construction	Potential to impact the community in terms of access to the site, visibility, road access, construction of mitigation measure in valley lands / parks, possible noise / odour / light,	Scores are assigned as follows: 4 – no impact on community 2 – moderate impact on community 0 – significant impact on community
Consistency with municipal, provinical and federal regulation and/or policy	Ability for the alternative to meet the governing, or soon to be implemented standards, regulations and policies.	Scores are assigned as follows: 4 - consistent with all standards/regulations/policies 2 - meets some standards/regulations/policies 0 – not consistent with standards/regulations/policies
Technical Impacts		
Level of Service provided	Anticipated level of treatment based on the size of the drainage area and the land available for the facility	Scores are assigned as follows: 4 – technique expected to be highly effective 2 – technique expected to be moderately effective 0 – technique expected to be least effective
Constructability	Degree of difficulty in constructing the SWM alternative given the existing site conditions and constraints.	Scores are assigned as follows: 4 – technique is easily implementable 2 – there are some obsticles to overcome before implementing techniques 0 – there are many obsticles to overcome before implementing techniques
Maintenance Requirements	Degree of anticipated future effort required to maintain the SWM alternative in good working order.	Scores are assigned as follows: 4 – limited to no maintenace required 2 – moderate amount of maintenance is required 0 – high amounts of maintenance is required
Economic Impacts		
Capital Costs	The relative estimated costs of implementing the proposed treatement based on factors such as location, access / egress and area to dispose material	Scores are assigned as follows: 4 - no capital costs 2 - moderate capital cost 0 - highest capital cost
Operation and Maintenance Costs	The relative cost of operating and maintaining the facility based on factors such as location, access / egress and availability of sediment drying area	Scores are assigned as follows: 4 - no operation and maintenance costs 2 - moderate operation and maintenance cost 0 - highest operation and maintenance cost
Imapct to Property Values	Potential impacts (positive or negative) to local property value, based on aesthetic benefits, potential land-use synergies and general economic incentives.	Scores are assigned as follows: 4 - high potential benefit to property values 2 - moderate potential benefit to property values 0 - no potential benefit property values

Site 1 1

Criteria	Description of Criteria	Measures for Assigning Scores	Alternative 1 Do Nothing	Alternative 2 Above Ground SWM Facility	Alternative 3 Below Ground SWM Facility
Natural Environment					
Potential Surface Flooding Benefit	Ability to reduce surface flooding associated with private properties and roads	Scores are assigned as follows: 4 - significant reduction in surface flooding risks 2 - potential reduction to surface flooding risks 0 - no change in surface flooding risk	0	2	2
Potential Erosion Control Benefit	Potential to reduce erosional forces in receiving stream based on existing condition of stream and ability to provide required erosion control volume	Scores are assigned as follows: 4 - high potential to reduce erosional forces 2 - moderate potential to reduce erosional forces 0 - limited to no potential to reduce erosional forces	0	4	4
Potential Aquatic Habitat Benefit	Potential to improve aquatic habitats or systems, including possible impacts on aquatic life, features and functions	Scores are assigned as follows: 4 - significant improvement to aquatic habitat or systems 2 - moderate improvement to aquatic habitat or systems 0 - no impact to aquatic habitat or systems	0	2	2
Potential Water Quality Benefit	Potential to improve water quality based on existing water quality conditions in stream and ability to provide required water quality control	Scores are assigned as follows: 4 - high potential that the proposed treatment will improve the water quality 2 - moderate potential that the treatment will improve the water quality 0 - limited to no potential that the treatment will improve the water quality	0	4	4
Potential Hydrologic Flow Benefit	Ability to reduce the peak flow rate and total flow in the downstream receiving water system	Scores are assigned as follows: 4 – significant potential to reduce the peak flow and total flow downstream 2 – moderate potential to reduce the peak flow and total flow downstream 0 – limited or no potential to reduce the peak flow and total flow downstream	0	4	4
Potential Terrestrial Habitat Benefit	Potential to improve terrestrial habitats based on the existing conditions of the terrestrial ecology	Scores are assigned as follows: 4 - high potential to impact existing terrestrial habitat 2 - moderate potential to impact existing terrestrial habitat 0 - limited to no potential to impact existing terrestrial habitat	NA	NA	NA
		Natural Environment Impacts Subtotal	0	16	16
		Weighted Score for Natural Environment Impact Criteria (maximum of 25 pts)	**0.00**	**20.00**	**20.00**
Socio-Cultural Impacts					
Impact to Aesthetics / Recreation	Potential for retrofit facility to be an asset to the community by integrating facility into activities such as walking, jogging, hiking	Scores are assigned as follows: 4 - high potential to integrate facility into existing activities 2 - moderate potential to integrate facility into existing activities 0 - limited to no potential to integrate facility into existing activities	4	2	4
Compatibility with Adjacent Land Uses	There are potential impacts associated with construction of facilities, particularly with respect to land uses such as residential, old age homes and schools. Access / egress also	Scores are assigned as follows: 4 - no impacts associated with construction and access / egress for operation / maintenance 2 - minor impacts associated with construction and access will be limited 0 - sensitive land uses are located adjacent to proposed facility and access / egress will be limited	4	2	2
Compatibility with Land Ownership	There are potential impacts associated with ownership of the land which could restrict access for construction and maintenance	Scores are assigned as follows: 4 - City owned lands or have easement 2 - most lands are owned by City, but some easrments may be required 0 – lands are privately owned	4	4	4
Community Impact -Disruption to Community During Construction	Potential to impact the community in terms of access to the site, visibility, road access, construction of mitigation measure in valley lands / parks, possible noise / odour / light,	Scores are assigned as follows: 4 – no impact on community 2 – moderate impact on community 0 – significant impact on community	4	0	2
Consistency with municipal, provinical and federal regulation and/or policy	Ability for the alternative to meet the governing, or soon to be implemented standards, regulations and policies.	Scores are assigned as follows: 4 - consistent with all standards/regulations/policies 2 - meets some standards/regulations/policies 0 – not consistent with standards/regulations/policies	0	4	4
		Socio-Cultural Impacts Subtotal	16	12	16
		Weighted Score for Socio-Cultural Impact Criteria (maximum of 25 pts)	**20**	**15**	**20**
Technical Impacts					
Level of Service provided	Anticipated level of treatment based on the size of the drainage area and the land available for the facility	Scores are assigned as follows: 4 – technique expected to be highly effective 2 – technique expected to be moderately effective 0 – technique expected to be least effective	0	4	2
Constructability	Degree of difficulty in constructing the SWM alternative given the existing site conditions and constraints.	Scores are assigned as follows: 4 – technique is easily implementable 2 – there are some obsticles to overcome before implementing techniques 0 – there are many obsticles to overcome before implementing techniques	4	0	2
Maintenance Requirements	Degree of anticipated future effort required to maintain the SWM alternative in good working order.	Scores are assigned as follows: 4 – limited to no maintenace required 2 – moderate amount of maintenance is required 0 – high amounts of maintenance is required	4	2	0
		Technical Impacts Subtotal	8	6	4
		Weighted Score for Technical Impact Criteria (maximum of 25 pts)	**16.67**	**12.50**	**8.33**
Economic Impacts					
Capital Costs	The relative estimated costs of implementing the proposed treatement based on factors such as location, access / egress and area to dispose material	Scores are assigned as follows: 4 - no capital costs 2 - moderate capital cost 0 - highest capital cost	4	2	0
Operation and Maintenance Costs	The relative cost of operating and maintaining the facility based on factors such as location, access / egress and availability of sediment drying area	Scores are assigned as follows: 4 - no operation and maintenance costs 2 - moderate operation and maintenance cost 0 - highest operation and maintenance cost	4	2	0
Imapct to Property Values	Potential impacts (positive or negative) to local property value, based on aesthetic benefits, potential land-use synergies and general economic incentives.	Scores are assigned as follows: 4 - high potential benefit to property values 2 - moderate potential benefit to property values 0 - no potential benefit property values	0	0	4
		Economic Impacts Subtotal	8	4	4
		Weighted Score for Economic Impact Criteria (maximum of 25 pts)	**16.66666667**	**8.333333333**	**8.333333333**
		FINAL WEIGHTED SCORE (maximum of 100 pts)	**53.33**	**55.83**	**56.67**

Site 2 1

Criteria	Description of Criteria	Measures for Assigning Scores	Alternative 1 Do Nothing	Alternative 2 Above Ground SWM Facility	Alternative 3 Below Ground SWM Facility
Natural Environment					
Potential Surface Flooding Benefit	Ability to reduce surface flooding associated with private properties and roads	Scores are assigned as follows: 4 - significant reduction in surface flooding risks 2 - potential reduction to surface flooding risks 0 - no change in surface flooding risk	0	2	2
Potential Erosion Control Benefit	Potential to reduce erosional forces in receiving stream based on existing condition of stream and ability to provide required erosion control volume	Scores are assigned as follows: 4 - high potential to reduce erosional forces 2 - moderate potential to reduce erosional forces 0 - limited to no potential to reduce erosional forces	0	4	4
Potential Aquatic Habitat Benefit	Potential to improve aquatic habitats or systems, including possible impacts on aquatic life, features and functions	Scores are assigned as follows: 4 - significant improvement to aquatic habitat or systems 2 - moderate improvement to aquatic habitat or systems 0 - no impact to aquatic habitat or systems	0	2	2
Potential Water Quality Benefit	Potential to improve water quality based on existing water quality conditions in stream and ability to provide required water quality control	Scores are assigned as follows: 4 - high potential that the proposed treatment will improve the water quality 2 - moderate potential that the treatment will improve the water quality 0 - limited to no potential that the treatment will improve the water quality	0	4	4
Potential Hydrologic Flow Benefit	Ability to reduce the peak flow rate and total flow in the downstream receiving water system	Scores are assigned as follows: 4 – significant potential to reduce the peak flow and total flow downstream 2 – moderate potential to reduce the peak flow and total flow downstream 0 – limited or no potential to reduce the peak flow and total flow downstream	0	4	4
Potential Terrestrial Habitat Benefit	Potential to improve terrestrial habitats based on the existing conditions of the terrestrial ecology	Scores are assigned as follows: 4 - high potential to impact existing terrestrial habitat 2 - moderate potential to impact existing terrestrial habitat 0 - limited to no potential to impact existing terrestrial habitat	NA	NA	NA
		Natural Environment Impacts Subtotal	0	16	16
		Weighted Score for Natural Environment Impact Criteria (maximum of 25 pts)	**0.00**	**20.00**	**20.00**
Socio-Cultural Impacts					
Impact to Aesthetics / Recreation	Potential for retrofit facility to be an asset to the community by integrating facility into activities such as walking, jogging, hiking	Scores are assigned as follows: 4 - high potential to integrate facility into existing activities 2 - moderate potential to integrate facility into existing activities 0 - limited to no potential to integrate facility into existing activities	2	4	4
Compatibility with Adjacent Land Uses	There are potential impacts associated with construction of facilities, particularly with respect to land uses such as residential, old age homes and schools. Access / egress also	Scores are assigned as follows: 4 - no impacts associated with construction and access / egress for operation / maintenance 2 - minor impacts associated with construction and access will be limited 0 - sensitive land uses are located adjacent to proposed facility and access / egress will be limited	4	2	2
Compatibility with Land Ownership	There are potential impacts associated with ownership of the land which could restrict access for construction and maintenance	Scores are assigned as follows: 4 - City owned lands or have easement 2 - most lands are owned by City, but some easrments may be required 0 – lands are privately owned	4	4	4
Community Impact -Disruption to Community During Construction	Potential to impact the community in terms of access to the site, visibility, road access, construction of mitigation measure in valley lands / parks, possible noise / odour / light,	Scores are assigned as follows: 4 – no impact on community 2 – moderate impact on community 0 – significant impact on community	4	2	2
Consistency with municipal, provinical and federal regulation and/or policy	Ability for the alternative to meet the governing, or soon to be implemented standards, regulations and policies.	Scores are assigned as follows: 4 - consistent with all standards/regulations/policies 2 - meets some standards/regulations/policies 0 – not consistent with standards/regulations/policies	0	4	4
		Socio-Cultural Impacts Subtotal	14	16	16
		Weighted Score for Socio-Cultural Impact Criteria (maximum of 25 pts)	**17.5**	**20**	**20**
Technical Impacts					
Level of Service provided	Anticipated level of treatment based on the size of the drainage area and the land available for the facility	Scores are assigned as follows: 4 – technique expected to be highly effective 2 – technique expected to be moderately effective 0 – technique expected to be least effective	0	4	4
Constructability	Degree of difficulty in constructing the SWM alternative given the existing site conditions and constraints.	Scores are assigned as follows: 4 – technique is easily implementable 2 – there are some obsticles to overcome before implementing techniques 0 – there are many obsticles to overcome before implementing techniques	4	2	0
Maintenance Requirements	Degree of anticipated future effort required to maintain the SWM alternative in good working order.	Scores are assigned as follows: 4 – limited to no maintenace required 2 – moderate amount of maintenance is required 0 – high amounts of maintenance is required	4	2	0
		Technical Impacts Subtotal	8	8	4
		Weighted Score for Technical Impact Criteria (maximum of 25 pts)	**16.67**	**16.67**	**8.33**
Economic Impacts					
Capital Costs	The relative estimated costs of implementing the proposed treatement based on factors such as location, access / egress and area to dispose material	Scores are assigned as follows: 4 - no capital costs 2 - moderate capital cost 0 - highest capital cost	4	2	0
Operation and Maintenance Costs	The relative cost of operating and maintaining the facility based on factors such as location, access / egress and availability of sediment drying area	Scores are assigned as follows: 4 - no operation and maintenance costs 2 - moderate operation and maintenance cost 0 - highest operation and maintenance cost	4	2	0
Imapct to Property Values	Potential impacts (positive or negative) to local property value, based on aesthetic benefits, potential land-use synergies and general economic incentives.	Scores are assigned as follows: 4 - high potential benefit to property values 2 - moderate potential benefit to property values 0 - no potential benefit property values	0	2	4
		Economic Impacts Subtotal	8	6	4
		Weighted Score for Economic Impact Criteria (maximum of 25 pts)	**16.66666667**	**12.5**	**8.333333333**
		FINAL WEIGHTED SCORE (maximum of 100 pts)	**50.83**	**69.17**	**56.67**

Site 3 3

Criteria	Description of Criteria	Measures for Assigning Scores	Alternative 1 Do Nothing	Alternative 2 Above Ground SWM Facility	Alternative 3 Below Ground SWM Facility
Natural Environment					
Potential Surface Flooding Benefit	Ability to reduce surface flooding associated with private properties and roads	Scores are assigned as follows: 4 - significant reduction in surface flooding risks 2 - potential reduction to surface flooding risks 0 - no change in surface flooding risk	0	2	2
Potential Erosion Control Benefit	Potential to reduce erosional forces in receiving stream based on existing condition of stream and ability to provide required erosion control volume	Scores are assigned as follows: 4 - high potential to reduce erosional forces 2 - moderate potential to reduce erosional forces 0 - limited to no potential to reduce erosional forces	NA	NA	NA
Potential Aquatic Habitat Benefit	Potential to improve aquatic habitats or systems, including possible impacts on aquatic life, features and functions	Scores are assigned as follows: 4 - significant improvement to aquatic habitat or systems 2 - moderate improvement to aquatic habitat or systems 0 - no impact to aquatic habitat or systems	NA	NA	NA
Potential Water Quality Benefit	Potential to improve water quality based on existing water quality conditions in stream and ability to provide required water quality control	Scores are assigned as follows: 4 - high potential that the proposed treatment will improve the water quality 2 - moderate potential that the treatment will improve the water quality 0 - limited to no potential that the treatment will improve the water quality	0	4	4
Potential Hydrologic Flow Benefit	Ability to reduce the peak flow rate and total flow in the downstream receiving water system	Scores are assigned as follows: 4 – significant potential to reduce the peak flow and total flow downstream 2 – moderate potential to reduce the peak flow and total flow downstream 0 – limited or no potential to reduce the peak flow and total flow downstream	0	4	4
Potential Terrestrial Habitat Benefit	Potential to improve terrestrial habitats based on the existing conditions of the terrestrial ecology	Scores are assigned as follows: 4 - high potential to impact existing terrestrial habitat 2 - moderate potential to impact existing terrestrial habitat 0 - limited to no potential to impact existing terrestrial habitat	NA	NA	NA
		Natural Environment Impacts Subtotal	0	10	10
		Weighted Score for Natural Environment Impact Criteria (maximum of 25 pts)	**0.00**	**20.83**	**20.83**
Socio-Cultural Impacts					
Impact to Aesthetics / Recreation	Potential for retrofit facility to be an asset to the community by integrating facility into activities such as walking, jogging, hiking	Scores are assigned as follows: 4 - high potential to integrate facility into existing activities 2 - moderate potential to integrate facility into existing activities 0 - limited to no potential to integrate facility into existing activities	2	2	4
Compatibility with Adjacent Land Uses	There are potential impacts associated with construction of facilities, particularly with respect to land uses such as residential, old age homes and schools. Access / egress also	Scores are assigned as follows: 4 - no impacts associated with construction and access / egress for operation / maintenance 2 - minor impacts associated with construction and access will be limited 0 - sensitive land uses are located adjacent to proposed facility and access / egress will be limited	4	2	2
Compatibility with Land Ownership	There are potential impacts associated with ownership of the land which could restrict access for construction and maintenance	Scores are assigned as follows: 4 - City owned lands or have easement 2 - most lands are owned by City, but some easrments may be required 0 – lands are privately owned	4	4	4
Community Impact -Disruption to Community During Construction	Potential to impact the community in terms of access to the site, visibility, road access, construction of mitigation measure in valley lands / parks, possible noise / odour / light,	Scores are assigned as follows: 4 – no impact on community 2 – moderate impact on community 0 – significant impact on community	4	2	2
Consistency with municipal, provinical and federal regulation and/or policy	Ability for the alternative to meet the governing, or soon to be implemented standards, regulations and policies.	Scores are assigned as follows: 4 - consistent with all standards/regulations/policies 2 - meets some standards/regulations/policies 0 – not consistent with standards/regulations/policies	0	4	4
		Socio-Cultural Impacts Subtotal	14	14	16
		Weighted Score for Socio-Cultural Impact Criteria (maximum of 25 pts)	**17.5**	**17.5**	**20**
Technical Impacts					
Level of Service provided	Anticipated level of treatment based on the size of the drainage area and the land available for the facility	Scores are assigned as follows: 4 – technique expected to be highly effective 2 – technique expected to be moderately effective 0 – technique expected to be least effective	0	4	2
Constructability	Degree of difficulty in constructing the SWM alternative given the existing site conditions and constraints.	Scores are assigned as follows: 4 – technique is easily implementable 2 – there are some obsticles to overcome before implementing techniques 0 – there are many obsticles to overcome before implementing techniques	4	2	0
Maintenance Requirements	Degree of anticipated future effort required to maintain the SWM alternative in good working order.	Scores are assigned as follows: 4 – limited to no maintenace required 2 – moderate amount of maintenance is required 0 – high amounts of maintenance is required	4	2	0
		Technical Impacts Subtotal	8	8	2
		Weighted Score for Technical Impact Criteria (maximum of 25 pts)	**16.67**	**16.67**	**4.17**
Economic Impacts					
Capital Costs	The relative estimated costs of implementing the proposed treatement based on factors such as location, access / egress and area to dispose material	Scores are assigned as follows: 4 - no capital costs 2 - moderate capital cost 0 - highest capital cost	4	2	0
Operation and Maintenance Costs	The relative cost of operating and maintaining the facility based on factors such as location, access / egress and availability of sediment drying area	Scores are assigned as follows: 4 - no operation and maintenance costs 2 - moderate operation and maintenance cost 0 - highest operation and maintenance cost	4	2	0
Imapct to Property Values	Potential impacts (positive or negative) to local property value, based on aesthetic benefits, potential land-use synergies and general economic incentives.	Scores are assigned as follows: 4 - high potential benefit to property values 2 - moderate potential benefit to property values 0 - no potential benefit property values	0	2	4
		Economic Impacts Subtotal	8	6	4
		Weighted Score for Economic Impact Criteria (maximum of 25 pts)	**16.66666667**	**12.5**	**8.333333333**
		FINAL WEIGHTED SCORE (maximum of 100 pts)	**50.83**	**67.50**	**53.33**

Site 4 2

Criteria	Description of Criteria	Measures for Assigning Scores	Alternative 1 Do Nothing	Alternative 2 Below Ground SWM Facility
Natural Environment				
Potential Surface Flooding Benefit	Ability to reduce surface flooding associated with private properties and roads	Scores are assigned as follows: 4 - significant reduction in surface flooding risks 2 - potential reduction to surface flooding risks 0 - no change in surface flooding risk	0	2
Potential Erosion Control Benefit	Potential to reduce erosional forces in receiving stream based on existing condition of stream and ability to provide required erosion control volume	Scores are assigned as follows: 4 - high potential to reduce erosional forces 2 - moderate potential to reduce erosional forces 0 - limited to no potential to reduce erosional forces	0	4
Potential Aquatic Habitat Benefit	Potential to improve aquatic habitats or systems, including possible impacts on aquatic life, features and functions	Scores are assigned as follows: 4 - significant improvement to aquatic habitat or systems 2 - moderate improvement to aquatic habitat or systems 0 - no impact to aquatic habitat or systems	NA	NA
Potential Water Quality Benefit	Potential to improve water quality based on existing water quality conditions in stream and ability to provide required water quality control	Scores are assigned as follows: 4 - high potential that the proposed treatment will improve the water quality 2 - moderate potential that the treatment will improve the water quality 0 - limited to no potential that the treatment will improve the water quality	0	4
Potential Hydrologic Flow Benefit	Ability to reduce the peak flow rate and total flow in the downstream receiving water system	Scores are assigned as follows: 4 – significant potential to reduce the peak flow and total flow downstream 2 – moderate potential to reduce the peak flow and total flow downstream 0 – limited or no potential to reduce the peak flow and total flow downstream	0	4
Potential Terrestrial Habitat Benefit	Potential to improve terrestrial habitats based on the existing conditions of the terrestrial ecology	Scores are assigned as follows: 4 - high potential to impact existing terrestrial habitat 2 - moderate potential to impact existing terrestrial habitat 0 - limited to no potential to impact existing terrestrial habitat	NA	NA
		Natural Environment Impacts Subtotal	0	14
		Weighted Score for Natural Environment Impact Criteria (maximum of 25 pts)	**0.00**	**21.88**
Socio-Cultural Impacts				
Impact to Aesthetics / Recreation	Potential for retrofit facility to be an asset to the community by integrating facility into activities such as walking, jogging, hiking	Scores are assigned as follows: 4 - high potential to integrate facility into existing activities 2 - moderate potential to integrate facility into existing activities 0 - limited to no potential to integrate facility into existing activities	4	4
Compatibility with Adjacent Land Uses	There are potential impacts associated with construction of facilities, particularly with respect to land uses such as residential, old age homes and schools. Access / egress also	Scores are assigned as follows: 4 - no impacts associated with construction and access / egress for operation / maintenance 2 - minor impacts associated with construction and access will be limited 0 - sensitive land uses are located adjacent to proposed facility and access / egress will be limited	4	2
Compatibility with Land Ownership	There are potential impacts associated with ownership of the land which could restrict access for construction and maintenance	Scores are assigned as follows: 4 - City owned lands or have easement 2 - most lands are owned by City, but some easrments may be required 0 – lands are privately owned	4	4
Community Impact -Disruption to Community During Construction	Potential to impact the community in terms of access to the site, visibility, road access, construction of mitigation measure in valley lands / parks, possible noise / odour / light,	Scores are assigned as follows: 4 – no impact on community 2 – moderate impact on community 0 – significant impact on community	4	2
Consistency with municipal, provinical and federal regulation and/or policy	Ability for the alternative to meet the governing, or soon to be implemented standards, regulations and policies.	Scores are assigned as follows: 4 - consistent with all standards/regulations/policies 2 - meets some standards/regulations/policies 0 – not consistent with standards/regulations/policies	0	4
		Socio-Cultural Impacts Subtotal	16	16
		Weighted Score for Socio-Cultural Impact Criteria (maximum of 25 pts)	**20**	**20**
Technical Impacts				
Level of Service provided	Anticipated level of treatment based on the size of the drainage area and the land available for the facility	Scores are assigned as follows: 4 – technique expected to be highly effective 2 – technique expected to be moderately effective 0 – technique expected to be least effective	0	4
Constructability	Degree of difficulty in constructing the SWM alternative given the existing site conditions and constraints.	Scores are assigned as follows: 4 – technique is easily implementable 2 – there are some obsticles to overcome before implementing techniques 0 – there are many obsticles to overcome before implementing techniques	4	2
Maintenance Requirements	Degree of anticipated future effort required to maintain the SWM alternative in good working order.	Scores are assigned as follows: 4 – limited to no maintenace required 2 – moderate amount of maintenance is required 0 – high amounts of maintenance is required	4	2
		Technical Impacts Subtotal	8	8
		Weighted Score for Technical Impact Criteria (maximum of 25 pts)	**16.67**	**16.67**
Economic Impacts				
Capital Costs	The relative estimated costs of implementing the proposed treatement based on factors such as location, access / egress and area to dispose material	Scores are assigned as follows: 4 - no capital costs 2 - moderate capital cost 0 - highest capital cost	4	0
Operation and Maintenance Costs	The relative cost of operating and maintaining the facility based on factors such as location, access / egress and availability of sediment drying area	Scores are assigned as follows: 4 - no operation and maintenance costs 2 - moderate operation and maintenance cost 0 - highest operation and maintenance cost	4	2
Imapct to Property Values	Potential impacts (positive or negative) to local property value, based on aesthetic benefits, potential land-use synergies and general economic incentives.	Scores are assigned as follows: 4 - high potential benefit to property values 2 - moderate potential benefit to property values 0 - no potential benefit property values	0	2
		Economic Impacts Subtotal	8	4
		Weighted Score for Economic Impact Criteria (maximum of 25 pts)	**16.66666667**	**8.333333333**
		FINAL WEIGHTED SCORE (maximum of 100 pts)	**53.33**	**66.88**

Site 5 2

Criteria	Description of Criteria	Measures for Assigning Scores	Alternative 1 Do Nothing	Alternative 2 Below Ground SWM Facility
Natural Environment				
Potential Surface Flooding Benefit	Ability to reduce surface flooding associated with private properties and roads	Scores are assigned as follows: 4 - significant reduction in surface flooding risks 2 - potential reduction to surface flooding risks 0 - no change in surface flooding risk	0	2
Potential Erosion Control Benefit	Potential to reduce erosional forces in receiving stream based on existing condition of stream and ability to provide required erosion control volume	Scores are assigned as follows: 4 - high potential to reduce erosional forces 2 - moderate potential to reduce erosional forces 0 - limited to no potential to reduce erosional forces	0	4
Potential Aquatic Habitat Benefit	Potential to improve aquatic habitats or systems, including possible impacts on aquatic life, features and functions	Scores are assigned as follows: 4 - significant improvement to aquatic habitat or systems 2 - moderate improvement to aquatic habitat or systems 0 - no impact to aquatic habitat or systems	NA	NA
Potential Water Quality Benefit	Potential to improve water quality based on existing water quality conditions in stream and ability to provide required water quality control	Scores are assigned as follows: 4 - high potential that the proposed treatment will improve the water quality 2 - moderate potential that the treatment will improve the water quality 0 - limited to no potential that the treatment will improve the water quality	0	4
Potential Hydrologic Flow Benefit	Ability to reduce the peak flow rate and total flow in the downstream receiving water system	Scores are assigned as follows: 4 – significant potential to reduce the peak flow and total flow downstream 2 – moderate potential to reduce the peak flow and total flow downstream 0 – limited or no potential to reduce the peak flow and total flow downstream	0	4
Potential Terrestrial Habitat Benefit	Potential to improve terrestrial habitats based on the existing conditions of the terrestrial ecology	Scores are assigned as follows: 4 - high potential to impact existing terrestrial habitat 2 - moderate potential to impact existing terrestrial habitat 0 - limited to no potential to impact existing terrestrial habitat	NA	NA
		Natural Environment Impacts Subtotal	0	14
		Weighted Score for Natural Environment Impact Criteria (maximum of 25 pts)	**0.00**	**21.88**
Socio-Cultural Impacts				
Impact to Aesthetics / Recreation	Potential for retrofit facility to be an asset to the community by integrating facility into activities such as walking, jogging, hiking	Scores are assigned as follows: 4 - high potential to integrate facility into existing activities 2 - moderate potential to integrate facility into existing activities 0 - limited to no potential to integrate facility into existing activities	2	4
Compatibility with Adjacent Land Uses	There are potential impacts associated with construction of facilities, particularly with respect to land uses such as residential, old age homes and schools. Access / egress also	Scores are assigned as follows: 4 - no impacts associated with construction and access / egress for operation / maintenance 2 - minor impacts associated with construction and access will be limited 0 - sensitive land uses are located adjacent to proposed facility and access / egress will be limited	4	2
Compatibility with Land Ownership	There are potential impacts associated with ownership of the land which could restrict access for construction and maintenance	Scores are assigned as follows: 4 - City owned lands or have easement 2 - most lands are owned by City, but some easrments may be required 0 – lands are privately owned	4	4
Community Impact -Disruption to Community During Construction	Potential to impact the community in terms of access to the site, visibility, road access, construction of mitigation measure in valley lands / parks, possible noise / odour / light,	Scores are assigned as follows: 4 – no impact on community 2 – moderate impact on community 0 – significant impact on community	4	2
Consistency with municipal, provinical and federal regulation and/or policy	Ability for the alternative to meet the governing, or soon to be implemented standards, regulations and policies.	Scores are assigned as follows: 4 - consistent with all standards/regulations/policies 2 - meets some standards/regulations/policies 0 – not consistent with standards/regulations/policies	0	4
		Socio-Cultural Impacts Subtotal	14	16
		Weighted Score for Socio-Cultural Impact Criteria (maximum of 25 pts)	**17.5**	**20**
Technical Impacts				
Level of Service provided	Anticipated level of treatment based on the size of the drainage area and the land available for the facility	Scores are assigned as follows: 4 – technique expected to be highly effective 2 – technique expected to be moderately effective 0 – technique expected to be least effective	0	2
Constructability	Degree of difficulty in constructing the SWM alternative given the existing site conditions and constraints.	Scores are assigned as follows: 4 – technique is easily implementable 2 – there are some obsticles to overcome before implementing techniques 0 – there are many obsticles to overcome before implementing techniques	4	2
Maintenance Requirements	Degree of anticipated future effort required to maintain the SWM alternative in good working order.	Scores are assigned as follows: 4 – limited to no maintenace required 2 – moderate amount of maintenance is required 0 – high amounts of maintenance is required	4	2
		Technical Impacts Subtotal	8	6
		Weighted Score for Technical Impact Criteria (maximum of 25 pts)	**16.67**	**12.50**
Economic Impacts				
Capital Costs	The relative estimated costs of implementing the proposed treatement based on factors such as location, access / egress and area to dispose material	Scores are assigned as follows: 4 - no capital costs 2 - moderate capital cost 0 - highest capital cost	4	0
Operation and Maintenance Costs	The relative cost of operating and maintaining the facility based on factors such as location, access / egress and availability of sediment drying area	Scores are assigned as follows: 4 - no operation and maintenance costs 2 - moderate operation and maintenance cost 0 - highest operation and maintenance cost	4	2
Imapct to Property Values	Potential impacts (positive or negative) to local property value, based on aesthetic benefits, potential land-use synergies and general economic incentives.	Scores are assigned as follows: 4 - high potential benefit to property values 2 - moderate potential benefit to property values 0 - no potential benefit property values	0	4
		Economic Impacts Subtotal	8	6
		Weighted Score for Economic Impact Criteria (maximum of 25 pts)	**16.66666667**	**12.5**
		FINAL WEIGHTED SCORE (maximum of 100 pts)	**50.83**	**66.88**

Site 6 1

Criteria	Description of Criteria	Measures for Assigning Scores	Alternative 1 Do Nothing	Alternative 2 Below Ground SWM Facility
Natural Environment				
Potential Surface Flooding Benefit	Ability to reduce surface flooding associated with private properties and roads	Scores are assigned as follows: 4 - significant reduction in surface flooding risks 2 - potential reduction to surface flooding risks 0 - no change in surface flooding risk	0	2
Potential Erosion Control Benefit	Potential to reduce erosional forces in receiving stream based on existing condition of stream and ability to provide required erosion control volume	Scores are assigned as follows: 4 - high potential to reduce erosional forces 2 - moderate potential to reduce erosional forces 0 - limited to no potential to reduce erosional forces	0	4
Potential Aquatic Habitat Benefit	Potential to improve aquatic habitats or systems, including possible impacts on aquatic life, features and functions	Scores are assigned as follows: 4 - significant improvement to aquatic habitat or systems 2 - moderate improvement to aquatic habitat or systems 0 - no impact to aquatic habitat or systems	0	2
Potential Water Quality Benefit	Potential to improve water quality based on existing water quality conditions in stream and ability to provide required water quality control	Scores are assigned as follows: 4 - high potential that the proposed treatment will improve the water quality 2 - moderate potential that the treatment will improve the water quality 0 - limited to no potential that the treatment will improve the water quality	0	4
Potential Hydrologic Flow Benefit	Ability to reduce the peak flow rate and total flow in the downstream receiving water system	Scores are assigned as follows: 4 – significant potential to reduce the peak flow and total flow downstream 2 – moderate potential to reduce the peak flow and total flow downstream 0 – limited or no potential to reduce the peak flow and total flow downstream	0	4
Potential Terrestrial Habitat Benefit	Potential to improve terrestrial habitats based on the existing conditions of the terrestrial ecology	Scores are assigned as follows: 4 - high potential to impact existing terrestrial habitat 2 - moderate potential to impact existing terrestrial habitat 0 - limited to no potential to impact existing terrestrial habitat	NA	NA
		Natural Environment Impacts Subtotal	0	16
		Weighted Score for Natural Environment Impact Criteria (maximum of 25 pts)	**0.00**	**20.00**
Socio-Cultural Impacts				
Impact to Aesthetics / Recreation	Potential for retrofit facility to be an asset to the community by integrating facility into activities such as walking, jogging, hiking	Scores are assigned as follows: 4 - high potential to integrate facility into existing activities 2 - moderate potential to integrate facility into existing activities 0 - limited to no potential to integrate facility into existing activities	4	4
Compatibility with Adjacent Land Uses	There are potential impacts associated with construction of facilities, particularly with respect to land uses such as residential, old age homes and schools. Access / egress also	Scores are assigned as follows: 4 - no impacts associated with construction and access / egress for operation / maintenance 2 - minor impacts associated with construction and access will be limited 0 - sensitive land uses are located adjacent to proposed facility and access / egress will be limited	4	0
Compatibility with Land Ownership	There are potential impacts associated with ownership of the land which could restrict access for construction and maintenance	Scores are assigned as follows: 4 - City owned lands or have easement 2 - most lands are owned by City, but some easrments may be required 0 – lands are privately owned	4	4
Community Impact -Disruption to Community During Construction	Potential to impact the community in terms of access to the site, visibility, road access, construction of mitigation measure in valley lands / parks, possible noise / odour / light,	Scores are assigned as follows: 4 – no impact on community 2 – moderate impact on community 0 – significant impact on community	4	2
Consistency with municipal, provinical and federal regulation and/or policy	Ability for the alternative to meet the governing, or soon to be implemented standards, regulations and policies.	Scores are assigned as follows: 4 - consistent with all standards/regulations/policies 2 - meets some standards/regulations/policies 0 – not consistent with standards/regulations/policies	0	4
		Socio-Cultural Impacts Subtotal	16	14
		Weighted Score for Socio-Cultural Impact Criteria (maximum of 25 pts)	**20**	**17.5**
Technical Impacts				
Level of Service provided	Anticipated level of treatment based on the size of the drainage area and the land available for the facility	Scores are assigned as follows: 4 – technique expected to be highly effective 2 – technique expected to be moderately effective 0 – technique expected to be least effective	0	2
Constructability	Degree of difficulty in constructing the SWM alternative given the existing site conditions and constraints.	Scores are assigned as follows: 4 – technique is easily implementable 2 – there are some obsticles to overcome before implementing techniques 0 – there are many obsticles to overcome before implementing techniques	4	0
Maintenance Requirements	Degree of anticipated future effort required to maintain the SWM alternative in good working order.	Scores are assigned as follows: 4 – limited to no maintenace required 2 – moderate amount of maintenance is required 0 – high amounts of maintenance is required	4	2
		Technical Impacts Subtotal	8	4
		Weighted Score for Technical Impact Criteria (maximum of 25 pts)	**16.67**	**8.33**
Economic Impacts				
Capital Costs	The relative estimated costs of implementing the proposed treatement based on factors such as location, access / egress and area to dispose material	Scores are assigned as follows: 4 - no capital costs 2 - moderate capital cost 0 - highest capital cost	4	0
Operation and Maintenance Costs	The relative cost of operating and maintaining the facility based on factors such as location, access / egress and availability of sediment drying area	Scores are assigned as follows: 4 - no operation and maintenance costs 2 - moderate operation and maintenance cost 0 - highest operation and maintenance cost	4	2
Imapct to Property Values	Potential impacts (positive or negative) to local property value, based on aesthetic benefits, potential land-use synergies and general economic incentives.	Scores are assigned as follows: 4 - high potential benefit to property values 2 - moderate potential benefit to property values 0 - no potential benefit property values	0	2
		Economic Impacts Subtotal	8	4
		Weighted Score for Economic Impact Criteria (maximum of 25 pts)	**16.66666667**	**8.333333333**
		FINAL WEIGHTED SCORE (maximum of 100 pts)	**53.33**	**54.17**

Site 7 1

Criteria	Description of Criteria	Measures for Assigning Scores	Alternative 1 Do Nothing	Alternative 2 Below Ground SWM Facility
Natural Environment				
Potential Surface Flooding Benefit	Ability to reduce surface flooding associated with private properties and roads	Scores are assigned as follows: 4 - significant reduction in surface flooding risks 2 - potential reduction to surface flooding risks 0 - no change in surface flooding risk	0	2
Potential Erosion Control Benefit	Potential to reduce erosional forces in receiving stream based on existing condition of stream and ability to provide required erosion control volume	Scores are assigned as follows: 4 - high potential to reduce erosional forces 2 - moderate potential to reduce erosional forces 0 - limited to no potential to reduce erosional forces	0	4
Potential Aquatic Habitat Benefit	Potential to improve aquatic habitats or systems, including possible impacts on aquatic life, features and functions	Scores are assigned as follows: 4 - significant improvement to aquatic habitat or systems 2 - moderate improvement to aquatic habitat or systems 0 - no impact to aquatic habitat or systems	0	2
Potential Water Quality Benefit	Potential to improve water quality based on existing water quality conditions in stream and ability to provide required water quality control	Scores are assigned as follows: 4 - high potential that the proposed treatment will improve the water quality 2 - moderate potential that the treatment will improve the water quality 0 - limited to no potential that the treatment will improve the water quality	0	4
Potential Hydrologic Flow Benefit	Ability to reduce the peak flow rate and total flow in the downstream receiving water system	Scores are assigned as follows: 4 – significant potential to reduce the peak flow and total flow downstream 2 – moderate potential to reduce the peak flow and total flow downstream 0 – limited or no potential to reduce the peak flow and total flow downstream	0	4
Potential Terrestrial Habitat Benefit	Potential to improve terrestrial habitats based on the existing conditions of the terrestrial ecology	Scores are assigned as follows: 4 - high potential to impact existing terrestrial habitat 2 - moderate potential to impact existing terrestrial habitat 0 - limited to no potential to impact existing terrestrial habitat	NA	NA
		Natural Environment Impacts Subtotal	0	16
		Weighted Score for Natural Environment Impact Criteria (maximum of 25 pts)	**0.00**	**20.00**
Socio-Cultural Impacts				
Impact to Aesthetics / Recreation	Potential for retrofit facility to be an asset to the community by integrating facility into activities such as walking, jogging, hiking	Scores are assigned as follows: 4 - high potential to integrate facility into existing activities 2 - moderate potential to integrate facility into existing activities 0 - limited to no potential to integrate facility into existing activities	4	4
Compatibility with Adjacent Land Uses	There are potential impacts associated with construction of facilities, particularly with respect to land uses such as residential, old age homes and schools. Access / egress also	Scores are assigned as follows: 4 - no impacts associated with construction and access / egress for operation / maintenance 2 - minor impacts associated with construction and access will be limited 0 - sensitive land uses are located adjacent to proposed facility and access / egress will be limited	4	2
Compatibility with Land Ownership	There are potential impacts associated with ownership of the land which could restrict access for construction and maintenance	Scores are assigned as follows: 4 - City owned lands or have easement 2 - most lands are owned by City, but some easrments may be required 0 – lands are privately owned	4	4
Community Impact -Disruption to Community During Construction	Potential to impact the community in terms of access to the site, visibility, road access, construction of mitigation measure in valley lands / parks, possible noise / odour / light,	Scores are assigned as follows: 4 – no impact on community 2 – moderate impact on community 0 – significant impact on community	4	2
Consistency with municipal, provinical and federal regulation and/or policy	Ability for the alternative to meet the governing, or soon to be implemented standards, regulations and policies.	Scores are assigned as follows: 4 - consistent with all standards/regulations/policies 2 - meets some standards/regulations/policies 0 – not consistent with standards/regulations/policies	0	4
		Socio-Cultural Impacts Subtotal	16	16
		Weighted Score for Socio-Cultural Impact Criteria (maximum of 25 pts)	**20**	**20**
Technical Impacts				
Level of Service provided	Anticipated level of treatment based on the size of the drainage area and the land available for the facility	Scores are assigned as follows: 4 – technique expected to be highly effective 2 – technique expected to be moderately effective 0 – technique expected to be least effective	0	2
Constructability	Degree of difficulty in constructing the SWM alternative given the existing site conditions and constraints.	Scores are assigned as follows: 4 – technique is easily implementable 2 – there are some obsticles to overcome before implementing techniques 0 – there are many obsticles to overcome before implementing techniques	4	0
Maintenance Requirements	Degree of anticipated future effort required to maintain the SWM alternative in good working order.	Scores are assigned as follows: 4 – limited to no maintenace required 2 – moderate amount of maintenance is required 0 – high amounts of maintenance is required	4	2
		Technical Impacts Subtotal	8	4
		Weighted Score for Technical Impact Criteria (maximum of 25 pts)	**16.67**	**8.33**
Economic Impacts				
Capital Costs	The relative estimated costs of implementing the proposed treatement based on factors such as location, access / egress and area to dispose material	Scores are assigned as follows: 4 - no capital costs 2 - moderate capital cost 0 - highest capital cost	4	0
Operation and Maintenance Costs	The relative cost of operating and maintaining the facility based on factors such as location, access / egress and availability of sediment drying area	Scores are assigned as follows: 4 - no operation and maintenance costs 2 - moderate operation and maintenance cost 0 - highest operation and maintenance cost	4	2
Imapct to Property Values	Potential impacts (positive or negative) to local property value, based on aesthetic benefits, potential land-use synergies and general economic incentives.	Scores are assigned as follows: 4 - high potential benefit to property values 2 - moderate potential benefit to property values 0 - no potential benefit property values	0	2
		Economic Impacts Subtotal	8	4
		Weighted Score for Economic Impact Criteria (maximum of 25 pts)	**16.66666667**	**8.333333333**
		FINAL WEIGHTED SCORE (maximum of 100 pts)	**53.33**	**56.67**

Site 8

Criteria	Description of Criteria	Measures for Assigning Scores	Alternative 1 Do Nothing	Alternative 2 Above Ground SWM Facility	Alternative 3 Below Ground SWM Facility
Natural Environment					
Potential Surface Flooding Benefit	Ability to reduce surface flooding associated with private properties and roads	Scores are assigned as follows: 4 - significant reduction in surface flooding risks 2 - potential reduction to surface flooding risks 0 - no change in surface flooding risk	0	4	4
Potential Erosion Control Benefit	Potential to reduce erosional forces in receiving stream based on existing condition of stream and ability to provide required erosion control volume	Scores are assigned as follows: 4 - high potential to reduce erosional forces 2 - moderate potential to reduce erosional forces 0 - limited to no potential to reduce erosional forces	0	2	2
Potential Aquatic Habitat Benefit	Potential to improve aquatic habitats or systems, including possible impacts on aquatic life, features and functions	Scores are assigned as follows: 4 - significant improvement to aquatic habitat or systems 2 - moderate improvement to aquatic habitat or systems 0 - no impact to aquatic habitat or systems	0	2	2
Potential Water Quality Benefit	Potential to improve water quality based on existing water quality conditions in stream and ability to provide required water quality control	Scores are assigned as follows: 4 - high potential that the proposed treatment will improve the water quality 2 - moderate potential that the treatment will improve the water quality 0 - limited to no potential that the treatment will improve the water quality	0	2	2
Potential Hydrologic Flow Benefit	Ability to reduce the peak flow rate and total flow in the downstream receiving water system	Scores are assigned as follows: 4 – significant potential to reduce the peak flow and total flow downstream 2 – moderate potential to reduce the peak flow and total flow downstream 0 – limited or no potential to reduce the peak flow and total flow downstream	0	2	2
Potential Terrestrial Habitat Benefit	Potential to improve terrestrial habitats based on the existing conditions of the terrestrial ecology	Scores are assigned as follows: 4 - high potential to impact existing terrestrial habitat 2 - moderate potential to impact existing terrestrial habitat 0 - limited to no potential to impact existing terrestrial habitat	NA	NA	NA
		Natural Environment Impacts Subtotal	0	12	12
		Weighted Score for Natural Environment Impact Criteria (maximum of 25 pts)	**0.00**	**15.00**	**15.00**
Socio-Cultural Impacts					
Impact to Aesthetics / Recreation	Potential for retrofit facility to be an asset to the community by integrating facility into activities such as walking, jogging, hiking	Scores are assigned as follows: 4 - high potential to integrate facility into existing activities 2 - moderate potential to integrate facility into existing activities 0 - limited to no potential to integrate facility into existing activities	2	2	2
Compatibility with Adjacent Land Uses	There are potential impacts associated with construction of facilities, particularly with respect to land uses such as residential, old age homes and schools. Access / egress also	Scores are assigned as follows: 4 - no impacts associated with construction and access / egress for operation / maintenance 2 - minor impacts associated with construction and access will be limited 0 - sensitive land uses are located adjacent to proposed facility and access / egress will be limited	4	2	2
Compatibility with Land Ownership	There are potential impacts associated with ownership of the land which could restrict access for construction and maintenance	Scores are assigned as follows: 4 - City owned lands or have easement 2 - most lands are owned by City, but some easrments may be required 0 – lands are privately owned	4	4	4
Community Impact -Disruption to Community During Construction	Potential to impact the community in terms of access to the site, visibility, road access, construction of mitigation measure in valley lands / parks, possible noise / odour / light,	Scores are assigned as follows: 4 – no impact on community 2 – moderate impact on community 0 – significant impact on community	4	2	2
Consistency with municipal, provinical and federal regulation and/or policy	Ability for the alternative to meet the governing, or soon to be implemented standards, regulations and policies.	Scores are assigned as follows: 4 - consistent with all standards/regulations/policies 2 - meets some standards/regulations/policies 0 – not consistent with standards/regulations/policies	0	4	4
		Socio-Cultural Impacts Subtotal	14	14	14
		Weighted Score for Socio-Cultural Impact Criteria (maximum of 25 pts)	**17.5**	**17.5**	**17.5**
Technical Impacts					
Level of Service provided	Anticipated level of treatment based on the size of the drainage area and the land available for the facility	Scores are assigned as follows: 4 – technique expected to be highly effective 2 – technique expected to be moderately effective 0 – technique expected to be least effective	0	4	2
Constructability	Degree of difficulty in constructing the SWM alternative given the existing site conditions and constraints.	Scores are assigned as follows: 4 – technique is easily implementable 2 – there are some obsticles to overcome before implementing techniques 0 – there are many obsticles to overcome before implementing techniques	4	2	0
Maintenance Requirements	Degree of anticipated future effort required to maintain the SWM alternative in good working order.	Scores are assigned as follows: 4 – limited to no maintenace required 2 – moderate amount of maintenance is required 0 – high amounts of maintenance is required	4	2	0
		Technical Impacts Subtotal	8	8	2
		Weighted Score for Technical Impact Criteria (maximum of 25 pts)	**16.67**	**16.67**	**4.17**
Economic Impacts					
Capital Costs	The relative estimated costs of implementing the proposed treatement based on factors such as location, access / egress and area to dispose material	Scores are assigned as follows: 4 - no capital costs 2 - moderate capital cost 0 - highest capital cost	4	2	0
Operation and Maintenance Costs	The relative cost of operating and maintaining the facility based on factors such as location, access / egress and availability of sediment drying area	Scores are assigned as follows: 4 - no operation and maintenance costs 2 - moderate operation and maintenance cost 0 - highest operation and maintenance cost	4	2	0
Imapct to Property Values	Potential impacts (positive or negative) to local property value, based on aesthetic benefits, potential land-use synergies and general economic incentives.	Scores are assigned as follows: 4 - high potential benefit to property values 2 - moderate potential benefit to property values 0 - no potential benefit property values	0	0	0
		Economic Impacts Subtotal	8	4	0
		Weighted Score for Economic Impact Criteria (maximum of 25 pts)	**16.66666667**	**8.333333333**	**0**
		FINAL WEIGHTED SCORE (maximum of 100 pts)	**50.83**	**57.50**	**36.67**

APPENDIX H: Detailed Evaluation for Flood Mitigation Opportunities

Criteria	Description of Criteria	Measures for Assigning Scores
Natural Environment		
Potential Erosion Control Benefit	Potential to reduce erosional forces in receiving stream based on existing condition of stream and ability to provide required erosion control volume	Scores are assigned as follows: 4 - high potential to reduce erosional forces 2 - moderate potential to reduce erosional forces 0 - limited to no potential to reduce erosional forces
Potential Aquatic Habitat Benefit	Potential to improve aquatic habitats or systems, including possible impacts on aquatic life, features and functions	Scores are assigned as follows: 4 - significant improvement to aquatic habitat or systems 2 - moderate improvement to aquatic habitat or systems 0 - no impact to aquatic habitat or systems
Potential Hydrologic Flow Benefit	Ability to reduce the peak flow rate and total flow in the downstream receiving water system	Scores are assigned as follows: 4 – significant potential to reduce the peak flow and total flow downstream 2 – moderate potential to reduce the peak flow and total flow downstream 0 – limited or no potential to reduce the peak flow and total flow downstream
Potential Terrestrial Habitat Benefit	Potential to improve terrestrial habitats based on the existing conditions of the terrestrial ecology	Scores are assigned as follows: 4 - high potential to impact existing terrestrial habitat 2 - moderate potential to impact existing terrestrial habitat 0 - limited to no potential to impact existing terrestrial habitat
Socio-Cultural Impacts		
Impact to Aesthetics / Recreation	Potential for retrofit facility to be an asset to the community by integrating facility into activities such as walking, jogging, hiking	Scores are assigned as follows: 4 - high potential to integrate facility into existing activities 2 - moderate potential to integrate facility into existing activities 0 - limited to no potential to integrate facility into existing activities
Compatibility with Adjacent Land Uses	There are potential impacts associated with construction of facilities, particularly with respect to land uses such as residential, old age homes and schools. Access / egress also	Scores are assigned as follows: 4 - no impacts associated with construction and access / egress for operation / maintenance 2 - minor impacts associated with construction and access will be limited 0 - sensitive land uses are located adjacent to proposed facility and access / egress will be limited
Compatibility with Land Ownership	There are potential impacts associated with ownership of the land which could restrict access for construction and maintenance	Scores are assigned as follows: 4 - City owned lands or have easement 2 - most lands are owned by City, but some easrments may be required 0 – lands are privately owned
Community Impact -Disruption to Community During Construction	Potential to impact the community in terms of access to the site, visibility, road access, construction of mitigation measure in valley lands / parks, possible noise / odour / light,	Scores are assigned as follows: 4 – no impact on community 2 – moderate impact on community 0 – significant impact on community
Technical Impacts		
Potential to Reduce Flood Limits	Ability to reduce flood limits by lowering the water surface elevation during flood events.	Scores are assigned as follows: 4 - significant reduction in flood limits 2 - potential reduction to flood limits 0 - no change in flood limits
Potential to Reduce Flood Risk	Ability to remove buildings from flood limits and decrease the frequency of road inundation.	Scores are assigned as follows: 4 - significant reduction to flood risks 2 - potential reduction to flood risks 0 - no change in flooding risk
Feasibility of Control Measure	The extent to whichg the alternative is feasible in terms of available sapce and accessibility	Scores are assigned as follows: 4 – there are no space and access constraints 2 – there are some space and access constraints 0 – space and access constraints could restrict the implementation of the alternative
Constructability	Degree of difficulty in constructing the SWM alternative given the existing site conditions and constraints.	Scores are assigned as follows: 4 – technique is easily implementable 2 – there are some obsticles to overcome before implementing techniques 0 – there are many obsticles to overcome before implementing techniques
Economic Impacts		
Capital Costs	The relative estimated costs of implementing the proposed treatement based on factors such as location, access / egress and area to dispose material	Scores are assigned as follows: 4 - no capital costs 2 - moderate capital cost 0 - highest capital cost
Operation and Maintenance Costs	The relative cost of operating and maintaining the facility based on factors such as location, access / egress and availability of sediment drying area	Scores are assigned as follows: 4 - no operation and maintenance costs 2 - moderate operation and maintenance cost 0 - highest operation and maintenance cost
Imapct to Property Values	Potential impacts (positive or negative) to local property value, based on aesthetic benefits, potential land-use synergies and general economic incentives.	Scores are assigned as follows: 4 - high potential benefit to property values 2 - moderate potential benefit to property values 0 - no potential benefit property values

FRA1 0

Criteria	Description of Criteria	Measures for Assigning Scores	Alternative 1 Do Nothing	Alternative 2 Structural Measures	Alternative 3 Preventative Programs	Alternative 4 Emergency Strategies	Alternative 5 Channel Modifications
Natural Environment							
Potential Erosion Control Benefit	Potential to reduce erosional forces in receiving stream based on existing condition of stream and ability to provide required erosion control volume	Scores are assigned as follows: 4 - high potential to reduce erosional forces 2 - moderate potential to reduce erosional forces 0 - limited to no potential to reduce erosional forces	0	NA	4	0	2
Potential Aquatic Habitat Benefit	Potential to improve aquatic habitats or systems, including possible impacts on aquatic life, features and functions	Scores are assigned as follows: 4 - significant improvement to aquatic habitat or systems 2 - moderate improvement to aquatic habitat or systems 0 - no impact to aquatic habitat or systems	0	NA	4	0	2
Potential Hydrologic Flow Benefit	Ability to reduce the peak flow rate and total flow in the downstream receiving water system	Scores are assigned as follows: 4 – significant potential to reduce the peak flow and total flow downstream 2 – moderate potential to reduce the peak flow and total flow downstream 0 – limited or no potential to reduce the peak flow and total flow downstream	0	NA	4	0	2
Potential Terrestrial Habitat Benefit	Potential to improve terrestrial habitats based on the existing conditions of the terrestrial ecology	Scores are assigned as follows: 4 - high potential to impact existing terrestrial habitat 2 - moderate potential to impact existing terrestrial habitat 0 - limited to no potential to impact existing terrestrial habitat	0	NA	0	0	2
		Natural Environment Impacts Subtotal	0	0	12	0	8
		Weighted Score for Natural Environment Impact Criteria (maximum of 20 pts)	**0.00**	**#DIV/0!**	**15.00**	**0.00**	**10.00**
Socio-Cultural Impacts							
Impact to Aesthetics / Recreation	Potential for retrofit facility to be an asset to the community by integrating facility into activities such as walking, jogging, hiking	Scores are assigned as follows: 4 - high potential to integrate facility into existing activities 2 - moderate potential to integrate facility into existing activities 0 - limited to no potential to integrate facility into existing activities	4	NA	2	2	4
Compatibility with Adjacent Land Uses	There are potential impacts associated with construction of facilities, particularly with respect to land uses such as residential, old age homes and schools. Access / egress also	Scores are assigned as follows: 4 - no impacts associated with construction and access / egress for operation / maintenance 2 - minor impacts associated with construction and access will be limited 0 - sensitive land uses are located adjacent to proposed facility and access / egress will be limited	4	NA	4	2	2
Compatibility with Land Ownership	There are potential impacts associated with ownership of the land which could restrict access for construction and maintenance	Scores are assigned as follows: 4 - City owned lands or have easement 2 - most lands are owned by City, but some easrments may be required 0 – lands are privately owned	4	NA	2	0	2
Community Impact -Disruption to Community During Construction	Potential to impact the community in terms of access to the site, visibility, road access, construction of mitigation measure in valley lands / parks, possible noise / odour / light,	Scores are assigned as follows: 4 – no impact on community 2 – moderate impact on community 0 – significant impact on community	4	NA	4	2	2
		Socio-Cultural Impacts Subtotal	16	0	12	6	10
		Weighted Score for Socio-Cultural Impact Criteria (maximum of 20 pts)	**20**	**#DIV/0!**	**15**	**7.5**	**12.5**
Technical Impacts							
Potential to Reduce Flood Limits	Ability to reduce flood limits by lowering the water surface elevation during flood events.	Scores are assigned as follows: 4 - significant reduction in flood limits 2 - potential reduction to flood limits 0 - no change in flood limits	0	NA	2	0	2
Potential to Reduce Flood Risk	Ability to remove buildings from flood limits and decrease the frequency of road inundation.	Scores are assigned as follows: 4 - significant reduction to flood risks 2 - potential reduction to flood risks 0 - no change in flooding risk	0	NA	2	4	2
Feasibility of Control Measure	The extent to whichg the alternative is feasible in terms of available sapce and accessibility	Scores are assigned as follows: 4 – there are no space and access constraints 2 – there are some space and access constraints 0 – space and access constraints could restrict the implementation of the alternative	4	NA	4	0	2
Constructability	Degree of difficulty in constructing the SWM alternative given the existing site conditions and constraints.	Scores are assigned as follows: 4 – technique is easily implementable 2 – there are some obsticles to overcome before implementing techniques 0 – there are many obsticles to overcome before implementing techniques	4	NA	2	2	2
		Technical Impacts Subtotal	8	0	10	6	8
		Weighted Score for Technical Impact Criteria (maximum of 40 pts)	**20.00**	**#DIV/0!**	**25.00**	**15.00**	**20.00**
Economic Impacts							
Capital Costs	The relative estimated costs of implementing the proposed treatement based on factors such as location, access / egress and area to dispose material	Scores are assigned as follows: 4 - no capital costs 2 - moderate capital cost 0 - highest capital cost	4	NA	2	2	2
Operation and Maintenance Costs	The relative cost of operating and maintaining the facility based on factors such as location, access / egress and availability of sediment drying area	Scores are assigned as follows: 4 - no operation and maintenance costs 2 - moderate operation and maintenance cost 0 - highest operation and maintenance cost	4	NA	0	4	2
Imapct to Property Values	Potential impacts (positive or negative) to local property value, based on aesthetic benefits, potential land-use synergies and general economic incentives.	Scores are assigned as follows: 4 - high potential benefit to property values 2 - moderate potential benefit to property values 0 - no potential benefit property values	0	NA	2	4	2
		Economic Impacts Subtotal	8	0	4	10	6
		Weighted Score for Economic Impact Criteria (maximum of 20 pts)	**13.33333333**	**#DIV/0!**	**6.666666667**	**16.66666667**	**10**
		FINAL WEIGHTED SCORE (maximum of 100 pts)	**53.33**	**#DIV/0!**	**61.67**	**39.17**	**52.50**

FRA2 0

Criteria	Description of Criteria	Measures for Assigning Scores	Alternative 1 Do Nothing	Alternative 2 Structural Measures	Alternative 3 Preventative Programs	Alternative 4 Emergency Strategies	Alternative 5 Channel Modifications
Natural Environment							
Potential Erosion Control Benefit	Potential to reduce erosional forces in receiving stream based on existing condition of stream and ability to provide required erosion control volume	Scores are assigned as follows: 4 - high potential to reduce erosional forces 2 - moderate potential to reduce erosional forces 0 - limited to no potential to reduce erosional forces	0	2	4	0	2
Potential Aquatic Habitat Benefit	Potential to improve aquatic habitats or systems, including possible impacts on aquatic life, features and functions	Scores are assigned as follows: 4 - significant improvement to aquatic habitat or systems 2 - moderate improvement to aquatic habitat or systems 0 - no impact to aquatic habitat or systems	0	2	4	0	0
Potential Hydrologic Flow Benefit	Ability to reduce the peak flow rate and total flow in the downstream receiving water system	Scores are assigned as follows: 4 – significant potential to reduce the peak flow and total flow downstream 2 – moderate potential to reduce the peak flow and total flow downstream 0 – limited or no potential to reduce the peak flow and total flow downstream	0	0	4	0	2
Potential Terrestrial Habitat Benefit	Potential to improve terrestrial habitats based on the existing conditions of the terrestrial ecology	Scores are assigned as follows: 4 - high potential to impact existing terrestrial habitat 2 - moderate potential to impact existing terrestrial habitat 0 - limited to no potential to impact existing terrestrial habitat	0	0	0	0	2
		Natural Environment Impacts Subtotal	0	4	12	0	6
		Weighted Score for Natural Environment Impact Criteria (maximum of 20 pts)	**0.00**	**5.00**	**15.00**	**0.00**	**7.50**
Socio-Cultural Impacts							
Impact to Aesthetics / Recreation	Potential for retrofit facility to be an asset to the community by integrating facility into activities such as walking, jogging, hiking	Scores are assigned as follows: 4 - high potential to integrate facility into existing activities 2 - moderate potential to integrate facility into existing activities 0 - limited to no potential to integrate facility into existing activities	4	4	2	2	4
Compatibility with Adjacent Land Uses	There are potential impacts associated with construction of facilities, particularly with respect to land uses such as residential, old age homes and schools. Access / egress also	Scores are assigned as follows: 4 - no impacts associated with construction and access / egress for operation / maintenance 2 - minor impacts associated with construction and access will be limited 0 - sensitive land uses are located adjacent to proposed facility and access / egress will be limited	4	4	4	2	4
Compatibility with Land Ownership	There are potential impacts associated with ownership of the land which could restrict access for construction and maintenance	Scores are assigned as follows: 4 - City owned lands or have easement 2 - most lands are owned by City, but some easrments may be required 0 – lands are privately owned	4	4	2	2	2
Community Impact -Disruption to Community During Construction	Potential to impact the community in terms of access to the site, visibility, road access, construction of mitigation measure in valley lands / parks, possible noise / odour / light,	Scores are assigned as follows: 4 – no impact on community 2 – moderate impact on community 0 – significant impact on community	4	0	4	2	2
		Socio-Cultural Impacts Subtotal	16	12	12	8	12
		Weighted Score for Socio-Cultural Impact Criteria (maximum of 20 pts)	**20**	**15**	**15**	**10**	**15**
Technical Impacts							
Potential to Reduce Flood Limits	Ability to reduce flood limits by lowering the water surface elevation during flood events.	Scores are assigned as follows: 4 - significant reduction in flood limits 2 - potential reduction to flood limits 0 - no change in flood limits	0	4	2	0	2
Potential to Reduce Flood Risk	Ability to remove buildings from flood limits and decrease the frequency of road inundation.	Scores are assigned as follows: 4 - significant reduction to flood risks 2 - potential reduction to flood risks 0 - no change in flooding risk	0	2	2	4	2
Feasibility of Control Measure	The extent to which the alternative is feasible in terms of available sapce and accessibility	Scores are assigned as follows: 4 – there are no space and access constraints 2 – there are some space and access constraints 0 – space and access constraints could restrict the implementation of the alternative	4	4	4	0	2
Constructability	Degree of difficulty in constructing the SWM alternative given the existing site conditions and constraints.	Scores are assigned as follows: 4 – technique is easily implementable 2 – there are some obsticles to overcome before implementing techniques 0 – there are many obsticles to overcome before implementing techniques	4	2	2	0	2
		Technical Impacts Subtotal	8	12	10	4	8
		Weighted Score for Technical Impact Criteria (maximum of 40 pts)	**20.00**	**30.00**	**25.00**	**10.00**	**20.00**
Economic Impacts							
Capital Costs	The relative estimated costs of implementing the proposed treatement based on factors such as location, access / egress and area to dispose material	Scores are assigned as follows: 4 - no capital costs 2 - moderate capital cost 0 - highest capital cost	4	0	2	2	2
Operation and Maintenance Costs	The relative cost of operating and maintaining the facility based on factors such as location, access / egress and availability of sediment drying area	Scores are assigned as follows: 4 - no operation and maintenance costs 2 - moderate operation and maintenance cost 0 - highest operation and maintenance cost	4	2	0	4	2
Imapct to Property Values	Potential impacts (positive or negative) to local property value, based on aesthetic benefits, potential land-use synergies and general economic incentives.	Scores are assigned as follows: 4 - high potential benefit to property values 2 - moderate potential benefit to property values 0 - no potential benefit property values	0	2	2	4	2
		Economic Impacts Subtotal	8	4	4	10	6
		Weighted Score for Economic Impact Criteria (maximum of 20 pts)	**13.33333333**	**6.666666667**	**6.666666667**	**16.66666667**	**10**
		FINAL WEIGHTED SCORE (maximum of 100 pts)	**53.33**	**56.67**	**61.67**	**36.67**	**52.50**

FRA3 0

Criteria	Description of Criteria	Measures for Assigning Scores	Alternative 1 Do Nothing	Alternative 2 Structural Measures	Alternative 3 Preventative Programs	Alternative 4 Emergency Strategies	Alternative 5 Channel Modifications
Natural Environment							
Potential Erosion Control Benefit	Potential to reduce erosional forces in receiving stream based on existing condition of stream and ability to provide required erosion control volume	Scores are assigned as follows: 4 - high potential to reduce erosional forces 2 - moderate potential to reduce erosional forces 0 - limited to no potential to reduce erosional forces	0	2	4	0	2
Potential Aquatic Habitat Benefit	Potential to improve aquatic habitats or systems, including possible impacts on aquatic life, features and functions	Scores are assigned as follows: 4 - significant improvement to aquatic habitat or systems 2 - moderate improvement to aquatic habitat or systems 0 - no impact to aquatic habitat or systems	0	2	4	0	2
Potential Hydrologic Flow Benefit	Ability to reduce the peak flow rate and total flow in the downstream receiving water system	Scores are assigned as follows: 4 – significant potential to reduce the peak flow and total flow downstream 2 – moderate potential to reduce the peak flow and total flow downstream 0 – limited or no potential to reduce the peak flow and total flow downstream	0	0	4	0	2
Potential Terrestrial Habitat Benefit	Potential to improve terrestrial habitats based on the existing conditions of the terrestrial ecology	Scores are assigned as follows: 4 - high potential to impact existing terrestrial habitat 2 - moderate potential to impact existing terrestrial habitat 0 - limited to no potential to impact existing terrestrial habitat	0	0	0	0	2
		Natural Environment Impacts Subtotal	0	4	12	0	8
		Weighted Score for Natural Environment Impact Criteria (maximum of 20 pts)	**0.00**	**5.00**	**15.00**	**0.00**	**10.00**
Socio-Cultural Impacts							
Impact to Aesthetics / Recreation	Potential for retrofit facility to be an asset to the community by integrating facility into activities such as walking, jogging, hiking	Scores are assigned as follows: 4 - high potential to integrate facility into existing activities 2 - moderate potential to integrate facility into existing activities 0 - limited to no potential to integrate facility into existing activities	4	0	2	2	4
Compatibility with Adjacent Land Uses	There are potential impacts associated with construction of facilities, particularly with respect to land uses such as residential, old age homes and schools. Access / egress also	Scores are assigned as follows: 4 - no impacts associated with construction and access / egress for operation / maintenance 2 - minor impacts associated with construction and access will be limited 0 - sensitive land uses are located adjacent to proposed facility and access / egress will be limited	4	0	4	4	2
Compatibility with Land Ownership	There are potential impacts associated with ownership of the land which could restrict access for construction and maintenance	Scores are assigned as follows: 4 - City owned lands or have easement 2 - most lands are owned by City, but some easrments may be required 0 – lands are privately owned	4	0	2	2	2
Community Impact -Disruption to Community During Construction	Potential to impact the community in terms of access to the site, visibility, road access, construction of mitigation measure in valley lands / parks, possible noise / odour / light,	Scores are assigned as follows: 4 – no impact on community 2 – moderate impact on community 0 – significant impact on community	4	0	4	2	2
		Socio-Cultural Impacts Subtotal	16	0	12	10	10
		Weighted Score for Socio-Cultural Impact Criteria (maximum of 20 pts)	**20**	**0**	**15**	**12.5**	**12.5**
Technical Impacts							
Potential to Reduce Flood Limits	Ability to reduce flood limits by lowering the water surface elevation during flood events.	Scores are assigned as follows: 4 - significant reduction in flood limits 2 - potential reduction to flood limits 0 - no change in flood limits	0	4	2	0	2
Potential to Reduce Flood Risk	Ability to remove buildings from flood limits and decrease the frequency of road inundation.	Scores are assigned as follows: 4 - significant reduction to flood risks 2 - potential reduction to flood risks 0 - no change in flooding risk	0	4	2	4	2
Feasibility of Control Measure	The extent to which the alternative is feasible in terms of available sapce and accessibility	Scores are assigned as follows: 4 – there are no space and access constraints 2 – there are some space and access constraints 0 – space and access constraints could restrict the implementation of the alternative	4	0	4	4	2
Constructability	Degree of difficulty in constructing the SWM alternative given the existing site conditions and constraints.	Scores are assigned as follows: 4 – technique is easily implementable 2 – there are some obsticles to overcome before implementing techniques 0 – there are many obsticles to overcome before implementing techniques	4	0	2	2	2
		Technical Impacts Subtotal	8	8	10	10	8
		Weighted Score for Technical Impact Criteria (maximum of 40 pts)	**20.00**	**20.00**	**25.00**	**25.00**	**20.00**
Economic Impacts							
Capital Costs	The relative estimated costs of implementing the proposed treatement based on factors such as location, access / egress and area to dispose material	Scores are assigned as follows: 4 - no capital costs 2 - moderate capital cost 0 - highest capital cost	4	0	2	2	2
Operation and Maintenance Costs	The relative cost of operating and maintaining the facility based on factors such as location, access / egress and availability of sediment drying area	Scores are assigned as follows: 4 - no operation and maintenance costs 2 - moderate operation and maintenance cost 0 - highest operation and maintenance cost	4	2	0	4	2
Imapct to Property Values	Potential impacts (positive or negative) to local property value, based on aesthetic benefits, potential land-use synergies and general economic incentives.	Scores are assigned as follows: 4 - high potential benefit to property values 2 - moderate potential benefit to property values 0 - no potential benefit property values	0	0	2	4	2
		Economic Impacts Subtotal	8	2	4	10	6
		Weighted Score for Economic Impact Criteria (maximum of 20 pts)	**13.33333333**	**3.333333333**	**6.666666667**	**16.66666667**	**10**
		FINAL WEIGHTED SCORE (maximum of 100 pts)	**53.33**	**28.33**	**61.67**	**54.17**	**52.50**

FRA4

0

Criteria	Description of Criteria	Measures for Assigning Scores	Alternative 1 Do Nothing	Alternative 2 Structural Measures	Alternative 3 Preventative Programs	Alternative 4 Emergency Strategies	Alternative 5 Channel Modifications
Natural Environment							
Potential Erosion Control Benefit	Potential to reduce erosional forces in receiving stream based on existing condition of stream and ability to provide required erosion control volume	Scores are assigned as follows: 4 - high potential to reduce erosional forces 2 - moderate potential to reduce erosional forces 0 - limited to no potential to reduce erosional forces	0	2	4	0	2
Potential Aquatic Habitat Benefit	Potential to improve aquatic habitats or systems, including possible impacts on aquatic life, features and functions	Scores are assigned as follows: 4 - significant improvement to aquatic habitat or systems 2 - moderate improvement to aquatic habitat or systems 0 - no impact to aquatic habitat or systems	0	2	4	0	2
Potential Hydrologic Flow Benefit	Ability to reduce the peak flow rate and total flow in the downstream receiving water system	Scores are assigned as follows: 4 – significant potential to reduce the peak flow and total flow downstream 2 – moderate potential to reduce the peak flow and total flow downstream 0 – limited or no potential to reduce the peak flow and total flow downstream	0	0	4	0	2
Potential Terrestrial Habitat Benefit	Potential to improve terrestrial habitats based on the existing conditions of the terrestrial ecology	Scores are assigned as follows: 4 - high potential to impact existing terrestrial habitat 2 - moderate potential to impact existing terrestrial habitat 0 - limited to no potential to impact existing terrestrial habitat	0	0	0	0	2
		Natural Environment Impacts Subtotal	0	4	12	0	8
		Weighted Score for Natural Environment Impact Criteria (maximum of 20 pts)	**0.00**	**5.00**	**15.00**	**0.00**	**10.00**
Socio-Cultural Impacts							
Impact to Aesthetics / Recreation	Potential for retrofit facility to be an asset to the community by integrating facility into activities such as walking, jogging, hiking	Scores are assigned as follows: 4 - high potential to integrate facility into existing activities 2 - moderate potential to integrate facility into existing activities 0 - limited to no potential to integrate facility into existing activities	4	4	2	0	4
Compatibility with Adjacent Land Uses	There are potential impacts associated with construction of facilities, particularly with respect to land uses such as residential, old age homes and schools. Access / egress also	Scores are assigned as follows: 4 - no impacts associated with construction and access / egress for operation / maintenance 2 - minor impacts associated with construction and access will be limited 0 - sensitive land uses are located adjacent to proposed facility and access / egress will be limited	4	4	4	0	0
Compatibility with Land Ownership	There are potential impacts associated with ownership of the land which could restrict access for construction and maintenance	Scores are assigned as follows: 4 - City owned lands or have easement 2 - most lands are owned by City, but some easrments may be required 0 – lands are privately owned	4	4	2	0	2
Community Impact -Disruption to Community During Construction	Potential to impact the community in terms of access to the site, visibility, road access, construction of mitigation measure in valley lands / parks, possible noise / odour / light,	Scores are assigned as follows: 4 – no impact on community 2 – moderate impact on community 0 – significant impact on community	4	2	4	0	0
		Socio-Cultural Impacts Subtotal	16	14	12	0	6
		Weighted Score for Socio-Cultural Impact Criteria (maximum of 20 pts)	**20**	**17.5**	**15**	**0**	**7.5**
Technical Impacts							
Potential to Reduce Flood Limits	Ability to reduce flood limits by lowering the water surface elevation during flood events.	Scores are assigned as follows: 4 - significant reduction in flood limits 2 - potential reduction to flood limits 0 - no change in flood limits	0	4	2	0	2
Potential to Reduce Flood Risk	Ability to remove buildings from flood limits and decrease the frequency of road inundation.	Scores are assigned as follows: 4 - significant reduction to flood risks 2 - potential reduction to flood risks 0 - no change in flooding risk	0	2	2	4	2
Feasibility of Control Measure	The extent to whichg the alternative is feasible in terms of available sapce and accessibility	Scores are assigned as follows: 4 – there are no space and access constraints 2 – there are some space and access constraints 0 – space and access constraints could restrict the implementation of the alternative	4	4	4	0	2
Constructability	Degree of difficulty in constructing the SWM alternative given the existing site conditions and constraints.	Scores are assigned as follows: 4 – technique is easily implementable 2 – there are some obsticles to overcome before implementing techniques 0 – there are many obsticles to overcome before implementing techniques	4	2	2	2	2
		Technical Impacts Subtotal	8	12	10	6	8
		Weighted Score for Technical Impact Criteria (maximum of 40 pts)	**20.00**	**30.00**	**25.00**	**15.00**	**20.00**
Economic Impacts							
Capital Costs	The relative estimated costs of implementing the proposed treatement based on factors such as location, access / egress and area to dispose material	Scores are assigned as follows: 4 - no capital costs 2 - moderate capital cost 0 - highest capital cost	4	0	2	2	2
Operation and Maintenance Costs	The relative cost of operating and maintaining the facility based on factors such as location, access / egress and availability of sediment drying area	Scores are assigned as follows: 4 - no operation and maintenance costs 2 - moderate operation and maintenance cost 0 - highest operation and maintenance cost	4	2	0	4	2
Imapct to Property Values	Potential impacts (positive or negative) to local property value, based on aesthetic benefits, potential land-use synergies and general economic incentives.	Scores are assigned as follows: 4 - high potential benefit to property values 2 - moderate potential benefit to property values 0 - no potential benefit property values	0	2	2	4	2
		Economic Impacts Subtotal	8	4	4	10	6
		Weighted Score for Economic Impact Criteria (maximum of 20 pts)	**13.33333333**	**6.666666667**	**6.666666667**	**16.66666667**	**10**
		FINAL WEIGHTED SCORE (maximum of 100 pts)	**53.33**	**59.17**	**61.67**	**31.67**	**47.50**

FRA5 0

Criteria	Description of Criteria	Measures for Assigning Scores	Alternative 1 Do Nothing	Alternative 2 Structural Measures	Alternative 3 Preventative Programs	Alternative 4 Emergency Strategies	Alternative 5 Channel Modifications
Natural Environment							
Potential Erosion Control Benefit	Potential to reduce erosional forces in receiving stream based on existing condition of stream and ability to provide required erosion control volume	Scores are assigned as follows: 4 - high potential to reduce erosional forces 2 - moderate potential to reduce erosional forces 0 - limited to no potential to reduce erosional forces	0	2	4	0	2
Potential Aquatic Habitat Benefit	Potential to improve aquatic habitats or systems, including possible impacts on aquatic life, features and functions	Scores are assigned as follows: 4 - significant improvement to aquatic habitat or systems 2 - moderate improvement to aquatic habitat or systems 0 - no impact to aquatic habitat or systems	0	2	4	0	2
Potential Hydrologic Flow Benefit	Ability to reduce the peak flow rate and total flow in the downstream receiving water system	Scores are assigned as follows: 4 – significant potential to reduce the peak flow and total flow downstream 2 – moderate potential to reduce the peak flow and total flow downstream 0 – limited or no potential to reduce the peak flow and total flow downstream	0	0	4	0	2
Potential Terrestrial Habitat Benefit	Potential to improve terrestrial habitats based on the existing conditions of the terrestrial ecology	Scores are assigned as follows: 4 - high potential to impact existing terrestrial habitat 2 - moderate potential to impact existing terrestrial habitat 0 - limited to no potential to impact existing terrestrial habitat	0	0	0	0	2
		Natural Environment Impacts Subtotal	0	4	12	0	8
		Weighted Score for Natural Environment Impact Criteria (maximum of 20 pts)	**0.00**	**5.00**	**15.00**	**0.00**	**10.00**
Socio-Cultural Impacts							
Impact to Aesthetics / Recreation	Potential for retrofit facility to be an asset to the community by integrating facility into activities such as walking, jogging, hiking	Scores are assigned as follows: 4 - high potential to integrate facility into existing activities 2 - moderate potential to integrate facility into existing activities 0 - limited to no potential to integrate facility into existing activities	4	4	2	2	4
Compatibility with Adjacent Land Uses	There are potential impacts associated with construction of facilities, particularly with respect to land uses such as residential, old age homes and schools. Access / egress also	Scores are assigned as follows: 4 - no impacts associated with construction and access / egress for operation / maintenance 2 - minor impacts associated with construction and access will be limited 0 - sensitive land uses are located adjacent to proposed facility and access / egress will be limited	4	4	4	4	2
Compatibility with Land Ownership	There are potential impacts associated with ownership of the land which could restrict access for construction and maintenance	Scores are assigned as follows: 4 - City owned lands or have easement 2 - most lands are owned by City, but some easrments may be required 0 – lands are privately owned	4	4	2	2	2
Community Impact -Disruption to Community During Construction	Potential to impact the community in terms of access to the site, visibility, road access, construction of mitigation measure in valley lands / parks, possible noise / odour / light,	Scores are assigned as follows: 4 – no impact on community 2 – moderate impact on community 0 – significant impact on community	4	2	4	2	2
		Socio-Cultural Impacts Subtotal	16	14	12	10	10
		Weighted Score for Socio-Cultural Impact Criteria (maximum of 20 pts)	**20**	**17.5**	**15**	**12.5**	**12.5**
Technical Impacts							
Potential to Reduce Flood Limits	Ability to reduce flood limits by lowering the water surface elevation during flood events.	Scores are assigned as follows: 4 - significant reduction in flood limits 2 - potential reduction to flood limits 0 - no change in flood limits	0	4	2	0	2
Potential to Reduce Flood Risk	Ability to remove buildings from flood limits and decrease the frequency of road inundation.	Scores are assigned as follows: 4 - significant reduction to flood risks 2 - potential reduction to flood risks 0 - no change in flooding risk	0	2	2	4	2
Feasibility of Control Measure	The extent to whichg the alternative is feasible in terms of available sapce and accessibility	Scores are assigned as follows: 4 – there are no space and access constraints 2 – there are some space and access constraints 0 – space and access constraints could restrict the implementation of the alternative	4	4	4	4	2
Constructability	Degree of difficulty in constructing the SWM alternative given the existing site conditions and constraints.	Scores are assigned as follows: 4 – technique is easily implementable 2 – there are some obsticles to overcome before implementing techniques 0 – there are many obsticles to overcome before implementing techniques	4	2	2	2	2
		Technical Impacts Subtotal	8	12	10	10	8
		Weighted Score for Technical Impact Criteria (maximum of 40 pts)	**20.00**	**30.00**	**25.00**	**25.00**	**20.00**
Economic Impacts							
Capital Costs	The relative estimated costs of implementing the proposed treatement based on factors such as location, access / egress and area to dispose material	Scores are assigned as follows: 4 - no capital costs 2 - moderate capital cost 0 - highest capital cost	4	0	2	2	2
Operation and Maintenance Costs	The relative cost of operating and maintaining the facility based on factors such as location, access / egress and availability of sediment drying area	Scores are assigned as follows: 4 - no operation and maintenance costs 2 - moderate operation and maintenance cost 0 - highest operation and maintenance cost	4	2	0	4	2
Imapct to Property Values	Potential impacts (positive or negative) to local property value, based on aesthetic benefits, potential land-use synergies and general economic incentives.	Scores are assigned as follows: 4 - high potential benefit to property values 2 - moderate potential benefit to property values 0 - no potential benefit property values	0	2	2	4	2
		Economic Impacts Subtotal	8	4	4	10	6
		Weighted Score for Economic Impact Criteria (maximum of 20 pts)	**13.33333333**	**6.666666667**	**6.666666667**	**16.66666667**	**10**
		FINAL WEIGHTED SCORE (maximum of 100 pts)	**53.33**	**59.17**	**61.67**	**54.17**	**52.50**

APPENDIX I: Impacts of Development on Annual Water Balance

PRMS Hydrologic Model of the Ramsey Lake Watershed Sudbury, Ontario

Prepared for:

Aquafor Beech Limited.

2600 Skymark Avenue
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Prepared by:

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3363 Yonge Street
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January, 2020

Earthfx Incorporated
Earth Science Information Systems

Wednesday, January 29, 2020

D. E. Maunder, M.Sc., P.Eng.
Principal/ President, Aquafor Beech Ltd.
Aquafor Beech Limited
2600 Skymark Avenue
Bldg 6, Suite 202
Mississauga, Ontario

RE: PRMS Hydrologic Model of the Ramsey Lake Watershed, Sudbury, Ontario

Dear Sir:

We are pleased to provide a final copy of our report documenting the assessment of the Water Budget of the Ramsey Lake watershed.

Should you have any questions regarding this report, please feel free to contact us.

Yours truly,
Earthfx Incorporated

Dirk Kassenaar, M.Sc., P.Eng.
President, Senior Hydrogeologist

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PRMS Hydrologic Model of the Ramsey Lake Watershed, Sudbury, Ontario

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1 PRMS Hydrologic Water Budget Model

1.1 Model Overview

A hydrologic model based on the U.S. Geological Survey (USGS) Precipitation-Runoff Modelling System (PRMS) was developed to estimate the water budget for the Ramsey Lake watershed study area. PRMS is an open-source code for calculating all components of the hydrologic cycle at the watershed, subwatershed, or cell-based scale. PRMS is a modular, deterministic, physically-based, fully-distributed model developed to evaluate the impacts of various combinations of precipitation, climate, topography, soil type, and land use on streamflow and groundwater recharge. The PRMS code is well documented in Leavesley *et al.* (1983).

To use PRMS, the study area is first discretized into a grid of cells. Each cell is assigned representative values to characterize slope, slope aspect, elevation, vegetation type, soil type, land use, and surficial geology; such that every cell within the model domain has a **unique set of properties**. The processes that occur within and between each cell are shown in the flow chart presented in Figure 1. Detailed descriptions of the program code and underlying theory can be found in Leavesley *et al.* (1983).

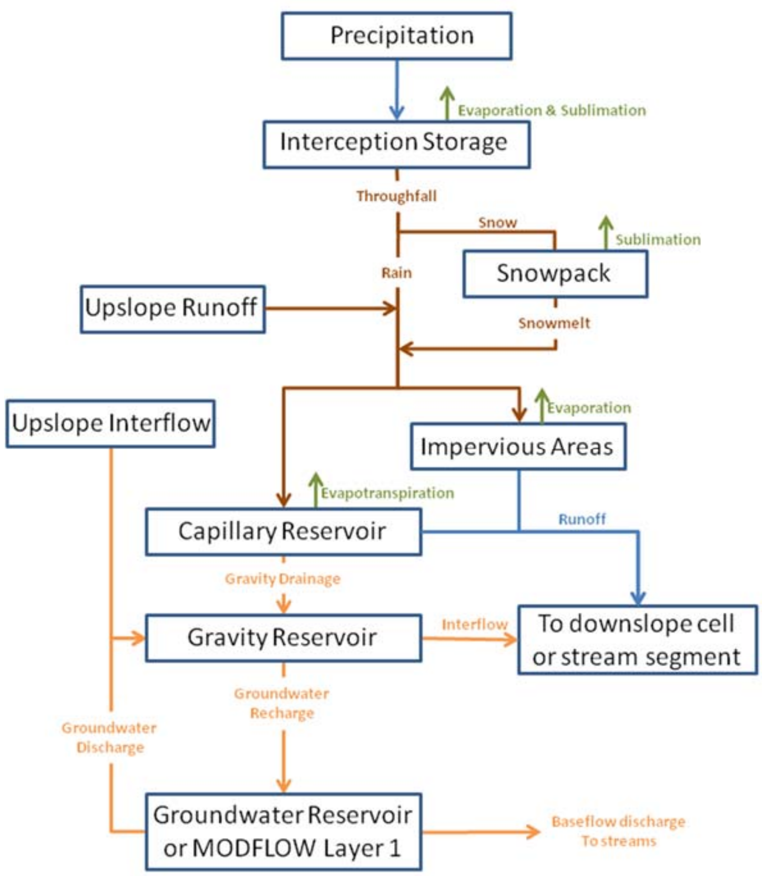

Figure 1: PRMS Flow Chart **for each cell** in the model. Water enters the cell as precipitation, runoff and interflow from upslope cells. Water exits the cell as groundwater recharge, runoff and interflow to downslope cells.

1.2 Objectives

The objective of this task is to estimate the various components of the water budget so as to protect and preserve both water quantity and water quality in the watershed. The objectives include the development of a spatially distributed model to as to determine how local land use changes will affect the water budget both locally, at the feature level, and on a watershed scale.

1.3 Background

Previous water budget analysis in the watershed includes the Source Water Protection Tier 2 and Tier 3 studies (Golder, 2009 and Golder, 2011). The focus of those studies was the assessment of the sustainability of the water supply, particularly under drought conditions. New lake level monitoring data collected since those studies were completed provides important additional information, and the focus of this study is more broadly watershed management.

1.4 Model Area and Cell Resolution

Square cells, 30 m on a side, were selected to represent the distribution of land use, topography and soil properties within the study area (Figure 2). The active model area includes a total of 46448 cells active cells.

1.5 Model Process Description

In brief, the PRMS model tracks volumes of water in a number of storage reservoirs represented within each unique cell. These reservoirs include interception storage, depression storage, snowpack storage, capillary zone (water below field capacity) soil moisture, gravity zone (above field capacity) soil moisture, and groundwater storage. In addition, a two-layer energy-balance model of the snowpack computes snowpack depth, density, albedo, temperature, sublimation, and snowmelt using maximum and minimum air temperature, solar radiation, and precipitation data.

1.5.1 Climate Processes

Daily climate data (i.e., rainfall, snowfall, and minimum and maximum temperature) are assigned to each cell using data interpolated from nearby climate stations using an inverse-distance-squared weighting scheme. Daily solar radiation values, where available, are interpolated from nearby stations, are assigned to each cell after the model adjusts for cell slope and aspect. Water and energy balances are computed on a daily time step for every cell. The routing of water between cells (i.e., overland flow and interflow) is defined by a cascade flow network based on basin topography (Figure 3). The cascade directs outflows from each upslope cell as run-on to downslope cells or as discharge to a stream segment.

The snowpack energy balance model is used to determine the amount of snowmelt on pervious and impervious areas on a sub-daily basis to account for differences in the night and day energy flux. The snowpack is treated as a porous medium, where liquid water can be stored and potentially re-freeze. The energy-balance snowpack model is combined with an aerial snow-depletion curve to simulate the sub-cell spatial coverage of the snowpack during the snowmelt phase at shallow snowpack depths (DeWalle and Rango, 2008).

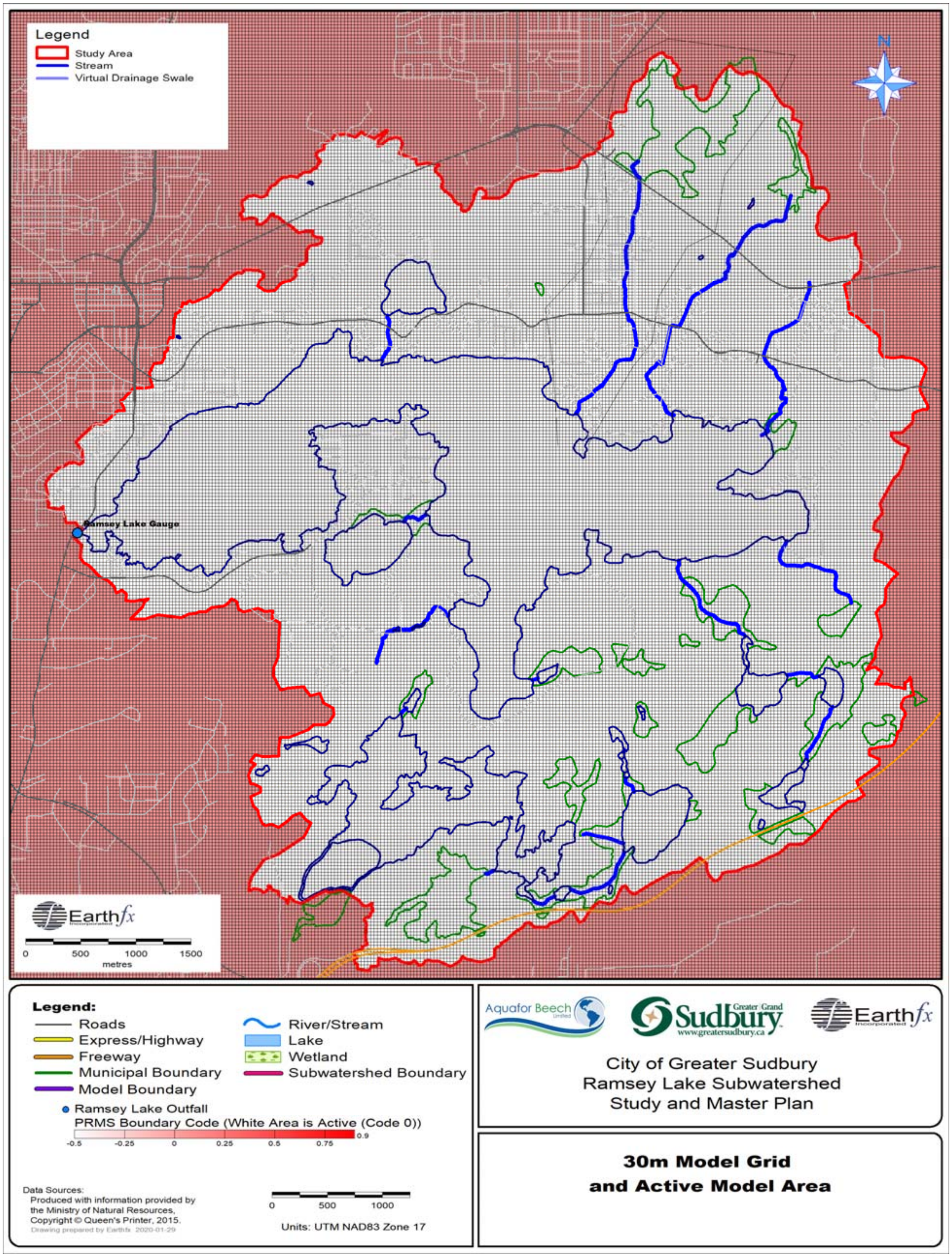

Figure 2: PRMS 30m Model Code Grid (Active Model Study Area)

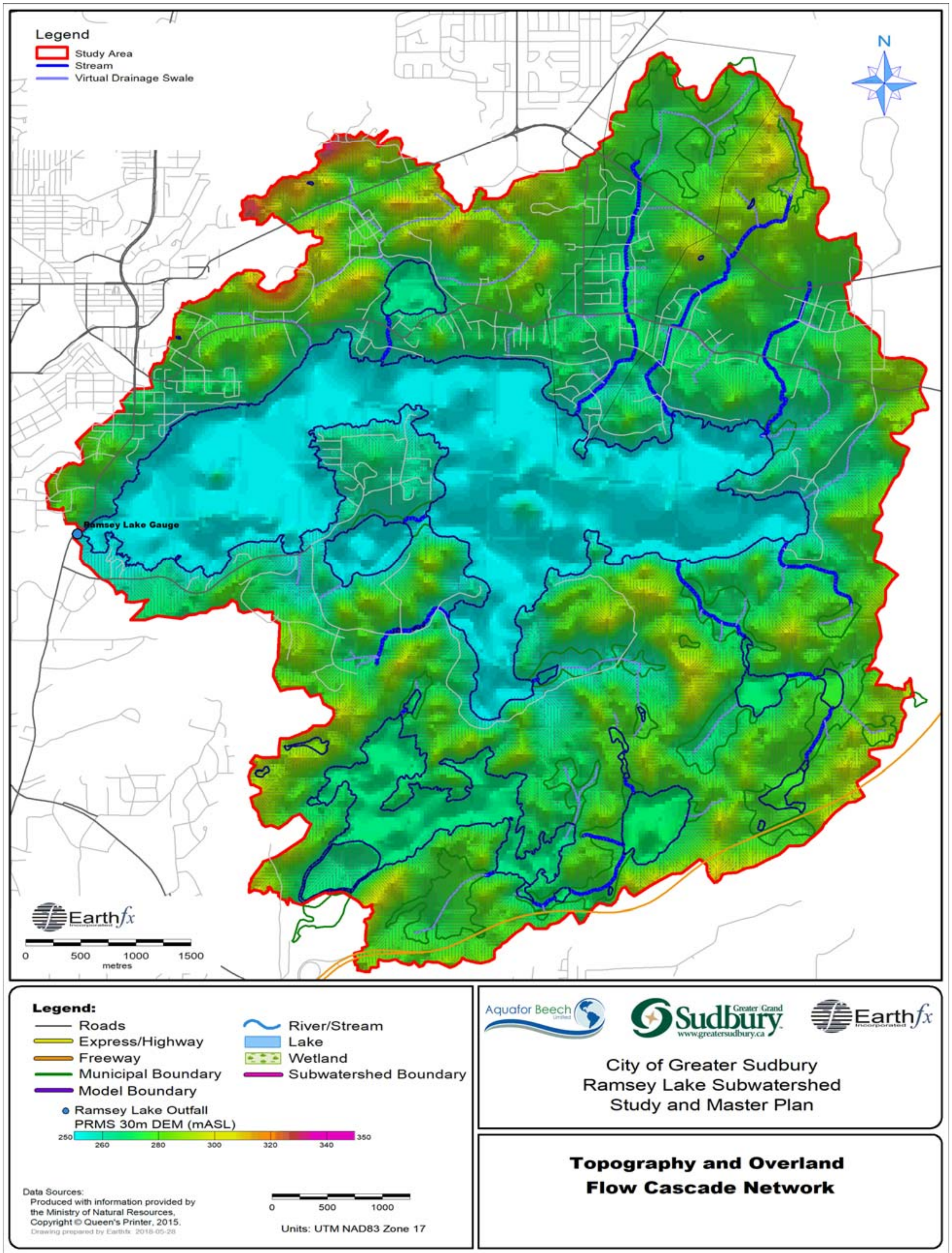

Figure 3: Topography and cascade flow network

1.5.2 Pervious and Impervious Cell Area Processes

Each cell can contain both pervious (with a soil zone) and impervious surfaces (i.e. buildings, parking lots with no active underlying soil zone) and a daily water balance is computed independently for each area type. The model first computes interception by vegetation for both area types. The amount intercepted depends on vegetation type, precipitation type (rain, snow, or mixed), and winter/summer vegetation cover density. If interception storage capacity is exceeded, the surplus is allowed to fall though onto the snowpack, if present, or directly onto the ground surface (a process termed throughfall). For impervious areas, the model computes the capture of precipitation and snowmelt by depression storage. When depression storage capacity is exceeded, the surplus is allowed to run off. Water is removed from the depression storage reservoir in each cell by evaporation. Water can be routed from

During precipitation events, the model first determines whether a snowpack exists. If the temperature is below a user-defined base temperature (T_b), all throughfall is added to the snowpack as new snow. If the temperature is higher than T_b, the throughfall is added as rain to the snowpack and is used to raise the temperature of the snowpack through sensible and latent heat exchange. If the energy input is high enough and the snowpack has become isothermal, all or part of the snowpack can melt. The snowpack can also melt or refreeze based on air temperature change and is subject to sublimation. Snowmelt is assumed to infiltrate the soil up to a maximum daily amount and any excess is allowed to run off.

1.5.3 Infiltration and Hortonian Runoff

Throughfall, in the absence of a snowpack, is partitioned between infiltration and runoff. The PRMS code includes a “contributing area” method to partition flows (Dickinson and Whiteley, 1970) however Earthfx has added the Green and Ampt method into the PRMS submodel to calculate infiltration using hourly or daily precipitation data. The Green and Ampt equation is based on a theoretical derivation of Darcy’s Law and the input parameters can be determined from measureable soil parameters. (Conversely, the empirical decay coefficients in the Horton equation can be difficult to estimate.) Water not infiltrating into the soil is added to overland runoff and routed down the cascade flow network (Figure 3 and Figure 4). This runoff is referred to as Hortonian or “infiltration excess” runoff.

1.5.4 Evapotranspiration

Water entering the soil in pervious areas is subject to evapotranspiration (ET). The PRMS code has three methods for calculating potential evapotranspiration (PET). The Priestly Taylor method, which requires three climate parameters - temperature, solar radiation, and atmospheric pressure - was used in this study to estimate daily PET.

Actual evapotranspiration (AET) processes are assumed to follow a hierarchy whereby ET is first extracted from interception storage and then depression storage. If there is insufficient water to meet the total PET demand, the deficit is extracted from the capillary zone (i.e., the upper soil zone) at a rate based on soil type and the ratio of the current volume of water stored in the capillary zone to its maximum storage capacity. If PET demand is still not met, moisture is extracted indirectly from the gravity soil zone reservoir which is used to replenish the capillary deficit (Markstrom *et al.*, 2008). Once below a specified evaporation extinction depth, transpiration can continue at a rate dependent on canopy coverage, vegetation type, soil type, and the ratio of the current volume of water stored in the capillary soil zone to its maximum storage capacity. Evapotranspiration processes can occur on days when rain also occurs.

1.5.5 Soil Zone Processes, Interflow and Dunnian Runoff

Soil zone processes are controlled by the amount of moisture in the soil zone as shown schematically in Figure 5. Evapotranspiration can remove water from the capillary zone only when the moisture content is above the wilting point. Water is retained against gravity drainage when the moisture content is between field capacity and wilting point. ET rates increase in proportion to the ratio of the available moisture content (i.e., moisture content minus the wilting point) to the maximum available moisture (field capacity minus the wilting point).

Gravity drainage is the principle process driving groundwater recharge. Gravity drainage occurs when infiltration raises the moisture content in the soil zone above field capacity. The PRMS model assumes that excess soil moisture (i.e., water above field capacity) leaves the cell as either interflow or gravity drainage at a rate proportional to the unsaturated hydraulic conductivity of the soil. The unsaturated hydraulic conductivities are selected using a Brooks-Corey relationship that depends on the current moisture content and saturated hydraulic conductivity. Water in excess of the amount that can be passed as interflow or gravity drainage is retained in the soil zone and the moisture content may build up to reach saturation. Additional rain falling on the area will run off as saturation-excess Dunnian (saturation excess) flow.

The maximum daily seepage rate controls the volume of water that is allowed to percolate from the soil zone to the groundwater system. Rates were assigned based on a factor multiplying the estimated saturated vertical hydraulic conductivity of the surficial soils. In PRMS, percolating water enters a linear groundwater reservoir associated with every cell. Lateral groundwater movement can be handled either using a separate groundwater reservoir cascade algorithm or by assigning a single groundwater reservoir to each gauged subcatchment. The latter option was used in this analysis. Discharge to streams from the groundwater reservoirs (baseflow) occurs at a rate dependent on the volume of water stored in the groundwater reservoir and a linear decay coefficient. The coefficient was selected to best match recession rates observed in gauge discharge records.

As previously noted, unique values for all parameters were assigned to each cell in the model. To simplify parameter assignment and to enforce parsimony and consistency across the study area, cells were first assigned classes based on land-use and surficial geology. Parameter values were then assigned to model cells using tables of lookup values for each land use and surficial geology class. For example, soil properties such as porosity and field capacity were assigned by geologic material while properties such as percent imperviousness were assigned by land-use class.

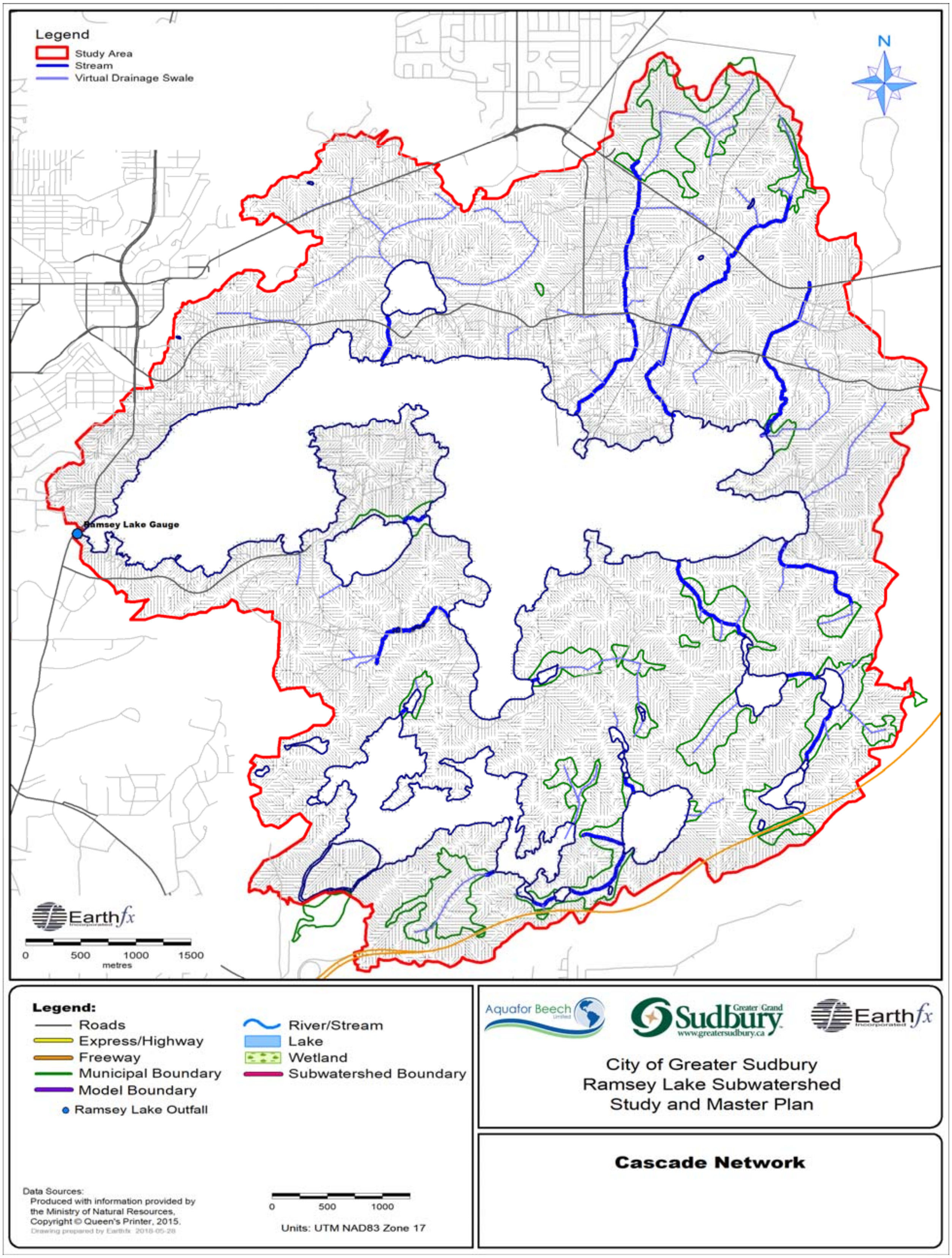

Figure 4: Overland runoff and interflow cascade network

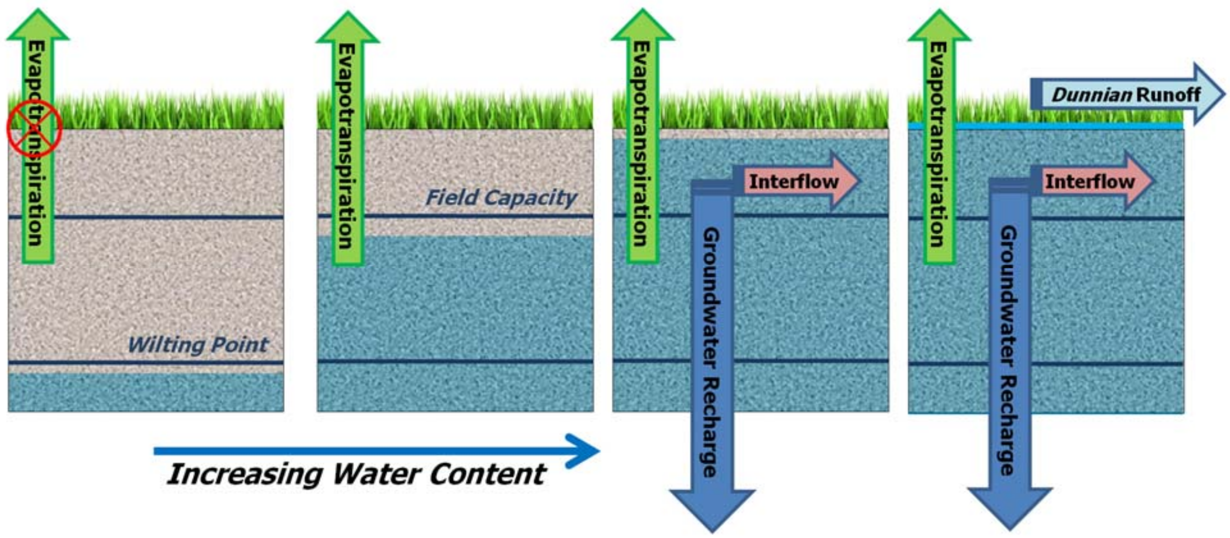

Figure 5: Influence of soil zone moisture on ET, recharge, interflow, and Dunnian runoff processes.

1.6 *Model Parameterization*

Initial estimates of model parameters, derived from previous studies, were defined prior to starting PRMS model runs and were adjusted during the calibration process. For parsimony, consistent assumptions and parameter values were applied, where possible, across the study area. Discussion of model parameters is grouped into the following sub-sections, including:

1. Climate related data
2. Topography-related properties (e.g., slope, slope aspect, and the cascade network);
3. Land use and land cover parameters (e.g., cover density and percent imperviousness);
4. Soil-type and surficial geology properties (e.g., field capacity and wilting point);

1.6.1 Climate Data and Parameters

Climate data used for this study were compiled from the Environment Canada's Atmospheric Environment Service (AES) Sudbury A station.

There are three main climate time-series required for the PRMS model:

1. Precipitation: (as separate rainfall and snowfall data)
2. Daily minimum and maximum temperature (required for calculation of evaporation/ET and snowmelt)
3. Daily net solar irradiation: also required for calculation of evaporation/ET and snowmelt

Data for the period of October 1, 2000 to February 7, 2015 was processed for model simulations (the simulation time period is primarily by the available lake outflow data, as discussed below).

Incoming solar radiation, used in computing potential ET and snowmelt, is controlled primarily by the number of possible hours of sunshine per day and the percent cloud cover. Solar radiation data are collected at very few stations in Ontario. As direct observations were unavailable in the area, solar radiation was estimated by the Hargreaves and Samani (1982) method which uses daily minimum and maximum temperatures to correct incidental extraterrestrial radiation to match observed local conditions.

1.6.2 Topography Parameters

Topography for the model area is based on a DEM produced by the Ontario Ministry of Natural Resources (MNR) which was directly mapped to the 30 m PRMS cells (Figure 3). Slope and slope aspect values were calculated from the DEM using a nine-point planar regression technique that fits a plane to every cell and its eight surrounding cells (see Moore *et al.,* (1991)).

PRMS incorporates a cascading flow algorithm that routes overland flow and interflow from one cell to adjacent cells (Markstrom *et al.*, 2008). The model allows the possibility of infiltration along the cascade pathway (Figure 4). Runoff from one cell is added as run-on to the adjacent cell, and the total volume of water is available for infiltration and/or runoff to a downslope cell. Interflow is also routed down the cascade network. Accumulation of flows from upstream cells and the convergence of the cascade network typically results in dendritic pattern for runoff to streams as well as enhanced recharge and actual ET in the downslope areas.

Topographic data and terrain analysis techniques were used to define the cascade overland flow routing network. An 8-direction steepest-descent method was selected because it generates an efficient many-to-one cascade network (Figure 4). A cascade pathline goes from cell to cell until a stream, lake, or a closed depression (referred to in PRMS as a “swale”) is encountered. While real closed depressions are present, in some cases swales are present in the DEM because of lack or elevation data or resolution. For example, some wetlands have undulating depressions in the DEM, but they ultimately discharge to a downstream lake. Similarly, some smaller “unmapped” ditches may locally direct overland flow. To address this issue a few select virtual streams were added to the network to route excess water from these swales to lakes and mapped streams. These virtual streams or ditches are shown in light blue in Figure 4.

1.6.3 Land-use Parameters

Land use and land cover are important inputs to the PRMS models because they strongly influence hydrologic response. The primary sources for land use information provided in the previous section of this report.

A number of hydrologic properties used in the PRMS model can be reasonably correlated with land use type. For the sake of parsimony and to simplify property assignment, these were assigned to model cells using a look-up table with parameter values for each land-use category. An underlying assumption was that properties for a particular land-use class (e.g., “Commercial”) were the same in one part of the model area as another. Hydrologic properties included:

- percent imperviousness - the proportion of the cell area assumed to be impervious;
- depression storage - the amount of water retained over impervious areas;
- vegetation index – dominant vegetation type (bare, grass, shrub, or trees) in the cell;
- vegetative cover density - the fraction of pervious area covered by vegetation and/or tree canopy. Two values are provided: one for the growing season and one for winter;
- interception storage - the amount of precipitation retained on vegetative surfaces and/or tree canopy. Three values are provided: interception storage for summer rain, winter rain, and winter snow. Effective interception capacity is the product of vegetative cover density and interception storage.

The land use lookup table for the study area is provided in Table 1.

1.6.1 Soils and Surficial Geology Parameters

Soil and shallow geologic properties have a significant influence on hydrological processes because they control the amount of water that can infiltrate and be transmitted to the water table as well as the amount of water lost to evaporation and transpiration by plants (i.e., actual ET). Soil water-holding capacity in the capillary and gravity reservoirs (see Markstrom *et al.*, 2008) were input as model parameters that were calculated as functions of soil zone thickness, porosity, field capacity, and wilting point. Parameters that controlled the partitioning of flow between interflow and percolation to the water table were also specified as soil-type properties.

To simplify parameter assignment and for the sake of parsimony, soil properties were assigned to cells using tabulated look-up values based on soil texture or surficial geology type. Geologic classes and associated parameter values used in the PRMS model are summarized in Table 2.

Table 1: Summary of land cover parameters

Index	Description	Source 1	New Land Use Description	Future Land Use	Depression Storage (in)	Depression Storage (mm)	RadTR	Vegetation Index	R1 Summer Cover Density	Summer Cover Density	Winter Cover Density	Summer Rain Interception Storage (mm)	Winter Rain Interception (mm)	Snow Interception Storage (mm)	SoilDepth (mm)	XIMP	Percent Impervious
170	Open Water/Shallow Aquatic	Lakes	Lakes		0	0	0.95	0	0	0	0	0	0	0	1219.2	0	0
160	Marsh	Wetland			0	0	0.95	1	0.6	0.5	0.2	15.24	1.27	1.27	609.6	0	0
325	Open Space	Parks & Open Space	Parks and Residential	Parks & Open Space	0	0	0.65	2	0.5	0.4	0.2	5.08	2.54	2.54	304.8	0.9	0.05
202	Built-Up Area Pervious	Medium Density Residential			0.1	2.54	0.65	1	0.4	0.3	0.15	5.08	2.54	2.54	304.8	0.2	0.45
303	Rural Development	Rural	Open Area		0.1	2.54	0.5	1	0.7	0.4	0.2	5.08	2.54	2.54	304.8	0.7	0.2
1303	Rural Development	Living Area 2		Living Area 2	0.1	2.54	0.5	1	0.7	0.4	0.2	5.08	2.54	2.54	304.8	0.7	0.2
317	Estate Residential	Living Area 1	Residential	Living Area 1	0.1	2.54	0.5	1	0.7	0.3	0.15	5.08	2.54	2.54	304.8	0.7	0.2
1317	Estate Residential	Low Density Residential	Open Area		0.1	2.54	0.5	1	0.7	0.3	0.15	5.08	2.54	2.54	304.8	0.7	0.2
320	Future Land Use	Land Dev 1			0.1	2.54	0.5	1	0.7	0.3	0.15	5.08	2.54	2.54	304.8	0.7	0.2
318	Roads and Housing	from road network	Other Roads		0.1	2.54	0.75	1	0.4	0.2	0.1	5.08	2.54	2.54	304.8	0.7	0.3
319	Major Roads	Land dev 2	Arterial and Express/highway		0.05	1.27	0.75	0	0.05	0.05	0.025	1.27	0.635	0.635	304.8	0	0.9
203	Built-Up Area Impervious	Regional Centre (commercial)			0.2	5.08	0.8	1	0.4	0.2	0.1	5.08	2.54	2.54	304.8	0	0.85
301	Urban	Downtown			0.2	5.08	0.9	1	0.4	0.2	0.1	5.08	2.54	2.54	304.8	0	0.85
306	Institutional	Institutional	Government and Institutional	Institutional	0.2	5.08	0.9	1	0.5	0.3	0.15	5.08	2.54	2.54	304.8	0.2	0.45
321	Commercial	Mixed Use Commercial	Commercial	Mixed Use Commercial	0.2	5.08	0.95	1	0.2	0.2	0.1	5.08	2.54	2.54	304.8	0	0.85
326	Industrial	General Industrial	Resource and Industial	General Industrial	0.2	5.08	0.95	1	0.2	0.1	0.05	5.08	2.54	2.54	304.8	0	0.25
1326	Industrial	Heavy Industrial and mines			0.1	2.54	0.95	0	0.2	0.05	0.025	1.27	0.635	0.635	304.8	0	0.2
250	Undifferentiated				0	0	0.89	1	0.7	0.7	0.04	8.89	4.445	4.445	304.8	0.98	0.2

Table 2: Summary of geologic and soil material parameters

EFX2code	Description	SupplementalDescription	SoilType	CN	Slow Interflow Coeff	Soil Thickness (in)	n	fc	wp	SatCond (m/s)	PAW	K metres per day
0	Open Water	Open Water	2	45.0	0.50	12.0	0.10	0.02	0.010	7.1E-05	0.010	1.00E-10
150	Bedrock	Paleozoic	1	85.0	0.50	4.0	0.10	0.02	0.010	7.1E-05	0.010	1.00E-03
513	Glacial Lacustrine	Silt	3	60.0	0.20	12.0	0.30	0.11	0.053	1.4E-06	0.053	4.32E-03
512	Ice Contact Stratified Deposits	Layered silt, sand and minor gravels	2	50.0	0.15	8.0	0.35	0.12	0.061	9.2E-07	0.061	1.20E+01
511	Glacial Lacustrine Sand and Silt		2	50.0	0.20	8.0	0.30	0.11	0.053	9.2E-07	0.053	1.20E+01
630	Glaciofluvial/lacustrine deposits	Sand	1	40.0	0.30	8.0	0.25	0.09	0.044	1.5E-05	0.044	1.00E-02
400	Glacialfluvial outwash	sand and gravel; proglacial deposits (outwash)	1	35.0	0.40	8.0	0.25	0.09	0.044	9.5E-06	0.044	4.32E+00
1700	Peat and Muck	Wetlands (organic deposits)	3	60.0	0.20	12.0	0.65	0.33	0.163	8.5E-06	0.163	5.00E-05

1.7 *Flow Calibration Targets*

Limited flow data was available for calibration. A PCSWMM subcatchment model was constructed to estimate the lake stage and related lake outflows. The outflows would include both flow over the dam and withdrawals for drinking water. The processing and preparation of this data is discussed in previous sections of this report.

Given the limited flow data, a model development and application strategy was developed to calibrate first to the overall catchment, and then assess component inflows to the lakes. The calibration and analysis strategy was thus:

1. Calibrate to the overall water budget for the Ramsey Lake Watershed

The overall inflows (precipitation) are balanced by the overall outflows (overall ET and estimated Ramsey Lake outflows).

2. Evaluation of lake inflows and outflows

The second stage of the analysis involves assessing the components of the *inflows* to the lakes (i.e. Ramsey Lake, Minnow Lake and the smaller lakes) against the outflows. Inflows include Runoff, interflow, surface water stream flow and groundwater discharge. Outflows include lake ET and the estimated lake outflows from the PCSWMM model. Once the components are assessed under current land use conditions, the change in flow under future land use can be assessed.

1.8 *Overall Water Budget*

The PRMS model was assessed for the four-year period spanning WY2010and WY2014, inclusive. This period spans the available climate and lake outflow measurements.

The overall basin results for the period are shown in Table 3. The overall error is small, at less than 1%, and can be attributed to errors in estimated (PCSWMM) flows, error in measured precipitation and potential changes in storage.

Table 3: Overall Water Budget

Flow Component	Flow (m3/sec)
Total Precipitation	1.180
ET Actual	-0.389
Lake Outflows (from PCSWMM Model)	-0.802
Difference	-0.011
Difference (%)	-0.89%

The water budget elements on a monthly basis are shown in Figure 6. The combination of Ramsey Lake storage changes (stop log operations) and winter snow pack accumulation (and spring melt) introduces storage effects and lag in the fluctuations in the water budget.

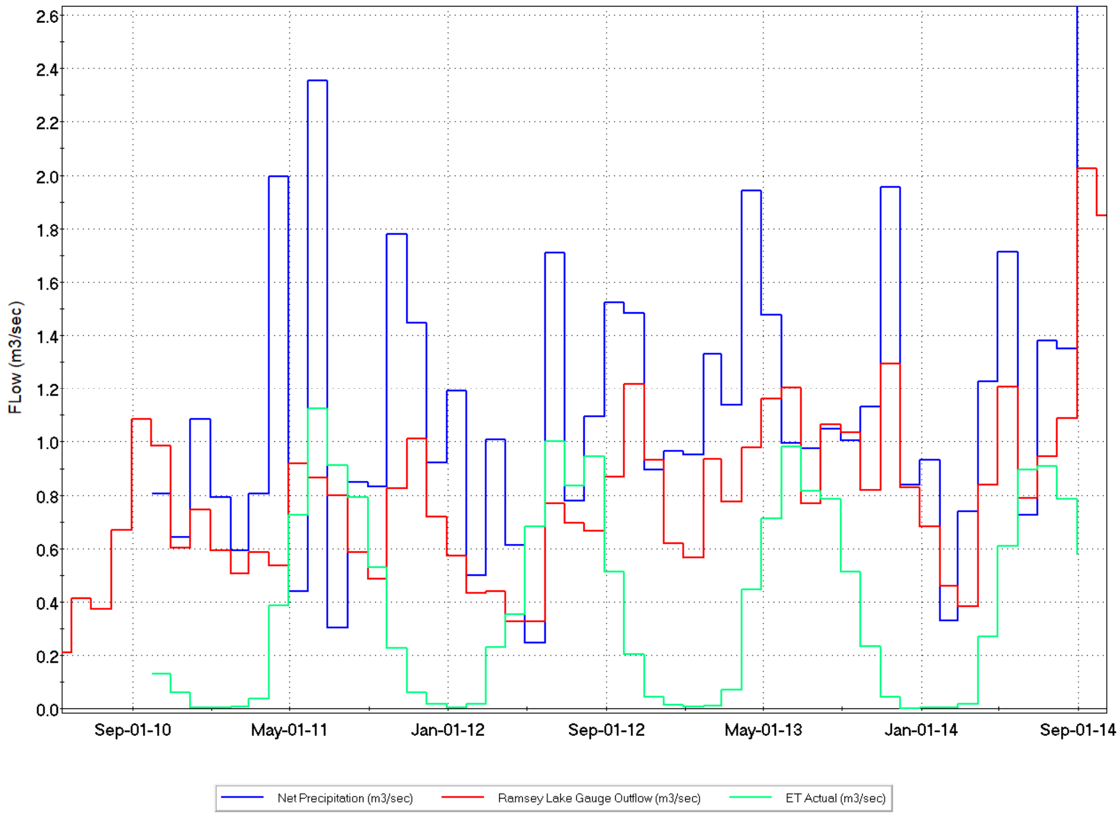

Figure 6: Monthly water budget elements

In summary, with an error of less than 1%, the model appears to produce a reasonable overall water budget estimate.

1.9 *Component Water Budget*

The distributed PRMS model allows the flow components to be evaluated on a cell-by-cell basis across the watershed. To better understand the effects of land development on the lakes the model results were assessed in two summation classes: lakes and land mass. The lake class includes Ramsey Lake and the smaller lakes in the watershed (i.e. Minnow Lake, etc.). Wetlands are considered part of the land class.

The overall water budget for the lakes is shown in Table 4:

Table 4: Water Balance for Lakes

Lake Water Balance	Inflow	Percent	Outflow	Percent
Inflows	(m³/s)		(m³/s)	
Precipitation (directly into the lakes)	0.2998	35%		
Hortonian runoff to lakes	0.0494	6%		
Lake Inflow from the Soil Zone	0.1287	15%		
Groundwater Recharge	0.1276	15%		
Runoff to Streams	0.2330	27%		
Interflow to Streams	0.0208	2%		
Outflows:				
Actual ET			-0.1277	14%
Lake Outflows (from PCSWMM Model)			-0.8017	86%
Totals	0.8593	100%	-0.9294	100%
		Difference	-0.0701	
	Percent Difference		8%	

The model results indicate that the lakes receive a complex variety of inputs. Precipitation is the largest direct input to the lakes (35% of the total inflows), while streamflow is second largest at 29% (this includes runoff to streams plus interflow to streams). Hortonian overland runoff (storm intensity driven infiltration excess) accounts for 6 percent of the inflow, while Dunnian (saturation excess runoff) and interflow account for 15% of the direct flow to the lakes.

Of the outflows, direct ET from the lakes accounts for 14% of the outflow water budget, while the remainder is the amount estimated to flow over the Ramsey Lake dam and supply the water treatment plant.

The percent difference between the lake inflows and outflows is 8%. This includes potential errors in the estimated flow at the dam, errors in ET estimates, changes in storage and other potential watershed losses (water can enter and exit the basin through other pathways). The overall watershed error, as previously noted, is less than 1%.

The spatial results provide insight into the processes functioning in the watershed. The average overland runoff and interflow, as shown in Figure 7, illustrates how flow accumulates downslope and enters the lakes at variety of focused locations. Runoff is significantly lower in the sandy areas in the vicinity of the Frobisher and Rogers Creek watersheds due to the higher rates of groundwater recharge (Figure 8). The 3-dimensional nature of the groundwater recharge is evident by the higher rates of recharge at the downslope boundaries of the sand units where overland runoff from the bedrock infiltrates.

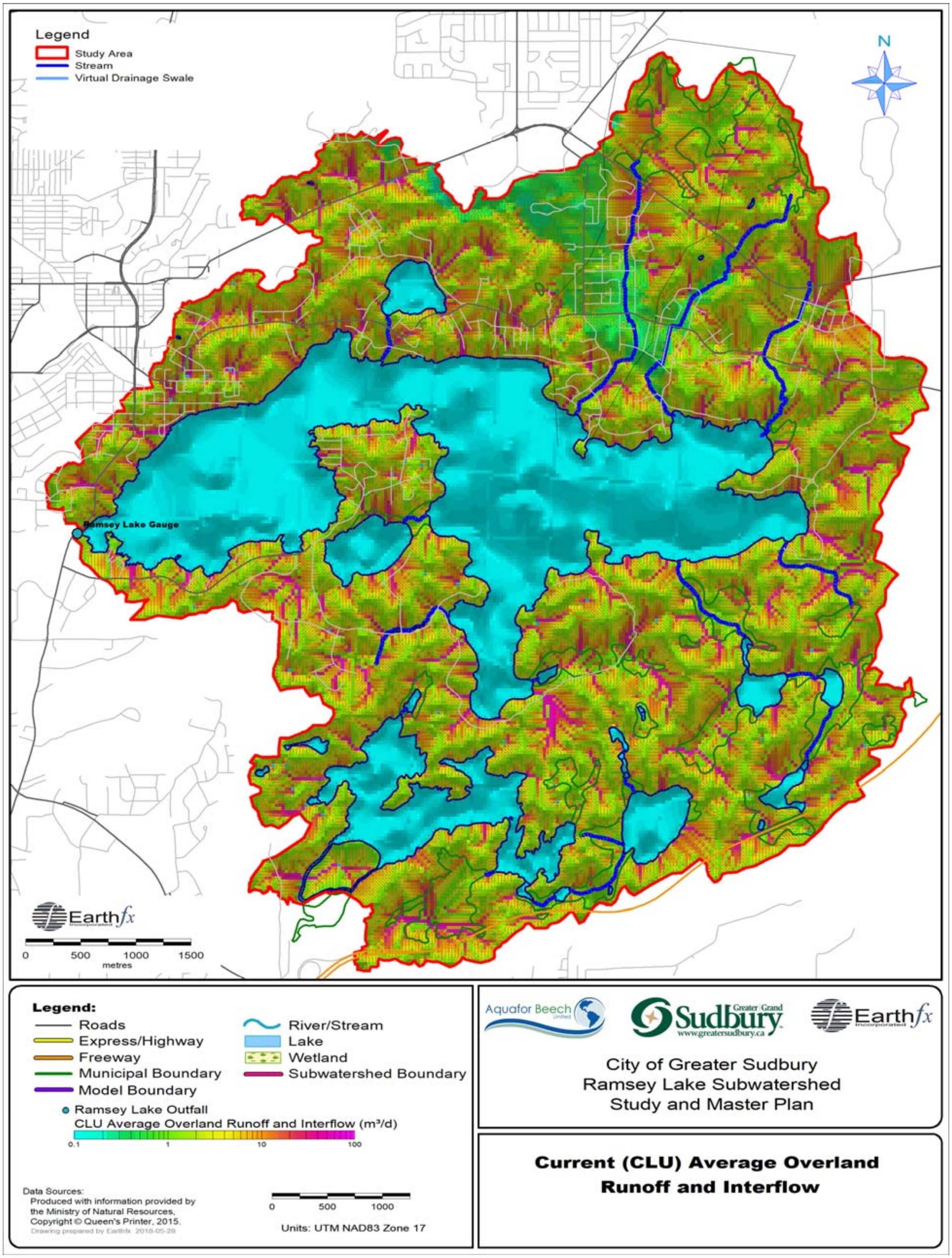

Figure 7: Average Overland Runoff and Interflow (Current Land Use)

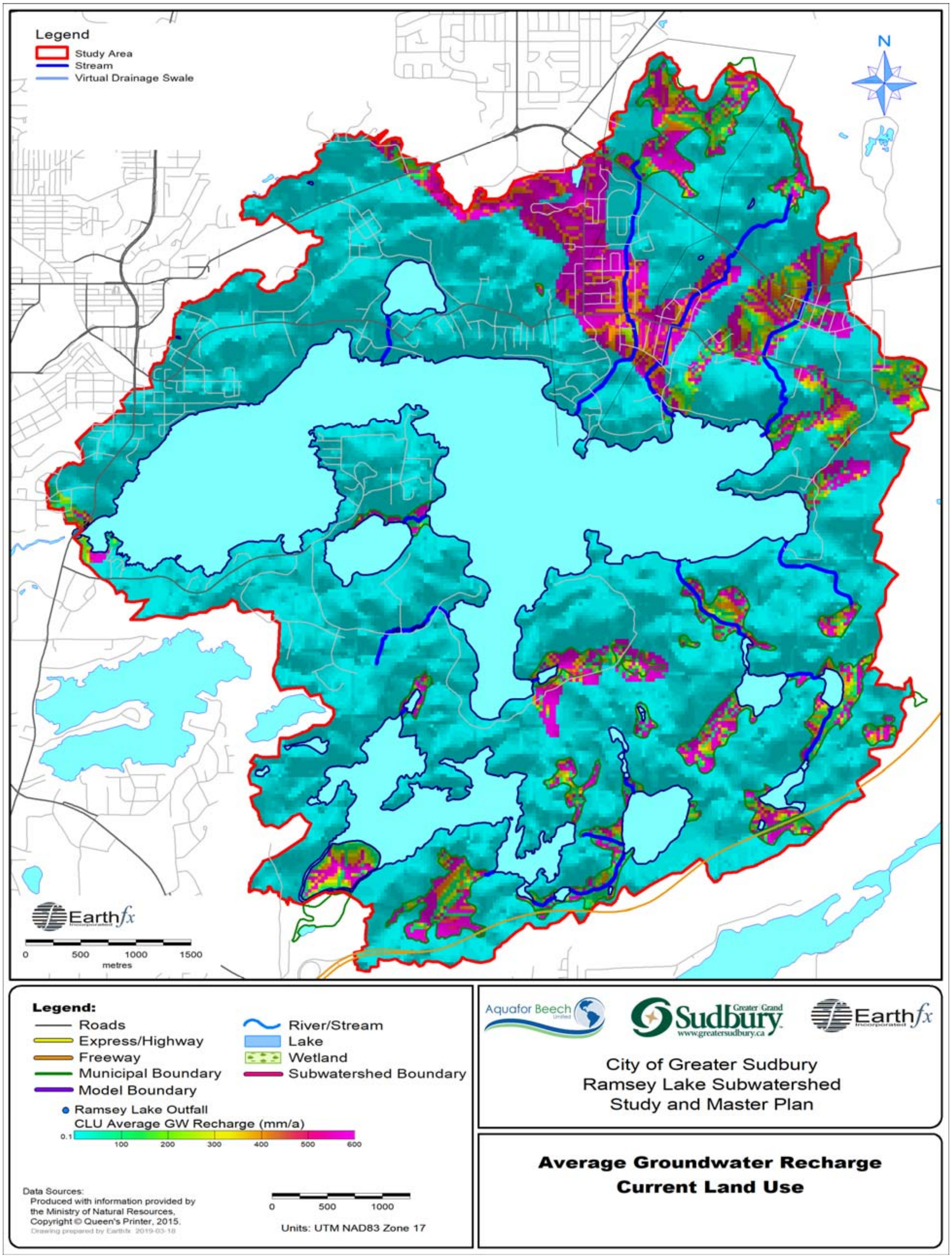

Figure 8: Average Annual Groundwater Recharge

The average annual rates of actual ET under current land use are shown in Figure 9. ET rates vary across the watershed and higher rates are evident on south facing slopes that receive more solar energy. Vegetation patterns and soil moisture variation due to converging runoff in topographic lows also affect the ET rates.

The average soil moisture content is shown in Figure 10. The water storage in wetlands is clearly evident in the figure, as well as topographic effects and swales.

The predicted average overland runoff to streams is shown in Figure 11. Runoff to both mapped streams and virtual streams (ditches, swales, etc.) is illustrated. The most prominent pattern in the streamflow pickup is the low rate of discharge (as illustrated in green) in the sandy soils in the vicinity of the Frobisher and Rogers Creek watersheds.

The summation table and maps of the water budget components indicate that the water budget components are relatively widely distributed both in terms of processes and spatial patterns. Runoff to streams together with direct runoff and interflow to the lakes is, as expected, the largest component of the inflow to the lake.

1.10 *Future Conditions*

The land use input parameters were modified to reflect the future land use conditions. (Future Draft Plan Conditions dated August 8, 2017) The model was re-run to assess the changes in the water budget. Both the current and future conditions water budget is summarized in Table 5.

Table 5: Current and Future Land Use Water Budget for Lakes

Lake Water Balance	Current	Percent	Future	Percent	Difference	Percent	Outflow	Percent
Inflows	(m3/sec)	of inflow	(m3/sec)	of inflow	(m3/sec)	Difference	(m3/day)	of outflow
Precipitation (directly into the lakes)	0.29976	34.88%	0.29976	34.85%	0.000000	0.032%		
Hortonian runoff to lakes	0.04943	5.75%	0.04944	5.75%	-0.000008	0.004%		
Lake Inflow from the Soil Zone	0.12873	14.98%	0.12877	14.97%	-0.000047	0.008%		
Groundwater Recharge	0.12759	14.85%	0.12713	14.78%	0.000456	0.066%		
Runoff to Streams	0.23296	27.11%	0.23419	27.23%	-0.001232	-0.119%		
Interflow to Streams	0.02082	2.42%	0.02077	2.41%	0.000050	0.008%		
Outflows:								
Actual ET							-0.1277	14%
Lake Outflows (from PCSWMM Model)							-0.8017	86%
Totals	0.8593	100%	0.8601	100%	-0.000781		-0.9294	100%
						Difference	-0.0701	
					Percent Difference		7.54%	

Overall, the change in the lake inflow water budget under future land use conditions is small. The largest change in the lake water budget is in the runoff to streams, which increases by 0.119 percent under future conditions.

While the change in the water budget is small, the local effects of the land development are more visible at select locations in the distributed model. In general, land development increases runoff, as illustrated in Figure 12, and a significant portion of the watershed area northeast of Highway 17 will change to “General Industrial” (Figure 13). Portions of this area include lowland/wetland areas that may or may not be infilled or preserved during re-development. Further, the proposed Kingsway development, including a new arena, hotel and casino, is planned to cover a portion of the SGRA zone located at the headwaters of Eugene Creek (Figure 14).

To evaluate the effects of future land development on the SGRA zones in the north east portion of the watershed a number of figures have been prepared to illustrate the current and future conditions. Note that the specific development plans are not represented in the model, only the general change in land use. Figure 15 shows the current runoff patterns in the area, while Figure 16 shows runoff under the future conditions. The change in runoff is shown in Figure 17.

While the exposed bedrock in this area has a naturally high runoff potential, two aspects of the change to “general industrial” are of note:

1. Significant change in runoff and recharge is predicted to occur in and around the wetlands north of Frobisher Creek. Air photos indicate that there is already infilling of wetlands at the east end of Frobisher Street and at the south end of Westbourne Street. Further infilling of wetlands, as indicated by the land use change, will increase runoff (Figure 17) and reduce groundwater infiltration (Figure 18).

2. The change in land use in and around the SGRA zone near the headwaters of Eugene Creek will produce complex changes to the water budget. The proposed land development in the upland areas around the Eugene SGRA zone will increase runoff (Figure 17) due to both an increase in imperviousness and a reduction in ET. A portion of this will move downslope and be available to infiltrate within the SGRA zone. Land development within the SGRA zone will, to a degree, limit this new recharge and generate additional runoff. With more water entering the SGRA zone, the net change will be both an increase in recharge and an increase in runoff (as indicated in the Eugene Creek SGRA zone (Figure 18)). The ecological impact of this additional runoff entering the SGRA zone will depend on whether the runoff water quality includes road salt.

1.11 *Conclusions*

The analysis of the Ramsey Lake watershed indicates that there will not, on a watershed basis, be any major changes in the overall water budget under the future land use conditions. The northeast portion of the watershed, including the Frobisher, Rogers and Eugene creeks and the surrounding SGRA zones, may, however, exhibit measureable impact under future land use in the Kingsway development area. Land development in the upland areas around the wetlands and SGRA zones will likely increase runoff (due to both an increase in imperviousness and a reduction in ET), and depending on how the lowland wetlands and SGRA zones are managed and modified, groundwater recharge and headwater flows may be adversely affected. The enhanced runoff from the upland areas may locally increase downslope groundwater recharge, and the water quality of the runoff may be detrimental to the ecology of the headwaters if the runoff contains road salt.

1.12 *Recommendations*

Targets/Objectives:

The primary objective of the groundwater management plan for the Ramsey Lake watershed should be on the preservation of groundwater recharge within the SGRA zones. The SGRA zones provide baseflow support for the riparian zones as well as storm flow runoff attenuation.

The SGRA protection plan must recognize that the SGRA zones receive significant runoff (and resulting groundwater recharge) from:

1. The surrounding upland areas; and
2. The upgradient riparian areas and streams where they enter into the SGRA zones.

The simulations indicate that a buffer of approximately 200 m around the SGRA zones would preserve the majority of the overland runoff that inflows to the SGRA features. LID infiltration and runoff management measures (including both water quantity and water quality measures) within this buffer may also be effective.

Where streams enter the SGRA zones (for example, where Rogers Creek enters the SGRA zone in Figure 17), this buffer should extend as much as 300 m upgradient of the SGRA zone. This will preserve riparian inflows into the SGRA zone.

There is also reason to believe, based on the depositional model of the glacial sediments, that a number of the wetlands may also overlie overburden sediments and locally significant aquifer system. These overburden deposits may provide both baseflow and deeper fracture flow throughout the year. For example, the groundwater upwelling noted in Moonlight Bay is likely supported by wetland and overburden storage that reaches the bay through the fracture and fault network. As with the SGRA protection plan, wetland protection should include a buffer to ensure runoff to the wetlands is preserved.

Recommendations for future studies:

Expanding the monitoring of surface water flows and both groundwater and lake levels is essential to improving the understanding and long term management of the water budget. A priority should be placed on the monitoring of Frobisher, Rogers and Eugene Creek, as the water budget simulations indicate that they are all at risk of impact from the Kingsway development.

The results from the simulations, particularly around the headwaters of Eugene Creek, indicate the complex hydrologic response to land development that can occur in this watershed. Both recharge and runoff are predicted to locally increase, and the resulting increase in groundwater levels may affect drainage patterns, storm water pond design, and groundwater seepage across a larger area. Additional surface and groundwater investigations and simulations are necessary at the site plan design stage to confirm and mitigate these effects.

The City should consider compiling a central database of high quality borehole logs and water levels to supplement and expand on the MOECP water well record database. The MOECP database structure is designed for private water wells and is not sufficient to support engineering investigations, watershed management and the analysis of surface water and groundwater interactions.

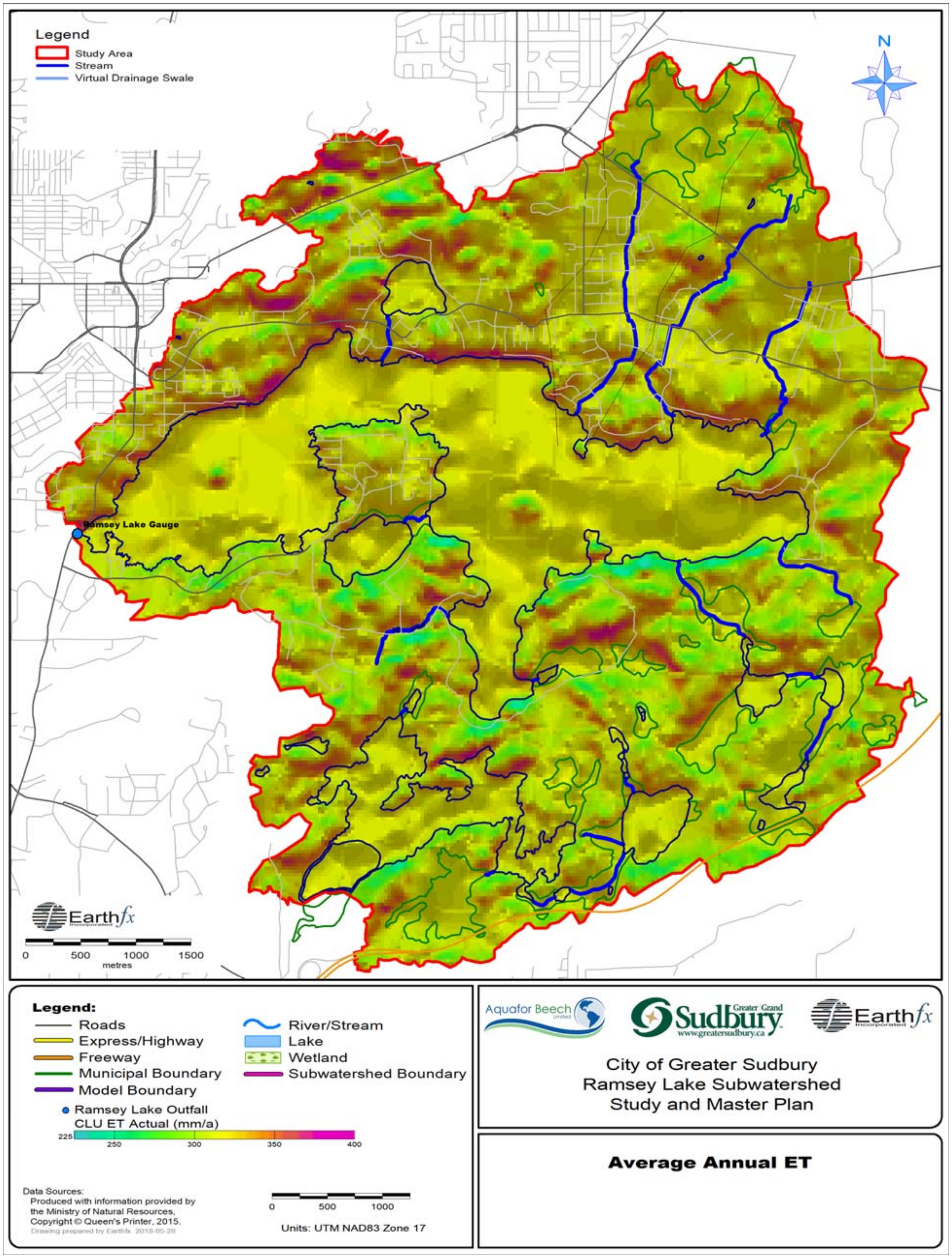

Figure 9: Average annual actual ET

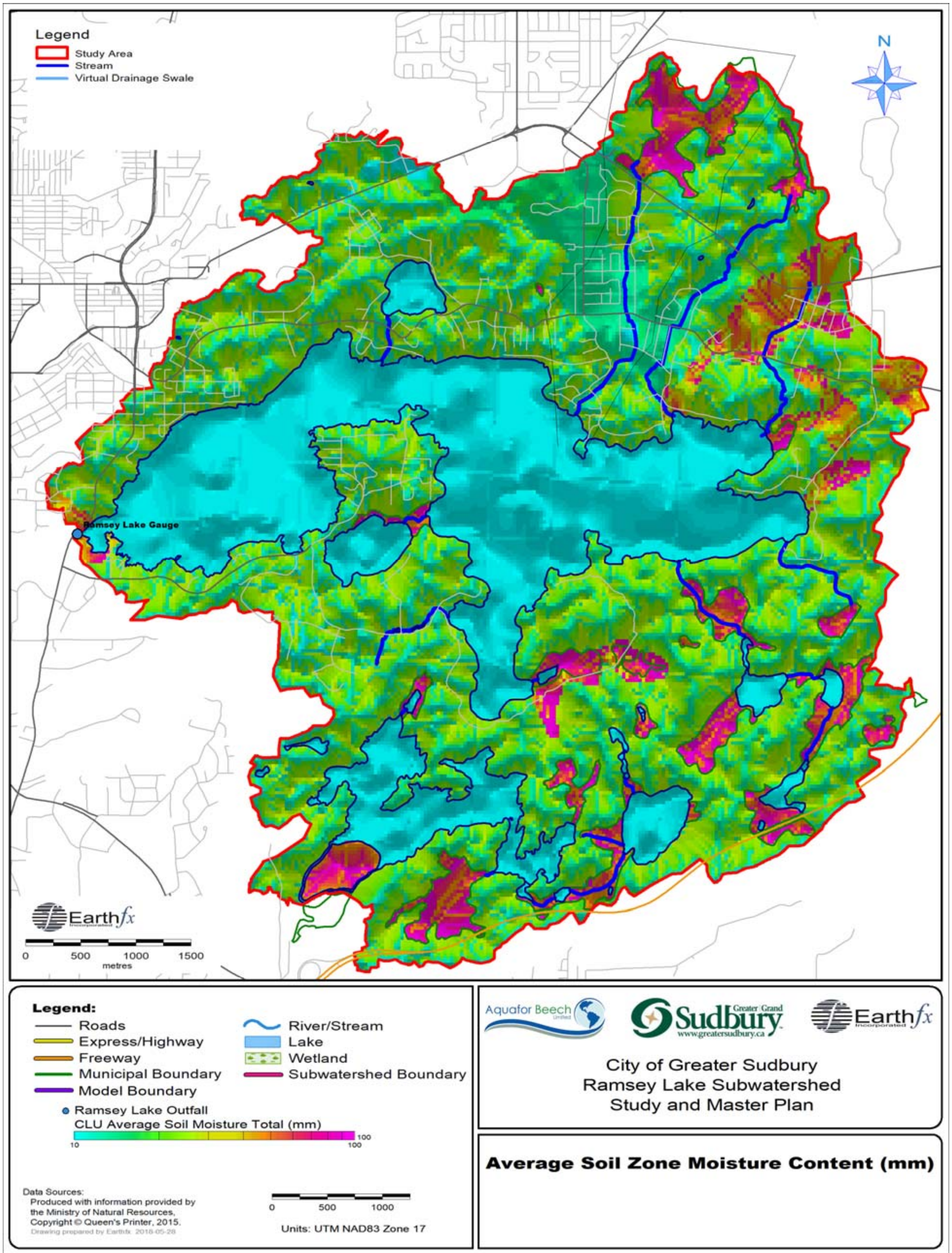

Figure 10: Average soil moisture content

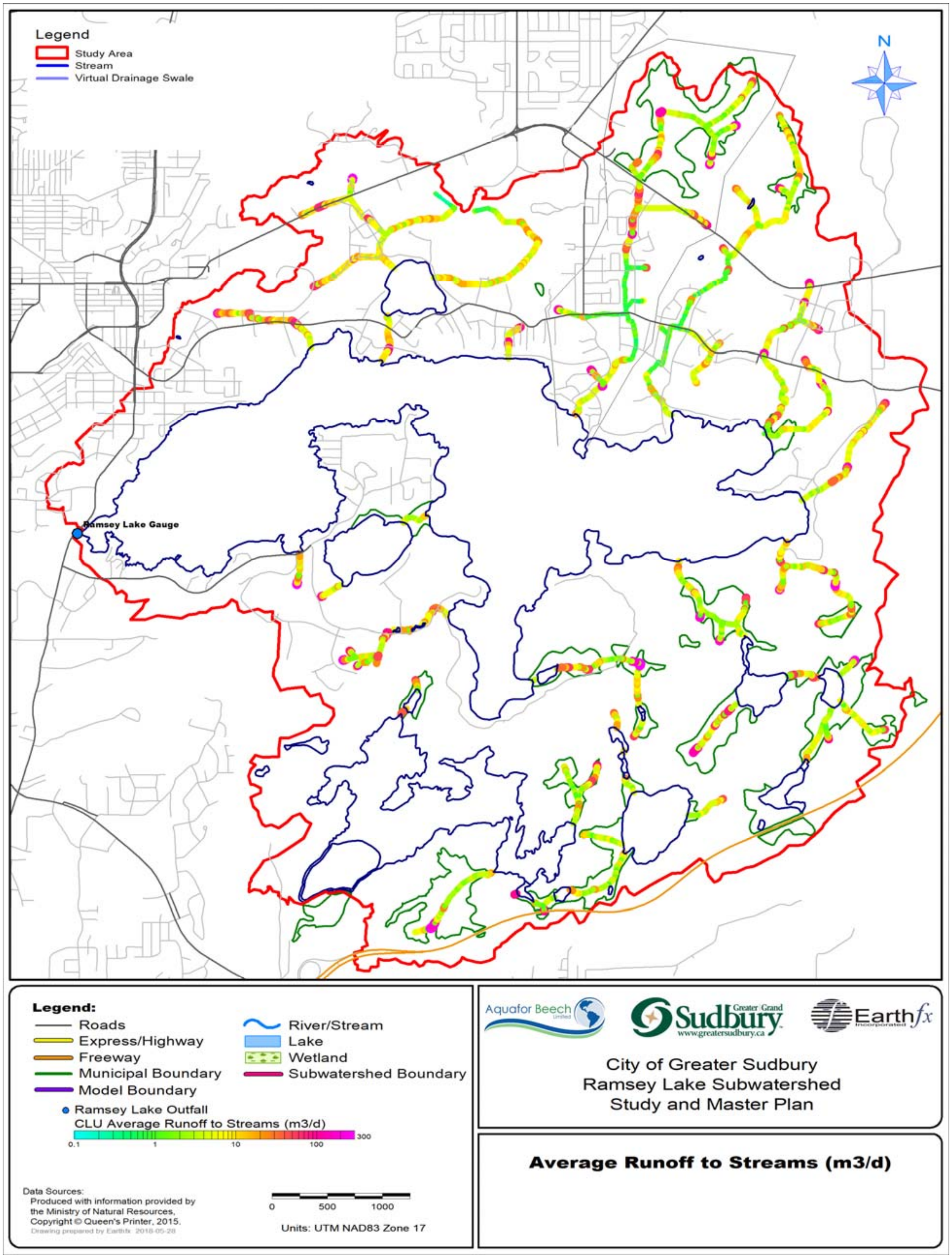

Figure 11: Average runoff to streams

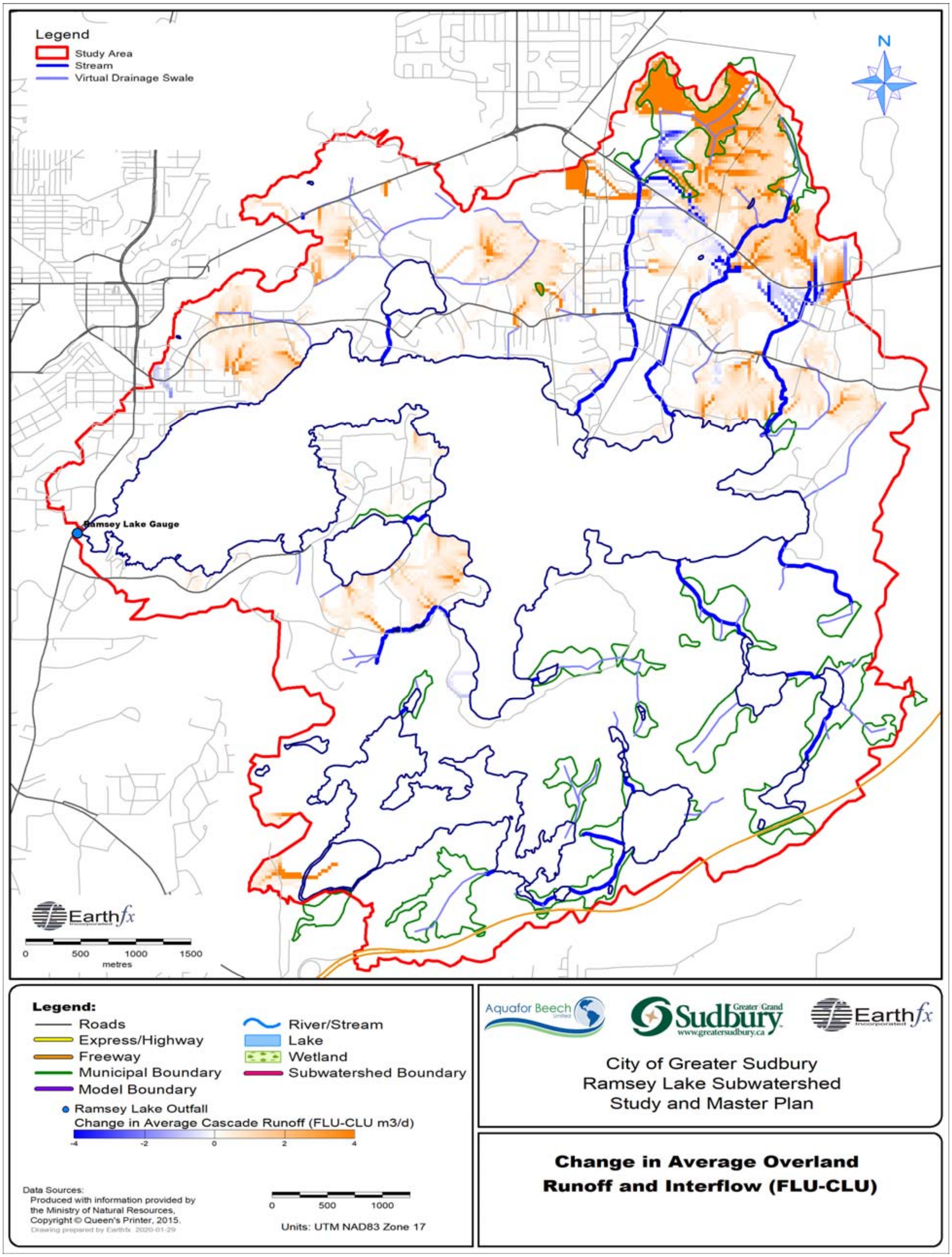

Figure 12: Change in overland runoff (Future land use - Current land use)

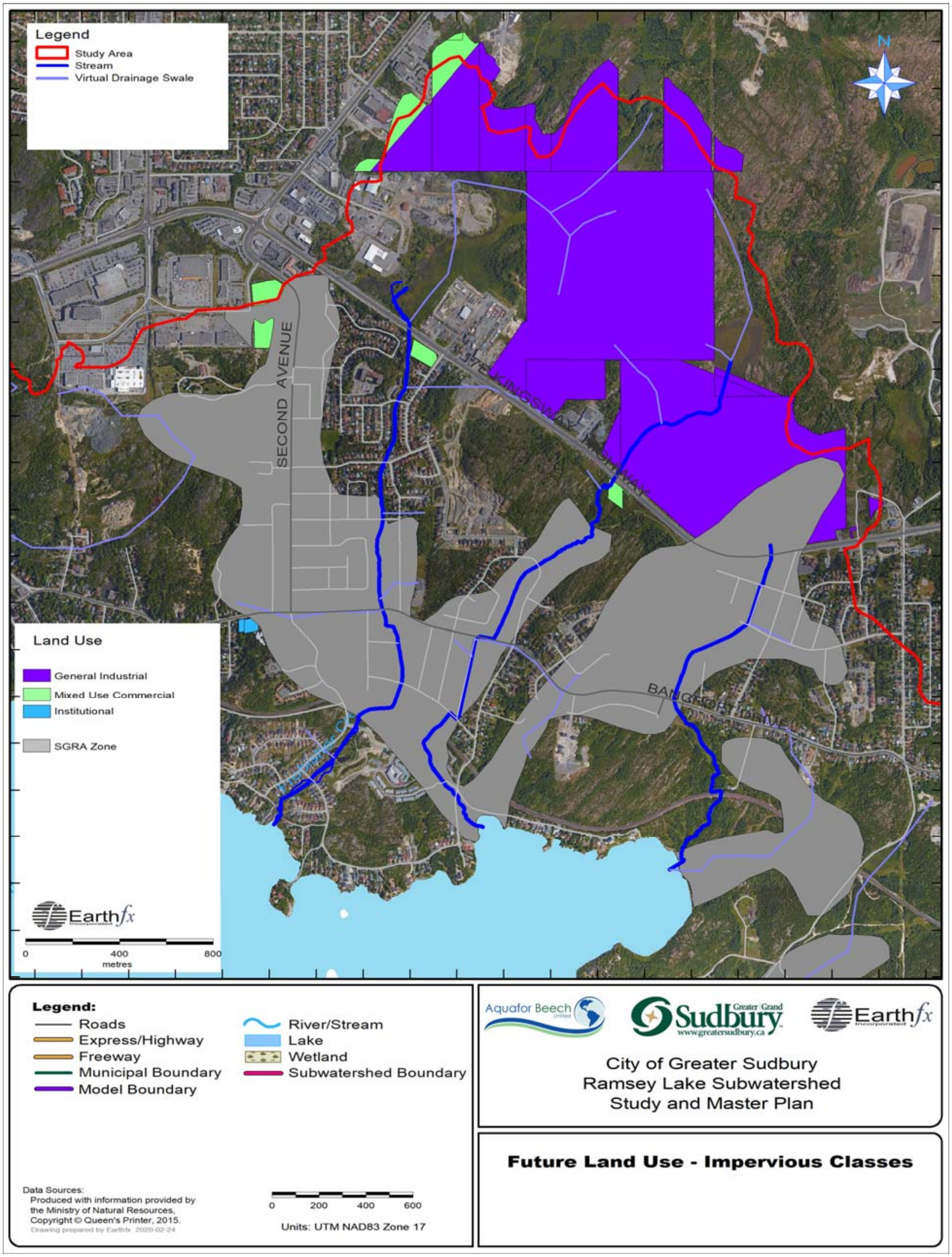

Figure 13: Future land use classes with high imperviousness (purple zones)

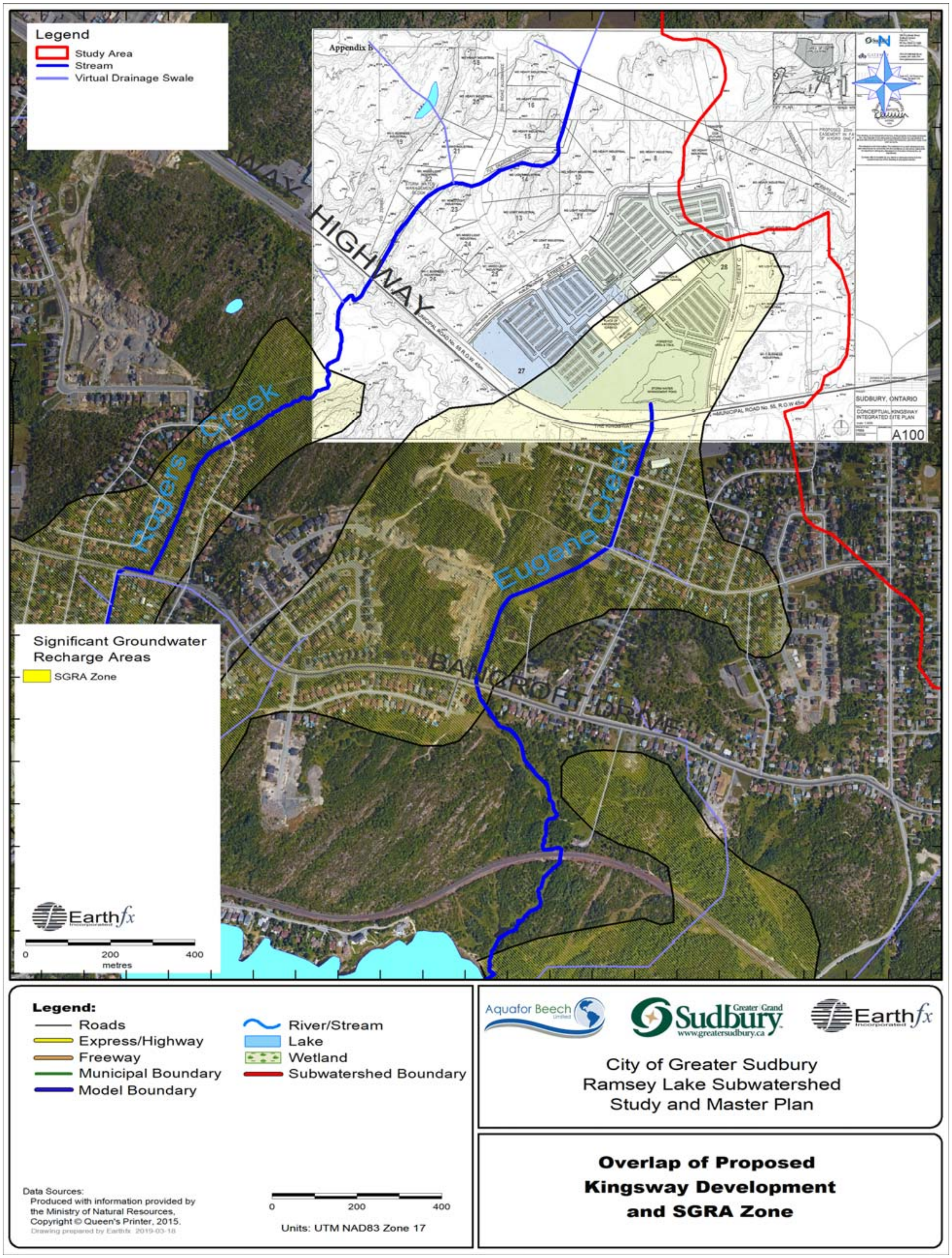

Figure 14: Overlap of proposed Kingsway development and SGRA Zone

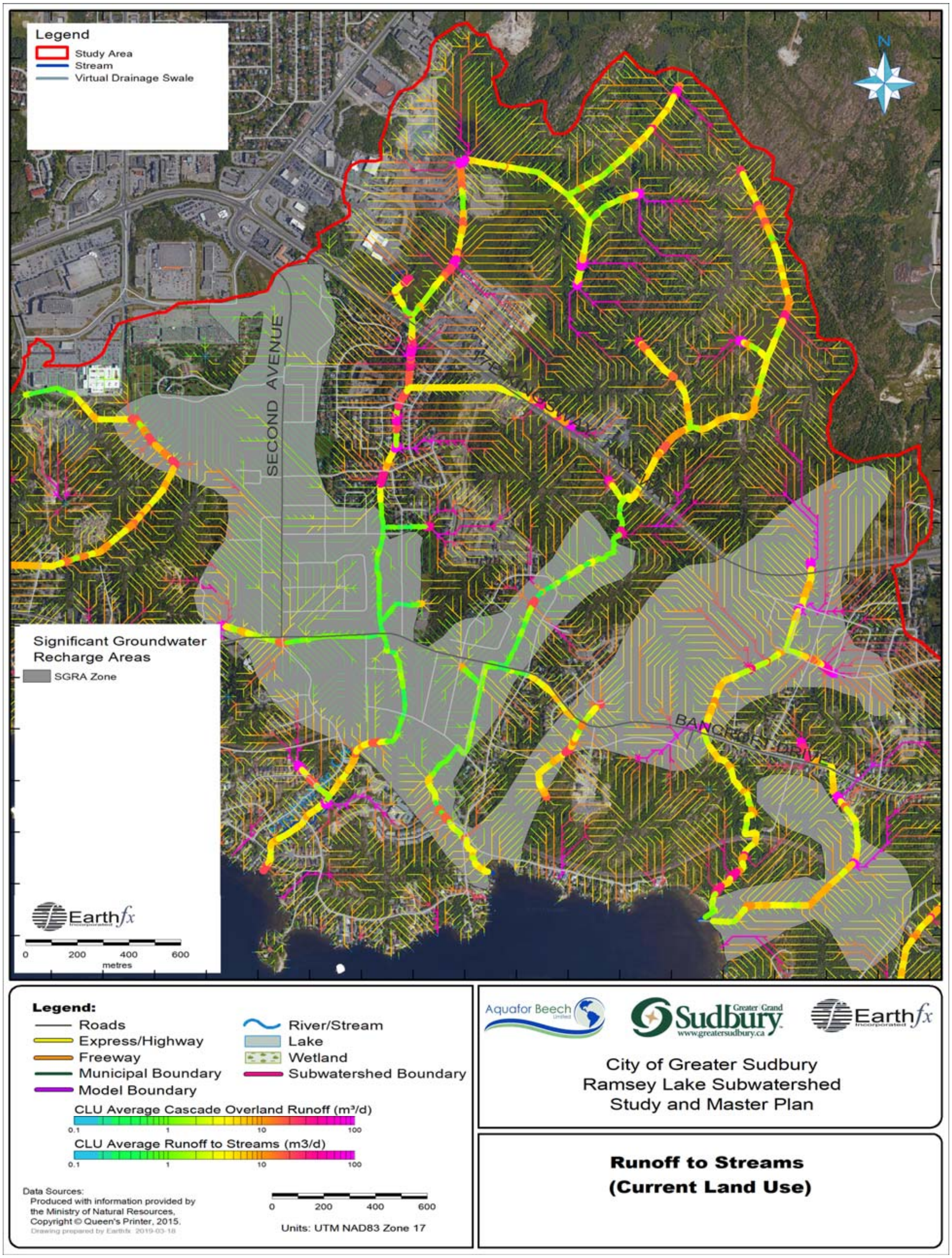

Figure 15: Runoff to streams - current land use

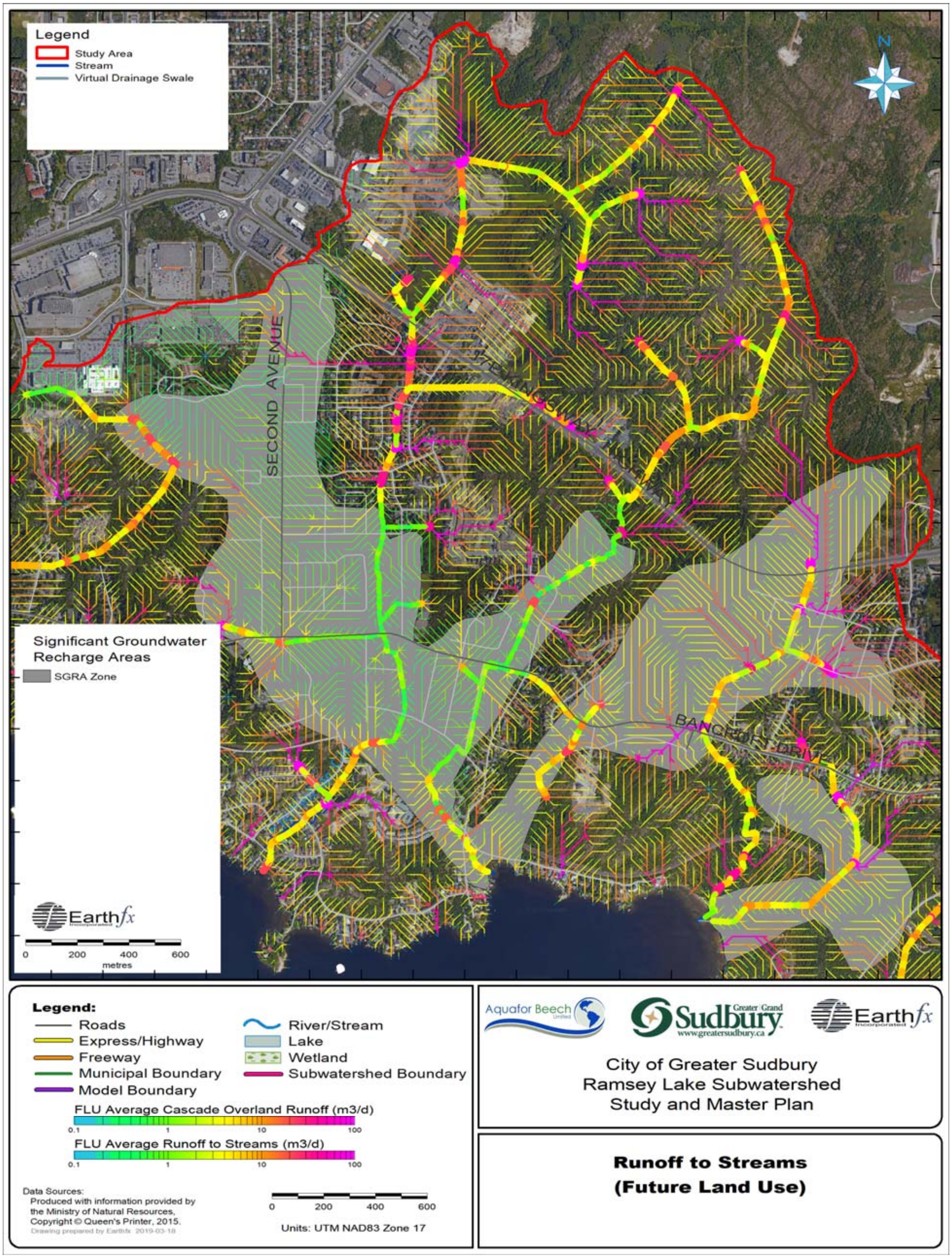

Figure 16: Runoff to streams - future land use

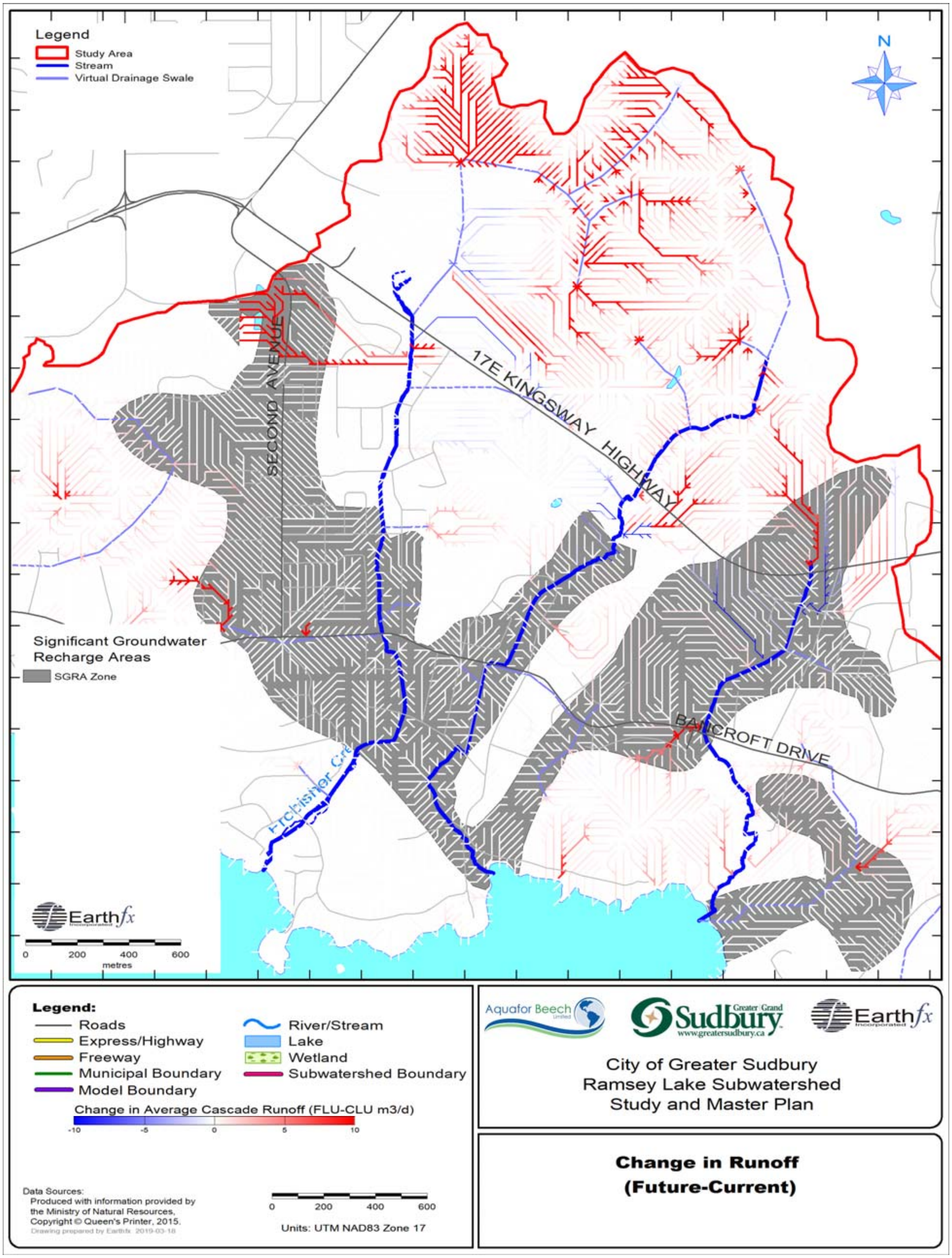

Figure 17: Change in runoff to streams (Future increase in runoff shown in red)

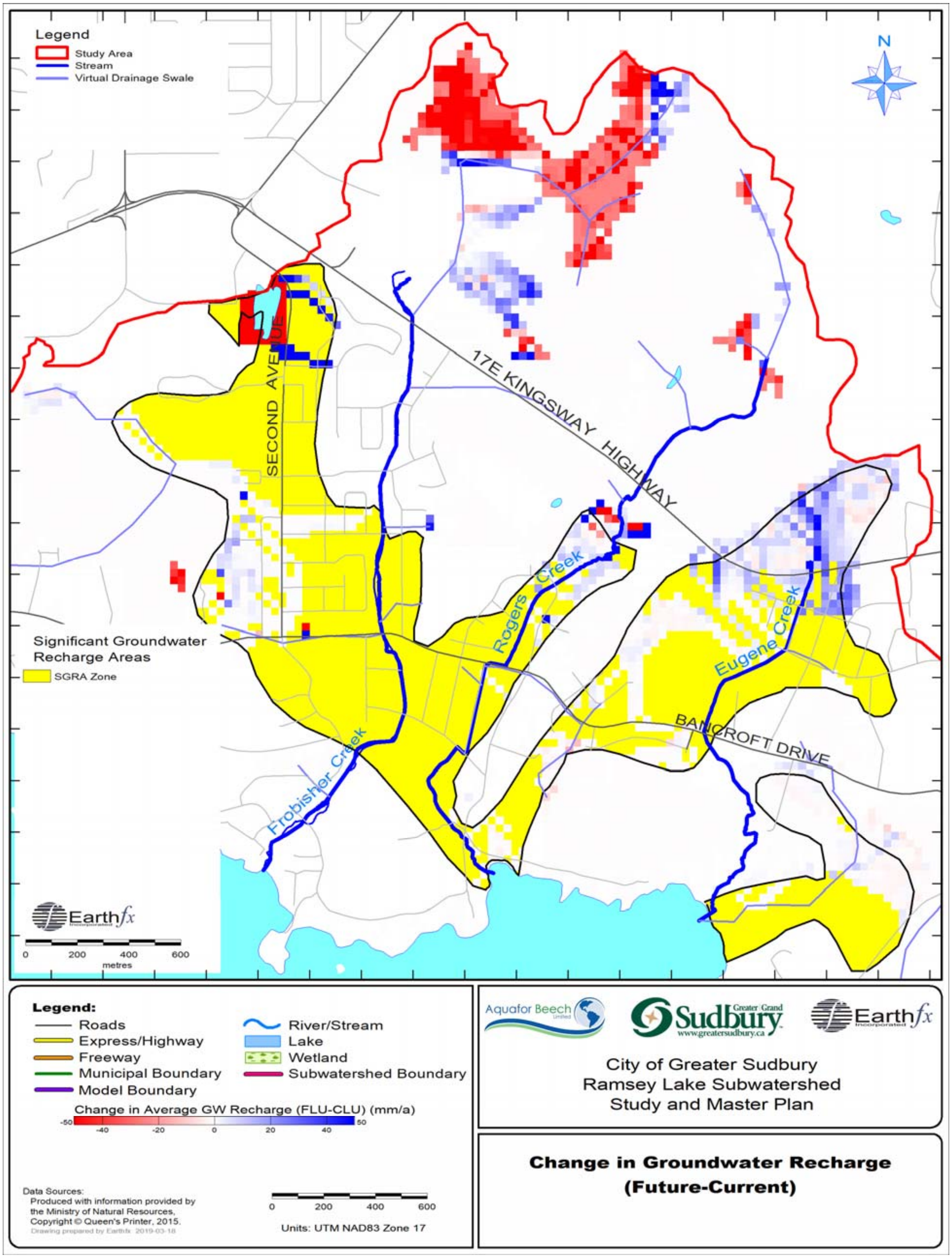

Figure 18: Change in groundwater recharge (Future reductions shown in red)

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