Junction Creek Subwatershed Study and Stormwater Master Plan

City of Greater Sudbury
Final Report
Wood Project Number: TY161021

Prepared for:

City of Greater Sudbury
200 Brady Street, Sudbury, Ontario, P3E 3L9
PO Box 3700 Station A
Sudbury, Ontario
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25-Mar-19

25-Mar-19

City of Greater Sudbury
200 Brady Street
Sudbury, ON   P3A 5P3

Attention: Mr. Paul Javor, P.Eng., Drainage Engineer

Dear Sir:

Re: Junction Creek Subwatershed Study and Stormwater Master Plan
Final Report
City of Greater Sudbury

Wood Environment & Infrastructure Solution, a division of Wood Canada Limited (Wood) has been retained by the City of Greater Sudbury (CGS) to prepare a Subwatershed Study and Stormwater Master Plan for the Junction Creek Subwatershed in Sudbury, Ontario. This report constitutes the Final Junction Creek Subwatershed Study and Stormwater Master Plan Report, which includes the Final Background Characterization Report.

Please accept this report in accordance with our commitment to complete the Junction Creek Subwatershed Study and Stormwater Master Plan.

Yours truly,

Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited

Dan Cacciotti

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EXECUTIVE SUMMARY

The main branch of Junction Creek flows for 52 kilometres (km) from its headwaters downstream of Garson Mine to its outflow into McCharles Lake, which then joins the Vermillion River, as a major tributary. The Junction Creek subwatershed consists of an area of 320 km^2, the majority of which lies within the City of Greater Sudbury (CGS), composed of 57.5% forested area, 9.1% wetland, 13% water, 1.6% field, 8.4% rock and a remaining 10.4% developed area (City of Greater Sudbury 2013). Several Conservation Sudbury (CS) control structures exist along a number of the contributing tributaries (Maley and Nickeldale) to assist with flood control. While flood control has been greatly improved through the installation and operation of these structures, there are still areas of low relief susceptible to flooding.

The Junction Creek subwatershed groundwater flow system, in general, mirrors topography with the potentiometric surface of the shallow aquifers following similar flow paths of the surficial drainage. There are three very distinct groundwater aquifers/flow systems within the Junction Creek Subwatershed: 1) the unconfined bedrock aquifer exposed at the ground surface along the valley flanks, which provides recharge conditions at several locations; 2) the confined or semi-confined glacial outwash deposits that are overlain by finer grained deposits at surface and are dominated by groundwater discharge zones; and 3) the unconfined Wanapitei Esker deposits. The Wanapitei Esker presents a high recharge potential, however the same characteristics allow for the expose of the aquifer, and thereby the municipal water supply within this area, to greater risks of contamination.

The underlying bedrock within the study area is comprised mainly of the Huronian Supergroup, with the Elliott Lake Group in the Southwestern parcel, while the Northeastern parcel is comprised primarily of the Hough Lake and Nipissing Gabbro groups, and secondarily Felsic intrusive rocks.

Land cover estimation supporting various aspects of the overall study was categorized into three groups. Impervious cover was calculated as consisting of water and infrastructure, semi-pervious cover as bedrock and tailings, and pervious cover as all other surficial cover types (forests, wetlands, sand and gravel, etc). The three land cover types make up the following percentage of the total area within the Junction Creek Subwatershed: 25.4% impervious, 50.3% semi-pervious, and 24.3% pervious. Nepahwin and Robinson subwatersheds hold the highest percent of impervious area, while Copper Cliff, Frood-Stobie and Central Tailings areas contain the lowest percent of impervious area and the highest semi-impervious area. The high percentage (by surface area) of low permeability surfaces has several implications on the water flow and flooding, during certain times of year and storm conditions.

Areas dominated by impervious surfaces can lead to increased contaminants in waterbodies due to overland flow. This may be reflected in the consistently high concentrations of copper, nickel, cadmium and zinc in the water samples taken within the Frood Branch. High contaminant levels in turn affect benthic macroinvertebrate and fish communities. The upper, middle, and lower sections of the Junction Creek subwatershed offer a variety of aquatic habitat types that support a variable fish and benthic community. Generally, aquatic habitat conditions are considered to be good throughout the upper subwatershed and deteriorate moving downstream to the lower subwatershed, where water quality and habitat conditions are more impaired.

Riparian cover was found to be generally lacking throughout the study area, which correlates to the evidence of erosion or active erosion sites within all reaches included in the geomorphological assessment conducted in May of 2017. Vulnerable areas such as riparian zones, especially those that are currently in an unfavourable condition, and have the potential to be further impacted through increasing climate change, as well as development and the ever-present mining industry in Sudbury.

The CGS has already experienced an overall increase in both temperature and precipitation between 1956 and 2008, and is expected to experience similar climate changes as elsewhere in Ontario. However, Sudbury has been proactive when it comes to climate change through the production of numerous studies reviewing climate change issues in the area, the presence of various active climate change groups, and numerous initiatives by the CS and CGS to manage the effects of climate change.

Following the characterization of the subwatershed, the Stormwater Management (SWM) Master Plan was prepared in accordance with the Municipal Class Engineer's Association Class Environmental Assessment (Class EA) procedures. The Master Plan has adopted *Approach #2* from the 2007 MEA Class EA Document. Under *Approach #2*, the Master Plan fulfills the Municipal Class EA requirements for all Schedule 'B' projects, the final public notice for the Master Plan becomes the Notice of Completion for the recommended stormwater management projects.

The SWM Master Plan has been managed by a CGS Project Manager and a Committee comprised of several Municipal Departments. This Committee provided guidance on Project priorities, local issues/needs, and general overall direction with respect to the project deliverables. In addition, the Project has received insight from a Technical Advisory Committee comprised of representatives from the CGS and CS.

A hydrologic model of the subwatershed was created using the PCSWMM modelling platform. The model conducts both a hydrologic analysis of runoff within the subwatershed and a hydraulic analysis of the capacity of Junction Creek. The hydrologic model was used to characterize the existing condition within the Junction Creek subwatershed with respect to peak flow along the creek and tributaries, and storage levels within key subwatershed features such as lakes and the Ponderosa wetland. In order to confirm that the model produces reasonable results, existing flow monitoring data from the Water Survey of Canada was utilized along with rainfall data from the CGS's David St. Water Treatment Plant to calibrate the hydrologic model.

Based on the hydrologic analysis, an updated HEC-RAS hydraulic floodplain model of Junction Creek and identified tributaries was created. The HEC-RAS modelling platform allows for the computation of water surface elevations along Junction Creek and its various tributaries to be established for each of the design storm events. The hydraulic model was used to gauge the sensitivity of the floodplain to each major bridge and/or culvert crossing, in order to identify and prioritize crossings for improvement.

An assessment of the CGS's trunk sewer (>900 mm) networks was conducted utilizing the PCSWMM modelling platform to conduct both hydrologic (flow) and hydraulic (capacity) assessments. The assessment of the minor system (trunk storm sewers) was conducted under a 5 year design storm event standard. The results of this assessment have indicated that there are a number of storm sewers with capacity issues. This includes both surcharging (water levels above the sewer but below the surface) and flooding (water levels above the surface). These areas appear to be primarily concentrated in older areas of the CGS, particularly the Flour Mill area. The assessment of the major system (roadways) has been conducted under the more significant 1 in 100 year storm event standard. The results of the roadway assessment have indicated that all of the areas analyzed would be susceptible to some surface flooding during the 1 in 100 year storm event, which is generally consistent with current practice for drainage systems. However, the results further indicate that the majority of areas analyzed would be susceptible to flooding to depths above typical curb height (0.15 m), and thus extend beyond the road right-of-way for a portion of the network. The most significant flooding depths are anticipated to occur at roadway sag points, where a lack of positive surface drainage means that drainage is limited to the minor system.

A long list of potential alternatives has been considered in this study in order to address the previously noted capacity issues within the minor and major systems. A number of different options have been advanced for consideration, including storm sewer upgrades, quantity control facilities (flood storage areas), diversion of flood water, restoration and reprofiling of Junction Creek, and other hydraulic improvements.

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1.0 INTRODUCTION

1.1 Study Overview

Wood Environment & Infrastructure Solution, a division of Wood Canada Limited (Wood) was retained by the City of Greater Sudbury (CGS) to prepare a Subwatershed Study and Stormwater Master Plan for the Junction Creek Subwatershed in Sudbury, Ontario. The "Junction Creek Subwatershed Study Area" or "Study Area" refers to the outlined area presented in **Appendix 'A'**. Ramsey Lake and its subwatershed are located within the Junction Creek Subwatershed, however, that area is not included within the scope of this Study and is instead the focus of a separate, individual subwatershed study. Therefore, specific data pertaining to Ramsey Lake and the lakes and streams within its subwatershed are not presented here.

The main intent of the Study is to establish measures to protect, maintain and enhance surface and groundwater quantity and quality through the implementation of integrated strategies and policies to support the realization of a practical and executable management plan.

As per the Terms of Reference (TOR), the main objectives of this Study are to:

i. Protect and manage quantity and quality of surface water and groundwater resources;
ii. Mitigate or minimize the risk of flooding and erosion in the Subwatershed;
iii. Preserve natural hydrological and hydrogeological systems;
iv. Identify the aquatic, wetland and terrestrial resources that should be protected or enhanced;
v. Produce an implementation plan and identify specific projects needed to achieve the goals identified by the Subwatershed Study;
vi. Provide recommendations for the responsible management of the ecosystem on a subwatershed level;
vii. Develop a monitoring plan, including key indicators needed to assess the measures implemented to allow for adaptive management and to guide future activities in the subwatershed; and,
viii. Develop a reporting plan to communicate the results of the study, plan implementation, monitoring and future activities.

1.2 Process Summary

The main phases per the scope of work for this study are as follows:

i. Existing Information Review and Data Collection;
ii. Characterization/Analysis;
iii. Alternative Subwatershed Management & Stormwater Master Plan Strategies; and,
iv. Recommended Subwatershed Management & Stormwater Master Plan.

As a first step, the Study Team completed a desktop review of current studies and data as well as gathered information made publicly available, the results of which were summarized in a report titled *Existing Information Review and Gap Analysis*, dated April 2017. The report summarizes information collected and reviewed, and also defines data gaps. Additionally, the Study Team completed a characterization of the Subwatershed Study Area with respect to the applicable disciplines (i.e., Terrestrial and Aquatic Systems, Surface Water (Hydrology/Hydraulics), Water Quality, Groundwater and Stream Morphology) as well as an analysis of environmental issues, constraints and opportunities for restoration and development. This Background Characterization of the Study Area had been updated and included in the current report as **Section 3**.

The Study Team has used the information presented in the Background Characterization Report to evaluate the impacts on surface water, ground water, and subsequently the potential impacts to the area features and biota (i.e., terrestrial and aquatic ecology and stream morphology). An identification of Opportunities and Areas of Concern is presented in **Section 4**.

As part of the Subwatershed Study and Stormwater Master Plan process, the data collected through the background study was used to create an overall hydrologic model of the subwatershed, as described in **Section 6**. The hydrologic model was then used to create a riverine floodplain model of Junction Creek and selected tributaries, as summarized in **Section 7**. To support Stormwater Master Planning, a dual drainage model of the trunk sewer networks and associated overland flow routes was created. Based on the results of the floodplain and dual drainage model analyses, various Stormwater Master Plan alternatives are identified in **Section 8**. Subwatershed Management and Stormwater Master Plan alternatives for water quality are presented in **Section 9**.

Furthermore, the report provides a detailed summary of several Stormwater Master Plan options, which are evaluated in accordance with the Municipal Class EA process, described in **Section 10**. The report also outlines the recommended Subwatershed Management and Stormwater Master Plan for the Junction Creek Subwatershed Study Area, including monitoring and implementation plans, in **Sections 11 & 12**.

1.3 Preliminary Goals and Objectives

The main goal of the Junction Creek Subwatershed Study and Stormwater Master Plan is to develop a long-term plan that will provide policy and management actions to protect, maintain and enhance the surface water, groundwater and natural resources of Junction Creek and its tributaries.

The objectives of the Junction Creek Subwatershed Study and Stormwater Master Plan include the following:

Water Quality

- Improve surface water and groundwater quality.
- Minimize pollutant loadings to surface water and groundwater.
- Improved aesthetics of Junction Creek and its tributaries.

Water Quantity

- Preserve and re-establish the natural hydrologic processes to protect, restore, and replenish surface water and groundwater resources.
- Reduce the impacts of erosion on aquatic and terrestrial habitats and property.

- Minimize the threats to life and property from flooding.

Natural Environment

- Protect, enhance and restore natural features and functions of wetlands, riparian and ecological corridors.
- Improve warmwater and coldwater fisheries as appropriate.

2.0 DATA COLLECTION AND FIELD INVESTIGATIONS

2.1 Historical Datasets and Reports

During the first phase of this Study, the Study Team completed a desktop review of current studies, data and publicly available information in order to create a list of available data and determine which information is lacking and necessary to complete the Junction Creek Subwatershed Study and Master Plan. The data gaps were assessed and used to determine the necessary field investigations which would need to be completed in order to address these gaps. The consolidation, review and summary of the existing information in the Study Area relevant to this Study was conducted and the findings are presented in **Section 3**.

As part of the Existing Information Review and Gap Analysis (Amec Foster Wheeler April 2017), various parties were contacted who have ownership of relevant data, studies, and reports to request access and use of this information for the purpose of completing this study. Titles of reports and information obtained from other parties are summarized in a Data Tracking Chart (**Appendix 'A'**: **Table A1**), which includes the data owner, data provider and details of the data request. Data owners and providers consist of: Junction Creek Stewardship Committee (JCSC), Vale Canada Limited, Cooperative Freshwater Ecology Unit (CFEU), Ontario Ministry of the Environment (MOE), Conservation Sudbury (CS, formerly known as the Nickel District Conservation Authority or NDCA), CGS, and Laurentian University.

Categories of data recorded in the Data Tracking Chart are as follows:

i. Data: rainfall, runoff, natural heritage, surveys (culverts & bridges), soil reports, and water quality;
ii. Mapping: topographic, aerial, LiDAR, and drawings;
iii. Land use: official plan, secondary, infill/intensification, and imagery;
iv. Models: hydraulics and groundwater;
v. Studies: groundwater (source), stormwater management, natural systems, miscellaneous studies and reports;
vi. Infrastructure: storm sewers, dam drawings, overland systems, creeks/bridges, stormwater management facilities, as-built drawings; and,
vii. Contacts: agencies, stakeholders & landowners, NGOs, and special interest groups.

In terms of available data and information, it is evident that considerable sources in various forms exist for this system. Notwithstanding, much of these data are from various citizen groups or non-government organizations (NGOs) and hence have been collected using varying standards and protocols. Where information from these sources has been used in system characterization, it has been acknowledged, otherwise it has been noted as available with the potential for future use in subsequent stages of planning and design within the Junction Creek subwatershed possible.

It was determined that sufficient data was available to complete the characterization of the natural heritage system with regards to aquatic and terrestrial habitat as well as fish and benthic invertebrate communities. Additionally, some data gaps were identified regarding both the surface water and groundwater quality of the Junction Creek Study Area.

With regards to the historical geomorphological data and studies reviewed, it was determined that systematic reporting on the physical characterization of the stream associated with aquatic habitat observations was available, however, there had been no quantification of erosion thresholds and no geomorphological specific reports have been completed for Junction Creek. That being stated, through a review of material that other disciplines have also examined, the Team identified several reports that do contain observations relevant to geomorphology which were used in the characterization.

Furthermore, it was determined that while sufficient hydrogeological data was available to facilitate a conceptual groundwater model for the Junction Creek subwatershed, there was limited information on the surficial geology data. In addition to this, the required hydraulic modelling data was partially available but lacked information regarding the water crossing structures (culverts and bridges) of the tributary watercourses.

In accordance with the findings of the Existing Information Review and Gap Analysis (Amec Foster Wheeler, April 2017), the disciplines that were determined to have data gaps and required supplementary data collection efforts to complete the characterization were the geomorphology, hydrogeology and hydrologic modelling of the Study Area. The gap analysis resulted in the following main tasks to fill gaps: perform a geomorphological field survey of Junction Creek, obtain the information required to complete the hydraulic model, and complete the extraction of borehole and monitoring well stratigraphy data from previous Wood project reports.

2.2 Field Investigations

Following the Existing Information Review and Gap Analysis (Amec Foster Wheeler, April 2017), additional data collection was recommended to assist with a complete characterization of the existing conditions (**Section 3**) where there may have been a lack of existing information, and to identify the specific site conditions that may have a direct bearing on the planning, size, location and implementation of mitigation approaches within the sub-watershed. It was determined that field investigations be completed to obtain necessary information regarding the geomorphologic conditions of the Study Area.

Through the desktop review of current data and studies, it was determined that there were very limited specific geomorphological observations available for the Study Area. In accordance with these findings, field investigations were conducted in order to better characterize Junction Creek and the specific reaches that were highlighted as “Tributaries for Hydraulic Modelling/Floodway Analysis” within the Terms of

Reference. The Reference Material provided by the CGS within the Terms of References were requested for the purpose of characterization.

Wood and GEO Morphix hosted a training seminar in Sudbury on April 26, 2017 to provide students with practical field skills in river sciences, including field measurement related to geomorphology, sedimentology, in stream aquatic ecology, proper data recording, interpretation, and quality control. All Wood employees and interns (i.e. students) also received CGS safety training offered through NORCAT prior to initiation of any field data collection activities. Following this training, Wood personnel, along with the interns, were deployed to complete additional work to refine the reaches utilizing the knowledge gained from the seminar and training session.

The collection of systematic observations with regards to physical characteristics, sensitivity to erosion, and long-term adjustments was completed on a reach scale. Through the application of the Ontario Ministry of the Environment's (2003) Rapid Geomorphic Assessment (RGA), reach observations and channel measurements were collected over several days in May 2017 to quantify the channel stability for reaches located on public lands within the CGS. Additionally, the Rapid Stream Assessment Technique (RSAT) was employed to provide a broader view of the system and consider the ecological functioning of the watercourse (Galli, 1996). Given that aquatic habitat data is lacking for the lower Junction Creek subwatershed, downstream of Kelly Lake, additional aquatic habitat information was also collected as part of the fluvial geomorphology field surveys conducted by the project team. Additional information related to barriers and impoundments was also collected during the field surveys by the project team. The results of this field investigation are presented in **Section 3.6**.

During the Hydrologic and Hydraulic (H & H) modelling efforts, information gaps were identified among the crossing structure and sewer pipe as-builts and construction drawings provided by the CGS. In order to appropriately fill the gaps and complete the H & H modelling accordingly, a change order request was submitted to the CGS on August 22, 2017 to obtain these missing data from the field. Pelto Consulting was retained to conduct the additional surveying, which was comprised of forty-one (41) water crossing structures, and twelve (12) sewer pipe systems.

3.0 SUBWATERSHED CHARACTERIZATION

3.1 General

As stated in **Section 2.1**, the gap analysis was performed to create a list of data available and to determine what information was lacking and necessary to complete the Junction Creek Subwatershed Study and Master Plan. The Background Characterization compiles findings from the previously noted reports and studies and characterizes the Junction Creek Subwatershed based on the following study disciplines:

- Natural Heritage System;
- Surface Water and Drainage Characteristics;
- Water Quality;
- Groundwater Characteristics and Water Balance; and,

- Fluvial Geomorphologic Assessment.

3.2 Natural Heritage System

The natural heritage characterization and analysis was focused on the Upper Junction Creek Subwatershed, extending from the upstream extent of Kelly Lake to the headwaters of the Garson Branch. Some high-level data were available for the Lower Junction Creek Subwatershed, including Kelly Lake, consisting of herpetofauna and mammal species lists and occurrences, and general descriptions in some natural environment studies. Detailed species lists, as well as species- and region-specific studies tended to focus on the Upper Subwatershed. As such, detailed characterization of natural features and wildlife habitats has been restricted to the Upper Subwatershed where sufficient data is available to complete detailed analyses. The Subwatershed is subdivided at several scales relevant to each field of study and analysis. For the purposes of the natural heritage characterization and analysis the study area refers to the Upper Junction Creek Subwatershed, upstream of Kelly Lake, as shown on **Figure B2** (refer to **Appendix 'B'**). This study area has been broken out into 3 sections for the description and analysis of natural features, habitats, and their sensitivities. These sections include the upper, middle and lower sections that are associated with refer to smaller portions within the subwatershed upstream of Kelly Lake as described below. The Study Area, refers to the larger Subwatershed as described in Section 1.0.

The upper section consists of the main stem of Junction Creek upstream from the Ponderosa Provincially Significant Wetland (PSW), including the Garson and Maley Branches. The middle section includes the main stem of Junction Creek between the inlet to the underground portion of the creek and the eastern extent of the Ponderosa PSW, including the Frood Branch. The lower section includes the main stem of Junction Creek from the outlet of the underground portion of the creek to the inlet to Kelley Lake and incorporates Nolin Creek and Copper Cliff Creek

3.2.1 Terrestrial and Wetland Resources

Background data sources indicate that the Junction Creek Subwatershed, upstream of Kelly Lake, is representative of the range of habitats found within the eco-region, with flora and fauna of both southern and northern affinities. Background studies within the Subwatershed are relatively diverse in their coverage, with comprehensive data from atlas projects for all major taxa found in Ontario, such as birds (BSC *et al.* 2008), herpetofauna (Ontario Nature 2016), Lepidoptera (Jones *et al.* 2016), Odonata (Ontario Ministry of Natural Resources 2005), and mammals (Dobbyn 1994).

Species and region-specific studies are also representative of the region, with several planning policies and natural heritage studies that inform the terrestrial ecology of the Subwatershed, upstream of Kelly Lake. The Greater Sudbury Natural Heritage Report (CGS 2013) and the CS Watershed Inventory (NDCA 1980) provide pertinent, region-specific studies and provide context from on the ground local sources.

Schedule 3 of the CGS's Official Plan (CGS 2016) indicates that Provincial and candidate Regional or Local Candidate Areas of Natural and Scientific Interest (ANSI) are present within the Junction Creek

Subwatershed. Although these areas are earth science, not life science ANSIs, the features and any natural habitats associated with them will be considered in the management of the subwatershed.

Provincial Earth ANSI's within the Study Area include:

- Kelly Lake Shatter Cones;
- Lively-Elsie Mountain Formation;
- Sudbury B-Norite;
- Sudbury A-Norite; and,
- McCrea Heights South Range Norite.

Candidate regional and local ANSI's within the Study Area include:

- Robinson Lake-Ramsey Lake Pecors Formation;
- Ramsey Lake Shatter Cones; and,
- Murray Mine Discovery Site.

3.2.1.1 *Flora and Fauna*

An integration of background information sources resulted in the identification of the following species from the Subwatershed: 174 birds (Appendix B-I), 25 herpetofauna (Appendix B-II), 52 Lepidoptera (Appendix B-III), 48 mammals (Appendix B-IV), and 16 Odonates (Appendix B-V).

A Species at Risk (SAR) and Species of Conservation Concern (SCC) screening was completed as part of the background review. This screening compares the species reported from the Subwatershed to natural features and areas that are present to determine the suitability of habitat and likelihood that SAR and SCC are present. The SAR and SCC screening is provided in Appendix B-VII.

Approximately 28 SAR (including 1 complex) and provincially tracked species are reported within the Junction Creek subwatershed, as follows:

- 5 species of herpetofauna (including 1 complex),
    - Snapping Turtle (*Chelydra serpentina serpentina*);
    - Blanding's Turtle (*Emydoidea blandingii*);
    - Northern Map Turtle (*Graptemys geographica*);
    - Massassauga Rattlesnake (*Sistrurus catenatus*); and,
    - Jefferson/Blue-spotted Salamander Complex (*Ambystoma* hybrid pop. 3).
- 19 birds (including 16 breeding species),
    - Eastern Whip-poor Will (Antrostomus vociferus);
    - Short-eared Owl (Asio flammeus);
    - Canada Warbler (Cardellina canadensis);
    - Chimney Swift (Chaetura pelagica);
    - Common Nighthawk (Chordeiles minor);
    - Olive-sided Flycatcher (Contopus cooperi);

  - Eastern Wood-Pewee (Contopus virens);
  - Bobolink (Dolichonyx oryzivorus);
  - Peregrine Falcon (Falco peregrinus anatum/tundrius);
  - Bald Eagle (Haliaeetus leucocephalus);
  - Red-headed Woodpecker (Melanerpes erythrocephalus);
  - Barn Swallow (Hirundo rustica);
  - Red-necked Grebe (Podiceps grisegena);
  - Bank Swallow (Riparia riparia);
  - Eastern Meadowlark (Sturnella magna); and,
  - Golden-winged Warbler (*Vermivora chrysoptera*).
- 2 mammals
  - Northern Myotis (Myotis septentrionalis); and,
  - Little Brown Myotis/Bat (*Myotis lucifugus*).
- 3 Butterflies
  - Western Tailed Blue (*Cupido amyntula*);
  - Monarch (*Danaus plexippus*); and,
  - Red-disked Alpine (*Erebia discoidalis*).

The preferences of these species cover a wide range of habitat types ranging from open meadows to mature woodlands, wetlands of various types, etc. As discussed below, conservation of these significant species will require consideration of a broad range of habitat types.

3.2.1.2 *Vegetation Communities*

Based on the CGS's historic challenges with acid rain and the associated negative impacts to the natural environment (Pearson *et al.* 2002), re-greening initiatives completed since 1978 have been highly effective in their mandated goal of restoring the natural environment within the CGS. The interactive re-greening application provided by the CGS (2017a) and its community partners provides an overview of the natural areas restored to-date, with forest cover comprising approximately 57% of the CGS (CGS 2013).

The Junction Creek Subwatershed supports a range of natural habitats including woodlands, and wetlands. Early succession habitats are also found scattered throughout the Subwatershed. The habitats within the subwatershed are well-connected to habitats outside the Subwatershed. The natural areas in the Subwatershed consist of large blocks of upland habitats, especially in the northeast and southwest, as well as some riparian habitats associated with the watercourses. Each is described below.

3.2.1.3 *Wetlands*

Within the CGS limits, wetlands comprise approximately 9% of the land base, with only one PSW and other significant features found throughout the Junction Creek Subwatershed. The Ponderosa PSW and other significant features were identified using available mapping from the Ministry of Natural Resources and Forestry (MNRF), Land Information Ontario (LIO) source. Inventory mapping has been completed to-date by MNRF (2017) and the CGS. Although wetlands represent only 10% of land coverage, they are an important component of the ecology within the Junction Creek Subwatershed. Under the Ontario Ministry of Municipal Affairs and Housing's (OMMAH) Provincial Policy Statement (PPS) (OMMAH 2014), wetlands and 'sensitive water features' are respectively defined as:

> Wetlands: *"lands that are seasonally or permanently covered by shallow water, as well as lands where the water table is close to or at the surface…The four major types of wetlands are swamps, marshes, bogs, and fens."*
>
> Sensitive Water features: *"ecologically important in terms of features, functions, representation or amount, and contributing to the quality and diversity of an identifiable geographic area or natural heritage system."*

Based on these definitions, numerous primarily unevaluated wetlands are mapped in the Subwatershed (MNRF 2017). The relatively large wetlands associated with Ramsey, Robinson, and Kelly Lakes, Junction Creek (specifically the Ponderosa wetland that provides an important linkage within CGS limits, deemed Provincially Significant by the MNRF in fall 2017) and the area to the north and west of Lively, form the most substantial features within the Junction Creek Subwatershed. The large size and good connectivity of these wetlands to other natural features within the Subwatershed add to the significance of these features and their ecological function (Appendix B).

Wetlands provide important habitat for several significant species found within the Junction Creek Subwatershed, such as Blanding's Turtle (*Emydoidea blandingii*), Northern Map Turtle (*Graptemys geographica*), Snapping Turtle (*Chelydra serpentina serpentina*), and Red-necked Grebe (*Podiceps grisegena*), among others.

3.2.1.4 *Wooded Areas*

Within the Junction Creek Subwatershed, large blocks of forest occur in two general areas: the northeast (loosely bounded by the former Town of Nickel Centre to the southeast, and roads 71, 73, and 86 to the south) and southwest (west of Lively and north of Hwy. 17). Scattered throughout these two forested areas are numerous small wetlands that further enhance the biodiversity and ecological function of these regions. These large forested blocks are particularly important due to interior habitat they provide for sensitive species, as well as the connectivity they provide to other features within the Subwatershed. Bird species reported from the Junction Creek watershed that are commonly found in large wooded areas include Eastern Whip-poor Will and Eastern Wood-Pewee. Of the 28 SAR and SCC species identified within the watershed, Canada Warbler is the only species that has a particular preference for interior habitat. Other woodland species include Blanding's Turtle, Little Brown Myotis (Little Brown Bat), and Northern Myotis. Within the CGS, 57% of land cover is comprised of forested areas. The composition is relatively diverse, indicating that the region is heavily mixed in its tree species composition (i.e. deciduous, coniferous, and mixed forests) (NDCA 1980 and CGS 2013).

3.2.1.5 *Riparian Areas*

Riparian zones can form linkages between terrestrial and aquatic environments that are potentially used by wildlife to move throughout the Subwatershed, and beyond, and provide corridors for the dispersal of plants. These riparian zones filter out contaminants, sediment, noise, and light inputs by providing a buffer to aquatic and wetland environments. Although there are existing riparian zones along the large wetlands, creeks (e.g., Junction Creek) and lakes (e.g., Ramsey, Robinson, and Kelly Lakes), in many areas the riparian areas are degraded, thereby limiting the current ecological contribution of these features.

3.2.2 Aquatic Resources

3.2.2.1 *Overview*

Aquatic habitat throughout the Upper Junction Creek Subwatershed has been historically well-documented. Historical logging, mining and smelting operations, pollution, shoreline alteration, and construction of impoundments have contributed substantially to the deterioration of aquatic conditions within the lakes and tributaries throughout the Subwatershed (Gorzynski 2000, Gunn *et a*l. 2010, Natho and Freeman 2006, NDCA 1980, Woods 2017, and Pearson *et al.* 2002). The impacts of these activities, including warming of Junction Creek and its tributaries and poor water quality conditions in tributaries and connecting lakes, have resulted in a decrease in benthic invertebrate and fish community abundance and diversity. On-going restoration efforts have been focused on the rehabilitation and improvement of aquatic conditions within the main stem of Junction Creek and its connecting tributaries (JCSC 2009, Natho and Freeman 2006). Monitoring programs and community outreach initiatives have also been implemented to study and address water quality concerns, including eutrophication and acidification, within CGS lakes (CGS 2016c, Vale Living with Lakes Centre 2016).

The existing aquatic habitat is variable throughout the upper, middle and lower sections of the study area. Generally, the main stem of Junction Creek is a low-gradient system characterized by relatively slow moving run habitat over fine substrates (i.e. silt and sand) with a vegetative cover of submergent macrophytes, particularly throughout the upper portion and in the vicinity of the Ponderosa PSW. Riffle habitat and rocky areas are also noted throughout the middle and lower sections of the main stem (Lemieux et al 2004, Sein 1993) upstream from Kelly Lake. The CGS contains the highest number of lakes found in any municipality in Canada (CGS website, 2018). Both warm and coldwater lakes are found throughout the Junction Creek Subwatershed, with the majority of lakes existing south and west of the CGS. However, many of these lakes exhibit relatively high levels of phosphorus that is generally indicative of eutrophication (CGS 2016c). Erosion and elevated metal concentrations have also impacted the chemistry and biology of these lakes (Pearson *et al.* 2002).

North of the CGS the Subwatershed is comprised mainly of coldwater tributaries that flow generally south or southwest into the main stem of Junction Creek (Woods 2017). These features include the Garson Branch, Maley Branch, Frood Branch, and Nolin Creek. The main stem of Junction Creek, which originates as part of the Garson Branch, flows southwest as a coldwater feature through the CGS and enters into a concrete culvert and flows underground between Lloyd Street and Elgin Street. Junction Creek is characterized as a warmwater feature from where it exits the underground pipe, downstream to where it outlets to the Vermillion River, outside the limits of the Junction Creek Subwatershed study area. Houle et al. (2007) indicated that water temperatures generally increase as water moves downstream, reflecting the solar impacts due to a lack of shade, the limited groundwater inputs, and the increased effects of urbanization in the downstream areas. West of Kelly Lake the main stem of Junction Creek flows northwest through several large warmwater lakes including Mud Lake, Simon Lake and McCharles Lake and eventually enters the Vermillion River at the western extent of the Subwatershed. A tributary flows from the southwest and connects several other lakes including Whitefish Lake, Wakemi Lake and Nemag Lake. This branch of the Subwatershed also occurs within the boundaries of the Atikameksheng Anishnawbek (Whitefish Lake 6) First Nation.

3.2.2.2 *Fish Species*

Background data indicate that the fish communities within the Junction Creek Subwatershed have been improving over recent years (JCSC 2009, Lemieux *et al.* 2004, Woods S. 2017) including the recent recolonization of Nolin Creek over the past several years by a few common minnow species (Woods 2017). The fish community throughout the main stem of Upper Junction Creek and its connecting tributaries is characterized by a variety of coolwater and warmwater fish species known to be relatively common throughout northern Ontario (Lemieux *et al.* 2004, Sein 2004). The fish community is also noted to have a higher diversity and abundance throughout the upper and middle portions of Junction Creek, upstream from where the main stem is diverted below downtown Sudbury. The species noted throughout the Upper Junction Creek and its tributaries are primarily small-bodied fishes that typically act as forage for recreationally-important species (Appendix B-VI). Based on background data, these features do not appear to support a substantial recreational fishery.

The warm and coldwater lakes found throughout the Junction Creek Subwatershed provide habitat for a variety of warm and coldwater fish species, including many recreationally important species. Several of the fish species present provide sport fishing opportunities including largemouth bass (Micropterus salmoides), smallmouth bass (Micropterus dolomieu), lake trout (Salvelinus namaycush) and Brook Trout (Salvelinus fontinalis) (Appendix B-VI). However, walleye (Sander vitreus) is considered to be the most sought after (CGS 2013).

As part of the efforts to rehabilitate the Upper Junction Creek, the JCSC has undertaken an annual Brook Trout stocking event in partnership with the Ontario Ministry of Natural Resources and Forestry (OMNRF). Since the year 2000, 8,600 Brook Trout have been released into Junction Creek, including 1,000 released at several different locations in New Sudbury (JCSC 2009). Suitable Brook Trout habitat is available throughout the main stem of Junction Creek, particularly in the vicinity of Donnelly Road within the Garson Branch. Further efforts to rehabilitate the creek and improve thermal conditions will benefit Brook Trout in the future. Brook Trout have been captured within the main stem of Junction Creek during past fish community surveys (Lemieux *et al*. 2004) and more recent sampling events as recent as 2016.

3.2.2.3 *Benthic Macroinvertebrate Species*

Background data indicate that the benthic community throughout the Junction Creek Subwatershed has been historically impaired due to mining and smelting activities and an increase in impervious cover and decreasing riparian cover (Jaagumagi and Bedard 2002, Davidson and Gunn 2012, and Pearson *et al.* 2002). The most heavily affected benthic communities appear to be within the Frood Branch, Nolin Creek and Copper Cliff Creek (Johnson and Owen 1966), which exhibit a limited density and diversity, with only a few tolerant taxonomic groups present. Many of the lakes exhibit metal contamination and acidification, which caused reductions or losses of a variety of sensitive species (Keller and Gunn, undated). Land-use changes have resulted in improvements in water quality, which has caused improvements to the benthic community, specifically within the Frood Branch where acid mine drainage from the Frood Mine was dammed and diverted away from the creek (Gunn *et al.* 2010, Waberi 2002). Reductions in atmospheric emissions from smelting operations have also benefitted the benthic communities. Data indicate that the benthic communities within the Junction Creek Subwatershed are more diverse and dense (Johnson and Owen 1966, Keller and Gunn, undated, and Pearson *et al.* 2002), although still impaired.

3.2.2.4 *Interpretation of Information and Data*

The Junction Creek Subwatershed contains a variety of aquatic features that are considered 'sensitive water features' under the PPS (OMMAH 2014). The main stem of Junction Creek and its inflowing tributaries provide intrinsic value to the CGS, and ecological importance to the surrounding landscape and the aquatic systems downstream. The PPS further identifies 'sensitive' as "areas that are particularly susceptible to impacts from activities or events including water withdrawals and the addition of pollutants". Historically, the aquatic habitat within the Junction Creek Subwatershed has experienced substantial degradation and deterioration of water quality, which has been reflected in the loss of fish and benthic invertebrate diversity and abundance. The primary driver for this has been the addition of pollutants (e.g. sewage) from the CGS, as well as effluent from smelting and mining operations, particularly along the headwaters of the Frood Branch and Copper Cliff Creek. Rehabilitation efforts are ongoing and focused on addressing these issues.

The following information provides discussion on the existing state of the aquatic features within the Subwatershed based on the upper, middle, and lower sections of the natural heritage study area.

Upper Junction Creek Subwatershed

The upper section consists of the main stem of Junction Creek upstream from the Ponderosa PSW, including the Garson and Maley Branches. The upper section of study area has been shown to support the most abundant and diverse fish community throughout the Junction Creek Subwatershed. The most abundant and diverse fish community is present in the upper reaches of the Garson Branch (upstream from Robin Street) and in the vicinity of Attlee Avenue. The Maley Branch, which outlets to the main stem just east of Lansing Avenue was noted to support a similarly rich fish community. This fish community is represented by a variety of common small to medium bodied fishes that exhibit a range of thermal preferences from warmwater to coldwater (Appendix B-VI). These stretches are located upstream from majority of the historic stressors (i.e. smelting and mining effluent, urbanization etc.) that have negatively affected the water quality and aquatic habitat throughout Junction Creek. Based on this, it is likely that this section of the Subwatershed has been the least affected and still maintains relatively high-quality habitat compared to the rest of the Subwatershed. The habitat in the upper section is dominated by low-gradient runs over soft substrates (mainly silt and sand). Some riffles are present, which are typically associated with small cobble, gravel and sand substrates. Pools over 1.0 m deep were observed by GEO Morphix during field surveys conducted in Spring 2017. Undercut banks, overhanging trees and vegetation, and woody debris provide a moderate level of cover for the fish community. See **Section 3.6** for more information on channel characteristics.

Several impoundments and potential barriers are located throughout the upper section of the study area. These features may affect the movement of fish throughout the system and have the potential to limit the recolonization of Brook Trout in the upper reaches of the system. These include the Maley Dam, located on the Maley Branch approximately 2.4 km upstream from its confluence with the main stem, several natural Beaver (*Castor canadensis*) dams, and the ponds located at the Cedar Green Golf Course. The Beaver dams and the Maley Dam are noted to increase instream water temperatures while the impoundments at the Cedar Green Golf Course had a cooling affect (Gorzynski 2000).

One of the main rehabilitation initiatives for Junction Creek is focused on re-establishing Brook Trout through stocking. Brook Trout generally prefer water temperatures below 20°C (Scott and Crossman 1973). Water temperatures in the upper section (Maley Branch and Garson Branch) are noted to be the lowest throughout the Subwatershed and have been found to increase moving downstream from the Maley Branch to the outlet of Junction Creek into Kelly Lake (Houle *et al*. 2007). The cooler water temperatures in the upper section are maintained through groundwater input, deep pools and a relatively high amount of overhanging bank vegetation (Gorzynski 2000) compared to the middle and lower sections. However, even though the upper section maintains the lowest water temperatures, summer temperatures exceed 20°C for part of the season (Houle *et al*. 2007). Another factor that may limit the reintroduction of a self-sustaining Brook Trout population is the availability of spawning habitat. The upper section of Junction Creek and the Maley Branch are dominated by run habitat over soft substrates while Brook Trout require areas of cool, well-oxygenated water over gravel and adjacent to areas of groundwater input (Scott and Crossman 1973). Currently, it is unknown if appropriate spawning locations are present within the Junction Creek Subwatershed.

Middle Junction Creek Subwatershed

The middle section includes the main stem of Junction Creek between the inlet to the underground portion of the creek and the eastern extent of the Ponderosa PSW, including the Frood Branch. The middle section of the study area, specifically throughout the Ponderosa PSW, supports an abundant and diverse fish community that is similar to the upper section (Sein 1993). The Frood Branch, which flows into the main stem of Junction Creek, supports a smaller fish community compared to that of both the main stem of Junction Creek in the study area and the Maley Branch. The fish community throughout the middle section consists of a variety of common small to medium bodied fishes that exhibit a range of thermal preferences from warmwater to coldwater (Appendix B-IV). No Brook Trout have been observed to date within the middle section of the study area even though aquatic conditions are suitable to support them for at least part of the year.

Iron staining was observed throughout the middle section of the main stem of Junction Creek and the Frood Branch, indicating groundwater input. Even though groundwater will have a cooling effect, summer water temperatures have still been shown to exceed the preferred thermal preference for Brook Trout (Houle *et al*. 2007). The aquatic habitat in the middle section is mainly dominated by slow moving, low-gradient runs over soft substrates (mainly silt and sand), particularly within the Ponderosa PSW that exists between the Frood Branch confluence and Arthur Street (Lemieux *et al*. 2004). Pools over 1.0 m deep were observed by GEO Morphix during field surveys conducted in 2017. Riffle habitat is present downstream from the Frood Branch confluence where the main stem of Junction Creek flows south parallel to Notre Dame Avenue. At these locations, substrate includes gravel, cobble and boulder, in addition to the predominantly finer substrates. Aquatic vegetation, pools, and woody debris provide a moderate level of cover for the fish community in addition to the rocky substrates, where present. The Frood Branch exhibits similar characteristics to that of the main stem of Junction Creek, downstream from the Ponderosa PSW. See **Section 3.6** for more information on channel characteristics.

The main impoundment located within the middle section of the study area is the Nickeldale Dam, located on the Frood Branch approximately 2.2 km upstream from its confluence with the main stem. Along the Frood Branch, the creek also flows underground through a concrete culvert below Lasalle Blvd. and a parking lot for a distance of approximately 170 m. This culvert likely limits fish movement upstream and downstream. Active Beaver dams have also been observed along the main stem of Junction Creek, particularly within the Ponderosa PSW. These features are not expected to significantly limit fish movement along the main stem of the creek. The Nickeldale Dam is noted to increase water temperatures within the Frood Branch (Gorzynski 2000).

Benthic data available for the middle section of the study area indicates an impaired but improving benthic community (Waberi 2002 and Gunn *et al.* 2010). Historically, acid mine drainage was occurring directly into the Frood Branch, which created toxic conditions that were reflected in the benthic community (Johnson and Owen 1966). This acid mine drainage was diverted from the creek in 2000 and even though a rapid re-colonization of many families of benthic invertebrates was observed the creek was still noted to be heavily impaired for over 8 years following the diversion (Gunn *et al.* 2010). Overall, the diversion improved water quality in the Frood Branch and had a positive effect on the benthic invertebrate community downstream (Waberi 2002). Conditions continue to improve.

Lower Junction Creek Subwatershed

The lower section of the study area includes the main stem of Junction Creek from the outlet of the underground portion of the creek to the inlet to Kelley Lake and incorporates Nolin Creek and Copper Cliff Creek. The lower section has experienced the greatest level of degraded water quality due to the variety of stressors that exist upstream and compound to affect the main stem of Junction Creek. Urbanization as well as the smelting and mining operations along Copper Cliff Creek, Nolin Creek, and the Frood Branch (middle section) have played major roles in the degradation of water quality throughout lower section. Poor water quality conditions are reflected in the fish and benthic communities. The fish community in the main stem of Junction Creek between Kelly Lake and the underground pipe outlet is known to be much less diverse and abundant than the middle and upper sections of the Subwatershed (Sein 1993 and Lemieux *et al*. 2004) and is even less so within Copper Cliff Creek and Nolin Creek (Appendix B-VI).

There is evidence that the fish community throughout the lower section is improving (Lemieux *et al*. 2004). Recent surveys have indicated that several coolwater fish species have started to re-colonize Nolin Creek (Woods 2017) including creek chub (*Semotilus atromaculatus*), golden shiner (*Notemigonus crysoleucas*), and white sucker (*Catostomus commersonii*). The lower portion of the main stem of Junction Creek is also likely to provide habitat for species reported from Kelly Lake, including recreationally important species such as northern pike (*Esox lucius*) and yellow perch (*Perca flavescens*). Refer to Appendix B-VI for a list of fish species reported to occur in Kelly Lake. The aquatic habitat throughout the lower section of the study area transitions from run and riffle habitat over silt, sand, gravel and cobble substrates to slow-flowing run habitat over silt and sand as it nears its outlet to Kelly Lake. The lower portion mimics the existing lake habitat where it is inundated.

Pools over 1.0 m deep were observed throughout the lower section by GEO Morphix during field surveys conducted in 2017. These field surveys also identified a high level of bank erosion throughout the lower section. Iron staining was observed during the 2017 field surveys, indicating groundwater inputs. However, the lack of shading and warm runoff from the surrounding urban landscape maintain the highest water temperatures observed throughout the Subwatershed, which are well above the preferred range for Brook Trout (Houle *et al*. 2007).

Benthic data available for the lower section of the study area indicate a general lack of sensitive taxa within Copper Cliff and Nolin Creek; a result of the historically toxic and poor conditions within these creeks (Johnson and Owen 1966). Changes in land use practices and overall improvements in the water quality throughout the Junction Creek Subwatershed will have a positive impact on the benthic community within the lower section and Kelly Lake. Improvements have already been noted within the Frood Branch, which will positively impact the main stem of Junction Creek downstream (Waberi 2002 and Gunn *et al*. 2010).

Fish movement throughout the lower section is limited by a variety of features including active Beaver dams along Junction Creek, as well as many culverts and dams along Copper Cliff creek and Nolin Creek. The confluence of Nolin Creek to the main stem is located along the underground piped section on the creek that flows under the CGS. This is expected to limit fish movement. Mine effluent is also expected to restrict fish movement into and through Copper Cliff Creek and Nolin Creek due to poor water quality conditions.

City of Greater Sudbury Lakes

Both warm and coldwater lakes are found throughout the Junction Creek Subwatershed, with the majority of lakes existing south and west of the CGS. Many of these lakes exhibit relatively high levels of phosphorus that is generally indicative of eutrophication (CGS 2016c). Spring phosphorus levels have been monitored as part of an annual Lake Water Quality Program in forty (40) lakes across the CGS between 2001 and 2016. Of the lakes sampled, seven (7) lakes have regularly shown phosphorus concentrations greater than the Interim Provincial Water Quality Objective of 20 µg/L (micrograms per litre). Three of those lakes (Mud Lake, Simon Lake, and McCharles Lake) are downstream of Kelly Lake and are connected by Junction Creek. Bethel Lake and Minnow Lake connect to Ramsey Lake (CGS 2016c) and are located within the middle section of the study area. The other two lakes are Robinson Lake, which Ramsey Lake flows into via Junction Creek, and Kelly Lake (Hutchinson Environmental Sciences Ltd. 2013).

Numerous CGS and community initiatives have been implemented to better understand the lake ecosystems and stressors affecting them, with a focus on phosphorus levels. Lake residents and lake stewardship groups are actively involved in a variety of community lake monitoring programs, while CGS initiatives have included the Shoreline Home Visit Initiative, the Water Gatherings and Living with Lakes Forum, and the Lake Water Quality Monitoring Program.

Erosion, acidification, and elevated metal concentrations have also impacted the chemistry and biology of lakes within the Subwatershed (Keller and Gunn, undated, and Pearson *et al.* 2002). Changes in land-use practices and reductions in smelting emissions have resulted in improvements in lake water quality, which have been shown to benefit the fish and benthic communities. To address acidification in a number of lakes and the surrounding landscapes, the CGS's Land Reclamation Program and more current Re-Greening Program applied lime treatments between 1978 and 2011, which helped to increase alkalinity and decrease metal concentrations in the lakes and surrounding soils (CGS 2017a, Lautenbach 1985, and Pearson *et al.* 2002).

3.2.2.5 *Summary of Aquatic Significant Features*

The upper, middle, and lower sections of the natural heritage study area offer a variety of aquatic habitat types that support a variable fish and benthic community. Generally, aquatic habitat conditions are considered to be good throughout the upper section, deteriorating downstream to the lower section where water quality and habitat conditions are more impaired. The following points describe the sensitive features and features known to limit aquatic habitat improvements throughout the Junction Creek subwatershed study area:

- The upper section of the study area has been identified as the most likely area to support a Brook Trout population due to the lower summer water temperatures, available habitat, and available forage base. This section also experiences less stress on water quality due to its proximity upstream from the City Centre and upstream from the existing mine and smelting operations.
    - Although summer water temperatures exceed the preferred range for Brook Trout, there is potential to improve thermal conditions by improving riparian cover and shading.
- Riparian cover is generally lacking throughout the Upper Junction Creek subwatershed but where it is available it is provided by overhanging grasses, aquatic vegetation, and a combination of trees and shrubs along the banks. The lack of riparian cover is a concern primarily as it relates to increases in water temperature from solar radiation. This becomes more important moving downstream as water temperatures continue to warm as a result of urbanization and run-off.
    - The upper section is expected to maintain cooler water temperatures because of groundwater inputs; however, it is still important to provide shading throughout this section to mitigate the impacts from compounding solar radiation that will warm temperatures downstream.
    - Iron staining was identified throughout the upper, middle, and lower sections, indicating groundwater contributions throughout the subwatershed. However, temperatures are still known to increase moving downstream, a result of a lack of shading as well as urban runoff and warming from dams and impoundments.
- Several dams and impoundments occur throughout study area. The Maley Dam and Nickeldale Dam are the two most substantial features, located within the upper and middle sections of the study area. These features are known to increase water temperatures and prevent fish movement. Many active Beaver dams are also present throughout the upper, middle, and lower sections. These features are likely to increase water temperatures and inhibit fish movement.
- Wetlands are known to improve water quality and provide a cooling effect on watercourses. Within the middle section of the study area the main stem of Junction Creek flows through the Ponderosa PSW. This feature supports a diverse and abundant fish community.

- The Junction Creek Subwatershed includes a substantial number of lakes that provide important recreational opportunities for residents and visitors, which includes fishing and boating. Improving water quality in the lakes is an important consideration that will benefit lake health and maintain these recreational opportunities. Historic and current Phosphorus levels in many lakes show significantly high levels and, in several cases, are well above the Interim Provincial Water Quality Objective of 20 µg/L. Many of the lakes with the highest levels are in the lower Subwatershed and downstream of Kelly Lake.

Limitations exist throughout the Subwatershed that may inhibit improvements within Junction Creek and its tributaries, specifically urbanization, which limits the available area for physical improvements adjacent to the watercourses and lakes. However, water quality conditions are improving as evidenced through improvements in the fish and benthic communities. Conditions will continue to improve following the various land use changes and on-going rehabilitation initiatives and monitoring programs that have been established.

3.3 Surface Water and Drainage Characteristics

3.3.1 Importance / Purpose

Hydrologic and hydraulic models are developed for urban subwatersheds to provide a better understanding of the amount and movement of water in the system under existing land use and proposed future land use conditions, as well as to analyze various Stormwater Management Plan alternatives, based upon the physical conditions in the subwatershed. By developing representative models that reasonably predict seasonal and storm-based runoff response, the impacts of proposed future urbanization can be better quantified and thereby appropriate integrated management strategies can be established.

3.3.2 Background Information

Numerous reports have been provided as reference material for characterizing the hydrology within the subwatershed, as well as the overall study area. The following summarizes the key sources of information:

- Storm Drainage Report for the City of Sudbury (Dillon and Lewis Ltd. April 1964);
- Junction Creek Watershed Report (M.M. Dillon Limited May 1969);
- Watershed Inventory (NDCA September 1980);
- Flood Plain Mapping of Junction Creek (Kilborn Limited November 1980);
- Junction Creek Watershed Management Study (Northland Engineering Limited October 1982);
- The Ponderosa (Dewit+Castellan Architects Inc. August 1988); and,
- Junction Creek Water Management (S.A. Kirchhefer Limited October 2000).

In addition to the foregoing information that provides an overview of the hydrologic and hydraulic conditions within the Junction Creek Subwatershed, various stormwater management as-built and construction drawings (in the order of 5,000) have been provided specifically for reference and use in this study. Other important infrastructure information includes dam drawings, photos, and information regarding overland systems, creeks/bridges, and the downtown box culvert.

The following mapping has been provided and used for the baseline characterization and assessment of the surface water hydrology and hydraulics in the Junction Creek Subwatershed Area:

- The CGS provided Wood with map data for all seven (7) map data areas, which included a Topographic file with contours and spot elevations, ortho-rectified imagery, and a Digital Terrain Model (DTM) with roads, stream, lakes, etc. The data was provided in the Universal Transverse Mercator (UTM) coordinate system (NAD 83 CSRS Zone 17), with a horizontal and vertical accuracy of ±30 cm, in AutoCAD file format (.dwg), and ortho-imagery in TIF with TFW file format and a scale of analogue aerial photography of 1:6,000, and 60 mm of Ground Sample distance (GSD) of digital aerial photography.
- A previous HEC-2 data model has been provided for review. A new model will be developed in an updated HEC-RAS environment.
- Different storm network GIS layers have been provided by the CGS (catch basins, manholes, inlets and discharge points, as well as the storm trunk sewer system of 900 mm and larger diameter pipes within 500 m of Junction Creek and identified main tributaries).
- A GIS layer with the geographic location of each as-built and construction drawings was provided by the CGS, as well as a road network layer.
- Pelto has completed cross sections of the creek and ground surveying to verify water crossing structures (culverts and bridges) at the four selected tributary watercourses to support the hydraulic modelling.
- Land Cover classification from Land Information Ontario (LIO) digital data warehouse (Web site: www.javacoeapp.lrc.gov.on.ca/geonetwork/srv/en/main.home). This provincial land cover classification is derived wholly from Landsat-7 Thematic Mapper (TM) satellite data frames recorded between 1999 and 2002, most from 2000 onward.

3.3.3 Methods / Analysis

3.3.3.1 *Baseline Characterization*

A baseline characterization of the hydrologic conditions within the Junction Creek Subwatershed area has been developed based upon a desktop review of the background information provided for this study. This review has characterized the existing drainage systems, soils, slopes, and land use conditions within the Subwatershed. For this characterization, twelve (12) main subwatersheds have been defined to comprise the Junction Creek subwatershed. These have been identified for hydrologic modelling purposes (refer to **Figure C1** in **Appendix 'C'**), as follows:

i. Main Branch of Junction Creek, conceptually subdivided into four (4) reaches:
    - from Garson to the Box Culvert Downtown;
    - from Nolin Creek to the Box Culvert Downtown;
    - from the Box Culvert downtown to Mud Lake; and,
    - from Mud Lake to the Vermillion River confluence.

ii. Five (5) major subwatershed tributaries have been identified upstream of Kelly Lake:
    - Maley Dam reach;

- Nickeldale Dam reach;
- Nolins Creek;
- Copper Cliff Creek; and,
- Robinson Lake, including Nepahwin Lake and Ramsey Lake (note that Ramsey Lake is the subject of an individual subwatershed study and is not addressed in this Study, as described previously).

iii. Downstream of Kelly Lake, two (2) major subwatersheds have been grouped:
   - Lively; and,
   - Whitefish Lake.

Note that the following two (2) subwatersheds have been modelled separately due to their size and since surface runoff and mine water is treated before it discharges to the environment (Junction Creek tributaries):

- Frood/Stobie Mine; and,
- Central Tailings.

As described in the sections below, the mine tailings areas of the subwatershed, notable the Frood/Stobie Mine and the Central Tailings, are routed through the Water Treatment Plant and do not contribute runoff directly to Junction Creek. Additionally, it was noted that a small area northeast of the Central Tailings surrounding Pump Lake was delineated on mine schematics but had not been included with the topographic LiDAR data, so this portion was manually added to the model.

A detailed flow schematic with all representative drainage elements of the study area is presented on **Figure C2** in **Appendix 'C'**.

3.3.3.2 *Storm Sewer Pipes*

As per the TOR, the storm trunk sewer network, which includes pipes with diameters of 900 mm and larger within 500 m of Junction Creek and its identified tributaries, forms the basis of the hydraulic modelled to establish the overall system capacity and potential needs for further analysis. The modelling analysis for this task applies the PCSWMM platform. PCSWMM is a fully dynamic hydrologic and hydraulic analysis software package, based on the US EPA SWMM model. This platform allows the development of dual drainage systems to be analyzed for existing and future conditions and for various storm events.

Based on the GIS layers provided by the CGS and a detailed background information review of approximately 5,000 as-built and construction drawings, 34 trunk storm sewer systems have been identified. The majority of these networks of trunk storm sewer systems are located on what is referred to as the Main Branch of Junction Creek, except for two (2) that are found on the Robinson Lake Subwatershed. The location of these trunk storm sewer systems is presented on **Figure C7** in **Appendix 'C'**, and **Table 3.3.1** presents a summary of their status following the initial background review and data characterization.

Table 3.3.1: **Trunk Storm Sewer Systems**

Area	Reference/ID	Initial Characterization
Garson	Garson Pond Outlet (G-1)	Missing invert elevation values: junctions (CB_98054, CB_98208, CB_102400); MH-Gar-11-11-0068; MHCB-GAR-11-11-0123.
New Sudbury	Lansing Ave. (NS-1)	Adequate for modelling
	Cambrian (NS-2)	Adequate for modelling
	LaSalle Blvd. 1 East (NS-3 E)	Adequate for modelling
	LaSalle Blvd. 1 West (NS-3 W)	Adequate for modelling
	LaSalle 2 / Roy Ave. (NS-4)	Adequate for modelling
	LaSalle 3 / Montrose Ave. (NS-5)	Adequate for modelling
	LaSalle 4 / Drummond Ave. (NS-6)	Adequate for modelling
	Alexander St. (NS-7)	Adequate for modelling
	Barry Down Rd (NS-8)	Adequate for modelling
	Canterbury (NS-9)	Missing invert elevation values: MHCB-NEE-01-01-0273; MH-NEE-01-01-0296; MH-NEE-01-01-0245; MH-NEE-01-01-0244; MH-NEE-01-01-0246.
Flour Mill Area	Notre Dame 1 / Patie St. (FM-1)	Adequate for modelling
	Notre Dame 2 / Cambrian Heights Dr. (FM-2)	Missing invert elevation values: MH-MCK-03-03-0063; MH-MCK-03-03-0062; MH-MCK-03-03-0061; MH-MCK-03-03-0060; MH-MCK-03-03-0059.
	Wilma St. (FM-3)	Adequate for modelling
	Notre Dame 3 / Burger King (FM-4)	Adequate for modelling
	St. George St. (FM-5)	Adequate for modelling
	Kathleen St. (FM-6)	Adequate for modelling
	Leslie St. (FM-7)	Adequate for modelling
	Rainbow Centre (FM-8)	Adequate for modelling
The Donovan	Donovan St (D-1)	Adequate for modelling
	Pine St (D-2)	Connection between MH-MCK-06-08-0132 and CB-MCK-06-08-0133_a is a 600mm pipe. Missing invert elevation values: ODP_1806; MHCB-MCK-06-08-0322; MH-MCK-06-08-0150; MH-MCK-06-08-0146; MH-MCK-06-08-0149; MH-MCK-06-08-0150; MH-MCK-06-08-0105.
Kingsway	Kingsway (DW-1)	Adequate for modelling
Downtown Area	Box Culvert (DW-2)	Missing elevations for the two entry points to the culvert and the exit point.
Gatchell	Lorne St. 1 / Douglas St. (GT-1)	Connection between MH-MCK-10-14-0152 and MH-MCK-10-10-0422 is a

Area	Reference/ID	Initial Characterization
		750mm pipe. Missing invert elevation values: MHCB-MCK-10-14-0172, MH-MCK-10-14-0152, MHCB-MCK-10-14-0153, MHCB-MCK-10-14-0172, ODP_123907.
	Lorne St. 2 / Byng St. (GT-2)	Connection between CB_580268 and Conduit 205841 is a 750mm pipe. Missing invert elevation values: MHCB-MCK-06-08-0226; MHCB-MCK-06-08-0246; MHCB-MCK-06-08-0254; MHCB-MCK-06-08-0255; MHCB-MCK-07-09-0437; MHCB-MCK-07-09-0437; MHCB-MCK-07-09-0455; MHCB-MCK-07-09-0456; MHCB-MCK-07-09-0458; MHCB-MCK-07-09-0459; ODP_123852.
	Lorne St. 3 / Bulmer Ave. (GT-3)	Missing invert elevation values: MHCB-MCK-10-14-0153; MHCB-MCK-10-14-0172; MHCB-MCK-10-14-0151; MH-MCK-10-14-0152; Conduits (114495, 118740, 105029
	Lorne St. 4 / Logan Ave. (GT-4)	Missing invert elevation values: MH-MCK-10-14-0152; MHCB-MCK-10-14-0153; MHCB-MCK-10-14-0172; MH-MCK-10-10-0422; ODP_123907; Conduits (118740, 105029, 115060, 115005).
South End Area	Lily Creek (SE-1)	Missing invert elevation values: MH-MCK-11-15-0102; MH-MCK-11-15-0103; MH-MCK-11-15-0104; MH-MCK-11-15-0105; ODP_123573.
	Regent St. (SE-2)	Adequate for modelling
	Stephen St. (SE-3)	Missing invert elevation values: MH-MCK-10-14-0230; Conduit 118226. Missing outlet node: Conduit 107793.
	The Four Corners (SE-4)	Adequate for modelling
	Loach's Rd. (SE-5)	Adequate for modelling
Lively	Bonnie Dr. (L-1)	Missing invert elevation values: ODP_123624; DMHCB-WAT-07-07-0027; ODP_123624.
	Herman Mayer Dr. (L-2)	Missing invert elevation values: MH-WAT-06-06-0020; MH-WAT-06-06-0021; ODP_124326; Conduit 114143; Conduit 114143.

Note that no systems with 900 mm and larger diameter pipes were identified within 500m of the main creek in the Copper Cliff or Lively (north of Hwy 24) areas. The five main GIS layers provided by the CGS (catchbasins, manholes, inlets and discharge points, as well as the trunk storm sewer system of 900 mm and larger diameter pipes within 500 m of Junction Creek and identified main tributaries), partially contained the required data compatible with the selected modelling platform. Significant effort has been allocated to manually transfer the required data (manhole layer) from the as-built and construction drawings to a model compatible format. Additionally, survey data was collected along Junction Creek, including for the Box Culvert. For some systems there remains a lack of accurate information and/or inconsistency on available references, hence three alternate methods were used to address these gaps:

i. Infer information from upstream and downstream data where available;
ii. Assume vertical data using topography and basic plan layouts; and,
iii. Spot check field surveys.

The method used to address the missing information has been noted in the PCSWMM hydraulic model as well as in the GIS data layers where applicable.

3.3.4 Hydrology

The PCSWMM model was used to conduct the integrated hydrology and hydraulic assessment as per the previous task (Storm Sewer Pipe Hydraulics) for the entire subwatershed. For each subwatershed, hydrologic characteristics have been determined, such as area, shape, slope, impervious percentage based on land use cover weighting, soil and land cover conditions. These parameters are discussed in detail in **Section 6.1** below.

3.3.4.1 *Design Storms and Meteorology*

Existing rainfall and flow monitoring data made available by the CGS, Environment Canada, Vale and CS have been reviewed and summarized. The historic rainfall and flow data for the Sudbury area, in addition to the proposed data collected as part of the Subwatershed Study, was used to calibrate the hydrologic and hydraulic models.

Different storms events and distributions have been studied for comparison and selection of the most appropriate for calibration purposes. This is discussed in more detail in **Section 6.3**.

Short Duration Rainfall Events (5 minute to 24 hour)

Short duration Intensity-Duration-Frequency (IDF) rainfall data were obtained from Environment Canada (EC) for "Sudbury A" Station ID 6068150 (data from 1971 to 2006). Rainfall depths for available durations and return periods are provided in **Table 3.3.2**.

Table 3.3.2: Rainfall Depths for Sudbury Airport (ON 6068150)

Duration (min)	Duration (h)	2 Year (mm)	5 Year (mm)	10 Year (mm)	25 Year (mm)	50 Year (mm)	100 Year (mm)
5	0.08	7.0	9.8	11.7	14.0	15.8	17.5
10	0.17	10.2	14.2	16.8	20.1	22.5	24.9
15	0.25	12.6	17.2	20.2	24.0	26.9	29.7
30	0.50	16.8	23.5	28.0	33.7	37.9	42.0
60	1	20.6	28.8	34.2	41.0	46.1	51.1
120	2	25.4	35.3	41.8	50.1	56.3	62.4
360	6	35.7	46.5	53.7	62.7	69.5	76.1
720	12	43.3	55.8	64.1	74.7	82.5	90.2
1440	24	49.4	64.6	74.6	87.4	96.8	106.2

For each storm event two different temporal distributions have been assigned: a Soil Conservation Service (SCS) Type II rainfall temporal distribution and a Chicago distribution. The SCS Type II storm distribution is generally critical for slower-draining larger rural subwatersheds (low percentage of impervious areas) where peak flow rates are largely influenced by the total depth of rainfall. The equations for the Chicago Distribution which describes the best-fit for these IDF curves for each return period are presented below[1]:

2-year return period

$$\text{Rainfall Intensity (mm/hr)} = \frac{429.4}{[t + 4.25]^{0.7}}$$

5-year return period

$$\text{Rainfall Intensity (mm/hr)} = \frac{600.9}{[t + 4.00]^{0.7}}$$

10-year return period

$$\text{Rainfall Intensity (mm/hr)} = \frac{726.6}{[t + 3.94]^{0.7}}$$

25-year return period

$$\text{Rainfall Intensity (mm/hr)} = \frac{847.0}{[t + 3.94]^{0.7}}$$

50-year return period

$$\text{Rainfall Intensity (mm/hr)} = \frac{986.3}{[t + 3.75]^{0.7}}$$

100-year return period

$$\text{Rainfall Intensity (mm/hr)} = \frac{1093.0}{[t + 3.66]^{0.7}}$$

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[1] City of Greater Sudbury Official Plan Stormwater Background study January 2006 Prepared by Earth Tech Canada Inc.

Where t is the duration in minutes.

Regional Storm

The Regional Storm for the Junction Creek Subwatershed area is the Timmins storm, a historical storm with 193 mm of precipitation occurring over a 12 hour period, as per the CGS's *Engineering Design Manual* (CGS, 2012). **Table 3.3.3** provides the temporal distribution of rainfall for this event.

Table 3.3.3: Timmins Storm

Time (hour)	1	2	3	4	5	6	7	8	9	10	11	12	**Total**
Incremental Precipitation (mm)	15	20	10	3	5	20	43	20	23	13	13	8	**193**

Long-Duration Snowmelt Plus Rainfall Event (30 days)

A 30 day rain-on snowmelt event (spring snowmelt plus rainfall) has also been obtained from Environment Canada (EC) for "Sudbury A" Station ID 6068150. It is noted that revised 30-day rain-on-snow data were acquired in January 2016 from Environment Canada. These data were revised by Environment Canada following a correction to its in-house computational software. The revised values are significantly higher than previously reported (for example, for the 100 year event the new precipitation value is 432.2 mm versus the previous value of 359.7 mm). The Environment Canada snow melt model has been selected, as no site specific data are available.

The rain-on snowmelt events have similarly been assigned a symmetrical, or balanced distribution, putting the most severe single day event in the centre of the event, with the second and third most severe days on either side, and continuing to fill in the 30 day distribution in this manner. This creates a conservative temporal distribution of the 30 day rain plus snowmelt data, as it delivers the most concentrated runoff in the shortest period of time and also contains the peak rain plus snowmelt depths for all shorter durations.

3.3.5 Hydraulics

Hydraulic analytic characterization of the regulated watercourses within the Junction Creek Subwatershed has been completed using the HEC-RAS hydraulic model. The HEC-RAS tool has been developed by the U.S. Army Corp of Engineers and uses energy and momentum equations to determine water surface elevations for given channel geometric cross-sections, crossings and boundary conditions.

To supplement available information for hydraulic modelling, field reconnaissance has been conducted and Pelto has completed cross sections of the creek and ground surveying to verify geometry and dimensions of the water crossing structures (culverts and bridges) along the four selected tributary watercourses. As required, a survey of cross sections and water crossings along the main branch of Junction Creek was performed, including a point at each of the inlets and outlets of the box culvert downtown.

A photographic inventory of the culverts and bridges has been reviewed and Total Station Survey completed at the structures in order to establish the structure inverts and dimensions. The hydraulic structure inventory has been supplemented by information provided by the CGS and the area landowners for various structures in the area.

Cross-sections of the open watercourses upstream and downstream of hydraulic structures have been obtained based on LiDAR mapping provided for use in this study. **Table 3.3.4** below shows all major road crossings along Junction Creek and four tributaries. The HEC-RAS model incorporates these road crossings and important water infrastructure such as culverts, bridges, etc. within the subwatershed (refer to **Figure C5** in **Appendix C** as a reference). Manning's roughness coefficients have been established based upon a review of air photos provided for use in this study. Development of the hydraulic model is discussed in **Section 7.1**.

Table 3.3.4: Location of Major Road Crossings

Stream	Description	No.	Location	Coordinates (NAD 83)	
Main Branch of Junction Creek	From Garson to the Box Culvert Downtown	1	Pine St (Garson)	510507.00 m E	5156766.00 m N
		2	Birch St (Garson)	510450.00 m E	5156189.00 m N
		3	Orell St	510276.00 m E	5155642.00 m N
		4	Margaret St	509953.00 m E	5155650.00 m N
		5	O'Neil Dr	508400.00 m E	5155221.00 m N
		6	Donnely Dr	507507.00 m E	5154617.00 m N
		7	Carr Ave	507231.00 m E	5154426.00 m N
		8	Matson Road	506802.00 m E	5153947.00 m N
		9	Maley Dr (East)	506646.00 m E	5153729.00 m N
		10	Madison Ave	505520.00 m E	5152973.00 m N
		11	Christina Dr	506254.00 m E	5152954.00 m N
		12	Lansing Ave	505441.00 m E	5152533.00 m N
		13	LaSalle at Main Creek	504931.00 m E	5152051.00 m N
		14	CN Rail @ Lasalle & Barrydowne	504727.00 m E	5151721.00 m N
		15	Barrydowne Rd	504277.00 m E	5151382.00 m N
		16	Atlee Ave	503606.00 m E	5151717.00 m N
		17	Arthur St	503187.00 m E	5151762.00 m N
		18	King St	501101.00 m E	5150077.00 m N
		19	Bond St	501100.00 m E	5149887.00 m N
		20	Leslie St	501167.00 m E	5149443.00 m N
		21	Louis St	500932.00 m E	5149149.00 m N

Stream	Description	No.	Location	Coordinates (NAD 83)	
	From Box Culvert Downtown to Kelly Lake	22	Douglas St / Brady St	500038.51 m E	5148101.82 m N
		23	Riverside Dr	499686.00 m E	5147765.00 m N
		24	Regent St	499451.00 m E	5147420.00 m N
		25	McLeod St	499172.00 m E	5147217.00 m N
		26	Martindale Rd	499177.52 m E	5147225.00 m N
		27	Kelly Lake Rd	497452.00 m E	5145917.00 m N
Tributaries upstream of Kelly Lake	Maley Dam	28	Maley Dr (West)	505838.00 m E	5153748.00 m N
		29	Madison Ave	505520.00 m E	5152973.00 m N
	Nickeldale Dam	30	Lasalle Blvd at Nickeldale	501584.00 m E	5152063.00 m N
	Nolins Creek	31	Beatty St	499455.00 m E	5149404.00 m N
		32	Dufferin St	499489.00 m E	5149304.00 m N
	From Ramsey Lake to Robinson Lake (Lily Creek)	33	Paris St	500270.00 m E	5146570.00 m N
		34	Regent St. (near Beverly Dr)	499499.00 m E	5146395.00 m N
		35	Martindale Rd. (near Beverly Dr.)	499046.00 m E	5146070.00 m N
		36	Bouchard St	498922.00 m E	5145279.00 m N

3.3.6 Climate Change

Watershed management must include climate change as a potential influence on both the natural and built elements of the subwatershed. Climate change has added new challenges that need to be addressed in planning subwatershed actions that will help to mitigate and adapt to possible impacts of our changing climate. The Greater Sudbury Area has already begun to experience changes in the local climate as reflected by an assessment of trends over the period 1956 to 2008 (**Figure 3.3.1**). As illustrated, there is an indication of upward trends for both precipitation and temperature. The exception to the overall trends is exhibited by total summer precipitation which has had a small decrease of 6 mm over the 53 years of record.

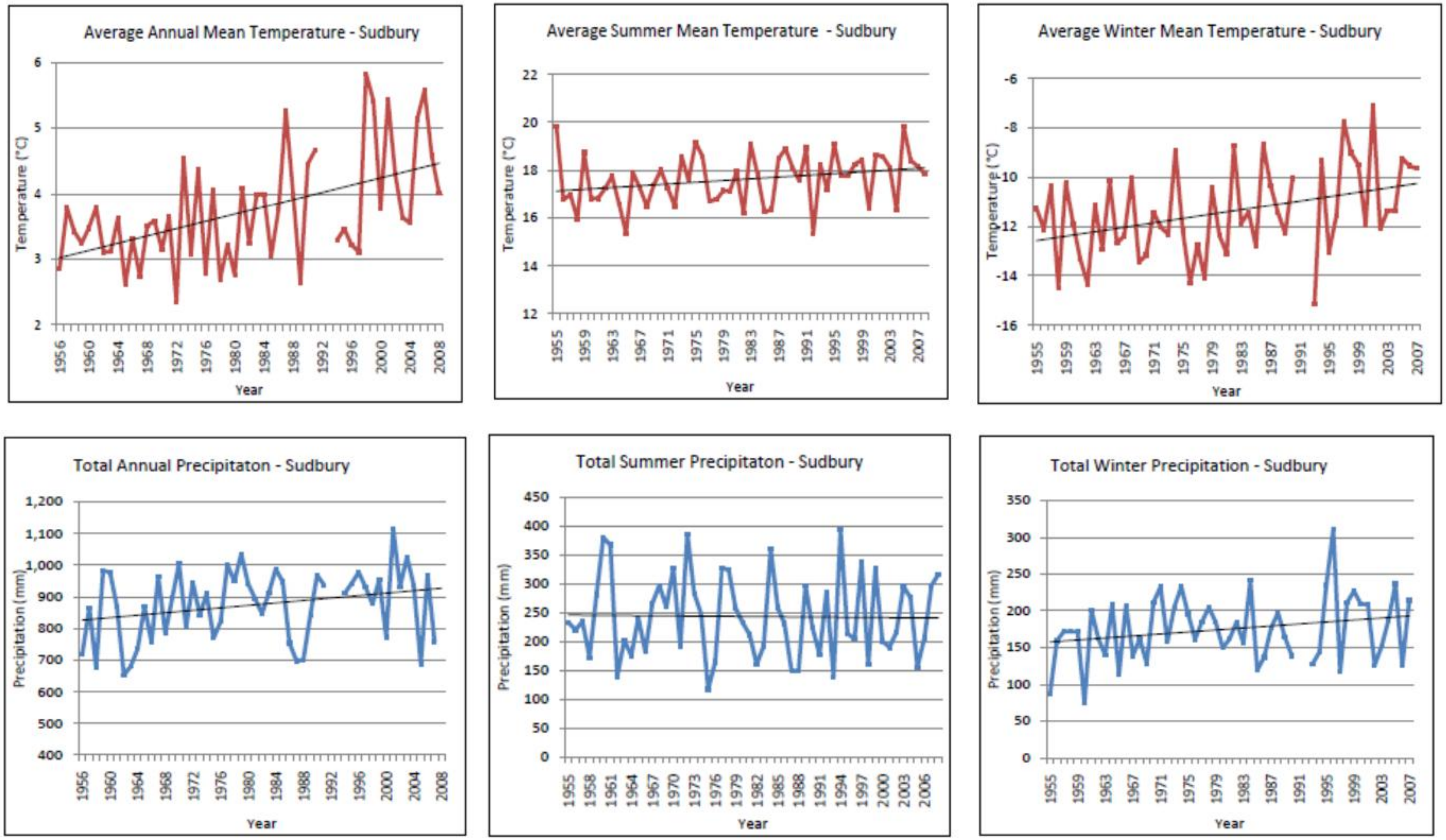

Figure 3.3.1: Temperature and Precipitation Trends for the Environment Canada Weather Station at Sudbury Airport

(Source: Ontario Centre for Climate Impacts and Adaptation Resources, n.d.)

Recent studies reviewing climate change issues in the Sudbury area that offer insight into possible futures with regard to climate variables and associated phenomena have included:

- *Promoting Community Sustainability through Adaptive Responses to Socio-Economic and Risk Assessments of the Potential of Climate Change Scenarios in a Natural resource-based, mid-sized Canadian Shield Community: Greater Sudbury, Ontario* by Dr. L. Vasseur, Laurentian University, 2007.
- *Climate Change Position Paper: Positioning the Nickel District Conservation Authority with the City of Greater Sudbury in a Future Climate*, prepared for CS by Dr. L. Vasseur (Brock University and E. McMillan (Laurentian University), March 2009.
- *Climate Change in Canada: Climate Scenarios for the Public Infrastructure Vulnerability Assessment – Sudbury Roads and Associated Infrastructure Case Study*, by Ouranos, January 2008. This study was completed as a component of the *First National Engineering Vulnerability Assessment Report – Roads and Associated Infrastructure, City of Greater Sudbury*, March 2008.
- Climate *Change Adaptation Case Study in the City of Greater Sudbury*, Ontario Centre for Climate Impacts and Adaptation Resources, no date (n.d.).

As indicated by these studies, the following changes in climate are anticipated in the future in the Greater Sudbury area:

- Temperatures could increase by as much as 2°C in summer and 1°C in winter for the period 2010 to 2039.
- Shorter winter and longer summer seasons with close to twice as many hot days (days with > 25°C) and 4-6 times as many days > 30°C, compared to baseline 1961-1990 data.
- A slight (1%) increase in annual precipitation by 2020 following the general trends for Ontario and Eastern Canada. Variable changes in seasonal distribution with more falling as rain and less as snow. Little change in rainfall amounts is expected during the summer months (June, July and August). Total precipitation could increase by up to 10-15% by 2050. Changes in spring rainfall intensity and snowmelt runoff has the potential to lead to flash flooding.
- Snowfall is expected to decrease overall, with fewer minor snow storms (less than 20 cm) and more large snow storms (20 cm or more). An increase in the occurrence and severity of "rain on snow" events is also suggested.
- Evapotranspiration rates will increase, particularly in the summer.
- Longer dry periods between rain events, with the possibility of drought conditions in some years.
- Water levels in Sudbury lakes may fluctuate thus impacting hydroelectricity, recreational activities, drinking water supply, the environment (e.g. wetlands, shorelines) and water quality.
- Vulnerable areas include water quality and quantity, municipal infrastructure, human health especially for vulnerable populations, tourism, mining and forestry, culture (e.g. shifting range of plants such as blueberries and others traditionally used by First Nations people and other Northern Ontarians).
- Higher temperatures and longer growing seasons may, over time, enhance forest and agriculture productivity.
- No changes are suggested with regard to wind frequency or intensity.
- A shorter frost season and a decrease in freeze-thaw cycles are suggested.

A variety of climate change groups are active in the area encompassing the CGS, the Junction Creek subwatershed and the surrounding region. Actions focusing on climate change (both mitigation and adaptation) are being championed by the CGS, CS, the Greater Sudbury Climate Change Consortium[2], Ontario Centre for Climate Impacts and Adaptation Resources (OCCIAR) at MIRARCO/ Laurentian University, and the Sudbury and District Health Unit.

The uncertainties associated with climate change can be a barrier to action. A "no regrets" climate adaptation approach embodies practices that are beneficial even in the absence of climate change. The CGS has taken a number of actions to date, following this approach that will help the CGS manage the effects of climate change even though the catalysts for these actions were founded in other initiatives and designed to meet other goals. Some examples include:

- The CGS adopted a policy of installing all utilities services (cable, phone, electricity) via underground wiring in new subdivisions and new roads. The cables are buried deep enough to avoid freeze-thaw cycle damage, and they are more resilient to ice or wind storms.
- Through the Clean Water Act, CS was mandated to develop a source water protection plan for the CGS's municipal drinking water supply. CS is developing a GIS database to locate and examine the status of groundwater resources, which could aid with future adaptation planning.
- CGS Emergency Services is mapping infrastructure within the Sudbury area that will help identify potentially vulnerable, and critical, major infrastructure. The GIS layers will include demographic data so that it is possible to map out vulnerable populations across the CGS, which will also aid with emergency response planning. Emergency Services will bring forward a policy document to Council based on the information obtained by this mapping exercise regarding the protection of public infrastructure and property.

Further, the 2008 PIEVC vulnerability assessment identified a lack of data available for the CGS's infrastructure, specifically, drainage related infrastructure. This lack of information hampered the quantification of the vulnerability of drainage infrastructure (culverts, bridges, ditches, catch basins and storm sewers) to the predicted increases in the severity and frequency of rainfall events associated with climate change. The present subwatershed and master planning study is directly assisting in addressing the information gap associated with drainage related infrastructure (refer to Section 2).

Additional climate information, with a particular focus on projected IDF rainfall data has been compiled for both the existing and future timeframes. Existing IDF data is available from Environment and Climate Change Canada (ECCC). Future estimates of frequency based rainfall are available from a variety of tools including:

- University of Western Ontario's IDFCC Tool;
- Ontario Climate Change Data Portal; and,
- Ontario Ministry of Transportation IDF Lookup Tool.

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[2] A partnership of the City of Greater Sudbury, Conservation Sudbury, Sudbury Catholic Schools, EarthCare Sudbury, conseil scolaire catholique du Nouvel-Ontario, Collège Boréal, Vale, Rainbow Schools, Cambrian College, Coalition for a Liveable Sudbury, Sudbury and District Health Unit, Laurentian University, Social Planning Council of Sudbury, Citizen's Climate Lobby

Two long-term ECCC weather stations are in operation in the Sudbury area, namely Sudbury Airport (ID 6068150) and Sudbury Science North (ID 6068158). IDF relationships for these stations are outlined in **Tables 3.3.5** and **3.3.6**.

Table 3.3.6 highlights a difference in the IDF data as published by ECCC and that used by the IDFCC Tool to support future projection. The difference in IDF data between the two sources stems from the annual maxima dataset used to create the IDF relationship. In the case of the ECCC 2014 published IDF, the full record from 1959 to 1995 is used to generate the IDF relationship although there is a gap in the data record from 1971 to 1985. The IDF relationship used for the IDFCC Tool is based solely on the contiguous data record from 1986 to 1995. However, within the 1971 to 1985 data record there are years with no data. As such, IDF data for associated durations are not calculated by the IDFCC Tool for this station.

Given the shorter data record associated with the Sudbury Science North ECCC station and the IDF data issue outlined above, it is recommended that frequency based rainfall from the Sudbury Airport station be used for this project as relevant.

Statistical trends analyses associated with the Sudbury Airport IDF relationship, provided as a component of the ECCC IDF data package, are illustrated in **Figure 3.3.2**. Slopes associated with the trend lines are in the range ±0.10 (3 of 9 being negative) with the exception of the 12 hour and 24 hour durations, which are larger and also negative. The IDF data outlined in **Table 3.3.5** supports this general downward trend in frequency rainfall.

Table 3.3.5: Sudbury Airport (ID 6068150) 2014 IDF Relationships

Duration		Total Rainfall (mm) by Return Period					
		2 year	5 year	10 year	25 year	50 year	100 year
Published 2007 (with data to 2002, based on 32 years of record)							
5	min	7.3	10.1	12.0	14.3	16.1	17.8
10	min	10.6	14.5	17.2	20.5	22.9	25.4
15	min	13.0	17.6	20.7	24.5	27.3	30.2
30	min	17.2	24.1	28.7	34.5	38.8	43.1
1	hour	21.3	29.6	35.0	41.9	47.0	52.1
2	hours	26.1	36.2	42.8	51.2	57.4	63.6
6	hours	36.4	47.5	54.8	64.1	71.0	77.8
12	hours	44.1	57.0	65.5	76.2	84.2	92.1
24	hours	50.2	65.8	76.1	89.2	98.9	108.5
Published 2014 (with data to 2006, based on 35 years of record)(used by the IDFCC Tool)							
5	min	7.0	9.8	11.7	14.0	15.8	17.5
10	min	10.2	14.2	16.8	20.1	22.5	24.9
15	min	12.6	17.2	20.2	24.0	26.9	29.7
30	min	16.8	23.5	28.0	33.7	37.9	42.0
1	hour	20.7	28.8	34.2	41.0	46.1	51.1
2	hours	25.4	35.3	41.8	50.1	56.3	62.4
6	hours	35.7	46.5	53.7	62.7	69.5	76.1

Duration		Total Rainfall (mm) by Return Period					
		2 year	5 year	10 year	25 year	50 year	100 year
12	hours	43.3	55.8	64.2	74.7	82.5	90.2
24	hours	49.4	64.6	74.6	87.4	96.8	106.2

Table 3.3.6: Sudbury Science North (ID 6068158) IDF Relationships

Duration		Total Rainfall (mm) by Return Period					
		2 year	5 year	10 year	25 year	50 year	100 year
Published 2007 (with data to 1995, up to 21 years of data)							
5	min	-99.9	-99.9	-99.9	-99.9	-99.9	-99.9
10	min	-99.9	-99.9	-99.9	-99.9	-99.9	-99.9
15	min	12.4	17.2	20.3	24.3	27.3	30.2
30	min	14.4	20.0	23.8	28.6	32.1	35.6
1	hour	17.9	24.9	29.6	35.4	39.8	44.1
2	hours	21.7	29.3	34.4	40.8	45.6	50.3
6	hours	30.3	41.4	48.8	58.1	65.1	71.9
12	hours	36.6	49.1	57.4	67.9	75.7	83.5
24	hours	42.0	57.2	67.2	79.9	89.3	98.6
Used by the IDFCC Tool (with data to 1995, 10 years of data)							
5	min	n/a	n/a	n/a	n/a	n/a	n/a
10	min	n/a	n/a	n/a	n/a	n/a	n/a
15	min	n/a	n/a	n/a	n/a	n/a	n/a
30	min	n/a	n/a	n/a	n/a	n/a	n/a
1	hour	n/a	n/a	n/a	n/a	n/a	n/a
2	hours	n/a	n/a	n/a	n/a	n/a	n/a
6	hours	n/a	n/a	n/a	n/a	n/a	n/a
12	hours	n/a	n/a	n/a	n/a	n/a	n/a
24	hours	37.9	50.6	59.0	69.6	77.5	85.3

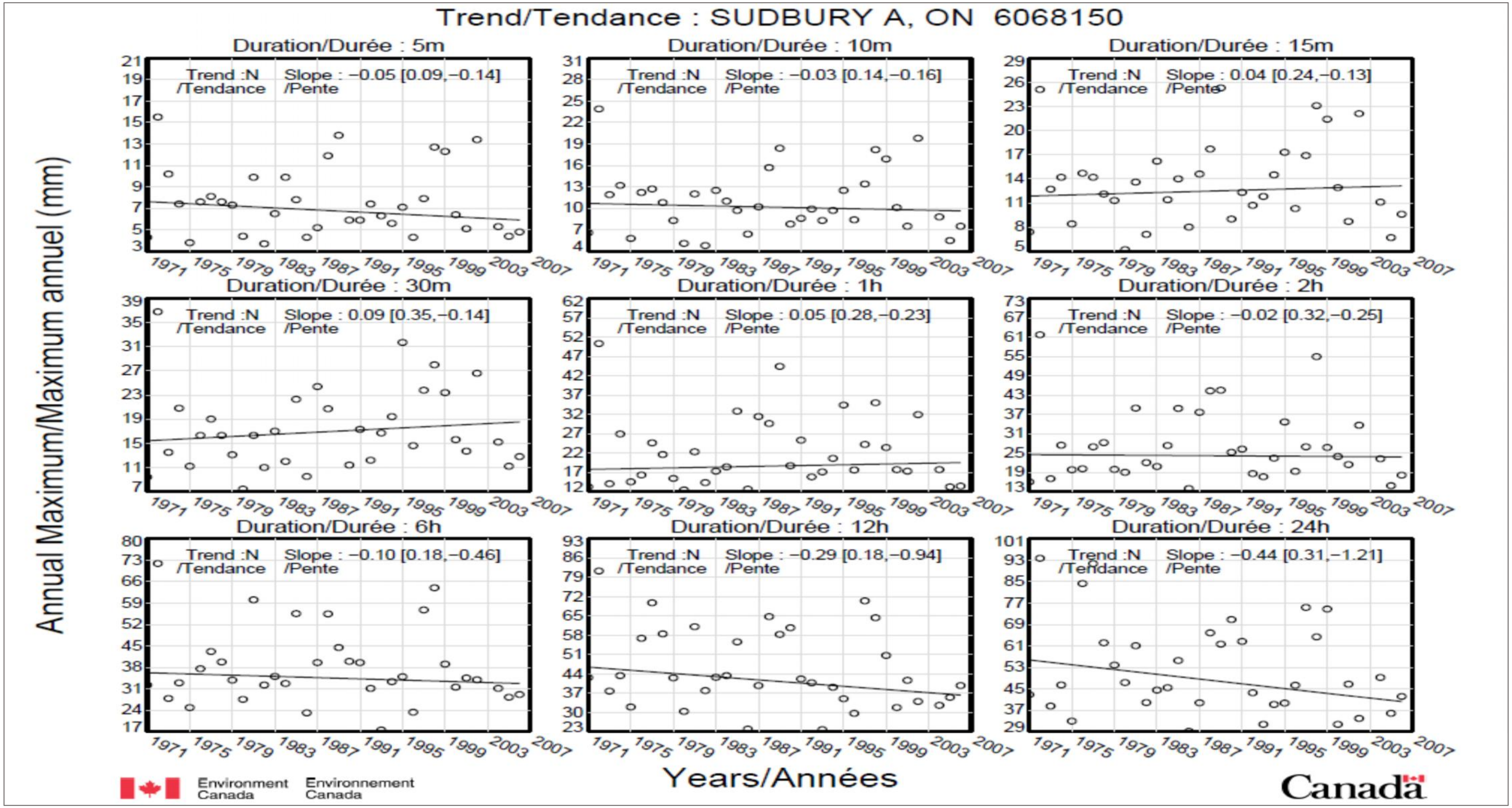

Figure 3.3.2: ECCC IDF Trend Analysis for Sudbury Airport (ID 6068150)

Estimation of future/projected IDF relationships has been completed using the previously noted tools as outlined below.

- *University of Western* Ontario's *IDFCC Tool*

  This computerized web-based IDF tool[3] integrates a user interface with a Geographic Information System (GIS). By creating or selecting a station anywhere in Canada, the user is able to carry out statistical analysis on historical precipitation data, as well as generate and verify possible future change based on a methodology using a combination of global climate modelling outputs and locally observed weather data. The tool presently embodies data from twenty-four (24) climate models.

  Using this tool, IDF relationships have been estimated using an ensemble approach for the Sudbury Airport (ID 6068150) weather station (ref. **Table 3.3.7**) for the three (3) available Representative Concentration Pathways (RCPs), namely RCPs 8.5, 4.5 and 2.6. RCP 8.5 corresponds to a "non-climate policy" scenario reflecting potentially high severity climate change impacts and RCP 2.6 represents a future adhering to stringent climate policy to limit greenhouse gas emissions, reflecting potentially low severity impacts. RCP 4.5 represents an intermediate scenario. In comparison to the Special Report Emissions Scenarios (SRES), RCP 8.5 is somewhat higher than SRES A2 (by 2100), RCP 4.5 is similar to SRES B1 and A1B scenarios and RCP 2.6 is lower than all of the SRES scenarios.

  The future estimates of IDF for this station are in the range of +10% to +16% and +9% to +28% for the 2050 and 2080 estimates, respectively, as compared with 2014 ECCC IDF 100 year 24 hour rainfall depth for the ECCC Sudbury Airport station.

- *Ontario Climate Change Data Portal*

  The Ontario Climate Change Data Portal[4] has incorporated the high-resolution (25 km x 25 km) climate projections developed by the Institute for Energy, Environment and Sustainable Communities (IEESC) at the University of Regina using the PRECIS model (under A1B emissions scenario) and the RegCM model (under RCP 8.5 emissions scenario). Presently, projected IDF data is only available based on climate projections under the A1B emissions scenario.

  Using this tool, IDF relationships have been estimated for 2050 and 2080 as represented by the tri-decade periods 2035 to 2065 and 2065 to 2095, respectively (ref. **Tables 3.3.7** to **3.3.9**). The grid location selected for projected IDF data is illustrated in **Figure 3.3.3**.

  The future IDF estimates for this station are +102% and +127% for the 2050 and 2080 estimates, respectively, as compared with 2014 ECCC IDF 100 year 24 hour rainfall depth for the ECCC Sudbury Airport station.

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[3] Available via URL https://www.idf-cc-uwo.ca/

[4] Available via URL http://ontarioccdp.ca/

Table 3.3.7: Sudbury Airport (ID 6068150) 2050 IDF Relationships based on the IDFCC Tool

Duration		2050[1] Total Rainfall (mm) by Return Period					
		2 year	5 year	10 year	25 year	50 year	100 year
RCP 2.6							
5	min	8.0	11.2	13.5	16.0	18.0	20.0
10	min	11.6	16.2	19.4	23.0	25.8	28.5
15	min	14.1	19.4	23.1	27.3	30.5	33.6
30	min	19.1	26.7	31.9	37.9	42.5	47.1
1	hour	23.2	32.5	38.9	46.2	51.8	57.3
2	hours	28.4	39.6	47.4	56.2	62.9	69.6
6	hours	38.9	51.0	59.4	69.0	76.3	83.5
12	hours	46.7	60.9	70.9	82.2	90.7	99.3
24	hours	53.5	70.8	82.9	96.6	106.9	117.3
RCP 4.5							
5	min	8.1	11.8	14.1	16.9	19.0	21.1
10	min	11.8	17.0	20.2	24.2	27.1	30.1
15	min	14.3	20.4	24.1	28.7	32.1	35.5
30	min	19.3	28.2	33.4	40.0	44.9	49.8
1	hour	23.6	34.3	40.7	48.8	54.7	60.7
2	hours	28.9	41.8	49.5	59.3	66.5	73.7
6	hours	39.3	53.4	61.8	72.4	80.3	88.1
12	hours	47.2	63.8	73.7	86.1	95.4	104.6
24	hours	54.2	74.3	86.2	101.4	112.6	123.7
RCP 8.5							
5	min	8.7	11.9	14.3	16.9	18.8	20.9
10	min	12.6	17.2	20.5	24.2	26.9	29.8
15	min	15.3	20.6	24.4	28.7	31.8	35.1
30	min	20.7	28.5	33.8	40.0	44.5	49.3
1	hour	25.3	34.7	41.3	48.8	54.3	60.0
2	hours	30.9	42.2	50.2	59.3	66.1	72.9
6	hours	41.5	53.9	62.6	72.5	79.9	87.3
12	hours	49.8	64.3	74.7	86.4	95.0	103.7
24	hours	57.3	74.9	87.4	101.6	112.1	122.6
Notes: defined by the tri-decade period 2035 to 2065							

Table 3.3.8: Sudbury Airport (ID 6068150) 2080 IDF Relationships based on the IDFCC Tool

Duration		2080[1] Total Rainfall (mm) by Return Period					
		2 year	5 year	10 year	25 year	50 year	100 year
RCP 2.6							
5	min	8.1	11.2	13.2	15.8	17.8	19.7
10	min	11.7	16.1	18.9	22.7	25.4	28.2
15	min	14.3	19.4	22.6	26.9	30.1	33.2

Duration		2080[1] Total Rainfall (mm) by Return Period					
		2 year	5 year	10 year	25 year	50 year	100 year
30	min	19.3	26.6	31.2	37.4	41.9	46.4
1	hour	23.5	32.4	38.0	45.5	51.1	56.5
2	hours	28.8	39.5	46.2	55.3	62.1	68.6
6	hours	39.2	50.8	58.1	68.0	75.4	82.4
12	hours	47.1	60.8	69.4	80.9	89.6	98.0
24	hours	54.0	70.6	81.1	95.1	105.6	115.7
RCP 4.5							
5	min	8.5	11.9	14.3	17.4	19.7	21.9
10	min	12.3	17.1	20.5	25.0	28.1	31.2
15	min	15.0	20.5	24.5	29.6	33.2	36.8
30	min	20.4	28.2	34.0	41.4	46.7	51.8
1	hour	24.8	34.4	41.4	50.4	56.8	63.1
2	hours	30.4	41.9	50.4	61.3	69.1	76.7
6	hours	41.0	53.5	62.7	74.6	83.1	91.5
12	hours	49.1	63.9	74.7	88.7	98.6	108.5
24	hours	56.5	74.4	87.5	104.4	116.4	128.4
RCP 8.5							
5	min	9.5	13.2	15.6	18.6	20.8	23.0
10	min	13.8	18.9	22.3	26.5	29.7	32.7
15	min	16.7	22.6	26.6	31.4	35.1	38.6
30	min	22.8	31.4	37.1	44.1	49.5	54.6
1	hour	27.7	38.3	45.2	53.7	60.3	66.5
2	hours	33.9	46.7	55.1	65.4	73.5	81.0
6	hours	44.8	58.7	68.0	79.2	88.1	96.3
12	hours	53.6	70.0	80.9	94.2	104.5	114.4
24	hours	61.9	81.7	95.0	111.0	123.5	135.5

Notes:

1. defined by the tri-decade period 2065 to 2095

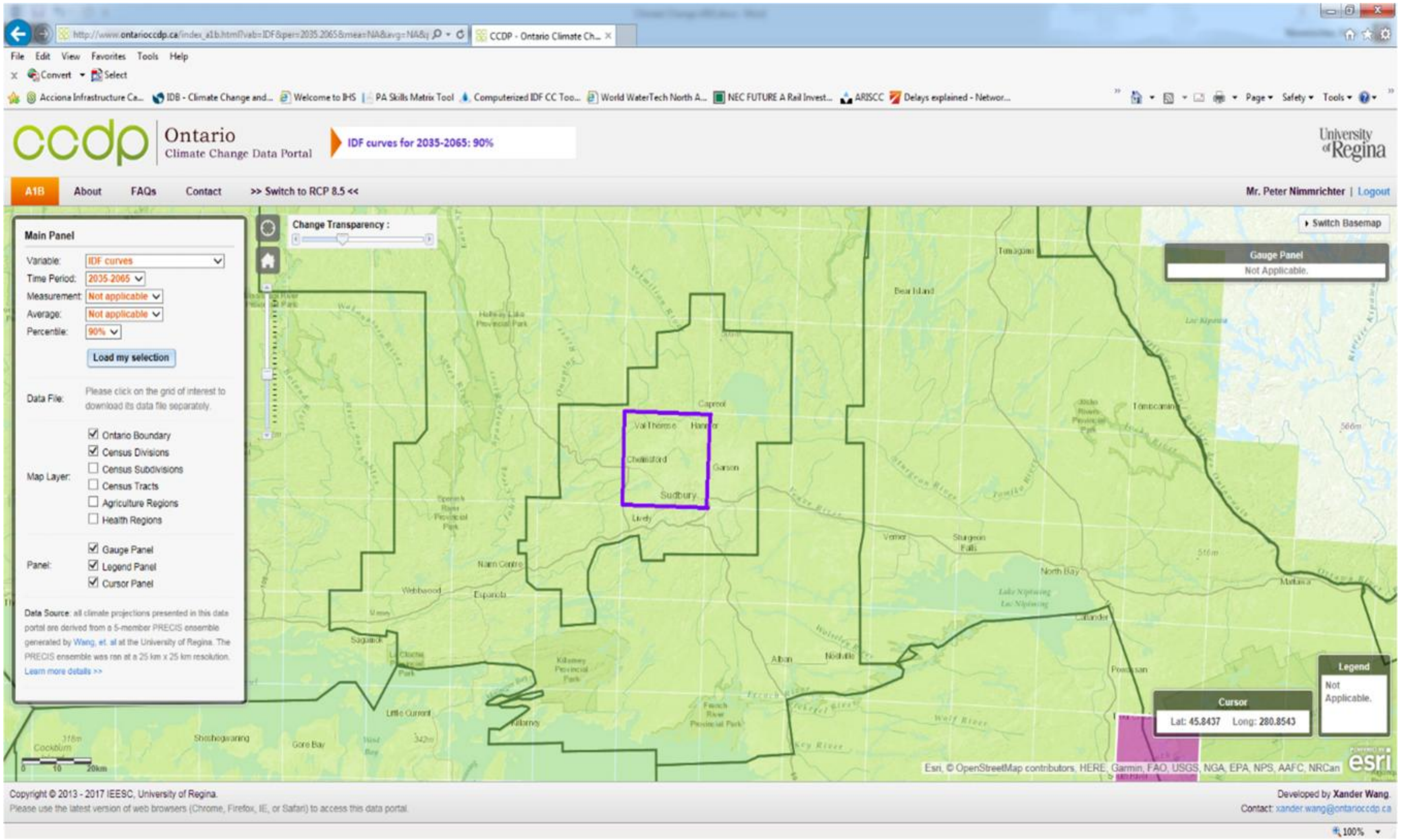
Table 3.3.9: Sudbury IDF Relationships based on the Ontario Climate Data Portal

Duration		Total Rainfall (mm) by Return Period					
		2 year	5 year	10 year	25 year	50 year	100 year
2050 (90th Percentile)							
5	min	6.3	10.3	13.0	16.4	19.0	21.5
10	min	9.9	16.4	20.7	26.1	30.2	34.2
15	min	12.5	20.7	26.1	33.0	38.1	43.1
30	min	17.6	29.1	36.7	46.2	53.2	60.2
1	hour	23.8	38.7	48.5	60.8	69.9	79.0
2	hours	31.2	49.7	61.9	77.3	88.8	100.1
6	hours	46.7	72.2	89.1	110.4	126.2	141.8

Duration		**Total Rainfall (mm) by Return Period**					
		2 year	**5 year**	**10 year**	**25 year**	**50 year**	**100 year**
12	hours	59.9	90.6	111.0	136.7	155.8	174.6
24	hours	76.3	113.3	137.8	168.5	191.5	214.1
2080 (90th Percentile)							
5	min	6.7	11.3	14.7	18.9	22.1	25.3
10	min	10.7	18.1	23.4	30.0	35.0	39.9
15	min	13.5	23.0	29.4	37.7	43.9	50.0
30	min	19.1	32.6	41.4	52.4	60.7	68.9
1	hour	25.8	43.5	55.0	69.4	80.1	90.8
2	hours	33.8	55.9	70.3	88.4	101.8	115.1
6	hours	50.1	80.0	99.7	124.4	142.7	160.9
12	hours	63.7	99.1	122.8	152.5	174.5	196.4
24	hours	80.6	122.4	151.0	187.2	214.1	240.7

Notes:

1. 2050 is represented by the tri-decade 2035 to 2065
2. 2. 2080 is represented by the tri-decade 2065 to 2095



Main Panel

Variable: IDF curves
Time Period: 2035-2065
Measurement: Not applicable
Average: Not applicable
Percentile: 90%

Load my selection

Data File: Please click on the grid of interest to download its data file separately.

Map Layer:
- ☑ Ontario Boundary
- ☑ Census Divisions
- ☐ Census Subdivisions
- ☐ Census Tracts
- ☐ Agriculture Regions
- ☐ Health Regions

Panel:
- ☑ Gauge Panel
- ☑ Legend Panel
- ☑ Cursor Panel

Data Source: all climate projections presented in this data portal are derived from a 5-member PRECIS ensemble generated by Wang, et. al at the University of Regina. The PRECIS ensemble was ran at a 25 km x 25 km resolution. Learn more details >>

Gauge Panel: Not Applicable.

Cursor: Lat: 45.8437 Long: 280.8543

Legend: Not Applicable.

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Please use the latest version of web browsers (Chrome, Firefox, IE, or Safari) to access this data portal.

Developed by Xander Wang.
Contact: xander.wang@ontarioccdp.ca

Figure 3.3.3: Ontario Climate Data Portal Grid Location Used for Projected IDF Estimation

- *Ontario Ministry of Transportation IDF Lookup Tool*
- The Ontario Ministry of Transportation (MTO) has implemented a number of recent updates to its IDF curves to ensure they are as current as possible and regularly incorporate additional and recent rainfall data. MTO has also developed an IDF modelling tool[5] that allows generation of a unique rainfall intensity curve for any point or area in the province. The most recent update to this tool also includes a predictive modelling component to enable generation of a future IDF curve accounting for the predictive impacts of climate change.

Using this tool, IDF relationships have been estimated for 2050 and 2080 (ref. **Table 3.3.10**). Upper and lower bounds to these estimates are also provided in **Table 3.3.11**. The future median estimates of IDF for this station are +20% and +22% for the 2050 and 2080 estimates, respectively, as compared with 2014 ECCC IDF 100 year 24 hour rainfall depth for the ECCC Sudbury Airport station. A similar comparison using the upper bound estimates yields a +56% and +58% for the 2050 and 2080 estimates, respectively.

Table 3.3.10: Sudbury IDF Relationships based on the MTO IDF Lookup Tool

Duration		**Total Rainfall (mm) by Return Period**					
		2 year	**5 year**	**10 year**	**25 year**	**50 year**	**100 year**
2050							
5	min	10.1	13.3	15.5	18.3	20.2	22.2
10	min	12.5	16.5	19.2	22.6	25.0	27.5
15	min	14.1	18.7	21.7	25.5	28.3	31.1
30	min	17.5	23.1	26.9	31.6	35.0	38.4
1	hour	21.7	28.6	33.2	39.0	43.2	47.4
2	hours	27.0	35.4	41.2	48.2	53.4	58.6
6	hours	37.8	49.8	57.6	67.8	75.0	82.2
12	hours	48.0	62.4	72.0	84.0	92.4	102.0
24	hours	60.0	76.8	88.8	103.2	115.2	127.2
2080							
5	min	10.3	13.6	15.7	18.5	20.5	22.5
10	min	12.8	16.8	19.5	22.9	25.3	27.8
15	min	14.6	19.1	22.1	26.0	28.7	31.5
30	min	18.1	23.7	27.5	32.2	35.6	39.0
1	hour	22.6	29.5	34.1	39.9	44.1	48.3
2	hours	28.2	36.6	42.4	49.4	54.6	59.8
6	hours	40.2	52.2	60.0	69.6	76.8	84.0
12	hours	50.4	64.8	74.4	86.4	96.0	104.4
24	hours	62.4	81.6	93.6	108.0	120.0	129.6

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[5] Available via URL: http://www.mto.gov.on.ca/IDF_Curves/.

Table 3.3.11: Sudbury IDF Relationships Lower/Upper Bounds based on the MTO IDF Lookup Tool

Duration	Lower and Upper Bound Total Rainfall (mm) by Return Period											
	2 year		5 year		10 year		25 year		50 year		100 year	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
2050												
5-min	-2.2	2.1	-3.2	3.3	-4.1	4.1	-5.3	5.2	-6.1	6.2	-7.0	7.0
10-min	-2.7	2.6	-40.0	4.0	-5.1	5.0	-6.5	6.4	-7.6	7.6	-8.7	8.6
15-min	-2.9	3.0	-4.5	4.5	-5.7	5.7	-7.3	7.4	-8.5	8.5	-9.8	9.7
30-min	-3.6	3.7	-5.5	5.6	-7.1	7.0	-9.1	9.0	-10.5	10.5	-12.0	12.0
1-hr	-4.5	4.5	-6.8	6.8	-8.7	8.7	-11.1	11.1	-12.9	13.0	-14.8	14.8
2-hr	-5.6	5.4	-8.4	8.4	-10.8	10.6	-13.6	13.8	-16.0	16.0	-18.2	18.2
6-hr	-7.2	7.8	-11.4	12.0	-14.4	15.0	-19.2	19.2	-22.2	22.2	-25.2	25.2
12-hr	-9.6	8.4	-14.4	14.4	-18.0	18.0	-24.0	24.0	-26.4	27.6	-31.2	31.2
24-hr	-12.0	12.0	-16.8	19.2	-21.6	24.0	-28.8	28.8	-33.6	33.6	-40.8	38.4
2080												
5-min	-2.1	2.1	-3.3	3.2	-4.1	4.1	-5.3	5.3	-6.2	6.1	-7.0	7.0
10-min	-2.6	2.6	-3.9	4.0	-5.0	5.1	-6.5	6.5	-7.5	7.6	-8.6	8.6
15-min	-3.0	2.9	-4.5	4.5	-5.7	5.7	-7.3	7.4	-8.6	8.6	-9.8	9.7
30-min	-3.7	3.7	-5.6	5.6	-7.0	7.1	-9.0	9.1	-10.5	10.6	-12.1	12.0
1-hr	-4.5	4.4	-6.9	6.8	-8.7	8.6	-11.2	11.1	-13.0	12.9	-14.9	14.8
2-hr	-5.6	5.4	-8.4	8.4	-10.8	10.6	-13.6	13.8	-16.0	16.0	-18.2	18.2
6-hr	-7.8	7.8	-12.0	11.4	-15.0	15.0	-18.6	19.2	-22.2	22.2	-25.2	25.8
12-hr	-9.6	9.6	-14.4	14.4	-18.0	19.2	-22.8	24.0	-27.6	27.6	-31.2	31.2
24-hr	-9.6	12.0	-16.8	16.8	-24.0	21.6	-28.8	28.8	-33.6	33.6	-38.4	38.4

The rainfall estimates developed through the use of these various tools highlights the uncertainty associated with the future anticipated climate in the Sudbury area. Nonetheless, these estimates provide a basis for municipal planning and better management of infrastructure risks, by increasing the understanding of uncertainty related to infrastructure planning and design. These future rainfall estimates will support the objectives of the project modelling to investigate how changing future precipitation patterns may exacerbate current drainage problems, be a catalyst for future problems, and provide a means to stress test flood risk mitigation and adaptation plans to be developed through this project.

3.3.6.1 *Preliminary Opportunities and Constraints*

Greater Sudbury has already experienced an increase in both temperature and precipitation, save precipitation during the summer months, between 1956 and 2008. The expected changes to Sudbury's climate include an increase in temperature, annual precipitation, evapotranspiration rates, length of dry periods between rain events, lake level fluctuation, and growing season length; with a decrease in snowfall, frost season length and freeze-thaw cycles. These changes together will impact vulnerable areas in Sudbury, including: water quality and quantity, municipal infrastructure, human health especially for vulnerable populations, tourism, mining and forestry, and culture. Sudbury has been proactive when it comes to climate change through the production of numerous studies reviewing climate change issues in the area, the presence of various active climate change groups, and numerous initiatives by the CS and CGS to manage the effects of climate change.

3.4 Water Quality Conditions

Junction Creek surface water samples have been collected monthly by the Junction Creek Stewardship Committee and analyzed at the Vale lab since 2004. Seven sites have been sampled consistently since the commencement of the surface water sampling program, and three additional sites (Brady, Maley and Paquette) were added in 2007. The surface water sampling program is still active, and the locations of the ten sites are presented on **Figure D1** in **Appendix 'D'**. Temporal changes in chemical concentrations for all 25 parameters analyzed are provided in **Appendix 'D'**. Concentrations were plotted through time and against the Provincial Water Quality Objectives (PWQOs), where applicable. The following PWQOs were compared to Junction Creek surface water samples: Arsenic (100 ppb), Cadmium (0.2 ppb), Copper (0.005 mg/L), Iron (0.3 mg/L), Mercury (0.2 ppb), Nickel (0.025 mg/L), pH (6.5-8.5), selenium (100 µg/L) and Zinc (0.3 mg/L). Pearson correlation tests were performed on each chemical parameter to test for significant trends and correlation between time and concentration, the results of which are displayed in **Table 3.4.1**. Both arsenic and selenium concentrations were well below the PWQOs at all sites, therefore the PWQOs were omitted from the figures displaying these temporal trends. Arsenic concentrations at the Donnelly site, and selenium at the Garson site were actually found to be decreasing over time.

Both copper and nickel concentrations were found to be high and well above the PWQO (**Appendix 'D'**), with a slight increase in nickel over time at three sites: Maley, Martindale and McLean. Copper levels appear to be decreasing at both the Paquette and Testmark sites, although the findings are not significant. Nickel concentrations are increasing slightly at the Donnelly, Maley and McLean sites, but slightly decreasing at the Martindale and Testmark sites. Cadmium concentrations were also found to be high and above the

PWQO during many sampling periods at every site (**Appendix 'D'**) and was in fact increasing slightly over time at three sites: Donnelly, Maley and McLean. However, cadmium was also found to be decreasing at three sites: Garson, Kelly and Testmark. The majority of mercury concentrations were extremely low or below the lowest detection levels (**Appendix 'D'**). A few spikes in mercury levels to concentrations above the PQWO values were seen, with one at each Testmark, Martindale and St. George.

The majority of iron concentrations are above the PWQO of 0.3 mg/L, with a temporal increase at the Brady site (**Appendix 'D'**). Many water samples were found to have zinc concentrations above the 0.03 µg/L PQWO, with levels slightly increasing over time at three sites: Brady, Maley and McLean (**Appendix 'D'**). However, zinc concentrations were decreasing significantly at the Garson headwaters site. Temporal trends in pH at each site are displayed in **Appendix 'D'**, with two red lines outlining the PWQO range of 6.5 to 8.5. Majority of sites are shown to stay within this range, however levels are increasing at both sites in Garson, and decreasing at the following three sites: Maley, McLean and Paquette.

Below Kelly Lake, surface water quality data exists for Junction Creek at Fielding Road, Meatbird Creek, Mud Lake, Simon Lake and McCharles Lake (near the inlet point) during 2013-2015 (CS 2017). During this time, it was found that Simon Lake held a low dissolved oxygen (DO) concentration, and McCharles Lake a high DO. Junction Creek at Fielding Road held the highest median value (118 mg/L) for chloride concentration during the study period. Sodium levels were found to be high below Kelly Lake, although below the 200 mg/L PWQO (CS 2017). Water samples from the Junction Creek site were found to contain copper, lead, cadmium, cobalt and zinc concentrations above the PWQOs during all sampling periods, and nickel levels were also higher than the PWQO of 25 µg/l at all five locations (CS 2017). Copper concentrations were above the PWQO of 5 µg/L during all sampling events in Meatbird Creek, Mud Lake and McCharles Lake, and during 12% of sampling events in Simon Lake. Lastly, lead levels were higher than the PWQO of 1 µg/L in Simon Lake (CS 2017).

3.5 Groundwater Characteristics

The hydrogeological conditions and geology of the Junction Creek Subwatershed are discussed in this section. The geological setting of the study area is presented along with a brief description of the implications of the geology on the groundwater conditions. The primary objectives for the groundwater component of this study are to:

- Identify water quantity and quality constraints;
- Identify recharge/discharge areas within the subwatershed; and,
- Confirm the relationship between land use, infiltration, water balance and base flow.

From these findings, management options will be developed associated with groundwater features and their functions, as they relate to land use, infiltration, water balance, and base flow within the Junction Creek Subwatershed.

3.5.1 Approach to Groundwater Characterization

Following review of the data gap analysis by the CGS project team, Wood coordinated a meeting with the TAC to review the data gaps in order to develop appropriate strategies. Completion of the current groundwater characterization was proposed to address the gap in stratigraphy and groundwater data within the Junction Creek Subwatershed. Stratigraphy (overburden and bedrock) and water table depths were extracted from boreholes logs of past projects (2003-2017) within the study area in order to develop a conceptual groundwater model. The following sections describe the specific aspects of Junction Creek's hydrogeological characterization that were compiled from past studies and geomorphology field work during May 2017. Findings from a groundwater monitoring program in Garson were also studied, as this area is particularly sensitive, with the Wanipetei Esker providing a significant overburden aquifer setting in this region, near the headwaters. The primary objectives of the Groundwater Characterization are to review existing hydrogeological data and establish current groundwater conditions within the Study Area.

3.5.2 Pre-existing Boreholes and Monitoring Wells

A groundwater monitoring program was implemented in Garson through the installation of four groundwater wells in 2012. The primary objective of the groundwater monitoring program was to complete an assessment of the aquifer with respect to the occurrence of tetrachloroethylene concentrations within the Garson #1 and #3 water municipal water supply wells. Groundwater monitoring wells were installed by Marathon Drilling Ltd. (Marathon), an Ontario licensed well driller, at locations suggested by "Aquifer Instrumentation Report, Garson Well Site, 3450 Falconbridge Road, Sudbury, Ontario" (AMEC 2012). All wells were installed in accordance with Ontario Regulation 903.

A track mounted soils drill rig and standard soils auger drilling, and diamond coring techniques were used to install the boreholes using 200 mm hollow stem augers and 89 mm NW casing. Monitoring wells were installed once the boreholes either achieved refusal or reached the target depth of 30 m (100 ft.) to allow for the collection of representative water samples. The four monitoring wells were constructed using 50 mm diameter Schedule 40 flush-joint threaded PVC monitoring well supplies. They were then completed with 3 to 6 m of #10 mil slotted intake screen that was extended to the ground surface using solid rise paper. A silica sand filter pack, extended to a minimum of 0.6 m above the top of the well screen, was placed between the intake screen and the borehole wall. A bentonite seal was positioned above the sand pack and to a height of approximately 0.3 m below grade, and each well was completed with an aluminum flush mount protective casing. For greater detail regarding installation of monitoring wells, and groundwater monitoring and sampling, please consult the "Aquifer Instrumentation Report, Garson Well Site, 3450 Falconbridge Road, Sudbury, Ontario" and the accompanying Appendix A, "CGS Groundwater Sampling Standard Operating Procedure."

Table 3.5.1: Garson Groundwater Monitoring Well Measurements at Installation

Monitoring Well #	Installation Depth (m)	Screen Length (m)	Refusal Depth (m)	Groundwater Depth (m)	Easting	Northing
MW12-01	17.7	3	17.7	11.4	510547	5155392
MW12-02	22.7	3	22.7	N/A	510235	5155355
MW12-03	24.4	6	30.5	8.99	510433	5155662
MW12-04	30.5	6	25.9	9.74	510367	5155023

Eastings and Northings recorded in NAD 83 datum. Table adapted from TY121017 “Groundwater Monitoring Well Installation, Garson Well Site, 3450 Falconbridge Road, Sudbury, Ontario”.

Pre-existing boreholes and monitoring wells throughout the study area (**Appendix ‘E’**) were used to create a conceptual groundwater model, which is explained further in **Section 3.5.4.3**.

3.5.3 Groundwater Quality Sampling

Groundwater quality was assessed at the four groundwater monitoring wells located in Garson. Groundwater from each well has been sampled 17 times from October 2012-June 2017, approximately quarterly. Temporal trends are displayed in **Figures 3.5.1** to **3.5.5** for all four wells. Majority of water chemistry concentrations fall below detection limits, therefore only parameters featuring concentrations above the detection limit were plotted (Bromoform, Chloroform, Chloromethane, Tetrachloroethylene, and Trichloroethylene). Additional VOCs sampled include Dichloroethane, Dichloroethylene, Trichlorobenzene, Acetone, Benzene, Bromobenzene, Carbon Tetrachloride, Dibromochloromethane, Dibromomethane, Ethylbenzene, Methyl ethyl ketone, Methyl isobutyl ketone, Toluene, total Xylenes, Vinyl chloride, and 32 others. Chemical concentrations were plotted through time and compared to the Ontario Drinking Water Standards (ODWS) Maximum Acceptable Concentrations (MACs) where applicable.

Bromoform levels were below lowest detection limits (LDLs) at all sites except during the 2015 November sampling at both monitoring wells MW12-02 and MW12-03. Chloroform was above the LDL in nearly every sample at MW12-01 and was higher at wells MW12-01, MW12-02 and MW12-03 during the November sampling in 2013. Chloroform was abnormally high (8.18 µg/L) in MW12-03 during the October 2012 sampling. Chloromethane concentrations were consistently below the LDL except during the August 2016 sampling in all four groundwater monitoring wells. Tetrachloroethylene and Trichloroethylene concentrations were far below the PWQO MACs during all sampling events, however concentrations were consistently below LDLs at MW12-01. MW12-04 held the highest concentration of both contaminants during October 2012 before dropping to below the LDL. Lastly, both Tetrachloroethylene and Trichloroethylene concentrations were consistently highest in MW12-03, followed by MW12-02.

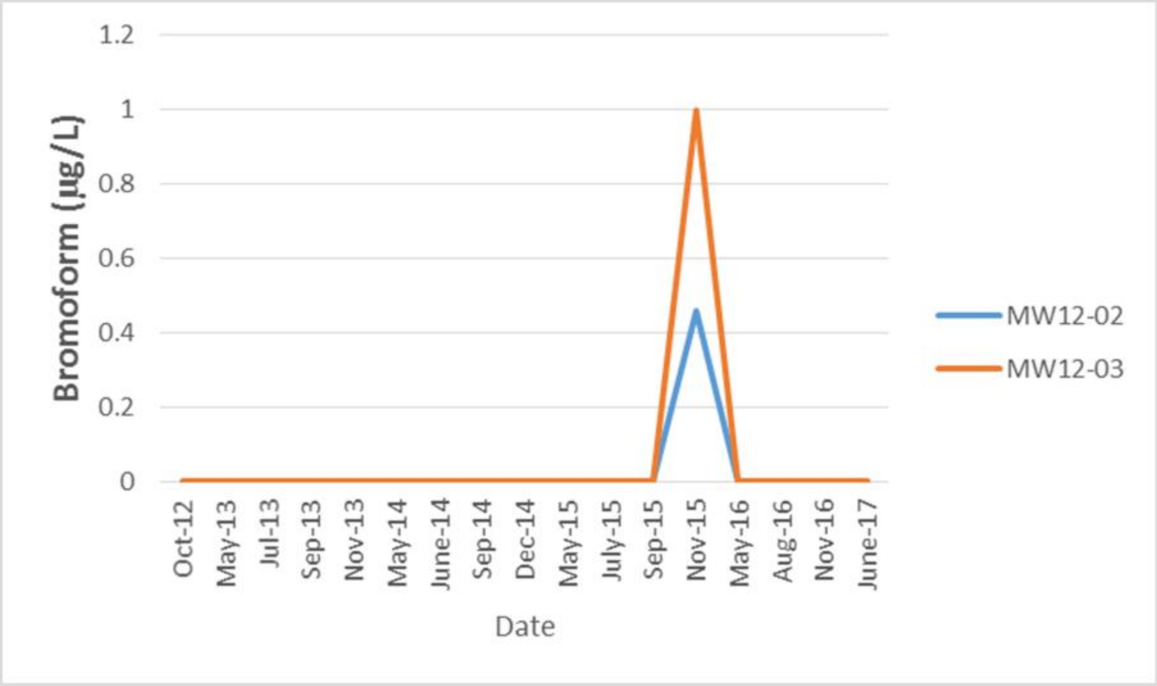


Figure 3.5.1: Bromoform Concentrations in Garson Groundwater Monitoring Wells that have Exceeded the Lowest Detection Limit (0.2 µg/L). *No ODWS exists for Bromoform

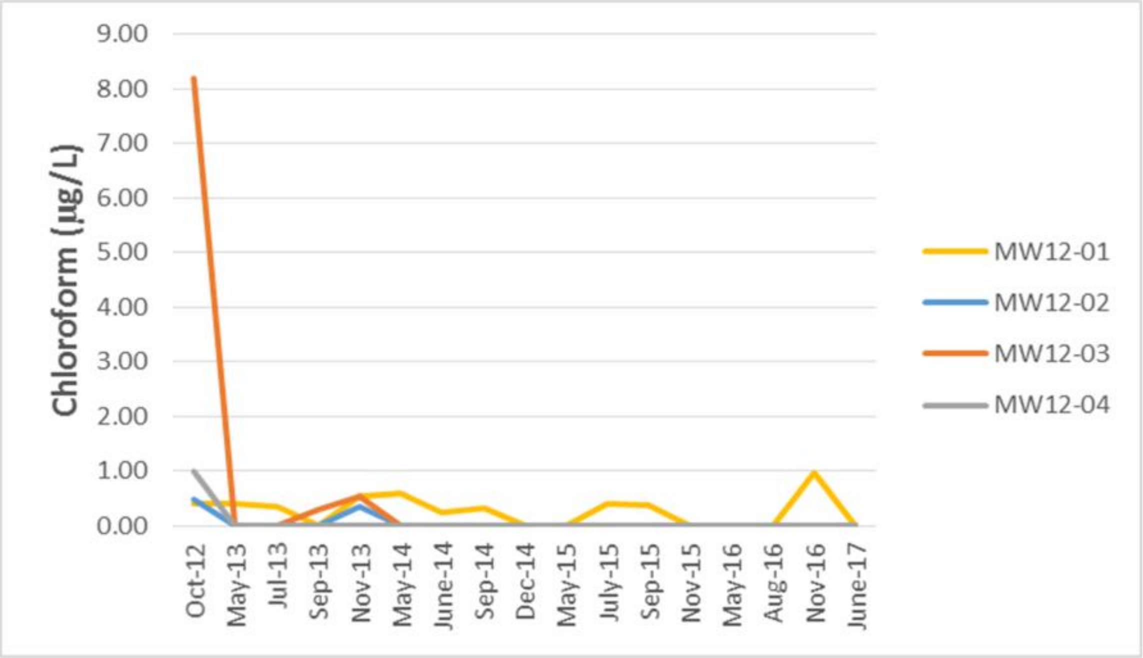


Figure 3.5.2: Chloroform Concentrations in Garson Groundwater Monitoring Wells that have Exceeded the Lowest Detectable Limit (0.2 µg/L). *No ODWS exists for chloroform

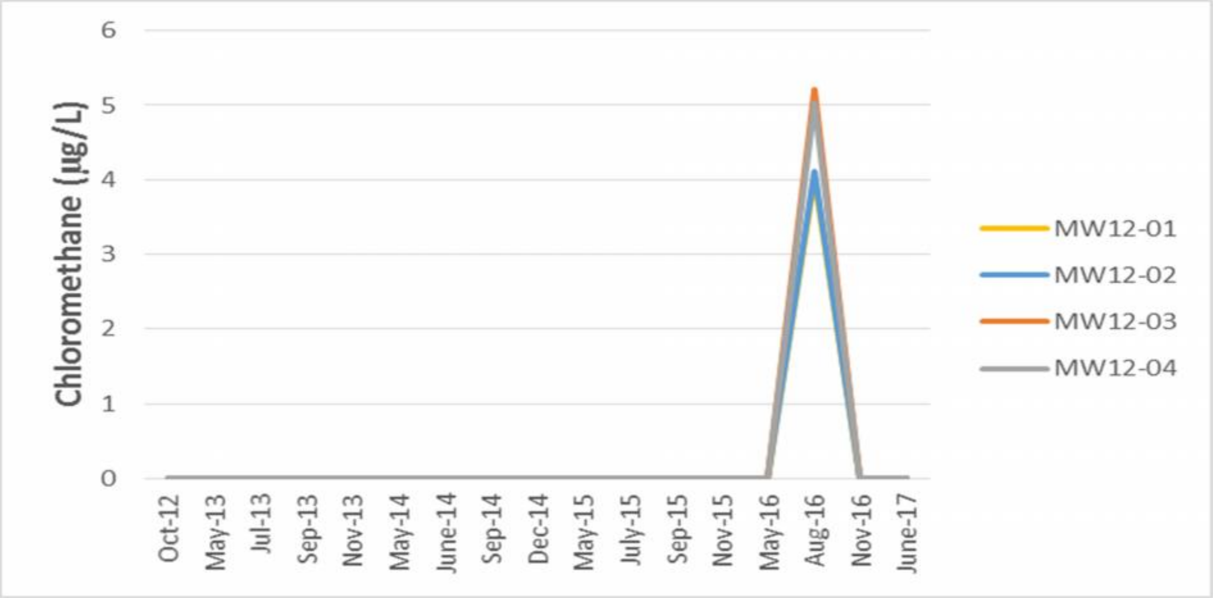


Figure 3.5.3: Chloromethane Concentrations in the Garson Groundwater Monitoring Wells that have Exceeded the Lowest Detectable Limit (0.2 µg/L). *No ODWS exists for chloromethane

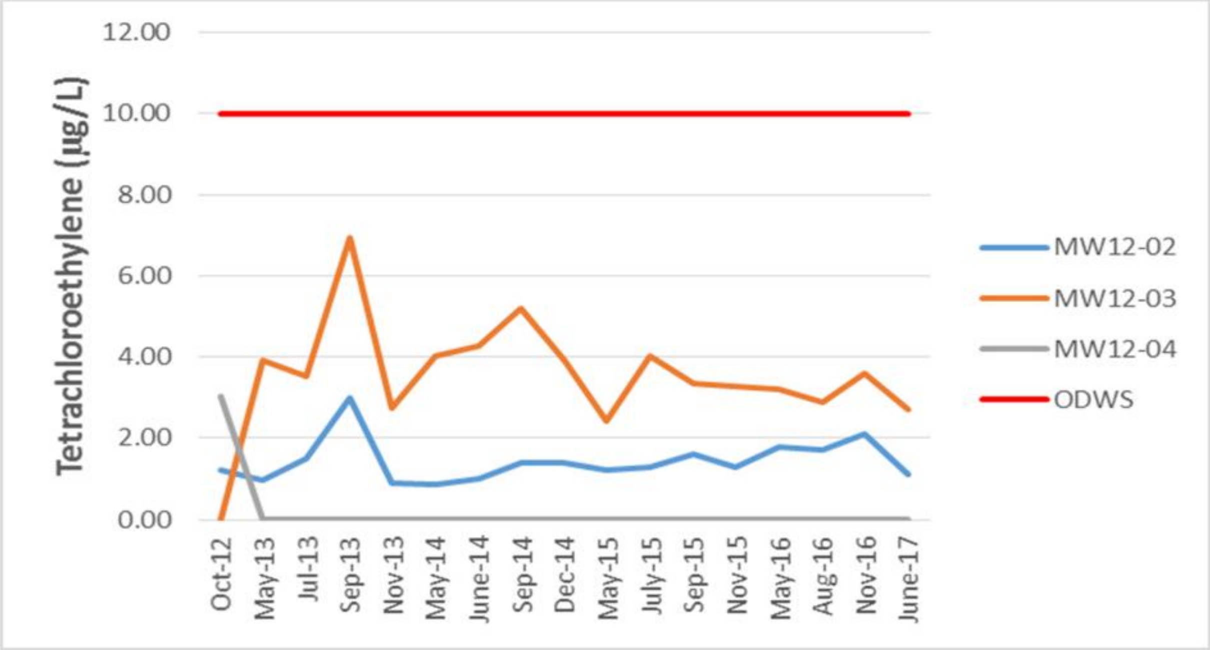


Figure 3.5.4: Tetrachloroethylene Concentrations in Garson Groundwater Monitoring Wells that have Exceeded the Lowest Detection Limit (0.2 µg/L)

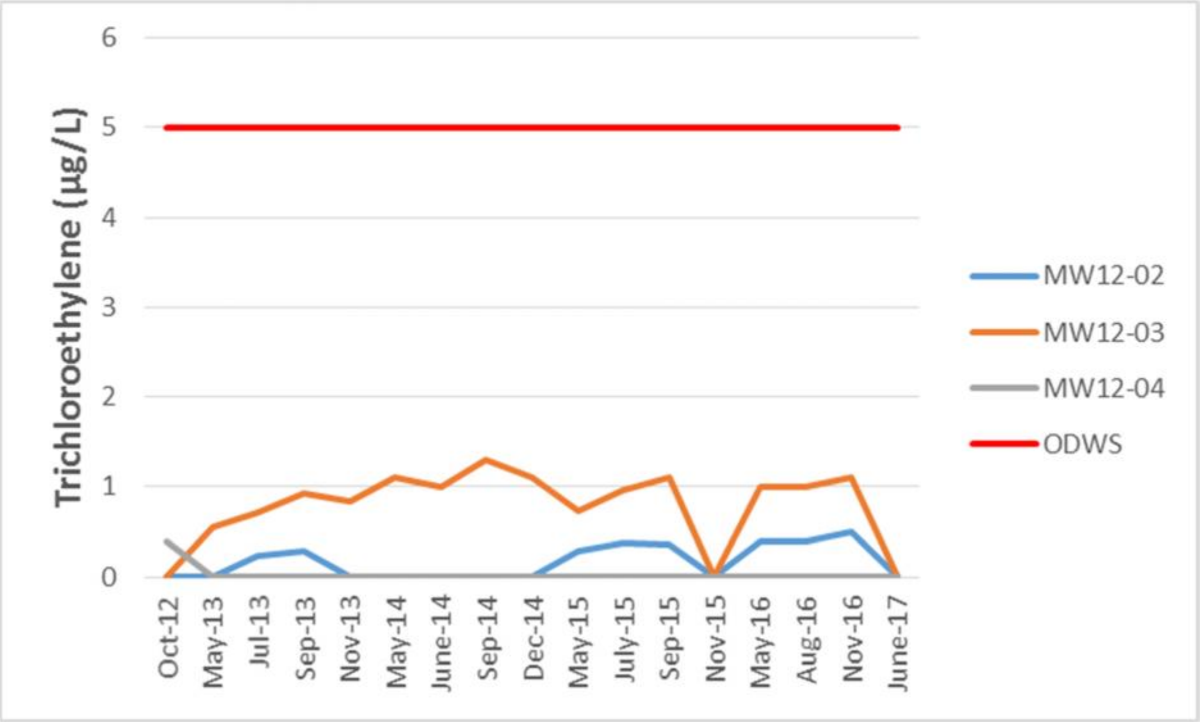


Figure 3.5.5: Trichloroethylene Concentrations in Garson Groundwater Monitoring Well that have Exceeded the Lowest Detection Limit (0.2 µg/L)

3.5.4 Interpretation/Key Findings

3.5.4.1 *Physiography*

The Junction Creek Subwatershed is contained within the CGS excluding the Whitefish Lake Subwatershed. This area includes the former towns of Garson, Minnow Lake, Copper Cliff, Lively, Naughton and Whitefish. Majority of the findings to-date pertain solely to the upper section of the Junction Creek subwatershed, from Garson to Kelly Lake, due to a lack of historical data in the lower reaches. Additionally, the upper section is historically heavily populated. A description of the relevant physical features and general information pertaining to land use activities are included within this section, with land use portrayed on **Figure E2** in **Appendix 'E**'.

The study area is characterized by cold dry winters and relatively warm dry summers. Snow typically occurs during 6 months of the year from November to May. The average annual precipitation at the Sudbury Airport is 899.3 mm. Daily mean temperatures range from a low of -13.6°C in January to a high of 19.0°C in July with an annual mean daily temperature of 3.7°C.

Many lakes are situated within the Subwatershed, including Bennett, Middle, Crooked, Lady MacDonald, Little Fly, Bass, Sand Pit, Meatbird, Clara Belle, Twin, Hannah, Pump, Ramsey, Mud, Kelly, Simon, Echo, Leach, Nepahwin, Nemag, Turner, St. Charles, Robinson, Still, Perch, Fly, Whitefish, Wakemi, McCharles, North Star Lake, and numerous small unnamed bodies of water. Lily and Meatbird Creeks are also part of the Subwatershed and discharge into Junction Creek above and below Kelly Lake, respectively.

Water from precipitation percolates or infiltrates into the ground. Water which reaches the water table may provide recharge to the overall groundwater flow system. Areas where water moves downward to the water table are known as recharge areas. These areas are commonly in areas of topographically higher relief. Areas where groundwater moves upward to the water table are known as discharge areas and these generally occur in areas of topographically low relief, such as stream valleys. Groundwater that discharges to streams maintains the baseflow of the stream. Wetlands may also be fed by groundwater discharge.

3.5.4.2 *Surficial Geology*

The surficial geology mapping and information used to characterize geology are found in The Physical Environment of Greater Sudbury Ontario, Geological Survey, Special Volume 6 (2002). The majority of the Junction Creek Subwatershed is characterized by the bedrock-dominated terrain that Sudbury is known for. The Wanapitei Esker overlays the majority of the subwatershed headwaters from Garson to New Sudbury, with a second glaciolacustrine deposit consisting of sand and silt directly below Kelly Lake. Additional glaciolacustrine deposits, consisting of silt and sand with minor amounts of clay, occur throughout the centre of the subwatershed, from the Wanapitei Esker in new Sudbury, through downtown to Kelly Lake, and along its Western shore; and in Lively. The purpose of the bedrock surface elevation mapping is twofold: to identify bedrock valleys in which there are thicker permeable overburden deposits, and therefore potential water supply aquifers; and to define bedrock highs and lows that could control groundwater occurrence and movement.

The overburden thickness within the study area is greatest in the Garson area, where the esker is situated, in the order of approximately 20 to 65 m. Majority of the study area holds an overburden thickness of 0 to 20 m. Elevation ranges from 111 to 389 meters above sea level. Areas with the lowest elevations are actually open pit mines. Both overburden thickness and elevation within the study area can be seen in **Appendix 'E'**.

3.5.4.3 *Bedrock Geology*

Understanding of the bedrock geology is a key component to understanding deeper aquifer distribution and groundwater movement within the Junction Creek Subwatershed. The geological description of the bedrock units within the Study Area is intended to identify regional aquifers for the purpose of assessing the groundwater resource. Geological bedrock information was compiled from numerous sources, mainly boreholes within the study area from past Wood projects, and The Physical Environment of Greater Sudbury Ontario, Geological Survey, Special Volume 6 (2002).

The underlying bedrock within the study area is comprised mainly of the Huronian Supergroup, with the Elliott Lake Group in the Southwestern parcel, while the Northeastern parcel is comprised primarily of the Hough Lake and Nipissing Gabbro groups, and secondarily Felsic intrusive rocks. The Huronian Supergroup is comprised of four subgroups, three of which are present in the study area: Quirke Lake, Hough Lake, and Elliot Lake. These three subgroups consist of conglomeritic greywacke, siltstone and argillite, and sandstone from the base to the top of each formative, respectively. Norite is found northeast of Garson, at the Maley headwaters, as The Sudbury Igneous Complex lays Northwest of the Junction Creek Subwatershed. Bedrock outcrops and geology of the study area are displayed in **Appendix 'E'** alongside the esker.

3.5.4.3.1 Stratigraphy

Geological cross sections across the study area have been prepared to present a perspective of the subsurface geology. The location of the cross sections and individual cross sections are included in **Appendix 'E'**. These cross sections present details of the interpreted Quaternary and bedrock geology, water table elevation, topography, and interpreted bedrock surface elevation in the area. The cross sections were prepared using borehole and monitoring well data from past Wood projects within the Junction Creek Subwatershed. The four cross sections were prepared for built-up areas where a greater concentration of wells was available. Water table, bedrock and sediment layer elevations were recorded from boreholes and monitoring wells clustered along these cross sections, with additional surface elevations from LiDAR surveys performed by the CGS. These data were used to create the conceptual groundwater model.

3.5.4.3.2 Conceptual Groundwater Flow

The bedrock valley is overlain and infilled with medium to fine-grained glacial outwash deposits, with evidence of some areas of cobbles and basal till unit overlying the bedrock. The medium to fine-grained deposits are comprised mainly of sandy silt to fine to medium-grained sand. These units are overlain by finer grained glaciolacustrine deposits, with the exception of the Wanapitei Esker in the Garson area and the exposed bedrock areas on the bedrock valley flanks.

In general, the Junction Creek Subwatershed groundwater flow system mirrors topography with the potentiometric surface of the shallow aquifers following similar flowpaths of the surficial drainage. There are three very distinct groundwater aquifers/flow systems within the Junction Creek Subwatershed: 1) the unconfined bedrock aquifer exposed at ground surface along the valley flanks; 2) the unconfined Wanapitei Esker deposits at the Junction Creek headwaters; and 3) the confined or semiconfined glacial outwash and till deposits overlain by fine grained glaciolacustrine deposits.

The unconfined bedrock aquifer exposed at ground surface does not provide very high recharge as the bedrock is fairly competent with low permeability and precipitation tends to run off, as opposed to infiltrating.

The Wanapitei Esker deposits present a high recharge potential, but the characteristics of the aquifer that provide this potential also expose the aquifer and the municipal water supply in this area to a greater risk to contamination from surface or near-surface activities. Note that runoff from the surrounding higher elevation bedrock to the esker acts to increase the infiltration potential to this aquifer.

In general, the static groundwater levels within the esker deposits exist at depths of approximately 10 m or more from surface for most wells. Groundwater movement within this deposit is towards Junction Creek with minor deviations in this flow pattern observed in the vicinity of Garson Supply wells, from the associated drawdown cone. Groundwater recharge to the esker, via direct recharge and infiltration from higher elevation bedrock runoff are interpreted to be major sources of cold water baseflow supporting the headwater of Junction Creek. The extent of the unconfined Wanapitei Esker deposits is presented in **Appendix 'E'**.

The confined or semiconfined deposits that extend from the Lasalle Boulevard, downstream towards Kelly Lake, are areas that are dominated by groundwater discharge zones. These areas appear to have low recharge potential due to the presence of a laterally continuous aquitard, which is further compounded by the amount of runoff in these areas induced by largely developed (i.e., paved and landscaped) areas. These reaches appear to have groundwater levels within the low permeability aquitard that that have the potential to discharge to Junction Creek along a number of reaches. Groundwater discharge to the creek and artesian conditions are well known and documented in several reaches of the Junction Creek system, including the Frood and Nolin Subwatersheds, as well as the area between Martindale and Kelly Lake Road.

3.5.4.3.3 Recharge and Discharge Conditions

In principle, areas where infiltration occurs can be defined as recharge areas. However, recharge areas are more realistically defined zones having significant downward groundwater gradients (where the groundwater flow is predominantly downwards vertically). The best recharge areas are thus topographically elevated areas having permeable formations exposed at surface.

Groundwater discharge occurs where the water table or piezometric surface intercepts the ground surface. In general, if the hydraulic head in the aquifer is higher than the ground surface, groundwater is said to be in discharging condition. This condition is essential to maintain a natural balance between the groundwater and surface water flow systems to maintain ecological health.

The Junction Creek Subwatershed does provide recharge conditions in several locations with topographic highs on the flanks of the bedrock valley, which is infilled with coarse grained basal till units. However, the presence of low to moderate permeability glaciolacustrine deposits in the floodplain near Junction Creek limits the areas where significant recharge of groundwater to the creek can occur. The Garson area, which hosts the Wanapitei Esker, provides a significant groundwater recharge area due to the unconfined condition.

Theoretical areas of groundwater discharge within the study were mapped by isolating areas within the subwatershed where the potentiometric surface is above ground level. These areas are displayed in **Appendix 'E'**. Through this analysis, a large part of the Sudbury downtown, Frood and Nolin Subwatersheds consist of areas of groundwater discharge.

3.5.4.3.4 Groundwater Quality

Groundwater occurrence in the subwatershed is in both bedrock and overburden. Throughout the subwatershed, bedrock water quality is typical of Northern Ontario bedrock groundwater, having a moderate degree of mineralization, and often elevated concentrations of manganese and iron. Other elements may be present in elevated concentrations, depending on the depth that groundwater is intercepted and the type of bedrock encountered. Groundwater generally becomes more mineralized with depth, owing to the residence time of the water in the bedrock aquifer.

In terms of overburden aquifers, background groundwater quality in the Junction Creek subwatershed varies, depending on the location with respect to the headwater, local hydrogeology and residence time of recharge water in the aquifer. In the upper subwatershed, the hydrogeology is characterized by a prominent glacial esker, with an unconfined aquifer condition and permeable aquifer materials (sand and gravel). This area is primarily residential, and there are several areas of open sand in active and abandoned sand and gravel pits. Groundwater quality characteristics in this area are typically calcium-magnesium carbonate type, with a relatively low TDS typical of recently recharged groundwater. This groundwater source feeds the CGS Garson municipal well field, and is a primary source of Junction Creek baseflow in this headwater area. The low level of mineralization in the esker water baseflow discharges are an important feature to maintain fisheries in the upper reaches, and to offset the addition of mineralized groundwater further downstream.

In the middle and lower subwatersheds (downtown and below Kelley Lake), hydrogeology is characterized as lower permeability sediments and bedrock, which limits percolation through the groundwater system. As such, groundwater residence times are typically longer than in the upper subwatershed, and the contribution of groundwater to Junction Creek as baseflow is lower per unit area than the upper subwatershed. Given the longer recharge water residence time in the aquifer, groundwater in the middle and lower subwatersheds have a typically higher dissolved solids content, and often have higher iron and manganese concentrations. Throughout much of the middle urbanized subwatershed area, anthropogenic influences on groundwater quality include the use of road salts, blast rock fill and the historic use of crushed nickel-making slag as an engineered fill. These fill materials have introduced sodium, chloride, nickel, copper and cobalt into the groundwater system at varying concentrations throughout the subwatershed. Groundwater impact on Junction Creek in this reach is typically the additional metals loading on the creek along the channel.

Further downstream, for Lively and southwest, the landforms are characterized by thin overburden and exposed bedrock. Where groundwater recharge to shallow overburden aquifers occurs, typical quality would range from a low level of mineralization for recently recharged water, to some mineralization with elevated iron and manganese concentrations for longer groundwater residence times. Another consideration for groundwater quality in the lower subwatershed is the frequent use of septic systems in unserviced residential areas, which often leads to increased nitrogen, phosphorous and bacteriological concentrations being released to groundwater. Subsequently, the groundwater loadings of these parameters, particularly phosphorous, report to the Junction Creek channel and surface water bodies as it passes through the area toward the southwest.

3.5.4.3.5 Infiltration Capacity

Precipitation for the Sudbury area is generally quoted in literature as being on the order of 900 mm/a (mm per annum). As an annual water balance, streamflow is the resultant of precipitation minus evapotranspiration. This difference can then be divided into direct runoff and infiltration or deep drainage. For a given land type, the balance between direct runoff will vary, with a higher proportion of direct runoff occurring from clay and bedrock terrain, and a lower proportion of direct runoff being experienced in areas of opened unconfined moderate to high permeability aquifers.

The publication "Average Annual Water Surplus in Ontario" (D. M. Brown) was reviewed to evaluate the range of runoff vs deep discharge figures for various locations discussed in the paper. In general, the Sudbury area has a water surplus on the order of 350 mm/a, implying that evapotranspiration is on the order of 550 mm/a.

The Junction Creek subwatershed is made up of several land types, which will influence the natural balance of infiltration and runoff. In the D. M. Brown paper, a table was presented from results of modelling at several locations in Ontario. It was noted that deep drainage (infiltration) in a clay plain area such as Kapuskasing is approximately 37%. Areas with open bedrock and glacial overburden are reported with deep drainage numbers of 84% (Mount Forest) and 88% (Wiarton) for example.

From the above, deep recharge to the groundwater aquifer on the Wanapitei esker (Garson headwater area) could be well over 80% for land in its natural state. Conversely, deep infiltration of excess precipitation could be 40% or less in the lower subwatershed areas covered by the glaciolacustrine overburden.

It should be reiterated that the landform surrounding the overburden is bedrock terrain, and additional runoff from bedrock can infiltrate where the bedrock meets the lower overburden deposit. If setting infiltration targets is proposed for managing and maintaining groundwater contributions to Junction Creek, consideration should be given to the additional contribution that bedrock terrain may provide. For example, changing the routing of runoff from bedrock highs may have undesired effects to the aquifer recharge that would need to be compensated if aquifer recharge is to be preserved.

3.6 Fluvial Geomorphic Assessment

3.6.1 Objective

The Fluvial Geomorphological Assessment section of this report provides a characterization and inventory, based on desktop and field assessments, of: the upper branch of Junction Creek between Kelly Lake and Gary Avenue, the Maley Branch between Maley Drive and the confluence with Junction Creek, and the Frood Branch between Nickeldale Dam and the confluence with Junction Creek. This characterization addresses the inventory component of the Study's Terms of Reference, which includes:

- Background review of existing documents related to Junction Creek, including topography, physiography, and geology maps;
- Reach delineation for the main branch of Junction Creek, the Maley Branch, and the Frood Branch;
- Historical assessment of changes in channel adjustment and human modification using historical aerial photographs;
- Site reconnaissance, including rapid geomorphological assessments and channel characterization, for reaches identified above;

- Inventory of active erosion sites within all the reaches assessed during the rapid geomorphological assessments;
- Detailed geomorphological assessments for erosion-sensitive reaches identified during the rapid geomorphic assessments; and,
- Planning level hazard delineation and erosion setbacks for both confined and unconfined reaches.

3.6.2 Background

Channel planform and morphology are largely governed by the flow regime and by the type and availability of sediment (i.e. surficial geology) within the stream corridor. Physiography, riparian vegetation, and land use also influence the channel. These factors provide insight to the existing conditions and perception to potential future changes as they relate to future development activity.

Physiographically, Junction Creek is primarily located on low relief, silt to sand textured glaciolacustrine plains (OGS, 2003). Bedrock knobs are located adjacent to, and within, these plains (OGS, 2003). The bedrock is composed of Nipissing mafic sills (mafic dikes, mafic sills, and related granophyre) and the McKim formation (siltstone, wacke, and argillite) (OGS, 2003).

During the winter months, most of the precipitation is in the form of snow. During spring, snowmelt and rain-on-snow events likely generate long-duration high flows in the watercourses, which result in the most significant flows with respect to shaping the channel. During the summer, convective storms are also likely to have a role in shaping the channel, but are less significant due to the shorter duration of high flows.

The gap analysis (ref. Amec Foster Wheeler, April 2017) found that there were no geomorphological specific reports completed for Junction Creek. Reports from other disciplines were examined for relevant geomorphological data, however information regarding physical observations, erosion sensitivity, active processes, and erosion hazard locations were missing. These gaps are collected and presented within this section of the report.

3.6.3 Branch Delineation

The Junction Creek Subwatershed flows from Garson Township, through downtown Sudbury and four lakes to the confluence with Vermilion River. There are seven major tributaries: Garson, Maley, Frood, Nolin, Lily Creek, Copper Cliff, and Meat Bird. These systems are subdivided at several scales. In this analysis, the main branch of Junction Creek is subdivided into the Upper Junction and the Lower Junction. Two of the seven tributaries that were assessed are the Frood and Maley Branch. This landscape scale allows the systems to be described in general terms before focusing on the smaller, more detailed reach scale.

Lower Junction extends downstream of Kelly Lake to the Vermilion River. Just downstream of Kelly Lake, Junction Creek meanders through a meadow riparian zone surrounded mainly by forest with infrequent residential housing. Lower Junction then flows through a few lakes, Mud Lake, Simon Lake, and McCharles Lake respectively, before it confluences with the Vermilion River.

Upper Junction extends upstream of Kelly Lake through the CGS. Upper Junction has been heavily influenced by urbanization through straightening of the channel and even piping a portion just downstream of the downtown area. The riparian area is narrow and land use is a mix of urban (residential, commercial, and industrial) and recreational. A section of Upper Junction flows through a wetland by the New Sudbury Conservation Area.

The Maley Branch is relatively unconfined by residential development, allowing it to irregularly meander with a high sinuosity within its flood plain. The downstream portion is less sinuous with irregular meanders as it travels between residential development and a sports field complex. A dam adjacent to a golf course north of Maley Drive creates a backwatered section upstream. Directly south of the sports field complex is the confluence of the Maley and Garson branches. The channel typically has continuous and dense riparian buffer zones, with a few sections of meadow.

The Frood Branch upstream of the confluence with Junction Creek has been previously straightened. Upstream of Lasalle Boulevard, the channel is confined through residential, commercial, and a large cemetery area, before ending at the Nickeldale dam.

Both the upper and lower sections of Junction Creek and the Maley and Frood Branch tributaries were delineated into reaches for further assessment.

3.6.4 Reach Delineation and Desktop Characterization

Reach level observations provide a more refined and detailed scale to systematically characterize Junction Creek. Reaches are homogeneous segments of channel used in geomorphological investigations and refine the landscape or branch scale. They are studied semi-independently as each is expected to function or respond in a manner that is consistent within a reach and at least slightly differently among adjoining reaches.

Reaches are delineated based on changes in the following:

- Channel planform;
- Channel gradient;
- Physiography;
- Land cover (land use or vegetation);
- Flow, due to tributary inputs;
- Soil type and surficial geology; and,
- Anthropogenic channel changes.

This follows scientifically defensible methodology proposed by Montgomery and Buffington (1997), Richards *et al.* (1997), and the Toronto and Region Conservation Authority (2004) as well as others.

Reaches were first delineated in a desktop exercise applying available data and information such as aerial photography, topographic maps and geology, and physiography information. These results were then verified in the field, where access was possible. A reach map is illustrated in **Appendix 'F'**. Reaches are numbered from downstream to upstream to provide geographic context.

A total of 20 reaches have been delineated, as displayed in **Figures 3.6.1 to 3.6.4**. Reaches J1 to J6 are within the lower section of Junction Creek. Reaches J7 to J17 are within the upper sections of Junction Creek. Reaches TJ-14 and TJ-14-1 comprise of the Frood Branch Tributary.

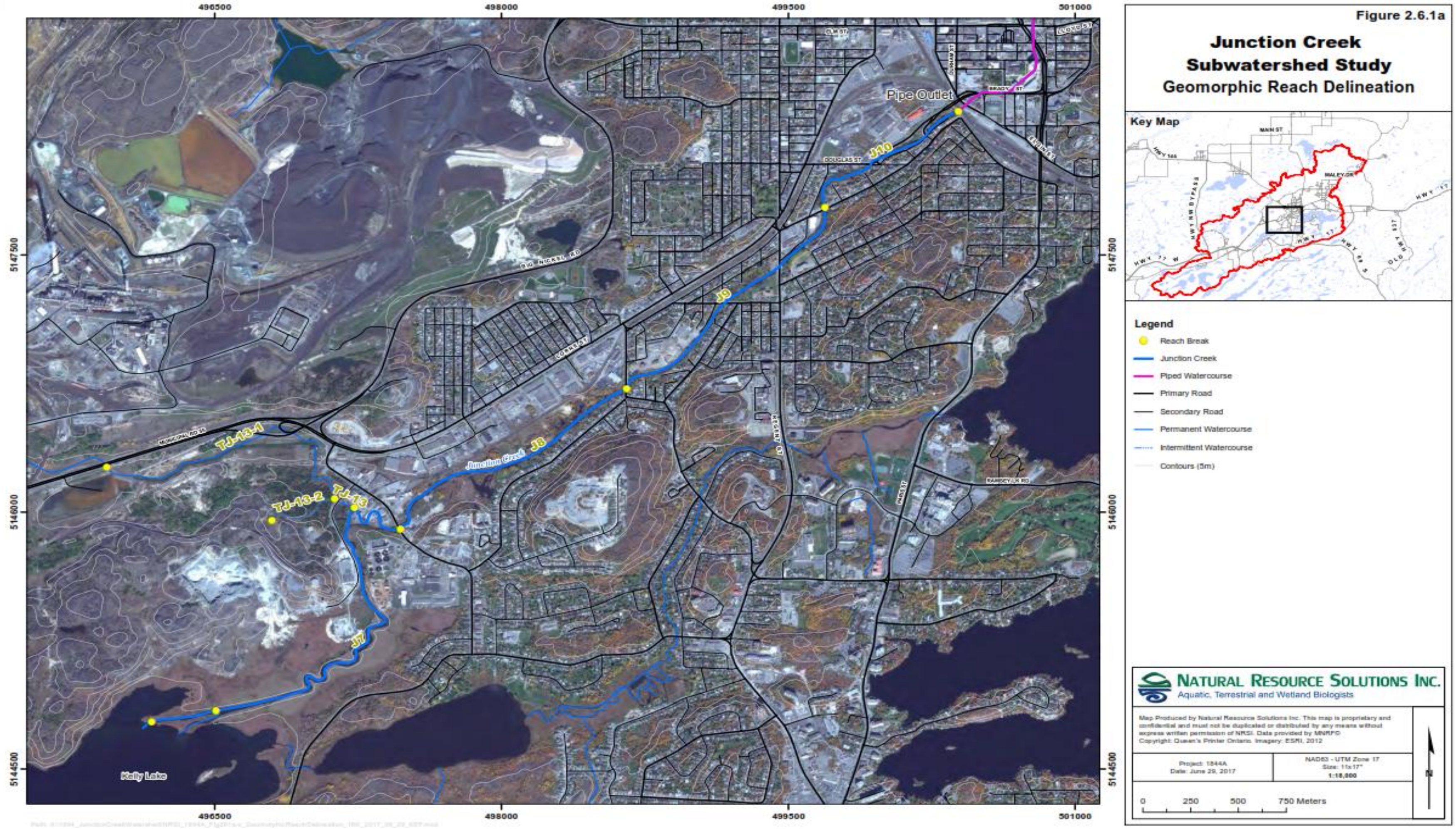


Figure 3.6.1: Geomorphic Reach Delineation

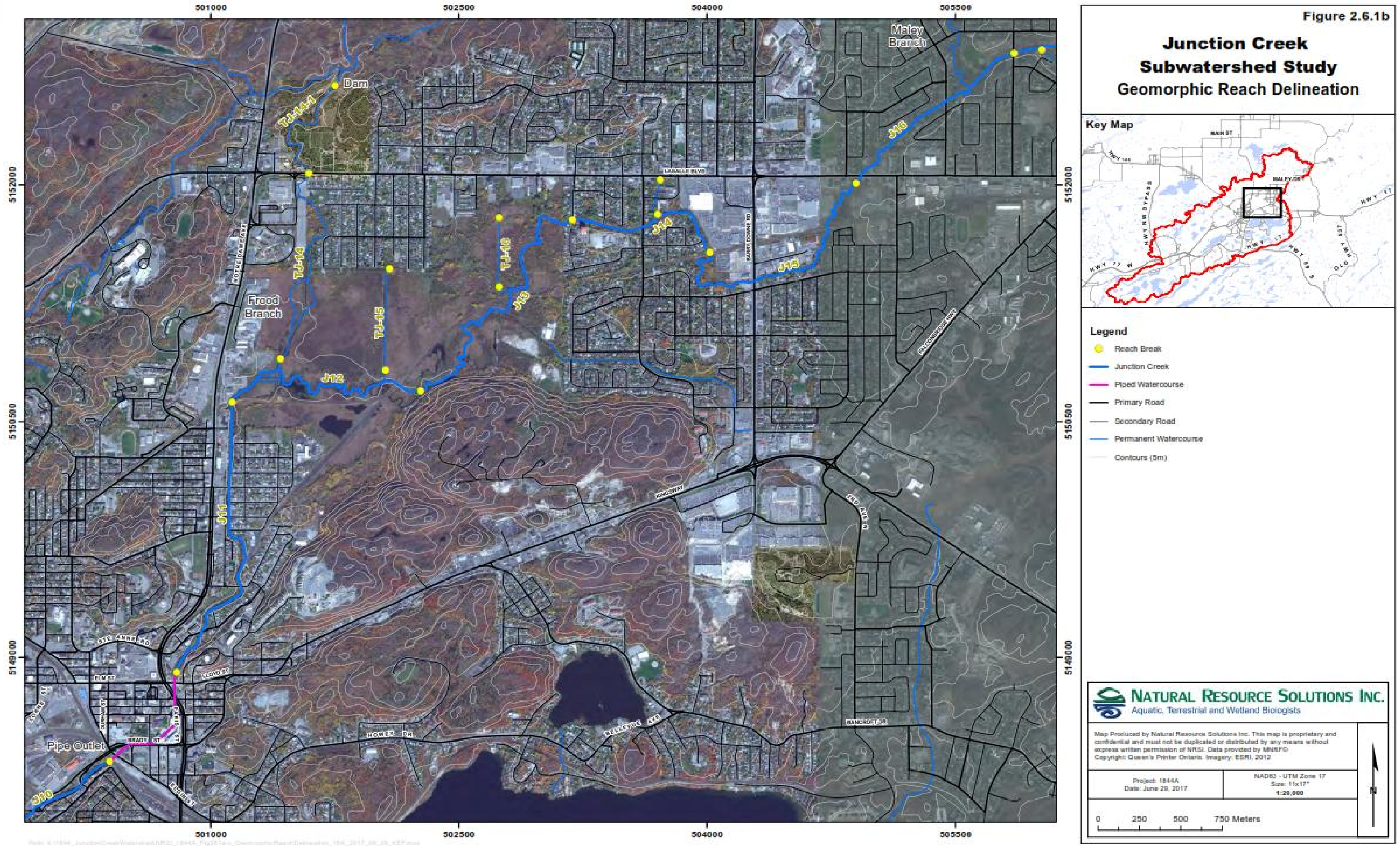


Figure 3.6.2: Geomorphic Reach Delineation

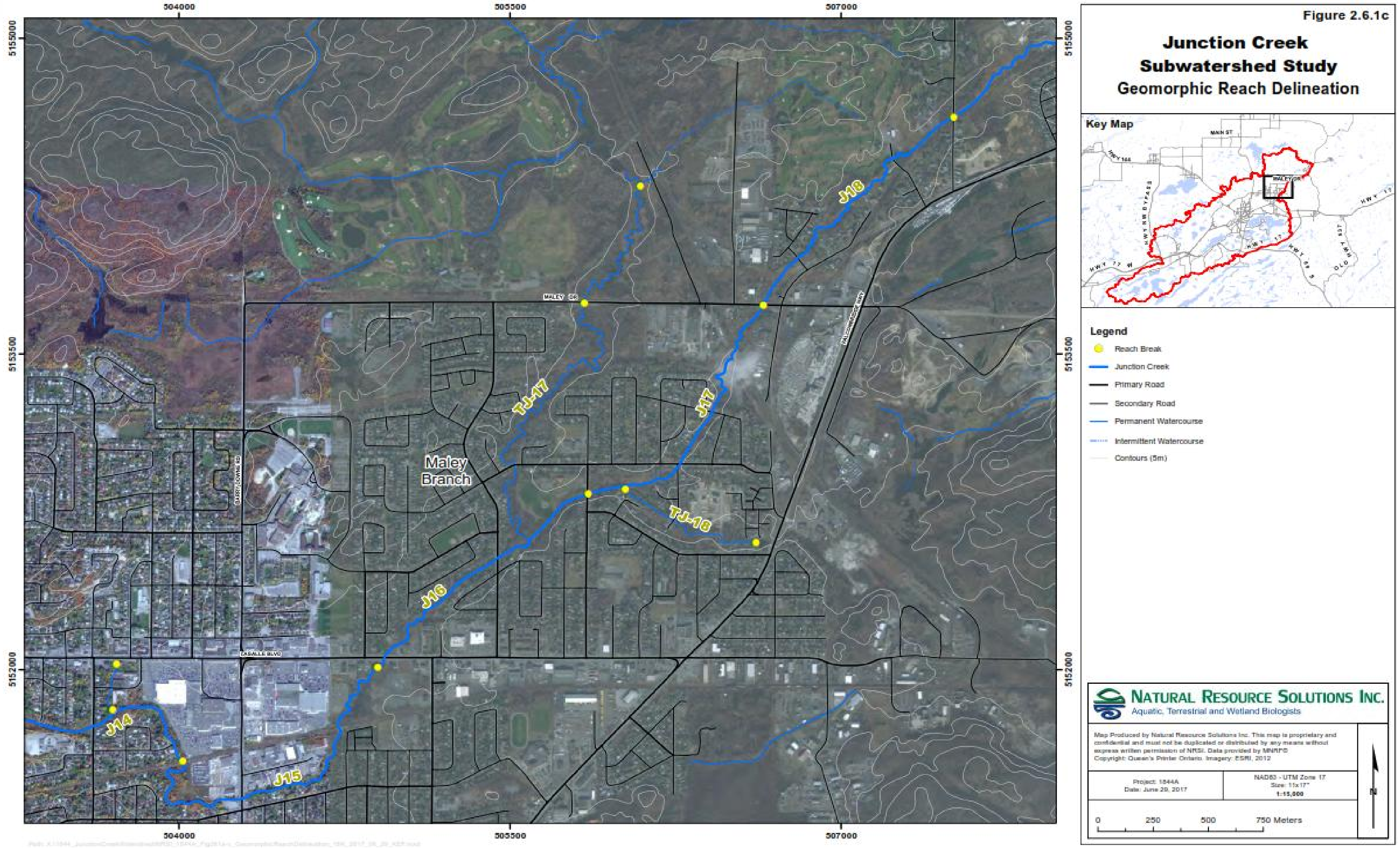


Figure 3.6.3: Geomorphic Reach Delineation

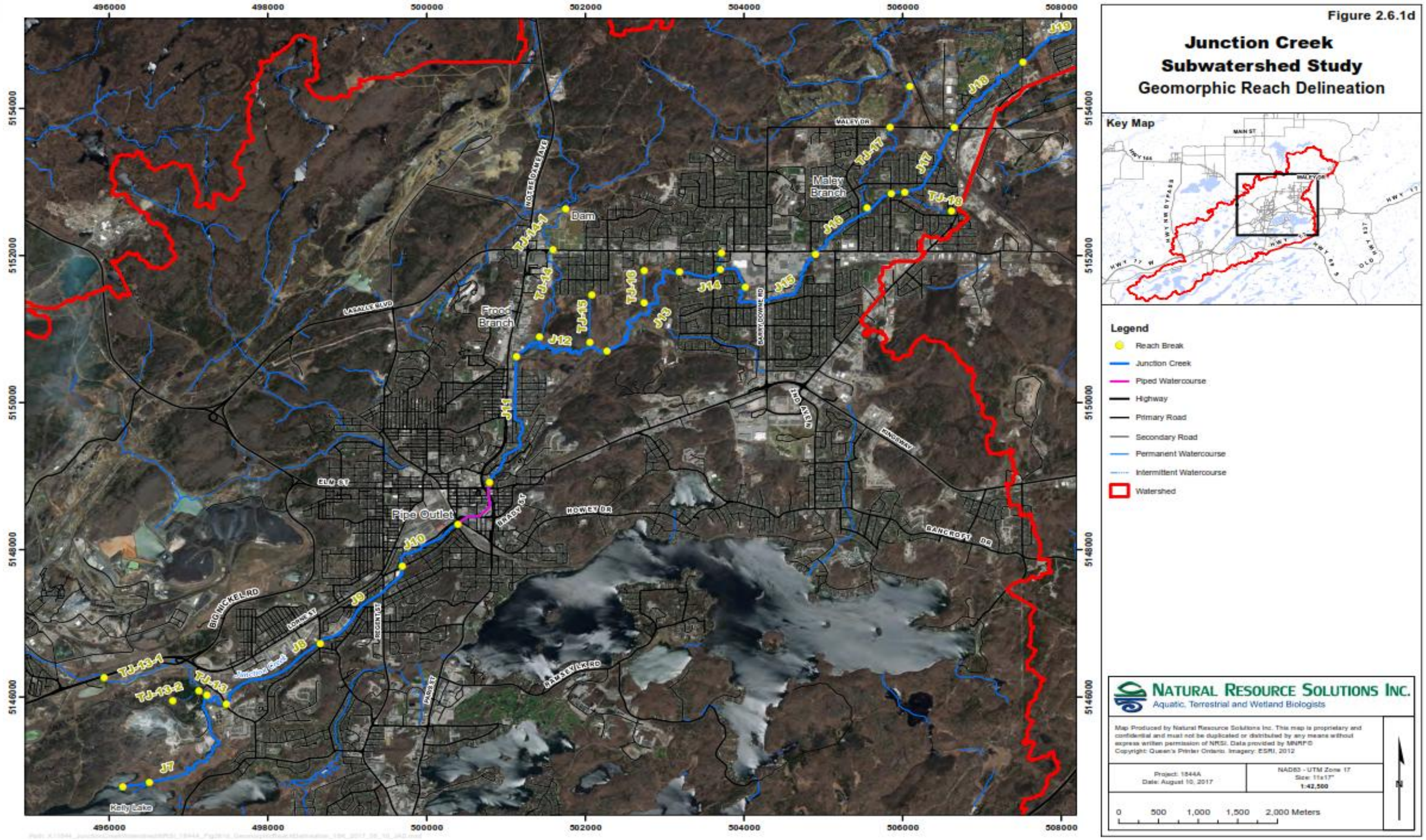


Figure 3.6.4: Geomorphic Reach Delineation

Reach TJ-17 is comprised of the Maley Branch Tributary. Several other tributaries were also delineated, however, as outlined in the terms of reference, the upper portion of Junction Creek, Maley and Frood were field verified. Those outside the study's scope have only been assessed at the desktop level and may require refinement in future planning studies based on field verification.

3.6.5 Historical Assessment

A historical assessment was completed for the watercourses within the upper section of Junction Creek, the Maley Branch, and the Frood Branch using historical aerial photographs. A historical assessment provides insight into the type and extent of changes that have occurred in an area over time. Aerial photographs were used to document land use change in the subcatchment and the channels response to historical changes, including both natural and anthropogenic alterations (i.e. channel straightening/realignment). Historical changes in channel form and function can provide an indication of future channel behavior. Aerial photographs from 1946, 1956, 1969, 1975, 1991, 2003, and orthophotography from 2016 were used to assess changes to the watercourses. Copies of the historical images and delineation of the channel for each year are included in **Appendix 'F'**. The last image in **Appendix 'F'** delineates all years that were assessed to demonstrate the changes of the channel alignment, natural or modified, over time.

3.6.5.1 *Channel Adjustment*

Tree cover within riparian zones was low throughout much of Upper Junction. Over time, existing riparian width and tree cover decreased, especially between 1946 and 1975, to accommodate development pressures. The most abundant tree cover was observed along the Frood Branch and the Maley Branch.

Much of the channel adjustments have been due to realignment. However, reach J13 and the downstream portions of J7 and J12 have not undergone human modification. Where these reaches have not been modified, meander migration is observed, however, no large avulsions were noted.

3.6.5.2 *Human Modification*

There have been significant changes in land cover and land use between 1946 and 2016. In 1946, much of the landscape within proximity to Junction Creek was dominated by native riparian vegetation and agricultural fields. This is especially true for the Frood Branch and Maley Branch. Junction Creek passed through few residential areas in this period, all located along the central reaches of the watercourse. In 1946, the channel planform of Junction Creek was represented by evident geomorphic units (including meanders), which were typically located in less-developed locations within the Boundary Area. Between 1946 and 1956 there was a shift from forest to an agricultural-dominated landscape. There was also an increase in development area. Though infrastructure associated with development was beginning to appear, including transportation networks and housing, forest and agriculture remained the dominant land covers and uses. There was increases in development surrounding all reaches of Junction Creek, however no major changes in the physical characteristics of the watercourse or surrounding banks were observed between 1956 and 1969. Between 1969 and 1975 there was continued conversion from rural to urban land uses. Through the 1991, 2003, and 2016 aerial photographs there was significant development, with the establishment of additional transportation networks, housing units, recreational facilities (including golf courses), and industrial landscapes in the form of mines and quarries.

With the increase in development, direct human modifications to the watercourse were identified. The straightening of Junction Creek to accommodate development is visible in all aerial photographs. In areas previously characterized by meanders, specifically stemming upstream of Kelly Lake in 1946, as well as areas occupied by transportation networks, specifically surrounding the train station located centrally near Junction Creek, watercourse straightening is present. It is understood that such straightening activities were completed prior to 1946, however establishment of the manipulated watercourse remains evident through time. Reaches J9 and J10 were previously straightened prior to 1946. The piped section of channel between reaches J10 and J11 was also completed prior to 1946. Reaches J8 and J11 were straightened between 1946 and 1956. Sections of J14, J15, and J16 were straightened for development between 1956 and 1969. As well, the upstream portion of reach J12 was realigned for the construction of the rail line between 1956 and 1969. The upstream portion of J7 was realigned between 1975 and 1991.

3.6.6 Channel Characterization from Field Observations

3.6.6.1 *Rapid Geomorphic Assessment*

Reach observations and channel measurements were collected over several days in May 2017. These field investigations were utilized to verify and refine reaches and gain insight into the conditions and general characteristics of each reach in the study area. Field observations were limited to reaches located on public lands within the CGS. The photographic record included in Appendix F2 documents the conditions from all observed reaches. Field observations are provided in Appendix F3 for reference.

The rapid geomorphological assessments included the following reach observations:

- Characterization of stream form, process, and evolution using the Rapid Geomorphological Assessment (RGA) (MOE, 2003, VANR, 2007);
- Assessment of the ecological function of the watercourse using the Rapid Stream Assessment Technique (RSAT) (Galli, 1996);
- Stream classification following a modified Downs (1995) and a modified Brierley and Fryirs (2005) River Styles Classification approach;
- Instream estimates of bankfull channel dimensions;
- Bed and bank material composition and structure; and,
- Georeferenced photographs to document the location of all observed erosion and infrastructure.

Channel instability was objectively quantified through the application of the Ontario Ministry of the Environment’s (2003) Rapid Geomorphic Assessment (RGA). Observations were quantified using an index that identifies channel sensitivity based on evidence of aggradation, degradation, channel widening, and planimetric adjustment. The index produces values that indicate whether the channel is stable/in regime (score <0.20), stressed/transitional (score 0.21-0.40), or adjusting (score >0.41).

The Rapid Stream Assessment Technique (RSAT) was also employed to provide a broader view of the system and consider the ecological functioning of the watercourse (Galli, 1996). Observations were made of channel stability, channel scouring or sediment deposition, physical instream habitat, water quality, and riparian habitat conditions. The RSAT score ranks the channel as maintaining a poor (<13), fair (13-24), good (25-34), or excellent (35-42) degree of stream health.

Reaches were classified according to a modified Downs (1995) Channel Evolution Model, which describes successional stages of a channel as a result of a perturbation, namely hydromodification. Understanding the current stage of the system is beneficial as this allows one to predict how the channel will continue to evolve, or respond to an alteration to the system.

The River Styles Framework (Brierley and Fryirs, 2005) provides a geomorphic approach in examining river characteristics, behaviour, conditions, and potential recovery through the identification of the Geomorphic Process Zone. Geomorphic attributes are assessed, larger scale interactions between zones are analyzed, and historical data are studied to quantify the historical evolution and future trajectories of those reaches. This knowledge ultimately provides a physical template for river management. A modified classification approach was applied to the reaches.

This combination of standardized approaches provides a holistic and detailed overview of form, function, dominant processes and adjustments, and potential future trajectories. The results of the rapid assessments are presented in **Table 3.6.1** and **Appendix 'F'**. General channel characteristics are provided in **Table 3.6.2**.

Table 3.6.1: Rapid Assessment Characteristics

Reach	RGA (MOE, 2003)			RSAT (Galli, 1996)			Down's Channel Evolution Model (1995)	River Styles Framework (Brierley and Fryirs, 2005)
	Score	Condition	Dominant Systematic Adjustment	Score	Condition	Limiting Features		
J7	0.23	In Transition / Stress	Evidence of Aggradation	23	Fair	Riparian Habitat	M – lateral Migration	Meandering, suspended load
J8	0.18	In Regime	Evidence of Widening	23	Fair	Riparian Habitat	E – enlarging	Slightly Meandering, mixed load
J9	0.27	In Transition / Stress	Evidence of Widening	19	Fair	Riparian Habitat	C- compound	Slightly Meandering, mixed load
J10	0.26	In Transition / Stress	Evidence of Widening	23	Fair	Riparian Habitat	E – enlarging	Slightly Meandering, mixed load
J11	0.20	In Regime	Evidence of Widening	20.5	Fair	Channel Stability	E – enlarging	Slightly Meandering, mixed load
J12	N/A: Wetland						S- stable	Meandering, suspended load
J13	0.27	In Transition / Stress	Evidence of Widening	24	Fair	Riparian Habitat	C – Compound	Meandering, suspended load
J14	0.29	In Transition / Stress	Evidence of Widening	23	Fair	Riparian Habitat	E – enlarging	Slightly Meandering, mixed load
J15	0.24	In Transition / Stress	Evidence of Widening	19	Fair	Riparian Habitat	E – enlarging	Meandering, mixed load
J16	0.21	In Transition / Stress	Evidence of Widening	23.5	Fair	Riparian Habitat	E – enlarging	Slightly Meandering, mixed load
TJ-14	0.18	In Regime	Planimetric Form Adjustment	27.5	Good	Riparian Habitat	S – stable	Straight, suspended load
TJ-14-1	0.09	In Regime	Evidence of Widening	29	Good	Riparian Habitat	E – enlarging	Slightly Meandering, mixed load
TJ17	0.28	In Transition / Stress	Evidence of Widening	21	Fair	Channel Stability	E – enlarging	Meandering, mixed load

Table 3.6.2: General Channel Characteristics

Reach	Average Bankfull Width (m)	Average Bankfull Depth (m)	Substrate		Valley Type	Riparian Vegetation	Notes
			Riffle	Pool			
J7	16.2	1.5	No riffle-pool development: clay, silt, sand, gravel		Unconfined	Shrubs and grasses dominant, scattered trees, fragmented	Slumping, overbank deposits, leaning and fallen trees, and re-worked point bars.
J8	19.7	1.8	Gravel, cobble, boulder	Clay, silt, gravel, cobble, till	Partially Confined	Trees and grasses, fragmented	Bank failure, beaver dam, and erosion scars.
J9	11.0	0.7	Sand, gravel, cobble, boulder	Clay, silt, sand, gravel, cobble	Partially Confined	Trees and grasses, fragmented	Lobate bar, bed forms, erosion scar, overbank sand deposits, some root exposure, and a beaver dam.
J10	9.5	1.8	Gravel, cobble, boulder	Clay, silt, sand, till	Unconfined	Trees, grasses, herbaceous vegetation, fragmented	Significant slumping and undercutting, exposed roots, and woody debris.
J11	11.0	1.0	Gravel, cobble, boulder	Clay, silt, sand, gravel, cobble	Confined	Grasses dominant, trees and shrubs, fragmented	Mostly runs, substrate poorly sorted, undercutting, and chutes.
J12	N/A: Wetland		No riffles present. Clay, silt, sand		Unconfined	Shrubs and grasses, continuous	Only small portion of reach accessed downstream of wetland system. Beaver dams present, and no defined banks present.
J13	7.7	1.4	No riffles present. Silt, sand		Unconfined	Trees, shrubs, grasses, continuous	Slumping, overbank deposits upstream of a beaver dam, and a large erosion scar.
J14	6.8	1.6	Sand, cobble, boulder	Clay, silt, sand, gravel	Partially confined	Trees and grasses, fragmented	Mostly runs, woody debris jams, slumping next to trail due to woody debris jam, and one riffle present.
J15	7.4	0.8	Cobble, boulder	Clay, silt, sand, cobble, boulders	Partially confined	Grasses and shrubs, fragmented	Islands present, undercutting, major slumping, fallen trees, thalweg out of line, beaver dam, and woody debris.
J16	5.7	1.0	Gravel	Clay, silt, sand, gravel	Unconfined	Trees and shrubs, fragmented	Beaver dams, leaning and fallen trees, woody debris jams, and more noted erosion upstream.
TJ-14	5.3	0.9	Sand, gravel, cobble	Clay, silt	Unconfined	Trees, fragmented	First 30 m has riffle- pool sequences; remainder of reach backwatering due to beaver dams, and an elevated outfall.
TJ-14-1	6.4	0.6	Sand, gravel, cobble, boulder	Sand, gravel, cobble	Confined	Trees, fragmented	Manholes follow along left bank, amourstone, and a beaver dam.
TJ-17	7.2	1.3	No riffles present. Clay, silt, cobbles, boulders, parent material		Partially confined	Trees and grasses, fragmented	Exposed till present, woody debris jam, undercutting, and slumping.

3.6.6.2 *Inventory of Active Erosion Sites*

Active erosion sites were documented during the rapid geomorphic assessments. The inventory is limited in the absence of current information on buried infrastructure. **Table 3.6.3** below provides the type, location, and extent, and the issues and concerns for each reach that had areas of significant and active erosion. Bank erosion (BE) has been identified as the primary type of active erosion within the Junction Creek Subwatershed. Valley wall contacts (VWC) were also observed in reach J9, J14, J15, and TJ-17. Sites considered either stable or experiencing minor erosion are not included in the inventory. Locations of the active erosion sites are provided in **Appendix 'F'**.

Table 3.6.3: Inventory of Active Erosion Sites

ID Code	Issues and Concerns
Reach J7	
BE1	-Rotational slumping and undercutting along both banks for an extensive area of approximately 300 m.
BE2	-Severe undercutting and rotational slumping along left bank.
BE3	-Large slump along left bank approximately 15 m long.
Reach J8	
BE4	- Large slump with scar approximately 10 m long; and - Woody debris jam across stream, perpendicular to slump.
BE5	-Rip rap and bank protection have been displaced and topsoil removed; -Directly downstream of a beaver dam; and -Erosion scar approximately 15 m long.
BE6	- Minor slumping directly downstream of a beaver dam.
Reach J9	
VWC1	- Undercutting, toe exposure along left bank.
BE7	- Slumping.
BE8	- Large scar on right bank directly downstream of bridge; and - Outfall pipe broken off.
BE9	- Erosion scar on right bank directly upstream of bridge.
Reach J10	
BE10	- Moderate undercutting and slumping on left bank at edge of residential property.
BE11	- Erosion scar at edge of residential property.
BE12	- Slumping of left bank directly downstream of bridge at edge of residential property.
BE13	- Erosion scar on left bank near parking lot of apartment complex.
Reach J11	
BE14	-Fracture lines and slumping along right bank.
Reach J12	
No notable large-scale erosion within accessed portion.	
Reach J13	

ID Code	Issues and Concerns
BE15	- Large erosion scar at edge of residential property.
Reach J14	
BE16	- Left bank sloughing into stream, directly upstream of bridge crossing
BE17	- Erosion scar on right bank directly upstream of small bridge crossing; and - Manhole column exposed in bank
BE18	- Rotational slumping scar at culvert, directly downstream of railway bridge crossing.
BE19	- Large slumping scar on left bank; and - Tree roots exposed.
VWC2	- Undercutting and toe expose of left bank.
VWC3	- Erosion scar along valley wall on left bank.
TJ-14	
BE20	- Outfall and gabion basket detached from bank.
BE21	- Elevated outfall.
TJ-14-1	
BE22	- Slumping edge of parking lot.
Reach J15	
BE23	- Erosion scar and undercutting.
BE24	- Guard rail falling into channel.
BE25	- Erosion scar along left bank beside road crossing; and - Exposed tree roots.
BE26	- Tree fall in channel due to undercutting and bank failure; and - Exposed tree roots.
BE27	- Erosion scar and fracture lines evident.
VWC4	- Toe erosion of the valley wall.
Reach J16	
BE28	- Undercutting, slumping, and fracture lines evident.
BE29	- Rotational slide and slumping scar bordering residential properties.
BE30	- Bank failure scar at edge of residential property.
Reach TJ-17	
BE31	- Rotational slide scar on outside of meander bend; - Leaning trees; and -Sheds from a residential property at top of bank.
BE32	- Erosion scar at edge of recreational trail.
VWC4	- Large erosion scar exposing valley toe at outside of meander bend.

3.6.6.3 *Detailed Geomorphic Assessments*

Detailed geomorphological assessments were completed on reaches TJ-14-1 and J15 in May 2017. These reaches were chosen based on accessibility to survey the sites. The locations and extents of the detailed assessments are provided in **Appendix 'F'**. As such, defining erosion thresholds is necessary to mitigate negative post-development impacts.

The detailed assessment includes the following:

- Longitudinal profile of the channel;
- Detailed cross-sectional surveys of the watercourse;
- Detailed instream measurements at each cross-section location including bankfull channel geometry, riparian conditions, bank material, bank height/angle, and bank root density;
- Bed material sampling at each cross-section following a modified Wolman's (1954) Pebble Count Technique or substrate sample; and,
- Velocity, discharge, and observations of active/inactive sediment transport at select representative cross-sections.

Summaries of the detailed assessment results are provided in **Appendix 'F'**.

3.6.7 Erosion Hazards

Erosion, although a natural process in river systems, can affect aquatic habitat, water quality, and interfere with human activity. As such, delineation of erosion hazards is a critical element of a Subwatershed Study as it is used to inform future development plans. Erosion hazards are delineated on a reach-by-reach basis and dependent on valley type and channel morphology (particularly channel planform).

3.6.7.1 *Confined and Unconfined Hazard Delineation*

When assessing channel erosion hazard, the Ontario MNRF treats unconfined and confined systems differently. Unconfined systems are those with poorly-defined valleys well-outside where the channel could realistically migrate. Confined systems are those where the watercourse is contained within a defined valley, where valley wall contacts are possible.

In unconfined systems, the erosion hazard is assumed to be the result of channel migration, which therefore requires a meander belt width assessment. A meander belt width assessment estimates the lateral extent that a meandering channel has historically occupied and will likely occupy in the future. This assessment is therefore useful for determining the potential hazard to proposed activities adjacent to the watercourse.

Delineation of the extent and position of the meander belt width required definition of the centreline of the channel and central tendency. Orthorectified aerial imagery are used to determine the current watercourse centreline and the channel's central tendency (i.e., meander belt axis), and outline the margins of the meander belt ensuring that its axis minimizes the number of breaks (i.e., direction changes) and that it encompass all the meanders within the reach. By overlaying historical aerial imagery (ortho-rectified and georeferenced), individual meander bends can also be tracked over time to determine the 100-year migration rate, or 100-year erosion setback. An appropriate factor of safety is then applied to define the erosion hazard limit.

In cases where the channel location is unable to be determined in the imagery – due to tree cover or poor photograph resolution, for example – a modelling approach is employed; more specifically, empirical models such as a modified Williams (1986) approach and the Toronto and Region Conservation Authority (2004). These models are suitable for ranges of channel types observed in southern Ontario.

With watercourses that are fully confined within a valley, the erosion hazard considers both channel erosion and slope stability. As such, the hazard assessment also requires a toe erosion allowance and determination of a stable top-of-bank. According to the TRCA (2004) protocol, the meander belt margin can be positioned half-way between toe and top of slope of the valley wall, viewed orthogonally.

This is the planning level hazard delineation for both meander belt widths and erosion setbacks. We assume that these proposed numbers will be refined in future studies by proponents.

3.6.7.2 *Unconfined Systems: Meander Belt Widths*

Meander belt widths were estimated for all unconfined and partially confined reaches. Several methods were utilized to estimate meander belt widths. The 1946 historical aerial imagery and the 2016 ortho image were used, where possible, to determine the largest historical meander amplitude for the reach in question. Where the largest meander is measurable meander belt widths can be calculated by including an appropriate factor of safety or erosion setback.

When the aerial photograph procedure could not be performed, empirical models were applied to provide estimates. **Table 3.6.4** outlines the planning level meander belt width estimates. The empirical relations from Williams (1986) were modified to include channel area and width, and applied using the bankfull channel dimensions such that:

$$\boldsymbol{B_w = 1\ \ A^{0.6}\ \ + W_b} \qquad \textbf{[Eq. 1]}$$

$$\boldsymbol{B_w = 4.3{W_b}^{1.1}\ \ + W_b} \qquad \textbf{[Eq. 2]}$$

where B_w is meander belt width (m), A is bankfull cross-sectional area (m^2), and W_b is bankfull channel width (m). An additional 20% buffer, or factor of safety, was applied to the computed belt width values.

Table 3.6.4: Meander Belt Width and 100 Year Erosion Set Back Estimates

Reach	Valley Type	Meander Belt Width (m)		*Largest Meander Amplitude (m)	Proposed Meander Belt Width (m)	Bank Material	100-yr Erosion Set Back (m)
		*Williams – Area (1986) (m)	*Williams – Width (1986) (m)				
J7	Unconfined	190	136	96	115	N/A	N/A
J8	Partially Confined#	244	170	150	180	Clay, silt, and sand	8 – 15
J9	Partially Confined#	95	89	No Meanders	95	Sand and gravel	8 – 15
J10	Unconfined#	150	76	54	65	Sand	8 – 15
J11	Confined#	116	89	81	97	Sand	8 - 15
J12	Unconfined	N/A: no access		96	115	N/A	N/A
J13	Unconfined	110	61	114	137	N/A	N/A
J14	Partially Confined#	108	53	43	52	Clay and silt	5 – 8
J15	Partially Confined#	79	58	67	80	Clay and silt	5 – 8
J16	Unconfined#	77	44	59	71	Clay and silt	5 – 8
TJ-14	Unconfined	64	40	46	55	N/A	N/A
TJ-14-1	Confined	N/A: confined				Clay, silt, sand, and bedrock	5 – 8
TJ17	Partially Confined#	101	56	59	71	Clay, silt, and till	5 – 8

* Includes 20% Buffer/Factor of Safety

\# Valley type defined from a desktop assessment

Partially confined reaches are those where the watercourse is within contact or close to the vicinity of only one defined valley walls. Therefore, there is a valley system still associated with these reaches. A meander belt width has been defined for these reaches. However, it should be noted that where valley walls greater than 2.0 m in height are present the hazard is managed as a confined system. A geotechnical study will be required to identify a stable top of bank where the creek contacts the valley wall.

There were no meanders to measure for reach J9. This reach had been straightened prior to 1946. Reach J12 was inaccessible to do water levels within the wetland at the time of assessment. However, meander amplitude was measured to determine the proposed meander belt width.

Proposed meander belt widths were determined by desktop measurement of the largest meander amplitude plus a 20% factor of safety. Meander amplitudes measured via desktop is a more appropriate method than modelled results. The model results in **Table 3.6.4** are for comparison with the measured amplitudes. Meander belt widths for unconfined or partially confined reaches are presented in Appendix F.

Proposed meander belt widths are for a planning level study. Valley type for many of the reaches are defined from a desktop level assessment and will need to be further refined. The proposed erosion setbacks are conservative in nature at this stage of the study. The proposed meander belt widths do not account for existing infrastructure. The hazard line cannot extend beyond existing infrastructure from a practical perspective.

3.6.7.3 *Confined Systems: Erosion Setbacks*

As stated previously, confined creek systems are not subject to meander belt widths, as the channel is confined to a valley corridor. The MNRF's Erosion Hazard Technical Guidance report defines confined creek systems as:

"those where the watercourse is located within a valley corridor, either with or without a floodplain, and is confined by valley walls. The watercourse may be located at the toe of the valley slope, in close proximity to the toe of the valley slope (less than 15 m), or removed from the toe of the valley slope (more than 15 m)", (MNRF, 2001).

The remaining watercourses were classified as confined systems, contained within well-developed valley walls. This includes the following reaches: TJ-14-1, J11.

The MNRF's Erosion Hazard Technical Guidelines require that erosion hazard limits in confined systems be defined by a toe erosion allowance and stable top-of-bank (MNR, 2001). If the toe of the valley slope is adjacent to the river, a toe erosion allowance is suggested to ensure safety if the stream erodes the channel banks. The toe erosion allowance is based on the channel's proximity to the toe of slope and evidence of active channel erosion. Toe erosion allowance and stable top-of-bank are also suggested where the watercourses are in contact with the valley walls within the partially confined reaches. These reaches are identified in **Table 3.6.4**.

In accordance with the MNRF's Technical Guidelines (2001), the confined reaches are assigned a toe erosion allowance based on the type of material, the native soil structure, and evidence of active erosion within the reach. Based on the observations thus far, the toe erosion allowance potential ranges from 5 m to 8 m for stiff/hard, cohesive soils such as clays, clay-silt, coarse granular, and tills. The toe erosion allowance for soft/firm cohesive soil, loose granular (sand and silt), or fill ranges from 8 m to 15 m.

To further refine the erosion hazard assessment, the stable top-of-bank for each reach should be defined through a valid geomorphological assessment and geotechnical study. The proposed erosion setbacks are conservative in nature.

3.6.8 Erosion Threshold Analysis

An erosion threshold can be defined as the magnitude of flow required to potentially entrain and transport channel bed and/or bank materials. Threshold targets are therefore established, to guide erosion targets for conceptual stormwater management designs to ensure that natural erosion rates in the receiving watercourse are not accelerated.

The erosion threshold analysis provides a depth, velocity, or discharge at which sediments of a particular size may potentially be entrained. The results of the detailed geomorphic assessments, outlined in **Section 3.6.6.3**, were used to inform the erosion threshold analysis. It is noted that even under the most typical conditions, due to natural variability of channel morphology and sediment characteristics within the reach, the computed flow characteristics would only provide first approximations of erosion thresholds.

An erosion threshold, in the form of a critical discharge, was quantified based on the bed and bank materials and local channel geometry for the two detailed assessment sites. Theoretically, above this discharge, entrainment and transport of sediment can occur.

Threshold targets are determined using different methods that are dependent on channel and sediment characteristics. For example, thresholds for non-cohesive sediments are commonly estimated using empirically-derived shear stress or velocity values such as those compiled by Fischenich (2001) or Julien (1998).

The shear stress of the banks depends on multiple variables. In addition to the size of the materials, the cohesiveness of the bank materials, as well as the effect of vegetation, which reinforce the banks, are taken into account. A typical approach is to determine thresholds for the banks by using empirically derived values for various materials, such as that of Fischenich (2001). An erosion threshold, in the form of a critical discharge, was quantified based on the bed and bank materials and local channel geometry. Theoretically, above this discharge, entrainment and transport of sediment can occur. The velocity, *U*, is calculated at various depths, until the average velocity in the cross section slightly exceeds the critical velocity of the bed material. The velocity is determined using a Manning's approach, where the Manning's n value is visually estimated. This is mathematically represented as:

$$U = \frac{1}{n} d^{2/3} S^{1/2} \qquad \textbf{[Eq. 3]}$$

where, *d* is depth of water, *S* is channel slope, and *n* is the Manning's roughness. The discharge is then calculated using the area of a typical cross section at that depth. Results of the erosion threshold analysis are provided below in **Table 3.6.5**.

Table 3.6.5: Erosion Thresholds and Average Channel Parameters for Detailed Sites

Parameter	**TJ-14-1**	**J15**
Average Bankfull Channel Width (m)	5.66	8.13
Average Bankfull Channel Depth (m)	0.46	0.97
Bankfull Gradient (%)	2.42	0.16
Bed Material D_{50} (m)	0.039†	0.002
Average Bankfull Velocity (m/s)	1.64	1.12
Average Bankfull Discharge (m^3/s)	3.55	8.78
Bankfull Shear Stress (N/m^2)	90.79	15.16
Manning's n (visually estimated)	0.050	0.035
Erosion thresholds for bed materials		
Critical Velocity (m/s)	1.14*	0.53**
Critical Discharge (m^3/s)	1.24	1.08
Critical Water Depth (m)	0.38	0.47
Apparent Shear Stress (N/m^2)	55.40	4.94

† D50 of riffles

* Critical velocity determined through Julien (1998)

** Critical velocity determined through Fischenich (2001)

The critical discharge needed to entrain the bed materials in reach TJ-14-1 was estimated at 1.24 m^3/s, based on a critical velocity of 1.14 m/s determined using Julien (1998) for noncolloidal bed materials ranging from silt to cobbles. The critical discharge needed to entrain the bed materials in reach J15 was estimated at 1.08 m^3/s, based on a critical velocity of 0.53 m/s determined using Fischenich (2001) for a sandy loam. Typically, the more conservative erosion threshold between the bed and bank materials is applied. However, the bed and bank materials were similar for both reaches.

These are planning level erosion threshold values and are characteristics of the creek. However, they may not be the most conservative values based on the most sensitive reaches. Erosion threshold values should be further refined in more a detailed study.

3.6.9 Summary of Activities Completed

The aim of this geomorphological component of the study was to develop an understanding of the existing conditions of Junction Creek. This included reach delineation for all watercourses; a historical evaluation of the changes in channel adjustment and human modification; rapid geomorphological assessments and inventory of active and significant erosion sites for reaches on participating lands; detailed geomorphological assessments for erosion-sensitive reaches; delineation of meander belt widths for unconfined reaches; erosion setbacks for confined reaches; and preliminary erosion thresholds for those reaches with a completed detailed geomorphological assessment.

4.0 OPPORTUNITIES AND AREAS OF CONCERN

4.1 Natural Heritage Features

4.1.1 Policy and Local Context

Provincial Policy Statement (PPS)

The PPS (OMMAH 2014) was issued under the authority of Section 3 of the Planning Act and came into effect on April 30, 2014, replacing the 2005 PPS. Section 3 requires that decisions affecting planning matters shall be consistent with policy statements under the Act. Section 4.4 of the PPS establishes that the PPS is to be read in its entirety and all relevant policies are to be applied to each situation. In this context, Section 2.1 of the PPS – Natural Heritage, establishes clear direction on the adoption of an ecosystem approach and the protection of resources that have been identified as 'significant'. These features are broadly defined within the PPS and rely on the MNRF and the municipality to identify and delineate specific natural features. The Natural Heritage Reference Manual (OMNR 2010) and the Significant Wildlife Habitat Technical Guide (OMNR 2000, MNRF 2015b) were prepared by the MNRF to provide guidance on identifying natural features and in interpreting the Natural Heritage sections of the PPS.

The *Provincial Policy Statement* (2014) states that:

2.1.1 Natural features and areas shall be protected for the long term.

2.1.2 The diversity and connectivity of natural features in an area, and the long-term ecological function and biodiversity of natural heritage systems, should be maintained, restored or, where possible, improved, recognizing linkages between and among natural heritage features and areas, surface water features and ground water features.

The MNRF provides guidance for the identification of a connected system of natural features in their Natural Heritage Reference Manual (OMNR 2010). These systems and their application to the Junction Creek Subwatershed Study Area are described in **Section 4.1.6** of this report.

The PPS provides protection for natural features as follows (for reference, the CGS and Junction Creek are substantially located within Ecoregion 5E):

2.1.4 Development and site alteration shall not be permitted in:

a) significant wetlands in Ecoregions 5E, 6E and 7E; and
b) significant coastal wetlands.

2.1.5 Development and site alteration shall not be permitted in:

a) significant wetlands in the Canadian Shield north of Ecoregions 5E, 6E and 7E;
d) significant wildlife habitat; e) significant areas of natural and scientific interest; and
f) coastal wetlands in Ecoregions 5E, 6E and 7E that are not subject to policy 2.1.4(b) unless it has been demonstrated that there will be no negative impacts on the natural features or their ecological functions.

2.1.6 Development and site alteration shall not be permitted in fish habitat except in accordance with provincial and federal requirements.

2.1.7 Development and site alteration shall not be permitted in habitat of endangered species and threatened species, except in accordance with provincial and federal requirements.

2.1.8 Development and site alteration shall not be permitted on adjacent lands to the natural heritage features and areas identified in policies 2.1.4, 2.1.5, and 2.1.6 unless the ecological function of the adjacent lands has been evaluated and it has been demonstrated that there will be no negative impacts on the natural features or on their ecological functions.

2.1.9 Nothing in policy 2.1 is intended to limit the ability of agricultural uses to continue.

The Natural Heritage Reference Manual (OMNR 2010) provides technical guidance for implementing the natural heritage policies of the PPS and represents the province's recommended technical criteria and guidance for identifying and protecting significant natural features as defined in the PPS.

The Significant Wildlife Habitat Technical Guide (SWHTG) was prepared to assist planning authorities and other participants in the land use planning system (OMNR 2000). The SWHTG is a detailed technical manual that provides information on the identification, description, and prioritization of Significant Wildlife Habitat. The manual is intended for use in the municipal policy and development process under the Planning Act. An addendum to the SWHTG provides further detail on characterizing and identifying Significant Wildlife Habitat in Ecoregion 5E (OMNR 2015).

City of Greater Sudbury Official Plan

The CGS Official Plan (OP) was adopted in 2006 and has been amended numerous times. The latest consolidation of the CGS OP was April 25, 2016. The CGS OP includes 3 key principles developed from the 6 vision statements, which will shape the growth and development of the CGS. These include:

1. A Healthy Community
    - One that offers a high quality of life for its residents, which is a product of the economic, social, and natural environments
2. Economic Development
    - The Official Plan provides a policy framework that supports economic development initiatives and facilitates the implementation of the Economic Development Strategic Plan.
    - The CGS OP supports economic initiatives through straightforward, concise policies that balance the demands of development with the protection and enhancement of the natural and built environments.
3. Sustainable Development
    - Using a long-term view for decision-making
    - Recognizing the value of a healthy ecosystem, using resources efficiently, and enhancing a locally based economy
    - Using a subwatershed-based approach to planning

- Implementing policies that protect natural resources to support long-term economic growth (e.g. mining, aggregate and agricultural lands)
- Recognizing the importance of energy conservation through alternative transportation, energy efficient urban design, and renewable energy projects.

CGS OP Section 7.0 addresses policies relating to parks and open spaces. Both public and private lands can be designated as Parks and Open Space as shown on Schedules 1a, 1b, and 1c. Designations recognize the importance of connectivity between open spaces and consider that the open space network should be viewed in its entirety. The objectives of the parks and open space policies are:

1. Develop and maintain a balanced distribution of parks, recreational facilities, open space and Conservation Areas that are conveniently accessible and safe
2. Recognize the importance of these areas to the ecosystem and assist in protecting areas comprised of unique or environmentally sensitive natural heritage features
3. Facilitate the preservation of natural habitats through the formation of parklands, greenbelts and Conservation Areas
4. Incorporate school lands and facilities into community parks and recreation programs, wherever possible
5. Provide parks, trails, and leisure facilities that are aesthetically pleasing, multi-purpose, multi-season and appeal to all ages and skill levels in order to attract and retain residents, especially young adults and families, and to enhance local tourism development
6. Promote the naturalization of CGS-owned open spaces
7. Support the formation of partnerships with the public, non-profit and/or private sectors in the provision and operation of recreation facilities and playgrounds, where a benefit to the community can be achieved
8. Capitalize on the location and number of lakes within the CGS by retaining and acquiring waterfront property to provide public access to area lakes

Permitted uses within publicly-owned Parks and Open Space areas may include active and passive recreational uses, arenas, recreation centres, Conservation Areas and cemeteries. However, development is generally prohibited except for accessory buildings and other compatible structures. Within privately-owned Parks and Open Space, permitted uses may include passive and active recreational uses, agriculture, forestry or other activities where buildings are incidental to those uses. Generally, the CGS encourages the protection of privately-owned Parks and Open Space, since in some instances these lands may form missing linkages in the open space network or provide buffers between incompatible land uses.

CGS OP Section 9.0 addresses the environmental policies. The plan focuses on the protection and maintenance of significant natural features and areas. They consist of:

- Wetlands
- Fish Habitat
- Significant Areas of Natural and Scientific Interest
- Significant Wildlife Habitat
- Sites of Geologic Interest

The goals of the environmental policies are:

1. Ensure the continued existence of significant natural features and areas and their ecological functions
2. Protect and enhance the ecological integrity of natural features and areas
3. Achieve a balanced relationship between development and the natural environment by preserving natural features and areas
4. Minimize the loss or fragmentation of natural features and areas

The onus to prove that development will not negatively impact the environment is on the developer. In certain situations, an Environmental Impact Study (EIS) will be required. Execution and submission of the EIS is the responsibility of the developer and must be done in accordance with Section 9.5. A scoped-EIS is required for small projects whereas a full-EIS is required where a scoped-EIS may be insufficient. If features are found that are not found in the most recent CGS OP, they must be addressed, and any impacts mitigated.

Additionally, the Land Reclamation Program has been highly successful within the CGS. Consequently, any development which is on land needing reclamation must be reclaimed to an acceptable level. Any development on previously reclaimed land must minimize and offset their impacts.

City of Greater Sudbury Natural Heritage Report

The CGS OP currently identifies natural features on an individual basis and includes one PSW, other wetlands, Sites of Geologic Interest (candidate Provincial, Regional, and local Areas of Scientific Interest (ANSI)), Critical Fish Spawning Areas, watercourses, lakes, and thermal regime, Significant Wildlife Habitat (SWH), Moose Wintering Areas, and Moose Aquatic Feeding Areas. As part of the recent Official Plan review, the Natural Heritage Background Report (2005) was updated and provides an overview of natural heritage information available for the CGS, and policies that reflect the values, objectives and goals laid out by the Province of Ontario. The Natural Heritage Report (2013) consolidates information on Sudbury's natural heritage and provides recommendations for natural heritage policy direction for consideration in the Official Plan. The report also identifies key differences between the southern Ontario model for natural heritage protection and the needs and requirements of Greater Sudbury. For example, the PPS (2014) includes several features in the definition of 'natural heritage features' that are not present in the CGS. The Natural Heritage Report also identifies the importance of geology and specific Sites of Geologic Interest, as well as the CGS's effort to reforest, and restore thousands of hectares of land that were impacted by mining activities. The report refers to the importance of the subwatershed as an ecologically sound scale of land use planning. The subwatershed context is different in the CGS compared to southern Ontario since there are many small and hydrologically independent lakes that are not connected to a larger river or lake system. This type of drainage system is very rare in southern Ontario and therefore, the subwatershed-based planning context is of even more importance for Greater Sudbury.

The Natural Heritage Report indicates that wetlands cover 9% of the land in the CGS. In the Junction Creek Subwatershed, wetlands cover approximately 6% of the land area within the study area, including marshes, fens, and swamps, open water, and treed wetlands. These wetlands provide a variety of economic, environmental, and social benefits including wildlife habitat, shoreline stabilization, groundwater recharge, and nutrient removal and transformation. Loss of these wetlands can have negative effects on environmental features, and habitats. Due to the nature of subwatersheds in the CGS (i.e. the presence of large and small subwatershed, hydrologically isolated, and connected through riverine systems, etc.) the loss of even a small wetland could have negative impacts on the quality of lakes and rivers in the system.

City of Greater Sudbury Final Report of the Green Space Advisory Panel
Section 7.2.1 of the CGS OP identifies two (2) programs to be completed regarding green space:

1. Establish a park classification system to address the range of park and open space types and characteristics and to guide park acquisition, development, and management
2. Further delineate natural areas that are in need of municipal protection, and develop appropriate strategies for their conservation and acquisition

In 2007, the Green Space Advisory Panel, comprised of citizen representatives, citizen experts, and CGS staff, was appointed to develop these programs and to address recurring green space issues. In 2010, the Panel released the Final Report of the Green Space Advisory Panel outlining the following items:

- A Parks Classification System
- A list of existing parks classified according to the Parks Classification System
- A Surplus Parkland Disposal Policy
- A rating structure for potential acquisitions
- A list of green space opportunities

This report holds high value within the CGS community and outlines the interests and goals that are important to the CGS's residents.

The Parks Classification System is an important tool for evaluating and managing the parks and open space system. By defining the diverse types and uses of parkland, it allows the most effective management of existing parks, and provides a more precise identification of any gaps in service. Parks were classified as Neighbourhood Park, Community Park, Regional Park, Linear Park, Natural Park, Cultural/Historical Special Purpose Park, or Ecological Reserve.

Once the Classification System was developed, the Panel conducted an inventory of green space within the existing Parks and Open Space system, other public and recreational lands, and areas for potential green space opportunities. Inventorying these lands and applying the new Classification System informed the development of a comprehensive strategy for making decisions and properly managing existing green spaces. The inventory also helped to identify important gaps and opportunities, and led to the development of a priority ranking system and other strategies for determining where to focus green space acquisition efforts.

Lastly, the Panel drafted a Parkland Disposal Policy to address the various factors that should be considered prior to declaring a parks property as surplus. The draft policy consists of 3 sections:

1. Criteria that must be met in order to consider whether to declare a site surplus
2. Requirements for public notification and public intent

3. Use of funds from the sale of surplus parkland

The Draft Parkland Disposal Policy was adopted by council and is presently detailed in the CGS By-Law 2011-273.

The research and findings outlined by the Panel in their final report offers an extremely valuable contribution to the overall strategy for managing parks, natural areas and important ecological features within the CGS. By considering the recommendations made by the Panel, the CGS's green spaces can be maintained and enhanced as a network of areas providing significant benefits to the urban environment and to the quality of life within the CGS.

Conservation Sudbury (CS)

The Junction Creek subwatershed is under the jurisdiction of the CS. Conservation Authorities deliver services and programs that protect and manage water and other natural resources in partnership with government, landowners, and other organizations. They promote an integrated subwatershed approach, aiming to balance human, environmental, and economic needs (Conservation Ontario 2015). Development taking place on regulated lands may require permission from the Conservation Authority to confirm that the control of flooding, erosion, dynamic beaches, pollution, or the conservation of land are not affected. The regulations also regulate the straightening, changing, diverting or interfering in any way with the existing channel of a river, creek, stream, or watercourse; and regulate the changing or interfering in any way with a wetland (Conservation Ontario 2015). The Ontario Regulation for all Conservation Authorities within the Junction Creek subwatershed protects wetlands and watercourses. Watercourses are generally also protected as they provide fish habitat, which is protected by the Fisheries Act and the Provincial Policy Statement.

4.1.1.1 *History of Deforestation and Re-Greening Initiatives in Greater Sudbury*

In 2008, the Sudbury Area Risk Assessment (SARA) Group released the Sudbury Soils Study, a comprehensive report detailing the results of a Human Health Risk Assessment and an Ecological Risk Assessment aimed at characterizing and assessing risks associated with elevated metal concentrations in surface soil within the Great Sudbury area. The following is summarized from Volume I of the Sudbury Soils Study (SARA Group 2008) to provide the historical context for the deforestation and subsequent re-greening initiatives.

In 1883, substantial mineral deposits were uncovered in the Sudbury basin during the construction of the Canadian Pacific Railroad. Deposits included vast amounts of copper and nickel ore, the latter of which is typically scarce in the accessible layers of the earth's crust. Sudbury came to be known globally as a leading nickel producer and was historically one of the largest point sources of acid-forming emissions in the world. Mining activities have resulted in the aerial dispersion of massive amounts of sulfur dioxide and metal-containing particulates from smelters. Over time, these emissions have led to the acidification and metal-loading of soils, the acidification of many lakes, and a dramatic decline in vegetation within a 17,000 km^2 deposition zone in the Sudbury Region. Prior to smelting operations, agriculture, logging activities, and frequent human- and lightning-induced fires had already resulted in significant impacts to vegetation in the region. Between 1888 and 1929, further reductions in forest cover also resulted from the harvest of timber for the purpose of feeding large ore roasting beds (where nickel-ore is placed on cords of wood to burn off sulphur contaminants prior to smelting).

Environmental degradation was apparent in the early 1900's, only 20 years after the initial discovery of ore deposits. The region's forests and vegetation communities were extensively damaged by poor air and soil quality associated with smelting ore. Sulphur dioxide emissions damaged vegetation as far away as 100 km away from the CGS, and more than 5,180 km^2 of vegetated habitats became barren or semi-barren areas. The natural recovery of vegetation was impeded in part by soil degradation and other factors including loss of soil microorganisms and organic matter, elevated metal concentration in surface soils, reduced root development leading to reduced drought tolerance, insects and disease, and a loss of seed sources.

However, the Sudbury community, government agencies, and the mining industry worked together to change operational procedures, implement monitoring programs, control emissions, and improve the local environment. Small efforts at recovery within barren and semi-barren areas were made as early as 1917, when community-led groups carried out topsoil replacement projects in select locations. Between the 1950's and 1970's, municipal, industry, and academic stakeholders conducted research and attempted several methods of amending soils and improving conditions for plant growth. In the 1970's, modernization of the mining process and more stringent government emissions guidelines set the stage for "re-greening" efforts aimed at reclaiming damaged habitats and improving the overall quality of the environment. However, effective treatments for re-greening were known for some site conditions but were not fully understood for all landscapes in the region.

Re-greening activities began in earnest in 1977 with the establishment of the Region of Sudbury Land Reclamation Program. The Program was designed to have both a large-scale operational component, and an experimental program. The operational core of the Program consisted of manual lime and fertilizer application, hand-seeding, tree planting, planning and mapping, and monitoring and assessing the success of reclamation efforts. Since the initiation of the Program, areas classified as barren and semi-barren have become significantly reduced. Recent analysis via remote sensing indicates that the majority of improvements are more likely to be attributed to the re-establishment of metal-tolerant native species and the expansion and growth of native white birch clonal communities. However, there is evidence that ecosystem recovery may be occurring at a faster rate in those areas where re-greening treatments have been applied. New methods and approaches are continually being developed to improve the Program and meet the changing goals of the overall re-greening initiative. While research and environmental recovery are ongoing, re-greening efforts resulting from the Region of Sudbury Land Reclamation Program have been very successful over the past 40 years and have led to dramatic increases in available plant and wildlife habitat in the region.

4.1.2 Summary of Junction Creek Subwatershed Characteristics

Details from the background review and characteristics of the Junction Creek Subwatershed are available in **Section 3.2**. The current section provides a brief overview of the natural features and areas, and natural processes within the Upper Subwatershed that have been used to inform the identification of significant natural features and areas, as well as assess these features based on potential changes to hydrology and stormwater management. This information will also inform the development of a connected Natural Heritage System (NHS) for the Urbanized Area landscape unit within the Junction Creek Subwatershed that can be applied at a broader scale across the CGS. The sensitivity analysis and the NHS focus on the Urbanized Area as this is the only location within the Junction Creek Subwatershed where natural features are within/surrounded by the urban area. Communities downstream of Kelly Lake, such as Lively, Naughton, and Walden, etc., are surrounded by relatively untouched and vast natural areas. These types of environments are not suitable for the development of an NHS. See **Section 4.1.6** for a discussion of the Sudbury Context, and the development of the NHS.

4.1.2.1 *Forested Areas*

Within the Junction Creek Subwatershed study area, large blocks of forest are present in two (2) general areas:

- The Northeast, loosely bounded by the former Town of Nickel Centre to the southeast, and LaSalle Boulevard, Maley Drive, and Falconbridge Road to the south
- The Southwest, west of Lively and north of Hwy 17

These large forested blocks are particularly important due to the interior habitat they provide for sensitive wildlife species, as well as the connectivity they provide to other features within the subwatershed. Within the CGS, 57% of land cover is comprised of forested areas, while approximately 26% of landcover is forested within the Junction Creek Subwatershed study area. The CGS has had substantial environmental challenges in the past due to the impacts of the mining industry and the effects of acid rain on natural features. The CGS has made great strides in environmental protection, in a relatively short period of time that have re-naturalized and brought vegetation back to barren areas. Re-greening initiatives, as summarized in the Policies and Local Context section of this report, have achieved considerable success to-date, specifically in regards to the habitat afforded by reforestation throughout the CGS.

Within the Urbanized Area of the natural heritage study area the majority of forested areas are located along the edge of the City, except for the area surrounding the Ponderosa PSW and the southeast side of the City near Robinson Lake and Nepahwin Lake. Many small forest stands are present within the residential areas, forming small parks and recreational areas within the Urbanized Area.

4.1.2.2 *Wetlands*

The Natural Heritage Report (CGS, 2013) indicates that wetlands cover 9% of the land in the CGS. In the Junction Creek Subwatershed, wetlands cover approximately 6% of the land area including marshes, fens, swamps, and open water and treed wetlands. These wetlands provide a variety of economic, environmental, and social benefits including wildlife habitat, shoreline stabilization, groundwater recharge, and nutrient removal and transformation. Loss of these wetlands can have negative effects on environmental features, and habitats. Due to the nature of subwatersheds in the CGS (i.e. the presence of large and small subwatersheds, hydrologically isolated, and connected through riverine systems, etc.) the loss of even a small wetland could have negative impacts on the quality of lakes and rivers in the system.

Wetlands represent an important component of the ecology and available wildlife habitat within the Junction Creek Subwatershed. Numerous unevaluated wetlands are mapped in the Subwatershed by the MNRF and are shown on **Figure B2** (refer to **Appendix 'B'**). Many more wetlands are present that are not mapped and may not be visible on aerial photographs. The relatively large wetlands associated with Ramsey, Robinson, and Kelly Lakes, Junction Creek (specifically the Ponderosa PSW) and the area to the north and west of Lively, form the most substantial features within the Junction Creek Subwatershed. The Ponderosa PSW is a particularly important feature in the Junction Creek Subwatershed. This wetland provides habitat for a variety of wildlife and plant species, is hydrologically connected to Junction Creek and the Frood Branch, is adjacent to upland areas provided by the Kingsway Hills, and provides an important linkage through the urbanized area.

4.1.2.3 *Other Natural Features*

Early succession habitats and areas of bedrock outcrops comprise a substantial amount of the land cover in the Junction Creek Subwatershed, particularly outside the Urbanized Area, in the Upper Junction Creek area. The most extensive area of early succession habitat and bedrock outcrops is on the west side of the Subwatershed, extending in a near continuous swath from the southwest terminus of O'Neil Drive West to the western shore of Kelly Lake. In addition, large blocks of upland habitat are present within the Subwatershed, particularly in the northeast and southwest portions of the natural heritage study area, as well as within the riparian areas associated with Junction Creek and its tributaries.

The study area is dissected by many hydroelectric and rail corridors that provide potential linkages and support the movement of wildlife and the dispersal of plants. These corridors tend to be areas with low lying vegetation such as shrubs or grasses and are typically devoid of large trees. Some of these corridors, particularly the hydro corridors, contain wetlands and cross over watercourses and lakes.

4.1.2.4 *Watercourses and Lakes*

Numerous small tributaries and lakes are scattered throughout the Junction Creek Subwatershed Study Area. Given the vast amount of bedrock within the study area, rainfall runs off the surface and into these features quickly after a rain event. These watercourses and lakes provide important connections between other natural features, as well as habitat for terrestrial and aquatic species. The main watercourse within the Study Area is Junction Creek. This watercourse flows through the Urbanized Area and provides a key linkage between natural features including forested areas, wetlands, other linkages and wildlife movement corridors within and outside of the Subwatershed. There are four (4) main tributaries of Upper Junction Creek (Garson, Maley, and Frood Branches, and Nolins Creek), and many more zero, first and second order streams. The watercourses provide important habitat for a variety of fish species and benthic invertebrates, and support amphibians, reptiles, birds, and mammals. The majority of lakes within the Subwatershed are hydrologically connected to either a watercourse or a wetland. These lakes provide additional wildlife habitat as well as retain surface water runoff and control the flow and release of water downstream. As such, these lakes are heavily influenced by land use practices and changes, particularly in the quality of water present. Riparian areas within the Upper Junction Creek (the natural heritage study area) are illustrated on **Figure B4** (refer to **Appendix 'B'**) for Junction Creek, Garson, Maley and Frood Branches, and Nolins Creek.

4.1.2.5 *Riparian Areas*

Riparian zones provide important linkages between natural features, and movement opportunities for wildlife and plants. They also serve as buffers for watercourses, wetlands, and water bodies, which provide environmental services such as nutrient filtration and transformation, erosion and sediment control, and benefits for decreasing water temperatures. Naturally vegetated riparian linkages are relatively well-established outside of the Urbanized Area. Within the Urbanized Area, riparian areas are limited, discontinuous or non-existent, are relatively narrow, and are degraded. Conserving and enhancing riparian areas will prove to be vital for wildlife and improving the quality of water and fish habitat within the CGS.

4.1.2.6 *Earth Science ANSIs*

Provincial Earth ANSI's within the Junction Creek Subwatershed include:

- Kelly Lake Shatter Cones
- Lively-Elise Mountain Formation
- Sudbury B-Norite
- Sudbury A-Norite
- McCrea Heights South Range Norite

Candidate regional and local ANSI's within the study area include:

- Robinson Lake-Ramsey Lake Pecors Formation
- Ramsey Lake Shatter Cones
- Murray Mine Discovery Site

The Ramsey Lake Shatter Cones are within the Ramsey Lake Subwatershed study area and are not discussed in this report.

Of the sites listed above, the majority are on the boundary of the Junction Creek Subwatershed or are within the areas surrounding the Urbanized Area. The Robinson Lake-Ramsey Lake Pecors Formation is within the Urbanized Area of the subwatershed.

4.1.3 Identification and Characterization of Landscape Units

Natural features and areas within the Junction Creek Subwatershed Study Area were identified through the background review described in **Section 3.2**, as well as through available base mapping, and aerial photo interpretation. The base mapping for the natural heritage study area (Upper Junction Creek) was refined based on aerial photo interpretation particularly for forested areas and bedrock outcrops. Based on these refinements, as well as a review of land use mapping (MNRF 2016) and Source Water Protection Area mapping, two (2) distinct landscape units were identified:

1. Areas outside the Urban Centre
2. The Urbanized Area

The areas outside the Urban Centre focus on the Upper Junction Creek area due to the availability of data required to complete the analysis detailed below and provide relevant recommendations. The Urbanized Area refers to the City of Sudbury. This area was identified as its own landscape unit due to its size and the urban and mining pressures that have, and will continue, to effect natural features. The recommendations provided for land use and natural feature management (e.g. buffers, further studies) are applicable to the communities outside the City of Sudbury (i.e. Lively, Mikkola, Naughton, Whitefish, and Walden); however, there is likely some flexibility that can be achieved in these areas since land use pressures are less intense and more land is available for growth without impacting natural features.

These landscape units have different dominant natural features, as well as differing land use pressures and associated impacts. The following sections discuss the land use pressures and impacts specific to these landscape units. Identification of significant natural features and areas is also provided. **Figure B1** and **B2** (refer to **Appendix 'B'**) illustrate the general landscape unit boundaries.

4.1.3.1 *Areas Outside of the Urban Centre*

Base mapping available from the MNRF (Land Information Ontario (LIO)) was examined to identify areas of wetlands, forested areas, watercourses, and water bodies. The base mapping was compared to aerial images from 2016. Bedrock outcrops, early successional habitat, and areas of rock barren are not identified on MNRF mapping. Large areas of woodland were mapped throughout this landscape unit. The base mapping was compared to aerial photographs (2016) and refinements were made to the LIO woodlands layer. Bedrock outcrops, rock barren, and early successional habitat were identified and mapped as Vegetated Bedrock Outcrops (see **Figure B1** in **Appendix 'B'**). Woodland areas are also identified on this Figure based on this analysis. The refined 'woodland areas' illustrated on **Figure B1** (**Appendix 'B'**), based on this analysis, are now titled 'Forested Areas (NRSI 2018)' on all Figures.

Within the areas outside the urban centre, wetlands comprise approximately 6% of the land cover, while forested areas account for 31% of the land cover. The wetlands tend to be relatively small, isolated features, or are associated with lakes and watercourses. Several riparian wetlands are present in the north end of the Subwatershed north of Garson. Wetlands within the CGS were mapped by the municipality using Forest Resource Inventory (FRI) mapping provided by the MRNF for the areas surrounding the urban centre. These wetlands are shown on Schedule 3 of the CGS OP (2016). The Ponderosa PSW is also mapped on Schedule 3. In the fall of 2017 the Ponderosa wetland was officially designated as a PSW through the efforts of the JCSC. No other PSWs are present within the Junction Creek Subwatershed Study Area, based on available mapping from the CGS OP and MNRF LIO base mapping.

Lakes in this landscape unit include tailings ponds and natural lakes of various sizes. The natural lakes include both hydrologically isolated lakes and lakes connected to riverine systems. Within the Junction Creek Subwatershed Study Area, the thermal regime is unknown for the majority of lakes; however, Kelly Lake, and several lakes to the east (Robinson, Hannah, Middle, St. Charles, etc.) are warmwater systems.

Ramsey Lake and Nepahwin Lake are coldwater systems and are mapped on Schedule 3 of the CGS OP (2016).

Land Use Pressures and Impacts

The areas surrounding the urban centre, within the Upper Junction Creek, have specific land use pressures and associated impacts that do not occur within the urbanized portions of the CGS (including the communities of Lively, Mikkola, Naughton, Whitefish, and Walden). These include industrial and mining pressures, and removal of large tracts of forested areas that support the expansion of mining and industrial sites. Potential impacts from these land use pressures include removal or reduction of interior and deep forest habitat and degradation of water quality and fish habitat. In addition, the large areas of exposed bedrock may impact the thermal regime of watercourses and lakes through the input of warm surface water runoff. Large hydro and rail corridors are present throughout the natural heritage study area that cut through a variety of natural features and habitat types, including wetlands, lakes and forested areas. These are generally devoid of large trees but do contain low lying vegetation such as shrubs and grasses that provide wildlife habitat and movement opportunities.

The CGS has made great strides in combating these land use pressures and the associated impacts. This is particularly evident through the revegetation of barren areas impacted by industrial and mining activities. The areas of re-forestation (as mapped on the CGS's re-greening web application) have increased the amount of habitat available for wildlife within the areas surrounding the urban centre. The reforested areas provide benefits for reducing thermal impacts on watercourses and lakes by providing shade to water features, and reducing the temperature of surface water runoff. The reforested areas also provide stabilization for slopes, and habitat for many wildlife species. Reforestation began in 1978 and represents 40 years of environmental benefits. The reforested areas are potentially sensitive to land use changes as the forests are relatively young and are undergoing successional changes as they mature.

The impacts of water quality degradation occur both within the areas surrounding the urban centre (in the Upper Junction Creek) and within the urbanized portions of the CGS (including Lively, Mikkola, Naughton, Whitefish, and Walden). For a discussion of water quality within the Junction Creek Subwatershed study area, see **Section 3.4** Water Quality Conditions. Further discussion on the impacts of water quality degradation is discussed in the context of fish habitat under the Urbanized Area and the Wanapitei Esker landscape unit.

4.1.3.2 *The Urbanized Area*

As mentioned above, the 'Urbanized Area' landscape unit is focused on the CGS. This decision was based on the amount of relevant data for analysis within the CGS, and the lack of detailed data in the towns and villages outside the main urban centers (i.e. Lively, Mikkola, Naughton, Whitefish, and Walden). The Wanapitei Esker, shown on **Figure E5** (refer to **Appendix 'E'**), was compared to the Urbanized Area landscape unit visible from aerial photographs. **Figure B3** (refer to **Appendix 'B'**) illustrates the boundary of the esker and the Urbanized Area. The City of Sudbury has been built on the Wanapitei Esker, and its boundaries generally match the mapped esker boundaries. The same mapping exercise completed for the areas surrounding the urban centre (within the Upper Junction Creek) was completed for the Urbanized Area landscape unit. Within the Urbanized Area, forested areas comprise nearly 14% of the land cover, and are generally quite small, particularly in the area north of the Ponderosa PSW. The largest forested areas within the Urbanized Area are in the northern extent of the Subwatershed along the Garson Branch, north of O'Neil Drive, and south of the Ponderosa PSW near the north shore of Ramsey Lake. These forested areas are large enough to support interior and deep forest habitat.

Wetlands within the Urbanized Area were digitized by the CGS using aerial photographs from 2003. These wetlands are illustrated on Schedule 3 of the CGS OP (2016). For the Junction Creek Subwatershed Study, wetland mapping from the MNRF (2016) was also used to identify wetlands within the C and surrounding areas. While adjustments were made to other natural feature mapping (e.g. MNRF LIO 'woodlands' to 'Forested Areas (NRSI 2018)'), no alterations were made to the wetland mapping. Within the Urbanized Area, the majority of wetlands are associated with Junction Creek, its tributaries, and lakes, such as Robinson Lake and Kelly Lake. Wetlands represent 4% of the total land cover within the Urbanized Area. These features provide riparian habitat and contribute to the connectivity of the natural system within the CGS. The largest and most ecologically important wetland is the Ponderosa PSW, located in the middle of the Upper Junction Creek area. The Ponderosa PSW provides an east-west connection across the CGS to natural areas beyond the Urbanized Area. Other key wetlands in the Urbanized Area are associated with the outlets and inlets of Ramsey, Robinson, and Kelly Lakes. In particular, the Kelly Lake wetland is located within the delta formed by the discharge of Junction Creek into Kelly Lake. This wetland provides specialized habitat for wildlife that require deltaic and shoreline conditions.

There are very few isolated lakes and waterbodies located within the urbanized area. The majority of lakes are connected to watercourses, including Junction Creek and its main tributaries. For the purposes of describing the watercourses in the study area, and as was done in the Characterization Report, the Junction Creek Subwatershed study area is divided into upper, middle, and lower sections. Each of these sections offers a variety of aquatic habitat types that support a variable fish and benthic community.

The upper section consists of Junction Creek upstream of the Ponderosa PSW as well as the Garson and Maley Branches. This section supports the most abundant and diverse fish community in the subwatershed study area, particularly in the upper reaches of the Garson Branch. The fish community in this section is represented by a variety of common small to medium bodied fishes that exhibit a range of thermal preferences from warmwater to coldwater. This section of the subwatershed provides the best potential habitat for Brook Trout due to the cooler water temperatures, presence of riffles composed of small cobbles, gravel and sands, and groundwater discharge areas. Continued rehabilitation efforts along this section of Junction Creek will provide ecological benefit to a number of wildlife species, as well as Brook Trout. Benthic data available for the upper section of the Junction Creek Subwatershed indicates a general lack of sensitive taxa and impaired benthic community along the main branch of Junction Creek. The Maley tributary is an exception to this, with a potentially impaired benthic community possibly due to a higher amount of riparian cover and absence of effluent from mining facilities and wastewater treatment plants.

The middle section includes the main stem of Junction Creek between the Ponderosa PSW and the section of buried watercourse at Lloyd Street. The middle section is quite small in comparison to the other sections and mainly consists of straightened channel through a narrow riparian corridor. The middle section also includes the Frood Branch that connects to Junction Creek in the southwest corner of the Ponderosa PSW. The middle section supports a variety of small to medium bodied fishes with a range of thermal preferences. While no Brook Trout have been observed in this section to date, conditions are suitable for this species for at least part of the year. Evidence of groundwater discharge was observed by GEO Morphix while conducting field surveys, including iron staining present within Junction Creek and the Frood Branch. Locations where coarse substrates are present that provide important spawning areas for Brook Trout are limited within the middle section. Benthic data available for the middle section of the Junction Creek Subwatershed indicates an impaired but improving benthic community following the elimination of acid mine drainage to the Frood Branch.

The lower section of the Junction Creek Subwatershed study area extends from the outlet of the buried watercourse near Elgin Street and Brady Street, to the confluence of Junction Creek with Kelly Lake. The lower section includes Nolins Creek and Copper Cliff Creek. This section has experienced the greatest level of degraded water quality particularly due to its location downstream of a variety of historic stressors, including mining and urbanization. The lower section contains a much less diverse and abundant fish community than the upper and middle sections and is even more degraded in Nolins Creek and Copper Cliff Creek. However, improvements have been noted recently, particularly through the recent records of coldwater fish in Nolins Creek. The lower section of the Junction Creek Subwatershed contains a variety of fish habitat, including riffle habitat with sands, gravels, and cobbles to slow-moving run habitat with silts and sands near the mouth of Kelly Lake. Benthic data available for the lower Subwatershed indicate a general lack of sensitive taxa within Copper Cliff and Nolin Creek, a result of the historically toxic and poor conditions within these creeks.

A number of barriers to fish movement are present within the subwatershed study area including several dams (e.g. Nickeldale Dam on the Frood Branch, Maley Dam), natural Beaver dams, online ponds such as those in the Cedar Green Golf Course, and the section of buried watercourse along Junction Creek. The confluence of Nolins Creek with Junction Creek occurs within the buried section of watercourse. The impoundments created by the dams and Beaver dams increase water temperatures within the subwatershed; however, the online ponds within Cedar Green Golf Course have a cooling effect, likely related to groundwater discharge.

Riparian areas within the Urbanized Area are narrow and limited, particularly through the Downtown section. The lack of overhanging vegetation, that provides shade to the watercourses, results in increased water temperatures throughout the subwatershed. The Frood and Maley Branches, as well as Nolins Creek and Copper Cliff Creek have limited riparian areas in the downstream reaches, which further exacerbates the temperature impacts within Junction Creek.

The riparian areas for Junction Creek, Garson, Frood, and Maley branches, and Nolins Creek were mapped to identify the extent of naturally vegetated riparian areas within the natural heritage study area. The mapping exercise captured naturally vegetated areas within 30m on either side of the watercourse and included wetlands and forested areas located adjacent to the feature. To be considered as part of the riparian area in this analysis, the wetlands and forested areas needed to be located within the 30m watercourse buffer, by more than just a small lobe or point of the feature. The riparian areas are illustrated on **Figure B5.**

Land Use Pressures and Impacts

The Urbanized Area has experienced a great deal of land use change as urban development has occurred over the years. Development is focused on a small area of the Junction Creek Subwatershed, with the majority occurring on the Wanapitei Esker where construction conditions are the most suitable, and to a lesser extent in the communities in the Lower Junction Creek area (i.e. Lively, Mikkola, Naughton, Whitefish, and Walden). Since the area of suitable development conditions is small within the Urbanized Area, the intensity of development has been quite high, encroaching on natural features. As mentioned earlier, forested areas within the Urbanized Area are generally small and unconnected (with a couple of exceptions), riparian areas are narrow, and watercourses have been re-aligned and piped. Wetlands are generally non-existent within the Urbanized Area with the exception of the Ponderosa PSW and the wetlands associated with Robinson and Kelly Lakes. In addition to these encroachments, water quality within Junction Creek and its tributaries is poor, primarily due to the historical addition of pollutants (e.g. road salt, oils and greases, etc.) from the CGS, and effluent from smelting and mining operations in the headwaters of the Junction Creek tributaries.

Garson Branch is located upstream of the majority of stressors and pollutants that affect Junction Creek and it provides some of the best quality fish habitat in the subwatershed. The middle and lower sections Junction Creek in the natural heritage study area are heavily impacted by urbanization and land use in the headwaters of the tributaries. Impacts on the water quality within Junction Creek and its tributaries are the most significant impact in the Urbanized Area. Water quality impacts occur due to historic land use practices upstream, a lack of stormwater management, and high water temperatures due to a lack of riparian vegetation and shade for the watercourses. The limited riparian vegetation, particularly overhanging vegetation, through the middle and lower sections of the study area results in high summer water temperatures as solar radiation warms the surface of the water. This warming is occurring despite the presence of groundwater discharge along the length of Junction Creek. A lack of overhanging riparian vegetation along the Frood Branch, and Nolins and Copper Cliff Creeks, especially in the headwaters of these features, further contributes to the high summer water temperatures in the middle and lower sections of Junction Creek in the natural heritage study area. In addition, areas of exposed bedrock throughout the subwatershed are warmed by the sun and increase the temperature of surface water as it runs off the bedrock outcrops and into Junction Creek and its tributaries. Dams also contribute to high water temperatures as the impounded areas are warmed by solar radiation, and the warm water is released downstream. The benthic community within Junction Creek is highly impaired due to historic mining and smelting operations along the tributaries. Acid mine discharge was diverted from the watercourses approximately 8 years ago; however, the benthic community has not fully re-colonized.

Sedimentation within Junction Creek is another impact from urbanization. Fine sediment is deposited into Junction Creek and its tributaries via overland flow and stormwater from the Urbanized Area, particularly since there is a general lack of stormwater management ponds that help to remove fine sediments through settling. The fine sediments fill in the spaces between coarse substrates and in riffles and choke out potential spawning habitat for species such as Brook Trout.

4.1.4 Natural Features Sensitivity Analysis

The MNRF identifies significant natural features and areas including wetlands and ANSIs using Provincially established evaluation procedures and criteria. Within the Urbanized Area, no Provincially identified significant features are present (see Schedule 3 Natural Heritage of the CGS OP) based on background information. The Ponderosa wetland was designated as a PSW in 2017 by the MNRF and is now protected under Provincial legislation.

The significance of other natural features is defined in the PPS as:

In regard to other natural features and areas in policy 2.1, ecologically important in terms of features, functions, representation or amount and contributing to the quality and diversity of an identifiable geographic area or natural heritage system.

Based on the above definition of significance, the Urbanized Area contains wetlands, forested areas, watercourses, and riparian areas that are important natural features in the Province of Ontario that require special consideration.

In addition to the analysis of significance, a sensitivity analysis was completed for natural features within the Urbanized Area. In terms of sensitivity, the analysis considers a spectrum of impact sources. Removal of natural features is a key concern, but in terms of the urbanized portion of the Subwatershed this analysis of sensitivity focuses on the sensitivity of natural features and their functions to changes in water regime. As such, the following discussion combines the significance of features and their functions with the sensitivity to modifications in water regime resulting from land management decisions, especially stormwater management.

This analysis focuses on the Urbanized Area landscape unit as this area has the most detailed background information and is the most impacted by existing development and potential future development. In addition, while the surrounding landscape is dominated by bedrock and natural systems associated with bedrock and thin soils, the Urbanized Area is an anthropogenically dominated system with unique land use and land management challenges. The Urbanized Area is much more likely to experience anthropogenic changes to the hydrology of natural features. The results of the analysis and recommendations discussed in **Section 4.1.6** can be applied to the smaller urban centres within the CGS (i.e. Lively, Mikkola, Naughton, Whitefish, and Walden).

Within the Urbanized Area, natural features tend to be isolated pockets, and are less connected to other natural features and systems within and outside of this landscape unit. Based on the general lack of natural features within the Urbanized Area and the isolated nature of most features that are present, all wetlands, watercourses and riparian areas require particular consideration and may be considered more significant and more sensitive to hydrological changes than natural features occurring in other areas of the CGS.

4.1.4.1 *Wetlands*

Of the wetlands located within the Urbanized Area, the Ponderosa PSW is the most sensitive to land use changes, and alterations to the water balance and hydrology. It is surrounded by urbanization and receives water from tributaries that are impacted by mining and smelting occurring upstream. The Ponderosa PSW and the features that surround it are also an important social and cultural feature in the CGS that should be protected for future enjoyment and use by local residents, as is currently done. The wetland also provides a key east-west connection across the Urbanized Area, linking Minnow and Ramsey Lakes, and forested areas in the east to watercourses (Maley Branch), forested areas, and vegetated bedrock outcrops in the west. The wetland provides a key connection for wildlife movement, and the dispersal of plants through the Urbanized Area. The importance of the Ponderosa PSW is heightened by its location adjacent to upland areas (i.e. the Kingsway Hills) that are designated as Parks and Open Space in the CGS OP. The combination of upland and wetland provides additional ecological, cultural, and social benefits. The Ponderosa PSW has been identified as a Core Area and a Highly Sensitive feature in the Junction Creek Subwatershed.

Other wetlands within the Urbanized Area are considered sensitive to land use and hydrologic changes. These wetlands are concentrated in the south portion of the landscape unit and are associated with the outlet of Ramsey Lake, and the inlet of Robinson and Kelly Lake. These wetlands provide specialized wildlife habitat for a variety of species and are recommended to be protected from development and hydrologic changes. This protection stems from the policies provided in the PPS as well as the CGS OP.

While wetlands provide many ecological and hydrological benefits, protection for all of these features may not be practical in the CGS's context. As such, several factors are provided below that the CGS should consider for determining the relative function of wetlands in the Urbanized Area, and other urban centres, and the level of protection required. This information was compiled based on major themes and principles in the Ontario Wetland Evaluation System (OWES) (MNRF 2014). The scoring system and methods described in OWES are not the focus of this criteria, but rather it is the identification of the important functions and roles that wetlands play in the larger landscape context. **Table 4.1.1** below provides a list of categories, and factors that are consistent with OWES. This information is not exhaustive, and if further evaluation of a particular wetland is required, it is recommended that the OWES system is implemented. The information below is meant to provide guidance for determining the functional value of a wetland without going through the full evaluation process.

Table 4.1.1: Recommended Factors to Identify Wetland Function

Category	Recommended Evaluation Criteria	Additional Information
Flood Mitigation	1) The number and total area of wetlands, ponds, storage basins, etc. upstream of the wetland in question	This includes both natural and anthropogenic systems (e.g. natural or created wetlands, stormwater management ponds, LID systems that provide attenuation, etc.) The role of the wetland to attenuate floodwater and reduce flood risk is the focus of this criterion. A low

		number of storage areas (wetlands, ponds, stormwater ponds, etc.) present upstream means that each individual wetland provides more hydrologic and flood mitigation function.
	2) Position of the wetland in the subwatershed or catchment area	The position of the wetland in the catchment / subwatershed determines how much benefit it provides for flood attenuation. All wetlands help to reduce flood impacts by retaining water, infiltrating water where soil conditions allow, and releasing water slowly, either downstream or into the groundwater table. Wetlands that occur in headwater areas, although providing specific hydrologic functions, do not provide as much benefit for flood attenuation as wetlands further downstream. This is because the amount of water directed to the wetland is greater further downstream than in the upper most areas of a catchment / subwatershed. Isolated wetlands are 100% efficient at attenuating flood flows as there is no outlet for excess water to runoff or out of the feature
	3) Abundance of wetlands within the subwatershed or catchment area	Wetland abundance is determined by identifying the number or area of wetlands per area of catchment / subwatershed. The fewer wetlands per area the more function each wetland provides for flood attenuation.
	4) Size of the wetland compared to the upstream catchment area	The hydrological function of a wetland in terms of its impact on flood attenuation will vary based on the size of the feature and the size of the subwatershed or catchment in which it is located.

		For example, small wetlands within large subwatersheds have less flood mitigation function than large wetlands in small catchments or subwatersheds. The ratio of wetland size to catchment / subwatershed size provides an indicator of function in terms of flood mitigation.
Water Quality	1) Previous / existing anthropogenic disturbance	Anthropogenically dominated landscapes. Wetlands provide an important and immediate benefit to water quality when land use practices immediately upstream and adjacent to the wetland produce organic or metal wastes that enter the wetland. Wetlands within a catchment / subwatershed where anthropogenically dominated land uses occur will have more functional benefit for water quality enhancement than those in forested and/or naturally vegetated areas. This benefit is enhanced when the wetland is in contact with flowing water (e.g. between a subdivision and a river, along a tributary)
	2) Hydrologic connection	Wetlands that are hydrologically connected to watercourse or water bodies can provide a higher water quality improvement function than wetlands that are hydrologically isolated. While water quality improvements occur in all wetlands, the benefit may be small and local (e.g. isolated wetlands). Whereas, a wetland along a watercourse or lake, that is connected to the floodplain and the groundwater table will provide water quality improvement that benefits the downstream ecosystem.

	3) Vegetation type	The type of vegetation present in the wetland will determine its efficiency at improving water quality. Emergent, submergent, or floating vegetation will provide the maximum rate of nutrient uptake due to their high root density. This uptake occurs at its maximum during the late spring and early summer when downstream ecosystems are most biologically active. However, nutrient removal may only provide temporary or seasonal benefits. Trees and shrubs are slower to uptake nutrients; however, they store a portion of those nutrients for longer periods.
Groundwater Interaction	1) Indicators of groundwater interaction	The presence of groundwater indicators such as seeps or springs, iron precipitates, coldwater vegetation (e.g jewelweed, skunk cabbage, watercress) is evidence that a wetland is connected to the groundwater table. Wetlands that are hydrologically connected to groundwater provide a higher level of ecological and hydrological function than isolated features. Several of the benefits that wetlands connected to groundwater systems provide are identified in the other categories listed above.
	2) Location near major aquifers	Wetlands that are located near major groundwater aquifers provide benefits to recharging groundwater stores. Wetlands that are located further from major aquifers and other groundwater resources provide less function for recharging groundwater; however, they may still provide benefits to shallow

		aquifers or other groundwater resources.
	3) Topographical location	Wetlands that occur along steep slopes may be indicative of groundwater seepage areas, as these features would not likely occur in locations such as these without groundwater interactions. Wetlands in flat or gently sloping locations may have a lower hydrologic function in terms of groundwater discharge
	4) Groundwater Recharge	This criterion focuses on the importance of maintaining groundwater stores as well as support to downstream ecosystems where groundwater discharge occurs. The linkages between the functions of groundwater recharge and water quality improvement provide for more diverse ecosystems. The proximity of the wetlands to other water features (e.g. watercourses, lakes) is the key indicator of function. Isolated wetlands are a valuable source of groundwater recharge, whereas wetlands along river or lakes provide recharge only in special circumstances or for short time during flooding events.
Ecology	1) Proximity of wetlands to natural features	This criterion addresses the value of habitat connectivity. The value and ecological function of a wetland is enhanced when it is located near other natural features (e.g. watercourses, forested areas, vegetated bedrock outcrops). Proximity of wetlands to other features is especially valuable when the wetland is small and provides specialized needs for specific wildlife species (e.g. Species at Risk) as the surrounding features provide

		additional protection and ecological support to the system.
	2) Diversity of surrounding habitat	The diversity of surrounding habitats addresses wildlife that make use of both upland and lowland/wetland habitats throughout their life cycle. In general, wildlife abundance and diversity will be greatest when habitat diversity surrounding the wetland is greatest.

4.1.4.2 *Forested Areas*

In general, forested areas are less sensitive to changes in hydrology and are more resilient to land use changes. This is particularly true for large forested areas that contain interior habitat and deep forest areas. The majority of large forested areas are outside of the Urbanized Area landscape unit as shown on **Figure B2** (refer to **Appendix 'B'**). In the Urbanized Area there are 3 sections that contain large forested areas: adjacent to the Garson Branch in the headwaters of Junction Creek; east of the Ponderosa PSW on the edge of the Ramsey Lake Subwatershed Study area; and in the south near Kelly Lake, Robinson Lake, St. Charles Lake and Hanna Lake. The forested areas in each of these sections provides wildlife habitat that connects features outside and on either side of the Urbanized Area. Each of these forested areas contains deep forest, which provides specialized habitat for wildlife. The deep forest ranges in size from 2.5 to 37 ha.

While the forested areas themselves are not particularly sensitive to land use changes or alterations to stormwater management, they are part of a connected system of natural areas that provide habitat diversity.

The CGS has successfully re-forested thousands of hectares of land impacted by historic mining and smelting practices. This year (2018) marks the 40th anniversary of this municipal project. The Re-greening Application (available at: www.greatersudbury.ca/maps) provides an interactive mapping tool to illustrate the areas that have undergone lime application and plantings, including canopy species seedlings, shrub and understory seedlings, and seed mix applications. The re-vegetated areas are susceptible to land use changes and disturbance as these forests are quite young and are still in the process of establishing. The CGS OP draws attention to the sensitivity of these re-vegetated areas and states that "every effort must be made during development to protect soils and vegetation on land that has been reclaimed" (Policy 9.4, pp 96). The overall objective of the Re-Greening Program is to improve the health of the CGS through enhancements to the terrestrial ecosystem in urban and rural areas. The importance of this program is highlighted through the Official Plan policies that require special care to be taken for development and municipal works within lands that have been previously reclaimed, and the requirement to reclaim soil and vegetation on lands in need of reclamation. **Figure B4** (refer to **Appendix 'B'**) identifies the areas within the Upper Junction Creek area that have been planted as part of the CGS's Re-Greening Program since 1978. Given that the re-forested areas are establishing themselves through natural vegetation succession, development and land use change, and changes in stormwater management and local hydrology should take care to avoid degrading or inhibiting the establishment of these areas.

4.1.4.3 *Watercourses*

The Junction Creek Subwatershed contains a variety of aquatic features that are considered ‘sensitive water features’ under the PPS (OMMAH 2014). The main stem of Junction Creek, its inflowing tributaries, and the numerous lakes within the Subwatershed provide intrinsic value to the CGS, and ecological importance to the surrounding landscape and the aquatic and hydrologic systems that connect these features. As such, all watercourses and lakes are considered sensitive environmental features for the purpose of the Subwatershed sensitivity analysis. Sensitivity mapping, provided in this report as **Figure B5** (refer to **Appendix ‘B’**) draws particular attention to the main branch of Junction Creek and its major tributaries (Maley and Frood Branches, and Nolins Creek) in the Upper Junction Creek area. Junction Creek, the lakes, and the tributaries in the Lower Junction Creek area are also considered sensitive environmental features.

Section 9.2.4 of the CGS OP states that “the spawning habitat for walleye, lake trout and Brook Trout is particularly sensitive to human disturbance occurring both in water and along the shoreline.” Schedule 3 of the CGS OP maps known spawning habitat for Walleye, Lake Trout and Brook Trout. Based on this mapping, no spawning areas are present within the Junction Creek Subwatershed Study Area. As part of the sensitivity analysis, the upper section of the Subwatershed Study Area, upstream of the Ponderosa PSW to the headwaters of Junction Creek in the Garson Branch have been identified as highly sensitive as these reaches have the potential to provide Brook Trout habitat. Currently, summer water temperatures through the upper section of the Subwatershed extend beyond the upper tolerance range for Brook Trout, which is 18-20°C. A key target for this section of Junction Creek is to lower summer water temperatures so that Brook Trout can survive in the headwaters during the summer months. The upper section of Junction Creek does not provide sufficient spawning areas for Brook Trout due to the fine substrate present throughout; however, coarser substrates are present in the middle and lower sections of Junction Creek, which could help support a self-sustaining population.

Poor water quality conditions in the middle and lower sections of the natural heritage study area, and within Kelly Lake, as well as several dams, culverts, and other barriers limit the overall quality of aquatic habitat. Continued efforts to improve water quality, remove or alter barriers to fish movement, and decrease water temperatures will have benefits for the aquatic and terrestrial ecology throughout the subwatershed.

4.1.4.4 *Riparian Areas*

The CGS OP identifies the importance of natural vegetative buffers along shorelines and watercourses for the protection of fish habitat and provides specific policies for identifying and protecting riparian areas (see Section 8.5.2 of the CGS OP). To improve the quality of fish habitat, lower watercourse temperatures, improve fish habitat (e.g. Brook Trout habitat), and stabilize banks, rehabilitation efforts should be focused on enhancing riparian areas. An analysis of the existing riparian areas for Junction Creek upstream of Kelly Lake, Maley and Frood Branches, and Nolins Creek, was completed for the sensitivity analysis. A 30 m buffer was applied to each of these watercourses and vegetated areas within the buffer were identified. Any natural areas (e.g. forested areas, wetlands) immediately adjacent to or within the buffer were captured and included in the riparian areas delineated on **Figure B5** (refer to **Appendix ‘B’**). This analysis could be carried out by the CGS for the remaining area of the Junction Creek Subwatershed to identify whether riparian corridors are in need of enhancement, in light of future urban expansion in the Lively, Mikkola, Naughton, Whitefish, and Walden areas.

4.1.5 Natural Heritage System

The PPS outlines policies that protect natural features, wildlife habitat and the hydrologic system. The Natural Heritage Reference Manual was developed to provide detailed guidance and methods for identifying significant natural features and areas. Section 2.2.1 of the PPS directs planning authorities to protect, improve and/or restore the quality and quantity of water by:

- identifying water resource systems consisting of *ground water features*, *hydrologic functions*, *natural heritage features and areas*, and *surface water features* including shoreline areas, which are necessary for the ecological and hydrological integrity of the subwatershed
- maintaining linkages and related functions among *ground water features*, *hydrologic functions*, *natural heritage features and areas*, and *surface water features* including shoreline areas;
- protect(ing), improv(ing) or restor(ing) *vulnerable* surface and ground water, *sensitive surface water features* and *sensitive ground water features*, and their *hydrologic functions*

By identifying and providing protection for these important systems and areas development and site alteration can be located outside sensitive features and areas, and development plans and construction activities can occur in environmentally sustainable ways. NHSs provide a framework for identifying areas to protect. The PPS defines NHSs as:

> *A system made up of natural heritage features and areas, and linkages intended to provide connectivity (at the regional or site level) and support natural processes which are necessary to maintain biological and geological diversity, natural functions, viable populations of indigenous species, and ecosystems. These systems can include natural heritage features and areas, federal and provincial parks and conservation reserves, other natural heritage features, lands that have been restored or have the potential to be restored to a natural state, areas that support hydrologic functions, and working landscapes that enable ecological functions to continue.*

Under the PPS there is no requirement to develop an NHS for municipalities within Ecoregion 5E, where the study area is located. However, the principles behind developing an NHS, which focus on connecting isolated natural areas (‘Cores’) to provide movement corridors (‘Linkages’) and connections between protected features for wildlife and the dispersal of plants, are universally important.

In more northerly communities in Ontario, vast, undisturbed natural areas exist outside of urban centres, and priorities for the protection of natural features and areas are specific to these regions. As such, traditional methods used to develop NHSs in southern Ontario are not appropriate for more northerly communities, such as the CGS and the Junction Creek Subwatershed Study Area. While the approach to identifying a connected system of natural features, areas, and systems may differ, the importance of these systems is relevant to all urbanized areas in Ontario.

Natural Heritage Systems "*support the natural processes and ecosystems that are necessary to maintain biological and geological diversity, natural functions and viable populations of native species. They provide essential ecosystem services such as carbon sequestration; resilience to climate change; temperature moderation; clean air; flood control; water storage, supply and purification; biodiversity conservation; and pollination. They also contribute to human health and well-being by providing opportunities for active recreation as well as social, mental and spiritual benefits*" (Crombie et al. 2015, p. 104) and are "*essential for the health of both human and wildlife populations now and in the years and millenia* [sic] *to come*" (Crombie et al. 2015, p. 98).

The fundamental components of an NHS consist of cores and linkages. Core areas are generally the building blocks of the NHS and consist of relatively large natural areas, which perform important ecological functions, such as PSWs. Cores are identified based on a number of factors including size, shape, rare species and other factors, and in many cases are comprised of clusters of several habitat types that form a habitat mosaic. It is the size, diversity, and adjacency of habitat types and mosaics that play a key role in defining Cores within an NHS.

Linkages are components of the NHS that allow movement of wildlife and plant species. In addition, the systems approach encourages the consideration of future natural environment conditions including restoration areas and connectivity; thereby including areas that do not currently contain significant natural features or functions, but by association with the Core have the potential to provide substantial ecological benefit.

4.1.5.1 *Identification of the Natural Heritage System*

An NHS includes Core natural features and linkages in a connected system that provides protection for important natural features such as wetlands, large forested areas, and watercourses. The NHS for the Junction Creek Subwatershed natural heritage study area focuses on the Urbanized Area as well as providing connections to the surrounding natural areas. This includes the headwaters of Junction Creek and the Garson Branch, the Maley and Frood Branches, and Nolins Creek, down to the inlet of Kelly Lake. The communities downstream of Kelly Lake have been excluded from this NHS as they do not have natural features within the urban areas. Rather they are surrounded by vast, relatively untouched natural areas that are difficult to categorize and highlight in an NHS. Natural features and areas within the Ramsey Lake subwatershed study area have been excluded from this NHS, except where a feature crosses the boundary of the two (2) subwatersheds.

Within the natural heritage study area, the key principles of NHS development were considered and applied in a locally derived context. These principles include:

- Maintain, restore, or improve the diversity, connectivity, and long-term ecological function and biodiversity of NHSs

- Recognition and protection of linkages and connectivity between and among natural features and areas, surface water features and groundwater features.
- Utilizing the subwatershed as the ecologically meaningful scale for integrated and long-term planning
- Identifying habitat mosaics that considers the diversity of habitat types, their proximity to each other, and their overall size

Several steps were undertaken to develop the NHS including a background review and Species at Risk screening, natural feature mapping, core area and linkage analysis, and final NHS mapping. The background review and Species at Risk screening were completed as part of the Subwatershed Characterization (see **Section 3.2**) and the results were carried forward to the development of the NHS. Natural features were mapped for the entire natural heritage study area for both the Urbanized Area and the surrounding areas using mapping available from the MNRF (2016). The extent and location of forested areas and vegetated bedrock outcrops was re-assessed and refined to provide a more accurate depiction of these natural features. Interior habitat and deep forest areas were mapped for all forested areas to identify specialized habitat areas. The location and extent of wetlands and watercourses were not revised, and the features shown are as the background mapping illustrates.

The identification of the Junction Creek Subwatershed NHS is based on a review of the natural heritage features in the Urbanized Area, as well as the current protection and conservation afforded these areas by existing policies and regulations (e.g. PPS, conservation authority regulations, CGS OP). Sensitive natural features and areas, as discussed above, make up the backbone of the NHS, with large continuous natural areas, habitat mosaics, and highly sensitive features constituting the Core Areas, and smaller sensitive features being captured within Linkages.

4.1.5.2 *Identification of Core Areas*

The mapping layers used to identify Core Areas were not ground-truthed, and the boundaries are based on aerial photo interpretation. As such local and site-specific refinements may be warranted. Mapping refinement is to be carried out by qualified individuals on a site-specific basis following provincial and local standards and methods. The strategy for identifying Core Areas focuses on the features present within the Urbanized Area and the existing and potential land use pressures and impacts specific to this area. Core Areas are comprised of wetlands, forested areas, and vegetated bedrock outcrops, and are shown on **Figure B6** (refer to **Appendix 'B'**)

Core Area 1

This Core Area is located along the Garson Branch of Junction Creek and includes two (2) large forested areas that contain both interior habitat and deep forest. The features are some of the largest forested areas in the Urbanized Area. They are located on either side of Junction Creek and provide a substantial area of continuous riparian vegetation. The forested areas are also located close to some of the largest forest stands in the Junction Creek Subwatershed.

Core Area 2
Ponderosa PSW, portions of Junction Creek and the Frood Branch, vegetated bedrock outcrops, and two (2) large forested areas, one of which is the largest forest stands within the Urbanized Area (approximately 37ha of deep forest) make up this Core. Core Area 2 is in the central part of the Urbanized Area, and it provides a key connection to the Ramsey Lake subwatershed to the east, as well as natural areas outside of the City of Sudbury.

Core Area 3
This is the smallest Core Area identified in the NHS. It is a forested area in the central portion of the Urbanized Area immediately southwest of the Ponderosa PSW Core. The feature is relatively isolated; however, it provides potential stepping stone habitat across the Urbanized Area. It also contains interior habitat and deep forest.

Core Area 4
Core Area 4 extends downstream from the outlet of Ramsey Lake towards the inlet of Kelly Lake. This Core consists of small forested areas, vegetated bedrock outcrops, Lily Creek and the wetland associated with Lily Creek. Core Area 4 provides a connected system of diverse habitats that link Ramsey Lake and Kelly Lake, with the help of linkages as identified below.

Core Area 5
This Core Area is the second largest in the NHS and it is located at the south end of the Urbanized Area. It consists of large areas of vegetated bedrock outcrop, two (2) forested areas, a small lake and several wetlands including one associated with Lily Creek and the inlet to Robinson Lake, and another wetland associated with Junction Creek and the delta area at the inlet of Kelly Lake.

4.1.5.3 *Identification of Linkages*

Following the identification of Core Areas, a series of linkages were identified to provide connectivity between Cores and establish a system of natural heritage. Linkages are designed to provide movement corridors for both plants and animals between Core Areas, as well as provide, and protect biodiversity, and the long-term viability of ecological systems (OMNR 2010). They support natural processes that are necessary to maintain biological and geological diversity, natural functions, viable populations of indigenous species, and ecosystems. The Linkages were identified based on several factors including areas of greatest natural cover (terrestrial and/or aquatic, as well as areas of interior habitat and deep forest, where possible), while focusing on the shortest distance between Core Areas, and natural features outside the Urbanized Area. The Linkages provide potential connections within the Urbanized Area; however, the focus was on connecting Core Areas to natural areas outside of the Urbanized Area. Linkages consist of watercourses and their riparian areas (as identified and described in detail above), narrow or small wooded features, and hydro-corridors.

The Linkages are illustrated on **Figure B6** (refer to **Appendix 'B'**). The ecologically sustainable width for linkages in urban areas is approximately 100 m wide. This width has been used in many subwatershed studies and NHS systems in southern Ontario, including in the City of Guelph, the Town of Oakville, and the

City of Barrie in the Annexed Lands. While 100 m wide Linkages are an excellent target, achieving this width in an urban area is unlikely. The ecological function and width of the proposed Linkages in the Junction Creek Subwatershed should be assessed on a site-specific basis. This assessment should occur as part of an EIS, prepared in accordance with the CGS OP. A landscape-level review that takes into account the local context and requirements in the CGS is recommended to provide guidelines for the site specific locations and widths of Linkages.

4.1.6 Natural Heritage Recommendations

The natural heritage features in the Junction Creek Subwatershed have important ecological, economic, and social functions. The CGS identifies strongly with the lakes and geologic features in the area and requires that these features, as well as forested areas, wetlands, and wildlife habitat, are protected, enhanced, and restored (CGS 2016). The goal of the sensitivity analysis and NHS, outlined in this report, is to:

- Identify natural heritage features and areas, and ecological functions;
- Determine the sensitivity of these features, areas, and functions to land use change, and changes in hydrology and water quality;
- Recommend protection, and enhancement or restoration opportunities to increase the resilience of these features, areas, and functions to future land use conditions.

Policies provided by the CGS OP and CS were reviewed and incorporated into the following recommendations to provide consistency and aid in achieving the overall goals of these agencies.

4.1.6.1 *Watercourses and Lakes*

The Junction Creek Subwatershed Study has identified sensitive and highly-sensitive watercourses within the Urbanized Area related to changes in hydrology and land use. This sensitivity identification is aimed at identifying fish and fish habitat that is particularly susceptible to land use and stormwater management changes. All watercourses are susceptible to changes in hydrology and stormwater management. While lakes are more resilient, they can also be impacted by such changes. The CGS OP prohibits new development that fronts on a lake or watercourse with recognized environmental constraints. A detailed study (such as an EIS prepared in accordance with the CGS OP) can be prepared that demonstrates that no impact to the natural feature or its function will occur due to the proposed activity, or that impacts can and will be mitigated. For new development proposed in or adjacent to watercourses or lakes, an EIS is required that is in accordance with the CGS OP. The EIS is required to identify additional, site-specific constraints for all natural features, as well as appropriate buffers and setbacks from these features to the development.

The CGS OP identifies that a 12 m buffer is required from the high-water mark for all new and existing waterfront development, and re-vegetation of shoreline buffer zones and upland areas is to be encouraged for existing developments (Section 8.5.2.1 c). The CGS OP also identifies that existing watercourses are to be left in their natural state whenever possible (i.e. not channelized, straightened, piped, or otherwise altered) (Section 8.6.2.4). Buffers and setbacks should be identified and evaluated through an EIS, in accordance with the CGS OP, and should take into account the recommended buffers identified in **Table 4.1.1** as well as CS policies identified under Ontario Regulation (O. Reg) 156/06.

4.1.6.2 *Forested Areas*

Forested areas and forestry resources are abundant within the CGS. Within the Junction Creek Subwatershed, substantial areas of forest that contain interior and deep forest habitat are present outside of the Urbanized Area, both upstream and downstream of Kelly Lake. Within the Urbanized Area, forested areas are mostly comprised of small forest stands, vegetated bedrock outcrops, or areas where re-forestation has occurred through the CGS's Re-Greening Program. Some larger forested areas are present, and these contain interior and deep forest habitat. These larger areas are included in the Core Areas identified on **Figure B6** (refer to **Appendix 'B'**) as they form part of a contiguous naturalized area, are connected to other important or sensitive natural features and habitats, and provide wildlife habitat for a variety of species. The CGS OP states that trees and major woodlots should be retained whenever possible, on private lands that do not support production forests (Section 9.3). Forested areas within the Urbanized Area should be protected from development and site alteration through the establishment of buffers. Buffers should be identified and evaluated through a site-specific EIS and should consider the recommended buffers provided in **Table 4.1.2**.

To protect the areas that have been re-forested through the CGS's Re-Greening Program, the CGS OP includes policies for development and site alteration in and near these areas. The policies continue to provide support for re-forestation activities. The policies also require mitigation for impacts to soil and vegetation within the re-forested areas, and where mitigation through avoidance is not possible, on site soil erosion shall be prevented and vegetation that is removed is required to be replaced. Where a site has been identified as being in need of reclamation, development and site alteration will be required to reclaim the soil and vegetation on site to a level equal to or greater than that which is achievable by the CGS. Landscape plans may be required for proposed subdivision developments. Policies outlining the requirements of landscape plans are in Section 9.4.4 of the CGS OP.

4.1.6.3 *Wetlands*

Wetlands provide a variety of ecological, economic, and social benefits and should be protected from incompatible land uses. The CGS OP states that development and site alteration are prohibited within sensitive wetlands (as identified through subwatershed or watershed studies) and PSWs. It is recommended that the ecological and hydrologic function of wetlands be assessed to determine their overall role and contribution for the natural system. This assessment will help to identify sensitive wetlands that require protection under the CGS OP and to ensure that these features continue to provide water quantity and quality benefits, and will provide support for CS's policies that prohibit development within wetlands (O. Reg 156/06). While the Junction Creek Subwatershed Study has identified wetlands within the study area through available base mapping provided by the MNRF, and has identified features that are sensitive to hydrological and land use changes, wetlands should be identified at the site-specific level. Small pocket wetlands occur that are not visible from aerial photographs. These features should be considered at the local and site-specific level. Wetland boundaries should be established, and features evaluated for significance using the OWES (MNRF 2014). An EIS is required, in accordance with the CGS OP, for development and site alteration proposed within 50m of sensitive wetlands and within 120m of PSWs.

Where development or site alteration is proposed in proximity to a wetland that is determined to be sensitive to changes in hydrology (see recommended criteria to evaluate wetland function in **Table 4.1.1**) the CGS should consider the need for a site-specific water balance analysis. The water balance should demonstrate that the pre-development or pre-site alteration condition (including surface water runoff, groundwater recharge and discharge, and overall volumes and flows, if applicable) will be maintained post-development or site alteration. This analysis is recommended to occur for sites with adjacent wetlands that are identified as sensitive, or are PSWs.

Where development or site alteration is proposed adjacent to a wetland, an EIS must be prepared in accordance with the CGS OP. The EIS is required to identify appropriate buffers, using the recommended buffer widths in **Table 4.1.2** as a guide. Buffers should be evaluated on a site-specific basis and based on the potential impacts from the proposed development or site alteration, taking into account areas regulated by CS and the buffer policies in O. Reg 156/06. A buffer enhancement plan and planting plan are recommended to be included in the EIS or as a condition of municipal approval for development and site alterations. The plan should use only native, non-invasive species that are local to the CGS and provide adequate protection to the wetland from adjacent land uses.

4.1.6.4 *Significant Wildlife Habitat (SWH)*

In developing the CGS OP, the CGS applied provincial guidance to create the approved policies for SWH. The CGS OP identifies specific SWH within the CGS and illustrates these on Schedule 3 Natural Heritage. These include:

- Habitat used by Moose during the critical later winter period;
- Great Blue Heron nesting sites;
- Osprey nesting sites; and
- Nesting sites of vulnerable raptor species

Based on the mapping shown on Schedule 3, none of these SWH types are found within the Junction Creek Subwatershed. It is recommended that the CGS continue to consider the provincial guidance documents (OMNR 2000, MNRF 2015b) to identify additional SWH as needed.

4.1.6.5 *Fish Habitat*

Fish and fish habitat are protected under the federal Fisheries Act. The Fisheries Act and provincial legislation protect all fish habitat from incompatible land uses and activities. The CGS OP states that natural vegetative buffers are to be maintained along shorelines and streambanks to protect fish and fish habitat. Buffers are measured from the high-water mark and are dependent on characteristics of the adjacent lands and the receiving water feature. Recommended buffer widths of watercourses are provided in **Table 4.1.2**. These buffers should be considered when development and site alteration are proposed in or within 30 m of a watercourse and should be evaluated on a site-specific basis. Buffers are also required to adhere to policies in the CGS OP (Section 8.5.2). To identify the appropriate buffer width, the EIS should establish the thermal regime of all applicable watercourses using approved methods (e.g. Chu et al. 2009). The fish species present in the watercourse should also be used as an indicator of thermal regime. For example, if cold water species are present, such as Brook Trout, the feature should be managed as a coldwater system as it is able to support these species for at least part of their life cycle.

Within the natural heritage study area, fish habitat that is sensitive to hydrological and land use changes includes Junction Creek from Garson Branch to Kelly Lake. Highly sensitive potential fish spawning areas are identified as the upper section of Junction Creek from Garson Branch to the upstream side of the Ponderosa PSW where Brook Trout habitat has the potential to occur.

As identified in the CGS OP, development is prohibited in fish habitat, except when in accordance with federal requirements, and construction impacts are required to be mitigated to prevent negative impacts on receiving waters. The CGS OP requires that an EIS is prepared for all new development on lots adjacent to fish habitat (i.e. within 30 m) and is required to demonstrate that no negative impacts will result from the development. A buffer enhancement plan and planting plan is recommended for watercourses and should be included in the EIS or as a condition of municipal approval for development and site alterations. The plan should use only native, non-invasive species that are local to the CGS and provide adequate stabilization and protection to the watercourse from adjacent land uses.

4.1.6.6 *Beaver Management*

Nuisance Beaver activity in the CGS, and the Junction Creek Subwatershed is a significant concern for residents and local authorities due to the impact Beavers have on private property, municipal infrastructure, stormwater management, surface water runoff and drainage, and aesthetics. Nuisance Beavers damage or remove trees to build dams, which can cause localized flooding and exacerbate flooding issues (e.g. basement flooding) during heavy rain events. Dams built along Junction Creek and its tributaries can turn minor rain events into major issues due to backwatering upstream of the dams. Beaver dams throughout the Subwatershed can significantly affect the amount of stormwater storage available in the system. Efforts to re-vegetate the City through the Re-Greening Program, while having major benefits to the ecosystem, have resulted in supplying more habitat for nuisance Beavers through a higher density of trees located close to creeks and rivers.

Management of nuisance Beavers is governed by several pieces of legislation including the Canadian Fisheries Act, Lakes and Rivers Improvement Act, Public Lands Act, and Fish and Wildlife Conservation Act. The City of Greater Sudbury manages nuisance Beavers on public land through trapping and dam removal, as well as employing prevention and exclusion techniques. Only trappers that are licensed by the MNRF are used for this purpose. Management of Beavers on private land is the responsibility of individual landowners. Property owners may be held liable for damages as a result of inaction on their part to deal with a Beaver dam on their property. The municipality has the authority to remove Beaver dams from private property if they represent a threat to municipal infrastructure. Should a Beaver dam located on private property represent a threat to municipal infrastructure, a letter will be sent to that property owner requesting that the Beaver dam be removed within a reasonable and defined timeframe. The letter will include details on how to address the problem, and the potential liability. If the property owner fails to respond within the deadline, the City will proceed to correct the problem and may pursue the recovery of these costs. Should the Beaver dam be determined an emergency by City Staff, the City will act immediately to remove it while providing as much notice to the property owner as possible (City of Greater Sudbury 2014).

The City is currently using a variety of prevention and exclusion methods, as well as trapping to manage nuisance Beavers. However, neither active, nor pro-active management is occurring at this time within the Junction Creek Subwatershed. To protect private property, municipal infrastructure, the integrity of the stormwater management system, and local drainage in the Junction Creek Subwatershed, several short-, medium-, and long-term recommendations are provided below for managing nuisance Beavers.

Nuisance Beaver Management Recommendations

While reactive management provides an immediate response to a particular issue or event, a pro-active approach is the best option for managing nuisance Beavers over the long-term. The City has undergone extensive training with the MNRF, Conservation Sudbury, and private trainers on the lifecycle of Beavers and nuisance Beaver management. In addition to these efforts, the following recommendations are provided as potential solutions, options, and techniques to manage nuisance Beavers in the short-, medium-, and long-term.

Short-term Recommendations

Active nuisance Beaver management (e.g. trapping and relocating, dam removal, etc.) is not currently taking place within the Junction Creek Subwatershed. It is recommended that this option be implemented in the short-term to address nuisance beaver activity, dams, flooding and infrastructure issues until the medium- and long-term recommendations can be considered and implemented, where possible. In addition to active management, a community or public education program should be implemented. This program could inform local residents of their responsibilities, potential liability, and available options to address nuisance Beavers on their property. A list of management strategies to deter or exclude nuisance Beavers that do not require destruction of dams, trapping or lethal control, are provided following this section on recommendations. Other options for the educational program include informing residence on the habits and life cycle of Beavers and their connection to the ecosystem, their symbiotic relationship to other species (e.g. providing habitat for hibernating turtles upstream of dams), and influence on natural features including forested areas and watercourses.

Medium-term Recommendations

Deterrent and exclusion techniques, as described in the Nuisance Beaver Management Techniques section below should be considered for medium-term management of nuisance Beavers. Several of these techniques provide a pro-active approach to management, including alterations to vegetation communities within the riparian corridors where nuisance Beaver activity is of particular concern. Pilot projects that implement some of these techniques could be a means of gathering data on the success and applicability of these techniques.

A monitoring program should be developed to gather data that will inform other pro-active management opportunities in the future. Some recommendations for monitoring data include:

- Locations of dams
- Dimensions and populations of each dam
- Timing of dam building activity
- Watercourse conditions where dams are located
    - channel dimensions
    - substrates
    - riparian characteristics
- Adjacent infrastructure (e.g. roads, bridges, buried pipes or cables)
- Locations of pilot projects and beaver activity in the vicinity
- Etc.

Long-term Recommendations

To establish a successful pro-active management program, a study should be initiated that uses the monitoring data collected, as described above. This Junction Creek Nuisance Beaver study should describe the habits and life cycle of beavers, utilizing the extensive information gathered by the CGS through the various training staff have received, to set the overall context for the study. The goal of this study could be to establish a pro-active management approach to be implemented within the Junction Creek Subwatershed. A classification system could be developed to identify areas that sensitive to the effects of beaver activities (e.g. high, medium, and low sensitivities). This system could then be used to identify priority areas that have the potential to have the largest, the greatest number of, or most expensive impacts due to nuisance Beaver activity. The priorities should be set by the CGS based on their overall goals and objectives for nuisance Beaver management. An example of a highly sensitive area could be locations on the Junction Creek that are particularly narrow, with limited floodplain areas, or where infrastructure density in the floodplain is high, in densely populated urban areas (e.g. downtown Sudbury). Low sensitivity could include large natural areas with low population densities, areas with limited infrastructure located near the area of Beaver activity, and/or wide floodplains.

This study should include a recommended program to be implemented by the CGS based on the goals and objectives for nuisance Beaver management, the results of monitoring and pilot projects implemented under the medium-term recommendations, and the results of the study. The Ponderosa PSW has been identified as a particular 'problem area' within the Junction Creek Subwatershed. As such, a management strategy for this should be considered as part of this study, with specific techniques to be applied that are approved by the MNRF and CS, due to the sensitivity of this wetland.

Specific policy recommendations based on the results of the Junction Creek nuisance Beaver study should be developed following the completion of the study. Recommendations for policies specific to the Junction Creek issues could be included in the study.

Policy Recommendations

The Ontario Fish and Wildlife Conservation Act protects Beaver dams and regulates their removal by requiring a licensed person to conduct trapping and dam removal. However, the protection of property allows for individuals to remove dams and deter Beavers without the need for a licensed person. The Act is somewhat vague in what constitutes 'reasonable grounds' for the removal of dams or deterring Beavers themselves. The CGS is looking to develop policies that address Beavers and their dams. The information provided here is meant to inform the policy decision makers on the techniques available for Beaver management, as well as existing policies and legislation that govern Beaver management in Ontario. The Ontario Fish and Wildlife Conservation Act must be adhered to for any policy that is created. A permit may be required under this Act and should be included in the policy. In addition, any Beaver dam removal must also adhere to Fisheries and Oceans Canada policies to avoid causing serious harm to fish and fish habitat downstream. Changes are currently proposed to the Fisheries Act. Any policies created for Beaver management will need to ensure compliance with the most current versions of the governing Acts. Several general recommendations are also provided here for Consideration in developing policies for Beaver management.

It is recommended that deterrent management techniques be the preferred method and the emphasis of policies; however, active management will likely need to be considered as well. Where these methods are not feasible due to property ownership or the amount of suitable habitat for Beavers, exclusion methods could be considered. The results of the Junction Creek nuisance Beaver study, described above, should be integrated into policy recommendations as well.

Nuisance Beaver Management Techniques

Excluding Beavers from local waterways is very difficult; however, there are management techniques that can be applied to help reduce the impact of Beaver activity. A variety of management strategies have been developed to address conflicts with nuisance Beavers. The MNRF recommends that property owners make efforts to prevent conflicts with nuisance Beavers by utilizing techniques that do not require destruction of Beaver dams. The MNRF provides a list of suggestions for addressing Beavers (MNRF 2015c). Some of the suggestions include:

- Planting trees and vegetation undesirable to Beavers (e.g. elderberry, ninebark, twinberry).
- Wrap the base of tree trunks with 1.0 m high galvanized welded wire fencing, hardware cloth, or multiple layers of chicken wire.
- Paint tree trunks with a sand and paint mix.

A link to this list is provided on the CGS's website under Animal Services and Wildlife.

There are a variety of methods to address flooding issues caused by Beaver dams that do not require destruction, trapping or lethal control. Methods to reduce flooding issues related to Beaver dams focus on two general factors: exclusion and deception (Taylor & Singleton, 2014). The goal of exclusion systems is to completely exclude Beavers from a given area and discourage dam building using fencing, whereas the goal of deception systems is to modify Beaver behavior to mitigate the effects their dams have on flooding (Taylor & Singleton, 2014).,

Exclusion Systems

Beavers prefer to construct their dams in locations where the watercourse is low gradient with natural constrictions in stream flow. Areas with these conditions also commonly have culverts, providing additional habitat for Beavers to utilize when building dams. Where feasible, and appropriate, replacing culverts with clean span bridges will eliminate the constriction that is attractive to beavers (MWLAP 2004). However, these bridges can be quite expensive, and replacing a culvert requires substantial time for planning, design, and construction. Other systems that discourage Beaver activity near culverts includes culvert screening and extension devices, such as the "Beaver Stop". Screening devices are affixed to the inlet of a culvert and are designed to prevent Beavers from building dams inside the culvert. Culvert extensions consist of a wire-mesh applied in either cylinder attached to the end of the culvert or across the face of the culvert. Cylindrical extensions can drain from all sides, which supports natural water flow and allows for fish passage, while preventing Beavers from plugging culvert inlets (Taylor & Singleton, 2014).

Deception Systems

Beaver baffles are the most common form of deception system used to deter Beaver activity. These systems are applied once a dam is already in place, and consist of installing a long pipe, or pipes, through the dam from the flooded area upstream and into the watercourse downstream. Water flows freely through these pipes and prevents backwater from occurring upstream. These pipes can also have perforations that address locations with higher flow rates and volumes (Brown & Shafer, 2001).

4.1.6.7 *Other Significant Natural Areas*

The CGS OP identifies specific ANSIs and Sites of Geologic Interest within the CGS and illustrates these areas on Schedule 3 Natural Heritage. Based on this mapping, no ANSIs or Sites of Geologic Interest are found within the Junction Creek Subwatershed. The identification and designation of ANSIs, Sites of Geologic Interest, and other environmentally significant areas (ESAs) are encouraged within the Junction Creek Subwatershed. ESAs are locally significant features and areas designated by the municipality that provide protection for natural features and areas that may not otherwise be protected. The Ponderosa PSW and its adjacent natural areas, including the upland areas of Kingsway Hills, is an example of a potential ESA. The CGS is encouraged to identify ESAs and provide policies for these areas in the CGS OP.

4.1.6.8 *Enhancement and Restoration Recommendations*

The watercourses and lakes within the Junction Creek Subwatershed provide habitat for a variety of fish and wildlife species. Due to historical land use practices these systems are degraded, with narrow riparian areas, high water temperatures, and poor water quality. It is important to enhance the aquatic habitat to improve water quality and the overall resiliency of these systems. It is recommended that, where possible, the natural vegetation within riparian zones along Junction Creek and its major tributaries is increased. Planting programs should be encouraged that include woody species and herbaceous vegetation with high root densities (e.g. grasses) along riparian corridors. These plantings will help to address stability and erosion concerns as well as provide shade, food, and woody habitat for fish. Overhanging vegetation will help to lower water temperatures by shielding the surface of the water from solar radiation. This is particularly important for the upper Subwatershed, as water temperatures are currently just above the threshold of tolerance for Brook Trout. Improving riparian conditions may help provide refuge areas for Brook Trout in the upper reaches of Junction Creek. Downstream of Kelly Lake, riparian corridors are well vegetated, and development has generally been set back from the edge of watercourses and lakes. The riparian areas downstream of Kelly Lake should continue to be protected based on recommendations provided in the Junction Creek Subwatershed Study and policies under the CGS OP and CS O.Reg 156/06.

The CGS is encouraged to continue re-forestation activities throughout the Subwatershed to reduce the areas of exposed bedrock. Surface water runoff over bare bedrock, which is exposed to solar radiation, can contribute to increased water temperatures in adjacent lakes and watercourses. Re-forestation will help to reduce the input of warm surface water and will improve overall water quality in the lakes and watercourses in the Junction Creek Subwatershed. The Re-Greening Program should continue to increase the diversity of planted species for canopy trees, and understory and forest floor vegetation, where possible to establish resiliency for the forested areas in the CGS.

4.1.6.9 *Natural Heritage System Recommendations*

The Junction Creek Subwatershed Study has identified a proposed NHS for the Urbanized Area within the natural heritage study area. This NHS is based on base mapping, background information, public comments, and aerial photo interpretation. As such, site specific assessment of the Core Areas and Linkages is needed to confirm the NHS. The ecological function of Core Areas and Linkages should be assessed for the features contained in these areas. This evaluation should occur through an EIS, prepared in accordance with the CGS OP, and should identify appropriate buffers on a site-specific basis.

It is recommended that the CGS consider preparing an NHS Study for the entire Greater Sudbury area that links NHSs for each urban centre to natural features in the surrounding lands and provides a connected and protected system of natural features. The CGS is encouraged to connect the Junction Creek Subwatershed NHS to other protected areas outside the study area. Given that the CGS contains a substantial amount of natural areas that are generally untouched by anthropogenic land use, natural heritage planning should be focused within urbanized and urbanizing areas so that the natural environment is protected, enhanced, and restored, and continues to contribute to the quality of life and overall well-being of residents.

As previously mentioned, the communities downstream of Kelly Lake are surrounded by vast swaths of natural areas. These communities do not contain natural features within the built-up areas and therefore, as with the ‘areas outside the urban centre’ described in Section 4.1.3, they were not included in the NHS. It is recommended that the CGS initiate studies in these communities to characterize the natural features, and fish and wildlife species present, and add to the data available for sensitivity and impact analyses. In addition, these studies should be conducted to identify area-specific natural environment issues (e.g. water quality, thermal regimes and water temperature, etc.). This information can then be input to a sensitivity analysis and identification of Core Areas and Linkages for these communities.

The community of Lively is located close to the City of Sudbury, and as such should be the first priority for further study, given the potential for land use pressures from the City of Sudbury to impact natural features and wildlife in the near term. Urbanization in this community has been concentrated to a specific area and large swaths of natural areas exist just beyond its borders. No Core Areas currently exist within the community's boundaries; however, forested areas, wetlands, watercourses, and vegetated bedrock outcrops exist between Lively and Mikkola that have the potential to be included in a CGS-wide NHS as Core Areas or Linkages.

The community of Naughton is concentrated along the shoreline of Simon Lake. The land outside of the community's borders consists of relatively untouched forested areas, with some vegetated outcrops and wetlands. The identification of Core Areas and Linkages in this community may only consist of wetlands just outside of the community that could be impacted by future urban expansion. It is recommended that natural feature protection and enhancement in this community focus on the shoreline of Simon Lake, and potential water quality and stormwater management issues.

Whitefish has a unique meadow community that is rare within the CGS. This vegetation community, located north of Old Highway 17 and the rail line, is associated with agricultural practices in the area. This area provides unique wildlife habitat in the CGS. Consideration should be given to the protection or replication of this habitat should urban expansion extend into this area in the future. Fairbank Creek and the wetland community within its riparian corridor is an important natural feature in the Whitefish community and should be considered in a CGS-wide NHS system for Core Areas or Linkage. Large, relatively untouched, forested areas are located adjacent to the community. These areas may form part of an NHS if they are shown to be particularly sensitive to land use, hydrologic, and stormwater management changes.

Walden is a low-density community that consists of vegetated bedrock outcrops, forested areas, watercourses, and wetlands. The topography in this community is quite variable offering a unique combination of lowland and upland areas. This combination provides habitat for wildlife that require both upland and lowland areas throughout their lifecycle. It is recommended that, should urban expansion occur in this community, a study of the function of this natural feature mosaic occur. Area specific recommendations should be identified that protect the unique combination of natural features and topographies. Sensitive natural areas and habitat mosaics should be considered for inclusion as Core Areas in a CGS-wide NHS, with watercourses providing Linkage opportunities.

Table 4.1.2: Summary of Natural Feature Recommendations

	Recommendations	Buffers, Setbacks, and Adjacent Lands
Natural Features and Areas		
Forested Areas	) Protect large forested areas within the Urbanized Area, including those identified as part of a Core Area in the NHS.	Adjacent lands for forested areas within the Urbanized Area are recommended to be 30 m
	) Identify an evaluate buffers to forested areas through an EIS when development or site alteration is proposed in or within the adjacent lands of a woodland	Buffer of 10 m from forested areas within the Urbanized Area

	Recommendations	Buffers, Setbacks, and Adjacent Lands
	• The CGS OP includes policies for proposed development and site alteration on lands that have undergone reforestation. Where a site has been identified for reclamation, development and site alteration is required to reclaim the soil and vegetation on site. • Landscape plans may be required for subdivision applications.	
Wetlands	• Identify and protect wetlands • Establish wetland boundaries • Evaluate wetlands for significance using the Ontario Wetland Evaluation System or through a review of wetland function based on the recommended factors provided in **Table 4.1.1** • Establish vegetated buffers to wetlands and evaluate the recommended width identified here on a site-specific basis. • Prepare a site-specific water balance analysis with wetlands identified as sensitive to hydrologic chance that demonstrates that the pre-development hydrological and hydrogeological conditions will be maintained in the post-development scenario • Evaluate impacts to wetlands and provide input to the site-specific water balance if needed. • Prepare buffer enhancement and planting plans that use native, non-invasive species, local to the CGS that provide protection to the wetland and its hydrologic and ecologic function	Adjacent lands for sensitive wetlands, as identified through this subwatershed study, is 50 m Adjacent lands for PSWs is 120 m Buffer of 30 m for wetlands less than 2ha and 120m for PSWs and wetlands greater than 2ha

	Recommendations	Buffers, Setbacks, and Adjacent Lands
Watercourses and Lakes	- Development and site alteration in or adjacent to watercourses and lakes is prohibited unless an EIS is prepared that demonstrates no negative impacts will occur based on the proposed activities. - The EIS should identify and evaluate appropriate site-specific buffers to watercourses and lakes that take into consideration the recommendations provided here.	15 m on either side of warmwater / sensitive watercourses and lakes 30 m on either side of cold/ cool water/highly sensitive watercourses and lakes 15 m from the high-water mark for inland lakes
Other Significant Natural Areas	- The CGS should continue to encourage the identification of ANSIs and Sites of Geologic Interest within the Junction Creek Subwatershed. - The CGS should establish and encourage the continued identification of ESAs in the Junction Creek Subwatershed.	N/A
Wildlife and Fish and Fish Habitat		
Significant Wildlife Habitat	- Continue to consider the provincial guidance documents to identify SWH as needed.	Protection and any applicable buffers to be determines on a site-specific and an as-needed basis
Fish Habitat	- Identify and evaluate appropriate buffers to watercourses on a site-specific basis through an EIS, using the recommendations provided in this subwatershed study and the policies provided in Section 8.5.2 of the CGS OP. - Prepare a buffer enhancement and planting plan for identified buffer areas that uses native, non-invasive species that are local to the CGS. - Identify the thermal regime for watercourses that come within 30m of proposed development or site alteration. - Prepare an EIS when development and site alteration is proposed in or within 30 m of fish habitat and demonstrate that no negative impacts will occur as a	Adjacent lands include land within 30 m of fish habitat A buffer of 5 m on either side of warmwater / sensitive watercourses and lakes A buffer of 30 m on either side of cold/coolwater/highly sensitive watercourses and lakes

	Recommendations	Buffers, Setbacks, and Adjacent Lands
	result of the development or site alteration.	
General Natural Heritage Recommendations		
Enhancement and Restoration	• Increase the width and natural vegetation within the riparian zone for Junction Creek and its major tributaries • Encourage riparian planting programs for watercourses and lakes • Continue re-forestation efforts and increase diversity of planted species, where possible	N/A
Natural Heritage System Study	• Core Areas and Linkages should be assessed on a feature and site-specific basis to evaluate the ecological function of these areas. • This assessment should occur through the preparation of an EIS • The CGS is encouraged to prepare an NHS Study that links NHSs in urbanized areas to natural features in the surrounding lands • Focus natural heritage planning within urbanized areas in the CGS	Buffer widths will vary based on the type of feature and habitat present, as well as the ecological function and quality

4.2 Surface Water Quality

4.2.1 Water Chemistry

Surface water quality was assessed using water chemistry information analysed in the light of PWQO levels, and following a scoring method based on the Conservation Ontario's 2013 summary of their '2011 Guide to Developing Conservation Authority Watershed Report Cards' and Toronto and Region Conservation Authority's 2009 'Interim Watershed Characterization Report: TRCA Watersheds'. The main purpose of the Subwatershed Report Cards is to evaluate the watershed health based on environmental indicators, and provide information to better target programs/measures to enhance environmental quality. Three indicators are used to assess surface water quality: Total Phosphorus, *Escherichia coli* (*E. coli*), and Benthic Macroinvertebrates. Respectively, these three indicators reflect water quality concerns regarding nutrient loading, sewage/waste contamination, and aquatic health.

The scoring method is based on a grading range for each indicator. **Table 4.2.1** displays Surface Water Indicator Scoring and Overall Grade Calculation, and **Table 4.2.2** presents the scoring system for Benthic Macroinvertebrates. Detailed results are displayed in the '2018 Junction Creek Subwatershed Report Card'.

Table 4.2.1: Conservation Ontario 2013 Surface Water Indicator Scoring and Overall Grade Calculation

Total Phosphorus (mg/L)	E. coli (CFU/100 mL)	Benthic Invertebrates (Hilsenhoff Biotic Index)	Point Score	Grade	Overall Surface water Quality Grade	
					Final Points	Final Grade
<0.020	0-30	0.00-4.25	5	A	>4.4	A
0.020-0.030	31-100	4.26-5.00	4	B	3.5-4.4	B
0.031-0.060	101-300	5.01-5.75	3	C	2.5-3.4	C
0.061-0.180	301-1000	5.76-6.50	2	D	1.5-2.4	D
>0.180	>1000	6.51-10.00	1	F	<1.5	F

Table 4.2.2: Benthic Macroinvertebrate scoring system from Toronto and Region Conservation Authority 2009 Interim Watershed Characterization Report: TRCA Watersheds

Water Quality Index	Unimpaired	Potentially Impaired	Impaired
EPT Richness	>10	5-10	<5
Taxa Richness	>13	-	<13
% Oligochaeta	<10	10-30	>30
% Chironomidae	<10	10-40	>40
% Isopoda	<1	1-5	>5
% Gastropoda	1-10	0 or >10	-
% Diptera	20-45	15-20 or 45-50	<15 or >50
% Insecta	50-80	40-50 or 80-90	<40 or >90
Hilnsenhoff Biotic Index (HBI)	<6	6-7	>7
Shannon-Wiener Diversity Index	>4	3-4	<3

Through conducting statistical analyses on twenty-five (25) water quality parameters at each of the ten (10) monitoring sites, as discussed in **Section 3.4**, no statistically significant trends were found (refer to **Appendix 'D'**). Copper, nickel, cadmium and zinc concentrations appeared to be slightly increasing at Maley (Maley Tributary) and McLean (Frood Tributary) both sites (although not statistically significant), and were well above the PWQOs at most sites. Copper, nickel and iron concentrations were well above the PWQOs during most sampling events at all sites. Remediation efforts may be necessary to address these high contaminant levels, particularly if they are due to re-suspension from the sediment or overflow from the surrounding soil (Jaagumagi and Bedard 2002, Nriagu *et al.* 1998).

4.2.2 Biological Indicators - Benthic Macroinvertebrates

The aquatic benthic community was used as a biological indicator of water quality in different sections of the Junction Creek subwatershed, based on information provided by the Canadian Aquatic Biomonitoring Network (CABIN). The provided data was evaluated for selected study areas located within the Junction Creek subwatershed according to the interpretation of Hilsenhoff Biotic Index (HBI) adapted from the

Toronto Region Conservation Authority's 2009 'Interim Watershed Characterization Report: TRCA Watersheds', as displayed in **Table 4.2.3**. The results for each study area are displayed in **Table 4.2.3** and **Figure D26** (refer to **Appendix D**).

Table 4.2.3: Benthic Macroinvertebrate Water Quality Index

Sampling Station	Section Description	Approximate Location	HBI	TRCA Water Quality Index
SUD102	Mine effluent and Urban stream	Fisher Wavy driveway	6.7	Potentially Impaired
SUD103	Mine effluent and Urban stream	Riverside Dr underground tunnel under city core	5.4	Unimpaired
SUD104	Urban stream	Louis St. upstream of tunnel with gabion baskets	4.6	Unimpaired
SUD404	Urban stream	Voyageur St.	4.1	Unimpaired
SUD406	Urban stream	At the end of George St.	6.9	Potentially Impaired
SUD407	Historical mine impact and urban stream	Martindale St.	6.2	Potentially Impaired
SUD408	Historical mine impact and urban stream	Copper St.	4.8	Unimpaired
SUD101	Mine effluent and Urban stream	Spruce St. (Garson) at a Public park	5.1	Unimpaired
SUD 401	Historical mine impact and urban stream	Margaret St. (Garson)	8.3	Impaired
SUD402	Historical mine impact and urban stream	Donnelly Dr. off Falconbridge Hwy	10.0	Impaired
SUD200	Urban stream	Madison Rd.	4.5	Unimpaired
SUD403	Historical mine impact and urban stream	Maley Dr. off Falconbridge Hwy	4.4	Unimpaired
FST1	Historical mine impact and urban stream	Notre Dame Ave. at LaSalle Blvd.	5.8	Unimpaired
JC2	Historical mine impact and urban stream	Notre Dame Ave. at LaSalle Blvd.	5.2	Unimpaired
SUD405	Historical mine impact and urban stream	McLean Park (Sudbury)	4.0	Unimpaired
NMCN	Mine effluent and Urban stream	McNeil Blvd. Park (Sudbury)	6.8	Potentially Impaired
RAM01	Urban stream	Beverly St.	7.8	Impaired
RAM09	Urban stream	Beverly St.	5.6	Unimpaired
ROB01	Urban stream	Southview Drive	9.2	Impaired

Sampling Station	Section Description	Approximate Location	HBI	TRCA Water Quality Index
SUD501	Urban stream	Ramsey view Court (Sudbury)	5.7	Unimpaired
SUD502	Urban stream	Walford Rd. (Sudbury)	4.0	Unimpaired
SUD515	Urban stream	Fielding Rd. Fielding Park (Lively)	4.0	Unimpaired

4.2.3 Excess Nutrients

Total Phosphorus (mg/L) includes dissolved phosphorus and forms of phosphorus bound to organic and inorganic material in water. Its concentration is used as an indicator of nutrient over-enrichment, which can lead to eutrophication. It is a common knowledge that Kelly Lake, Simon Lake, Mud Lake and McCharles Lake retain high phosphorus levels that lead to excessive algae blooms in the warm summer months.

Total Phosphorus (mg/L) was calculated for ten (10) water sampling sites: Garson, Testmark, Donnely, Maley (Branch), Paquette, McLean, St George, Brady, Martindale, and Kelly. These sites have been sampled on a monthly basis by the Junction Creek Stewardship Committee, and the samples are analyzed by Vale. Site locations are illustrated in **Figure D1** (refer to **Appendix 'D'**), and an annual phosphorus grade for each site is presented in **Table 4.2.4**. The range grading system presented is the same as presented in **Table 4.2.1** (A: Excellent; B: Good; C: Fair; D: Poor; F: Very Poor)

Table 4.2.4: Total Phosphorus Scoring Results

Year	Garson	Testmark	Donnelly	Maley (Branch)	Paquette	McLean (Branch)	St George	Brady	Martindale	Kelly
2004	—	—	F	B	B	B	B	B	—	B
2005	—	—	F	B	B	C	B	C	—	B
2006	—	—	D	B	B	B	A	B	—	B
2007	B	B	F	B	B	B	A	C	B	B
2008	B	B	F	B	B	B	B	D	B	B
2009	D	A	C	B	B	B	B	D	C	C
2010	D	A	D	B	B	B	A	F	B	B
2011	B	A	D	B	B	B	B	D	B	B
2012	B	A	D	B	B	B	B	F	B	D
2013	B	A	C	B	B	F	A	D	B	B
2014	B	A	B	B	B	C	B	F	B	C
2015	B	B	C	B	A	B	B	C	B	D
2016	B	B	B	C	A	B	B	F	B	D

Notes:

1. A: Excellent
2. B: Good
3. C: Fair
4. D: Poor
5. F: Very Poor

For the '2018 Junction Creek Subwatershed Report Card', the Conservation Ontario scoring system (Conservation Ontario 2013) was followed to calculate a final grade for Total Phosphorus (mg/L) using phosphorus data from the CGS Lake Water Quality Program. Lily Creek, Junction Creek (Fielding Road), Mud Lake, Simon Lake, McCharles Lake (East), McCharles Lake (Middle), Robinson Lake, and Kelly Lake, presented grade C for phosphorus. McCharles Lake (West) presented grade A, while the Nepahwin Lake phosphorus grade was B.

4.2.4 Bacteria

E. coli is broadly used as a relevant indicator of fecal contamination and presence of pathogens. It is a valuable tool to identify potential contamination within the subwatershed and compared to land use activities. Unfortunately, just a few sites have been monitoring within the Junction Creek subwatershed. The lack of data for *E. coli* was a limiting factor during the development of the subwatershed Report Card.

E. coli data was provided by The Vermillion Stewardship Committee, and it was collected from the following sites: Lily Creek, Junction Creek (Fielding Road), Mud Lake, Simon Lake, and McCharles Lake (East, Middle, West). All sites presented grade A for *E. coli* results.

4.2.5 Preliminary Recommendations

The main problem verified during surface water quality analysis was the lack of data and inconsistency. Water quality parameters used to evaluate water quality are collected by different institutions, and there is no harmonization between sample sites and frequency.

Regarding the water chemistry, the monitoring program has been active since 2004, and as described in the previous sections, it is a partnership program between JCSC (water sampling) and Vale (laboratory analysis). During data analysis, a lack of lotic water chemistry was verified on Copper Cliff Creek and Meatbird Creek, and below Kelly Lake (lotic refers to flowing water systems, as opposed to lentic water systems which are generally still). It is therefore suggested to include sampling sites near these locations.

The current Lake Water Quality Program sampling sites cover majority of lakes in the subwatershed, focusing on nutrient levels. It is suggested that sampling and analysis efforts should be expanded to include a larger suite of water chemistry parameters. Additional chemical parameters that could help us obtain a more complete image of the quality of Sudbury lakes include salt, chlorophyll-a, blue-green algae, E. coli, Potential cost-saving methods to allow for this expansion include an increase in the time between sampling efforts to possibly two years, if necessary, or incorporation of citizen scientists and lake stewards in sampling efforts. However, it will be important to continue sampling Mud Lake, McCharles Lake and Simon Lake annually and to maintain the long-term water quality dataset in order to capture trends in water quality through time. Additionally, it is recommended to look at individual point sources of phosphorus; it would be beneficial to add sampling sites below the Garson Sewage Lagoons, Timberwolf Golf Course and Lively.

Expanding the monitoring program would be beneficial to develop more assertive projects dedicated to water quality improvement. For example, consistent phosphorus data can support a nutrient offset program implementation to meet instream nutrient targets in designated waterways by way of a combination of stormwater management and enhanced wastewater treatments. The water quality or nutrient trading concept can be used as an economic instrument to help manage environmental impacts within a subwatershed with the general goal of a net reduction of pollutants, such as phosphorus.

4.3 Infrastructure

The CGS's stormwater management infrastructure includes storm sewers, overland drainage systems, stormwater management facilities, and wastewater treatment facilities. A general description of the systems and information is provided below.

4.3.1 Storm Sewers

Most of the urbanized areas of the Junction Creek Subwatershed Study Area are serviced by a storm sewer system which discharges stormwater into a lake or watercourse. As stated in the Background Characterization, thirty-four (34) trunk sewer systems were initially identified, with the majority of these networks located on Junction Creek, except for two (2) on Nepahwin Lake.

4.3.2 Overland Drainage System

The overland drainage system is the "major" component of the major and minor "dual drainage" concept of stormwater management. The minor system consists of storm sewers and ditches to convey smaller, frequent storm flows, typically up to the peak flow of a 1:2, 1:5, or 1:10 year storm event. The major system consists of surface drainage systems and overland flow routes such as roadways and major ditches to convey larger, infrequent storm flows up to the peak flow of a 100 year or Regional storm event.

The other main component of the overland drainage system are the various creeks, watercourses, and rivers traversing the Junction Creek Subwatershed Study Area. The main branch of Junction Creek begins at its headwaters downstream of Garson Mine and outflows into McCharles Lake, which then joins the Vermillion River.

4.3.3 Stormwater Management Facilities

There are various stormwater management facilities located throughout the CGS and within the Junction Creek subwatershed. The types of existing facilities currently include:

- Oil and grit separators;
- Stormwater management wet and dry ponds;
- Stormwater management hybrid wet pond and wetland structure;
- Control weirs; and,
- Super pipes for storage.

A database was developed by the CGS establishing an inventory of the locations, types, environmental compliance approvals, inspection and sampling information associated with each existing stormwater management facility.

4.3.4 Wastewater Treatment Facilities

There are several wastewater treatment facilities located within the Junction Creek subwatershed. One of the primary stormwater issues associated with the effluent discharge from these facilities is the potential impact to cause poor water quality in Junction Creek. Within the Junction Creek subwatershed, treated effluent is discharged from outfalls at the following facilities:

- Lively Wastewater Treatment Plant
- Walden Wastewater Treatment Plant
- Copper Cliff Wastewater Treatment Plant
- Garson Sewage Lagoon
- Sudbury Wastewater Treatment Plant

4.4 Groundwater Characteristics

Sudbury is known for its exposed bedrock terrain and thin overburden. Within the study area there are few areas consisting of glaciolacustrine deposits: the Wanapitei Esker from the headwaters to New Sudbury; a second large deposit below Kelly Lake; and smaller deposits consisting silt, sand and minor amounts of clay, dispersed throughout the centre area of the subwatershed. The large amount of bedrock making up the subwatershed's surficial geology increases the impervious surface of the subwatershed as a whole.

There are three very distinct groundwater aquifers/flow systems within the Junction Creek Subwatershed: 1) the unconfined bedrock aquifer exposed at ground surface along the valley flanks; 2) the unconfined Wanapitei Esker deposits; and 3) the confined or semiconfined glacial outwash deposits that are overlain by finer grained deposits at surface. The unconfined bedrock aquifer exposed at ground surface does not provide very high recharge as the bedrock is fairly competent with low permeability and precipitation tends to runoff, as opposed to infiltrating.

The Wanapitei Esker deposits present a high recharge potential, but the characteristics of the aquifer that provide this potential also expose the aquifer and the municipal water supply in this area to a greater risk to contamination from surface or very surface activities. The confined or semi-confined deposits that extend from the Lasalle Boulevard, downstream towards Kelly Lake, are areas that are dominated by groundwater discharge zones. These areas appear to have low recharge potential do to the presence of a laterally continuous aquitard, which is further compounded by the amount of runoff in these areas induced by largely developed (i.e., paved and landscaped) areas.

The Junction Creek Subwatershed does provide recharge conditions in several locations, however, the presence of low to moderate permeability glaciolacustrine deposits in the floodplain near Junction Creek limits the areas where significant recharge of groundwater to the creek can occur. The Garson area, which hosts the Wanapitei Esker, provides a significant groundwater recharge area due to the unconfined condition.

4.5 Fluvial Geomorphic Assessment

Upon completion of a geomorphologic survey within specified reaches of Junction Creek (**Section 3.6**), it was noted that Tree cover within riparian zones was low throughout much of Upper Junction. Over time, existing riparian width and tree cover decreased and land use has been altered especially between 1946 and 1975, to accommodate development pressures. The most abundant tree cover was observed along the Frood Branch and the Maley Branch. Additionally, much of the channel adjustments have been due to realignment.

With the increase in development, direct human modifications to the watercourse were identified. The straightening of Junction Creek to accommodate development is visible in all aerial photographs. Watercourse straightening is present in areas previously characterized by meanders, specifically upstream of Kelly Lake in 1946, as well as areas occupied by transportation networks, specifically surrounding the train station located centrally near Junction Creek.

The Rapid Stream Assessment Technique (RSAT) and Rapid Geomorphological Assessments (RGA) were employed as part of the fluvial geomorphology assessment. All reaches received a "Fair" RSAT condition, except for reaches TJ-14 and TJ-14-1, which are part the Frood Branch on either side of Lasalle Boulevard (**Table 3.6.1**). RGA conditions were low, "In Transition / Stress" for all reaches except J8, J11, TJ-14 and TJ-14-1. These reaches received an "In Regime" condition, with J8 and J11 situated along the main branch of Junction Creek, directly upstream of the Caesar Road, and in the Flour Mill, respectively. Active erosion, or evidence of erosion, was found in every reach.

5.0 LAND USE PLANNING

5.1 Existing Policies

The Subwatershed Study and Master Plan must address several Municipal, Provincial and Federal regulations and policies related to stormwater quantity and quality. The following section summarizes the objectives and regulatory requirements of the relevant policies.

5.1.1 Ministry of the Environment (MOE)

The Stormwater Management Planning and Design Manual (MOE, 2003) provides planning and design guidelines and criteria for stormwater management in Ontario. The Manual outlines design criteria for water quality, erosion and flood control. The following policies apply specifically to the Subwatershed Master Plan (SWSMP):

- Water quality control to be established to the standards outlined in the Stormwater Management Planning and Design Manual for the requisite level of control required by the receiving watercourse; and,
- Provide the requisite erosion control for protection of downstream watercourses to ensure they remain stable (Ontario Water Resources Act as administered by the Ministry of the Environment).

In addition, the MOE provides guidance on the assessment of phosphorus loading and management through the Phosphorus Budget Tool (Hutchinson Environmental Services Ltd, March 2012).

The Draft Low Impact Development Stormwater Management Guidance Manual (MOE, 2017) is intended to complement the 2003 Manual by providing planning and design guidelines and criteria for stormwater management in Ontario that accounts for recent stormwater innovation and climate change mitigation. The Draft 2017 Manual outlines criteria for stormwater volume control requirements, selecting water budget and water modelling tools, groundwater protection considerations from infiltration based Low Impact Development (LID) Best Management Practices (BMPs), criteria for model selections, and climate change considerations regarding future scenarios, risks and vulnerabilities.

5.1.2 Ministry of Natural Resources and Forestry (MNRF)

The Ministry of Natural Resources and Forestry (MNRF) provides planning and technical guidelines for the establishment and management of Natural Hazards as they relate to river and stream systems including flooding, erosion, and slope stability. Policies are aimed at directing development away from Natural Hazards where there is a risk to public safety or a risk of property damage. The Natural Hazard Policies are applied under the Provincial Policy Statement which is issued under the Planning Act and administered by the MNRF according to the Technical Guide for River & Stream Systems (MNRF, 2002). The following policies apply specifically to the SWSMP:

- Mitigate potential offsite flood impact by providing flood control (post- to pre-development peak flow control) or conveyance improvements or securing permission from any impacted land owners, if appropriate; and,
- Provide hydraulic structures that provide safe access and egress for emergency vehicles.

5.1.3 Ministry of Transportation (MTO)

The Ministry of Transportation has a number of documents to address drainage considerations in highway design and corridor management. Of specific interest to the current study are the design requirements for hydraulic structures crossing watercourses. The following policies apply specifically to the SWSMP:

- Provide hydraulic structures that meet MTO guidelines for freeboard (Directive B-100, Highway Design Standards, MTO, January 2008).
- Provincial Engineering Memo (PEM) DSCO #2016-14 - In October 2016 MTO issued a policy requiring all highway drainage infrastructure to be designed using future rainfall predictions.

5.1.4 Conservation Sudbury (CS)

Conservation Sudbury (CS), formerly known as the Nickel District Conservation Authority (NDCA), provides environmental and planning expertise to developers and municipalities and ensures provincial, federal and conservation authority policies and regulations are followed with respect to development and construction in the Vermilion, Wanapitei and Whitefish subwatersheds.

CS also manages all regulated areas within the subwatershed, such as floodplains, steep slopes, wetlands, shorelines and waterways according to Ontario Regulation 156/06 – Development, Interference with Wetlands and Alterations to Shorelines and Watercourses Regulation. Accordingly, CS reviews development proposals within or adjacent to regulated areas pertaining to the conservation and management of watershed resources and applicable provincial policies and guidelines. In most instances this involvement is required as a result of regulations passed under the authority of Ontario's Planning Act and by Provincially delegated responsibility for the management of natural hazards via the Conservation Authorities Act.

5.1.5 City of Greater Sudbury (CGS)

The CGS OP was adopted by Council in 2006 and has been updated to reflect all amendments in effect up to September 2016. Phase One of the CGS Official Plan review began in 2012, and Phase Two of the Official Plan review is currently underway. This Subwatershed Study & Stormwater Master Plan is consistent with all policies in the current Official Plan.

The CGS is the largest municipality in Ontario based on total area, which presents unique challenges regarding land use, growth and environmental management. The environment and economy of Greater Sudbury is further defined by its abundance in natural resources, predominantly metals and minerals, as it contains one of the largest mining industrial complexes in the world. Part III of the Official Plan, Protecting the Natural Environment, highlights the conflicts between urban development and the protection of the environment, noting that water resources are negatively impacted by metal contamination, deforestation and urbanization.

The SWSMP is completed in accordance with Section 8.1 to undertake a subwatershed-based planning approach and employ mitigative measures and/or alternative development approaches to protect, improve and restore water resources. Section 8.2 identifies three types of subwatershed-based plans: source water protection plans, subwatershed plans and lake-based recreational and habitat issues. Subwatershed plans typically address flooding and water quality issues.

The SWSMP is required to satisfy the following relevant policy objectives of the Official Plan:

1. Regardless of the particular focus of the three types of subwatershed-based plans outlined above, all should fulfill the following requirements in a manner and scope appropriate to the type of plan [*Ref. CGS OP Section 8.2(1)*]:
    a. Identify the boundaries of the subwatershed and, where appropriate, those of its subwatersheds;

   b. Identify and assess human activities in the subwatershed, surface water features, hydrologic functions, natural heritage features and areas and, where possible and appropriate, groundwater features, which are necessary for the ecological and hydrological integrity of the subwatershed; and,
   c. Propose recommendations for protecting, improving or restoring vulnerable surface water and groundwater, sensitive surface water features and, where possible and appropriate, sensitive groundwater features, and their hydrologic functions.
2. Council will support and take part in the development and implementation of subwatershed-based source water protection plans. These plans will fulfill the requirements outlined in Section 8.2, with an emphasis on identifying sensitive features of the CGS's drinking water resources as well as identifying measures required to protect, improve or restore these resources. *(Ref. CGS OP Section 8.3.2)*
3. Watershed-based plans incorporating accepted lake capacity models will identify the sensitive surface water features of individual subwatersheds and specific measures required to protect, enhance or restore these features. *(Ref. CGS OP Section 8.5)*
4. Stormwater management in the CGS is needed to *(Ref. CGS OP Section 8.6.1)*:
   a. ensure that the constraints and opportunities associated with urban drainage are properly recognized and are integrated into community plans and designs;
   b. reduce, to acceptable levels, the potential risk of health hazards, loss of life and property damage from flooding;
   c. reduce, to acceptable levels, the incidence of inconvenience caused by surface ponding and flooding;
   d. ensure that the quality of stormwater reaching outlet-receiving lakes and rivers meets provincially accepted criteria;
   e. ensure that any development or redevelopment minimizes the impact of change to the groundwater regime, increased pollution, increased erosion or increased sediment transport, especially during construction; and,
   f. maintain the natural stream channel geometry, insofar as it is feasible while achieving the above objectives.
5. 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. *[Ref. CGS OP Section 8.6.2(3)]*
6. Existing watercourses will be left in their natural state whenever possible. The banks must be able to convey either the Regional or 100-year storm peak flow. *[Ref. CGS OP Section 8.6.2(4)]*
7. Watershed and subwatershed plans will determine the sensitivity of wetlands and establish appropriate land use policies. *[Ref. CGS OP Section 9.2.3(1)]*
8. New development, redevelopment, and municipal infrastructure works on previously restored land will be required to mitigate any impacts to existing soil and vegetation. Where mitigation through avoidance is not possible, onsite soil erosion shall be prevented and all vegetation removed shall be replaced through appropriate and adequate site landscaping and/or land reclamation measures. *[Ref. CGS OP Section 9.4(2)]*
9. New development, redevelopment, and municipal infrastructure works on land in need of reclamation, will be required to reclaim the soil and vegetation onsite to a level equal to or

greater than would be achieved through the CGS's Land Reclamation Program. *[Ref. CGS OP Section 9.4(3)]*

5.2 Future Growth and Development Areas

The CGS has provided mapping depicting the planned location of future development for areas within the Junction Creek Subwatershed, derived from the CGS Water and Wastewater Master Plan (WSP, 2015). This mapping has subsequently been updated to reflect development by Community and Neighbourhood, as per the CGS mapping (CGS, 2014). The mapping of future development sites within the Junction Creek Subwatershed is presented in **Figure G1** (refer to **'Appendix G'**).

The future land use conditions for the development sites presented in **Figure G1** have been established based upon the information presented in the CGS Water and Wastewater Master Plan (WSP, 2015). The impervious coverage for future development sites have been estimated based upon the land use specified in the CGS Water and Wastewater Master Plan (WSP, 2015) and using the assumed impervious coverage values presented in **Table 5.2.1**. The amount of impervious coverage is further defined by development type by Community in **Table 5.2.1**.

Future development to the ultimate growth forecast projects that 959.42 hectares of growth will occur within the Junction Creek Subwatershed, which will include 635.19 hectares of impervious area (**Tables 5.2.2** & **5.2.3**). Future residential development will account for the greatest increase in impervious area, accounting for 60%. The South End area will absorb 26.1% of growth in impervious coverage (166.06 ha), followed by the Community of Lively which will absorb 23.6% (149.80 ha).

Table 5.2.1: Additional Impervious Coverage by Development Type (to Ultimate Buildout)

Development Type	# of Properties	Area (ha)	Imperviousness (%)	Impervious Area (ha)
Commercial	95	49.30	96%	47.33
Industrial	85	206.93	96%	198.69
Institutional	16	9.69	80%	7.75
Residential	688	693.50	55%	381.43
Total	884	959.42	66%	**635.19**

Table 5.2.2: Summary of Additional Impervious Coverage by Community/Neighbourhood (to Ultimate Buildout)

Community/ Neighbourhood	# of Properties	Area (ha)	Average Imperviousness (%)	Impervious Area (ha)	Percent of Total Impervious Area
Copper Cliff	13	16.95	93%	15.88	2.5%
Donovan	54	8.97	57%	5.10	0.8%
Downtown	24	13.97	73%	10.22	1.6%
Flour Mill	89	29.54	60%	17.69	2.8%
Garson	99	77.79	86%	66.55	10.5%

Community/ Neighbourhood	# of Properties	Area (ha)	Average Imperviousness (%)	Impervious Area (ha)	Percent of Total Impervious Area
Kingsmount-Bell Park	23	1.94	59%	1.15	0.2%
Lively	93	262.73	57%	149.80	23.6%
Minnow Lake	21	48.70	61%	29.68	4.7%
Naughton	25	30.52	55%	16.88	2.7%
New Sudbury	143	104.40	66%	69.33	0.2%
Rural South End	2	1.01	96%	0.97	0.2%
South End	196	267.32	62%	166.06	26.1%
Walden Rural	38	75.47	96%	72.40	11.4%
West End	64	20.11	67%	13.47	2.1%
Total	884	959.42	66%	635.19	100%

*Note: The future development property sizes are derived from the CGS Water and Wastewater Master Plan (WSP, 2015). Residential properties identified as less than 10 hectares may be developed in conjunction with adjacent properties as part of a larger development (subdivision), in which case any development greater than 10 hectares will be subject to additional retrofit measures. Future development patterns are unknown at this time and may result in modifications to the number of residential developments that are greater or less than 10 hectares.

Table 5.2.3: Additional Impervious Coverage by Community/ Neighbourhood (to Ultimate Buildout)

Copper Cliff				
Development Type	# of Properties	Area (ha)	Imperviousness (%)	Impervious Area (ha)
Commercial	3	0.16	96%	0.16
Industrial	2	15.74	96%	15.11
Residential	8	1.05	55%	0.58
Total	**13**	16.95	93%	**15.84**
Donovan				
Development Type	# of Properties	Area (ha)	Imperviousness (%)	Impervious Area (ha)
Commercial	2	0.41	96%	0.39
Residential	52	8.57	55%	4.71
Total	54	8.97	57%	**5.10**
Downtown				
Development Type	# of Properties	Area (ha)	Imperviousness (%)	Impervious Area (ha)
Commercial	11	0.90	96%	0.86
Industrial	5	3.64	96%	3.49
Institutional	2	2.70	80%	2.16

Residential	6	6.73	55%	3.70
Total	**24**	**13.97**	73%	**10.22**
Flour Mill				
Development Type	# of Properties	Area (ha)	Imperviousness (%)	Impervious Area (ha)
Commercial	4	0.90	96%	0.86
Industrial	4	2.12	96%	2.04
Institutional	1	0.82	80%	0.66
Residential	80	25.69	55%	14.13
Total	**89**	**29.54**	60%	**17.69**
Garson				
Development Type	# of Properties	Area (ha)	Imperviousness (%)	Impervious Area (ha)
Commercial	7	0.66	96%	0.63
Industrial	13	57.27	96%	54.98
Institutional	1	0.08	80%	0.06
Residential	78	19.79	55%	10.88
Total	**99**	**77.79**	86%	**66.55**
Kingsmount-Bell Park				
Development Type	# of Properties	Area (ha)	Imperviousness (%)	Impervious Area (ha)
Commercial	1	0.14	96%	0.13
Institutional	1	0.10	80%	0.08
Residential	21	1.70	55%	0.94
Total	**23**	**1.94**	59%	**1.15**
Lively				
Development Type	# of Properties	Area (ha)	Imperviousness (%)	Impervious Area (ha)
Commercial	10	9.72	96%	9.33
Industrial	1	2.25	96%	2.16
Institutional	2	1.58	80%	1.26
Residential	80	249.18	55%	137.05
Total	**93**	**262.73**	57%	**149.80**
Minnow Lake				
Development Type	# of Properties	Area (ha)	Imperviousness (%)	Impervious Area (ha)
Commercial	4	0.55	96%	0.53
Industrial	3	6.22	96%	5.98
Institutional	2	0.45	80%	0.36
Residential	12	41.47	55%	22.81

Total	**21**	**48.70**	61%	**29.68**
Naughton				
Development Type	# of Properties	Area (ha)	Imperviousness (%)	Impervious Area (ha)
Institutional	1	0.39	80%	0.31
Residential	24	30.13	55%	16.57
Total	**25**	**30.52**	55%	**16.88**
New Sudbury				
Development Type	# of Properties	Area (ha)	Imperviousness (%)	Impervious Area (ha)
Commercial	21	8.93	96%	8.58
Industrial	10	19.83	96%	19.04
Institutional	1	0.47	80%	0.38
Residential	111	75.16	55%	41.34
Total	143	104.40	66%	**69.33**
Rural South End				
Development Type	# of Properties	Area (ha)	Imperviousness (%)	Impervious Area (ha)
Industrial	2	1.01	96%	0.97
Total	2	1.01	96%	**0.97**
South End				
Development Type	# of Properties	Area (ha)	Imperviousness (%)	Impervious Area (ha)
Commercial	24	26.08	96%	25.04
Industrial	4	19.23	96%	18.46
Institutional	3	1.84	80%	1.47
Residential	165	220.17	55%	121.09
Total	196	267.32	62%	**166.06**
Walden Rural				
Development Type	# of Properties	Area (ha)	Imperviousness (%)	Impervious Area (ha)
Industrial	37	75.36	96%	72.34
Residential	1	0.11	55%	0.06
Total	38	75.47	96%	**72.40**
West End				
Development Type	# of Properties	Area (ha)	Imperviousness (%)	Impervious Area (ha)
Commercial	8	0.85	96%	0.82
Industrial	4	4.27	96%	4.10
Institutional	2	1.25	80%	1.00

Residential	50	13.74	55%	7.56
Total	64	20.11	67%	**13.47**
Grand Total	**884**	**959.42**	**66%**	**635.19**

The CGS Stormwater Background Study (2006) provides stormwater best management practices for a variety of activities. New development is recommended to meet, at minimum, the best management practices listed in **Table 5.2.4**.

Table 5.2.4: CGS 2006 Background Study Stormwater Management for New Developments

	Residential		**Commercial / Industrial**
	< 10 hectares	**> 10 hectares**	
On-Site Measures	Roof leader to rain barrels Roof leader to soak away pit Rear lot drainage Accepted minimum grades Rain gardens Oil/grit separators for paved areas	Roof leader to rain barrels Roof leader to soak away pit Rear lot drainage Accepted minimum grades Rain gardens Oil/grit separators for paved areas	Oil/grit separators On-site detention (roof storage, parking lot storage) Buffer strips Enhanced swales Infiltration trenches Rain gardens
Subwatershed Management Strategy	N/A	Wet Pond Dry Pond Constructed Wetland	Wet Pond Dry Pond Constructed Wetland

Future development sites within the Junction Creek Subwatershed have been categorized by development type and lot size in order to identify the recommended stormwater management best practice for each site in accordance with the CGS Stormwater Background Study. The location of these properties is illustrated in **Figure G1**.

Table 5.2.5: Future Development Sites by Development Type (to Ultimate Buildout)

Land Use	**Residential**		**Institutional/ Commercial / Industrial (ICI)**	**Total**
	< 10 hectares	> 10 hectares		
# of Properties	669	19	196	**884**

6.0 HYDROLOGICAL MODEL, EVALUATION AND ANALYSIS

6.1 Modelling Requirements

As described in **Section 3.3**, hydrologic models are developed to provide a better understanding of the amount and movement of water in the system under both existing land use, and proposed future land use conditions, as well as to analyze various stormwater alternatives, based upon the physical conditions in the subwatershed. The goal of the Junction Creek hydrologic model is to provide an overall subwatershed-scale representation of the hydrologic conditions, which may be used to test the various Stormwater Master Plan alternatives and options (discussed in **Section 10**), as well as to provide peak flow information for the hydraulic floodplain model, for various design storm events, as described in **Section 7**. Further, the overall hydrologic model will also be used as a basis to develop individual large-scale hydrologic models of trunk sewer networks along Junction Creek, as described in **Section 8**. By developing a representative model which reasonable predicts seasonal and storm-based runoff response, the impacts of future urbanization can be better quantified, and various stormwater management strategies can be established and modelled.

6.2 Software

The PCSWMM modelling platform has been selected for the overall subwatershed hydrologic modelling. PCSWMM combines hydrologic modelling to generate storm runoff response rates from land areas with hydraulic modelling to evaluate water surface elevations and velocities within the conveyance system. Though the hydraulic floodplain modelling will be performed using HEC-RAS (as described in **Section 7**), the hydraulic capabilities of PCSWMM will provide an additional source of data and model analysis. PCSWMM is capable of importing HEC-RAS geometry files directly, which allows subwatershed surface watercourses to be quickly modelled.

The model applied both an Event Methodology for single storm events and continuous simulation of a long-term period or record of multiple storm events. For the Event Methodology, synthetic design storms are typically used to evaluate flood frequency or risk, and PCSWMM is able to generate design runoff events automatically based on common design rainfall formulae. For continuous simulation, rainfall records are required, and are easily imported from a variety of formats using PCSWMM tools.

The PCSWMM software is able to import GIS data layers and shapefiles directly, including DTM files, to allow for the automatic delineation of hydrologic features. Based on a DTM file, PCSWMM tools allow for the automatic delineation of subcatchments, overland flow paths, average subcatchment slopes, and other features which assist in creating an overall subwatershed hydrologic model.

PCSWMM employs the EPA SWMM engine as its base, this modelling files created in PCSWMM can be open and executed within the EPA SWMM program as well as PCSWMM. This also provides an additional degree of reliability and quality assurance to the modelling program.

6.3 Subcatchment Delineation

Subcatchment delineation within the Junction Creek subwatershed was completed using a combination of the received LiDAR DTM information, the PCSWMM model built-in functions, past reports and as-built drawings, and discussions with the CGS, CS, and other members of the project team. The general arrangement of subcatchments within the Junction Creek subwatershed is discussed in **Section 3.3** above and shown on **Figure C1** (refer to **Appendix C**).

The delineation of subcatchments was initially completed in PCSWMM using the DTM information, based on a relatively small (10-50ha) subcatchment size. These small, highly discretized subcatchments were then combined based on the overall drainage patterns of the area to form a reasonable number of subcatchments for the overall subwatershed hydrologic modelling. The overall subcatchment shapes were selected to provide peak flow output at reasonable points along Junction Creek and tributaries for eventual export to the HEC-RAS hydraulic floodplain model. For example, subcatchments have been divided at watercourse junctions in order to provide separate peak flow calculations for each incoming watercourse reach.

Care has been taken to delineate the subcatchment areas draining to the Kirkwood, Nickeldale, and Maley Dams, as well as to the mine tailings Water Treatment Plans, as accurately as possible based on available information and historical reports. The main tailings areas contain many large pumps which redirect water between various ponds and the Central Tailings Area, including a pump which brings the Frood-Stobie mine subcatchment drainage to the Central Tailings Area.

The Ramsey Lake subwatershed areas have not been delineated through this process, rather, the separate Ramsey Lake subwatershed model outflow (received from the CGS) was used as a direct inflow to the Junction Creek subwatershed hydrologic model, at the start of Lily Creek (the outlet of Ramsey Lake).

6.4 Subcatchment Parameterization

The average slopes within each of the Junction Creek subcatchments were calculated using ArcGIS software in conjunction with the received LiDAR DTM data. The CGS is uniquely located among bedrock topography with large amounts of relief throughout some areas of the Junction Creek subwatershed. As such, overland slopes in some areas can be higher than is typical for similar large cities in southern Ontario.

Subcatchment curve number (CN) and imperviousness were estimated based on the Provincial Landcover 2000 – 27 Class, as available from the Ontario Ministry of Natural Resources and Forestry (MNRF). As shown on **Figure C3** (refer to **Appendix 'C'**), the following land classes are visible in the Junction Creek area:

- Water
- Settlement/Infrastructure
- Sand / Gravel / Mine Tailings
- Bedrock
- Forest Depletion – Cuts
- Forest – Sparse

- Forest – Dense Deciduous
- Forest – Dense Mixed
- Forest – Dense Coniferous
- Bog – Open
- Bog – Treed

The various land cover percentages of each subcatchment were calculated using ArcGIS software, and are shown in **Table 6.4.1** below.

Based on previous experience in the Sudbury area on other hydrologic modelling projects, SCS curve numbers and overall imperviousness were initially assigned as shown in **Table 6.4.2**.

Table 6.4.1: Subcatchment Land Cover Area

Subcatchment	**Water**	**Settlement / Infrastructure**	**Sand / Gravel / Mine Tailings**	**Bedrock**	**Forest Depletion - Cuts**	**Forest - Sparse**	**Forest - Dense Deciduous**	**Forest - Dense Mixed**	**Forest - Dense Coniferous**	**Bog - Open**	**Bog - Treed**
	Z17 LC Zone Area (ArcGIS) *(ha)*										
	1	**3**	**4**	**5**	**7**	**10**	**11**	**12**	**13**	**22**	**23**
COP-0	14.7%	4.4%	22.0%	44.2%	0.0%	13.1%	0.5%	1.0%	0.2%	0.0%	0.0%
COP-1	11.0%	0.0%	23.4%	56.7%	0.0%	8.1%	0.0%	0.9%	0.0%	0.0%	0.0%
COP-2	6.7%	0.0%	49.0%	38.3%	0.0%	4.9%	0.0%	0.9%	0.2%	0.0%	0.0%
COP-3	6.8%	0.0%	93.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
COP-4	0.2%	0.8%	89.4%	8.1%	0.0%	1.0%	0.1%	0.0%	0.3%	0.0%	0.0%
FROOD-1	3.1%	0.0%	67.8%	25.4%	0.0%	3.7%	0.0%	0.0%	0.0%	0.0%	0.0%
JC-1a	0.8%	64.0%	2.5%	31.7%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%
JC-1b	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
JC-2	1.3%	70.7%	0.8%	7.3%	0.0%	17.7%	0.0%	1.6%	0.7%	0.0%	0.0%
JC-3	0.4%	90.4%	0.0%	1.6%	0.0%	6.1%	0.2%	1.3%	0.0%	0.0%	0.0%
JC-4	0.0%	98.8%	0.0%	0.0%	0.0%	0.8%	0.0%	0.4%	0.0%	0.0%	0.0%
JC-5	0.1%	65.6%	0.0%	7.2%	0.0%	22.3%	4.3%	0.6%	0.0%	0.0%	0.0%
JC-6	0.0%	97.9%	0.0%	0.7%	0.0%	0.7%	0.0%	0.7%	0.0%	0.0%	0.0%
JC-7	0.0%	94.0%	0.0%	0.5%	0.0%	4.7%	0.7%	0.2%	0.0%	0.0%	0.0%
JC-8a	0.0%	78.1%	0.0%	5.1%	0.0%	16.7%	0.0%	0.1%	0.0%	0.0%	0.0%
JC-8b	0.0%	60.0%	0.0%	28.0%	0.0%	11.0%	0.5%	0.3%	0.0%	0.0%	0.0%
JC-9a	0.0%	50.4%	0.0%	23.5%	0.0%	26.1%	0.0%	0.0%	0.0%	0.0%	0.0%
JC-9b	0.0%	8.9%	0.0%	76.4%	0.0%	14.6%	0.0%	0.0%	0.0%	0.0%	0.0%
JC-10	0.0%	60.4%	0.0%	24.6%	0.0%	14.1%	0.0%	0.8%	0.0%	0.0%	0.0%
JC-11	0.0%	84.5%	0.0%	4.1%	0.0%	9.1%	0.0%	1.3%	1.0%	0.0%	0.0%
JC-12a	1.2%	88.6%	0.0%	8.7%	0.0%	0.9%	0.0%	0.1%	0.5%	0.0%	0.0%
JC-12b	0.0%	39.7%	0.0%	56.3%	0.0%	0.6%	0.0%	0.0%	3.4%	0.0%	0.0%

Subcatchment	**Water**	**Settlement / Infrastructure**	**Sand / Gravel / Mine Tailings**	**Bedrock**	**Forest Depletion - Cuts**	**Forest - Sparse**	**Forest - Dense Deciduous**	**Forest - Dense Mixed**	**Forest - Dense Coniferous**	**Bog - Open**	**Bog - Treed**
	Z17 LC Zone Area (ArcGIS) *(ha)*										
	1	**3**	**4**	**5**	**7**	**10**	**11**	**12**	**13**	**22**	**23**
JC-13	0.0%	57.9%	0.0%	26.1%	0.0%	16.1%	0.0%	0.0%	0.0%	0.0%	0.0%
JC-14	0.3%	93.7%	1.7%	1.5%	0.0%	0.0%	0.0%	2.1%	0.6%	0.0%	0.0%
JC-15	1.9%	47.5%	49.7%	0.7%	0.0%	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%
JC-16	0.0%	23.3%	72.6%	1.3%	0.0%	0.0%	0.0%	2.8%	0.0%	0.0%	0.0%
JC-19	1.5%	9.0%	0.0%	82.1%	0.0%	7.4%	0.0%	0.0%	0.0%	0.0%	0.0%
JC-20	4.5%	1.1%	0.0%	81.1%	0.0%	12.6%	0.1%	0.7%	0.0%	0.0%	0.0%
JC-21	2.0%	10.3%	0.0%	64.9%	0.0%	22.6%	0.0%	0.0%	0.2%	0.0%	0.0%
JC-22	4.0%	30.9%	19.4%	23.2%	0.0%	19.2%	0.9%	2.4%	0.0%	0.0%	0.0%
JC-23	0.0%	59.3%	7.2%	10.1%	0.0%	20.2%	0.5%	2.6%	0.0%	0.0%	0.0%
JC-25	0.7%	0.0%	0.0%	43.1%	0.0%	44.2%	1.9%	9.9%	0.2%	0.0%	0.0%
JC-27	0.3%	0.0%	0.0%	2.1%	0.0%	34.0%	9.7%	53.1%	0.8%	0.0%	0.0%
JC-28	1.0%	19.0%	0.0%	7.2%	0.0%	36.4%	4.7%	30.2%	1.4%	0.0%	0.0%
JC-29	24.4%	8.6%	0.0%	3.7%	0.0%	19.4%	5.6%	38.0%	0.2%	0.0%	0.0%
JC-30	17.3%	25.4%	0.0%	2.6%	0.0%	19.0%	19.3%	15.7%	0.6%	0.0%	0.0%
JC-31	16.0%	5.5%	0.0%	0.6%	2.4%	18.7%	22.7%	27.2%	1.7%	2.5%	2.6%
LIV-1	2.6%	20.2%	2.4%	12.0%	0.0%	48.5%	8.3%	5.4%	0.6%	0.0%	0.0%
MAL-1	2.5%	5.6%	0.0%	47.1%	0.0%	36.2%	2.9%	5.1%	0.5%	0.0%	0.0%
MAL-2	4.3%	12.7%	0.0%	35.5%	0.0%	39.1%	3.1%	4.9%	0.4%	0.0%	0.0%
MAL-3	1.9%	14.5%	0.0%	23.2%	0.0%	48.5%	4.8%	6.4%	0.6%	0.0%	0.0%
MAL-4	2.6%	24.7%	0.0%	39.1%	0.0%	29.0%	2.9%	1.0%	0.8%	0.0%	0.0%
NEP-1	22.6%	60.5%	0.0%	7.8%	0.0%	6.5%	0.7%	1.6%	0.2%	0.0%	0.0%
NIC-1	0.3%	16.3%	13.2%	40.1%	0.0%	27.9%	0.0%	2.1%	0.1%	0.0%	0.0%
NOL-1	1.3%	1.5%	65.7%	29.2%	0.0%	1.5%	0.0%	0.3%	0.5%	0.0%	0.0%
NOL-2	2.0%	0.8%	10.7%	75.6%	0.0%	9.2%	0.0%	1.2%	0.5%	0.0%	0.0%
NOL-3	0.0%	76.9%	2.8%	13.0%	0.0%	6.1%	0.0%	0.9%	0.3%	0.0%	0.0%
ROB-1	0.9%	97.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.6%	0.0%	0.0%
ROB-2	17.9%	44.2%	0.0%	31.6%	0.0%	5.4%	0.0%	0.9%	0.0%	0.0%	0.0%
ROB-4	0.0%	89.6%	0.0%	4.6%	0.0%	4.0%	0.3%	1.4%	0.2%	0.0%	0.0%
ROB-5	12.9%	29.1%	0.0%	41.5%	0.0%	14.3%	0.0%	2.2%	0.0%	0.0%	0.0%
TAIL-1	9.1%	2.6%	35.8%	26.8%	0.0%	24.2%	0.5%	0.2%	0.8%	0.0%	0.0%
TAIL-2	30.7%	0.0%	68.6%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TAIL-3	15.0%	0.0%	84.7%	0.0%	0.0%	0.0%	0.1%	0.0%	0.2%	0.0%	0.0%
WHITE-1	29.1%	0.0%	0.0%	0.0%	0.0%	10.1%	25.5%	32.2%	0.9%	2.0%	0.2%
WHITE-2	35.1%	0.0%	0.0%	1.1%	0.0%	9.9%	16.3%	35.9%	1.2%	0.1%	0.4%

Table 6.4.2: Initial Assigned Hydrologic Parameters

Land Classification		Assigned SCS Curve Number	Assigned Imperviousness
Description	Number		
Water	1	98	100%
Settlement / Infrastructure	2	Impervious - 98 Pervious - 79	35%
Sand / Gravel / Mine Tailings	4	98	0%
Bedrock	5	98	0%
Forest Depletion - Cuts	7	79	0%
Forest - Sparse	10	79	0%
Forest - Dense Deciduous	11	79	0%
Forest - Dense Mixed	12	79	0%
Forest - Dense Coniferous	13	79	0%
Bog - Open	22	79	0%
Bog - Treed	23	79	0%

6.5 Model Routing Elements

6.5.1 Lakes

Within the Junction Creek subwatershed, four (4) lakes have been modelled as individual routing elements:

- Kelly Lake
- Robinson Lake
- Nepahwin Lake
- Mud Lake

The invert elevation of each lake storage unit was based on the received LiDAR information. Stage-storage curves were generated using the overall water body area from available GIS mapping layers, and extrapolating to upper stages assuming a circular perimeter with a 3:1 slope. The outlet of each lake is controlled by the downstream conduit section, as imported from the riverine floodplain model discussed in **Section 7**.

6.5.2 The Ponderosa Wetland

The Ponderosa wetland was created as three separate storage units, which are created naturally by the intersection of the railways in the area, as well as a large bedrock mound. The general configuration of the natural storage areas is shown on **Figure C4** (refer to **Appendix 'C'**).

The first storage area, Ponderosa 1, is located along Junction Creek between Arthur Street and the railway. Based on the LiDAR information, there is approximately 17,500 m^3 of storage available between elevations 257.20 m and 258.20 m. Water from Ponderosa 1 is able to flow freely beneath the railway into the second natural storage area, Ponderosa 2. Water is also able to flow from the first natural storage area directly into the third natural storage area, Ponderosa 3, through two overland flow routes, starting at approximately elevation 257.80 m. The top of the railway through this area is approximately 258.20 m, so above this elevation the storage areas are combined.

The second natural storage area, Ponderosa 2, is located along Junction Creek behind the railway. Based on the LiDAR, there is approximately 212,000 m^3 of storage available between elevations 255.80 m and 258.00 m. Water from Ponderosa 2 flows through five (5) large concrete culverts beneath the railway to Ponderosa 3. The top of the railway through this area is approximately 258.00 m, so above this elevation the storage areas are combined.

The third natural storage area, Ponderosa 3, is located along Junction Creek northwest of the rail lines, south of the Nickeldale subdivision, and west of Notre Dame Avenue, within the main body of the Ponderosa. Based on the LiDAR information, there is approximately 2,090,000 m^3 of storage available between elevations 255.40 m and 258.40 m. Water from Ponderosa 3 is able to flow freely beneath the railway towards the Flour Mill and downtown Sudbury.

6.5.3 Maley Dam

The Maley Dam is a flood control structure located on the east branch of Junction Creek. The dam was built in 1971 and the primary function of the dam is to retain storm water and to provide control of water released into the CGS via the headwaters of Junction Creek. The dam is comprised of a central concrete control structure with earth fill embankments on either side (spanning between the concrete control structure and the abutments). The drainage area upstream of the dam is approximately 2,900 ha (29 km^2). The storage curve for the dam is shown in **Figure 6.5.1** below (storage capacity is the dark blue Amec 2017 line).

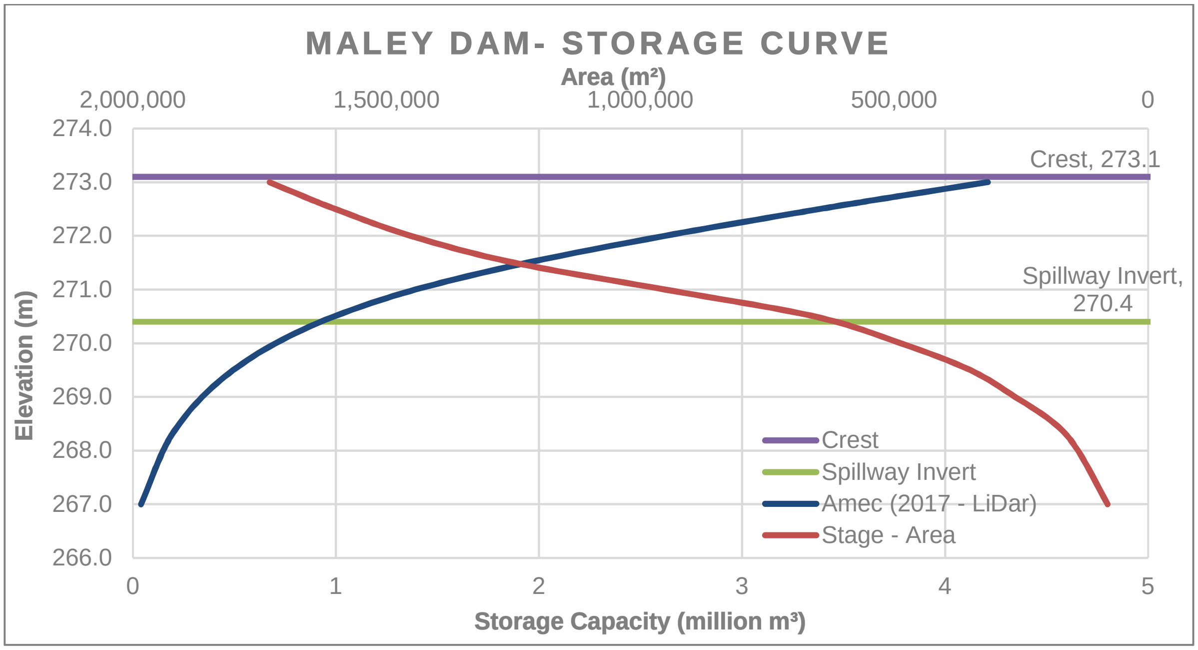


Figure 6.5.1: Maley Dam Storage Curve

A 1.8 m wide and 1.5 m high sluice gate, and a 0.36 m culvert, both at elevation 266.10 m, are the main outlets for the Maley Dam under frequent storm events. The Maley Dam spillway is comprised of a concrete ogee section surmounted by four bays affixed with steel weir gates. The crest of the steel weir gates is at elevation 271.6 m and the gates are designed to be sequentially opened as the water level rises from 271.9 m to 272.3 m. Above this water level all flow would be controlled by the concrete ogee section.

The maximum outflow of the Maley Dam is 11.927 m^3/s, based on the results of a 100-year storm event simulation. The peak storage elevation in the Maley Dam under the 100 year storm event is 269.09 m, which is below the elevation of the spillway, so only the sluice gate and culvert are active in the Maley Dam up to the 100 year storm event. An analysis of the potential to increase or optimize the storage of the Maley Dam, discussed in **Section 10.3.9** below.

6.5.4 Nickeldale Dam

The Nickeldale Dam is a flood control structure located on the west branch of Junction Creek, north of LaSalle Boulevard in Sudbury, Ontario. The dam was built in 1978 and 1979, officially opened in May of 1980, and provides flood protection for residences and businesses downstream. The dam is comprised of a central concrete control structure and two earth fill structures on either side. The drainage area is approximately 1051 ha (10.5 km^2). A photo of the dam is shown in **Figure 6.5.2**, and the storage curve for the dam is shown in **Figure 6.5.3** below (storage capacity is the dark blue Amec 2017 line).

Figure 6.5.2: Photo of Nickeldale Dam

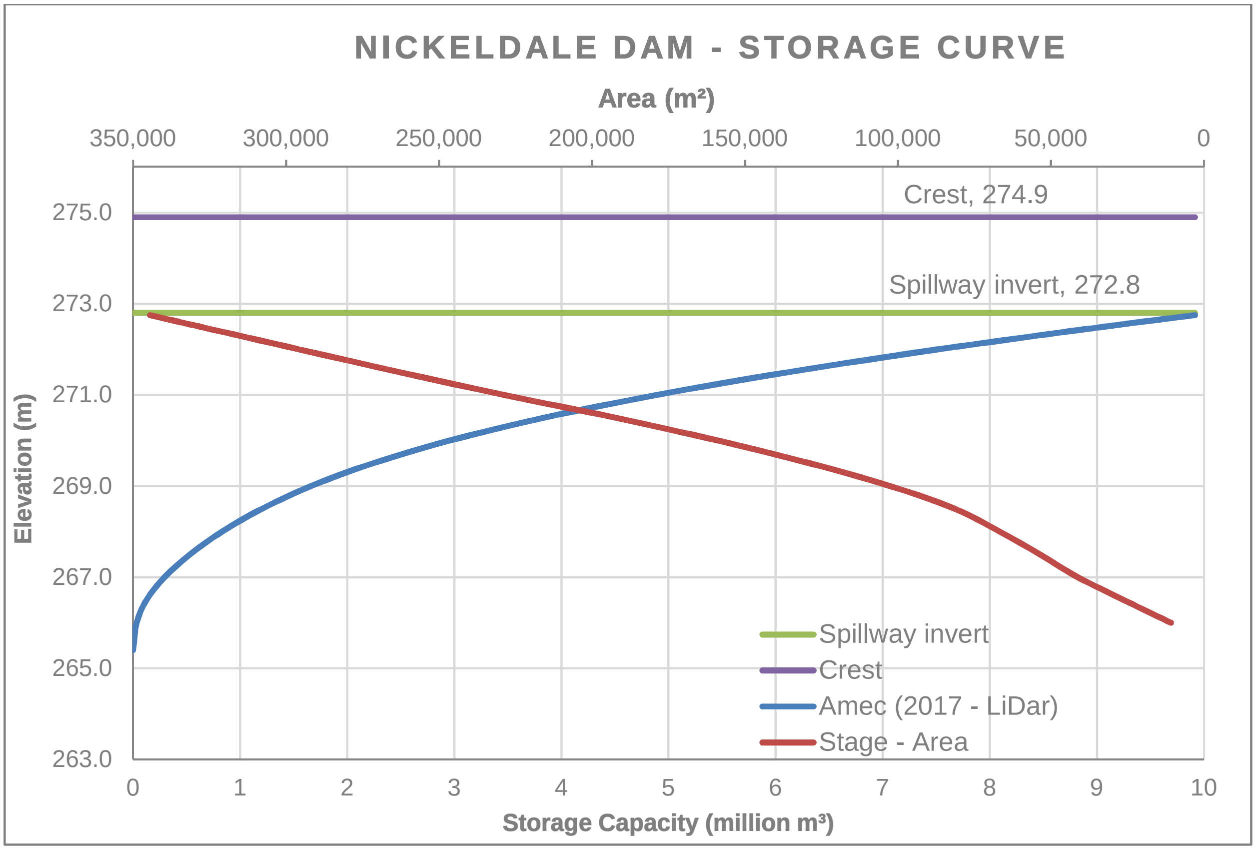


Figure 6.5.3: Nickeldale Dam Storage Curve

The main outlet of the Nickeldale Dam is modelled in PCSWMM as two pipe culverts, one 1.0 m diameter at elevation 265.40 m, and one 1.2 m in diameter at elevation 265.60 m. A 47 m long uncontrolled ogee shaped concrete overflow weir, located in the centre of the dam at elevation 273.20 m, serves as the flood control overflow structure.

The maximum outflow of the Nickeldale Dam is 8.581 m^3/s, based on the results of a 100-year storm event simulation. The peak storage elevation in the Nickeldale Dam under the 100 year storm event is 266.50 m, well below the elevation of the concrete overflow. There is likely some potential to increase or optimize the storage of the Nickeldale Dam, as discussed in **Section 10.3.9** below.

6.5.5 Kirkwood Dam

The Kirkwood Dam is located at the closed Kirkwood Mine site, currently owned by Vale, located in the CGS, just north of the community of Garson, Ontario. The dam is a Water Retention Pond Dam which controls the water level at the site using a concrete spillway. It is the only remaining water management infrastructure at the site. The maximum outflow at Kirkwood Dam is 0.27 m^3/s, based on the results of a 100-year storm event simulation. The storage curve for the dam is shown in **Figure 6.5.4** below.

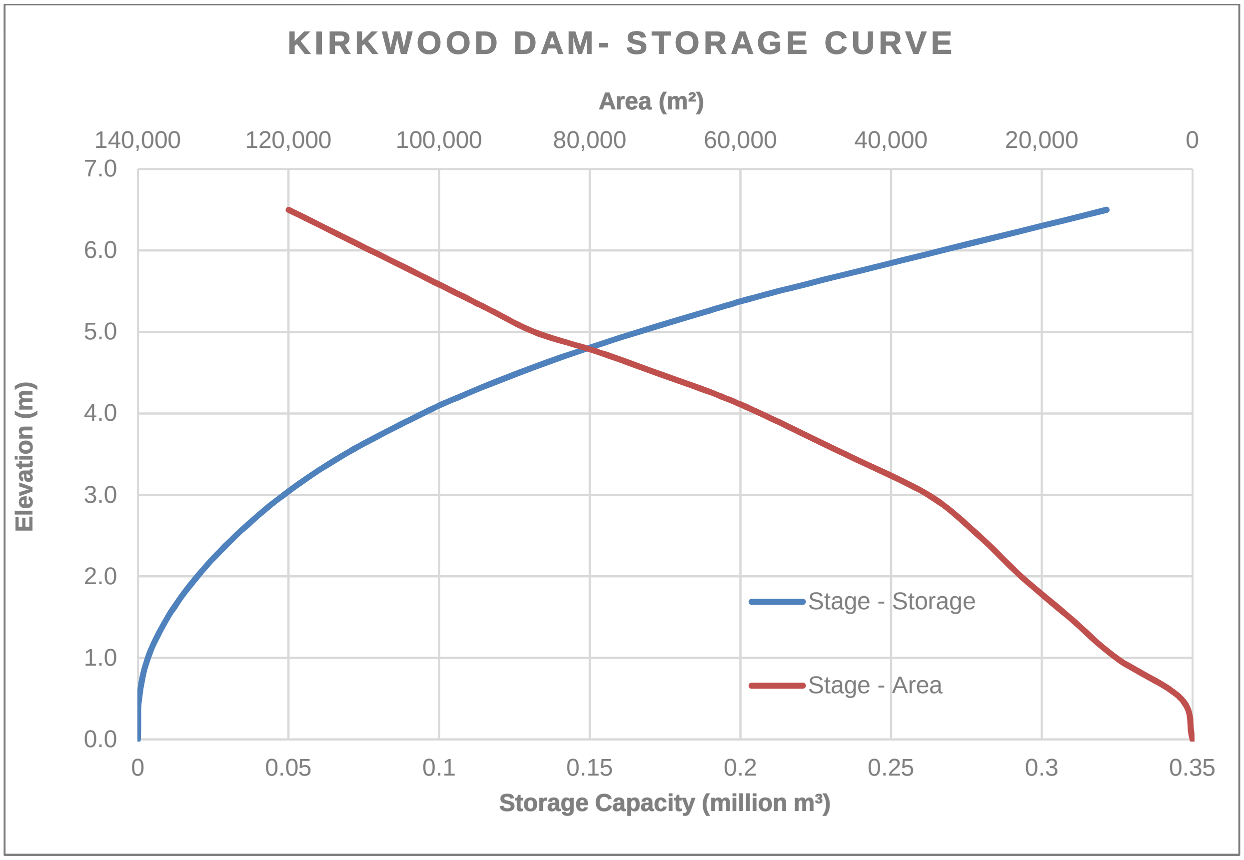


Figure 6.5.4: Kirkwood Dam Storage Curve

6.5.6 The Tailings Water Treatment Plant

Water from the mining areas within the Junction Creek subwatershed is treated at the Copper Cliff Water Treatment Plant (WTP). This storage unit receives runoff pumped from the Frood-Stobie complex, as well as runoff from the Central Tailings areas, which is treated and pumped back up to Meatbird Lake for storage.

Total storage capacity of the WTP has initially been modelled based on the total ponding area available within the central tailings facility, as estimated from the LiDAR data.

Daily outflow rates from the WTP are recorded by Vale and were used to create the hydrologic model. The average and maximum daily pumping rates were 133,955 m^3/d and 210,610 m^3/d, respectively. These daily rates were converted to 1.55 m^3/s and 2.44 m^3/s, and were applied as a rating curves at depths of 0.25 m and 0.50 m, respectively. The initial storage curve was based on the area of the Central Tailings Ponds, as measured from the received orthophotography, and the initial depths were arbitrarily selected, then iteratively adjusted through calibration, as discussed in **Section 6.6.2** below.

These initial assumptions regarding the WTP routing curves have been refined through calibration, as discussed below in **Section 6.6.2**.

6.6 Model Calibration and Validation

6.6.1 Data Sources & Calibration Events

Calibration of the existing conditions model has been completed to develop a suite of hydrologic input parameters which, when applied consistently for the selected events, best reproduces the observed runoff response for the associated storm. The intent of hydrologic model calibration has been to ensure the developed model generates realistic results, and thus can be relied upon for the simulation of more formative storm flows and analysis of impacts of differing scenarios and conditions.

Precipitation data within the Junction Creek subwatershed are available from Environment Canada weather stations in daily increments, as shown in **Table 6.6.1** below. In addition, the CGS records precipitation at the David Street Water Treatment Plant in 5 minute increments, and has done so since September 2012.

Table 6.6.1: Environment Canada Weather Stations

Station	Climate ID	WMO ID	Start Date	End Date	Latitude	Longitude
Sudbury A	6068150, 6068153	71730	Feb. 1954	N/A	46°37'32" N	80°47'52" W
Sudbury Climate	6068145	71733	Aug. 2011	N/A	46°37'56" N	80°47'46" W
Sudbury	6068148	N/A	Aug. 1914	Sept. 1977	46°29'00" N	80°59'00" W
Sudbury MOE	6068155	N/A	Oct. 1977	May 1979	46°28'00" N	81°02'00" W
Sudbury Science North	6068158	N/A	May 1986	Oct. 1996	46°28'00" N	81°00'00" W

Flow monitoring data within the subwatershed are available from Environment Canada hydrometric stations in daily increments, as shown in **Table 6.6.2** below.

Table 6.6.2: Environment Canada Hydrometric Stations

Station	ID	Drainage Area (km^2)	Start Date	End Date	Latitude	Longitude	Location
Junction Creek at Sudbury	02CF005	87.04	Mar. 1958	Jul. 2016	46°28'43.4¨ N	81°0'37.5¨ W	Upstream of McLeod St.
Nolin Creek at Sudbury	02CF009	21.5	Apr. 1959	Oct. 1994	46°29'51.0¨ N	81°0'25.0¨ W	Downstream of Beatty St. & Rail
Junction Creek below Kelly Lake	02CF012	198.8	Jan. 1977	Nov. 2016	46°25'38.3¨ N	81°5'54.4¨ W	Downstream of Fielding Rd.

Please note that station 02CF005 was changed to a water level only station on July 1, 2016 and no longer collects flow data, due to “poor hydrometric conditions” as noted on the Environment Canada website.

A summary of potential calibration events from the 2012-2016 period have been identified in **Table 6.6.3**, including the measured daily flow and rainfall statistics from nearby stations.

Table 6.6.3: Preliminary Potential Calibration Events

Event	Date	Rainfall (mm)			Measured Daily Flow *(m^3/s)*		Measured Peak Flow *(m^3/s)*	
		David St. WTP	Sudbury A	Sudbury Climate	02CF005	02CF012	02CF005	02CF012
Dec-15	12/13/2015	8.0	12	8.2	2.13	4.59	—	—
	12/14/2015	59.6	46	56.6	11.2	9.88		
	12/15/2015	6.2	11.7	5.2	16.5	24		
	12/16/2015	0.8	1.8	1.2	13.7	23		
	12/17/2015	1.8	0.7	1.6	9.88	18.4		
	12/18/2015	0.6	1.5	1.6	5.78	14.4		
Apr-14	4/13/2014	8.0	9.2	8.2	11.2	22.1	—	—
	4/14/2014	34.4	36.2	34.1	19.7	32.7		
	4/15/2014	1.6	3.6	0	18.3	35.4		
	4/16/2014	0.0	0	0	15.7	29.8		
	4/17/2014	1.2	0.2	0.4	12.2	25.2		
Apr-15	4/13/2015	6.2	8.8	6.4	13.3	20.6	—	—
	4/14/2015	0.0	0	0	13.1	21.8		
	4/15/2015	0.0	0	0	11.4	20.2		
Oct-14	10/13/2014	1.4	2.8	2.5	0.348	4.97	21.82	31.23
	10/14/2014	31.0	52.4	34.1	3.06	5.54		
	10/15/2014	24.8	19.4	16.4	10.9	14.2		
	10/16/2014	35.2	22	0	13.2	22.1		
	10/17/2014	10.8	12.6	10	12.8	30.3		
	10/18/2014	1.6	2.2	1.6	10.1	26.1		
Apr-13	4/18/2013	21.0	23.4	21.7	10.8	22.2	—	—
	4/19/2013	14.2	0	22.1	13.9	26.7		
	4/20/2013	1.0	0	1.3	13.5	27.4		
May-14	5/15/2014	43.4	35.2	32.5	7.71	11.4	14.44	18.83
	5/16/2014	0.0	0	0	9.31	18.3		
Nov-14	11/23/2014	1.6	3.6	2.1	2.59	5.34	9.83	16.46
	11/24/2014	23.8	23.4	22.1	6.92	8.76		
	11/25/2014	8.6	14.3	6.5	9.04	15		
	11/26/2014	0.4	0	0.2	7.11	15.1		
Aug-14	8/30/2014	63.0	62.7	60.8	2.51	4.45	9.28	14.88

Event	Date	Rainfall (mm)			Measured Daily Flow (m^3/s)		Measured Peak Flow (m^3/s)	
		David St. WTP	Sudbury A	Sudbury Climate	02CF005	02CF012	02CF005	02CF012
	8/31/2014	9.8	26.2	28.2	7.5	13.6		
	9/1/2014	3.0	4.1	4.1	5.68	13.3		
May-13	5/19/2013	4.0	4.4	5.1	0.917	3.86	8.51	13.55
	5/20/2013	26.8	24	23.3	1.61	4.2		
	5/21/2013	16.4	17.2	15.5	3.93	6.41		
	5/22/2013	10.2	6.2	3.7	4.25	9.1		
	5/23/2013	16.2	0	15.4	6.24	12		
	5/24/2013	0.0	0	0	5.85	12.7		
Oct-12	10/13/2012	0.0	6.2	3.3	0.868	1.49	—	—
	10/14/2012	0.0	33.8	33.5	2.76	2.62		
	10/15/2012	0.0	22.6	18.8	4.83	8.15		
	10/16/2012	0.0	0.4	0	2.84	10.4		
May-15	5/11/2015	29.2	14.8	23.3	2.61	4.77	9.75	10.89
	5/12/2015	5.0	5.2	4.4	5.64	9.08		
	5/13/2015	0.0	0	0	5.42	10.6		

Due to the fact that snow pack depth information was not readily available for calibration, events have been selected with a bias towards months that are snow-free in Sudbury. Some potential storm events have also been screened on the basis of differing rainfall characteristics between the presented rain gauge stations, as this suggests a spatially varied or localized storm which would not be well reproduced by modelling. Based on the storm data presented in **Table 6.6.3**, the following storm events have been identified for model calibration:

- October 2014
- May 2014
- August 2014
- May 2013
- May 2015

As precipitation data from the Environment Canada Weather Stations are only available in daily increments, data from only the CGS's David St. Water Treatment Plant has been utilized for calibration purposes. Rainfall measurements in millimeters, measured every 5 minutes from the David St. Water Treatment Plant, were used to create calibration rainfall events utilizing PCSWMM time series and rain gage functions.

In order to account for the Ramsey Lake subwatershed area (covered under a separate individual subwatershed study as described previously), the Ramsey Lake subwatershed PCSWMM model (received from the CGS) was run for each of the created calibration events. The outflow hydrograph of the Ramsey model for each calibration event was saved, and imported into PCSWMM to be used as an input flow to the upstream end of Lily Creek within the Junction Creek subwatershed model.

In addition to the publicly accessible daily flow data maintained by Environment Canada, historical flow data in 5 minute increments was requested and obtained from the Water Survey of Canada. This data allows for a detailed comparison of hydrograph peak, timing, and overall volume. The peak flow logged at each station from each selected event is also displayed in **Table 6.6.3**.

6.6.2 Hydrograph Calibration

Initial model runs indicate that modelled peak flows are consistently higher than observed values at hydrometric station 02CF005, as is typically the case for uncalibrated hydrologic models. However, initial model flows were also well below the observed values at hydrometric station 02CF012. A number of iterations were completed by varying the subcatchment parameter calculations and comparing the resultant hydrographs, graphed below in **Figures 6.6.1** to **6.6.10**.

After some initial adjustments, overall subcatchment imperviousness was reduced to 75% of its calculated value as described above, in order to bring modelled flows in the upper subwatershed more in line with measured values, plotted as Trial 7 on the hydrographs. In most cases, flows are higher than measured values, most notable at the upstream station 02CF005. One notable exception is that flows at the downstream station 02CF012 are vastly underestimated in the events of May 2014 and May 2015.

The initial model runs were completed using the imported hydraulic cross sections generated for the riverine floodplain analysis, discussed in **Section 7** below. In order to better approximate the behaviour of the large lakes and Ponderosa wetland, these areas were added as storage units, as described in **Section 6.5** above. The large conduit routing elements through the lakes and Ponderosa were simultaneously removed, in order to avoid double-counting the effect of these areas on the overall hydrology. The wide cross sections, or transects, used to build the conduits also had high routing error percentages in PCSWMM, and their removal lowers the overall error into a reasonable range. The addition of storage units to the model is plotted as Trial 8 on the hydrographs. Generally, this slightly increased the flows in the model, with the exception of station 02CF012 during the event of May 2015.

An additional trial (not plotted) was run with the overall imperviousness reduced to 50% of its initial calculated valued (down from 75%). This was seen to slightly decrease flows, but not substantially. This is likely because many pervious areas were initially assigned a curve number of 98, which effectively makes them impervious already.

In order to bring the modelled flows more in line with measured values, lower curve numbers were assigned to the various subcatchment land uses. These lowered SCS Curve Numbers are shown in **Table 6.3.4** below.

Table 6.6.4: Lowered Hydrologic Parameters

Land Classification		Assigned SCS Curve Number	Assigned Imperviousness
Description	Number		
Water	1	98	100%
Settlement / Infrastructure	3	Impervious - 98 Pervious - 72	35%
Sand / Gravel / Mine Tailings	4	89	0%
Bedrock	5	89	0%
Forest Depletion - Cuts	7	72	0%
Forest - Sparse	10	72	0%
Forest - Dense Deciduous	11	72	0%
Forest - Dense Mized	12	72	0%
Forest - Dense Coniferous	13	72	0%
Bog - Open	22	72	0%
Bog - Treed	23	72	0%

After lowering the assigned SCS Curve Numbers, the overall subcatchment imperviousness was lowered by 90%. The models were run both with the lakes and Ponderosa modelled as hydraulic conduits, and with those areas modelled as storage units, and these are shown on the hydrographs as Trials 6 and 9, respectively. As expected, Trial 6 generally follows the pattern of Trial 7 but is somewhat reduced, and Trial 9 generally follows the pattern of Trial 8, but it somewhat reduced. The modelled and measured hydrographs agree particularly well at station 02CF005 for the events of May 2014 and May 2013.

As discussed, there is a notable relative imbalance in the modelled and measured flows between stations 02CF005 and 02CF012. The modelled flows are much higher relative to the measured flows at station 02CF005 than at station 02CF012. In other words, when the hydrographs match well at station 02CF005, they are underestimated at station 02CF012, and when they match well at station 02CF012, they are over-estimated at station 02CF005. This points to an indication that there may be an issue with the drainage area between these stations, which is very large and contains Kelly Lake, which receives all of the inflow from Ramsey Lake and Lily Creek, as well as from the Central Tailings area.

In order to attempt to correct this issue, the rating curve for the tailings area water treatment plant, discussed in **Section 6.5.6** above, was altered. The modelled total inflow received by the water treatment plant under an SCS Type II 25 mm event design storm event is approximately 25.6 ML, or 25,600 m^3. The recorded maximum daily flow from the water treatment plant is 210,610 m^3/d, or 2.438 m^3/s. The storage and rating curves for the water treatment plant were therefore created such that there is a peak outflow of 6.094 m^3/s (applying a peaking factor of 2.5) at a storage volume of 25,600 m^3. This represents a substantial increase over the previous rating curve. This is plotted in the hydrographs as Trial 10. As anticipated, this has a significant effect on modelled flows at station 02CF012, and generally improves the agreement between modelled and measured hydrographs across all events.

Note that there is still a large difference between modelled and measured hydrographs at one of the two stations during some calibration events. This may be due to a variety of factors, but given the size of the Junction Creek subwatershed it is possible that rain events are spatially varied enough that the modelled precipitation events do not accurately predict runoff in all cases. The calibrated model (Trial 10) represents a compromise between the various events and stations. In general, the most severe flooding issues, and most of the settled area of the subwatershed, are upstream of station 02CF005, and the calibrated model appears to provide a conservative estimation of flow from that area.

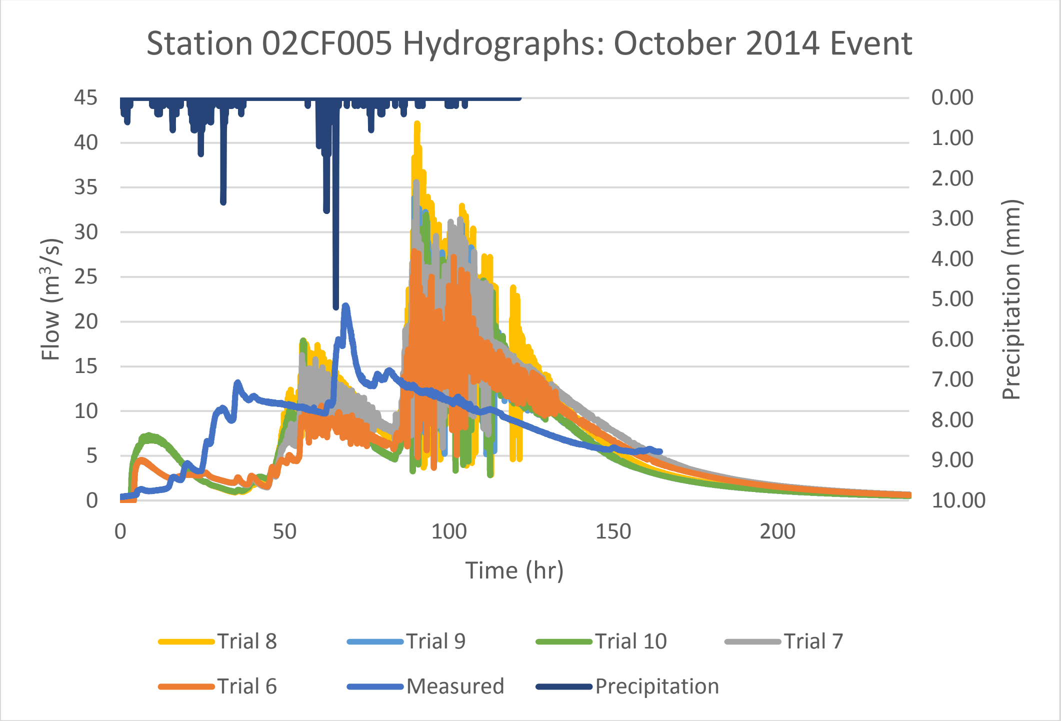


Figure 6.6.1: Station 02CF005 October 2014 Event Hydrographs

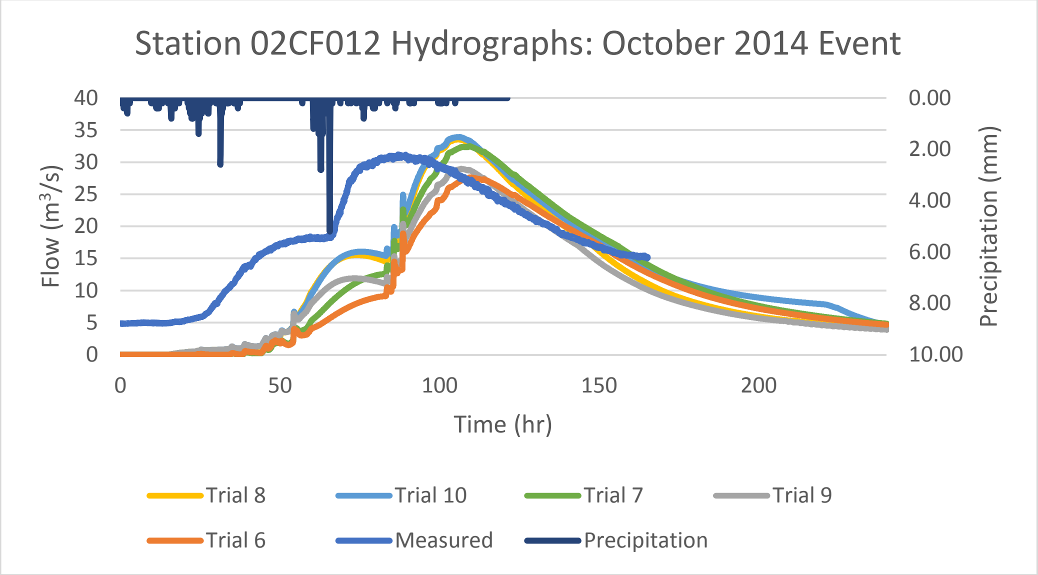


Figure 6.6.2: Station 02CF012 October 2014 Event Hydrographs

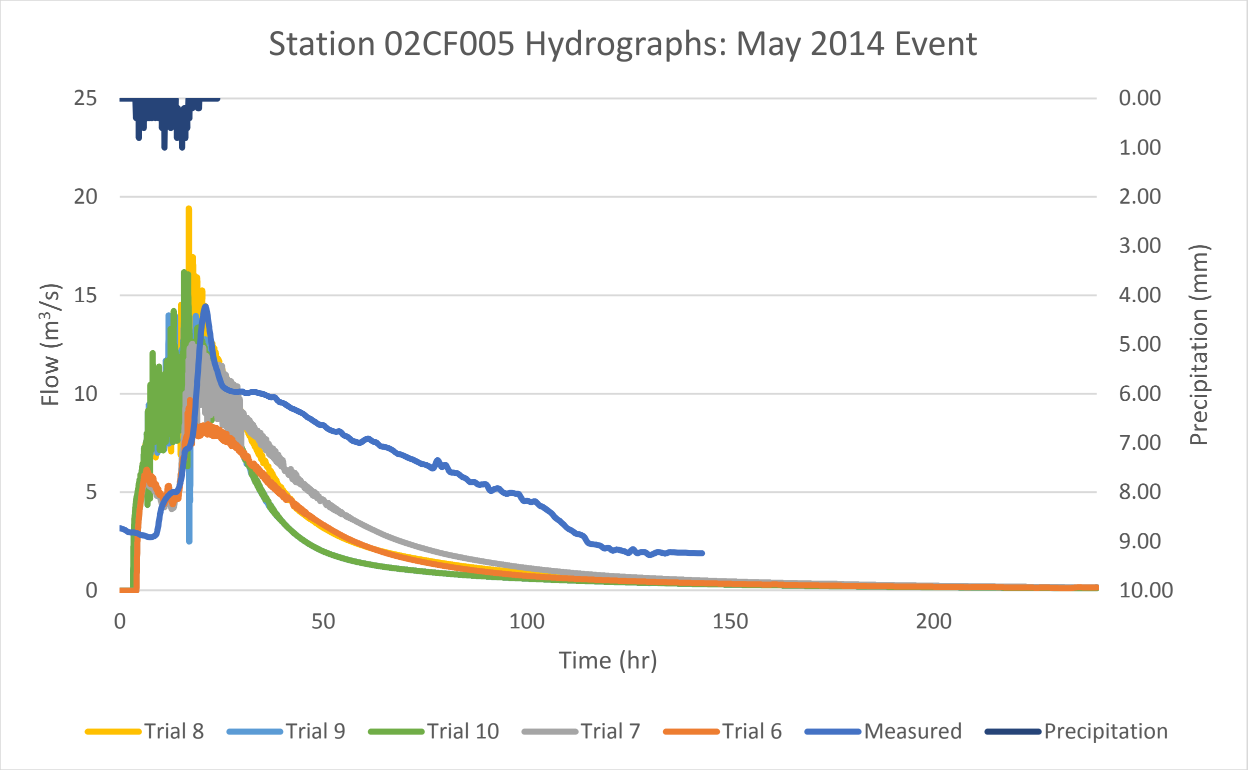


Figure 6.6.3: **Station 02CF005 May 2014 Event Hydrographs**

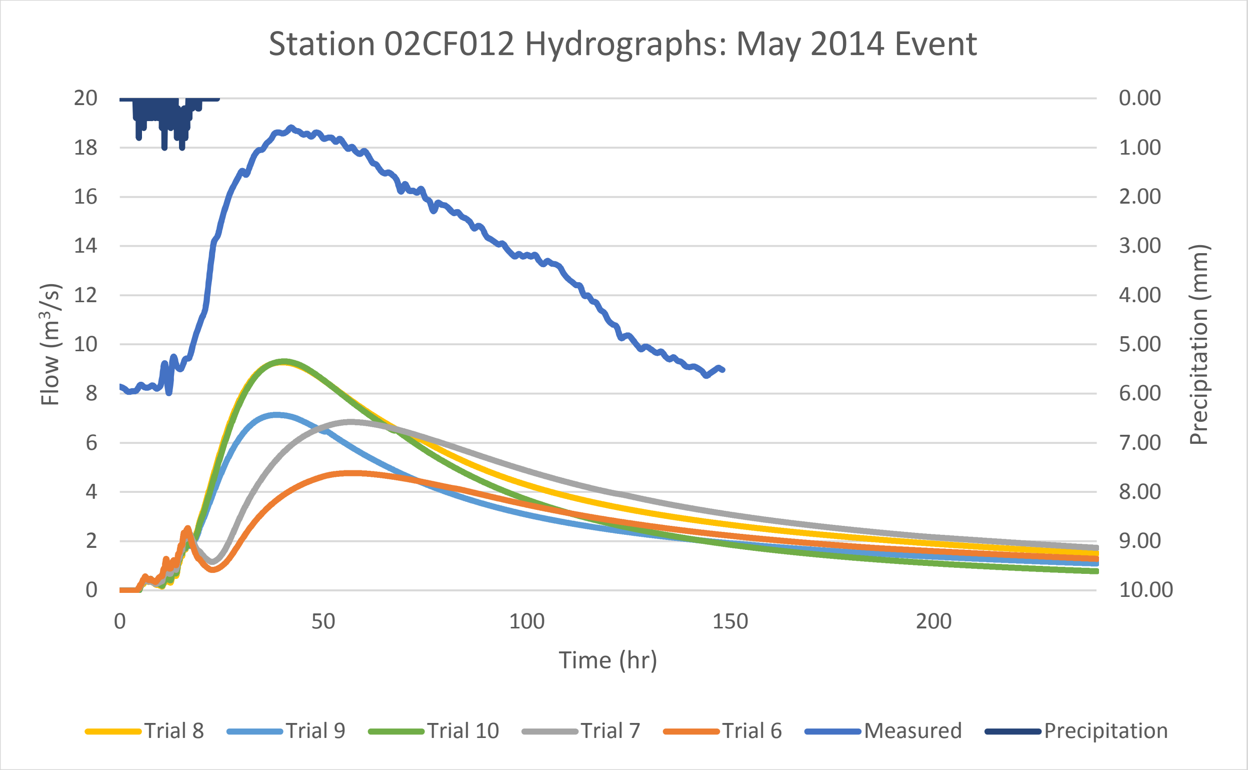


Figure 6.6.4: **Station 02CF012 May 2014 Event Hydrographs**

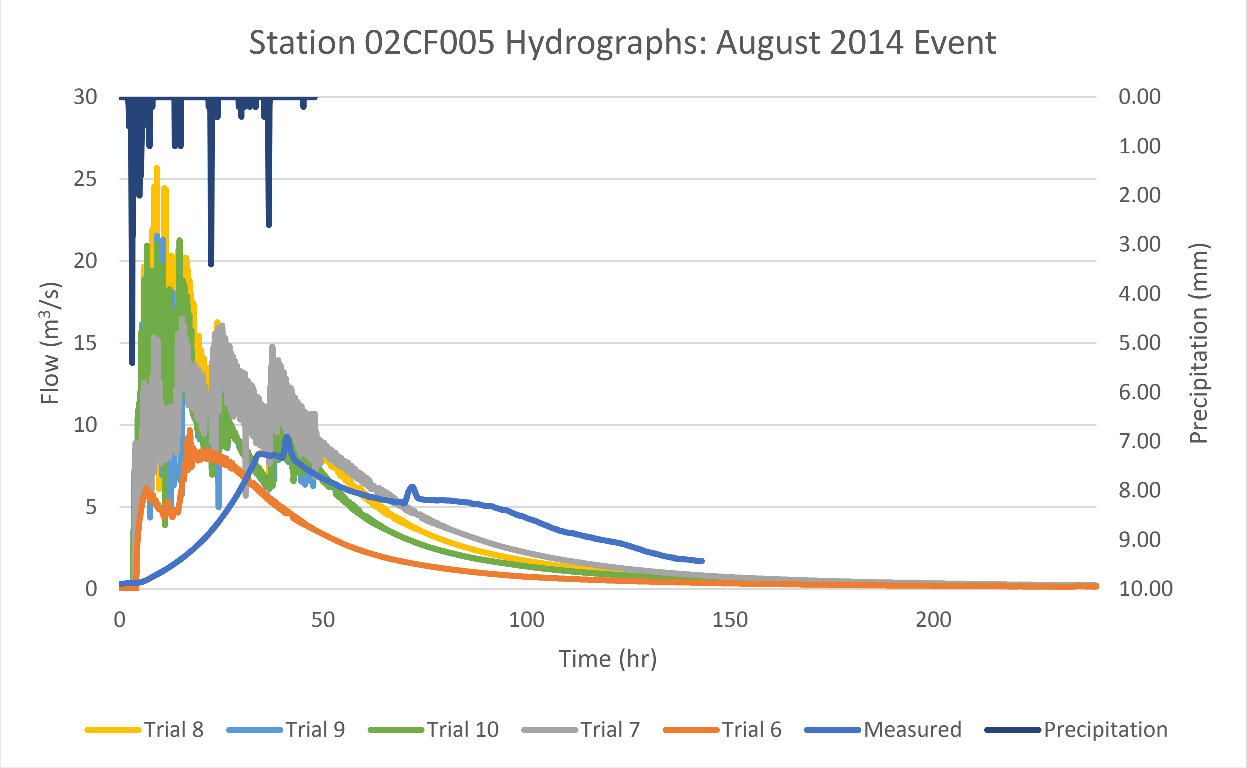


Figure 6.6.5: Station 02CF005 August 2014 Event Hydrographs

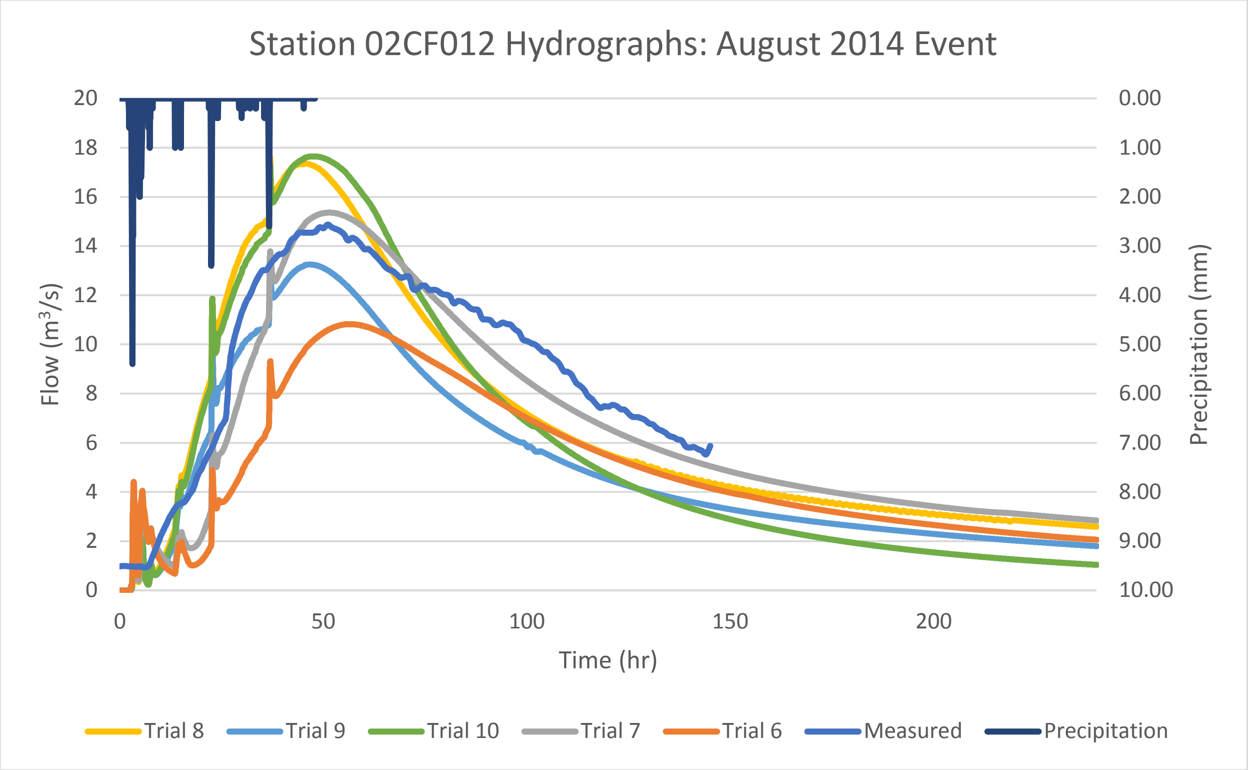


Figure 6.6.6: Station 02CF012 August 2014 Event Hydrographs

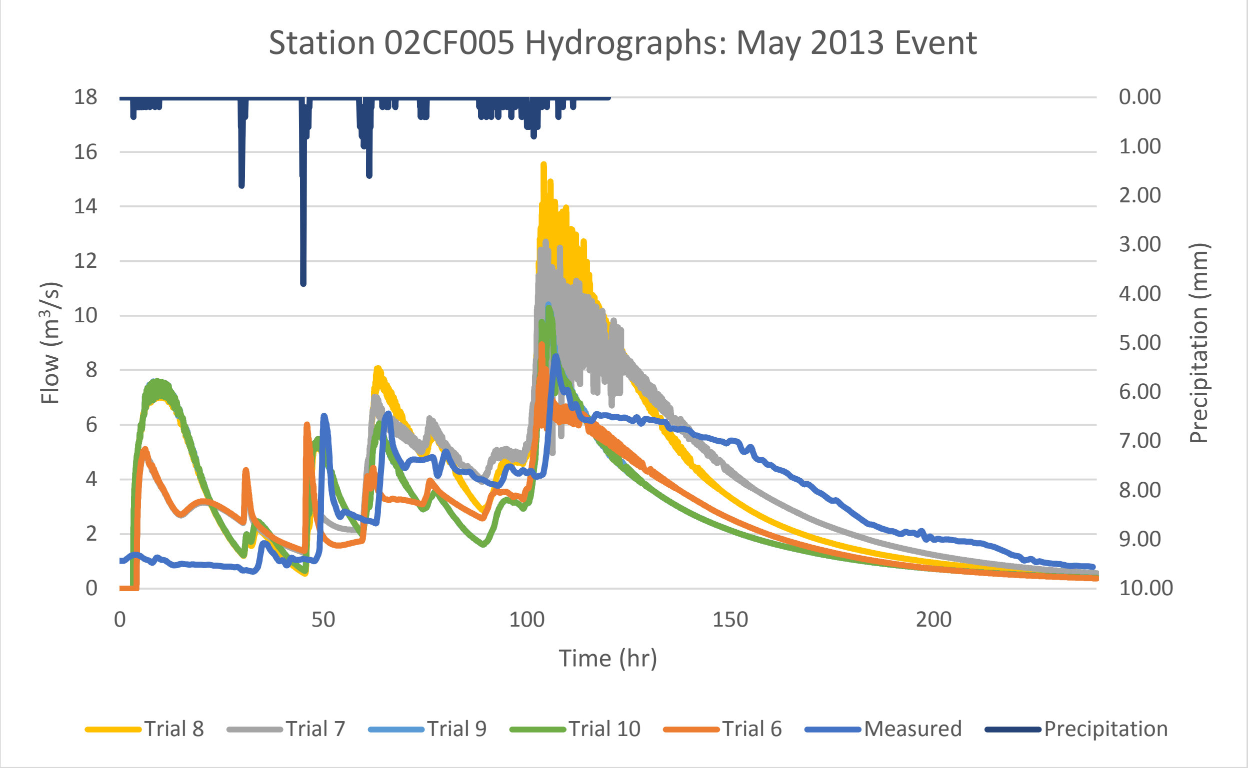


Figure 6.6.7: Station 02CF005 May 2013 Event Hydrographs

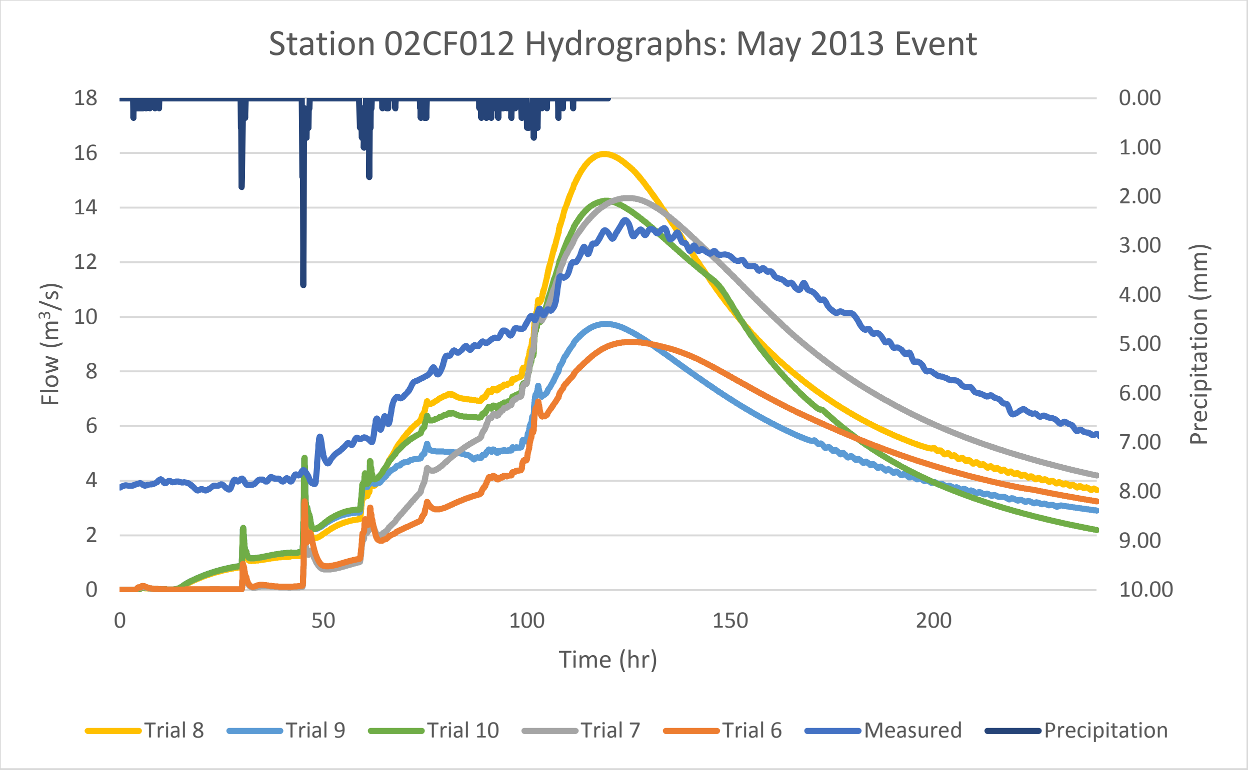


Figure 6.6.8: Station 02CF012 May 2013 Event Hydrographs

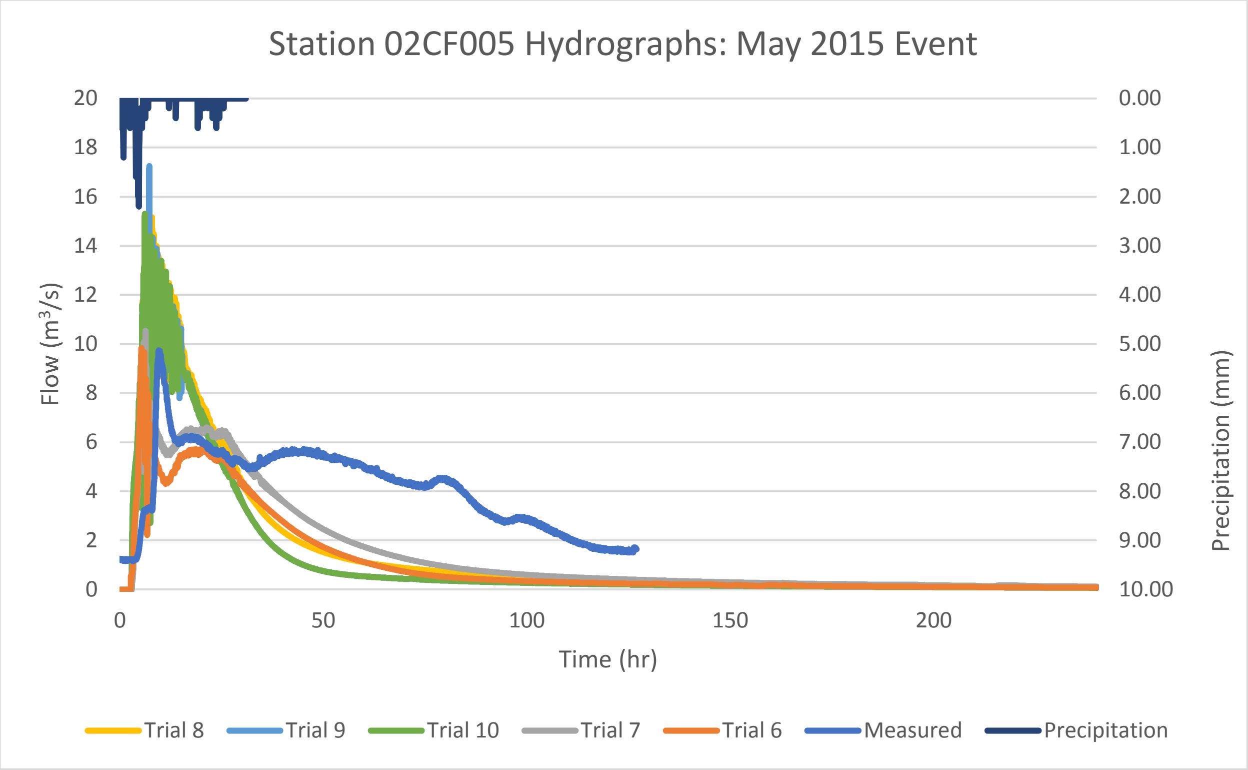


Figure 6.6.9: Station 02CF005 May 2015 Event Hydrographs

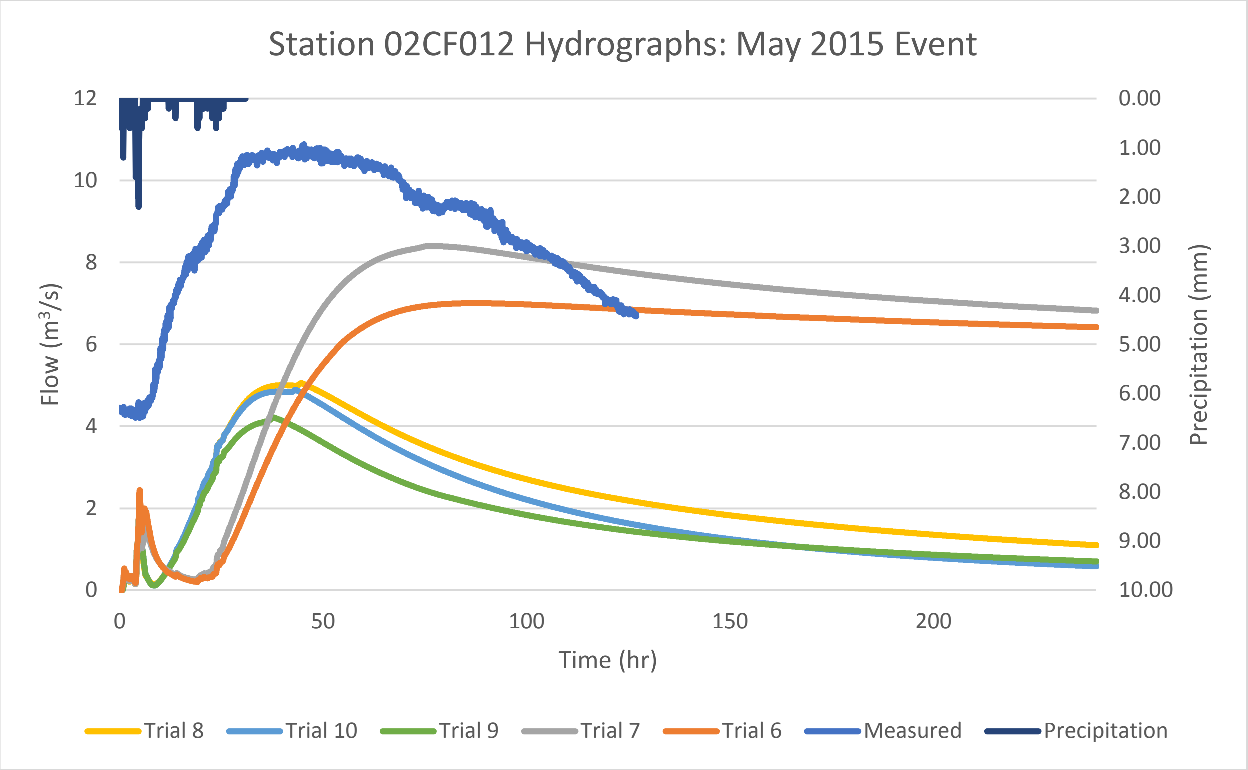


Figure 6.6.10: Station 02CF012 May 2015 Event Hydrographs

6.7 Existing Conditions Analysis

The calibrated existing conditions model has been used to simulate both frequency flows (2 through 100 year return periods, for the 6 hour Chicago design storm and 24 hour SCS Type II storm), as well as the Regional (Timmins) Storm Event, using the storm methodology described in **Section 3.3.4**. The Ramsey Lake subwatershed outlet hydrograph for each event is included as an inflow to the model at the upstream end of Lily Creek. Modelled peak flow results for key nodes of interest are summarized in **Table 6.7.1** below. Runoff results are summarized by subcatchment in **Table 6.7.2**. Refer to **Figure C1** in **Appendix C** for the overall subwatershed drainage areas.

Based on the simulated results, the Regional (Timmins) Storm Event is the Regulatory Storm for all locations except the upstream-most end of Junction, Lily, and Fly Creeks. It is worth noting that, for regulation and enforcement purposes, this Subwatershed Study does not update the existing regulatory floodplain delineation maintained by the CS. The update of the Regulatory floodplain boundary is completed through a separate process, which will build on the initial work completed through this study.

The existing conditions flows presented in **Tables 6.7.1** and **6.7.2** will serve as a basis of comparison for the assessment of stormwater master plan alternatives, discussed in **Sections 8.2.5 and 10.3** below.

Table 6.7.1: Existing Conditions Summary

Location	Simulated Peak Flow (m^3/s)												
	2 Year		5 Year		10 Year		25 Year		50 Year		100 Year		Reg.
	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Tim.
Birch Street	4.7	5.8	6.7	7.9	8.0	9.4	9.4	11.5	11.3	13.1	12.9	14.7	9.8
O'Neil Drive West	3.5	4.5	5.8	6.9	7.2	8.3	8.5	10.1	10.1	11.4	11.5	12.9	17.0
Railway	9.4	11.6	13.3	15.6	15.8	18.4	18.6	22.3	22.3	25.4	25.3	28.7	29.9
Maley Dam Outlet	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	16.1
Twin Forks	13.5	15.5	18.2	19.2	20.9	22.4	23.7	25.1	28.5	27.8	31.0	30.5	49.7
Supermall	11.3	14.8	16.2	19.2	19.5	22.8	23.0	27.5	27.6	31.2	31.4	35.0	65.0
Northeast of Ponderosa	10.8	13.3	14.0	16.7	16.4	19.0	19.6	22.4	24.8	25.3	29.3	29.6	240.0
Southeast of Ponderosa	11.1	19.8	16.4	25.8	20.0	30.0	24.2	35.4	29.4	39.7	33.5	44.0	319.1
Nickeldale Dam Outlet	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.7	17.6	18.2	17.6	21.0
Ponderosa Junction	31.5	28.5	39.6	35.9	43.4	40.3	47.4	45.4	52.3	49.7	56.1	53.6	141.1
Downstream of Ponderosa	12.2	12.5	14.3	14.5	15.9	15.7	17.9	18.7	20.7	21.4	23.1	24.1	62.5
Box Culvert Inlet	11.4	13.9	13.5	16.3	15.0	18.1	17.2	20.3	20.6	22.5	23.5	25.3	55.5
Nolin Box Culvert	4.4	6.0	7.1	9.3	9.0	11.8	11.2	15.7	14.6	18.8	17.4	22.2	65.8

Location	Simulated Peak Flow (m^3/s)												
	2 Year		5 Year		10 Year		25 Year		50 Year		100 Year		Reg. Tim.
	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	
Box Culvert Outlet	12.1	17.9	15.9	21.5	18.6	24.3	22.7	29.9	28.7	34.5	34.1	39.5	107.5
McLeod St. / Sta. 02CF005	19.1	22.0	25.7	30.0	29.9	39.7	38.5	52.3	49.1	60.5	60.1	70.4	125.6
Tailings Water Treatment Plant	1.5	5.3	4.5	10.6	6.9	14.8	10.5	20.8	16.0	25.6	21.3	30.7	113.1
Upstream Kelly Lake	14.8	28.3	21.4	35.7	25.9	40.7	30.8	47.1	38.5	51.0	45.7	56.3	132.6
Ramsey Outflow	1.1	0.8	1.6	2.5	2.1	3.4	2.7	4.5	2.7	6.2	4.3	7.7	11.3
Robinson Lake	9.8	13.5	16.3	20.8	20.7	26.2	25.9	33.9	34.2	40.8	40.8	47.3	45.5
Kelly Lake	57.5	79.1	84.5	102.4	102.5	120.0	120.6	145.3	144.2	166.1	164.7	187.1	262.6
Fielding Road / Sta. 02CF012	4.6	11.8	8.7	20.2	13.3	26.1	17.7	35.2	23.7	42.7	30.3	51.7	135.2
Fly Creek	24.3	30.9	40.0	45.3	49.8	55.4	61.3	69.1	76.2	79.6	88.7	90.7	83.9
Fly Junction	24.5	31.2	40.2	45.4	49.9	55.2	61.3	68.9	76.3	79.0	88.6	90.0	203.6
Mud Lake	16.3	24.7	27.5	42.6	36.4	59.5	48.4	82.4	65.6	101.0	80.8	118.8	258.4
Into Simon Lake	1.5	12.0	6.1	22.1	10.3	29.6	16.7	41.8	26.5	51.4	35.6	64.0	244.5

Table 6.7.2: Existing Conditions Subcatchment Runoff Results Summary

Subcatchment	Area (ha)	Imp. (%)	Runoff Results													
			Timmins		100yr		50yr		25yr		10yr		5yr		2yr	
			Depth (mm)	Peak (m^3/s)	Depth (mm)	Peak (m^3/s)	Depth (mm)	Peak (m^3/s)	Depth (mm)	Peak (m^3/s)	Depth (mm)	Peak (m^3/s)	Depth (mm)	Peak (m^3/s)	Depth (mm)	Peak (m^3/s)
COP-0	387.62	14.57	144.14	18.57	66.16	24.31	57.59	21.56	49.15	18.92	37.96	15.52	29.53	13.02	17.54	9.50
COP-1	428.37	9.86	445.33	47.95	201.78	24.34	175.36	21.31	149.31	18.44	114.63	14.81	88.40	12.20	50.81	8.63
COP-2	406.09	6.07	147.36	13.84	65.99	11.61	57.27	10.22	48.68	8.90	37.25	7.21	28.62	5.99	16.31	4.29
COP-3	138.50	6.09	1526.23	51.62	689.97	14.53	599.52	11.90	510.30	9.49	391.53	6.65	301.68	4.81	172.98	2.81
COP-4	1057.06	0.48	713.28	113.07	302.03	30.73	259.62	25.56	218.14	20.81	163.67	14.81	123.26	10.59	67.30	5.25
FROOD-1	483.08	2.80	149.48	21.87	68.09	10.97	59.26	9.22	50.53	7.61	38.88	5.67	30.02	4.36	17.23	2.74
JC-1a	81.05	20.86	142.31	5.41	65.40	7.45	57.11	6.58	48.98	5.74	38.22	4.69	30.13	3.92	18.58	2.86
JC-1b	56.62	31.50	137.32	4.40	63.47	7.30	55.68	6.48	48.06	5.71	38.01	4.72	30.49	3.99	19.76	2.98
JC-2	196.20	23.42	129.12	11.33	57.86	18.24	50.21	16.28	42.76	14.40	33.02	11.97	25.80	10.16	15.78	7.58
JC-3	240.24	28.83	135.07	18.09	61.77	28.67	54.04	25.43	46.49	22.34	36.56	18.41	29.14	15.55	18.60	11.59
JC-4	114.62	31.12	134.50	7.59	62.06	13.75	54.30	12.32	46.73	10.94	36.78	9.13	29.36	7.77	18.91	5.80
JC-5	210.18	20.71	123.70	9.86	54.63	16.75	47.09	15.01	39.78	13.32	30.29	11.10	23.34	9.44	13.88	7.04
JC-6	415.04	20.74	137.81	22.97	62.80	35.04	54.63	31.22	46.63	27.54	36.08	22.77	28.20	19.24	17.11	14.21
JC-7	261.82	30.85	132.25	15.65	60.92	30.07	53.20	27.01	45.68	24.01	35.82	20.05	28.51	17.05	18.32	12.66
JC-8a	116.01	29.60	129.11	6.27	59.12	12.43	51.47	11.16	44.04	9.92	34.34	8.27	27.19	7.02	17.36	5.18
JC-8b	148.35	24.60	131.52	9.51	59.29	14.81	51.59	13.18	44.08	11.62	34.24	9.62	26.92	8.15	16.66	6.07
JC-9a	150.72	18.91	117.74	5.15	51.61	9.96	44.09	8.93	36.86	7.92	27.58	6.57	20.92	5.55	12.26	4.05
JC-9b	76.37	15.88	127.50	3.66	55.98	5.03	48.21	4.46	40.64	3.92	30.77	3.24	23.48	2.73	13.45	2.02
JC-10	129.61	19.03	133.37	7.26	59.78	10.30	51.82	9.14	44.06	8.03	33.86	6.61	26.27	5.58	15.66	4.12
JC-11	169.25	26.60	130.61	9.66	59.30	17.23	51.59	15.45	44.08	13.71	34.26	11.44	26.98	9.73	16.86	7.25
JC-12a	119.38	29.00	137.36	8.47	63.28	13.98	55.38	12.45	47.66	10.99	37.49	9.11	29.88	7.72	19.07	5.75
JC-12b	38.57	12.50	152.47	3.08	71.36	3.26	62.63	2.78	54.01	2.33	42.49	1.78	33.72	1.40	20.96	0.91
JC-13	119.43	18.22	131.78	6.19	58.81	8.95	50.88	7.95	43.15	7.00	33.01	5.78	25.49	4.89	15.02	3.62
JC-14	443.30	29.82	132.74	27.86	60.92	50.64	53.20	45.41	45.68	40.32	35.81	33.66	28.47	28.65	18.19	21.38
JC-15	185.63	16.63	135.02	8.43	60.81	12.52	52.62	11.15	44.61	9.84	34.09	8.14	26.26	6.88	15.35	5.07
JC-16	137.34	7.35	143.35	6.65	64.89	5.39	56.29	4.67	47.81	3.99	36.57	3.16	28.10	2.57	16.03	1.79
JC-17	147.53	17.94	130.98	8.30	58.14	11.23	50.31	9.93	42.67	8.70	32.65	7.14	25.22	6.01	14.86	4.44
JC-18	763.05	53.24	154.73	66.81	76.96	144.87	68.60	130.10	60.35	115.58	49.36	96.27	41.00	81.56	28.82	59.91
JC-19	107.64	4.16	148.72	5.87	68.33	3.81	59.56	3.19	50.89	2.62	39.33	1.93	30.55	1.47	17.86	0.91
JC-20	726.04	4.37	162.15	26.84	70.94	16.10	61.12	14.03	51.46	12.10	38.70	9.67	29.13	7.95	15.68	5.63
JC-21	353.97	5.10	131.58	14.31	57.21	9.42	48.97	8.14	40.92	6.95	30.36	5.48	22.53	4.47	11.73	3.14
JC-22	405.25	13.34	120.04	13.42	51.87	20.70	44.16	18.53	36.72	16.43	27.11	13.67	20.17	11.59	11.01	8.57
JC-23	275.49	18.67	120.17	10.69	52.61	19.20	45.09	17.22	37.83	15.30	28.45	12.76	21.65	10.83	12.61	8.02
JC-24	311.62	18.67	128.39	18.33	56.61	24.71	48.96	21.83	41.50	19.11	31.76	15.66	24.54	13.18	14.48	9.76
JC-25	656.39	0.61	111.45	15.57	43.64	3.52	36.18	2.79	29.02	2.22	19.89	1.58	13.43	1.17	5.31	0.72
JC-26	429.13	3.60	98.58	11.13	38.66	6.81	31.79	5.97	25.28	5.18	17.13	4.21	11.50	3.52	4.71	2.60
JC-27	99.97	0.28	110.54	5.00	43.36	1.88	36.34	1.42	29.58	1.03	20.87	0.61	14.55	0.37	6.07	0.13
JC-28	246.93	6.92	115.06	11.49	47.30	8.62	40.05	7.38	33.04	6.26	23.99	4.92	17.41	4.01	8.58	2.88
JC-29	207.07	24.68	129.55	11.79	58.36	19.93	50.69	17.83	43.21	15.81	33.44	13.17	26.21	11.19	16.17	8.35
JC-30	695.30	23.60	124.81	35.00	55.68	62.36	48.16	55.93	40.87	49.69	31.39	41.49	24.42	35.31	14.91	26.32

Subcatchment	**Area**	**Imp.**	**Runoff Results**													
	(ha)	*(%)*	**Timmins**		**100yr**		**50yr**		**25yr**		**10yr**		**5yr**		**2yr**	
			Depth	**Peak**	**Depth**	**Peak**	**Depth**	**Peak**	**Depth**	**Peak**	**Depth**	**Peak**	**Depth**	**Peak**	**Depth**	**Peak**
			(mm)	*(m^3/s)*	*(mm)*	*(m^3/s)*	*(mm)*	*(m^3/s)*	*(mm)*	*(m^3/s)*	*(mm)*	*(m^3/s)*	*(mm)*	*(m^3/s)*	*(mm)*	*(m^3/s)*
JC-31	1310.76	16.11	181.05	80.17	78.60	95.94	67.31	85.35	56.39	75.19	42.26	62.08	31.96	52.40	18.06	38.61
LIV-1	2398.33	2.85	146.44	142.67	66.65	89.80	57.99	73.30	49.45	58.30	38.08	40.55	29.46	29.01	17.04	15.72
MAL-1	425.76	8.69	95.20	8.15	37.62	13.47	31.04	12.09	24.85	10.74	17.21	8.95	12.04	7.59	6.06	5.60
MAL-2	963.84	4.05	117.87	28.29	48.69	18.19	40.95	15.89	33.46	13.74	23.82	11.06	16.87	9.18	7.81	6.64
MAL-3	939.60	7.84	108.37	23.04	44.17	28.66	36.90	25.63	29.94	22.71	21.12	18.88	14.93	16.02	7.26	11.88
MAL-4	793.78	6.29	361.44	51.74	141.64	23.41	117.15	20.78	93.76	18.27	64.20	15.04	43.52	12.67	18.02	9.29
NEP-1	651.82	10.11	106.25	15.16	43.53	24.43	36.40	21.91	29.60	19.45	21.03	16.20	15.05	13.74	7.72	10.14
NIC-1	827.25	39.44	137.80	52.55	65.54	109.97	57.65	98.57	49.94	87.37	39.80	72.45	32.26	61.09	21.69	44.41
NOL-1	1042.34	5.45	114.04	32.55	47.29	25.11	39.73	22.07	32.45	19.22	23.11	15.63	16.40	13.07	7.72	9.58
NOL-2	877.42	1.67	141.19	27.10	61.21	10.53	52.67	8.89	44.27	7.39	33.17	5.58	24.86	4.35	13.20	2.82
NOL-3	305.79	2.08	133.16	7.43	55.20	3.43	47.03	2.97	39.06	2.54	28.65	2.00	20.99	1.63	10.57	1.14
ROB-1	139.98	24.23	127.71	6.84	57.51	12.64	49.81	11.34	42.32	10.07	32.57	8.40	25.39	7.13	15.58	5.28
ROB-2	217.55	31.55	135.56	15.06	62.66	26.78	54.89	23.97	47.29	21.25	37.30	17.71	29.83	15.06	19.27	11.26
ROB-3	296.95	29.99	137.23	16.03	63.89	31.37	55.79	28.11	47.87	24.92	37.48	20.67	29.75	17.44	18.97	12.72
ROB-4	204.01	29.99	134.23	10.54	62.23	20.98	54.25	18.79	46.46	16.64	36.27	13.79	28.73	11.62	18.33	8.44
ROB-5	251.46	28.21	409.15	44.30	189.03	53.97	165.05	47.52	141.65	41.34	110.95	33.36	88.13	27.51	56.17	19.34
TAIL-1	584.44	9.00	135.68	21.55	59.64	22.60	51.29	20.02	43.11	17.56	32.35	14.40	24.35	12.09	13.27	8.83
TAIL-2	886.23	27.62	237.51	42.21	105.24	63.51	91.42	56.08	77.88	48.86	60.08	39.43	46.85	32.41	28.45	22.44
TAIL-3	1046.01	13.52	340.50	54.60	147.48	59.42	127.65	52.80	108.26	46.37	82.83	37.92	63.96	31.60	37.79	22.50
WHITE-1	1473.98	26.21	113.75	56.75	51.04	112.04	43.87	99.84	37.01	87.89	28.30	72.05	22.14	60.08	14.25	42.71
WHITE-2	1426.88	31.61	234.80	93.23	105.88	155.01	91.16	137.57	77.02	120.57	58.91	98.20	45.92	81.42	28.76	57.30

6.8 Future Conditions Analysis

The future growth areas discussed in **Section 5.2** above were mapped along with the hydrologic subcatchments, and ArcGIS software was used to derive the total projected future development within each subcatchment area. The overall subcatchment imperviousness was then adjusted based on the values in **Table 5.2.1**, and the resulting projected future imperviousness for each subcatchment is shown in **Table 6.8.1** below.

Table 6.8.1: Future Development by Subcatchment

Sub-catchment	Existing Area Imp.		Future Development							Future Area Imp.	
			Ind. Area	Comm. Area	Inst. Area	Res. Area	Total Future Area	Impervious			
	(ha)	(%)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(%)	(ha)	(%)
COP-0	387.62	14.57	0.00	0.00	0.00	0.00	0.00	0.00	N/A	387.62	14.57
COP-1	428.37	9.86	0.00	0.00	0.00	0.00	0.00	0.00	N/A	428.37	9.86
COP-2	406.09	6.07	0.00	0.00	0.00	0.00	0.00	0.00	N/A	406.09	6.07
COP-3	138.50	6.09	0.00	0.00	0.00	0.00	0.00	0.00	N/A	138.50	6.09
COP-4	1057.06	0.48	15.74	0.16	0.00	1.05	16.95	15.84	93.47	1057.06	1.97
FROOD-1	483.08	2.80	0.00	0.00	0.00	0.00	0.00	0.00	N/A	483.08	2.80
JC-1a	81.05	20.86	0.00	0.00	0.00	0.00	0.00	0.00	N/A	81.05	20.86
JC-1b	56.62	31.50	0.00	0.23	0.08	2.47	2.77	1.64	59.02	56.62	32.85
JC-2	196.20	23.42	0.00	0.43	0.00	3.71	4.14	2.45	59.26	196.20	24.18
JC-3	240.24	28.83	7.30	0.00	0.00	12.45	19.75	13.85	70.15	240.24	32.23
JC-4	114.62	31.12	0.58	0.00	0.00	4.17	4.75	2.85	60.01	114.62	32.32
JC-5	210.18	20.71	31.53	0.00	0.00	10.31	41.84	35.94	85.90	210.18	33.69
JC-6	415.04	20.74	11.37	0.99	0.00	1.26	13.62	12.56	92.19	415.04	23.08
JC-7	261.82	30.85	0.00	0.45	0.00	10.00	10.45	5.94	56.78	261.82	31.89
JC-8a	116.01	29.60	0.00	1.79	0.47	8.47	10.73	6.76	62.94	116.01	32.68
JC-8b	148.35	24.60	0.00	0.00	0.00	0.05	0.05	0.03	55.00	148.35	24.61
JC-9a	150.72	18.91	0.00	0.00	0.00	1.45	1.45	0.80	55.00	150.72	19.26
JC-9b	76.37	15.88	0.00	0.00	0.00	0.00	0.00	0.00	N/A	76.37	15.88
JC-10	129.61	19.03	0.00	0.29	0.00	5.78	6.07	3.46	56.98	129.61	20.81
JC-11	169.25	26.60	2.12	0.56	0.82	12.29	15.80	10.00	63.27	169.25	30.02
JC-12a	119.38	29.00	0.00	0.00	0.21	1.48	1.69	0.98	58.14	119.38	29.41
JC-12b	38.57	12.50	0.00	0.00	0.00	5.75	5.75	3.16	55.00	38.57	18.84
JC-13	119.43	18.22	0.00	2.00	1.75	21.39	25.14	15.08	60.01	119.43	27.02
JC-14	443.30	29.82	3.64	0.67	1.25	12.00	17.56	11.74	66.85	443.30	31.29
JC-15	185.63	16.63	3.63	0.25	0.00	0.20	4.08	3.83	94.01	185.63	18.33
JC-16	137.34	7.35	0.64	0.00	0.00	0.00	0.64	0.61	96.00	137.34	7.76
JC-17	147.53	17.94	0.54	0.00	0.00	3.25	3.79	2.31	60.87	147.53	19.04
JC-18	763.05	53.24	0.00	0.00	0.00	0.00	0.00	0.00	N/A	763.05	53.24
JC-19	107.64	4.16	0.00	0.00	0.00	0.00	0.00	0.00	N/A	107.64	4.16
JC-20	726.04	4.37	0.00	0.00	0.00	0.00	0.00	0.00	N/A	726.04	4.37
JC-21	353.97	5.10	0.00	0.00	0.00	0.00	0.00	0.00	N/A	353.97	5.10
JC-22	405.25	13.34	39.96	0.00	0.00	0.00	39.96	38.36	96.00	405.25	21.49
JC-23	275.49	18.67	33.09	0.00	0.00	0.00	33.09	31.76	96.00	275.49	27.96
JC-24	311.62	18.67	0.00	0.00	0.00	59.20	59.20	32.56	55.00	311.62	25.57
JC-25	656.39	0.61	0.00	0.00	0.00	0.00	0.00	0.00	N/A	656.39	0.61

Sub-catchment	**Existing Area**	**Imp.**	**Future Development**							**Future Area**	**Imp.**
			Ind. Area	**Comm. Area**	**Inst. Area**	**Res. Area**	**Total Future Area**	**Impervious**			
	(ha)	*(%)*	*(ha)*	*(ha)*	*(ha)*	*(ha)*	*(ha)*	*(ha)*	*(%)*	*(ha)*	*(%)*
JC-26	429.13	3.60	0.00	0.00	0.00	0.00	0.00	0.00	N/A	429.13	3.60
JC-27	99.97	0.28	0.00	0.00	0.00	0.00	0.00	0.00	N/A	99.97	0.28
JC-28	246.93	6.92	0.00	2.83	0.61	75.68	79.11	44.82	56.66	246.93	22.86
JC-29	207.07	24.68	0.00	0.21	0.00	11.21	11.42	6.36	55.74	207.07	26.39
JC-30	695.30	23.60	2.53	0.00	0.39	2.40	5.32	4.06	76.34	695.30	24.00
JC-31	1310.76	16.11	0.00	0.00	0.00	28.13	28.13	15.47	55.00	1310.76	16.94
LIV-1	2398.33	2.85	2.02	6.68	0.98	105.92	115.60	67.39	58.30	2398.33	5.52
MAL-1	425.76	8.69	0.00	0.00	0.00	0.00	0.00	0.00	N/A	425.76	8.69
MAL-2	963.84	4.05	2.94	0.00	0.00	0.00	2.94	2.83	96.00	963.84	4.33
MAL-3	939.60	7.84	0.00	0.00	0.00	0.00	0.00	0.00	N/A	939.60	7.84
MAL-4	793.78	6.29	15.50	0.00	0.00	21.47	36.97	26.69	72.19	793.78	9.36
NEP-1	651.82	10.11	19.16	12.30	0.61	60.70	92.77	64.08	69.07	651.82	18.50
NIC-1	827.25	39.44	0.00	0.00	0.00	21.40	21.40	11.77	55.00	827.25	39.84
NOL-1	1042.34	5.45	0.00	0.00	0.00	0.45	0.45	0.25	55.00	1042.34	5.47
NOL-2	877.42	1.67	0.00	0.00	0.00	0.44	0.44	0.24	55.00	877.42	1.70
NOL-3	305.79	2.08	0.00	0.67	0.46	5.26	6.40	3.91	61.11	305.79	3.31
ROB-1	139.98	24.23	0.00	0.09	1.23	2.28	3.60	2.32	64.54	139.98	25.27
ROB-2	217.55	31.55	0.00	11.96	0.00	67.75	79.71	48.74	61.15	217.55	42.40
ROB-3	296.95	29.99	0.00	0.00	0.00	19.14	19.14	10.53	55.00	296.95	31.60
ROB-4	204.01	29.99	0.00	1.40	0.00	16.29	17.69	10.30	58.25	204.01	32.44
ROB-5	251.46	28.21	0.00	0.00	0.00	39.26	39.26	21.59	55.00	251.46	32.39
TAIL-1	584.44	9.00	0.00	0.00	0.00	0.00	0.00	0.00	N/A	584.44	9.00
TAIL-2	886.23	27.62	0.00	0.00	0.00	0.00	0.00	0.00	N/A	886.23	27.62
TAIL-3	1046.01	13.52	0.00	0.00	0.00	0.00	0.00	0.00	N/A	1046.01	13.52
WHITE-1	1473.98	26.21	0.00	0.00	0.00	0.00	0.00	0.00	N/A	1473.98	26.21
WHITE-2	1426.88	31.61	0.00	0.00	0.00	0.00	0.00	0.00	N/A	1426.88	31.61

In total, new development is planned within 42 of the hydrologic subcatchments in the subwatershed. Based on the results of **Table 6.8.1**, a future conditions hydrologic model scenario was created in PCSWMM. The full suite of design storm events were run for the future conditions model, and the results are shown in **Table 6.8.2** below.

Table 6.8.2: Future Conditions Subcatchment Runoff Results

Subcatchment	Area	Imp.	Future Conditions Runoff Results													
			Timmins		100yr		50yr		25yr		10yr		5yr		2yr	
			Depth	Peak	Depth	Peak	Depth	Peak	Depth	Peak	Depth	Peak	Depth	Peak	Depth	Peak
	(ha)	*(%)*	*(mm)*	*(m^3/s)*	*(mm)*	*(m^3/s)*	*(mm)*	*(m^3/s)*	*(mm)*	*(m^3/s)*	*(mm)*	*(m^3/s)*	*(mm)*	*(m^3/s)*	*(mm)*	*(m^3/s)*
COP-0	387.62	14.57	144.17	18.57	66.16	24.31	57.59	21.56	49.15	18.92	37.96	15.52	29.53	13.02	17.54	9.50
COP-1	428.37	9.86	445.37	47.90	201.78	24.34	175.36	21.31	149.31	18.44	114.63	14.81	88.40	12.20	50.81	8.63
COP-2	406.09	6.07	147.37	13.84	65.99	11.61	57.27	10.22	48.68	8.90	37.25	7.21	28.62	5.99	16.31	4.29
COP-3	138.50	6.09	1526.37	51.46	689.97	14.53	599.52	11.90	510.30	9.49	391.53	6.65	301.68	4.81	172.98	2.81
COP-4	1057.06	1.97	714.72	113.35	303.35	30.87	260.90	25.67	219.37	20.90	164.82	14.91	124.33	10.68	68.20	5.33
FROOD-1	483.08	2.80	149.49	21.87	68.09	10.97	59.26	9.22	50.53	7.61	38.88	5.67	30.02	4.36	17.23	2.74
JC-1a	81.05	20.86	142.34	5.41	65.40	7.45	57.11	6.58	48.98	5.74	38.22	4.69	30.13	3.92	18.58	2.86
JC-1b	56.62	32.85	138.53	4.47	64.34	7.57	56.51	6.73	48.85	5.93	38.75	4.91	31.17	4.16	20.34	3.10
JC-2	196.20	24.18	129.83	11.50	58.36	18.77	50.69	16.76	43.22	14.83	33.45	12.33	26.20	10.48	16.12	7.82
JC-3	240.24	32.23	138.01	18.86	63.95	31.60	56.14	28.09	48.49	24.74	38.42	20.45	30.86	17.32	20.08	12.92
JC-4	114.62	32.32	135.63	7.74	62.86	14.23	55.07	12.76	47.47	11.33	37.46	9.45	29.99	8.05	19.45	6.01
JC-5	210.18	33.69	136.01	13.02	63.49	25.84	55.62	23.20	47.94	20.62	37.85	17.19	30.33	14.59	19.79	10.77
JC-6	415.04	23.08	139.60	24.05	64.15	38.44	55.94	34.30	47.89	30.30	37.27	25.10	29.32	21.23	18.09	15.68
JC-7	261.82	31.89	133.27	15.96	61.63	30.98	53.89	27.82	46.33	24.74	36.43	20.66	29.07	17.56	18.79	13.03
JC-8a	116.01	32.68	132.19	6.69	61.29	13.54	53.56	12.16	46.03	10.80	36.18	9.00	28.89	7.63	18.78	5.61
JC-8b	148.35	24.61	131.57	9.51	59.29	14.82	51.59	13.18	44.09	11.62	34.25	9.62	26.93	8.15	16.66	6.08
JC-9a	150.72	19.26	118.11	5.21	51.87	10.12	44.34	9.07	37.09	8.04	27.79	6.67	21.12	5.63	12.42	4.11
JC-9b	76.37	15.88	127.52	3.66	55.98	5.03	48.21	4.46	40.64	3.92	30.77	3.24	23.48	2.73	13.45	2.02
JC-10	129.61	20.81	134.81	7.51	60.85	11.12	52.86	9.88	45.05	8.70	34.79	7.18	27.15	6.07	16.42	4.49
JC-11	169.25	30.02	133.78	10.31	61.59	19.21	53.80	17.23	46.19	15.31	36.21	12.78	28.79	10.87	18.40	8.08
JC-12a	119.38	29.41	137.74	8.52	63.53	14.15	55.63	12.61	47.90	11.13	37.71	9.23	30.08	7.82	19.25	5.82
JC-12b	38.57	18.84	155.55	3.27	73.95	4.13	65.17	3.58	56.49	3.05	44.87	2.40	36.01	1.93	23.06	1.32
JC-13	119.43	27.02	138.90	7.36	64.16	12.63	56.06	11.30	48.13	10.00	37.68	8.31	29.86	7.05	18.82	5.22
JC-14	443.30	31.29	134.13	28.58	61.90	52.89	54.15	47.44	46.59	42.14	36.65	35.19	29.25	29.95	18.85	22.34
JC-15	185.63	18.33	136.33	8.79	61.80	13.61	53.58	12.15	45.54	10.73	34.96	8.89	27.08	7.52	16.07	5.54
JC-16	137.34	7.76	143.60	6.67	65.09	5.60	56.48	4.86	48.00	4.16	36.75	3.30	28.27	2.69	16.19	1.89
JC-17	147.53	19.04	131.90	8.47	58.82	11.81	50.96	10.46	43.29	9.18	33.24	7.55	25.77	6.36	15.33	4.70
JC-18	763.05	53.24	154.78	66.81	76.96	144.87	68.60	130.10	60.35	115.58	49.36	96.27	41.00	81.56	28.82	59.91
JC-19	107.64	4.16	148.73	5.87	68.33	3.81	59.56	3.19	50.89	2.62	39.33	1.93	30.55	1.47	17.86	0.91
JC-20	726.04	4.37	162.16	26.83	70.94	16.10	61.12	14.03	51.46	12.10	38.70	9.67	29.13	7.95	15.68	5.63
JC-21	353.97	5.10	131.59	14.31	57.21	9.42	48.97	8.14	40.92	6.95	30.36	5.48	22.53	4.47	11.73	3.14
JC-22	405.25	21.49	127.69	16.59	57.38	31.24	49.49	28.00	41.83	24.83	31.87	20.62	24.58	17.43	14.73	12.74
JC-23	275.49	27.96	129.39	13.75	59.13	27.24	51.38	24.44	43.83	21.69	34.01	18.03	26.78	15.25	16.89	11.17
JC-24	311.62	25.57	134.25	20.59	60.98	32.41	53.17	28.84	45.54	25.43	35.51	21.04	28.04	17.81	17.50	13.26
JC-25	656.39	0.61	111.45	15.57	43.64	3.52	36.18	2.79	29.02	2.22	19.89	1.58	13.43	1.17	5.31	0.72
JC-26	429.13	3.60	98.57	11.13	38.66	6.81	31.79	5.97	25.28	5.18	17.13	4.21	11.50	3.52	4.71	2.60
JC-27	99.97	0.28	110.54	4.99	43.36	1.88	36.34	1.42	29.58	1.03	20.87	0.61	14.55	0.37	6.07	0.13
JC-28	246.93	22.86	129.35	14.71	57.83	22.77	50.18	20.28	42.74	17.89	32.99	14.83	25.77	12.57	15.71	9.38
JC-29	207.07	26.39	131.13	12.18	59.49	21.17	51.78	18.96	44.26	16.81	34.41	14.01	27.11	11.92	16.93	8.89
JC-30	695.30	24.00	125.23	35.33	55.96	63.31	48.43	56.80	41.13	50.46	31.62	42.14	24.64	35.86	15.09	26.72
JC-31	1310.76	16.94	182.13	80.77	79.36	100.42	68.04	89.39	57.08	78.81	42.90	65.12	32.55	54.99	18.55	40.52

Subcatchment	Area	Imp.	Future Conditions Runoff Results													
			Timmins		100yr		50yr		25yr		10yr		5yr		2yr	
			Depth	Peak	Depth	Peak	Depth	Peak	Depth	Peak	Depth	Peak	Depth	Peak	Depth	Peak
	(ha)	*(%)*	*(mm)*	*(m^3/s)*	*(mm)*	*(m^3/s)*	*(mm)*	*(m^3/s)*	*(mm)*	*(m^3/s)*	*(mm)*	*(m^3/s)*	*(mm)*	*(m^3/s)*	*(mm)*	*(m^3/s)*
LIV-1	2398.33	5.52	147.80	148.81	67.78	112.78	59.09	94.28	50.53	77.27	39.12	56.77	30.46	43.07	17.96	26.48
MAL-1	425.76	8.69	95.19	8.15	37.62	13.47	31.04	12.09	24.85	10.74	17.21	8.95	12.04	7.59	6.06	5.60
MAL-2	963.84	4.33	118.11	28.35	48.88	19.16	41.13	16.77	33.64	14.54	23.98	11.75	17.02	9.77	7.94	7.09
MAL-3	939.60	7.84	108.37	23.04	44.17	28.66	36.90	25.63	29.94	22.71	21.12	18.88	14.93	16.02	7.26	11.88
MAL-4	793.78	9.36	365.54	52.85	144.79	33.09	120.16	29.51	96.62	26.05	66.81	21.55	45.87	18.18	19.90	13.33
NEP-1	651.82	18.50	115.20	20.65	49.95	40.61	42.55	36.36	35.45	32.19	26.37	26.64	19.93	22.43	11.69	16.25
NIC-1	827.25	39.84	138.22	52.94	65.82	110.87	57.92	99.37	50.19	88.07	40.04	73.02	32.48	61.56	21.87	44.73
NOL-1	1042.34	5.47	114.05	32.56	47.30	25.19	39.74	22.14	32.46	19.28	23.12	15.68	16.42	13.12	7.73	9.62
NOL-2	877.42	1.70	141.22	27.11	61.23	10.63	52.68	8.98	44.29	7.47	33.19	5.64	24.88	4.41	13.21	2.86
NOL-3	305.79	3.31	134.10	7.54	55.98	4.78	47.78	4.20	39.78	3.65	29.33	2.95	21.62	2.45	11.10	1.76
ROB-1	139.98	25.27	128.72	7.01	58.22	13.11	50.49	11.77	42.98	10.45	33.17	8.72	25.95	7.40	16.05	5.47
ROB-2	217.55	42.40	145.18	17.50	69.76	34.97	61.71	31.39	53.81	27.90	43.34	23.31	35.45	19.84	24.08	14.78
ROB-3	296.95	31.60	138.67	16.59	64.93	32.75	56.79	29.34	48.84	26.00	38.38	21.55	30.59	18.18	19.69	13.23
ROB-4	204.01	32.44	136.53	11.14	63.87	22.34	55.83	20.00	47.98	17.71	37.69	14.65	30.05	12.33	19.45	8.93
ROB-5	251.46	32.39	423.14	48.24	199.25	63.96	174.89	56.48	151.07	49.27	119.70	39.92	96.25	33.02	63.10	23.27
TAIL-1	584.44	9.00	135.69	21.55	59.64	22.60	51.29	20.02	43.11	17.56	32.35	14.40	24.35	12.09	13.27	8.83
TAIL-2	886.23	27.62	237.53	42.08	105.24	63.51	91.42	56.08	77.88	48.86	60.08	39.43	46.85	32.41	28.45	22.44
TAIL-3	1046.01	13.52	340.51	54.47	147.48	59.42	127.65	52.80	108.26	46.37	82.83	37.92	63.96	31.60	37.79	22.50
WHITE-1	1473.98	26.21	113.75	56.75	51.04	112.04	43.87	99.84	37.01	87.89	28.30	72.05	22.14	60.08	14.25	42.71
WHITE-2	1426.88	31.61	234.80	92.87	105.88	155.01	91.16	137.57	77.02	120.57	58.91	98.20	45.92	81.42	28.76	57.30

In order to minimize the impact of increased runoff and peak flows as shown in **Table 6.8.2**, post to pre-development flow control should be provided for new development areas. In order to model the capture of runoff from the future development areas specifically, each hydrologic subcatchment containing projected future development was divided into a "100% impervious" portion, and an "unchanged" portion, such that the unchanged portion remains at the pre-development imperviousness while the 100% impervious portion is modelled as completely impervious and represents the increase in imperviousness from the projected future development area. To avoid confusion, it is worth noting that the area of the "100% impervious" portion will not be precisely the same as the projected future development impervious area from **Table 6.5.1** above as that would not account for the initial imperviousness of the subcatchment being development. The area of the "100% impervious" portion is determined using the equation below:

$$A_I = A_T \frac{(I_F - I_U)}{(1 - I_U)}$$

Where A_I is the area of the "100% impervious" portion, A_T is the total area of the initial undivided hydrologic subcatchment, I_F is the imperviousness of the entire future development hydrologic subcatchment from **Table 6.8.1**, and I_U is the imperviousness of the "unchanged" portion of the subcatchment, the same as the existing imperviousness from **Table 6.8.1**. The area of the "100% impervious" and the "unchanged" portions of the divided subcatchments are shown in **Table 6.8.3** below.

Table 6.8.3: Future Development Modelling Hydrologic Subcatchment Division

Subcatchment	100% Imp.	Unchanged Portion	
	Area	Area	Imp.
	(ha)	*(ha)*	*(%)*
COP-4	15.84	1041.22	0.48
JC-1b	1.11	55.51	31.50
JC-2	1.94	194.26	23.42
JC-3	11.46	228.77	28.83
JC-4	1.99	112.63	31.12
JC-5	34.40	175.78	20.71
JC-6	12.28	402.76	20.74
JC-7	3.92	257.90	30.85
JC-8a	5.08	110.92	29.60
JC-8b	0.02	148.33	24.60
JC-9a	0.65	150.08	18.91
JC-10	2.84	126.77	19.03
JC-11	7.89	161.36	26.60
JC-12a	0.69	118.68	29.00
JC-12b	2.79	35.78	12.50
JC-13	12.84	106.59	18.22
JC-14	9.27	434.04	29.82
JC-15	3.78	181.85	16.63
JC-16	0.61	136.73	7.35
JC-17	1.98	145.55	17.94

Subcatchment	100% Imp. Area (ha)	Unchanged Portion Area (ha)	Unchanged Portion Imp. (%)
JC-22	38.12	367.14	13.34
JC-23	31.46	244.03	18.67
JC-24	26.45	285.18	18.67
JC-28	42.27	204.65	6.92
JC-29	4.71	202.36	24.68
JC-30	3.67	691.63	23.60
JC-31	13.04	1297.73	16.11
LIV-1	65.97	2332.36	2.85
MAL-2	2.82	961.02	4.05
MAL-4	26.00	767.79	6.29
NEP-1	60.85	590.96	10.11
NIC-1	5.50	821.75	39.44
NOL-1	0.24	1042.10	5.45
NOL-2	0.24	877.18	1.67
NOL-3	3.86	301.93	2.08
ROB-1	1.91	138.07	24.23
ROB-2	34.47	183.08	31.55
ROB-3	6.84	290.11	29.99
ROB-4	7.14	196.87	29.99
ROB-5	14.65	236.81	28.21

It is worth noting that the runoff from the divided hydrologic subcatchments in the PCSWMM hydrologic model was consistently slightly less than the runoff from the equivalent combined subcatchment shown in **Table 6.8.2**, however the difference was minor (generally less than 5%) and is most likely a function of the PCSWMM model routing procedure.

Conceptual storage units were introduced to the divided subcatchment model to receive runoff from each of the new "100% impervious" hydrologic subcatchment portions representing the projected future development. For each storage unit, the storage rating curve was set as uniform storage with vertical walls over the entire "100% impervious" area from **Table 6.8.3**. The outflow rating curve from the storage unit was determined from the pre-development peak flow shown in **Table 6.7.2**, and the depth of storage was iteratively adjusted, to the nearest millimetre, until the post-development peak flow from **Table 6.8.2** was attenuated to equal or less than the pre-development flow. The results of this analysis are shown in **Table 6.8.4** below for the Lively area subcatchment (used for example as it contains the largest area of projected future development).

Through the existing conditions analysis described in **Section 6.7** above, it was determined that the SCS design storms were more severe than the Chicago design storms for the Junction Creek subwatershed, so the derivation of rating curves for overall stormwater management has focused on the former.

Table 6.8.4: Future Development Rating Curve – Subcatchment LIV-1 (Lively)

				Total Subcatchment Area (ha):		2398.33
LIV-1				**"100% Impervious" Area (ha):**		65.97
Storm Event	**Existing Runoff**		**Future Runoff**		**Required Stormwater Management Rating Curve for Future Impervious Areas**	
	Depth *(mm)*	**Peak** *(m^3/s)*	**Depth** *(mm)*	**Peak** *(m^3/s)*	**Depth** *(mm)*	**Outflow** *($m^3/s/ha$)**
2 Year	17.0	15.7	18.0	26.5	32.0	0.007
5 Year	29.5	29.0	30.5	43.1	40.0	0.012
10 Year	38.1	40.6	39.1	56.8	45.0	0.017
25 Year	49.5	58.3	50.5	77.3	51.0	0.024
50 Year	58.0	73.3	59.1	94.3	56.0	0.031
100 Year	66.7	89.8	67.8	112.8	60.0	0.037
Timmins	146.4	142.7	147.8	148.8	80.0	0.059

**Rating curve outflow displayed per unit impervious future development area*

Rating curves for individual subcatchments should be derived as development proceeds, as shown above. Proposed future developments should aim to provide the stated depth of storage at the required unit outflow rate from their impervious areas, in order to mimic pre-development runoff conditions. The results of this analysis may be superseded by an individual site hydrologic model created for a specific development proposal which provides pre to post-development stormwater management flow control, but care should be taken to ensure that a similar or greater degree of precision is used.

7.0 RIVERINE FLOODPLAIN (HEC-RAS) MODEL

7.1 Model Development and Parameterization

As part of the Junction Creek Subwatershed Study and Stormwater Master Plan, an updated hydraulic model of Junction Creek, as well as related floodplain mapping, has been created using the HEC-RAS modelling platform. As described in **Section 3.3.1** above, The HEC-RAS tool has been developed by the U.S. Army Corp of Engineers and uses energy and momentum equations to determine water surface elevations for given channel geometric cross-sections, crossings and boundary conditions. Based on the computed event flows from they hydrologic model described in **Section 6** above, the hydraulic floodplain model computes water surface elevations along Junction Creek and the Maley, Nickeldale, Nolin Creek, and Lily Creek tributaries, and maps the resultant floodplain extent based on the topographic LiDAR DEM data.

The latest version of the HEC-RAS software is Version 5.0.3, which was released in September 2016. HEC-RAS underwent a significant update with the release of Version 5.0 in February 2016, prior to that the industry had been working with HEC-RAS 4.1 since its release in January 2010. Both HEC-RAS 5.0.3 and 4.1 have been used to generate the hydraulic modelling, as discussed in **Section 7.3.1** below.

In order to assist in the creation of the HEC-RAS model, the HEC-GeoRAS extension for ESRI ArcMap 10.4 was utilized. This extension contains a suite of tools which allow GIS data to be automatically exported to and imported from HEC-RAS. It also allows for easy integration of elevation information from the LiDAR digital elevation model (DEM).

7.1.1 Stream Centreline & Banks

Stream bank information for Junction Creek was received from CS. A few edits were necessary to ensure that the stream bank lines only cross each river station cross section at one point, as is necessary to establish the left and right bank stations with HEC-GeoRAS.

A detailed stream centreline was digitized by Wood staff for each of the modelled tributaries and reaches, based on high-resolution ortho-imagery.
Short duration (5 minute to 24 hour) rainfall and long duration (1 to 30 day) rain-on-snow Intensity-Duration-Frequency (IDF) rainfall data was obtained from Environment Canada for the Sudbury A Weather Station (Climate ID numbers 6068150 and 6068153, the former is for data prior to March 2013). Total precipitation depths for the 24 hour rainfall and 30 day rain-on-snow events are summarized in **Table 4**. The 2 to 100 year depths shown in the table were provided by the IDF data, whereas the 1000 years depths were statistically extrapolated.

7.1.2 Bridges

In HEC-RAS, a bridge refers to any elevated structure, be it a roadway, berm, or true bridge, which allows water to pass under it, whether through a culvert or otherwise.

An important step in the creation of a HEC-RAS model is the establishment of bridge crossings. The placement of cross sections is entirely built around the bridges and crossings in the model, so it is important to represent these areas as accurately as possible.

Based on the DEM, a bridge deck line was drawn using HEC-GeoRAS, along each of the roads and trails that cross Junction Creek and the selected tributaries. This line represents the centreline of the bridge crossing and is used by HEC-GeoRAS to extract bridge deck elevation data from the DEM, as well as to determine the station number of the crossing. Bridge deck and section elevations were determined based on the LiDAR data, and supplemented by topographic surveys of major bridge crossings, including the upstream and downstream channel cross section.

Other information about the bridge and culvert, such as the distance to upstream cross section, the height of the bridge if required, any information about piers if they are significant, and information about any culverts (invert, size, left/right station, roughness, entrance loss coefficients, etc.) are entered by manually (refer to **Tables 7.1.1, 7.1.2, and 7.1.3** below). Additionally, it is considered good practice to include any railings on the bridge deck as part of the bridge deck, as they are likely to become clogged with debris during a flood event, and in some cases the bridge deck elevations have been raised to reflect a railing, as estimated from available photographs of the bridges.

Table 7.1.1: Junction Creek Upper Model Culvert Crossing

Reach	ID	Description	Culvert					
			Shape	Length	Manning n	US Inv.	DS Inv.	No.
Upper 1	17299.81	Spruce/Birch Streets	Circular	310.7	0.023	287.76	285.95	2
	16351.52	Orell Street	Arch	35.0	0.023	284.22	284.14	1
	16014.38	Margaret Street Trail	Box	15.5	0.015	282.80	282.70	1
	14157.42	O'Neil Drive West	Circular	15.4	0.023	278.18	277.39	1
	12965.63	Donnely Drive	Circular	18.4	0.023	273.00	272.92	1
	12617.83	Carr Avenue	Circular	12.0	0.015	272.91	272.84	1
	11828.6	Matson Road	Circular	15.1	0.023	268.42	268.33	1
	11558.35	Maley Drive	Box	37.5	0.015	268.30	268.00	1
	11253.31	Old Falconbridge Railway	Circular	13.5	0.015	267.41	267.25	1
	10872.4	Robin Street	Arch	15.6	0.023	265.86	265.79	1
	10575.22	Madison Avenue	Box	58.5	0.015	264.82	264.60	1
	10106.06	Gary Avenue	Circular	12.0	0.015	262.90	263.11	2
	9926.225	Twin Forks Trail	Circular	7.4	0.015	262.63	262.72	1
Maley	2088.469	Maley Drive	Box	30.0	0.015	263.98	263.81	1
	1051.964	Gary Avenue Trail	N/A – No culvert at crossing.					
	552.5201	Madison Avenue	Box	30.4	0.015	261.30	261.43	2
Upper 2	9540.086	Lansing Avenue	Circular	42.0	0.023	260.70	260.40	2
	8777.025	Lasalle Boulevard	Box	38.7	0.015	259.69	259.49	1
	8303.139	New Sudbury Railway 1	Circular	35.5	0.023	259.54	259.71	1
	7624.32	Barry Downe Road	Box	27.4	0.015	257.57	257.55	1
	7543.684	Mall Vehicle Crossover	Circular	13.5	0.03	256.39	256.35	1
	6939.086	New Sudbury Railway 2	N/A – No culvert at crossing.					
	6730.062	Mountview Crescent Trail	N/A – No culvert at crossing.					
	6300.411	Attlee Avenue	Box	32.6	0.015	255.18	254.95	1
	6048.625	Stafford Street Trail	N/A – No culvert at crossing.					
	5864.298	Arthur Street	Box	26.8	0.015	255.15	255.19	1
	4882.635	Railway 1	N/A – No culvert at crossing.					
	3521.141	Railway 2	Circular	18.0	0.015	255.86	255.79	6
Nickeldale	1519.694	Lasalle Boulevard	Box	170.0	0.015	260.56	260.50	1
Upper 3	1997.857	Notre Dame Railway	N/A – No culvert at crossing.					
	1469.087	King Street	Box	15.0	0.015	253.04	253.00	1
	1282.803	Bond Street	Box	13.4	0.015	253.61	253.59	1
	1193.742	Agnes Street Trail	N/A – No culvert at crossing.					
	767.3227	Leslie Street	N/A – No culvert at crossing.					
	368.0284	Mountain Street	Box	59.3	0.015	252.39	252.39	1

Note: The "No." column refers to the number of culverts in the crossing.

Table 7.1.2: Nolin Creek Culvert Crossings

Reach	ID	Description	Culvert					
			Shape	Length	n	US Inv.	DS Inv.	No.
Nolin	2414.87	Elm Street	N/A	—	—	—	—	—
	2063.12	Nolin Railway 1	Circular	17.0	—	262.10	261.78	2
	1766.62	Nolin Railway 2	Circular	11.3	—	261.06	260.99	2
	1457.72	Ruisseau Nolin Creek Trail	Circular	15.5	—	260.56	260.48	2
	785.36	Beatty Street	Box	24.0	—	258.40	258.49	1
	733.97	Nolin Railway 3	N/A	—	—	—	—	—
	651.74	Dufferin Street	Box	11.2	—	258.61	258.52	1
	204.33	Railway/Frood Road	Box	56.2	—	257.00	256.95	1

Table 7.1.3: Junction Creek Lower Model Culvert Crossings

Reach	ID	Description	Culvert					
			Shape	Length	n	US Inv.	DS Inv.	No.
Middle 1	23527.96	Broadway Street	Box	46.0	0.015	251.06	251.03	1
	23204.38	Douglas Street / Brady Street	Box	134.7	0.015	251.37	251.15	1
	22768.21	Riverside Drive	Box	20.6	0.015	250.18	250.18	1
	22526.71	Trail	N/A	—	—	—	—	—
	22338.38	Regent Street	Box	35.6	0.015	250.15	250.15	1
	21977.23	McLeod Street	Box	54.5	0.015	249.16	248.98	1
	21846.53	Struthers Trail	N/A	—	—	—	—	—
	21229.66	Martindale Road	Box	39.0	0.015	248.42	248.39	1
	19716.22	Kelly Lake Road	Box	33.5	0.023	247.70	247.70	1
Lily	4746.57	Regent Street	Ellipse	78.5	0.015	248.20	248.20	1
	4054.35	Martindale Road	Box	28.6	0.023	247.80	247.80	1
	3157.05	Bouchard Street	Box	17.2	0.015	247.70	247.74	1
	2245.13	Robinson Trail	N/A	—	—	—	—	—
	804.81	Southview Drive	Box	19.4	0.015	246.48	246.48	1
Middle 2	12016.81	Fielding Road	N/A	—	—	—	—	—
	11190.69	Trans Canada Highway	N.A	—	—	—	—	—
	9389.62	Mikkola Road	N/A	—	—	—	—	—
	6477.04	Black Lake Road	N/A	—	—	—	—	—
Fly	N/A	—	—	—	—	—	—	—
Lower	330.79	Reserve Road	N/A	—	—	—	—	—

7.1.3 Cross Section Placement

Once the bridge deck lines have been drawn in ArcMAP, the cross section lines may be drawn in a similar manner. As per HEC-RAS modelling best practices, it is important to have one cross section immediately upstream, and immediately downstream each bridge/culvert crossing (but far enough that it does not capture the side slopes of the roadway). It is also important to have a second cross section, where possible, at the start of the flow contraction upstream of the crossing, and at the end of the flow expansion downstream of the crossing, as described in HEC-RAS documentation.

In general, cross sections for HEC-RAS modelling must be drawn perpendicular to the flow lines of the watercourse. This means that they should always intersect the stream centreline at approximately 90° but may be angled differently further from the centreline and through the overbank area. This also means that as flow converges at a junction, the cross sections from the two joining watercourses should become parallel with one another. The one exception to this rule is at bridge crossings which do not intersect the stream at 90°, it is often more important to be parallel to the bridge than it is to be perpendicular to the centreline of the watercourse, but this is dependant on the prominence of the bridge structure and how much it will determine local flow patterns. There is an option in the HEC-RAS program to add a skew angle to bridges and cross sections for these cases.

Cross sections were built using AutoCAD and HEC-GeoRAS, using the LiDAR data, and supplemented by topographic surveys of the stream cross section upstream and downstream of major bridge crossings.

In general, cross sections have been spaced no more than 150 m apart, and often significantly closer as required by bridges or to otherwise accurately represent the flow pattern of the watercourses.

7.1.4 Lateral Structures

As a primarily one-dimension modelling program, HEC-RAS uses lateral structures to refer to weirs which allow flow through the side of the watercourse, as one way of representing two-dimensional flow. Though cases of true lateral weir structures in watercourses are relatively rare, they are often used to represent common natural watercourse flow patterns.

For example, they are often used between two approaching tributaries at a junction, to help balance the water surface elevation across adjoining cross-sections. This method has been applied at junctions in the Junction Creek HEC-RAS modelling, particularly through the very flat Ponderosa wetland area. There are also several areas along Junction Creek where the watercourse flows along elevated railways, and lateral structures have been used in some cases to model flow over or across the rail beds.

Similar to bridge structures, lateral structure cut lines were drawn in HEC-GeoRAS. These lines are used by the program to extract elevation information from the DEM, as well as to determine the river station/location of the lateral structure. HEC-GeoRAS bases its determination on the closes stream centreline to the lateral structure, so often some adjustment is required to suit the local flow patterns of the watercourse and ensure the structure is represented in the correct location.

7.1.5 Flow Paths

A useful ability of HEC-GeoRAS is to estimate the downstream flow lengths of the watercourse. Similar to the bank lines and stream centreline, overbank flow paths may be drawn in the program which will be used by HEC-RAS to determine the downstream flow lengths from each cross section.

According to HEC-RAS modelling best practices, the overbank flow path is meant to represent the centre of mass of flow, in other words the centroid of the cross sectional area of flow. Assuming that the overbank flow cross section is roughly triangular, the flow path should be located approximately one third of the distance between the bank line and the floodplain line. Flow paths were estimated on this basis using the received bank lines and the historical floodplain mapping from CS.

7.1.6 Ineffective Flow Areas

Ineffective flow areas in HEC-RAS refer to locations which are able to store water, but not convey it. The most common use of ineffective flow areas is to represent the contraction and expansion reaches surrounding each bridge and culvert crossing.

Ineffective flow areas have been drawn in HEC-RAS assuming a 1:1 contraction ration, and a 4:1 expansion ratio, based on common industry practice. These areas are drawn in plan and are used by HEC-GeoRAS to determine the ineffective area, if any, of each cross section, as well as the elevation of the ineffective area. In the case of the ineffective flow area surrounding a culvert, the ineffective area should end at the top of the bridge deck, above which the area once again becomes effective flow.

7.1.7 Blocked Obstructions

Blocked obstructions in HEC-RAS are used to represent local obstructions above the general topography in the watercourse. They have been used in the Junction Creek HEC-RAS modelling to represent buildings and other permanent structures. Blocked obstructions are drawn in HEC-GeoRAS similar to ineffective flow areas, and their location and elevation along each cross section are extracted based on the DEM. Blocked obstructions have been given a height of 5m in the model.

7.1.8 Other Parameters

Additional HEC-RAS parameters have been established or estimated best on common industry practice:

- Manning's 'n' roughness coefficients for the cross sections have been based on the *HEC-RAS 5.0 Reference Manual Table 3-1*, and have been set at 0.45 for the main channel and vary from 0.35 for grassy floodplain areas to up to 0.60 for floodplain areas with dense brush or trees.
- Contraction and expansion coefficients have been set at 0.1 and 0.3, respectively.
- Manning's 'n' roughness coefficients for culverts has been set at 0.015 for concrete culverts, and 0.023 for corrugated steel pipe (CSP) culverts.

7.2 Flow Data and Boundary Conditions

Based on the complexities associated with modelling the downtown box culvert using HEC-RAS, it has been determined that the HEC-RAS models will be divided around the box culvert. The box culvert will be modelled using the overall PCSWMM hydrologic model, and the resultant modelled water surface elevation will be used as a boundary condition for the HEC-RAS modelling. Therefore, the HEC-RAS models have been divided into three parts:

- **Upper Junction Creek** from Garson to the Box Culvert (including the Maley and Nickeldale tributaries)
- **Nolin Creek** to the Box Culvert
- **Lower Junction Creek** from the Box Culvert to Simon Lake (including Lily Creek and the Fly tributary)

Flow change locations have been specific at the outlet of each individual subcatchment along Junction Creek. In order to provide a conservative estimation of floodplain elevation, the flow at the downstream end of each subcatchment will be applied to the upstream end of the reach passing through that subcatchment in the HEC-RAS model, as it is not known precisely where the runoff will enter the creek.

In the overall PCSWMM hydrologic model, the Ponderosa has been modelled as a series of three natural storage areas, as described in **Section 6.2.2**. However, in the HEC-RAS hydraulic model, the Ponderosa is modelled as two separate intersecting tributaries which come to a junction. The flows in **Table 6.4.1** surrounding the Ponderosa are also irregularly high, due to the stage storage routing of the PCSWMM model. In order to provide a hydraulic calculation of flow along the individual tributaries of the Ponderosa, a separate version of the PCSWMM hydrologic model has been created which models the intersection of the Ponderosa tributaries as per the HEC-RAS model (note that lateral weirs have been included at this junction, as described in **Section 7.1.4** above, to balance the water surface elevation between the two tributaries,). This will allow for a more specific calculation of flow along each incoming tributary.

A summary of the PCSWMM model flows applied to the Upper Junction Creek, Nolin, and Lower Junction Creek HEC-RAS models is shown in **Tables 7.2.1, 7.2.2, and 7.2.3** below, respectively.

Table 7.2.1: HEC-RAS Upper Junction Creek Model Flows

HEC-RAS			1:2 Year		1:5 Year		1:10 Year		1:25 Year		1:50 Year		1:100 Year		Timmins Storm
Project	Reach	Applied Station[1]	Chi	SCS	Chicago	SCS	Chicago	SCS	Chicago	SCS	Chicago	SCS	Chicago	SCS	
			(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
Upper	Upper 1	17356.9	3.80	5.08	5.53	6.97	6.68	8.30	7.99	10.09	9.74	11.49	11.18	12.99	10.23
Upper	Upper 1	17026.43	5.30	7.60	8.28	10.75	10.16	12.94	12.27	15.75	14.99	17.87	17.15	20.04	19.05
Upper	Upper 1	14928.24	8.35	10.21	10.99	12.32	12.41	14.93	14.34	18.44	17.72	21.14	20.41	24.02	32.39
Upper	Upper 1	11046.3	5.06	6.39	7.18	8.50	8.48	10.18	10.18	12.65	12.53	14.94	15.03	16.05	32.15
Upper	Upper 2	9644.078	8.58	11.70	12.39	15.82	15.11	18.66	18.68	23.57	24.27	27.77	28.80	31.84	69.07
Upper	Upper 2	7939.164	9.33	11.54	13.83	16.47	17.14	20.21	21.16	26.42	27.52	31.10	32.76	35.76	78.73
Upper	Upper 2	6272.662	19.13	21.05	21.96	23.66	23.58	25.32	25.78	27.21	28.25	31.76	33.59	36.61	88.44
Upper	Upper 2	4870.862	8.66	11.66	15.18	18.47	19.15	22.83	23.85	29.14	30.44	33.69	36.01	39.06	86.53
Upper	Upper 2	3641.376	5.96	8.34	9.68	12.12	12.04	14.27	14.18	16.58	16.88	18.95	20.15	21.79	33.56
Upper	Upper 2	3497.94	6.61	10.02	11.64	15.23	14.81	19.55	19.67	25.40	26.17	28.93	31.13	32.99	45.67
Upper	Upper 3	2209.086	5.65	8.89	8.78	12.32	10.59	14.55	12.77	17.32	15.50	19.55	17.87	21.73	42.39
Upper	Upper 3	1763.267	6.05	8.97	8.79	12.45	10.62	14.71	12.83	17.50	15.58	20.47	17.76	22.97	50.68
Upper	Upper 3	926.8911	5.66	8.91	8.78	12.35	10.59	14.57	12.77	17.33	15.46	19.57	17.63	21.74	42.24
Upper	Upper 3	64.75401	11.03	15.35	17.03	22.49	20.81	27.68	25.60	34.83	32.54	40.49	38.63	46.43	108.82
Upper	Maley	3177	1.85	4.17	3.64	6.76	4.84	8.26	6.57	10.08	8.42	11.21	9.83	12.17	16.87
Upper	Nickeldale	2350.343	9.10	9.41	10.36	10.22	10.98	10.71	11.64	11.29	12.45	11.94	13.26	12.55	17.18
Boundary W.S.			253.84	253.99	254.02	254.24	254.16	254.42	254.35	254.64	254.61	254.79	254.81	254.96	257.24

Table 7.2.2: HEC-RAS Nolin Creek Model Flows

HEC-RAS			1:2 Year		1:5 Year		1:10 Year		1:25 Year		1:50 Year		1:100 Year		Timmins Storm
Project	Reach	Applied Station[1]	Chi	SCS	Chicago	SCS	Chicago	SCS	Chicago	SCS	Chicago	SCS	Chicago	SCS	
			(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
Nolin	Nolin	2709.86	8.39	11.67	12.44	16.38	15.20	19.67	18.20	24.03	22.16	27.51	25.50	31.17	38.77
Nolin	Nolin	1363.7	8.03	11.69	12.65	16.87	15.48	20.83	18.98	26.54	23.87	31.05	28.23	35.88	68.92
Nolin	Nolin	928.98	7.36	10.66	11.47	15.83	14.33	19.58	17.70	24.77	22.29	28.95	26.32	33.46	76.18
Boundary W.S.			256.71	256.83	256.85	256.98	256.94	257.09	257.03	257.22	257.16	257.32	257.26	257.43	258.49

Table 7.2.3: HEC-RAS Lower Junction Creek Model Flows

HEC-RAS			1:2 Year		1:5 Year		1:10 Year		1:25 Year		1:50 Year		1:100 Year		Timmins Storm
Project	Reach	Applied Station[1]	Chi	SCS	Chicago	SCS	Chicago	SCS	Chicago	SCS	Chicago	SCS	Chicago	SCS	
			(m^3/s)	*(m^3/s)*	*(m^3/s)*	*(m^3/s)*	*(m^3/s)*	*(m^3/s)*	*(m^3/s)*	*(m^3/s)*	*(m^3/s)*	*(m^3/s)*	*(m^3/s)*	*(m^3/s)*	*(m^3/s)*
Middle Lower	Middle 1	23730.3	15.09	19.37	19.90	24.92	23.14	29.10	28.82	37.27	37.10	43.86	44.48	50.95	120.47
Middle Lower	Middle 1	19916.26	18.69	24.14	25.18	31.44	29.35	36.61	33.97	43.16	40.13	48.20	47.48	54.24	127.50
Middle Lower	Middle 1	19916.26	19.25	25.62	27.17	34.06	31.99	40.03	38.51	48.13	48.01	55.50	56.28	63.26	139.15
Middle Lower	Middle 1	19218.82	20.54	24.38	27.62	33.47	33.32	40.46	41.03	50.41	51.96	59.13	62.44	68.74	144.45
Middle Lower	Lily	5570.92	2.15	2.64	2.90	3.34	3.36	3.81	3.85	4.80	4.87	5.65	5.81	6.57	12.52
Middle Lower	Lily	4601.54	3.65	3.98	4.07	5.41	4.78	6.75	6.20	28.45	31.83	28.43	32.23	28.34	58.04
Middle Lower	Lily	1970.92	2.17	4.08	5.38	8.06	7.15	9.05	9.05	11.69	11.49	13.17	13.31	14.42	17.44
Middle Lower	Middle 2	17108.15	13.01	21.29	18.93	30.33	22.78	37.18	28.57	47.26	36.87	56.26	44.64	65.93	136.88
Middle Lower	Middle 2	14840.02	13.01	21.29	18.93	30.33	22.78	37.18	28.57	47.26	36.87	56.26	44.64	65.93	136.88
Middle Lower	Middle 2	12770.96	13.01	21.29	18.93	30.33	22.78	37.18	28.57	47.26	36.87	56.26	44.64	65.93	136.88
Middle Lower	Middle 2	12770.96	13.01	21.57	19.04	30.91	22.97	38.01	28.95	48.45	37.53	57.84	45.58	67.96	139.81
Middle Lower	Middle 2	11874.35	13.01	21.72	19.06	31.22	23.03	38.47	29.09	49.14	37.83	58.77	46.05	69.22	143.62
Middle Lower	Middle 2	11080.39	12.90	21.77	19.07	31.35	23.04	38.69	29.10	50.33	38.32	60.35	46.11	72.21	144.23
Middle Lower	Middle 2	7401.31	13.03	22.40	19.41	32.53	23.58	40.32	29.98	52.86	39.84	63.50	48.08	76.59	158.90
Middle Lower	Middle 2	7257.21	12.97	22.74	19.54	33.17	23.79	41.20	30.35	57.93	42.13	69.79	49.02	84.60	163.35
Middle Lower	Fly	1539.53	27.51	33.77	43.38	48.54	53.28	59.60	65.35	74.12	80.60	85.16	93.59	97.05	89.90
Middle Lower	Lower	5909.79	16.32	25.18	22.86	37.50	27.43	47.14	34.40	61.97	45.22	75.52	56.29	90.32	237.02
Middle Lower	Lower	2674.35	17.29	28.14	28.46	41.69	35.62	51.89	45.41	67.57	58.99	82.76	70.69	99.23	308.51
Middle Lower	Lower	2199.92	17.29	28.14	28.46	41.69	35.62	51.89	45.41	67.57	58.99	82.76	70.69	99.23	308.51

7.3 Discussion of Warnings, Errors and Uncertainties

7.3.1 HEC-RAS Version

The HEC-GeoRAS information was imported using the latest version of the HEC-RAS software, version 5.0.3. However, when running the Upper Junction Creek and Lower Junction Creek models in HEC-RAS version 5.0.3, the process becomes stuck at "Computing XS Interpolation Surfaces" and does not complete. Due to the fact that the Nolin Creek model does work in HEC-RAS Version 5.0.3, this is likely related to the modelling of junctions in the HEC-RAS model. For the scope of analysis of this study, there is no practical difference between HEC-RAS versions 5.0.3 and 4.1, the Upper and Lower Junction Creek modelling was completed using HEC-RAS version 4.1.

7.3.2 Flow Optimizations

In order to provide the best possible estimate of water surface elevation, the HEC-RAS model tries to "optimize" the flow across the lateral structures. Due to the fact that the flow across a lateral structure is dependent on the water surface on either side, an iterative approach must be taken by the program to balance the computation of water surface and flow.

Due to the flatness of the Ponderosa wetland, the lateral weirs between the two incoming junctions (reaches Upper 2 and Nickeldale in the Upper Junction Creek model) cannot be optimized within the 30 iterations utilized by HEC-RAS. This is not necessarily a significant issue, and often occurs with very wide and flat hydraulic cross sections, due to the large change in volume and flow with small changes in water surface elevation. The computation of the water surface in this area of the HEC-RAS model appears to be reasonable, despite the fact that the flow optimizations fail to converge.

7.3.3 Errors and Warnings

The HEC-RAS software reports no errors when running the models, however, there are several warnings, as is typical for any HEC-RAS model.

The most common warning in HEC-RAS modelling is related to computation of critical depth. In order to provide a conservative estimate of floodplain elevation, the HEC-RAS model has been run in a subcritical flow regime. In some cases, HEC-RAS is not able to calculate a valid subcritical flow, either due to the cross sectional information, or because the flow regime is truly subcritical, which causes it to default to critical depth and issue a warning message. This is not considered to be a significant issue when generating performing a conservative hydraulic modelling exercise.

There are a number of warnings related to HEC-RAS suggesting a need for additional cross sections. In general, more cross sections are often better, but even with a very high number of cross sections there will often be errors of this nature. In general, as good judgement has been used in the establishment of cross sections, unless there is another reason to suspect an error with the calculation of the water surface profile in this area, errors of this nature are not considered a significant issue.

7.4 Floodplain Mapping

After creating the HEC-RAS model geometry using HEC-GeoRAS and running the flow data from the PCSWMM hydrologic model, the computed water surfaces were exported from HEC-RAS back to HEC-GeoRAS to delineate the flood inundation zone.

HEC-GeoRAS creates a three-dimensional water surface based on the computed elevation of each event flow at each cross section. This water surface is then compared to the LiDAR DEM surface (previously used to generate the HEC-RAS geometry), and the intersection between the two surfaces is delineated as the floodplain for that event. Note that HEC-GeoRAS does not extrapolate the water surface beyond the drawn cross section lines, and so it is important that the initial cross sections are large enough to contain the computed water surfaces, in order to avoid truncating the floodplain.

The resultant floodplain delineations for each storm event for the Junction Creek subwatershed have been plotted on **Figures C6.1 to C6.7** (refer to **Appendix 'C'**). The existing Junction Creek regulatory floodplain boundary, received from CS, has been plotted as well for comparison. In general, the new floodplain mapping for the Regional Timmins event matches well with the existing CS boundary. As the updated floodplain mapping has been computed using updated modelling software, and based on a new hydrologic model, an exact match to the existing mapping is not expected. Some of the irregularities are likely due to the usage of more up-to-date and higher resolution topographic data than the existing mapping. Other differences may be due to changes in stream hydraulics, such as culvert improvements or other changes since previous model development.

As mentioned previously, this Subwatershed Study does not update the legal Regulatory Floodplain boundary maintained by CS; that update is completed through a separate process which will build on the work completed through this Study.

7.5 Culvert & Bridge Analysis

In general, bridge and culvert crossings along a watercourse are one of the most significant engineered influences on the resultant floodplain elevation, and so ensuring that they have adequate capacity, and determining any effects of increasing their capacity, is key to fixing any potential flooding issues along the watercourse.

The existing computing water surface elevations upstream of each crossing are shown in **Tables 7.5.1, 7.5.2, and 7.5.3** below for the Upper Junction Creek, Nolin Creek, and Lower Junction Creek models respectively. In order to determine the effect of each crossing along Junction Creek on the floodplain, a culvert and bridge analysis has been performed. Each bridge and culvert crossing within the HEC-RAS modelling was removed from the model, and the resultant water surface elevations were computed. These water surface elevations were then compared to the existing unaltered model, in order to gauge the sensitivity of the floodplain to that particular crossing. The resulting difference in water surface elevation for the Upper Junction Creek, Nolin Creek, and Lower Junction Creek models are shown in **Table 7.5.4, 7.5.5, and 7.5.6** respectively.

7.6 Creek Daylighting

"Daylighting", with respect to stormwater management planning, refers to the practice of changing an enclosed culvert or other belowground system into an above-ground channel. Typically, this reverts previously buried infrastructure, and returns the watercourse to a more natural state. Daylighting is usually performed to improve riparian habitat availability for local species, as well as for aesthetic improvements associated with a surface watercourse. Additionally, a surface channel may have larger stormwater flow capacity than a buried culvert, depending on its design, and may potentially be used to reduce any upstream flooding issues (in that case, capacity and risk of downstream areas would need to be assessed).

Specific location along Junction Creek have not been assessed in detail for their potential for daylighting, however it is recognized that potential areas for daylighting likely exist within the subwatershed. Daylighting should be considered as a potential option for appropriate culvert improvement and/or replacement related projects within the subwatershed. Where there is a roadway over top of the enclosed culvert, daylighting is not possible (as it would conflict with the road).

It is important to create a stable surface stream when daylighting, to avoid any risk of erosion. Culverts generally have a straight, uniform alignment between two points, as opposed to surface streams which tend to have natural meanders and variations in slope. A detailed design for the day lighted stream should be performed which includes a natural channel design and/or appropriate erosion protection measures. Any potential slope stabilization techniques should be assessed for their habitat creation potential for local species.

Daylighting projects are potentially high cost, and as such should be targeted to have the highest potential ecological benefit. It is important to focus projects to create natural linkages between existing surface watercourses, rather than provide a slight break in an otherwise enclosed system (Jones, 2001).

Table 7.6.1: Upper Junction Creek Crossing Analysis

Reach	Bridge Station	Description	Event Water Surface Elevation (m)												
			1:2 Year		1:5 Year		1:10 Year		1:25 Year		1:50 Year		1:100 Year		Regional
			Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Timmins
Upper 1	17299.81	Spruce/Birch Streets	289.06	289.12	289.14	289.18	289.17	289.21	289.20	289.76	289.55	289.81	289.80	289.84	289.83
	16351.52	Orell Street	285.96	286.51	286.70	287.59	287.36	288.52	288.22	289.76	289.54	289.80	289.79	289.83	289.82
	16014.38	Margaret Street Trail	284.44	284.83	284.95	285.46	285.29	286.11	285.93	286.45	286.39	286.53	286.52	286.61	286.58
	14157.42	O'Neil Drive West	279.60	279.56	279.58	279.60	279.60	279.64	279.63	279.69	279.69	279.72	279.72	279.76	279.84
	12965.63	Donnely Drive	274.59	274.63	274.64	274.67	274.66	274.69	274.68	274.73	274.73	274.77	274.75	274.79	274.87
	12617.83	Carr Avenue	273.99	274.01	274.02	274.03	274.03	274.06	274.05	274.08	274.08	274.09	274.10	274.12	274.17
	11828.6	Matson Road	270.94	270.97	270.99	271.01	271.01	271.07	271.04	271.32	271.29	271.38	271.36	271.44	271.55
	11558.35	Maley Drive	270.33	270.42	270.48	270.61	270.61	270.89	270.80	271.32	271.28	271.38	271.36	271.44	271.53
	11253.31	Old Falconbridge Railway	269.73	269.85	269.91	269.99	269.99	270.44	270.29	271.32	271.28	271.38	271.36	271.44	271.52
	10872.4	Robin Street	267.89	268.24	268.54	268.64	268.64	268.71	268.71	268.77	268.78	268.83	268.83	268.86	269.10
	10575.22	Madison Avenue	266.72	266.94	267.05	267.15	267.14	267.22	267.22	267.29	267.29	267.36	267.36	267.39	267.49
	10106.06	Gary Avenue	264.42	264.47	264.50	264.66	264.66	264.83	264.83	265.07	265.05	265.26	265.27	265.37	266.07
	9926.225	Twin Forks Trail	264.05	264.08	264.11	264.13	264.13	264.16	264.16	264.21	264.18	264.25	264.25	264.41	265.12
Maley	2088.469	Maley Drive	265.21	265.43	265.39	265.62	265.48	265.75	265.61	265.92	265.76	266.05	265.90	266.16	266.78
	1051.964	Gary Avenue Trail	263.79	264.15	264.08	264.47	264.24	264.68	264.44	264.98	264.96	265.02	264.98	265.03	265.26
	552.5201	Madison Avenue	263.32	263.56	263.51	263.74	263.61	263.81	263.74	263.91	263.87	264.08	264.14	264.46	265.18
Upper 2	9540.086	Lansing Avenue	262.57	262.77	262.81	263.01	262.96	263.16	263.17	263.48	263.55	263.88	264.00	264.36	265.04
	8777.025	Lasalle Boulevard	261.88	262.09	262.14	262.33	262.29	262.48	262.48	262.85	262.95	263.25	263.36	263.69	264.61
	8303.139	New Sudbury Railway 1	261.35	261.52	261.59	261.74	261.74	261.88	261.90	262.12	262.21	262.35	262.41	262.53	264.51
	7624.32	Barry Downe Road	260.69	260.84	260.98	261.12	261.14	261.28	261.32	261.54	261.73	261.84	261.90	261.99	263.36
	7543.684	Mall Vehicle Crossover	260.62	260.75	260.87	260.98	261.01	261.12	261.15	261.33	261.56	261.65	261.69	261.75	262.90
	6939.086	New Sudbury Railway 2	260.29	260.41	260.50	260.62	260.63	260.76	260.79	260.97	261.39	261.45	261.47	261.51	262.51
	6730.062	Mountview Crescent Trail	260.17	260.27	260.34	260.45	260.46	260.57	260.61	260.77	261.31	261.35	261.37	261.40	262.37
	6300.411	Attlee Avenue	260.09	260.17	260.21	260.27	260.27	260.33	260.35	260.39	260.43	260.56	260.63	260.70	262.29
	6048.625	Stafford Street Trail	259.74	259.80	259.83	259.88	259.87	259.92	259.94	259.98	260.01	260.11	260.18	260.29	261.86
	5864.298	Arthur Street	259.54	259.60	259.63	259.68	259.68	259.73	259.74	259.79	259.82	259.93	259.98	260.08	260.68
	4882.635	Railway 1	258.70	258.83	258.74	258.76	258.74	258.76	258.78	258.80	258.85	258.94	258.98	259.08	259.28
	3521.141	Railway 2	257.16	257.28	257.34	257.47	257.43	257.66	257.57	257.94	257.86	258.18	258.19	258.18	258.96
Nickeldale	1519.694	Lasalle Boulevard	263.30	263.31	263.34	263.34	263.37	263.36	263.39	263.37	263.41	263.40	263.43	263.42	263.54
Upper 3	1997.857	Notre Dame Railway	256.73	256.94	256.95	257.14	257.04	257.26	257.17	257.40	257.31	257.53	257.41	257.64	258.96
	1469.087	King Street	256.46	256.67	256.68	256.88	256.78	257.01	256.91	257.16	257.06	257.31	257.18	257.44	258.92
	1282.803	Bond Street	256.31	256.52	256.53	256.73	256.63	256.86	256.76	257.01	256.91	257.16	257.03	257.29	258.77
	1193.742	Agnes Street Trail	256.15	256.34	256.36	256.53	256.44	256.65	256.56	256.79	256.70	256.93	256.83	257.06	258.59
	767.3227	Leslie Street	255.57	255.75	255.78	256.00	255.90	256.17	256.06	256.39	256.29	256.58	256.48	256.76	258.49
	368.0284	Mountain Street	255.08	255.36	255.45	255.71	255.61	255.93	255.83	256.21	256.11	256.42	256.33	256.62	258.42

Table 7.6.2: Nolin Creek Crossing Analysis

Reach	Bridge Station	Description	Event Water Surface Elevation (m)												
			1:2 Year		1:5 Year		1:10 Year		1:25 Year		1:50 Year		1:100 Year		Regional
			Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Timmins
Nolin	2414.87	Elm Street	267.56	267.75	267.80	267.93	267.89	268.01	267.98	268.11	268.07	268.17	268.13	268.24	268.36
	2063.12	Nolin Railway 1	263.93	263.92	263.99	265.19	265.12	265.29	265.25	265.35	265.33	265.39	265.37	265.42	265.61
	1766.62	Nolin Railway 2	262.93	263.34	263.47	264.14	264.02	264.24	264.21	264.30	264.28	264.34	264.32	264.38	265.57
	1457.72	Ruisseau Nolin Creek Trail	262.07	262.40	262.48	262.87	262.75	263.20	263.06	263.40	263.33	263.49	263.45	263.58	265.55
	785.36	Beatty Street	259.90	260.17	260.23	260.53	260.43	260.76	260.64	261.09	260.93	261.34	261.19	261.63	265.53
	733.97	Nolin Railway 3	260.00	260.23	260.29	260.55	260.46	260.76	260.66	261.04	260.90	261.26	261.13	261.52	265.53
	651.74	Dufferin Street	259.81	260.05	260.10	260.36	260.27	260.55	260.46	260.84	260.70	261.06	260.93	261.33	265.53
	204.33	Railway/Frood Road	258.64	258.89	258.94	259.23	259.13	259.58	259.41	260.08	259.82	260.47	260.25	260.87	265.52

Table 7.6.3: Lower Junction Creek Crossing Analysis

Reach	Bridge Station	Description	Event Water Surface Elevation (m)												
			1:2 Year		1:5 Year		1:10 Year		1:25 Year		1:50 Year		1:100 Year		Regional
			Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Timmins
Middle 1	23527.96	Broadway Street	253.35	253.63	253.66	253.93	253.83	254.14	254.12	254.54	254.53	254.89	254.92	255.29	258.00
	23204.38	Brady/Douglas Street	253.33	253.56	253.59	253.84	253.75	254.03	254.02	254.40	254.39	254.70	254.74	255.04	256.74
	22768.21	Riverside Drive	252.88	253.07	253.10	253.31	253.23	253.48	253.47	253.83	253.83	254.11	254.14	254.44	256.61
	22526.71	Trail	252.79	252.98	253.00	253.22	253.14	253.39	253.38	253.72	253.71	253.97	253.99	254.29	256.53
	22338.38	Regent Street	252.46	252.70	252.73	252.99	252.90	253.19	253.18	253.56	253.55	253.84	253.86	254.13	256.50
	21977.23	McLeod Street	252.31	252.56	252.58	252.85	252.76	253.04	253.03	253.39	253.38	253.65	253.68	253.92	256.47
	21846.53	Struthers Trail	252.02	252.23	252.25	252.46	252.39	252.62	252.61	252.87	252.86	253.05	253.06	253.22	254.86
	21229.66	Martindale Road	251.64	251.83	251.85	252.03	251.97	252.17	252.16	252.40	252.39	252.56	252.57	252.71	254.35
	19716.22	Kelly Lake Road	250.08	250.30	250.37	250.59	250.55	250.81	250.78	251.08	251.09	251.31	251.35	251.54	253.49
Lily	4746.57	Regent Street	249.33	249.37	249.38	249.51	249.45	249.62	249.58	250.74	250.91	250.74	250.93	250.74	251.70
	4054.35	Martindale Road	249.23	249.27	249.28	249.40	249.34	249.51	249.47	250.67	250.86	250.67	250.88	250.67	251.63
	3157.05	Bouchard Street	248.55	248.57	248.57	248.67	248.62	248.74	248.71	249.53	249.89	249.53	249.92	249.52	250.47
	2245.13	Robinson Trail	248.07	248.12	248.14	248.30	248.26	248.60	248.41	248.54	248.56	248.54	248.56	248.54	248.95
	804.81	Southview Drive	247.42	247.66	247.60	247.97	247.77	248.13	247.98	248.29	248.23	248.35	248.31	248.39	248.93
Middle 2	12016.81	Fielding Road	246.32	246.56	246.49	246.77	246.59	246.91	246.73	247.09	246.90	247.25	247.04	247.40	248.30
	11190.69	Trans Canada Highway	243.72	243.99	243.92	244.20	244.02	244.34	244.15	244.53	244.33	244.69	244.48	244.86	245.75
	9389.62	Mikkola Road	241.35	241.62	241.55	241.86	241.65	242.00	241.81	242.13	241.99	242.26	242.08	242.40	243.24
	6477.04	Black Lake Road	235.66	235.96	235.90	236.30	236.06	236.63	236.37	237.17	236.85	237.73	237.27	238.28	242.58
Lower	330.79	Reserve Road	234.35	234.98	235.00	235.76	235.42	236.37	236.05	237.06	236.69	237.68	237.19	238.24	242.57

Table 7.6.4: Upper Junction Creek Water Surface Change with Crossing Removal

Reach	Upstream Station	Description	Change in Event Water Surface Elevation with Removal of Crossing (m)												
			1:2 Year		1:5 Year		1:10 Year		1:25 Year		1:50 Year		1:100 Year		Regional
			Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Timmins
Upper 1	17331.36	Spruce/Birch Streets	-0.03	0.06	0.10	0.07	0.11	-0.10	-0.19	0.01	0.01	0.00	0.00	0.00	0.00
	16373.48	Orell Street	-0.59	-1.02	-1.18	-1.93	-1.76	-2.36	-2.22	-3.28	-3.12	-3.23	-3.24	-3.18	-3.20
	16029.39	Margaret Street Trail	-0.30	-0.58	-0.68	-1.11	-0.96	-1.70	-1.54	-1.97	-1.93	-2.01	-2.01	-2.04	-2.03
	14167.21	O'Neil Drive West	-0.63	-0.56	-0.57	-0.56	-0.56	-0.56	-0.56	-0.55	-0.56	-0.56	-0.56	-0.56	-0.54
	12983.74	Donnely Drive	-0.25	-0.24	-0.24	-0.25	-0.24	-0.22	-0.22	-0.21	-0.23	-0.22	-0.21	-0.21	-0.19
	12626.69	Carr Avenue	-0.57	-0.56	-0.55	-0.54	-0.54	-0.53	-0.53	-0.50	-0.51	-0.48	-0.50	-0.48	-0.44
	11841.78	Matson Road	-0.59	-0.53	-0.49	-0.39	-0.39	-0.17	-0.23	0.00	0.00	0.00	0.01	0.01	-0.01
	11587.87	Maley Drive	-0.12	-0.02	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
	11261.59	Old Falconbridge Railway	-0.70	-0.79	-0.84	-0.90	-0.90	-1.32	-1.17	-2.17	-2.14	-2.21	-2.20	-2.26	-2.28
	10886.26	Robin Street	-0.41	-0.66	-0.90	-0.94	-0.95	-0.95	-0.95	-0.91	-0.93	-0.90	-0.89	-0.89	-0.71
	10611.49	Madison Avenue	0.02	-0.12	-0.18	-0.22	-0.21	-0.21	-0.21	-0.17	-0.18	-0.14	-0.14	-0.14	-0.03
	10121.9	Gary Avenue	0.02	0.03	0.02	-0.10	-0.10	-0.23	-0.23	-0.42	-0.40	-0.56	-0.57	-0.64	-0.86
	9935.841	Twin Forks Trail	-0.02	0.02	0.01	0.04	0.04	0.05	0.05	0.05	0.08	0.03	0.04	0.07	0.01
Maley	2110.753	Maley Drive	0.04	0.05	0.05	0.01	0.04	-0.03	0.02	-0.09	-0.04	-0.13	-0.09	-0.19	-0.60
	1056.255	Gary Avenue Trail	0.00	-0.04	-0.02	-0.14	-0.07	-0.24	-0.13	-0.44	-0.51	-0.42	-0.42	-0.31	-0.01
	570.796	Madison Avenue	0.03	0.03	0.04	0.03	0.04	0.04	0.03	0.03	0.03	0.01	0.01	-0.01	-0.05
Upper 2	9565.417	Lansing Avenue	-0.01	-0.06	-0.07	-0.13	-0.11	-0.17	-0.18	-0.28	-0.30	-0.41	-0.45	-0.58	-0.31
	8799.811	Lasalle Boulevard	-0.10	-0.14	-0.15	-0.19	-0.17	-0.24	-0.23	-0.44	-0.48	-0.66	-0.73	-0.95	-0.02
	8324.466	New Sudbury Railway 1	0.00	-0.02	-0.02	-0.04	-0.04	-0.06	-0.06	-0.10	-0.11	-0.13	-0.14	-0.17	-0.95
	7648.655	Barry Downe Road	0.06	0.06	0.06	0.05	0.05	0.06	0.06	0.05	0.03	0.03	0.03	0.03	-0.06
	7555.253	Mall Vehicle Crossover	0.02	0.02	0.01	0.01	0.00	-0.01	-0.01	-0.04	-0.05	-0.07	-0.09	-0.10	-0.39
	6949.916	New Sudbury Railway 2	-0.01	-0.01	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
	6735.047	Mountview Crescent Trail	-0.03	-0.04	-0.06	-0.09	-0.10	-0.13	-0.15	-0.23	-0.73	-0.65	-0.61	-0.56	-0.01
	6323.053	Attlee Avenue	0.00	0.00	-0.01	0.00	-0.01	0.00	-0.01	0.00	-0.01	-0.02	-0.02	0.02	-0.16
	6055.51	Stafford Street Trail	0.00	0.00	-0.01	-0.01	0.00	0.00	-0.01	0.00	0.00	0.00	-0.02	-0.04	-0.96
	5879.601	Arthur Street	-0.04	-0.06	-0.06	-0.08	-0.08	-0.09	-0.09	-0.12	-0.13	-0.16	-0.18	-0.23	-0.19
	4891.29	Railway 1	-0.85	-0.95	-0.83	-0.82	-0.80	-0.79	-0.81	-0.77	-0.84	-0.75	-0.78	-0.88	-0.32
	3543.166	Railway 2	-0.14	-0.23	-0.28	-0.30	-0.32	-0.38	-0.37	-0.53	-0.53	-0.63	-0.76	-0.53	0.00
Nickeldale	1554.479	Lasalle Boulevard	-3.02	-3.01	-3.01	-3.01	-3.01	-3.01	-3.00	-3.00	-2.99	-3.00	-2.99	-3.00	-2.98
Upper 3	2014.724	Notre Dame Railway	0.00	-0.01	-0.03	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00
	1492.274	King Street	0.11	0.10	0.08	0.10	0.09	0.09	0.09	0.08	0.08	0.07	0.08	0.06	-0.05
	1300.804	Bond Street	0.05	0.05	0.02	0.04	0.04	0.03	0.04	0.03	0.04	0.02	0.03	0.02	-0.12
	1209.752	Agnes Street Trail	-0.02	-0.03	-0.06	-0.03	-0.03	-0.04	-0.03	-0.03	-0.02	-0.02	-0.03	-0.02	-0.04
	787.4537	Leslie Street	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	-0.01
	403.1859	Mountain Street	0.03	0.03	0.00	0.02	0.02	0.01	0.01	0.00	0.01	0.00	0.00	-0.01	-0.22

Table 7.6.5: Nolin Creek Water Surface Change with Crossing Removal

Reach	Upstream Station	Description	Event Water Surface Elevation (m)												
			1:2 Year		1:5 Year		1:10 Year		1:25 Year		1:50 Year		1:100 Year		Regional
			Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Timmins
Nolin	2443	Elm Street	-0.24	-0.28	-0.29	-0.25	-0.26	-0.21	-0.22	-0.18	-0.21	-0.15	-0.14	-0.18	-0.14
	2073.24	Nolin Railway 1	-0.79	-0.44	-0.40	-1.03	-1.08	-1.03	-1.02	-1.02	-1.02	-1.01	-1.02	-1.00	-0.03
	1776.75	Nolin Railway 2	-0.35	-0.61	-0.69	-1.10	-1.07	-0.93	-1.03	-0.80	-0.85	-0.74	-0.77	-0.69	-0.01
	1491.59	Ruisseau Nolin Creek Trail	-0.60	-0.81	-0.87	-1.14	-1.05	-1.37	-1.27	-1.43	-1.42	-1.41	-1.44	-1.35	0.00
	805.69	Beatty Street	0.22	0.16	0.15	0.10	0.12	0.06	0.09	0.00	0.03	-0.04	-0.02	-0.09	0.00
	742.14	Nolin Railway 3	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	661.04	Dufferin Street	0.05	0.05	0.04	0.03	0.04	0.01	0.02	-0.04	-0.02	-0.07	-0.05	-0.11	0.00
	231.83	Railway/Frood Road	0.20	0.16	0.16	0.11	0.13	-0.06	0.02	-0.32	-0.18	-0.56	-0.42	-0.83	-4.55

Table 7.6.6: Lower Junction Creek Water Surface Change with Crossing Removal

Reach	Upstream Station	Description	Event Water Surface Elevation (m)												
			1:2 Year		1:5 Year		1:10 Year		1:25 Year		1:50 Year		1:100 Year		Regional
			Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Timmins
Middle 1	23559.97	Broadway Street	0.22	0.15	0.14	0.10	0.12	0.06	0.07	0.00	0.01	-0.08	-0.08	-0.18	-1.20
	23332.97	Brady/Douglas Street	0.07	0.05	0.04	0.01	0.02	-0.02	-0.02	-0.08	-0.08	-0.13	-0.15	-0.19	-0.04
	22785.45	Riverside Drive	0.10	0.10	0.09	0.09	0.10	0.08	0.08	0.04	0.03	0.00	-0.01	-0.04	-0.01
	22534.72	Trail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.05	-0.02
	22356.42	Regent Street	0.04	0.01	0.01	-0.01	0.00	-0.03	-0.04	-0.08	-0.08	-0.11	-0.11	-0.14	-0.01
	22015.97	McLeod Street	-0.04	-0.07	-0.07	-0.12	-0.10	-0.16	-0.16	-0.25	-0.24	-0.32	-0.33	-0.41	-1.35
	21851.56	Struthers Trail	0.00	-0.01	0.00	0.00	0.00	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	-0.04
	21247.21	Martindale Road	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	-0.37
	19738.3	Kelly Lake Road	0.05	0.03	0.03	0.00	0.00	-0.05	-0.04	-0.11	-0.10	-0.16	-0.16	-0.21	-1.06
Lily	4801.19	Regent Street	0.03	0.03	0.03	0.02	0.03	0.01	0.02	-0.01	-0.01	-0.01	0.00	-0.01	-0.04
	4094.81	Martindale Road	0.03	0.02	0.02	0.03	0.03	0.02	0.02	-0.14	-0.20	-0.14	-0.21	-0.14	-0.32
	3172.08	Bouchard Street	0.18	0.18	0.19	0.19	0.19	0.17	0.20	0.16	-0.11	0.16	-0.13	0.17	-0.37
	2250.17	Robinson Trail	-0.14	-0.16	-0.17	-0.28	-0.22	-0.44	-0.37	-0.20	-0.24	-0.16	-0.19	-0.12	-0.01
	826.54	Southview Drive	0.10	0.03	0.09	-0.13	0.01	-0.22	-0.13	-0.26	-0.31	-0.22	-0.31	-0.16	0.00
Middle 2	12030.4	Fielding Road	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.04
	11200.83	Trans Canada Highway	-0.15	-0.17	-0.17	-0.17	-0.17	-0.16	-0.16	-0.17	-0.17	-0.19	-0.17	-0.20	-0.27
	9405.98	Mikkola Road	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
	6492.06	Black Lake Road	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Lower	353.17	Reserve Road	-0.23	-0.02	-0.02	0.01	0.01	0.00	0.01	0.00	0.00	-0.04	-0.01	0.00	0.00

A summary of those crossings which are projected to have a net water surface reduction of greater than 0.30 m when they are removed from the HEC-RAS model is displayed in **Table 7.5.7** below. For the sake of consistency, all of the culvert crossings have been analysed considering a 1:25 year event, which is a typical design event for local roads with spans greater than 6 m, as per the *Ministry of Transportation and Communications Directive B-100: M.T.C. Design Flood Criteria* (MTO, 1980). The table provides a conceptual circular pipe culvert configuration to convey the 25 year design flow.

Table 7.6.7: Junction Creek Culvert Crossing Improvement Cost Benefit Summary

Reach	ID	Description	1:25 Year Water Surface Reduction (m)	Flow (m^3/s)	Length (m)	Slope (%)	Req. Diameter (mm)	Req. No. of Culverts	Capacity (m^3/s)	% Full (%)	Relative Costing ($)
Upper 1	16351.52	Orell Street	1.93	15.75	35.0	0.23	2700	2	18.32	86.0	$710,031
Upper 1	16014.38	Margaret Street Trail	1.11	15.75	15.5	0.65	2550	1	20.26	77.8	$141,565
Upper 1	14157.42	O'Neil Drive West	0.56	18.44	15.4	5.12	2100	1	22.19	83.1	$93,961
Upper 1	12617.83	Carr Avenue	0.54	18.44	12.0	0.58	2700	1	22.43	82.2	$121,720
Upper 1	11828.6	Matson Road	0.39	18.44	15.1	0.60	2400	2	21.60	85.4	$244,892
Upper 1	11253.31	Old Falconbridge Railway	0.90	18.44	13.5	1.19	2400	1	23.38	78.9	$109,269
Upper 1	10872.4	Robin Street	0.94	12.65	15.6	0.45	3000	1	16.97	74.5	$194,390
Nic	4882.635	Railway 1	0.82	27.21	N/A - No culvert present, difference due to length of railway						
Nic	3521.141	Railway 2	0.30	16.58	18.0	0.36	2250	2	21.55	76.9	$249,479
Nic	1519.694	Lasalle Boulevard	3.01	11.29	170.0	0.04	3000	2	14.62	77.2	$4,225,860
Nolin	2063.12	Nolin Railway 1	1.03	24.03	17.0	1.91	2400	1	29.64	81.1	$138,056
Nolin	1766.62	Nolin Railway 2	1.10	24.03	11.3	0.62	3000	1	30.62	78.5	$140,448
Nolin	1457.72	Ruisseau Nolin Creek Trail	1.14	24.03	15.5	0.52	3000	1	27.94	86.0	$192,774

Note: Nic = Nickeldale

Costs for culvert upgrades have been estimated using the same approach as has been applied for the storm sewer analysis which follows in **Section 8.2.6**. Costs have been estimated as three (3) times the required pipe supply cost (based on a 2017 price list for 65-D concrete pipe) in order to account for installation, resurfacing of the roads, and other associated costs. Culverts have been sized using a simple Manning's formula calculation to provide the required design flow (using the minimum number of pipes required), and a more detailed hydraulic modelling analysis should be completed at a detailed design stage for any culvert improvements.

8.0 DRAINAGE SYSTEM PERFORMANCE ASSESSMENT

8.1 Standards

Stormwater management facilities have been implemented within the CGS since the 1960's. The CGS is in the process of creating a Municipal Document with standards for Stormwater Management, however the CGS Official Plan – Stormwater Background Study from 2006, provides valuable information and policies regarding stormwater management. Provincially, requirements for stormwater quantity control practices first became common during the late 1970's and early 1980's, and formal standards for stormwater quality control were first implemented in 1991 with draft policies, and then in 1994 (subsequently updated in 2003) when guidelines were issued.

The CGS's current IDF curves were developed using rainfall data collected by Environment Canada, at Sudbury Airport and Science North. The data from both sites were integrated to extend the record for 43 years. The data from both sites were combined to the CGS's current IDF parameters are described in detail in the **Section 3.3.4.1**.

Current practice for stormwater management system design requires the design of a major-minor drainage system (overland and subsurface networks). The minor system for stormwater conveyance infrastructure is intended to convey runoff from the more frequent storm events in such a manner as to minimize or prevent nuisance flooding of the surface system. Typically, the minor system consists of storm sewers, swales, gutters and catchbasins within urban areas, and ditches and swales within rural areas. The majority of these systems are located within the public right-of way in order to allow the CGS which owns the systems, access for maintenance, repair, or replacement. While storm sewers may also be located on private properties (i.e. under parking lots, between adjacent residential properties), the maintenance requirements are generally the responsibility of the property owner in the case of commercial or institutional properties, or else are done in response to concerns from the public in the case of residential properties, and are thus not included within the CGS's maintenance program. All minor storm systems within the CGS are currently required to be designed to a 2 year design storm standard for local streets, and to a 5 year design storm standard for trunk storm sewers and collector streets, as per the CGS's *Engineering Design Manual* (CGS, 2012).

The major system for stormwater infrastructure is intended to convey runoff from the less frequent storm events in such a manner as to minimize flooding of private properties and prevent flooding of structures during these storm events. The major system is generally comprised of natural streams, valleys, constructed channels, ponds, and roads, and represents the routes of the storm runoff during events which exceed the capacity of the minor system (i.e. events above the 5 year standard). The major system is required to be designed in order to convey runoff from the Regulatory Storm event, which for Sudbury is the greater of the 100 year or the Regional Storm (the Timmins storm).

8.2 Major/Minor System Modelling

8.2.1 Modelling Platform & Setup

Hydrologic and hydraulic analyses of the CGS's major and minor system have been completed using the PCSWMM software platform. The following objectives for the selection of the modelling platform have been used:

1. The platform should be a singular tool for assessing hydrology, minor and major system hydraulics, and stormwater quantity and quality facility functions.
2. The platform should have the flexibility to be used under event based and continuous hydrologic modelling approaches.
3. The hydrologic continuous simulation should provide output to assess annual water balance.
4. The platform should allow for the modelling of at-source, conveyance, and end-of-pipe best stormwater management BMPs for both water quantity and quality assessment, including Low Impact Development (LID) techniques.
5. The hydraulic model should allow for the assessment of variable hydraulic systems, such as creeks, storm systems and stormwater management infrastructure.
6. The platform should allow for easy import and export of stormwater management infrastructure data from and to typical database utilities and be compatible with GIS and AutoCAD^{TM}.
7. The platform should be easily upgradable and customizable to serve future CGS stormwater management infrastructure design and assessment.

The PCSWMM software combines hydrologic modelling to generate storm runoff response (i.e. hydrographs) from land areas, with hydraulic modelling to evaluate water surface elevations and velocities within the conveyance system (i.e. sewers, road surfaces, open watercourses, culverts). The integration of hydrologic and hydraulic analyses allows PCSWMM to account for detention in ponding areas, backflow in pipes, surcharging of manholes, tailwater conditions (which may affect upstream storage and flow capacity within pipes), capacity at inlets to the sewer network (which would reduce the amount of runoff entering the sewer network and increase the amount of runoff conveyed overland during storm events), and depth of flooding of overland conveyance systems; these capabilities of the PCSWMM software make it particularly well-suited for analyzing urban drainage systems.

The model applies the Event Methodology for single storm events, where synthetic design storms are typically used in order to evaluate flood frequency or risk. The model is capable of accounting for various conditions at outlets (i.e. open/unobstructed/free-flowing, partially/completely submerged to a constant depth, time-varying depth conditions, gated conditions). The hydraulic routing component within PCSWMM can be completed for unsteady state (i.e. time-varying flow) conditions using Kinematic Wave or Dynamic Wave routing techniques. The numerical stability of the PCSWMM platform allows for complex networks and systems to be readily modelled in the unsteady state condition, with little to no requirement for network simplification.

PCSWMM employs the EPA-SWMM engine as its base, thus modelling files created in PCSWMM can be opened and executed within the EPA-SWMM program as well as PCSWMM. This also provides an additional degree of reliability and quality assurance to the modelling program.

The PCSWMM software requires the following input data for completing a coupled hydrologic and hydraulic analysis:

- Areas and directly connected impervious coverages for the land segments contributing to the conveyance system of interest.
- Soils information (infiltration parameters) for the soils underlying the land segments, including initial abstraction.
- Surface slopes for the contributing drainage areas.
- Land use characteristics for both the pervious and impervious components of the land segments in order to establish the "roughness" of the surface.
- Length, size, and inverts of the sewer network.
- Material of the sewer network.
- Manhole rim elevations.
- Typical cross-section and elevations of the surface drainage system (i.e., roads).
- Locations of sewer inlets (catchbasins, ditch inlets).
- Elevation and surface area relationships for surface storage zones (i.e., channels or designated off-line storage areas).

The PCSWMM storm sewer network has been created based upon the following information, provided by the CGS for the development of the major/minor system models:

- GIS database of the CGS's storm sewers, manholes, and catchbasins
- Key Plans of storm sewer infrastructure (provided by the CGS)
- As-built drawings of stormwater infrastructure (provided by the CGS)
- Site servicing plans for key properties (provided by the CGS)
- Various stormwater management reports (provided by the CGS and CS).
- Property boundary mapping (provided by the CGS)
- Provincial Land Cover mapping from the Ministry of Natural Resources and Forestry
- High resolution Digital Elevation Model (DEM) LiDAR data (provided by the CGS)
- Watercourse mapping (provided by CS)
- Mapping of the roads within the CGS (provided by the CGS)

A considerable effort has been spent to gather, assess, and gap fill missing data in order to ensure that the integrated model data is reasonable and correct. This has primarily consisted of obtaining correct storm sewer and manhole data. In both cases, as-built drawings have been used extensively to verify and update erroneous information. Approximately 500 as-built drawings were obtained and reviewed for this purpose, primarily for gap filling and verification, as well as to update recent sewer works from the past several years that were not included in the original database supplied by the CGS. Despite these efforts, there remain some areas of the CGS for which storm sewer information, primarily manhole rim and invert elevations, were not available. These elements have been approximated in the PCSWMM modelling using interpolation, or assigned a "typical" slope based on similar sewers in the network, and an appropriate description has been added to these elements in the GIS database.

The sewer database has been reviewed in order to identify and map the entire CGS's trunk sewers to be modelled (i.e. sewers greater than 900 mm). Catchment boundaries for the CGS's sewer network have been developed based upon the sewer locations and the LiDAR, key plan, and as-built data provided by the CGS. Based on this process, a total of 36 sewershed networks have been identified for modelling, as shown on **Figure C7** (refer to **Appendix 'C'**).

In order to facilitate drainage network identification, a standard naming convention has been applied. The first one or two letters of the drainage network refer to the neighbourhood in which it is found, with networks within each neighbourhood then numbered sequentially. The identified neighbourhood areas are as follows:

- G – Garson
- NS – New Sudbury
- FM – Flour Mill
- D – Donovan
- DW – Downtown
- GT – Gatchel
- SE – South End
- L – Lively

8.2.2 Analysis Approach

A discussion of the various modelling parameters and techniques utilized for the previously identified sewershed network areas is provided within this section of the report:

General Approach

- An event based methodology has been applied, with the CGS's standard 2, 5, 10, 25, 50, and 100 year design storms (Chicago storms with variable durations of approximately 6 hours, as per the *City of Greater Sudbury Official Plan Stormwater Background Study* dated January 2006, and as described in **Section 3.3.4** above.

Hydrologic Parameters

- Slopes and overland flow lengths have been calculated using the provided DEM and aerial imagery.

- Manning's roughness coefficients of 0.013 and 0.2 have been applied for impervious and pervious catchment portions respectively.
- Depression storage values of 1.3 and 7.6 mm have been applied for impervious and pervious catchment portions respectively, based on previous project experience in the Sudbury area.
- The recommended default value of 25% has been applied for the zero depression storage imperviousness ratio (the portion of the impervious area with no depression storage).
- The Curve Number infiltration methodology has been applied.
- Total Imperviousness and Curve Number (the values required by PCSWMM) were calculated based on standard assumed values for different land uses, based on previous project experience in the Sudbury area. These starting values were then later adjusted as part of the hydrologic calibration process, as detailed in **Section 6.3.2**.

Hydraulic Parameters

- Hydraulic elements (storm sewers and manholes) have been imported directly into PCSWM from the GIS database. The resulting data as then been screened for errors or missing data, with as-built drawings used principally to fill data gaps.
- A roughness value of 0.013 has been applied for concrete and PVC sewers, and a value of 0.023 has been applied for CSP sewers.
- Conduit exit losses have been applied to account for the hydraulic losses associated with sharp bends. Head loss coefficients from US Federal Highway Administration (FHWA) Hydraulic Engineering Centre No.22 (HEC-22) design manual have been applied for this purpose.

Stormwater Management Facilities

- In general, end-of-pipe stormwater management facilities were not considered as part of the modelling effort.
- Facilities that are located within a sewershed network such that they discharge back into the storm sewer system have necessarily been included in order to properly account for their impact.
- Stage-storage-discharge information for these facilities has been based on a review of as-built drawings, and information provided by the CGS.

Dual Drainage Model Creation

- A generic 2-lane and 4-lane road section have been applied for major system modelling, based on an assumed 4 m lane width, 2% cross-fall, 0.15 m curb height, and 2% right-of-way slope. These values appear to be generally representative of roadway values found within the CGS. Additional cross sections have been used in individual cases where conditions dictate.
- Orifice functions have been used to represent the connection between the surface and sub-surface drainage systems (catchbasins). An opening of 0.35 m x 0.35 m has been assumed for each catchbasin. Accordingly, the total number of catchbasins in each subcatchment have been calculated using the GIS database information and as-built drawings, to determine each orifice size in the model.

8.2.2.1 *Model Boundary Conditions – Tailwater Analysis*

Generally, storm sewer analysis is completed assuming that there is an open, or free, tailwater condition at the sewer outlet. Within the CGS, particularly near the Ponderosa wetland area, there are several sewer outlets which are within the 5 year floodplain extent. In other words, these sewer outlets are submerged during the design storm event for which they are designed, which is likely to cause flooding regardless of the capacity of the sewer system.

The total extent of the 5 year floodplain relative to the modelled trunk sewers is shown on **Figure C8** (refer to **Appendix 'C'**). The elevation of each trunk storm sewer outfall relative to each of the 2 year and 5 year events is shown in **Table 8.2.1** below. Sewer outfalls located below the 5 year event flood elevation in Junction Creek will not be able to function as design during the 5 year event. This has not been assessed directly in the modelling, but is intended to provide an additional consideration when prioritizing upgrades to trunk storm sewer networks.

Table 8.2.1: Storm Sewer Outfall to Minor Event Floodplain Comparison

Outlet	Invert	Receiving Watercourse			Event Water Surface Elevation (m)				Outlet Invert vs. 5 Year Water Surface
		HEC-RAS			1:2 Year		1:5 Year		
		River	Reach	Station	Chi	SCS	Chi	SCS	
D-1	259.95	Nolin	Nolin	928.98	260.30	260.51	260.55	260.80	-0.85
D-2	—	Nolin	Nolin	661.04	259.81	260.05	260.10	260.36	-260.36
FM-1	257.86	Nickeldale	Nickeldale	745.6761	256.82	256.97	256.98	257.16	0.70
FM-2	255.19	Junction Creek	Upper 3	2014.724	256.73	256.94	256.95	257.14	-1.95
FM-3	254.98	Junction Creek	Upper 3	1890.508	256.72	256.93	256.94	257.14	-2.16
FM-4	254.95	Junction Creek	Upper 3	1890.508	256.72	256.93	256.94	257.14	-2.19
FM-5	255.27	Junction Creek	Upper 3	1549.371	256.56	256.78	256.79	257.00	-1.73
FM-6	254.71	Junction Creek	Upper 3	1174.399	256.00	256.21	256.22	256.42	-1.71
G-2	284	Junction Creek	Upper 1	16474.75	285.97	286.52	286.71	287.60	-3.60
G-3	284.4	Junction Creek	Upper 1	16373.48	285.96	286.51	286.70	287.59	-3.19
GT-1	250.43	Junction Creek	Middle 1	22857.71	253.16	253.35	253.38	253.59	-3.16
GT-2	251.44	Junction Creek	Middle 1	21851.56	252.02	252.23	252.25	252.46	-1.02
GT-3	250.5	Junction Creek	Middle 1	21188.27	251.67	251.85	251.88	252.06	-1.56
GT-4	249.36	Junction Creek	Middle 1	20493.69	251.25	251.40	251.42	251.59	-2.23
L-1	242.69	Junction Creek	Middle 2	9250.51	241.04	241.17	241.12	241.31	1.38
L-2	234.57	Junction Creek	Lower	3955.05	235.09	235.37	235.36	235.92	-1.35
NS-1	264.61	Maley	Maley	700.782	263.41	263.66	263.62	263.86	0.75
NS-2	260.97	Junction Creek	Upper 2	9115.994	262.18	262.34	262.37	262.51	-1.54
NS-3	260.28	Junction Creek	Upper 2	8799.811	261.88	262.09	262.14	262.33	-2.05
NS-4	260.24	Junction Creek	Upper 2	8799.811	261.88	262.09	262.14	262.33	-2.09
NS-5	259.78	Junction Creek	Upper 2	7939.164	260.98	261.13	261.26	261.39	-1.61
NS-6	260.89	Junction Creek	Upper 2	6515.994	260.12	260.20	260.25	260.32	0.57
NS-7	260.13	Junction Creek	Upper 2	7648.655	260.69	260.84	260.98	261.12	-0.99
NS-8	258.33	Junction Creek	Upper 2	5363.508	258.75	258.86	258.77	258.79	-0.46

Outlet	Invert	Receiving Watercourse			Event Water Surface Elevation (m)				Outlet Invert vs. 5 Year Water Surface
		HEC-RAS			1:2 Year		1:5 Year		
		River	Reach	Station	Chi	SCS	Chi	SCS	
NS-9	257.17	Nickeldale	Nickeldale	1370.487	258.44	258.45	258.50	258.50	-1.33
NS-10	255.04	Nickeldale	Nickeldale	1160.644	257.67	257.69	257.75	257.74	-2.71
SE-1	248.14	Lily Creek	Lily	5170.92	249.35	249.39	249.40	249.52	-1.38
SE-2	248.16	Lily Creek	Lily	2974.23	248.14	248.18	248.19	248.33	-0.17
SE-3	247.78	Lily Creek	Lily	1970.92	247.53	247.70	247.72	247.99	-0.21
SE-4	259.7	N/A (Nepahwin)	—	—	N/A	N/A	N/A	N/A	N/A
SE-5	259.57	N/A (Nepahwin)	—	—	N/A	N/A	N/A	N/A	N/A
DW-1	253.09	Box Culvert	—	—	N/A	N/A	N/A	N/A	N/A
DW-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DW-3	253.86	Junction Creek	Upper 3	203.1759	255.04	255.31	255.41	255.66	-1.80
DW-4	254.932	Box Culvert	—	—	N/A	N/A	N/A	N/A	N/A
DW-5	251.173	Junction Creek	Middle 1	23730.3	253.89	254.09	254.11	254.34	-3.17
DW-6	255.41	Box Culvert	—	—	N/A	N/A	N/A	N/A	N/A

In some cases, the results of **Table 8.2.1** and **Figure C8**, do not match exactly, in that a sewer outfall may be below the 5 year event floodplain elevation in the table, yet appear outside of the floodplain in plan on the drawing. This is likely due to imperfections in the LiDAR data, and the fact that as the LiDAR does not penetrate water, small tributaries and depressions surrounding storm sewer outfalls are sometimes not reflected in the resultant surface and are therefore not included by HEC-GeoRAS during floodplain mapping (as described in **Section 7.4** above).

8.2.3 Minor System Assessment

The hydrologic/hydraulic analyses have been completed specifically in order to identify deficiencies within the CGS's trunk sewer network, based upon simulated incidences of flooded manholes and/or surcharged sewers within the CGS's minor system during a 5 year and 100 year storm event, with particular emphasis upon the occurrence of flooding during the former. A minor system only model (pipes only – no overland component) has been used for this assessment, with an event methodology (CGS's standard 5 year design storm). Digital copies of the modelling files have been provided to the CGS. Results are summarized by percentage below in **Table 8.2.2** below. Results have been sorted by sewer network, as described in **Section 8.2.1**., and are summarized graphically on **Figures C9.1** to **C9.8** (refer to **Appendix 'C'**).

Table 8.2.2: Minor Storm System Simulated Performance Summary

System	Drainage Area *(ha)*	5 Year Event Analysis			
		Sewer Length *(m)*	Percent Unsurcharged	Percent Surcharged	Percent Flooded
G-2	17.1	28.3	100.0%	0.0%	0.0%
G-3	8.2	86.0	100.0%	0.0%	0.0%
NS-1	28.2	219.8	35.5%	64.5%	0.0%

System	Drainage Area *(ha)*	5 Year Event Analysis			
		Sewer Length *(m)*	Percent Unsurcharged	Percent Surcharged	Percent Flooded
NS-2	24.8	386.8	98.3%	1.7%	0.0%
NS-3	27.8	424.1	100.0%	0.0%	0.0%
NS-4	55.0	464.6	83.0%	17.0%	0.0%
NS-5	122.7	1606.5	79.9%	20.1%	0.0%
NS-6	144.7	1894.6	39.7%	45.3%	15.0%
NS-7	108.0	500.7	0.0%	13.0%	87.0%
NS-8	48.6	536.7	66.6%	33.4%	0.0%
NS-9	28.2	555.5	100.0%	0.0%	0.0%
NS-10	16.0	407.9	0.0%	50.8%	49.2%
FM-1	39.4	356.1	0.0%	0.0%	100.0%
FM-2	50.0	538.3	0.0%	69.5%	30.5%
FM-3	95.6	1196.6	0.0%	14.2%	85.8%
FM-4	8.6	286.3	0.0%	100.0%	0.0%
FM-5	36.1	275.0	0.0%	0.0%	100.0%
FM-6	31.7	123.1	0.0%	100.0%	0.0%
D-1	109.9	792.2	59.8%	0.7%	39.5%
D-2	70.9	1414.4	54.2%	42.0%	3.8%
DW-1	76.4	1614.6	94.1%	5.9%	0.0%
DW-2	180.2	N/A	N/A	N/A	N/A
DW-3	18.3	145.4	0.0%	57.7%	42.3%
DW-4	21.0	285.9	100.0%	0.0%	0.0%
DW-5	26.5	66.8	46.4%	53.6%	0.0%
DW-6	29.9	68.1	0.0%	34.7%	65.3%
GT-1	52.8	503.3	100.0%	0.0%	0.0%
GT-2	32.0	324.5	100.0%	0.0%	0.0%
GT-3	37.2	650.4	100.0%	0.0%	0.0%
GT-4	41.0	1104.1	100.0%	0.0%	0.0%
SE-1	23.7	354.3	30.4%	69.6%	0.0%
SE-2	58.2	494.1	25.4%	14.6%	60.0%
SE-3	34.9	326.0	100.0%	0.0%	0.0%
SE-4	37.4	550.8	100.0%	0.0%	0.0%
SE-5	187.4	1044.5	23.5%	33.8%	42.7%
L-1	50.8	213.6	100.0%	0.0%	0.0%
L-2	77.7	107.8	0.0%	100.0%	0.0%

The results presented in **Table 8.2.2** indicate a significant number of sewershed networks with high percentages of simulated surcharging and flooding under the 5-year event.

Note that this analysis assumes an unrestrained outlet condition, and represents the capacity of the sewers if they were allowed to flow freely. In addition to the flooded sewers listed above, sewer outfalls located within or below the 1:5-year event floodplain (refer to **Table 8.2.1** above and **Figure C8** in **Appendix 'C'**) are also highly likely to be flooded during these events.

8.2.4 Major System Assessment

The results of the PCSWMM hydrologic/hydraulic analyses for major overland flow have been reviewed in order to identify the incidences of flooding of the major system (i.e. roadways) during sever storm events. Current practice for drainage system design provides for safe and positive conveyance of flows within road right-of-ways (i.e. conveyance of flows overland within the public right-of-way and outside of private properties) during less frequent storms. As such, this assessment has considered the depth of flooding within the right-of-way during the 100 year storm event in order to evaluate the risk of flooding to private properties during the design event for overland storm conveyance. The depths of flooding have been subdivided into specific ranges, corresponding approximately to the key stages associated with the height of the curb along the urban roadways, and associated flood risks or hazards associated with the road right-of-way, and the potential for flooding of adjacent private properties. The calibrated sewershed network models previously discussed have been used for this purpose. A dual drainage system model (storm sewers and roadways) has been used for this assessment, with an event methodology (CGS's standard 100-year design storm). Digital copies of the modelling files have been provided to the CGS. Again, results have been sorted by sewer network, as described in **Section 8.2.1**, and are summarized graphically on **Figures C10.1 to C10.8** (refer to **Appendix 'C'**).

Table 8.2.3: Major Storm System Simulated Performance Summary

System	**Drainage Area** *(ha)*	**100 Year Event Analysis**			
		Road Length *(m)*	**Percent <0.15m**	**Percent 0.15 - 0.25 m**	**Percent >0.25 m**
NS-1	25.5	179.1	43.6%	56.4%	0.0%
NS-2	5.3	254.5	100.0%	0.0%	0.0%
NS-3	24.4	260.1	86.2%	13.8%	0.0%
NS-4	54.6	1460.3	92.3%	7.7%	0.0%
NS-5	112.4	1560.5	45.5%	39.2%	15.3%
NS-6	144.3	1874.2	65.6%	29.4%	4.9%
NS-7	107.8	480.7	70.4%	12.0%	17.6%
NS-8	46.1	528.7	47.1%	42.3%	10.6%
NS-9	26.2	522.6	91.5%	8.5%	0.0%
NS-10	15.0	327.9	33.4%	66.6%	0.0%
FM-1	38.4	312.9	0.0%	100.0%	0.0%
FM-2	33.7	239.1	25.2%	74.8%	0.0%
FM-3	49.1	229.5	51.8%	48.2%	0.0%
FM-4	8.0	195.5	100.0%	0.0%	0.0%
FM-5	31.9	197.3	36.1%	63.9%	0.0%
FM-6	26.2	33.0	0.0%	0.0%	100.0%
D-1	66.6	636.0	35.7%	64.3%	0.0%

System	Drainage Area *(ha)*	100 Year Event Analysis			
		Road Length *(m)*	**Percent <0.15m**	**Percent 0.15 - 0.25 m**	**Percent >0.25 m**
D-2	70.5	1395.9	84.7%	15.0%	0.3%
DW-1	76.4	1663.9	33.7%	66.3%	0.0%
DW-2	180.2	N/A	N/A	N/A	N/A
DW-3	18.3	123.8	0.0%	100.0%	0.0%
DW-4	21.0	179.0	22.0%	78.0%	0.0%
DW-5	26.5	41.8	0.0%	100.0%	0.0%
DW-6	29.9	68.1	41.6%	58.4%	0.0%
GT-1	52.8	487.5	100.0%	0.0%	0.0%
GT-2	32.0	310.7	100.0%	0.0%	0.0%
GT-3	37.2	526.2	100.0%	0.0%	0.0%
GT-4	41.0	756.5	100.0%	0.0%	0.0%
SE-1	23.7	384.5	68.1%	31.9%	0.0%
SE-2	58.2	586.9	3.4%	96.6%	0.0%
SE-3	34.9	175.2	40.9%	59.1%	0.0%
SE-4	37.4	478.0	62.8%	37.2%	0.0%
SE-5	187.4	907.9	54.8%	43.8%	1.4%
L-1	50.8	135.9	48.2%	51.8%	0.0%
L-2	77.7	87.3	0.0%	100.0%	0.0%

The results presented in **Table 8.2.3** indicate that all of the networks analyzed would be susceptible to some surface flooding during the 100 year storm event, which is generally consistent with current practice for drainage system designs. The results further indicate that the majority of the networks analyzed are anticipated to be susceptible to flooding depths above 0.25 m during the 100 year storm event, and thus the depth of flooding for the 100 year storm event could exceed the capacity of the curb and gutter system within the road and extend beyond the road right-of-way for a portion of the network.

8.2.5 Assessment of Alternatives

Based upon the results of the integrated hydrologic/hydraulic assessment, a long list of alternatives to mitigate the surcharge and flooding conditions for the minor system during the 5 year storm event, as well as to alleviate the depth of flooding during the 100 year storm event, has been developed. Based upon discussions with CGS Staff and the Project Team during this process, the following alternatives were considered:

i. Do Nothing.
ii. Increase size of affected storm sewers, or twinning.
iii. Implement super pipes to provide on-line stormwater quantity control.
iv. Implement on-site stormwater management for individual private properties.
v. Implement off-line storage areas within available public spaces.

vi. Retrofit existing stormwater management facilities to provide additional quantity control.
vii. Redirect flow to other systems (diversions).
viii. Optimize the outlet configuration and storage of the Maley and Nickeldale Dams.
ix. Improve the conveyance capacity of Junction Creek through culvert improvements, creek restoration, reprofiling, and/or daylighting/opening the watercourse.
x. Low Impact Development (LID) and Best Management Practice (BMP) stormwater management approaches.
xi. Utilize pumps and/or lift stations to mechanically reduce flooding.
xii. Combinations.

The following alternatives were screened out for further consideration:

- Alternative i. (Do Nothing) does not address the issues associated with deficient infrastructure capacity and flooding and has therefore been screened from further consideration.
- Alternative iii. (Super-Pipes) are generally not a cost-effective option, and provide minimal flood control benefit. They are also dependent on having a sufficient grade difference (to avoid backwater effects) and sufficient space within CGS-owned land. Given these difficulties, this option has been screened from further consideration.
- Alternative iv. (On-site SWM) would necessitate participation from private landowners (which may not be obtained) and would not give the CGS control over the system. This option has therefore been screened from further consideration.
- Alternative vi. (Retrofit existing SWM facilities) is generally not considered to be a viable option, as the majority of existing SWM facilities have likely already been maximized. This option has therefore been screened from future consideration.

Accordingly, the short-listed possibilities for alleviating flooding within the subwatershed are:

- Alternative ii. (Increase size of affected storm sewers, or twinning) is typically the most effective alternative for minor storm events – possible issues with cost and existing utility locations, ground cover should be considered however.
- Alternative v. (Implement off-line storage areas within available public spaces) is possible, however limited space available, and a possible reduction in public use area (unless underground storage used which is significantly more expensive). This alternative can be an effective option in appropriate locations however.
- Alternative vii. (Diversions) is possible, and can be an effective option, however, this alternative assumes that there is a system or facility which sufficient extra capacity to accept the additional flow, and that a diversion is possible given existing grades.
- Alternative viii. (Dam Optimization). The existing dam structures on Junction Creek have already reduced flooding within the subwatershed, however additional efficiencies may be possible.
- Alternative ix. (Conveyance Improvements) The flat topography through some reaches of the creek and sedimentation due to erosion have caused backwater effects and flooding in some areas. Improvements to the creek may be possible, however effects on local riparian habitat must be considered.

- Alternative x. (LID and BMP measures) Opportunities for infiltration-based LIDs may be limited given the extensive impervious bedrock coverage within the subwatershed, but they are a possible solution where suitable pervious soils exist. Vegetative buffer strips and filtration can be broadly applied to new development and retrofit projects. Site-specific limitations such as available space, grading constraints, utilities, etc. must be considered.
- Alternative xi. (Pumping) Due to the flat grade of Junction Creek and some areas of the floodplain, pumping of flood water may be the only potentially viable solution for some areas.
- Alternative xii. (Combinations) are likely an appropriate solution where no single alternative is sufficient to address issues.

The evaluation of each of the above alternatives requires a thorough assessment of the constraints and opportunities of each specific area (i.e. technical/hydraulic considerations, water quality considerations, ecological & natural heritage considerations, and social & cultural considerations), which are beyond the scope of this drainage system performance assessment and upgrade analysis. These alternatives are discussed in more detail, within the framework of an Environmental Assessment process, in **Section 11.3**.

8.2.6 Alternative 2: Storm Sewer Upgrades

To conclude the PCSWMM analysis of the trunk sewer networks, a drainage system upgrade analysis has been conducted in order to determine the requirements to mitigate surcharge and flooding under the 5 year event (Alternative ii). The majority of applied upgrades have consisted of storm sewer pipe size increases, as they are generally considered to be the simplest and in many cases most effective solution.

Costs for storm sewer upgrades have been estimated using the same approach as has been applied in similar studies and other budget estimates conducted elsewhere in Ontario. Costs have been estimated as three (3) times the required pipe supply cost (based on a 2017 price list for 65-D concrete pipe) in order to account for installation, replacement appurtenances (i.e. catchbasins and manholes), and resurfacing of the roads. It should be noted that the costs listed apply only to the sewers modeled – any upgrade project would likely involve the upgrade of similar connected storm sewers as well.

Although not evaluated directly as part of this upgrade analysis (for the reasons noted previously), LID and related BMPs (Alternative ix) should be encouraged and promoted wherever possible. LID and related BMPs would have to be assessed on an individual site basis for each of these areas to determine their appropriateness.

The results for those networks that require upgrades are presented in **Table 8.2.4**.

Table 8.2.4: Summary of Preliminary Recommended Upgrades

City Area	Network	Total Number of Sewers Upgraded	Total Length of Required Upgrades (m)	Estimated Total Cost
Garson	G-2	0	0.0	$0
	G-3	0	0.0	$0
	Total	**0**	**0.0**	**$0**
New Sudbury	NS-1	2	56.8	$114,600
	NS-2	0	0.0	$0
	NS-3	0	0.0	$0
	NS-4	5	226.7	$717,900
	NS-5	9	352.8	$655,000
	NS-6	14	643.5	$1,800,000
	NS-7	6	416.0	$1,543,100
	NS-8	3	217.1	$437,500
	NS-9	0	0.0	$0
	NS-10	4	297.4	$495,200
	Total	**43**	**2210.2**	**$5,763,100**
Flour Mill	FM1	2	73.6	$190,500
	FM2	1	60.1	$155,600
	FM3	16	858.3	$2,497,500
	FM4	0	0.0	$0
	FM5	5	275.0	$1,044,300
	FM6	0	0.0	$0
	Total	**24**	**1266.9**	**$3,887,900**
Donovan	D1	8	318.2	$641,400
	D2	15	501.4	$1,253,100
	Total	23	819.7	$1,894,500
Downtown	DW-1	22	1316.1	$6,839,900
	DW-2	N/A	N/A	N/A
	DW-3	4	123.0	$6,796,700
	DW-4	8	261.8	$537,800
	DW-5	3	66.8	$169,600
	DW-6	3	68.1	$137,200
	Total	**40**	**1835.8**	**$14,481,300**
Gatchell	GT-1	0	0.0	$0
	GT-2	0	0.0	$0
	GT-3	0	0.0	$0
	GT-4	0	0.0	$0
	Total	**0**	**0.0**	**$0**
South End	SE1	0	0.0	$0
	SE2	0	0.0	$0
	SE3	0	0.0	$0

City Area	Network	Total Number of Sewers Upgraded	Total Length of Required Upgrades (m)	Estimated Total Cost
	SE4	0	0.0	$0
	SE5	6	585.1	$3,041,200
	Total	**6**	**585.1**	**$3,041,200**
Lively	L-1	0	0.0	$0
	L-2	1	20.5	$41,300
	Total	**1**	**20.5**	**$41,300**

As is evident from **Table 8.2.4**, a substantial cost has been estimated to address all of the identified issues of surcharging and flooding under a 5 year event within the trunk storm sewer networks within the CGS. Given the cost, there is a clear need to prioritize the recommended drainage system upgrades in order to target those areas of greatest concern. This is discussed in **Section 8.3** below.

Increasing the size of storm sewers to mitigate surface flooding (Alternative ii) is not considered to be a cost-effective or feasible solution to major event flooding given the substantial costs already associated with upgrading only to a 5 year unsurcharged capacity (**Table 8.2.4**). Similar analyses for other municipalities have also confirmed an excessively high cost associated with sizing storm sewers to mitigate major event flooding. Although not analyzed directly, it is likely that incorporating the recommended storm sewer upgrades (to a 5 year unsurcharged capacity) would offer some benefit in reducing major system flooding in the identified areas.

It should be noted that these upgrades have not been assessed directly with respect to basement flooding. Cases of basement flooding should be examined individually for potential causes. Foundation drains (such as weeping tiles or sump pumps) should ideally discharge to the surface rather than into the storm sewer. Backflow preventers should also be considered for implementation. Sanitary sewer improvements should also be considered in conjunction with the recommended storm sewer upgrades in areas prone to basement flooding.

8.3 Prioritization of Drainage Network Upgrades

8.3.1 Prioritization Evaluation Criteria

Given the large number of required sewer upgrades, a prioritization approach has been advanced to assist in identifying those sewershed networks which are in the most need of upgrades on a priority basis. A modified version of the network prioritization criteria has been employed to assess the upgrade of each storm sewer system as discussed in **Section 8.2.6**.

The current prioritization scheme has been based on several factors, namely:

- 5 year system performance
- 100 year system performance
- Number of instances of reported historic flooding

- Average age of sewers requiring upgrades

Each sewershed network has been assessed based on the foregoing. The specifics of the criteria are summarized in **Table 8.3.1**.

Table 8.3.1: Network Prioritization Criteria for Drainage System Upgrades

Criteria	Prioritization Criteria		
	Low Priority	**Medium Priority**	**High Priority**
5 Year Performance	<10% Surcharged, No Flooding	>10% Surcharged, No Flooding	>10% Surcharged, Any Flooding
100 Year Performance	No Roadway >0.25 m	<15% Roadways >0.25 m	>15% Roadways >0.25 m
Historic Flooding	None reported	1 instance	2 or more instances
Average Sewer Age	<20 years	20-50 years	>50 years

For each criteria, a score of one (1) point has been assessed for a low priority value, two (2) points for a medium priority value, and three (3) points for a high priority value. The scores for each of the four criteria have then been summed and assessed as per the criteria outlined in **Table 8.3.2**.

Table 8.3.2: Network Prioritization Scoring for Drainage System Upgrades

Total Score	Overall Network Priority
less than 7 points	Low
8 to 10 points	Medium
11 to 12 points	High

8.3.2 Drainage Network Prioritization

The criteria described in **Section 8.3.1** have been applied to the 36 trunk sewer networks which have been assessed for drainage system upgrades. The results of this application are summarized in **Table 8.3.3** (refer to **Figure C7** in **Appendix 'C'** for sewer networks). Note that this list of prioritizations is based solely on the drainage systems themselves, and opportunities to coordinate other infrastructure improvements with this work would result in cost savings for the CGS. As noted previously, these upgrades relate only to achieving a 5 year unsurcharged capacity, and have not been assessed directly with respect to effectiveness at reducing major system overland flooding.

Table 8.3.3: Sewershed Network Prioritization for Upgrades

City Area	Network	5 Year Priority	100 Year Priority	Historic Flooding Priority	Sewer Age Priority	Overall Priority
Downtown	DW-1	Low	Low	Low	High	Low
	DW-2	Low	Low	Low	High	Low
	DW-3	High	Low	Low	Medium	Low

City Area	Network	5 Year Priority	100 Year Priority	Historic Flooding Priority	Sewer Age Priority	Overall Priority
	DW-4	Low	Low	Medium	Medium	Low
	DW-5	Medium	Low	Low	Medium	Low
	DW-6	High	Low	Low	Medium	Low
South End	SE-1	Medium	Low	Low	Medium	Low
	SE-2	High	Low	Low	Medium	Low
	SE-3	Low	Low	Low	Medium	Low
	SE-4	Low	Low	Low	Medium	Low
	SE-5	High	Medium	Low	Medium	Medium
Garson	G-2	Low	Low	Low	Medium	Low
	G-3	Low	Low	Low	Medium	Low
New Sudbury	NS-1	Medium	Low	Low	Medium	Low
	NS-2	Low	Low	Low	Medium	Low
	NS-3	Low	Low	Low	Medium	Low
	NS-4	Medium	Low	Low	Medium	Low
	NS-5	Medium	High	Medium	Medium	Medium
	NS-6	High	Medium	Medium	Medium	Medium
	NS-7	High	High	Medium	Medium	Medium
	NS-8	Medium	Medium	Medium	Medium	Medium
	NS-9	Low	Low	Medium	Medium	Low
	NS-10	High	Low	Medium	Medium	Medium
Flour Mill	FM-1	High	Low	Low	Medium	Low
	FM-2	High	Low	High	Medium	Medium
	FM-3	High	Low	High	High	Medium
	FM-4	Medium	Low	Medium	High	Medium
	FM-5	High	Low	Medium	High	Medium
	FM-6	Medium	High	Medium	High	Medium
Donovan	D-1	High	Low	Medium	Medium	Medium
	D-2	High	Medium	Medium	Medium	Medium
Gatchel	GT-1	Low	Low	Medium	Medium	Low
	GT-2	Low	Low	Medium	Medium	Low
	GT-3	Low	Low	Medium	Medium	Low
	GT-4	Low	Low	Medium	Medium	Low
Lively	L-1	Low	Low	Low	Medium	Low
	L-2	Medium	Low	Low	Medium	Low

9.0 STORMWATER QUALITY MANAGEMENT ASSESSMENT

9.1 Process

In accordance with the Provincial Policy Statement and the CGS's Official Plan, it was determined that a management strategy for the Junction Creek subwatershed was required in order to allow for sustainable future development in this area. Recognizing that stormwater management is an essential component to the management of water quality issues and flood mitigation which would need to be addressed, the Junction Creek Subwatershed Study and Stormwater Master Plan has included the development of preferred alternatives for the provision of stormwater quality control for the Study Area.

9.2 Stormwater Quality Management Approaches

9.2.1 Alternative No. 1 – 'Do Nothing'

Under the 'Do Nothing' alternative, untreated run-off from surrounding urban areas would be permitted to discharge uncontrolled to receiving watercourses such as Junction Creek and its tributaries. This approach would be contrary to current prevailing Provincial guidelines regarding stormwater, as the untreated discharge would cause continued degradation of water quality in receiving water bodies within the subwatershed and potentially result in loss of habitat and destruction to the natural environment. Due to the issues associated with this practice, this alternative has not been advanced further for consideration.

9.2.2 Alternative No. 2 – Provide On-Site Stormwater Management for the Junction Creek Subwatershed Study Area

Various techniques for stormwater quality control include:

- Soakaway pits
- Infiltration trenches
- Grassed swales
- Pervious pipe systems
- Pervious catchbasins
- Vegetated filter strips
- Buffer strips
- Oil/Grit separators
- Wet ponds
- Wetlands
- Hybrids wet pond/wetland system
- LID techniques

The application of grassed swales or oil/grit separators is generally the most common BMP for smaller size drainage areas due to reduced land requirements compared to the other alternatives, as well as their applicability regardless of soil conditions (i.e., infiltration technologies require relatively permeable soil conditions). Of these two options, oil/grit separators are commonly used for commercial/industrial applications where the impervious coverage for the site is relatively high (i.e., greater than 85%) since they are implemented in place of conventional manholes in the storm sewer system. The major benefit of oil/grit separators is the improvement in water quality and effective treatment of stormwater runoff when implemented at the source. However, in order for these devices to be effective, proper maintenance/cleaning and inspections are necessary and therefore can result in significant maintenance costs. Oil/grit separators can be considered for larger drainage areas if placed in series rather than as single units.

For larger areas, wet ponds, wetlands or hybrid facilities are considered appropriate due to drainage area limitations associated with other techniques. Another effective technique would be the implementation of buffer strips to protect the stream and restore vegetated riparian areas. Buffer strips would also provide benefits to wildlife, aquatic and terrestrial habitat as well as linkages between natural areas. In order for these to be most effective, buffer strips should be preceded by filter strips to prevent untreated stormwater flow from entering the buffer and ensure that impacts on water quality in the stream are minimized.

LID represents the application of a suite of BMPs normally related to source and conveyance stormwater management controls to promote infiltration and pollutant removal on a local basis. These measures rely on eliminating the direct connection between impervious surfaces (e.g., roofs, roads, parking areas) and the storm drainage system to reduce runoff to the receiving water bodies in the drainage area. With respect to water quality and applying LID practices, all urban stormwater runoff is not equal, therefore the application of LID practices has to be considered carefully.

As discussed in **Sections 3.5 and 4.4**, the Junction Creek Subwatershed is typically characterized by shallow bedrock without a large amount of overburden soil and with a high water table, which presents issues for infiltration-based stormwater management techniques. The feasibility of many LID techniques is dependent on the infiltration capacity of the soils in that area and therefore this type of strategy may not be applicable in the majority of the areas in the Junction Creek Subwatershed Study Area, except in areas of significant overburden soils and appropriate water table, as indicated on **Figure E5** in **Appendix 'E'**.

9.2.3 Alternative No. 3 – Cash in Lieu of On-Site Stormwater Management

The Province has recognized that applying financial contributions (FC), or "cash-in-lieu" requirements would limit the number of stormwater facilities being constructed. Monies, which would have been used for stormwater management, would be directed into larger, more centralized facilities, or for the upgrading of existing facilities and/or infrastructure.

The two fundamental approaches to establishing off-site retrofits consist of modifications to Existing (or Planned) SWM Facilities and/or treatment provisions at Existing Storm Outfalls.

9.2.3.1 *Existing/Planned SWM Facilities*

This method of stormwater quality control involves modifying existing stormwater management facilities (quantity or quality control) to provide targeted water quality control. Although this method is primarily intended for existing stormwater facilities, it can also be considered during the planning stages for new quantity facilities if it is expected that upstream stormwater runoff (i.e. pond outflow) would adversely affect downstream watercourses and habitat through water quality degradation. When possible, retrofitting existing/planned facilities is considered to be a cost-effective approach since land costs (if any) would generally be less than that required for a new facility. Also, the majority of the infrastructure of an existing facility is already in place (headwalls, access paths, berms) and hence would only require modification. A reduction in future maintenance costs could be realized since both quantity and quality control functions have been consolidated into one facility, therefore, the number of facilities requiring maintenance would be reduced.

There are four methods generally considered available for the retrofitting of an existing or planned SWM facility:

1. Construct a permanent pool, or in the case of an existing quality facility, deepen or expand the existing permanent pool.
2. Modify the facility to provide for extended detention storage.
3. Provide longer, extended flow paths through the facility to promote settling of suspended solids.
4. Provide additional or enhanced vegetation within the facility to promote nutrient uptake, water polishing, and temperature control (shading).

In determining the feasibility of retrofitting an existing or planned stormwater management facility, a number of factors must be considered:

- Ability to physically enlarge/retrofit a facility. Is land available (i.e. public lands, parks etc.) adjacent to the facility? Is it possible to implement retrofits within the confines of the existing/planned facility?
- Size of the catchment area draining to the facility.
- Upstream land use within the catchment area.
- Facility location versus groundwater resources sensitive to infiltrated contaminated runoff.
- Sensitivity of downstream (receiving) watercourses and the need for improved stormwater quality.
- Cost-benefit of retrofit. Is maximum benefit being realized from monies spent, or should monies be directed elsewhere to realize greater water quality benefits?

9.2.3.2 *Existing Storm Outfalls*

Existing storm outfalls provide opportunities to implement online treatment of various upstream land uses within the context of new retrofit facilities typically constructed on existing available public lands. Water quality facilities in the form of wetlands, wet ponds or hybrids would provide both permanent pool and extended detention volumes. Oil and grit separators (OGSs) may also be used to provide water quality treatment and may be used in combination with, or on sites without available space for, surface treatment ponds or wetlands. Possible sites would be evaluated on factors similar to those listed in the foregoing for retrofit of existing/ planned SWM facilities. Candidate sites for providing stormwater quality control at existing storm outfalls are generally evaluated based upon the following additional criteria:

i. Land availability, land use flexibility and ownership
ii. Storm outfall location within the available land
iii. Storm outfall tributary drainage area and respective characteristics
iv. Storm outfall location versus sensitive groundwater resources
v. Potential outlet location with respect to receiving waters
vi. Downstream aquatic resource benefit potential and water quality requirements
vii. Financial resource allotment and potential cost/benefit ratio

The list of candidates retrofit sites for implementing stormwater quality retrofits were based on the existing outfalls from trunk sewers greater than 900 mm. For this preliminary screening three overall types of criteria were assessed: physical suitability, physical environment, and social environment. A qualitative rating of "high", "medium", or "low" was assigned to each sub-criteria and used to classify the overall retrofit potential for each candidate site, and **Table 9.2.1** presents the ranking results (refer to **Figure C7** in **Appendix C**).

An important criterion to be considered in further analysis is to identify the current land use associated with each candidate retrofit site. Land use ownership information should be reviewed to identify current land use associated with each publicly owned space, and prioritize areas within public lands. Municipalities frequently implement retrofits for stormwater quality control on public lands, due to the advantages associated with long-term operation and maintenance as well as the reduced cost for implementation. In addition, field reconnaissance should be completed for the list of candidate sites in order to obtain a photographic inventory and to identify any physical constraints and features at each of the sites.

Table 9.2.1: Trunk Sewer Outfall Stormwater Quality Retrofit Assessment

Outfall Modelling No.	Location		Physical Suitability				Physical Environment			Social Environment		Overall Stormwater Quality Retrofit Potential
			Drainage Area (ha)	Topographic Compatibility	Soils Compatibility	Available Space	Sensitivity of Receiving Watercourse	Compatibility with Natural Ecosystem	Erosion Mitigation Potential	Adjacent Land Use	Aesthetics	
ODP_124235	D1	McKim St	109.9	L	L	H	M	H	U	Rs	M	**M**
ODP_1806	D2	Stanley St	70.9	L	L	L	U	H	U	Rs	L	**L**
ODP_124239	FM1	Notre dame Ave	39.408	H	L	H	H	H	L	Cm	M	**H**
GDP_123551	FM2	Railway	50.042	L	L	L	M	H	L	Rc	L	**M**
ODP_123925	FM3	Wilma St	37.898	L	L	M	M	H	L	Rc	L	**L**
ODP_123930	FM4	Wilma St	37.898	L	L	M	M	H	L	Rc	L	**M**
ODP_123897	FM5	St George St	95.611	L	L	L	M	H	L	Rc	L	**M**
OF162	FM6	Murray St	33.18	L	L	L	M	H	M	Rc	L	**M**
OF162	G2	William St	17.1	M	L	H	H	H	L	Rs	M	**H**
MH-GAR-11-11-0099	G3	Orell St	8.178	L	L	L	H	H	L	Rs	M	**M**
ODP_123952	Gt1	Cross St	52.757	—	L	L	M	H	H	Cm/Rs	M	**M**
ODP_123934	Gt2	Norman St	32.011	—	L	L	M	H	L	Cm/Rs	L	**M**
OF1	Gt3	Lorne St	37.178	—	L	L	M	H	M	Cm/Rs	M	**M**
OF2	Gt4	Lorne St	40.981	—	L	M	M	H	H	Cm/Rs	M	**H**
ODP_123625	L1	Bonnie Dr	50.782	—	L	H	U	U	U	Rs	L	**L**
ODP_124326	L2	Herman Mayer Dr	77.744	—	L	M	U	U	U	Rs	L	**L**
ODP_123749	NS-1	Havenbrook Dr	28.18	H	L	H	L	M	L	Rs	L	**M**
ODP_124321	NS-2	Prestige Pl	24.816	L	L	M	H	M	H	Rs	L	**M**
1	NS-3	Lasalle Blvd	27.849	L	L	L	H	H	H	Cm/Rs	L	**H**
2	NS-4	Lasalle Blvd	54.965	L	L	L	H	H	H	Cm/Rs	L	**H**
ODP_123989	NS-5	Hawthorne Dr	122.734	L	L	M	H	H	M	Rs	L	**M**
ODP_124222	NS-6	Sparks St	144.665	H	L	L	M	H	L	Cm/Rs	L	**L**
OF1	NS-7	Barrydowne Rd	107.975	L	L	H	H	H	H	Cm/Rs	L	**M**
ODP_123445	NS-8	Lasalle Blvd	48.625	L	L	H	M	H	L	Rs	L	**M**
OF2	NS-9	Lasalle Blvd	28.183	L	L	L	M	H	M	Cm/Rs	L	**M**
ODP_124176A	NS-10	Alexander St	15.959	L	L	L	H	H	L	Rs	L	**M**
ODP_123573	SE1	Centennial Dr	23.65	—	L	H	U	U	L	Cm/Rc	L	**L**
ODP_124200	SE2	Marcel St	58.157	—	L	L	M	U	L	Rs	M	**L**
OF162	SE3	Southview Dr	34.903	—	L	H	U	U	L	Rs	L	**L**
ODP_173560	SE4	Paris St	37.447	—	L	M	U	U	L	Rs	L	**M**
ODP_713560	SE5	Stewart St	187.437	—	L	L	U	U	L	Rs	L	**L**
1799	DW-1	Cedar St.	76.449	L	L	L	U	M	L	Cm/Rs	L	**L**
J8560	DW-2	Box Culvert	180.195	N/A	L	N/A	M	M	M	Cm/Rs	L	**L**
ODP_123667	DW-3	Louis St.	18.294	L	L	M	M	M	L	Cm/Rs	L	**M**
ODP_1804 and ODP_1803	DW-4	Paris St.	20.994	L	L	L	M	M	L	Cm/Rs	L	**M**
ODP_123468	DW-5	Brady St.	26.469	L	L	M	M	M	H	Cm/Rs	L	**M**
MH-MCK-07-07-1422	DW-6	College St.	29.915	L	L	L	L	M	U	Cm/Rs	L	**L**

*Land Use Legend: Rs - Residential Land Use; Rc - Recreational Land Use; Cm - Commercial.

**Rating System: H - High; M - Medium; L - Low; U - Unknown.

10.0 STORMWATER MASTER PLAN OPTIONS

10.1 Summary of the Environmental Assessment Master Planning Process

In accordance with the Ontario *Environmental Assessment Act*, the Junction Creek Subwatershed Study and Stormwater Master Plan was conducted following the process outlined by the Municipal Engineers Association's (MEA) Municipal Class Environmental Assessment (Class EA) Master Planning Process. Specifically, this Master Plan has adopted Approach #2 from the MEA Class EA Document and satisfies Phases 1 and 2 of the process. The scope of the Master Planning is broad and considers a variety of integrated perspectives, providing a recommended set of works to be distributed geographically throughout the study area over an extended period of time. Throughout the process, engagement with stakeholders and indigenous groups that may be affected by, or have an interest in, the proposed project will occur.

The Class EA Phase 1 of the Master Plan identifies the problem or opportunity and was completed in 2 stages (Stages 1 and 2). This was achieved by developing an understanding of the current (baseline) conditions in the Study Area. The Class EA Phase 2 of the Master Plan, completed in 3 stages (Stages 3, 4, and 5), identifies alternative solutions to address the problem or opportunity identified in Phase 1 by taking into account the existing environment. Each of the proposed alternative solutions are evaluated against the baseline conditions and the potential impacts as well as mitigation strategies, where necessary, are identified. The preferred solution is then established, taking into account public and review agency input.

The stages in which the Master Planning process were conducted for the Junction Creek Subwatershed Study and Master Plan are as follows:

Stage 1
- Review of existing conditions
- Identify problem or opportunity

Stage 2
- Identify environmental opportunities and constraints
- Confirm problem or opportunity
- Establish objectives and targets

Stage 3
- Develop alternative subwatershed management strategies
- Evaluate alternative subwatershed management strategies

Stage 4
- Identify preferred subwatershed management strategy
- Develop implementation, monitoring, adaptive management and reporting plans

Stage 5

- Finalize Subwatershed Plan and Master Plan
- Implementation

10.2 Public Consultation and Correspondence

Communication and consultation are an important aspect of the Junction Creek Subwatershed Study and Master Plan. The needs and standards of the project and stakeholders as well as the principles and best practices endorsed by the International Association for Public Participation (IAP2) and Municipal Class EA are taken into consideration through the implementation of the Public and Community Outreach Program Strategy (Strategy). The Strategy executed by Wood on behalf of the CGS for the Junction Creek Subwatershed Study and Master Plan include:

- Public meetings (5, with 4 held to date);
- Technical Advisory Committee meetings (18);
- City staff, agencies, and Watershed Advisory Panel meetings (5);
- Indigenous group meetings (1);
- Stakeholder meetings (i.e., property owners, education/research institute or similar) (5);
- Related preparation, notification, recording and documentation;
- Develop responses to all comments, inquiries and questions pertaining to the project;
- Tracking of consultation activities and efforts; and,
- Participation and facilitation.

Additionally, throughout the project, Wood developed a Project Mailing List to issue approved notices (including Commencement, Public Meetings, and Completion) to keep Study Area property owners, Indigenous groups, relevant agencies, utilities and other interested stakeholders informed throughout the process. Furthermore, to communicate with the public and stakeholders in a streamlined, user-friendly manner, Wood prepared an over subwatershed status update, as well as a number of fact sheets for each subwatershed in the Study Area to convey progress and results.

In accordance with Phase 2 of the Municipal Class EA Master Planning Process, the recommended alternatives determined in the Junction Creek Subwatershed Study and Master Plan were evaluated through a review with the public, agencies, and the Technical Advisory Committee (TAC). Additionally, prior to approval of the Master Plan by the municipality, the Master Plan document will be made available for public review and comments.

The implementation of this Strategy is envisaged to generate the provision of first-hand information to interested stakeholders and Indigenous groups, recognition of stakeholder and Indigenous groups issues and concerns, better understanding of shared interests, better informed environmentally-sound decisions, and positive working relationships. The Strategy was outlined in a report titled "Public and Community Outreach Program Strategy", January 2017.

10.3 Evaluation of Alternatives

Short-listed alternative strategies to improve surcharging and flooding issues identified through the major and minor (dual drainage) system assessment have been identified as follows (**Section 8.2.5**):

- Increase size of affected storm sewers, or twinning,
- Implement off-line storage areas within available public spaces,
- Redirect flow to other systems (diversions),
- Optimize the outlet configuration and storage of the Maley and Nickeldale Dams,
- Improve the conveyance capacity of Junction Creek through culvert improvements, creek restoration, reprofiling, and/or daylighting/opening the watercourse,
- LID BMP stormwater management approaches,
- Utilize pumps and/or lift stations to mechanically reduce flooding, and
- Combinations.

From this list of general alternatives, more specific options for master plan scale stormwater management projects have been developed in consultation with the project team and Technical Advisory Committee (TAC). In some cases, the options combine themes from multiple alternative strategies (i.e. a stormwater management facility may both store and divert stormwater runoff, as well as offer opportunities for LID BMPs and water quality measures). Specific stormwater master plan options have been identified as follows, and are shown graphically on **Figure C11** (refer to **Appendix 'C'**).

- **Option A** – Construct a stormwater management facility in Garson, on the available land north of Junction Creek and west of Ravina Avenue.
- **Option B** – Utilize some of the public land in the Twin Forks area for stormwater management (B1), or elsewhere along the incoming Maley tributary (B2).
- **Option C** – Construct a stormwater management facility east of the Supermall, on the vacant land on the east side of Junction Creek between Lasalle Boulevard and the Railway.
- **Option D** – Construct a stormwater management facility along the Nickeldale Branch at the northwest end of the Ponderosa, on the west side of Junction Creek, east of Notre Dame Avenue.
- **Option E** – Construct a stormwater management facility at the east end of the Ponderosa, southeast of the railway, including the potential to divert flood flows southwest down the old railway line to tie into the recently completed Mountain/Leslie St. Overflow Channel. Effects on the Ponderosa wetland will need to be analyzed in detail and managed.
- **Option F** – Construct a flood diversion within Junction Creek east of Donnelly Drive to direct flows southeast through the hydro corridor, and either construct a stormwater management facility or utilize the existing gravel pits to provide runoff storage and potential infiltration.
- **Option G** – Restoration and reprofiling of Junction Creek downstream of the Ponderosa, through the downtown area with the most severe flooding issues, to provide optimal conveyance to the Box Culvert. Ecological enhancements including stream rehabilitation will need to be considered in detail.

In addition to these specific options for new stormwater management projects, LIDs and water quality BMPs may be implemented as part of existing infrastructure retrofit projects. In a similar way, Natural

Infrastructure, such as the re-greening initiatives completed within the CGS since 1978, is believed to have additional hydrological benefits by reducing the runoff generation potential and improving the infiltration and retention of precipitation in the area. Re-greening, as proven in recent complementary studies, while having major benefits to the ecosystem over the past 40 years (i.e. available plant and wildlife habitat in the region), has achieved considerable reduction of estimated runoff reporting to strategic infrastructure by changing some of the historical bald bedrock cover to a tree and topsoil cover.
The potential to improve the existing trunk storm sewer systems was covered in **Section 8** above.

The optimization of the Maley and Nickeldale Dams has not been listed as an individual "option", rather carried forward as a "no-regrets" recommendation, and is covered in **Section 10.3.9** below.

Further, stormwater management policy recommendations have been made based on the results of the hydrologic analyses, and presented in **Section 11.2** below. In general, policies have been grouped into two categories:

- Policies for New Development Lands (i.e. development of greenfield or agricultural lands)
- Policies for Re-Development, Intensification, and/or Infill, (i.e. existing urban lands)

10.3.1 Evaluation Criteria

In order to better assist the CGS staff in targeting the most critical stormwater management projects from the list of options provided above, a project specific evaluation has been conducted. Each of the options has been analyzed based on four main criteria:

1. The *Technical / Engineering* benefit of the project.
2. Whether the project has any *Natural Heritage or Ecological* benefits or drawbacks.
3. Whether the project has any *Social or Cultural* implications.
4. *Financial Considerations*, including the estimated *Cost* of the project.

The technical benefit of each project has been assessed utilizing the newly developed overall Junction Creek subwatershed model in PCSWMM.

Costs for surface stormwater management facilities have been estimated based on $25 per cubic metre of excavation, and $120 per square metre of surface lining, plus additional material contingencies, engineering costs, and other associated costs if required (based on typically applied costing methods). For recommended underground storage facilities, additional costs have been estimated based on $360 per cubic metre of underground storage required. Note that the costs of property acquisition, which may be substantial, have not been included in the cost estimate. A contingency of 30%, as well as HST of 13%, have been applied to the total cost including materials and engineering.

10.3.2 Option A: Garson Facility

10.3.2.1 *Technical / Engineering Considerations & Cost*

A conceptual layout of the diversion and stormwater management facility is shown on **Drawing C11.1**. There is a large amount of land available which may be acquirable by the CGS for stormwater management. There is, however, limited potential for flood mitigation with additional storage in this area, given that the land currently receives very little drainage, and is located in the headwaters of the creek before it carries much flow.

The facility has been conceived as an off-line storage facility, which will divert flood water at the upstream end of the property above the 2 year flood elevation. The facility is shown as a 50 m wide diversion storage facility which follows the contour of the updated floodplain mapping, with a 30 m buffer. A pipe culvert outlet and overflow weir at the far end of the pond direct flow back to Junction Creek. The facility has been shown with storage down to elevation 282.50 m, in order to allow outlet above the downstream floodplain, and with a maximum storage elevation of 284.00 m, in order to prevent backwater effects upstream. The groundwater potentiometric surface in this area (refer to **Appendix E)** is generally below 280.00 m, and therefore there should be no conflict with the groundwater table.

In order to direct flow into the facility, an in-line weir was introduced to Junction Creek. This weir was conceptually designed to pass the 25 mm event without increasing the flood elevation upstream, and restricts flow during higher duration storm events to direct flow into the storage facility. The arrangement of this weir flow splitting device should be further refined at a detail design stage, in conjunction with the facility outlet, to ensure that an appropriate amount of water is directed to the storage facility without compromising floodplain elevations upstream.

The stage-storage relationship for the conceptual **Option A** storage facility, as well as the peak storage volume for the various modelled storm events as described below, is shown in **Table 10.3.1** below.

Table 10.3.1: Option A Conceptual Stage-Storage Relationship

Elevation *(masl)*	**Depth** *(m)*	**Area** *(m^2)*	**Volume**		**Note**
			Increment *(m^3)*	**Cumulative** *(m^3)*	
282.50	0.00	14241	0	0	—
282.60	0.10	14599	1,442	1,442	—
282.70	0.20	14956	1,478	2,920	—
282.80	0.30	15314	1,514	4,433	—
282.90	0.40	15671	1,549	5,983	—
283.00	0.50	16029	1,585	7,568	—
283.10	0.60	16386	1,621	9,188	197 m^3 1:2yr Event
283.20	0.70	16744	1,657	10,845	1409 m^3 1:5yr Event
283.30	0.80	17101	1,692	12,537	3788 m^3 1:10yr Event
283.40	0.90	17459	1,728	14,265	8725 m^3 1:25yr Event

Elevation *(masl)*	**Depth** *(m)*	**Area** *(m²)*	**Volume** **Increment** *(m³)*	**Volume** **Cumulative** *(m³)*	**Note**
283.50	1.00	17816	1,764	16,029	13885 m³ 1:50yr Event
283.60	1.10	18174	1,800	17,828	19666 m³ 1:100yr Event
283.70	1.20	18532	1,835	19,664	22424 m³ Timmins Event
283.80	1.30	18889	1,871	21,535	—
283.90	1.40	19247	1,907	23,442	—
284.00	1.50	19604	1,943	25,384	—

Based on the conceptual facility design, a PCSWMM model simulation was run for the 1:2 through 1:100 and Timmins design storm events, to compare to the existing conditions model. The relative reduction in peak flow at the various subwatershed points of interest (refer to **Table 6.4.1**) are shown in **Table 10.3.2** below. As may be seen from the table, the facility provides a significant flow reduction immediately downstream, in the area of the crossing with O'Neil Drive West, however, there are no significant effects modelled further downstream. This is consistent with the issues identified at the start of this section, due to the fact that the facility is located at the start of Junction Creek, it does not receive much upstream drainage area, and flood reduction benefit downstream is limited.

Table 10.3.2: Percent Reduction in Hydrologic Peak Flow with Conceptual Option A

Location	Drainage Area	Reduction in Simulated Peak Flow (%)												
		2 Year		5 Year		10 Year		25 Year		50 Year		100 Year		Regional Timmins
	(ha)	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	
O'Neil Drive West	333.9	-5.0	11.6	7.6	23.2	15.7	29.2	23.4	34.7	30.1	38.2	34.8	42.2	0.2
Railway	574.1	0.0	0.2	0.0	0.4	0.0	0.5	0.0	0.8	0.0	0.9	0.0	0.5	1.1
Twin Forks	3596.1	0.0	0.0	0.0	0.1	0.0	0.3	0.0	0.6	0.0	0.0	0.0	0.0	2.5
Supermall	4011.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2
Northeast of Ponderosa	4389.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.3	0.0	0.6	1.6
Southeast of Ponderosa	4613.7	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.3	0.0	0.5	1.7
Ponderosa Junction	5721.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7
Downstream of Ponderosa	5890.6	0.0	0.2	0.0	0.2	0.0	0.3	1.2	0.2	1.3	0.3	1.6	0.3	-2.2
Box Culvert Inlet	6048.5	0.0	0.2	0.0	0.3	0.8	0.3	0.9	0.3	1.0	0.4	1.2	0.4	-5.5
Box Culvert Outlet	8393.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
McLeod St. / Sta. 02CF005	8393.5	-0.5	-1.9	-5.4	-3.8	-0.1	0.0	0.2	-0.4	1.6	0.0	0.8	0.6	-0.3
Upstream Kelly Lake	14577.1	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	-0.3	-0.1	-0.1	0.1	0.1
Fielding Road / Sta. 02CF012	18190.6	0.0	0.0	0.2	0.1	0.8	0.1	1.3	0.2	1.2	0.3	1.8	0.3	-0.5
Whitefish Junction	22864.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2
Mud Lake	25716.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Into Simon Lake	25716.4	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	-0.1	0.1	0.0

10.3.2.1.1 Cost Analysis

The main costs associated with the construction of Option A is the construction of the stormwater management facility and associated grading, as well as approximately 50 m of the new flood diversion channel, the construction of the outlet pipe and overflow weir, and any other additional associated work. It is therefore difficult to provide an accurate estimate of costs, but for comparative purposes, the cost has been estimated assuming a storage volume of 25,400 m^3, based on the peak storage volume at 1.5 m depth within Option A. Based on the list shown below and the methods described above, the cost is estimated to be approximately $2.61M.

Table 10.3.3 Option A Cost Estimate

Option A							
Item	**Quantity**	**Unit**	**Material Contingency**	**Quantity with Material Contingency**	**Unit Cost**	**Total cost with material contingency**	**Total cost with material contingency ($ x 1,000,000)**
Facility Excavation	25,400	m^3	20%	30,480	$25	$762,000	$0.76
Inlet Structures	1	L.S		1	$200,000	$200,000	$0.20
Outlet Structures	1	L.S		1	$200,000	$200,000	$0.20
					Subtotal	**$1,162,000**	**$1.16**
Access	1	L.S	20%	1	$50,000	$50,000	$0.05
Mobilization / Demobilization	1	L.S		1	$50,000	$50,000	$0.05
Permitting support (consultation with permitting agencies)	1	L.S		1	$100,000	$100,000	$0.10
Engineering Design	1	L.S		1	$300,000	$300,000	$0.30
Project & Construction Management	1	L.S		1	$166,200	$166,200	$0.17
Total Capital Cost without Contingency						**$1,828,200**	**$1.83**
Project Contingencies (30%)						**$548,460**	**$0.55**
HST (13%)						**$237,666**	**$0.24**
Grand Total						**$2,614,326**	**$2.61**
Note: This cost do not include the cost to purchase the lands							

10.3.2.2 *Natural Heritage / Ecological Considerations*

The area considered for the stormwater management facility is heavily treed, and is marked as Interior Forest Habitat and Re-Forested Land as per the Natural Heritage Mapping (refer to **Figure B2** and **Figure B4** in **Appendix B**). Additionally, the area has been delineated as a Sensitive Natural Feature as per **Figure**

B5, as it represents a major area of urban forest habitat within the upper subwatershed. Finally, the land has been identified as one of four Core Areas within the Natural Heritage System, as per **Figure B6**.

As such, the proposed stormwater management facility should be considered to have a high level of environmental impact, as any land used for stormwater management will be taking land away from an important natural heritage area. Additionally, the construction process has potential to cause noise and other environmental disturbances which may upset the natural heritage system beyond the limits of merely the construction site.

Stormwater management facilities may offer opportunities for water quality improvements and habitat enhancements. However, the potential to disturb the natural system must be carefully considered and mitigated if work is considered in this area.

Given the sensitivity of the area, erosion and sediment control must be carefully considered during the construction process to mitigate any negative impact on the creek or sensitive riparian areas. Erosion and sediment control best management practices may be implemented as per the *Erosion & Sediment Control Guidelines For Urban Construction*, dated December 2006, by the Greater Golden Horseshoe Area Conservation Authorities (GGHA CAs, 2006).

10.3.2.3 *Social / Cultural Considerations*

Any effect on potential social cultural uses of the area must be considered, however based on discussion with the CGS, the area is currently considered to have little development or recreational potential without alterations to the road network. No future development (as discussed in **Section 5.2**) is planned in the area.

Stormwater management facilities offer opportunities to increase the cultural value of an area by providing recreational enhancements such as walking trails, gardens, and decorative ponding features. The potential to incorporate recreational enhancements should be considered at a detail design stage and implemented where appropriate.

10.3.3 Option B1: Twin Forks Facility

10.3.3.1 *Technical / Engineering Considerations & Cost*

A conceptual layout of the diversion and stormwater management facility is shown on **Drawing C11.2a**. The facility was conceived as an underground off-line storage facility, which will divert flow from the Maley tributary of Junction Creek, downstream of the Maley Dam, and provide storage of large storm events before release back to the creek.

The ground elevation around the existing soccer fields at the Twin Forks playground, under which the underground facility may be constructed, ranges from approximately elevation 265.00 m to 266.00 m. The underground facility should be buried at least 2.0 m as per *Ontario Provincial Standard Drawing (OPSD) 3090.100 Frost Depths for Northern Ontario*, for an obvert elevation of approximately 263.00 m. However, the 2 year floodplain elevation at the conceptual outlet location for the facility is upwards of 263.60 m, therefore the facility must be located sufficiently above this elevation to provide a valid outlet. Additionally, the groundwater potentiometric surface through this area is generally above 268.00 m, and this is therefore likely an area of groundwater discharge (refer to **Appendix E**). Due to the issues with both the frost line, the groundwater table, and the general lake of vertical space between the inlet and outlet floodplain elevations for storage, the design of this facility has not been advanced further at this time.

10.3.3.1.1 Cost Analysis

The main costs associated with the construction of Option B is the construction of the underground stormwater management storage facility, as well the construction of an inlet and flow diversion structure, outlet, and any other additional associated work. It is therefore difficult to provide an accurate estimate of costs, but for comparative purposes, the cost has been estimated assuming a storage volume of 6,200 m^3, based on an available area of 0.62 ha and a conceptual storage depth of 1 m. Based on the list shown below and the methods described above, the cost is estimated to be approximately $5.63M.

Table 10.3.4 Option B1 Cost Analysis

Option B1							
Item	**Quantity**	**Unit**	**Material Contingency**	**Quantity with Material Contingency**	**Unit Cost**	**Total cost with material contingency**	**Total cost with material contingency ($x1,000,000)**
Underground Storage	6,200	m^3	20%	7,440	$360	$2,678,400	$2.68
Inlet Structures	1	L.S		1	$200,000	$200,000	$0.20
Outlet Structures	1	L.S		1	$200,000	$200,000	$0.20
					Subtotal	**$3,078,400**	**$3.08**
Access	1	L.S	20%	1	$50,000	$50,000	$0.05
Mobilization / Demobilization	1	L.S		1	$50,000	$50,000	$0.05
Permitting support (consultation with permitting agencies)	1	L.S		1	$100,000	$100,000	$0.10
Engineering Design	1	L.S		1	$300,000	$300,000	$0.30
Project & Construction Management	1	L.S		1	$357,840	$357,840	$0.36
Total Capital Cost without Contingency						**$3,936,240**	**$3.94**
Project Contingencies (30%)						**$1,180,872**	**$1.18**
HST (13%)						**$511,711**	**$0.51**
Grand Total						**$5,628,823**	**$5.63**
Note: This cost do not include the cost to purchase the lands							

10.3.3.2 *Natural Heritage / Ecological Considerations*

The area considered for the stormwater management facility is located within a public park space, and the majority of the area is marked as an urbanized landscape unit, although any connection from Junction Creek to the park area would necessarily pass through some forest and woodland area immediately near the creek (refer to **Figure B2** and **Figure B4** in **Appendix B**). Though the area has not been delineated as a Sensitive Natural Feature (refer to **Figure B5**), and has not been included as one of the Core Areas within the Natural Heritage System, there are many Natural Heritage Linkages that intersect at the Twin Forks, as shown on **Figure B6**.

Given the importance of the Twin Forks as a Linkage in the Natural Heritage System, any proposed stormwater management works in the area must maintain these natural linkages. Care must be taken at a detail design stage to ensure that habitat enhancements and wildlife pathways are incorporated where appropriate.

As with all stormwater management facilities near a watercourse, erosion and sediment control must be carefully considered during the construction process to mitigate any negative impact on the creek or sensitive riparian areas. Erosion and sediment control best management practices may be implemented as per the *Erosion & Sediment Control Guidelines For Urban Construction*, dated December 2006, by the Greater Golden Horseshoe Area Conservation Authorities (GGHA CAs, 2006).

10.3.3.3 *Social / Cultural Considerations*

The Twin Forks playground is currently used for a variety of recreational purposes, which must be maintained. Notably, there are tennis courts, soccer fields, and a baseball diamond, as well as several walking trails in the area. The protection and restoration, or perhaps the replacement, of the recreational facilities must be carefully considered at a detailed design stage.

10.3.4 Option B2: Maley Facility

10.3.4.1 *Technical / Engineering Considerations & Cost*

A conceptual layout of the diversion and stormwater management facility is shown on **Drawing C11.2b**. The facility was conceived as an off-line surface storage facility, which will divert flow from the Maley tributary of Junction Creek, downstream of the Maley Dam, and provide storage of large storm events before release back to the creek.

The facility is conceptually located on the east side of the Maley tributary, on approximately 4.87 ha of sparsely treed land outside of the regulatory floodplain delineation, west of the Hydro One industrial complex and north of a residential area. Based on CGS key plans, there is an existing storm sewer servicing the residential area, which flows along Dollard Avenue towards Junction Creek, and may potentially be redirected into the proposed facility. Additionally, the Hydro One complex appears to be a largely impervious, paved area which would create significant runoff, and may benefit from being routed through a stormwater management facility.

It is worth noting that there is an overhead utility line in this area, likely related to the Hydro One complex. The utility will have to be considered at a future design stage, and either relocated, avoided, or integrated into the facility design.

The 2 year floodplain elevation at the far upstream and downstream ends of the area is approximately 265.93 m and 265.32 m, respectively, in the updated HEC-RAS modelling. As there is little hydraulic slope in the creek through this area, the facility is likely to be most effective when designed as a control for incoming drainage areas (i.e. the Hydro One complex and residential areas), rather than as a diversion storage facility for the creek itself. To suit the storage of flood waters and provide a valid outlet back to Junction Creek above the 2 year floodplain elevation, the facility has been shown with a bottom elevation of 265.00 m. In order to provide adequate separation from the Regulatory Floodplain elevation, the facility top has been modelled as 269.00m, and a berm will likely be required on the west side of the facility along Junction Creek.

In order to model the technical benefit of the conceptual facility, the subcatchment containing the area was divided at the location of the facility in the PCSWMM hydrologic model, and the upstream portion was routed through the facility.

The stage-storage relationship for the conceptual **Option B2** storage facility, as well as the peak storage volume for the various modelled storm events as described below, is shown in **Table 10.3.3.1.1.1** below.

Table 10.3.5: Option B2 Conceptual Stage-Storage Relationship

Elevation *(masl)*	**Depth** *(m)*	**Area** *(m^2)*	**Volume**		**Note**
			Increment *(m^3)*	**Cumulative** *(m^3)*	
265.00	0.00	34193	0	0	—
265.10	0.10	34502	3,435	3,435	1982 m^3 1:2yr Event
265.20	0.20	34811	3,466	6,900	2782 m^3 1:5yr Event
265.30	0.30	35121	3,497	10,397	3329 m^3 1:10yr Event
265.40	0.40	35430	3,528	13,925	4046 m^3 1:25yr Event
265.50	0.50	35739	3,558	17,483	4714 m^3 1:50yr Event
265.60	0.60	36048	3,589	21,072	5470 m^3 1:100yr Event
265.70	0.70	36357	3,620	24,693	14479 m^3 Timmins Event
265.80	0.80	36666	3,651	28,344	—
265.90	0.90	36976	3,682	32,026	—
266.00	1.00	37285	3,713	35,739	—
266.10	1.10	37594	3,744	39,483	—
266.20	1.20	37903	3,775	43,258	—
266.30	1.30	38212	3,806	47,063	—
266.40	1.40	38521	3,837	50,900	—
266.50	1.50	38831	3,868	54,768	—

Elevation (masl)	**Depth** (m)	**Area** (m^2)	**Volume** **Increment** (m^3)	**Cumulative** (m^3)	**Note**
266.60	1.60	39140	3,899	58,666	—
266.70	1.70	39449	3,929	62,596	—
266.80	1.80	39758	3,960	66,556	—
266.90	1.90	40067	3,991	70,547	—
267.00	2.00	40377	4,022	74,570	—
267.10	2.10	40686	4,053	78,623	—
267.20	2.20	40995	4,084	82,707	—
267.30	2.30	41304	4,115	86,822	—
267.40	2.40	41613	4,146	90,967	—
267.50	2.50	41922	4,177	95,144	—
267.60	2.60	42232	4,208	99,352	—
267.70	2.70	42541	4,239	103,591	—
267.80	2.80	42850	4,270	107,860	—
267.90	2.90	43159	4,300	112,161	—
268.00	3.00	43468	4,331	116,492	—
268.10	3.10	43777	4,362	120,854	—
268.20	3.20	44087	4,393	125,247	—
268.30	3.30	44396	4,424	129,671	—
268.40	3.40	44705	4,455	134,127	—
268.50	3.50	45014	4,486	138,612	—
268.60	3.60	45323	4,517	143,129	—
268.70	3.70	45632	4,548	147,677	—
268.80	3.80	45942	4,579	152,256	—
268.90	3.90	46251	4,610	156,865	—
269.00	4.00	46560	4,641	161,506	—

Based on the conceptual facility design, a PCSWMM model simulation was run for the 1:2 through 100 year and Timmins design storm events, to compare to the existing conditions model. The relative reduction in peak flow at the various subwatershed points of interest (refer to **Table 6.4.1**) are shown in **Table 10.3.4** below. As may be seen from the table, there is a small (~3%) benefit in terms of peak flow reduction at the Twin Forks junction, which may help reduce the severity of flooding around properties in the region. It is worth noting that the stage discharge outlet curve of the facility may be optimized to provide a more significant benefit at a future detailed design stage.

Table 10.3.6: Percent Reduction in Hydrologic Peak Flow with Conceptual Option B2

Location	Drainage Area	Reduction in Simulated Peak Flow (%)												
		2 Year		5 Year		10 Year		25 Year		50 Year		100 Year		Regional
	(ha)	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Timmins
Twin Forks	3596.1	3.3	3.3	3.3	3.3	3.3	3.3	3.3	2.5	2.6	3.1	2.7	3.5	1.1
Supermall	4011.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
Northeast of Ponderosa	4389.0	0.6	0.4	0.4	0.3	0.4	0.3	0.5	0.5	0.6	0.6	1.0	1.0	0.4
Southeast of Ponderosa	4613.7	0.5	0.4	0.3	0.3	0.3	0.3	0.4	0.5	0.5	0.5	0.9	0.9	0.4
Ponderosa Junction	5721.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Downstream of Ponderosa	5890.6	0.0	0.2	0.0	0.2	0.0	0.2	0.3	0.2	0.3	0.2	0.3	0.2	-1.5
Box Culvert Inlet	6048.5	0.3	0.2	0.2	0.2	0.3	0.2	0.3	0.2	0.2	0.4	0.2	0.2	0.0
McLeod St. / Sta. 02CF005	8393.5	-0.2	0.1	-3.2	0.6	0.8	-0.8	0.6	-0.8	-0.3	0.1	1.2	0.6	7.8

10.3.4.1.1 *Cost Analysis*

The main costs, associated with the construction of Option B2, are the construction of the stormwater management facility and associated grading, as well as grading and potential works to direct incoming drainage areas, an outlet, and any other additional associated work. For comparative purposes, the cost has been estimated assuming a storage volume of 54,800 m^3, based on a storage depth of 1.5m (the facility design should be refined to no larger than required at a future design stage). Based on the list shown below and the methods described above, the cost is estimated to be approximately $4.00M. Depending on the final outlet design, a larger or smaller facility may be required, which will alter the cost estimate.

Table 10.3.7 Option B2 Cost Estimate

Option B2							
Item	**Quantity**	**Unit**	**Material Contingency**	**Quantity with Material Contingency**	**Unit Cost**	**Total cost with material contingency**	**Total cost with material contingency ($ x 1,000,000)**
Facility Excavation	54,800	m^3	20%	65,760	$25	$1,644,000	$1.64
Inlet Structures	1	L.S		1	$200,000	$200,000	$0.20
Outlet Structures	1	L.S		1	$200,000	$200,000	$0.20
					Subtotal	**$2,044,000**	**$2.04**
Access	1	L.S	20%	1	$50,000	$50,000	$0.05
Mobilization / Demobilization	1	L.S		1	$50,000	$50,000	$0.05
Permitting support (consultation with permitting agencies)	1	L.S		1	$100,000	$100,000	$0.10
Engineering Design	1	L.S		1	$300,000	$300,000	$0.30
Project & Construction Management	1	L.S		1	$254,400	$254,400	$0.25
Total Capital Cost without Contingency						**$2,798,400**	**$2.80**
Project Contingencies (30%)						**$839,520**	**$0.84**
HST (13%)						**$363,792**	**$0.36**
Grand Total						**$4,001,712**	**$4.00**
Note: This cost do not include the cost to purchase the lands							

10.3.4.2 *Natural Heritage / Ecological Considerations*

The area considered for the stormwater management facility is somewhat treed, and is marked as Woodlands and Forested Areas, and Re-Forested Land, as per the Natural Heritage Mapping (refer to **Figure B2** and **Figure B4** in **Appendix B**). The area has not been delineated as a Sensitive Natural Feature as per **Figure B5**, however it is located along a Natural Heritage System Linkage as shown on **Figure B6**.

Stormwater management facilities may offer opportunities to maintain the environmental value of an area by providing habitat enhancements such as ponded areas and wildlife plantings. The potential for habitat enhancements should be considered at a detail design stage and implemented where appropriate.

Given the location of the proposed facility along a natural heritage linkage of the subwatershed, any potential for damage to downstream features must be carefully considered and mitigated. Erosion and sediment control best management practices may be implemented as per the *Erosion & Sediment Control Guidelines For Urban Construction*, dated December 2006, by the Greater Golden Horseshoe Area Conservation Authorities (GGHA CAs, 2006).

10.3.4.3 *Social / Cultural Considerations*

The area has little social and cultural value, as it is a sparsely wooded area with no amenities, between a large industrial area and the creek. It is possible that the area provides some outdoor recreational value to the local residents, but this usage could be maintained and improved with the construction of a stormwater management facility by incorporating trails and other cultural features.

Stormwater management facilities offer opportunities to increase the cultural value of an area by providing recreational enhancements such as walking trails, gardens, and decorative ponding features. The potential to incorporate recreational enhancements should be considered at a detail design stage and implemented where appropriate.

10.3.5 Option C: Lasalle Boulevard & Railway Facility

10.3.5.1 *Technical / Engineering Considerations & Cost*

A conceptual layout of the diversion and stormwater management facility is shown on **Drawing C11.3**. There are two existing trunk sewer lines which may potentially be diverted to the stormwater storage facility to help reduce peak flows from those areas.

The facility has been conceived as a surface stormwater management facility which will receive flood water both from a diversion along Junction Creek, utilizing the LaSalle Boulevard crossing, and from two trunk sewer systems which run along LaSalle Boulevard and outlet into Junction Creek.

The 2 year floodplain elevation upstream of LaSalle Boulevard is approximately 262.18m. The 2 year event floodplain elevation downstream of the conceptual location for the facility, upstream of the railway, is 261.59 m. This only allows for 0.59 m of storage of floodwaters by diverting the 2 year event, and as such the facility is not likely to be efficient for the diversion of frequent storm events. The difference between the 100 year floodplains is larger (1.13 m), but it will be difficult to provide a large enough inlet structure to receive and the store the 100 year event flood flow.

Trunk storm sewer systems NS-3 and NS-4 (refer to **Drawing C7** in **Appendix C**) run along LaSalle Boulevard and capture drainage areas of 27.85 ha and 54.97 ha respectively. System NS-3 currently outlets on the west side on Junction Creek at LaSalle Boulevard at an invert elevation of 260.28 m, and system NS-4 outlets on the east side at an invert elevation of 260.24 m. A connection could be made to existing system NS-4 at an upstream manhole along LaSalle Boulevard, with an existing invert elevation of 261.66 m, to divert incoming storm flows into the facility. It is not possible given current conditions to capture the drainage area on the west side of the creek serviced by system NS-3 due to grading constraints with the trunk storm sewer system, and crossing the creek may be difficult. To suit the incoming trunk storm sewer system, the facility is shown with a bottom elevation of 261.50 m.

The 2 year event floodplain elevation downstream of the facility at the conceived outlet location, upstream of the railway, is 261.59 m. This does not allow for a sufficient outlet for a connection to the trunk storm sewer systems to be made. However, it may be possible to provide a piped outlet to a point further downstream along the creek, with a lower water surface, in order to achieve valid outlet.

The potentiometric surface of the groundwater table in the area of the facility, as per the *City of Greater Sudbury Municipal Groundwater Study* by Golder Associates, dated August 2005, is roughly above 267.50 m, and the area is a potential location of groundwater discharge (refer to **Appendix E**). As such any stormwater management facility would need to incorporate an impermeable liner.

The stage-storage relationship for the conceptual **Option C** storage facility, as well as the peak storage volume for the various modelled storm events as described below, is shown in **Table 10.3.5** below.

Table 10.3.8: Option C Conceptual Stage-Storage Relationship

Elevation *(masl)*	**Depth** *(m)*	**Area** *(m^2)*	**Volume** **Increment** *(m^3)*	**Volume** **Cumulative** *(m^3)*	**Note**
261.50	0.00	26781	0	0	—
261.60	0.10	27116	2,695	2,695	—
261.70	0.20	27451	2,728	5,423	—
261.80	0.30	27787	2,762	8,185	—
261.90	0.40	28122	2,795	10,981	—
262.00	0.50	28457	2,829	13,810	—
262.10	0.60	28792	2,862	16,672	—
262.20	0.70	29127	2,896	19,568	—
262.30	0.80	29463	2,930	22,497	21619 m^3 1:2yr Event
262.40	0.90	29798	2,963	25,460	—
262.50	1.00	30133	2,997	28,457	—
262.60	1.10	30468	3,030	31,487	30600 m^3 1:5yr Event
262.70	1.20	30803	3,064	34,551	—
262.80	1.30	31139	3,097	37,648	36674 m^3 1:10yr Event
262.90	1.40	31474	3,131	40,778	—
263.00	1.50	31809	3,164	43,943	44591 m^3 1:25yr Event
263.10	1.60	32144	3,198	47,140	—
263.20	1.70	32479	3,231	50,371	50498 m^3 1:50yr Event
263.30	1.80	32815	3,265	53,636	—

Elevation *(masl)*	**Depth** *(m)*	**Area** *(m^2)*	**Volume**		**Note**
			Increment *(m^3)*	**Cumulative** *(m^3)*	
263.40	1.90	33150	3,298	56,934	56469 m^3 1:100yr Event
263.50	2.00	33485	3,332	60,266	—
263.60	2.10	33820	3,365	63,631	—
263.70	2.20	34155	3,399	67,030	—
263.80	2.30	34491	3,432	70,462	—
263.90	2.40	34826	3,466	73,928	—
264.00	2.50	35161	3,499	77,428	77427 m^3 Timmins Event

Based on the conceptual facility design, a PCSWMM model simulation was run for the 1:2 through 100 year and Timmins design storm events, to compare to the existing conditions model. The relative reduction in peak flow at the various subwatershed points of interest (refer to **Table 6.4.1**) are shown in **Table 10.3.6** below. As may be seen from the table, there is a fairly large (~17%) benefit in terms of peak flow reduction at in the area of the Supermall, which may help reduce the severity of flooding around properties in the region. It is worth noting that the stage discharge outlet curve of the facility may be optimized to provide a more significant benefit at a future detailed design stage.

Table 10.3.9: Percent Reduction in Hydrologic Peak Flow with Conceptual Option C

Location	Drainage Area	Reduction in Simulated Peak Flow (%)												
		2 Year		5 Year		10 Year		25 Year		50 Year		100 Year		Regional
	(ha)	**Chi**	**SCS**	**Chi**	**SCS**	**Chi**	**SCS**	**Chi**	**SCS**	**Chi**	**SCS**	**Chi**	**SCS**	**Timmins**
Supermall	4011.2	17.2	17.2	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	17.3	1.1
Northeast of Ponderosa	4389.0	10.1	10.1	10.0	9.4	9.6	9.6	9.6	11.1	9.6	8.6	8.6	8.1	0.6
Southeast of Ponderosa	4613.7	9.8	5.2	9.6	6.9	9.0	6.1	8.9	9.0	9.1	8.7	8.0	7.5	0.6
Ponderosa Junction	5721.3	0.6	0.7	0.7	0.3	0.8	0.2	0.4	0.0	0.3	-0.2	0.4	-0.3	0.7
Downstream of Ponderosa	5890.6	0.0	2.5	0.0	2.2	0.0	2.3	2.1	2.0	2.9	2.1	2.7	2.0	-3.8
Box Culvert Inlet	6048.5	3.7	2.7	2.9	2.3	3.1	2.2	2.9	2.0	2.7	2.9	2.5	2.1	-0.4
Box Culvert Outlet	8393.5	-0.5	0.3	-0.2	0.3	-0.2	0.3	0.5	0.3	1.0	0.3	0.8	0.3	0.8
McLeod St. / Sta. 02CF005	8393.5	0.9	1.7	-3.1	0.7	1.0	1.6	0.5	-0.1	2.7	0.8	1.6	2.2	0.1
Upstream Kelly Lake	14577.1	1.1	0.1	0.9	0.1	0.8	0.2	0.6	0.2	0.5	0.1	0.2	0.4	0.4

10.3.5.1.1 Cost Analysis

The main costs, associated with the construction of Option C, are the construction of the stormwater management facility and associated grading, as well as the new connection to the trunk storm sewer system, an outlet, and any other additional associated work. There is potential that an impermeable liner will have to be incorporated into the design to prevent unintentional seepage of the stored flood waters. It is therefore difficult to provide an accurate estimate of costs, but for comparative purposes, the cost has been estimated assuming a storage volume of 77,500 m^3, based on the volume of the excavation down to elevation 261.50 m as described above. Based on the list shown below and the methods described above, the cost is estimated to be approximately $13.05M.

Table 10.3.10 Option C Cost Estimate

Option C							
Item	**Quantity**	**Unit**	**Material Contingency**	**Quantity with Material Contingency**	**Unit Cost**	**Total cost with material contingency**	**Total cost with material contingency ($ x 1,000,000)**
Facility Excavation	77,500	m^3	20%	93,000	$25	$2,325,000	$2.33
Facility Lining	35,200	m^2		42,240	$120	$5,068,800	$5.07
Inlet Structures	1	L.S		1	$200,000	$200,000	$0.20
Outlet Structures	1	L.S		1	$200,000	$200,000	$0.20
Subtotal						**$7,793,000**	**$7.79**
Access	1	L.S	20%	1	$50,000	$50,000	$0.05
Mobilization / Demobilization	1	L.S		1	$50,000	$50,000	$0.05
Permitting support (consultation with permitting agencies)	1	L.S		1	$100,000	$100,000	$0.10
Engineering Design	1	L.S		1	$300,000	$300,000	$0.30
Project & Construction Management	1	L.S		1	$829,380	$829,380	$0.83
Total Capital Cost without Contingency						**$9,123,180**	**$9.12**
Project Contingencies (30%)						**$2,736,954**	**$2.74**
HST (13%)						**$1,186,013**	**$1.19**
Grand Total						**$13,046,147**	**$13.05**
Note: This cost do not include the cost to purchase the lands							

10.3.5.2 *Natural Heritage / Ecological Considerations*

The majority of the area considered for the stormwater management facility is located on vacant land, marked as an urbanized landscape unit, with a small area of woodland near the creek (refer to **Figure B2** and **Figure B4** in **Appendix B**). The area is not a sensitive natural feature, nor is it park of any Core Area or

Linkage within the Natural Heritage System, other than the main linkage which goes along Junction Creek itself, as shown on **Figures B5** and **B6**.

Stormwater management facilities offer opportunities to improve the environmental value of an area by providing habitat enhancements such as ponded areas and wildlife plantings. The potential for habitat enhancements should be considered at a detail design stage and implemented where appropriate.

As with all stormwater management facilities near a watercourse, erosion and sediment control must be carefully considered during the construction process to mitigate any negative impact on the creek or sensitive riparian areas. Erosion and sediment control best management practices may be implemented as per the *Erosion & Sediment Control Guidelines For Urban Construction*, dated December 2006, by the Greater Golden Horseshoe Area Conservation Authorities (GGHA CAs, 2006).

10.3.5.3 *Social / Cultural Considerations*

The area currently has little social or recreational value, as it is largely vacant land with no amenities or facilities. Future development (as discussed in **Section 5.2**) is planned in the area, and it is identified as a Mixed Use Commercial Block in the CGS's land use mapping.

Stormwater management facilities offer opportunities to increase the cultural value of an area by providing recreational enhancements such as walking trails, gardens, and decorative ponding features. The potential to incorporate recreational enhancements should be considered at a detail design stage and implemented where appropriate.

10.3.6 Option D: Nickeldale Facility

10.3.6.1 *Technical / Engineering Considerations & Cost*

A conceptual layout of the diversion and stormwater management facility is shown on **Drawing C11.4**. There is a large paved parking area and several large roofs on the west side of the incoming tributary to the north of the Ponderosa area, which could be captured by the facility, as well as the potential for off-line storage of flood waters diverted from the creek.

The facility is conceptually located on the west side of the aforementioned creek tributary on approximately 0.64 ha of sparsely treed land outside of the existing regulatory floodplain delineation, and immediately east of the large paved parking area. Based on the received CGS water infrastructure base mapping, there may be an existing ditch or drainage course along the east edge of the parking area which currently directs water south to Junction Creek, which may be easily redirected into the proposed facility. Additionally, the incoming Nickeldale tributary to Junction Creek is encased in a culvert for approximately 170 m immediately upstream of this location, under LaSalle Boulevard, so it may be possible to redirect the creek itself into the facility relatively easily if desired.

The 2 year floodplain elevation at the far upstream and downstream ends of the area is approximately 258.00 m and 256.89 m, respectively, in the updated HEC-RAS modelling. This allows for approximately 1 m of storage with a shallow inlet and outlet slope. The edge of the existing paved parking area ranges from approximately 259.50 m to 260.50 m based on the LiDAR data. To suit the storage of flood waters, the facility has been conceptually shown excavated to a bottom elevation of 257.00 m.

The potentiometric surface of the groundwater table in the area of the facility, as per the *City of Greater Sudbury Municipal Groundwater Study* by Golder Associates, dated August 2005, is roughly above 290.00m, which is approximately 30m above the existing grade, and the area is a potential location of groundwater discharge (refer to **Appendix E**). The difference between the groundwater surface and existing grade is remarkable, and further investigation is required to determine whether any stormwater management facility would need to incorporate an impermeable liner.

In order to model the technical benefit of the conceptual facility, the subcatchment containing the area was divided at the location of the facility in the PCSWMM hydrologic model, and the upstream portion was routed through the facility. It is anticipated that due to the existing culvert containing Junction Creek, and the drainage course to the east of the area, it will be possible to direct upstream flow through the facility as desired.

The stage-storage relationship for the conceptual **Option D** storage facility, as well as the peak storage volume for the various modelled storm events as described below, is shown in **Table 10.3.7** below.

Table 10.3.11: Option D Conceptual Stage-Storage Relationship

Elevation *(masl)*	**Depth** *(m)*	**Area** *(m^2)*	**Volume** **Increment** *(m^3)*	**Cumulative** *(m^3)*	**Note**
257.00	0.00	4003	0	0	—
257.10	0.10	4093	405	405	—
257.20	0.20	4183	414	819	—
257.30	0.30	4273	423	1,241	—
257.40	0.40	4363	432	1,673	1570 m^3 1:2yr Event
257.50	0.50	4453	441	2,114	1952 m^3 1:5yr Event
257.60	0.60	4543	450	2,564	2222 m^3 1:10yr Event
257.70	0.70	4633	459	3,023	2614 m^3 1:25yr Event
257.80	0.80	4723	468	3,490	2927 m^3 1:50yr Event
257.90	0.90	4813	477	3,967	3262 m^3 1:100yr Event
258.00	1.00	4903	486	4,453	—
258.10	1.10	5000	495	4,948	—
258.20	1.20	5096	505	5,453	—
258.30	1.30	5193	514	5,967	—
258.40	1.40	5289	524	6,492	6207 m^3 Timmins Event
258.50	1.50	5386	534	7,025	—
258.60	1.60	5487	544	7,569	—
258.70	1.70	5587	554	8,123	—
258.80	1.80	5688	564	8,686	—

Elevation *(masl)*	**Depth** *(m)*	**Area** *(m^2)*	**Volume**		**Note**
			Increment *(m^3)*	**Cumulative** *(m^3)*	
258.90	1.90	5789	574	9,260	—
259.00	2.00	5890	584	9,844	—

Based on the conceptual facility design, a PCSWMM model simulation was run for the 1:2 through 100 year and Timmins design storm events, to compare to the existing conditions model. The relative reduction in peak flow at the various subwatershed points of interest (refer to **Table 6.4.1**) are shown in **Table 10.3.8** below. As may be seen from the table, there is a small (~3%) benefit in terms of peak flow reduction into the Ponderosa area, which may help reduce the severity of flooding around properties bordering the wetland. A substantial benefit may be seen downstream of the Ponderosa during the large Regional Timmins storm event, but this should be confirmed at a detailed design stage based on the final facility drainage area. Additionally, there may be quality control benefits associated with directing local sewer outlets into a facility for treatment prior to entering the Ponderosa wetland.

Table 10.3.12: Percent Reduction in Hydrologic Peak Flow with Conceptual Option D

Location	Drainage Area	Reduction in Simulated Peak Flow (%)												
		2 Year		5 Year		10 Year		25 Year		50 Year		100 Year		Regional
	(ha)	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Timmins
Ponderosa Junction	5721.3	8.1	7.6	8.0	8.0	8.0	8.1	8.3	8.4	8.2	8.7	8.9	7.2	0.2
Downstream of Ponderosa	5890.6	0.0	0.2	0.0	0.3	0.0	0.3	0.5	0.2	0.4	0.2	0.3	0.2	12.7
Box Culvert Inlet	6048.5	0.8	0.3	1.0	0.4	0.8	0.3	0.5	0.2	0.4	0.3	0.3	0.2	0.7
Box Culvert Outlet	8393.5	0.3	0.1	0.3	0.1	0.4	0.1	0.4	0.1	0.3	0.1	0.2	0.1	0.0
McLeod St. / Sta. 02CF005	8393.5	0.2	-1.1	-0.7	0.2	0.3	-0.1	0.5	-1.0	2.0	-0.1	0.8	1.0	8.7
Upstream Kelly Lake	14577.1	0.4	0.0	0.4	-0.1	0.5	0.0	0.3	0.1	0.4	0.1	0.1	0.5	0.0

10.3.6.1.1 Cost Analysis

The main costs, associated with the construction of Option D, are the construction of the stormwater management facility and associated grading, as well as grading and potential works to direct incoming drainage areas, an outlet, and any other additional associated work. There is potential that an impermeable liner will have to be incorporated into the design to prevent unintentional seepage of the stored flood waters. It is therefore difficult to provide an accurate estimate of costs, but for comparative purposes, the cost has been estimated assuming a storage volume of 10,000 m^3, based on the volume of the excavation down to elevation 257.00 m as described above. Based on the list shown below and the methods described above, the cost is estimated to be approximately $1.89M.

Table 10.3.13 Option D Cost Esitmate

Option D							
Item	**Quantity**	**Unit**	**Material Contingency**	**Quantity with Material Contingency**	**Unit Cost**	**Total cost with material contingency**	**Total cost with material contingency ($ x 1,000,000)**
Facility Excavation	10,000	m^3	20%	12,000	$25	$300,000	$0.30
Inlet Structures	1	L.S		1	$200,000	$200,000	$0.20
Outlet Structures	1	L.S		1	$200,000	$200,000	$0.20
					Subtotal	**$700,000**	**$0.70**
Access	1	L.S	20%	1	$50,000	$50,000	$0.05
Mobilization / Demobilization	1	L.S		1	$50,000	$50,000	$0.05
Permitting support (consultation with permitting agencies)	1	L.S		1	$100,000	$100,000	$0.10
Engineering Design	1	L.S		1	$300,000	$300,000	$0.30
Project & Construction Management	1	L.S		1	$120,000	$120,000	$0.12
Total Capital Cost without Contingency						**$1,320,000**	**$1.32**
Project Contingencies (30%)						**$396,000**	**$0.40**
HST (13%)						**$171,600**	**$0.17**
Grand Total						**$1,887,600**	**$1.89**
Note: This cost do not include the cost to purchase the lands							

10.3.6.2 *Natural Heritage / Ecological Considerations*

The area considered for the stormwater management facility is somewhat treed, and is marked as Woodlands and Forested Areas, and Re-Forested Land, as per the Natural Heritage Mapping (refer to **Figure B2** and **Figure B4** in **Appendix B**). The area has not been delineated as a Sensitive Natural Feature as per

Figure B5, however it is at the border to the central Core Area of the Natural Heritage System as shown on **Figure B6**.

Stormwater management facilities may offer opportunities to maintain the environmental value of an area by providing habitat enhancements such as ponded areas and wildlife plantings. The potential for habitat enhancements should be considered at a detail design stage and implemented where appropriate.

Given the proximity of the proposed facility to the sensitive core natural heritage areas of the subwatershed, any potential for damage to downstream features must be carefully considered and mitigated. Erosion and sediment control best management practices may be implemented as per the *Erosion & Sediment Control Guidelines For Urban Construction*, dated December 2006, by the Greater Golden Horseshoe Area Conservation Authorities (GGHA CAs, 2006).

10.3.6.3 *Social / Cultural Considerations*

The area has little social and cultural value, as it is a sparsely wooded area with no amenities, between a large parking lot and the creek. No future development (as discussed in **Section 5.2**) is planned in the area.

Stormwater management facilities offer opportunities to increase the cultural value of an area by providing recreational enhancements such as walking trails, gardens, and decorative ponding features. The potential to incorporate recreational enhancements should be considered at a detail design stage and implemented where appropriate.

10.3.7 Option E: Diversion & Facility East of Ponderosa

Recently, the CGS completed the construction of a storm overflow channel from Mountain Street and Leslie Street, through the old railway corridor, to Junction Creek, as described in the *Mountain Street and Leslie Street Stormwater Improvements Report*, by the CGS Infrastructure Services Department Roads and Transportation Division, dated February 2011.

Additionally, there is a proposal to divert stormwater management runoff from the Sunrise Ridge development stormwater management pond, as well as a large existing drainage area, away from the Leslie and Mountain Street area and north towards a proposed berm that will control the flow north towards the Ponderosa, as described in the *Mountain Street Stormwater Management Report*, by WSP, dated November 2017. This may reduce flows to the Leslie and Mountain Street area, but it increases the total drainage area to the Ponderosa and will likely increase flow through the Flour Mill area, which already has severe flooding issues. Through analysis of the overall area, it is not advisable to direct the Sunrise Ridge and area flows north. As flooding issues on Mountain Street have been addressed through the overflow channel, the outstanding issue is the Sunrise Ridge outfall which would be more effectively addressed through procurement of the homes in the immediate vicinity of the outfall, or other mitigative measures. It is also recommended to landscape the area of these homes to provide a defined path for major events to reach the existing Mountain Street overflow channel.

As an option of this Stormwater Master Plan, the themes of these options may be combined into a larger stormwater management diversion and potential storage facility, by providing a connection from the area of the proposed berm (characterized as the second natural storage area of the Ponderosa, Ponderosa 2, as described in **Section 6.2.2**), through the existing railway corridor, to the Mountain Street overflow channel. This would allow incoming major storm flood flows from Junction Creek, a second outlet to drain away from the Flour Mill and other area neighbourhoods. The goal of this option will be to provide lower flood event flows and therefore a reduction in flood risk to properties along Junction Creek between the Ponderosa and the Box Culvert. Given the high natural heritage value and ecological sensitivity of the Ponderosa wetland, habitat enhancements and protection for local species must be carefully considered before finalizing the design of any works. As such, this option will require additional study and documentation beyond this Stormwater Master Plan. It is important to note that during further analysis of this option, a staged design and construction approach should be considered. Due to the aforementioned ecological restrictions, there may be benefits on proposing, as a first phase, the design and construction of the diversion channel and as a later phase the potential berming and creation of stormwater management facilities around the area to additionally promote regulation and attenuation of higher peak flows.

10.3.7.1 *Technical / Engineering Considerations & Cost*

A conceptual layout of the diversion and stormwater management facility is shown on **Figure C11.5a**. The conceptual facility was created in PCSWMM by altering the storage curve of the second natural storage area of the Ponderosa (as described in **Section 6.2.2**), and adding an additional outlet through the railway corridor to the Mountain St. overflow channel.

One of the most important factors in the technical effectiveness of Option E is the elevation of the diversion channel from the second natural storage area of the Ponderosa (Ponderosa 2). The invert elevation of the existing Mountain St. overflow channel at the point of connection (i.e. where it enters the railway corridor and turns to flow southwest towards Junction Creek) is approximately 257.67 m. Based on the existing conditions hydrologic analysis of the Ponderosa storage units in PCSWMM, only very large storm events flood substantially above that elevation. Therefore, in order to additionally divert flood water from more frequent storm events, the diversion channel must be lowered.

An examination of the design drawings for the Mountain St. overflow channel reveals that the majority of the channel is sloped at 0.3%, but that there are several areas of 10% slope, which might provide potential to lower the overall channel profile. The Mountain St. overflow channel has been lowered by 1 m from Junction Creek to the point of connection with Option E in the PCSWMM modelling, to elevation 256.55m. This allows the inlet of the diversion (at Ponderosa 2) to be around elevation 257.25m, which is approximately the elevation of the 5 year storm, allowing for flood water above this elevation to enter the diversion.

Additionally, all but one of the culverts through the railway between the second and third natural storage areas of the Ponderosa have been closed in the model. A single culvert has been left open to provide water balance through Junction Creek. A detailed continuous simulation model may be required to provide a more accurate water balance design, and should be refined at a future detail design stage. The peak flow into Ponderosa 3 under existing conditions during a typical 25 mm summer event (modelled as a SCS Type

II design storm in PCSWMM), which is a common target for water balance, is approximately 351,000 m^3. With a single culvert left open, the peak outflow during the 100 year SCS Type II design storm through the culvert is 327,000 m^3 (with no flow through the diversion channel), and therefore this is considered to be a reasonable water balance concept. The water balance volumes could be matched more precisely at a future design stage by providing a weir in front of the outlet pipes, including possibly leaving more than one pipe open.

It is anticipated that the design of the channel will be similar to the Mountain St. overflow channel. The peak flow and velocity through the channel from the PCSWMM model during the Timmins design storm event are 6.342 m^3/s and 1.04 m/s respectively.

Based on the conceptual facility design, a PCSWMM model simulation was run for the 1:2 through 1:100 and Timmins design storm events, to compare to the existing conditions model. The relative reduction in peak flow at the various subwatershed points of interest (refer to **Table 6.4.1**) are shown in **Table 10.3.9** below. Note that flows "Northeast of the Ponderosa" and "Southeast of the Ponderosa" are much higher in the Option E modelling, but these are an artefact of the storage unit routing in PCSWMM. Storage requirements and water surface elevations within "Ponderosa 2" are increased, but decreased within "Ponderosa 3", as shown in **Table 10.3.10**. The most critical point for this analysis is "Downstream of Ponderosa", and it is clear that peak flows are much reduced through this reach under Option E. The reduction benefit is also seen downstream, until approximately the downtown Box Culvert.

Table 10.3.14: Percent Reduction in Hydrologic Peak Flow with Conceptual Option E

Location	Drainage Area *(ha)*	Reduction in Simulated Peak Flow (%)												
		2 Year		5 Year		10 Year		25 Year		50 Year		100 Year		Regional
		Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Timmins
Northeast of Ponderosa	4389.0	0.0	0.0	0.0	-59.9	-11.1	-154.0	-93.2	-147.1	-119.9	-176.8	-165.8	-179.0	21.1
Southeast of Ponderosa	4613.7	0.1	0.0	0.0	-107.3	-56.7	-196.2	-136.3	-190.2	-165.2	-218.3	-208.2	-220.7	23.2
Ponderosa Junction	5721.3	25.3	30.9	29.7	32.6	31.4	31.7	31.2	29.9	29.7	28.2	28.9	26.9	6.2
Downstream of Ponderosa	5890.6	0.0	5.7	0.0	13.8	0.0	17.9	2.1	20.1	6.3	21.9	9.5	19.1	25.5
Box Culvert Inlet	6048.5	10.5	4.3	9.4	5.4	9.6	5.3	9.9	5.0	9.0	8.6	7.1	2.6	-7.5
Box Culvert Outlet	8393.5	0.6	0.7	0.7	0.9	0.8	1.1	1.8	1.2	4.1	1.5	4.4	1.5	-2.8
McLeod St. / Sta. 02CF005	8393.5	-17.6	0.9	5.2	4.5	5.2	7.2	8.2	5.2	5.6	4.7	5.1	3.3	5.8
Upstream Kelly Lake	14577.1	6.1	0.0	5.9	0.0	5.1	0.3	4.5	0.2	3.5	0.1	2.6	1.2	-2.2
Robinson Lake	344.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0
Kelly Lake	17785.3	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.1
Fielding Road / Sta. 02CF012	18190.6	-0.5	1.0	1.1	2.5	2.2	2.9	3.3	2.5	3.3	2.2	2.5	1.6	-0.1
Mud Lake	25716.4	0.0	0.0	-0.1	-0.1	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Into Simon Lake	25716.4	-0.1	0.2	0.0	0.3	0.0	0.5	0.0	0.6	0.0	1.3	0.0	0.9	0.1

The maximum storage within the Ponderosa under existing conditions, compared to the implementation of Option E as described above, is shown in **Table 10.3.6.1.1.2** below. As expected, the required storage upstream of the diversion channel (Ponderosa 1 & 2) is increased overall, and the storage within the main body of the Ponderosa closest to the flooding (Ponderosa 3) is decreased overall, with the implementation of Option E.

Table 10.3.15: Ponderosa Peak Storage and Water Level Comparison

Peak Storage in Ponderosa (m^3)

Event	Ponderosa 1		Ponderosa 2		Ponderosa 3	
	Existing	**Option E**	**Existing**	**Option E**	**Existing**	**Option E**
1:2 Year Chicago	751	751	707	34,451	108,136	100,498
1:2 Year SCS	831	831	1,358	51,603	175,992	163,448
1:5 Year Chicago	935	935	1,560	78,245	182,882	155,791
1:5 Year SCS	994	1,698	7,663	136,544	311,956	253,628
1:10 Year Chicago	1,020	1,403	3,751	115,792	242,185	192,126
1:10 Year SCS	1,081	5,059	17,223	210,706	420,913	312,598
1:25 Year Chicago	1,116	3,072	9,240	177,182	328,310	238,671
1:25 Year SCS	1,216	12,847	39,975	300,133	558,979	381,207
1:50 Year Chicago	1,264	9,622	23,281	264,008	456,630	300,103
1:50 Year SCS	1,323	14,060	64,662	310,782	656,747	483,581
1:100 Year Chicago	1,402	13,890	44,524	309,235	561,881	365,804
1:100 Year SCS	1,460	14,933	94,897	318,074	753,688	591,621
Timmins	21,865	22,355	356,126	369,432	1,857,847	1,790,209

Peak Water Level in Ponderosa (m)

Event	Ponderosa 1		Ponderosa 2		Ponderosa 3	
	Existing	**Option E**	**Existing**	**Option E**	**Existing**	**Option E**
1:2 Year Chicago	257.57	257.57	256.71	257.41	256.70	256.68
1:2 Year SCS	257.60	257.60	256.89	257.50	256.88	256.86
1:5 Year Chicago	257.63	257.63	256.91	257.61	256.90	256.84
1:5 Year SCS	257.65	257.82	257.12	257.80	257.10	257.02
1:10 Year Chicago	257.66	257.76	257.02	257.74	257.00	256.92
1:10 Year SCS	257.68	258.01	257.27	258.00	257.23	257.10
1:25 Year Chicago	257.69	257.93	257.15	257.91	257.12	256.99
1:25 Year SCS	257.71	258.21	257.44	258.21	257.37	257.18
1:50 Year Chicago	257.73	258.14	257.33	258.12	257.26	257.08
1:50 Year SCS	257.74	258.23	257.56	258.23	257.47	257.29
1:100 Year Chicago	257.76	258.23	257.47	258.23	257.38	257.16
1:100 Year SCS	257.77	258.25	257.67	258.25	257.56	257.41
Timmins	258.36	258.37	258.33	258.36	258.30	258.27

As may be seen from the table, the conceptual Option E results in an increase in water level of approximately 0.15 m in the first natural storage area, approximately 0.75 m in the second natural storage area, and a decrease of approximately 0.15 m in the third natural storage area of the Ponderosa, during the 100 year SCS design storm event. The water level through Junction Creek downstream of the Ponderosa, based on the PCSWMM model, is similarly decreased by approximately 0.15 m with the construction of the diversion. Though the water surface elevations shown in **Appendix C** are in fact taken from the HEC-RAS model, the flows and hydraulic results of the PCSWMM model (shown in the tables above) provide a better indication of the expected results of each stormwater management facility option, as it is an overall hydrologic and hydraulic model capable stormwater management storage facility modelling. Once again, a more detailed. and potentially staged, modelling effort may be required in a future detail design stage to provide more accurate and more significant case-specific results for this option.

It is worth noting that Option E, as it is presented in this Stormwater Master Plan, is anticipated to provide a water surface reduction of approximately 0.15 m, and therefore does not significantly reduce the number of lots affected by extraordinary flooding events. However, further preliminary scenarios have shown that there are more significant improvements and benefits for the Flour Mill area with a diversion channel during lower but more frequent events. It is also expected that a combination of this option with others (i.e. creek restoration and re-profiling, Nickeldale facility, etc) will affect major improvements on the drainage of the Ponderosa and Flour Mill areas by reducing the frequency of flooding scenarios.

10.3.7.1.1 Cost Analysis

The main costs, associated with the construction of Option E as presented in this Stormwater Master Plan, are the construction of a berm approximately 2 km in length and a control structure on the main channel, as well as approximately 1.2 km of the new flood diversion channel, and any work related to increasing the available storage area. There is potential that an impermeable liner will have to be incorporated into the design to prevent unintentional seepage of the stored flood waters. It is estimated that some sections of this new flood diversion channel will require to be tunneled or with the use of concrete box culverts. It is therefore difficult to provide an accurate estimate of costs, but for comparative purposes, the cost has been estimated assuming a channel excavation of 110,000 m^3, based on the conceptual slope and alignment of the channel for Option E. Based on the list shown below and the methods described above, the cost is estimated to be approximately $24.23M.

Table 10.3.16 Option E Cost Estimate

Option E							
Item	**Quantity**	**Unit**	**Material Contingency**	**Quantity with Material Contingency**	**Unit Cost**	**Total cost with material contingency**	**Total cost with material contingency ($ x 1,000,000)**
Berm	67,000	m^3	20%	80,400	$45	$3,618,000	$3.62
Control Structure	1	L.S		1	$1,000,000	$1,000,000	$1.00
					Subtotal	**$4,618,000**	**$4.62**
Channel Excavation	110,000	m^3	20%	132,000	$25	$3,300,000	$3.30
Channel Lining	18,000	m^2		21600	$120	$2,592,000	$2.59

Option E							
Item	**Quantity**	**Unit**	**Material Contingency**	**Quantity with Material Contingency**	**Unit Cost**	**Total cost with material contingency**	**Total cost with material contingency ($ x 1,000,000)**
Tunnel	300	m		360	$11,657	$4,196,592	$4.20
					Subtotal	**$10,088,592**	**$10.09**
Access	1	L.S	20%	1	$50,000	$50,000	$0.05
Mobilization / Demobilization	1	L.S		1	$50,000	$50,000	$0.05
Permitting support (consultation with permitting agencies)	1	L.S		1	$100,000	$100,000	$0.10
Engineering Design	1	L.S		1	$500,000	$500,000	$0.50
Project & Construction Management	1	L.S		1	$1,540,659	$1,540,659	$1.54
					Total Capital Cost without Contingency	**$16,947,251**	**$16.95**
					Project Contingencies (30%)	**$5,084,175**	**$5.08**
					HST (13%)	**$2,203,143**	**$2.20**
					Grand Total	**$24,234,569**	**$24.23**
Note: This cost do not include the cost to purchase the lands							

In order to provide context to the extraordinarily large estimated cost for the project (which is only an approximate cost), the cost to purchase affected lots in the area has been analyzed. The average price of the lots in the Flour Mill and Ponderosa area, based on current listings, was determined to be approximately $173,500, and a cost of $2,000,000 was assumed for larger buildings. In total 230 houses and 10 larger buildings are affected by the 100 year floodplain (as per the updated HEC-RAS modelling), and 375 houses and 23 larger buildings are affected by the Timmins floodplain. The total theoretical cost to purchase all properties affected by flooding in this area is therefore approximately $59,900,000 and $111,000,000 for the 100 year and Timmins events respectively. As a result of these preliminary cost estimates, a berm and pumping option, complementary to the berm proposed in this Option E, has been presented in Section 10.3.7.4.

10.3.7.2 *Natural Heritage / Ecological Considerations*

The area considered for the Ponderosa storage facility is heavily treed, and is marked as a Wetland in the Natural Heritage Mapping (refer to **Figure B2** in **Appendix B**). Additionally, the area has been delineated as a Highly Sensitive Natural Feature as per **Figure B5**, as it represents a major wetland habitat area within the Junction Creek subwatershed. Finally, the area has been identified as part of one of four Core Areas within the Natural Heritage System, as per **Figure B6**.

Based on recent conversations with the CGS and CS, it is understood that the Ponderosa wetland area has been delineated as a PSW within Ontario. The relationship of the PSW area to the proposed storage facility should be established and confirmed at a future design stage.

As such, the proposed stormwater management facility should be considered to have a high level of environmental impact, as any land used for stormwater management will be taking land away from an important natural heritage area. Additionally, the construction process has potential to cause noise and other environmental disturbances which may upset the natural heritage system beyond the limits of merely the construction site. Any potential disturbance to Species at Risk or other wildlife must be carefully considered at a detail design stage.

Stormwater management facilities may offer opportunities for water quality improvements and habitat enhancements. However, the potential to disturb the natural system must be carefully considered and mitigated if work is considered in this area. Habitat enhancements to the storage facility and diversion channel, including perhaps creation of a natural meandering stream channel in the area, should be carefully considered at a detail design stage and implemented as appropriate.

Given the sensitivity of the area, erosion and sediment control must be carefully considered during the construction process to mitigate any negative impact on the creek or sensitive riparian areas. Erosion and sediment control best management practices may be implemented as per the *Erosion & Sediment Control Guidelines For Urban Construction*, dated December 2006, by the Greater Golden Horseshoe Area Conservation Authorities (GGHA CAs, 2006).

10.3.7.3 *Social / Cultural Considerations*

Both the berm proposed in the *Mountain Street Stormwater Management Report* and Option E have potential implications on the trail system that crosses near the Ponderosa wetland. It is common for trails to be integrated into the design of stormwater management facilities and works, and it is anticipated that any project undertaken in this area would maintain or enhance the existing trail network and connections. There is potential for Option E to affect the inundation frequency of the Ponderosa 2 natural storage area, and so the elevation of the trail relative to the final designed ponding elevations, periods, and frequencies must be carefully considered.

10.3.7.4 *Analysis of Potential Pumping in the Ponderosa*

The potential to mitigate flooding by creating large stormwater management berms to separate flood waters within Junction Creek and the Ponderosa from adjacent residential areas. In order to prevent flooding and backwater effects into the neighbourhoods, the hydraulic connection with Junction Creek would need to be severed. Therefore, in order to provide an outlet for stormwater in the area (the current outlet is Junction Creek), large pump stations would be required to de-water the bermed areas. A conceptual layout of stormwater management berms which would be required to separate nearby residential properties from the floodplain in the Ponderosa area is shown on **Figure C11.5b**.

There are two main residential neighbourhoods around the Ponderosa which would theoretically require berming. The first neighbourhood is the Nickeldale area, north of the Ponderosa and south of LaSalle Boulevard. Both the east and west sides of the incoming Nickeldale branch are prone to flooding, however the west side is mainly businesses while the east side is residential, so the berm has been focused on the latter. The average grade in the Nickeldale residential neighbourhood is around 257masl, and the elevation of the Regional (Timmins) floodplain is around 258.8m. Therefore, in order to provide adequate separation from Junction Creek, the berm would be as high as 2m in some locations.

The second neighbourhood at risk of major flooding in the Ponderosa is the area of Perrault Street, south of the Ponderosa, in the area of the Percy Playground. This area is generally low relative to the floodplain, and residents have experienced continual drainage issues including storm sewers surcharging into the roadway during storm events. The average grade in the area is around 256-257masl, and the elevation of the Regional (Timmins) floodplain is around 258.8m. Therefore, in order to provide adequate separation from Junction Creek during storm events, the berm would be as high as 3m in some locations. With a 3:1 slope, the resultant berm width is approaching 20m, which represents a substantial intrusion into the available neighbourhood area and is likely to require the appropriation of some lots in the neighbourhood to provide sufficient space.

However, even though separating the aforementioned areas from Junction Creek and the Ponderosa using berms and introducing pump stations may relieve flooding within those neighbourhoods, it is likely increase flooding elsewhere in the subwatershed. Effectively, berming the areas up to the Regional storm event "fills-in" these areas in the floodplain, and removes that storage capacity from the floodplain. As the areas do not represent a significant percentage of the drainage area to Junction Creek, the water flowing to the Ponderosa will be similar, and therefore any reduced storage capacity will increase water surface elevations in the area. Based on preliminary identified elevations, and a volume surface analysis using the existing DEM received from the CGS, constructing the berms as shown on **Figure C11.6b** would remove 180,000m^3 of floodplain storage from the Nickeldale area, and 210,000 m^3 of floodplain storage from the Perrault Street area.

Due to concerns regarding potential effects on upstream flood elevations, berming within the floodplain is not recommended. A detailed floodplain encroachment analysis may help determine the effect of filling within the floodplain in these areas. It may be possible to fill in some areas, particularly in the Nickeldale neighbourhood, without causing a significant water surface increase upstream. However, as the Perrault Street neighbourhood is built right up to the creek, it is anticipated that any filling in these areas will result in an upstream water surface increase.

10.3.8 Option F: Diversion & Facility East of Donnelly Drive

10.3.8.1 *Technical / Engineering Considerations & Cost*

A conceptual layout of the diversion and stormwater management facility is shown on **Figure C11.6**. Conceptually, a berm could be constructed to divert flood waters from Junction Creek (there is an existing constriction along the creek in this area already from a railway berm) through a culvert through the existing hydro corridor, to a facility located to the southeast of the creek. As the pits were previously used for aggregate extraction, and as the area is hydrogeologically connected to the Junction Creek subwatershed, there is potential for flood waters to infiltrate and return to the creek as baseflow, through the construction of an infiltration and storage facility. This has a wide range of benefits from peak flow attenuation, to water quality improvements such as temperature reduction. Without more detailed information on the infiltrative capacity of the area, the facility has been modelled as a storage facility only at this time.

The facility has been conceived as an off-line storage facility, which will divert flood water upstream of the railway construction, above the 25 mm or 2 year event flood elevation. The facility is shown as a storage facility located between the existing right-of-way and property lines and an existing watercourse to the southeast of the creek, as per a previous design by the CGS (Kevin Reynish, personal correspondence, April 2018). A pipe culvert outlet and overflow weir at the far end of the pond direct flow back to Junction Creek. As per the previous design, the facility has been shown with storage down to elevation 275.15 m, in order to allow outlet above the downstream floodplain, and with a maximum conceptual storage elevation of approximately 277.00 m, in order to prevent backwater effects upstream. The southeast end of the property must be filled in order to reach elevation 277.00 m to contain flood waters, and a concept berm is shown on **Drawing 11.6**. The groundwater potentiometric surface in this area (refer to **Appendix E)** varies between 273.50 m and 278.00 m, and therefore an impermeable pond liner may be required towards the northeast end of the facility where groundwater is higher.

In order to direct flow into the facility, the downstream transect in Junction Creek was modified such that flow is only able to pass through the small opening in the railway berm. This acts as a kind of natural weir and flow diversion which allows flow to be directed into a conceptual 3000 mm diameter inlet pipe. The design of the facility flow diversion, inlet, and outlet structure should be refined at a detail design stage.

The stage-storage relationship for the conceptual **Option F** storage facility, as well as the peak storage volume for the various modelled storm events as described below, is shown in **Table 10.3.11** below.

Table 10.3.17: Option F Conceptual Stage-Storage Relationship

Elevation *(masl)*	**Depth** *(m)*	**Area** *(m^2)*	**Volume**		**Note**
			Increment *(m^3)*	**Cumulative** *(m^3)*	
275.20	0.00	158858	0	0	—
275.30	0.10	159796	15,933	15,933	—
275.40	0.20	160734	16,026	31,959	—
275.50	0.30	161672	16,120	48,079	—
275.60	0.40	162610	16,214	64,294	1444 m^3 1:2yr Event
275.70	0.50	163548	16,308	80,602	5500 m^3 1:5yr Event
275.80	0.60	164486	16,402	97,003	9706 m^3 1:10yr Event
275.90	0.70	165425	16,496	113,499	16447 m^3 1:25yr Event
276.00	0.80	166363	16,589	130,088	21950 m^3 1:50yr Event
276.10	0.90	167301	16,683	146,771	27588 m^3 1:100yr Event
276.20	1.00	168239	16,777	163,548	—
276.30	1.10	169177	16,871	180,419	—

Elevation *(masl)*	**Depth** *(m)*	**Area** *(m^2)*	**Volume**		**Note**
			Increment *(m^3)*	**Cumulative** *(m^3)*	
276.40	1.20	170115	16,965	197,384	—
276.50	1.30	171053	17,058	214,442	—
276.60	1.40	171991	17,152	231,594	103852 m^3 Timmins Event
276.70	1.50	172930	17,246	248,840	—
276.80	1.60	173868	17,340	266,180	—
276.90	1.70	174806	17,434	283,614	—
277.00	1.80	175744	17,527	301,142	—

Based on the conceptual facility design, a PCSWMM model simulation was run for the 1:2 through 1:100 and Timmins design storm events, to compare to the existing conditions model. The relative reduction in peak flow at the various subwatershed points of interest (refer to **Table 6.4.1**) are shown in **Table 10.3.12** below. As may be seen from the table, the facility provides a significant flow reduction immediately downstream, in the area of the crossing with the Falconbridge area Railway, however, effects modelled further downstream are much less significant.

Table 10.3.18: Percent Reduction in Hydrologic Peak Flow with Conceptual Option F

Location	**Drainage Area**	**Reduction in Simulated Peak Flow (%)**												
		2 Year		**5 Year**		**10 Year**		**25 Year**		**50 Year**		**100 Year**		**Regional**
	(ha)	**Chi**	**SCS**	**Chi**	**SCS**	**Chi**	**SCS**	**Chi**	**SCS**	**Chi**	**SCS**	**Chi**	**SCS**	**Timmins**
O'Neil Drive West	333.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.0	0.0
Railway	574.1	44.0	41.8	43.2	41.4	43.2	41.4	43.3	41.4	43.3	41.6	43.5	41.9	16.5
Twin Forks	3596.1	3.0	1.6	3.0	0.9	2.7	1.3	4.6	1.6	2.4	0.0	0.5	0.0	9.7
Supermall	4011.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4
Northeast of Ponderosa	4389.0	0.7	1.2	0.6	0.6	0.7	0.3	1.0	0.4	1.5	0.7	3.4	2.8	3.4
Southeast of Ponderosa	4613.7	0.6	1.1	0.6	0.6	0.6	0.3	0.9	0.4	1.2	0.6	2.8	1.6	3.6
Ponderosa Junction	5721.3	0.0	0.4	0.0	0.1	0.0	-0.1	0.0	-0.3	0.0	-0.3	0.0	-0.4	3.7
Downstream of Ponderosa	5890.6	0.0	-0.2	0.0	0.4	0.0	0.6	1.3	0.8	1.6	1.0	1.8	1.1	21.8
Box Culvert Inlet	6048.5	3.3	0.0	1.8	0.4	1.2	0.7	1.2	0.8	1.4	1.3	1.5	1.3	-1.7
Nolin Box Culvert	2225.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Box Culvert Outlet	8393.5	0.0	0.3	0.0	0.3	0.0	0.3	0.6	0.2	0.8	0.2	0.5	0.2	0.7
McLeod St. / Sta. 02CF005	8393.5	0.5	-1.2	2.3	-0.2	0.6	1.6	1.9	0.0	1.5	0.2	0.8	0.0	8.5
Upstream Kelly Lake	14577.1	0.4	0.2	0.4	0.1	0.2	0.2	0.2	0.1	0.3	0.2	-0.3	0.0	0.2
Ramsey Outflow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.3	0.0	0.0	0.0	0.0	0.0
Kelly Lake	17785.3	0.2	0.0	0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Fielding Road / Sta. 02CF012	18190.6	0.0	0.0	0.2	0.2	0.2	0.3	0.4	0.9	0.4	0.5	0.4	0.5	-0.8
Into Simon Lake	25716.4	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.2	-0.1	0.2	0.1

10.3.8.1.1 Cost Analysis

The main costs associated with the construction of Option F are the construction of the stormwater management facility and associated grading, as well the construction of the diversion and inflow pipe, the construction of the outlet pipe and overflow weir, and any other additional associated work. Given the extensive inlet and outlet tunneling expected for this facility, it is difficult to provide an accurate estimate of costs. For comparative purposes, the cost has been estimated assuming a storage volume of 300,000 m^3, based on the conceptual stage-storage relationship for Option F. Based on the list shown below and the methods described above, the cost is estimated to be approximately $28.21M.

Table 10.3.19 Option F Cost Analysis

Option F							
Item	**Quantity**	**Unit**	**Material Contingency**	**Quantity with Material Contingency**	**Unit Cost**	**Total cost with material contingency**	**Total cost with material contingency ($ x 1,000,000)**
Facility Excavation	301,142	m^3	20%	361,370	$25	$9,034,260	$9.03
Facility Lining	50,000	m^2		60,000	$120	$7,200,000	$7.20
Inlet Structures	1	L.S		1	$500,000	$500,000	$0.50
Outlet Structures	1	L.S		1	$500,000	$500,000	$0.50
					Subtotal	**$17,234,260**	**$17.23**
Access	1	L.S	20%	1	$50,000	$50,000	$0.05
Mobilization / Demobilization	1	L.S		1	$50,000	$50,000	$0.05
Permitting support (consultation with permitting agencies)	1	L.S		1	$100,000	$100,000	$0.10
Engineering Design	1	L.S		1	$500,000	$500,000	$0.50
Project & Construction Management	1	L.S		1	$1,793,426	$1,793,426	$1.79
Total Capital Cost without Contingency						**$19,727,686**	**$19.73**
Project Contingencies (30%)						**$5,918,306**	**$5.92**
HST (13%)						**$2,564,599**	**$2.56**
Grand Total						**$28,210,591**	**$28.21**
Note: This cost do not include the cost to purchase the lands							

10.3.8.2 *Natural Heritage / Ecological Considerations*

The area considered for the stormwater management facility is vacant and not very treed, largely part of the old hydro corridor, and is marked as Urbanized Area on the Natural Heritage Mapping (refer to **Figure**

B2 in **Appendix B**). The area has not been marked as a Sensitive Natural Feature nor a Core Area, however there is a Natural Heritage Linkage delineated along the hydro corridor, as per **Figure B6**.

Given the importance of the hydro corridor as a Linkage in the Natural Heritage System, any proposed stormwater management works in the area must maintain this natural link. Care must be taken at a detail design stage to ensure that habitat enhancements and wildlife pathways are incorporated where appropriate.

As with all stormwater management facilities near a watercourse, erosion and sediment control must be carefully considered during the construction process to mitigate any negative impact on the creek or sensitive riparian areas. Erosion and sediment control best management practices may be implemented as per the *Erosion & Sediment Control Guidelines For Urban Construction*, dated December 2006, by the Greater Golden Horseshoe Area Conservation Authorities (GGHA CAs, 2006).

10.3.8.3 *Social / Cultural Considerations*

The area has some social and cultural value, as part of the "hydro corridor" is in fact marked as residential lots and is planned for future residential development (as per **Section 5.2**). The potential of planned residential development to affect the proposed stormwater management works should be examined at a detail design stage, once plans for the residential development are known. Note that the hydro utility corridor, which must presumably be maintained, may provide a means of access for stormwater management.

Stormwater management facilities offer opportunities to increase the cultural value of an area by providing recreational enhancements such as walking trails, gardens, and decorative ponding features. The potential to incorporate recreational enhancements should be considered at a detail design stage and implemented where appropriate. It is common in southern Ontario that quarry pits storing water are used for swimming and other recreational purposes.

10.3.9 Option G: Restoration and Reprofiling of Junction Creek Downstream of Ponderosa

10.3.9.1 *Technical / Engineering Considerations & Cost*

There are a variety of conveyance improvements which may be applied to Junction Creek. A discussion of the sensitivity of the floodplain to each crossing along Junction Creek has been included within the hydraulic modelling **Section 7.5**. The potential for daylighting the creek was also discussed in **Section 7.6**. In addition to improvements to crossings and daylighting, there is potential to restore and reprofile Junction Creek downstream of the Ponderosa to help alleviate flooding through that critical area.

10.3.9.1.1 Ponderosa to Box Culvert

Downstream of the Ponderosa, through the area known as the Flour Mill, Junction Creek is very flat with an effectively no slope, based on the received LiDAR data and topographic information. This causes the hydraulic floodplain to be high through this area, such that the area of Perrault St., Percy St., and Dell St., on the east side of Junction Creek, are within even the 2 year floodplain, as shown on **Figure C6.1** (refer to **Appendix 'C'**). This additionally causes many of the storm sewer outfalls in the area to have a submerged tailwater condition, as discussed in **Section 8.2.2.1**. As may be seen from **Table 8.2.1**, the outfalls for trunk storm sewer systems FM-2 through FM-6 are far below the 5 year floodplain, which is likely to cause backwater conditions and flooding in these regions.

Junction Creek has more slope and begins to fall more steeply south of Bond Street, and again south of Leslie Street. There is potential to increase the slope of Junction Creek immediately downstream of the Ponderosa by interpolating a new profile through these areas to the lower sections of the creek downstream. Two new creek profiles have been analyzed:

1. Profile 1 - Interpolating from the downstream face of the railway south of the Ponderosa (Upper Junction Creek Sta. 1989.123, invert 255.45 m) to south of Bond Street (Upper Junction Creek Sta. 1043.254, invert 254.76 m) for a slope of 0.073%; and,
2. Profile 2 - Interpolating from the downstream face of the railway south of the Ponderosa to south of Leslie Street (Upper Junction Creek Sta. 621.6208, invert 253.86 m), for a slope of 0.116%.

In order to determine the hydraulic benefit of increasing the slope of Junction Creek downstream of the Ponderosa, a new channel profile was cut into the HEC-RAS model using the program's channel modification tools. The channel was assumed to be trapezoidal with a 4 m bottom and 3:1 side slopes, based on the existing size of the Junction Creek channel from ortho-imagery and LiDAR data. The results of the reprofile modelling for the 5 year event surface profile at each of the trunk storm sewer outfalls through this reach are shown in **Table 10.3.13** below.

Table 10.3.20: Comparison of Restored and Existing Creek Profiles at Trunk Sewer Outfalls

Outlet	Invert	HEC-RAS Upper Model Station	Event Water Surface Elevation (m)					
			1:5 Year					
			Chi			SCS		
			Ex.	Profile 1	Profile 2	SCS	Profile 1	Profile 2
FM-2	255.19	2014.724	256.95	256.82	256.61	257.14	256.91	256.85
FM-3	254.98	1890.508	256.94	256.79	256.53	257.14	256.89	256.80
FM-4	254.95	1890.508	256.94	256.79	256.53	257.14	256.89	256.80
FM-5	255.27	1549.371	256.79	256.56	256.17	257.00	256.68	256.49
FM-6	254.71	1174.399	256.22	256.27	255.84	256.42	256.38	256.18

As may be seen from the table, both new profiles offer a significant reduction (0.20 to 0.30 m) to the 5 year event water surface elevation at each of the trunk storm sewer outfalls. However, it is not sufficient to relieve the submerged tailwater condition, as the sewers are far below the modelled existing water surface elevations.

10.3.9.1.2 Cost Analysis

The main costs associated with the construction of Option G are permitting, access, sediment excavation and sediment disposal. Given the unknown costs related with the main construction tasks, it is difficult to provide an accurate estimate of costs. However, for comparative purposes, the cost has been estimated assuming a sediment volume of 124,605 m^3 to be removed, based on the conceptual new creek profile for Option G. Based on the list shown below and the methods described above, the cost is estimated to be approximately $9.42M.

Table 10.3.21 Option G Cost Estimate

Option G							
Item	**Quantity**	**Unit**	**Material Contingency**	**Quantity with Material Contingency**	**Unit Cost**	**Total cost with material contingency**	**Total cost with material contingency ($ x 1,000,000)**
Creek Restoration	124,605	m^3	20%	149,526	$25	$3,738,150	$3.74
Material Disposal	124,605	m^2		149,526	$5	$747,630	$0.75
Miscellaneous	1	L.S		1	$1,000,000	$1,000,000	$1.00
					Subtotal	**$5,485,780**	**$5.49**
Access	1	L.S	20%	1	$50,000	$50,000	$0.05
Mobilization / Demobilization	1	L.S		1	$50,000	$50,000	$0.05
Permitting support (consultation with permitting agencies)	1	L.S		1	$200,000	$200,000	$0.20
Engineering Design	1	L.S		1	$200,000	$200,000	$0.20
Project & Construction Management	1	L.S		1	$598,578	$598,578	$0.60
Total Capital Cost without Contingency						**$6,584,358**	**$6.58**
Project Contingencies (30%)						**$1,975,307**	**$1.98**
HST (13%)						**$855,967**	**$0.86**
Grand Total						**$9,415,632**	**$9.42**
Note: This cost do not include the cost to purchase the lands							

10.3.9.2 *Natural Heritage / Ecological Considerations*

The area proposed for restoration and reprofiling is along the main channel of Junction Creek, and as such it has been marked as a Highly Sensitive Natural Feature as per **Figure B5** (refer to **Appendix B**). Additionally, the area is within the boundary of one of the four Core Areas of the Natural Heritage System, as shown on **Figure B6**. Junction Creek also acts as an important natural Linkage.

As such, the proposed creek restoration should be judged to have a high potential for environmental impact, and the potential for damage to sensitive natural features must be carefully considered and mitigated. Natural habitat enhancements would be essential to the design of any in-water works along Junction Creek such as the new creek profile, should be used as an opportunity to restore, as much as possible, the natural pattern of the creek.

As mentioned in **Section 3.2.2**, one of the main contributors to habitat degradation within Junction Creek has been the past introduction of pollutants as sewage from the CGS, and mining waste from the Copper Cliff area. The proposed restoration and reprofiling of Junction Creek may improve the habitat condition over the long term by removing accumulated sediment from the top layers of the channel, and allowing the natural habitat to reestablish itself over time and through restoration efforts.

Also as mentioned in **Section 3.2.2**, one of the main restoration initiatives for Junction Creek has bene the re-establishment of a Brook Trout population. As discussed, Brook Trout prefer cooler water habitat with groundwater input. As such, restoring and reprofiling Junction Creek to lower the grade of the main channel may positively benefit habitat conditions by increasing the proximity to groundwater, providing cooler, deeper baseflow conditions.

As recommended in **Section 4.1.7**, habitat enhancements are recommended for Junction Creek such as overhanging plantings and vegetation to increase fish habitat. In addition to physical cover, plantings provide shade which helps contribute to lower water temperatures necessary for species such as Brook Trout. Overhanging vegetative plantings should be incorporated into the design and remediation of any works along the creek.

10.3.9.3 *Social / Cultural Considerations*

In general, Junction Creek is highly confined and somewhat isolated through the downtown area downstream of the Ponderosa wetland. Any potential for increased velocities in the creek from the increased conveyance of water, and the mitigation of any anticipated risk, must be carefully considered. Access to the creek for any necessary equipment or machinery may be difficult, and should be coordinated with riparian landowners.

10.3.10 Optimization of Existing Flood Control Dams

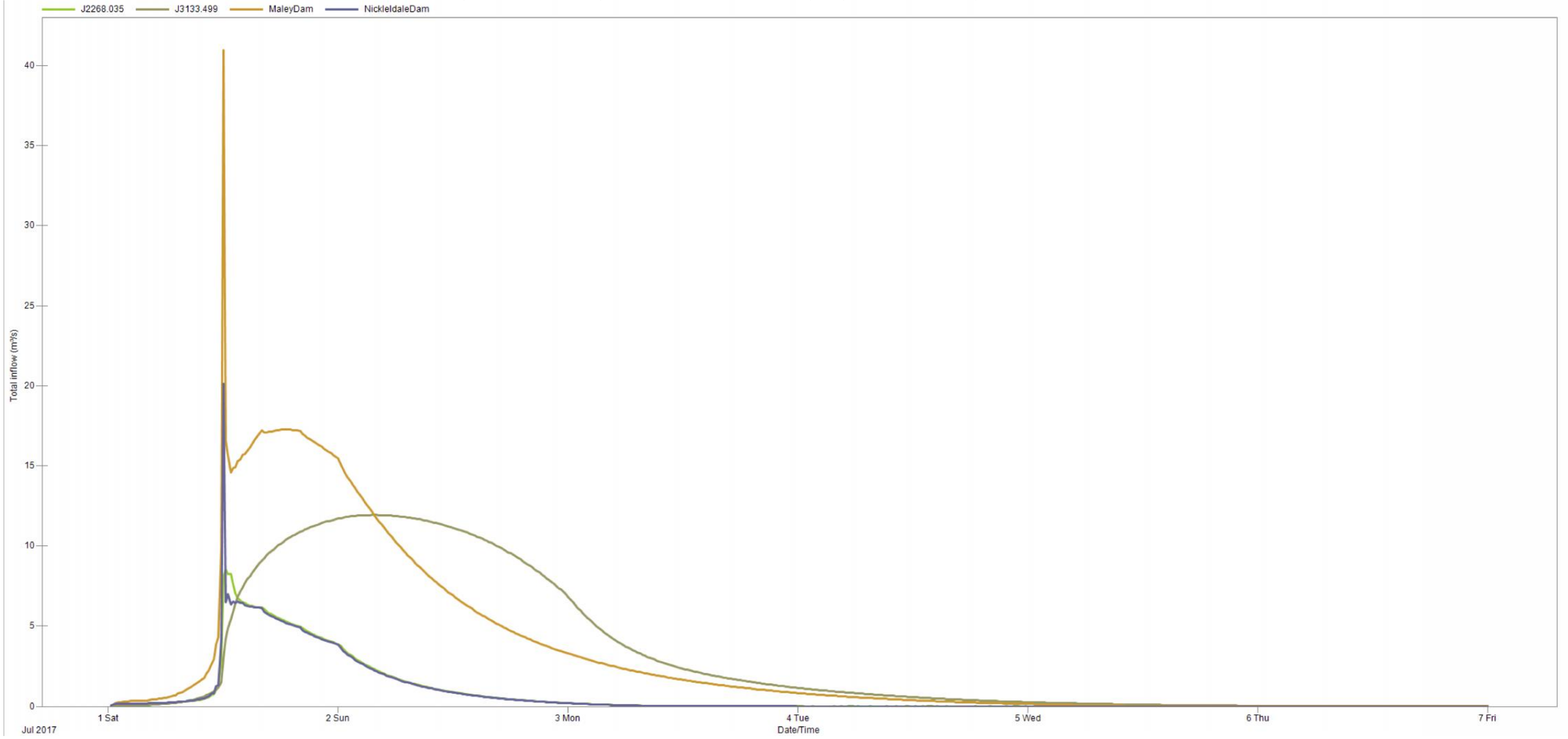
10.3.10.1 *Maley Dam*

The stage-storage results of the existing conditions PCSWMM hydrologic analysis for various storm events for the Maley Dam is shown in **Table 10.3.14** below. The inlet hydrograph for the Maley Dam, as well as the inlet hydrograph for Junction J3133.499, which is effectively the outlet hydrograph for the Maley Dam, are shown on **Figure 10.3.1** below. As may be seen from the figure, the Maley Dam provides effective attenuation of the 24 hour SCS design storm inlet hydrograph, and provides a much smoother outflow curve.

Table 10.3.22: Maley Dam Existing Conditions Modelling

Elevation *(masl)*	**Depth** *(m)*	**Storage** *(m^3)*	**Existing Conditions**
264.00	0.00	0	—
265.00	1.00	13,333	—
266.00	2.00	53,333	266.10m Sluicegate
267.00	3.00	119,999	—
268.00	4.00	229,174	2yr Event 267.10
268.50	4.50	309,754	5yr Event 267.51
269.00	5.00	421,193	10yr Event 267.82
269.50	5.50	574,285	25yr Event 268.34
270.00	6.00	783,808	50yr Event 268.72
270.50	6.50	1,070,071	100yr Event 269.09
271.00	7.00	1,472,376	Timmins Event 271.31
271.50	7.50	2,022,596	—
272.00	8.00	2,698,031	271.60m Spillway
272.50	8.50	3,461,477	—
272.75	8.75	3,870,094	—
273.00	9.00	4,294,906	—
274.00	10.00	6,160,301	—

Figure 10.3.1: Existing Conditions Inlet and Outlet Hydrographs for the Maley and Nickeldale Dams



In order to determine the potential effect on the overall PCSWMM hydrologic model of storing more water behind the Maley Dam, a trial of the model was created where the sluice gate was only left open a small amount, 0.30 m, while the 36 cm valve gate remains open. This greatly reduces the potential outflow from the Dam until the spillway elevation of 271.60 m. The stage-storage results for the Maley Dam with the partially closed sluice gate are shown in **Table 10.3.15** below. As may be seen from the table, the 100 year storm event ponds approximately 1.4 m higher than in existing conditions with the closed sluicegate. The Timmins Storm event also ponds 0.5 m higher and would be expected to cause flow through the spillway of the Maley Dam with the partially closed sluice gate.

Table 10.3.23: Maley Dam Partially Closed Sluicegate Modelling

Elevation	**Depth**	**Storage**	**Existing Conditions**
(masl)	*(m)*	*(m^3)*	
264.00	0.00	0	—
265.00	1.00	13,333	—
266.00	2.00	53,333	266.10m Sluicegate
267.00	3.00	119,999	—
268.00	4.00	229,174	2yr Event 267.97
268.50	4.50	309,754	5yr Event 268.88
269.00	5.00	421,193	10yr Event 269.37
269.50	5.50	574,285	25yr Event 269.90
270.00	6.00	783,808	50yr Event 270.23
270.50	6.50	1,070,071	100yr Event 270.51
271.00	7.00	1,472,376	Timmins Event 271.88
271.50	7.50	2,022,596	—
272.00	8.00	2,698,031	271.60m Spillway
272.50	8.50	3,461,477	—
272.75	8.75	3,870,094	—
273.00	9.00	4,294,906	—
274.00	10.00	6,160,301	—

The relative reduction in peak flow at the various subwatershed points of interest (refer to **Table 6.4.1**) are shown in **Table 10.3.16** below. As may be seen from the table, closing the sluice gate provides a significant flow reduction immediately downstream, as well as a small reduction in the Ponderosa area. These results suggest that partially closing the Maley Dam sluice gate up to the 100 year storm event may have positive benefits, however, the potential for increased flooding upstream must be considered. As can be seen from **Drawing C6.2** (refer to **Appendix C**), there is potential for flooding among the lots to the southwest of the Maley Dam along Lillian Boulevard, with some backyards as low as 271.20 m. The Timmins storm event currently extends onto these properties under existing conditions, but any changes to the Maley Dam should avoid worsening, and if possible improve, this condition.

Table 10.3.24: Reduction in Peak Flow with Partially Closed Maley Dam Sluice Gate

Location	Drainage Area	Reduction in Simulated Peak Flow (%)												
		2 Year		5 Year		10 Year		25 Year		50 Year		100 Year		Regional
	(ha)	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Timmins
Maley Dam Outlet	2697.2	27.6	41.6	44.6	56.0	51.8	61.5	59.2	66.2	64.6	68.6	67.5	70.2	30.3
Twin Forks	3596.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.9
Supermall	4011.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.2
Northeast of Ponderosa	4389.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	3.4
Southeast of Ponderosa	4613.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5
Ponderosa Junction	5721.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7
Downstream of Ponderosa	5890.6	0.0	6.0	0.0	9.2	0.0	10.2	2.1	10.3	3.2	10.9	3.1	9.7	4.6
Box Culvert Inlet	6048.5	0.0	6.2	0.0	7.2	1.8	8.3	2.6	6.5	2.4	11.1	1.2	10.1	3.9
Box Culvert Outlet	8393.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
McLeod St. / Sta. 02CF005	8393.5	-0.7	0.0	-0.6	1.1	0.0	0.3	-0.1	0.0	0.8	0.9	0.9	-0.9	8.8
Upstream Kelly Lake	14577.1	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	-0.3	0.3	0.2
Fielding Road / Sta. 02CF012	18190.6	1.6	2.1	2.4	2.6	1.8	2.2	2.0	1.8	1.4	1.6	1.0	1.2	0.0
Into Simon Lake	25716.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0

10.3.10.2 *Nickeldale Dam*

The stage-storage results of the existing conditions PCSWMM hydrologic analysis for various storm events for the Nickeldale Dam is shown in **Table 10.3.17** below. The inlet hydrograph for the Nickeldale Dam, as well as the inlet hydrograph for Junction J3133.499, which is effectively the outlet hydrograph for the Nickeldale Dam, are shown on **Figure 10.3.1** above. As may be seen from the figure, the Nickeldale Dam does not greatly change the shape of the 24 hour SCS design storm hydrograph. Additionally, the low storage elevations shown in **Table 10.3.17** indicate that there may be additional potential to store water behind the Nickeldale Dam.

Table 10.3.25: Nickeldale Dam Existing Conditions Modelling

Elevation	Depth	Storage	
(masl)	*(m)*	*(m³)*	**Existing Conditions**
265.40	0.00	0	265.40m Outlet Culvert
266.00	0.60	3,231	—
266.50	1.10	12,476	2yr Event 266.07
267.00	1.60	29,329	5yr Event 266.18
267.50	2.10	53,028	10yr Event 266.25
268.00	2.60	83,110	25yr Event 266.35
268.50	3.10	120,145	50yr Event 266.42
269.00	3.60	166,130	100yr Event 266.50
269.50	4.10	223,971	—
270.00	4.60	295,913	Timmins Event 269.41
270.50	5.10	383,735	—
271.00	5.60	489,006	—
271.50	6.10	611,924	—
272.00	6.60	751,588	—
272.50	7.10	907,582	—
272.75	7.35	991,669	273.20m Spillway

In order to determine the potential to increase storage and reduce outflow from the Nickeldale Dam, a trial of the model was created in which the two existing outlet pipes were changed to a single 0.30 m outlet pipe, maintaining the 265.40 m invert elevation. This greatly reduces the potential outflow from the Nickeldale Dam until the spillway elevation of 273.30 m. The stage-storage results for the Nickeldale Dam with the single reduced outlet are shown in **Table 10.3.18** below. As can be seen from the table, the 100 year storm even ponds over 4.5 m higher, up to elevation 271.05 m.

Table 10.3.26: Nickeldale Dam Single Reduced Outlet Culvert Modelling

Elevation	Depth	Storage	
(masl)	*(m)*	*(m³)*	**Existing Conditions**
265.40	0.00	0	265.40m Outlet Culvert
266.00	0.60	3,231	—
266.50	1.10	12,476	2yr Event 269.40
267.00	1.60	29,329	5yr Event 269.84

Elevation	**Depth**	**Storage**	
(masl)	*(m)*	*(m^3)*	**Existing Conditions**
267.50	2.10	53,028	10yr Event 270.14
268.00	2.60	83,110	25yr Event 270.52
268.50	3.10	120,145	50yr Event 270.79
269.00	3.60	166,130	100yr Event 271.05
269.50	4.10	223,971	—
270.00	4.60	295,913	Timmins Event 272.85
270.50	5.10	383,735	—
271.00	5.60	489,006	—
271.50	6.10	611,924	—
272.00	6.60	751,588	—
272.50	7.10	907,582	—
272.75	7.35	991,669	273.20m Spillway

The relative reduction in peak flow at the various subwatershed points of interest (refer to **Table 6.4.1**) are shown in **Table 10.3.19** below. As may be seen from the table, providing a single reduced outlet culvert provides a large flow reduction immediately downstream, which is also seen downstream within the Ponderosa area. Given the large increase in storage depth upstream of the dam in this scenario, any potential for flooding must be carefully considered. As seen on **Drawing C6.2**, there do not appear to be any areas which are at risk from flooding upstream of the Nickeldale Dam. The only infrastructure in the area below the spillway elevation of the dam appears to be Notre Dame Avenue, at approximately elevation 272.00 m. Therefore, it appears that there is potential to reduce flow downstream of the Nickeldale Dam by providing a smaller outlet configuration, and thereby increasing the amount of water stored behind the dam. The precise outlet configuration should be refined at a future detail design stage.

Table 10.3.27: Reduction in Peak Flow with Reduced Nickeldale Outlet Culvert

Location	Drainage Area	Reduction in Simulated Peak Flow (%)												
		2 Year		5 Year		10 Year		25 Year		50 Year		100 Year		Regional
	(ha)	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Chi	SCS	Timmins
Nickeldale Dam Outlet	827.3	93.3	94.4	95.0	95.4	95.6	95.8	96.0	96.2	96.3	96.2	96.3	96.2	93.2
Ponderosa Junction	5721.3	0.8	1.6	1.9	1.8	2.0	2.2	2.1	2.4	2.3	2.5	2.7	2.6	26.3
Downstream of Ponderosa	5890.6	0.0	4.2	0.0	7.3	0.0	8.4	2.1	10.1	6.3	12.1	9.5	12.0	30.7
Box Culvert Inlet	6048.5	2.4	3.8	3.3	6.9	5.1	8.2	6.5	9.5	8.3	15.7	8.9	14.4	6.6
Box Culvert Outlet	8393.5	-6.6	-1.0	-4.6	-0.5	-3.2	-0.3	-1.9	-0.1	1.1	-0.1	2.5	0.0	2.9
McLeod St. / Sta. 02CF005	8393.5	0.3	0.9	-1.3	2.3	1.6	2.9	1.3	1.6	4.0	2.6	1.7	3.6	5.2
Upstream Kelly Lake	14577.1	0.8	-1.2	1.0	-0.8	1.1	-0.5	1.3	-0.6	1.5	-0.3	1.3	0.8	1.6
Robinson Lake	344.0	-0.6	-0.2	-0.3	-0.2	-0.3	-0.5	-0.2	-0.7	-1.0	-2.7	-1.1	-4.5	0.1
Kelly Lake	17785.3	0.0	-0.9	0.7	-0.1	0.1	0.0	-0.4	0.2	-0.3	1.7	0.7	-0.5	0.3
Fielding Road / Sta. 02CF012	18190.6	1.5	1.7	2.6	2.9	2.6	3.1	3.4	3.2	3.7	3.6	3.5	3.7	0.2
Fly Creek	3000.8	0.1	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1
Fly Junction	22864.0	-0.1	-0.2	-0.2	-0.2	-0.2	-0.1	0.0	-0.1	-0.2	-0.1	-0.2	0.0	0.1
Mud Lake	25716.4	0.5	0.2	0.2	1.2	0.3	1.7	0.0	0.0	0.0	-0.4	0.0	-0.6	0.4
Into Simon Lake	25716.4	7.1	2.5	4.7	1.9	3.9	1.7	3.3	1.4	2.5	2.1	2.3	2.1	0.5

10.3.11 Combined Storage Options Modelling

10.3.11.1 *Technical / Engineering Considerations*

In order to gauge the combined effect of implementing all of the identified storage options modelled in PCSWMM above (i.e. Options A, B2, C, D, E, and F), a conceptual PCSWMM model was created including all of the implementing storage areas, additional inlets, and outlets. Changes to the Junction Creek channel described under Option G were assessed using HEC-RAS and therefore not included in this "all Options" PCSWMM model.

The relative reduction in peak flow at the various subwatershed points of interest (refer to **Table 6.4.1**) resulting from the conceptual modelling of all options combined are shown in **Table 10.3.20** below. As may be seen from the table, there is a substantial reduction in peak flow, in the range of 25-35%, in some key areas of the subwatershed.

Additionally, there is a sharp increase in peak flow at two junction, "Northeast of Ponderosa" and "Southeast of Ponderosa", which represent the increase in storage within Ponderosa 1 and Ponderosa 2 with Option E, as described in **Section 10.3.7** above. It is worth noting that the overall flow within Ponderosa 3, described as "Downstream of Ponderosa" in the table, is much reduced, and this represents the most important area of the Ponderosa in terms of flooding as it borders the most vulnerable residential areas (i.e. the Flour Mill and Nickeldale neighbourhoods).

Somewhat surprisingly, the model shows a reduction in peak flow downstream of Kelly Lake, at Fielding Road, although it is a small (<5%) difference. This suggests that storage capacity improvements within the upper subwatershed may have some benefit downstream in areas of the lower subwatershed.

Table 10.3.28: Percent Reduction in Hydrologic Peak Flow with All Conceptual Options

Location	**Drainage Area**	**Reduction in Simulated Peak Flow (%)**												
		2 Year		**5 Year**		**10 Year**		**25 Year**		**50 Year**		**100 Year**		**Regional**
	(ha)	**Chi**	**SCS**	**Chi**	**SCS**	**Chi**	**SCS**	**Chi**	**SCS**	**Chi**	**SCS**	**Chi**	**SCS**	**Timmins**
O'Neil Drive West	333.9	-5.1	11.2	4.9	14.4	5.7	13.5	5.1	12.4	4.8	12.0	5.2	13.0	-0.2
Railway	574.1	0.0	0.2	0.0	0.4	0.0	0.5	0.0	0.8	0.0	1.0	0.0	0.5	1.6
Twin Forks	3596.1	11.8	16.7	11.8	9.7	10.2	8.8	9.5	5.0	6.4	6.5	7.0	6.2	1.2
Supermall	4011.2	17.5	17.5	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	2.3
Northeast of Ponderosa	4389.0	11.9	11.8	11.9	-40.2	11.0	-132.1	-62.6	-129.8	-108.9	-158.7	-140.7	-169.7	23.5
Southeast of Ponderosa	4613.7	11.4	6.3	11.4	-86.3	-23.5	-176.3	-100.7	-176.2	-150.7	-198.3	-180.2	-210.1	25.6
Ponderosa Junction	5721.3	33.4	38.6	37.9	40.6	39.7	40.4	39.8	38.7	38.6	37.6	37.9	36.5	8.0
Downstream of Ponderosa	5890.6	0.0	6.0	0.0	14.6	0.0	17.9	2.1	20.1	6.3	21.9	9.5	21.9	26.2
Box Culvert Inlet	6048.5	13.9	7.0	12.6	7.8	12.6	8.0	12.6	7.6	12.0	11.3	10.7	5.8	-7.5
Nolin Box Culvert	2225.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Box Culvert Outlet	8393.5	0.3	1.2	0.8	1.3	1.0	1.5	1.9	1.6	4.3	1.9	5.7	1.9	-1.9
McLeod St. / Sta. 02CF005	8393.5	-15.3	3.5	8.3	5.5	8.3	10.1	11.2	7.0	7.4	6.4	5.9	6.2	6.0
Upstream Kelly Lake	14577.1	6.7	0.4	6.2	0.2	5.7	0.3	5.6	0.5	4.6	0.6	3.5	1.5	-1.3
Kelly Lake	17785.3	0.0	0.0	0.2	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3
Fielding Road / Sta. 02CF012	18190.6	0.4	1.7	2.1	3.5	3.1	3.9	4.4	3.5	4.4	3.4	3.6	2.7	0.3
Whitefish Junction	22864.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Mud Lake	25716.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.2
Into Simon Lake	25716.4	0.0	0.3	0.0	0.5	0.0	0.6	-0.1	0.8	0.0	1.8	-0.1	1.5	0.2

11.0 RECOMMENDATIONS

11.1 Recommended Stormwater Master Plan Projects

Given the number of factors considered, and the complexity of each option and the interconnection between several of them, no specific numeric ranking scheme system has been employed for this prioritization. Rather, each of the listed stormwater master plan options has been analyzed individually, based on the previously noted criteria. The results are presented in

Table 11.1.1.

As mentioned earlier, in addition to the specific new stormwater management options presented in Table 11.1.1., LIDs and water quality BMPs may be implemented as part of existing infrastructure retrofit projects. In a similar way, Natural Infrastructure, such as the re-greening initiatives completed within the CGS since 1978, is believed to have additional hydrological benefits by reducing the runoff generation potential and improving the infiltration and retention of precipitation in the area. Re-greening, as proven in recent complementary studies, while having major benefits to the ecosystem over the past 40 years (i.e. available plant and wildlife habitat in the region), has achieved considerable reduction of estimated runoff reporting to strategic infrastructure by changing some of the historical bald bedrock cover to a tree and topsoil cover.

Finally, most of the options presented in this master plan consider adding storage capacity to attenuate high flows at different locations of the Junction Creek subwatershed. With the inclusion of these facilities into the Junction Creek hydraulic system, not only the retention of runoff is achieved, but also the reduction of excess sediment along the watercourse would be achieved, which presently negatively impacts its conveyance potential and negatively impacts important infrastructure (i.e. culverts, catchbasins, bridges, downtown box culvert, etc) due to sediment deposition.

Table 11.1.1 Option Evaluation Summary

Option	Project Description	Effect on Social / Cultural Resources?	Effect on Sensitive Natural Features?	Overall Technical / Engineering Potential	Class EA Process Schedule	Approx. Storage Volume (m^3)	Estimated Cost
A	Garson Facility	Low	High	Medium	B	25,400	$2.6M
B1	Twin Forks Facility	High	Medium	Low	B	6,200	$5.6M
B2	Maley Branch Facility	Low	Low	Medium	B	54,800	$4.0M
C	Lasalle Blvd. & Railway Facility	Medium	Low	Medium	B	77,500	$13.1M
D	Nickeldale Facility	Low	High	Medium	B	10,000	$1.9M
E	Ponderosa Diversion	Medium	High	High	Individual	367,500	$24.2M
F	Gravel Pit Diversion	Medium	Low	Medium	B	301,000	$28.2M
G	Creek Restoration and Reprofiling	Low	High	High	B	N/A	$8M - $10M

11.2 Recommended Development Criteria and Policies

A Subwatershed Study needs to address the predicted impacts from planned urbanization, in the context of the physical, social and regulatory environments, as well as approved and ongoing development, as part of current urbanization plans. This section has bene organized to provide the CGS and practitioners guidance on criteria and specific policies affecting new development, including road reconstruction projects.

The CGS's current Policies, By-Laws, and Guidelines related to stormwater and environmental protection/management have been reviewed. The main objectives and regulatory requirements of various regulatory bodies with policies related to stormwater management are described in **Section 5.1**. The CGS's existing stormwater management infrastructure related policies and guidelines have been summarized in **Section 8.1**. In addition, various emerging directions in the stormwater management field have been identified for consideration. Regardless, any revisions brought forward by the City must comply with current Provincial policies and regulations, and should also build upon the current practices within the industry as applicable to the CGS.

Stormwater management policies for the Junction Creek subwatershed have been made from both a technical perspective stemming from the results of the Study, and from a planning/operational perspective through consultation with CGS staff and stakeholders including CS. Stormwater management policy recommendations have been grouped into two general categories:

- Policies for New Development Lands (i.e. development of greenfield or agricultural lands)
- Policies for Re-Development, Intensification, and/or Infill, (i.e. existing urban lands)

As described in **Section 5.1** above, the provincial stormwater management policies which apply to the Junction Creek subwatershed are:

- Provide water quality control as per the *Stormwater Management Planning and Design Manual* (MOE, 2003) for the requisite level of control required by the receiving watercourse;
- Provide the requisite erosion control for protection of downstream watercourses to ensure they remain stable, as per the *Ontario Water Resources Act* as administered by the MOE; and,
- Mitigate potential offsite flood impact by providing post-development to pre-development peak flow control, as per CGS, MOE, and MNRF guidelines.

11.2.1 New Development

11.2.1.1 *Flooding*

As described above, in accordance with local and Provincial regulations all stormwater management must fully mitigate flooding impacts associated with new development. As specified in the MOE 2003 *Stormwater Management Planning and Design Manual* and the CGS's 2006 *Official Plan Stormwater Background Study*, the minimum acceptable level of quantity control required to mitigate any potential flooding impacts of new development is:

- Control of the post-development flow rates to pre-development rates for the 2 to 100-year design storm events.

Additionally, to mitigate the impacts of climate change, the *Stormwater Background Study* further recommends that:

- All new stormwater management facilities target a release rate of 85% of pre-development rates for the 100-year storm.

It is noted that the climate change recommendation of the *Stormwater Background Study* has so far not been implemented by the CGS. However, given the extent of flooding within the Junction Creek subwatershed upstream of the Box Culvert, it is necessary to consider new development policies which improve upon the existing condition.

Through this Study, various options for stormwater management and flood reduction have been suggested and analysed, including the potential to provide additional stormwater management facilities, creek restoration and other hydraulic improvements along the creek, retrofitting/upgrading existing sewers, optimizing existing dams and other infrastructure, and various other high level alternatives as described in previous sections. No solution, or combination of solutions, has been seen to be sufficient to relieve the flooded condition on all of the residential properties near Junction Creek. As such, in addition to the Stormwater Master Plan projects selected for implementation, it is recommended that a risk-based approach for over-control of new-development on greenfield lands be established based on key infrastructure within the Junction Creek subwatershed.

Notably, the Downtown Box Culvert represents a fixed infrastructure condition along Junction Creek. Given the extent of surrounding development there is little potential for major hydraulic retrofits to this structure to alter its capacity. The greatest areas of flooding are seen upstream of the Downtown Box Culvert, surrounding the Ponderosa area, as discussed in this report. As such, it is recommended that greenfield development projects upstream of the Downtown Box Culvert target a release rate of 85% of pre-development rates for all storm events. This conservative release will necessitate some additional stormwater storage in the upper subwatershed, which will provide some relief for flooding issues upstream of the Box Culvert by allowing the natural storage capacity of the Ponderosa area some time to recover, as well as mitigate any potential increased storage requirements due to climate change.

11.2.1.2 *Erosion*

The erosion threshold analysis for Junction Creek is discussed in **Section 3.6.8**. Critical velocities for reaches TJ-14-1 and J15 were determined to be 1.14 m/s and 0.53 m/s respectively, as shown in **Table 3.6.5**. A continuous modelling approach could be used to establish a baseline number of erosion hours, that is, the number of hours per year for which the critical erosive velocities are exceeded. This model could then be updated for any proposed development stormwater management scheme to ensure that the proposed stormwater management works maintained or reduced the number of erosion hours in the watercourse. Continuous modelling was not performed for this study, but is included as a recommendation in **Section 11.4**.

Without a more specific erosion model, it is recommended that any proposed development within the Junction Creek subwatershed provide stormwater management best management practices to capture and retain the runoff from the 25 mm event for a minimum of 24 hours on site for erosion control. As discussed, a more specific target could be developed based on future continuous modelling.

11.2.1.3 *Water Quality*

Management of water quality in the Province of Ontario falls within the mandate of the MOE which requires the implementation of stormwater management measures to minimize the environmental impacts from urban runoff. Through the *Stormwater Management Planning and Design Manual* (MOE, 2003) the Province provides the minimum design standards for achieving certain pollutant removal criteria, which can vary by watercourse and/or subwatershed. The MOE measures pollutant removal by stormwater management using Total Suspended Solids (TSS) as a surrogate for all pollutants, including nutrients, metals, bacteria, and others.

As identified through this study, urban land use results in increased sedimentation which is a negative pressure on habitat for sensitive fish species in Junction Creek such as Brook Trout. Additionally, existing sewer outfalls throughout the subwatershed were observed to be full of sediment due to continual deposition. In order to ensure that the water quality of Junction Creek is maintain or improved through new development, an *Enhanced* (80% TSS removal) level of quality control, as per the *Stormwater Management Planning and Design Manual* (MOE, 2003) is recommended for all new development projects within the subwatershed. Additionally, the creation of shoreline buffers for properties along lakes and creeks is recommended.

Given the water quality and phosphorus issues described in **Section 3.4** and **4.2** above, it is recommended that a Phosphorus Budget be undertaken for new development lands as a “no-regrets” best management approach. The MOE has developed a phosphorus budget tool for the Lake Simcoe Protection Plan (LSPP) which may be used for this purpose, which is described in the document *Phosphorus Budget Tool in Support of Sustainable Development for the Lake Simcoe Watershed*, prepared by Hutchinson Environmental Services Ltd. for the MOE, dated March 30, 2012. In re-purposing that tool to provide a Phosphorus Budget for development lands within the Junction Creek subwatershed, care must be taken to select a listed Subwatershed which most closely approximates the area of development.

11.2.1.4 *Water Balance*

The MOE 2003 *Stormwater Management Planning and Design Manual* suggests that water balance could be calculated on a site by site basis, based on the soil and drainage characteristics of the area, with the goal of maintaining the level of pre-development infiltration through stormwater management BMPs such as infiltration facilities.

The *Draft LID Stormwater Management Guidance Manual* (MOE, April 2017) describes a runoff volume control target (RVCT) based on limiting the total site runoff to less than 10% of the total rainfall volume (by capturing the 90th percentile event), to mimic the pre-development hydrologic water balance conditions, for all new development projects. The manual describes a “mandatory control hierarchy” that should be applied to the capture of the 90th percentile event RVCT, as follows:

1. Control Hierarchy Priority 1: Retention (infiltration, evapotranspiration, or reuse)
2. Control Hierarchy Priority 2: LID Volume Capture and Release (LID filtration controls)
3. Control Hierarchy Priority 3: Other Volume Detention and Release (end of pipe facilities)

For reference, based on Figure 3.1.4 of the draft manual the regionally specific 90th percentile RVCT for the Junction Creek subwatershed area is a 28 to 30 mm rainfall event.

The complete retention of the 90th percentile event RVCT is not considered to be realistic within the majority of the Junction Creek subwatershed, due to the high amounts of bedrock coverage and lack of infiltrative capacity. The CGS is located on the Canadian Shield, an area of highly prominent bedrock with little overburden, as illustrated on **Figure E5** (refer to **Appendix 'E'**).

Note that it is also unreasonable in the lower reaches of the subwatershed (i.e. those areas not in the esker with glaciolacustrine – clay – deposits) to meet the 90th percentile capture. Based on published typical water surplus balance values as discussed in **Section 3** of the report, the runoff volume target may be reasonable (and desirable) in areas mapped as esker (Garson area).

Otherwise, a retention to "better than pre-development" (starting from control Hierarchy Priority 2, as described above) would be appropriate.

11.2.1.5 *Infill / Redevelopment*

In general, these sorts of projects increase impervious cover on small areas (i.e. larger home footprint, severances, infills). Individually, the impacts of these developments to the overall system are nominal, however, when the impacts of these types of developments are considered in their entirety, the cumulative impacts can be significant. The impacts relate to local lot grading and drainage, increases in peak flow, volume, and duration of surface runoff, as well as increased foundation drainage due to larger or deeper home footprints.

The location and type of these developments are difficult to predict and can be complex to assess cumulatively or holistically as part of a higher level study (i.e. Subwatershed Study), as such planning applications are typically submitted as individual site plans. Holistic or centralized stormwater management strategies are best established as part of detailed neighbourhood studies through Class Environmental Assessments. In the absence of comprehensive investigations, it is important to encourage a level of responsibility on the individual landowner through effective source controls, which may be accomplished in part through an education and outreach program, as described in **Section 11.3.2** below.

11.2.2 Existing Development

11.2.2.1 *SWM Retrofits*

11.2.2.1.1 Storm Sewer Outfalls

A performance assessment of the trunk sewer networks within the Junction Creek subwatershed was performed as described in **Section 8.0** above, and the results are summarized by network in **Table 8.3.3**. Additionally, the potential feasibility and effect of water quality retrofits at each outfall was assessed in **Section 9.2.3.2**, and the results are summarized in **Table 9.3.1**. The results of these two analyses are summarized in **Table 11.2.1** below.

In general, areas of the Flour Mill and New Sudbury have the highest number of outfalls that have been prioritized both on the basis of hydraulic performance upgrades but also for the potential for water quality retrofits. However, all areas of the CGS have some potential to improve the function of the stormwater sewer networks and outfalls, and water quality retrofits and best management practices should be considered on a site by site basis, if and when funds become available or as part of other redevelopment projects.

Table 11.2.1: Stormwater Outfall Evaluation Summary

City Area	Network	Hydraulic Performance Priority (Table 8.3.3)	Water Quality Retrofit Potential (Table 9.2.1)
Downtown	DW-1	Medium	Low
	DW-2	—	—
	DW-3	Medium	Medium
	DW-4	Low	Medium
	DW-5	Medium	Medium
	DW-6	Medium	Low
South End	SE-1	Medium	Low
	SE-2	Medium	Low
	SE-3	Low	Low
	SE-4	Low	Medium
	SE-5	Medium	Low
Garson	G-2	Low	High
	G-3	Low	Medium
New Sudbury	NS-1	Medium	Medium
	NS-2	Medium	Medium
	NS-3	Medium	High
	NS-4	Medium	High
	NS-5	Medium	Medium
	NS-6	Medium	Low
	NS-7	Medium	Medium

City Area	Network	Hydraulic Performance Priority (Table 8.3.3)	Water Quality Retrofit Potential (Table 9.2.1)
	NS-8	Low	Medium
	NS-9	Low	Medium
	NS-10	Medium	Medium
Flour Mill	FM-1	Medium	High
	FM-2	High	Medium
	FM-3	High	Low
	FM-4	Medium	Medium
	FM-5	High	Medium
	FM-6	Medium	Medium
Donovan	D-1	Medium	Medium
	D-2	Medium	Low
Gatchel	GT-1	Low	Medium
	GT-2	Low	Medium
	GT-3	Low	Medium
	GT-4	Low	High
Lively	L-1	Low	Low
	L-2	Low	Low

11.2.2.2 *Road Reconstruction*

Each road reconstruction project comes with a unique set of opportunities and challenges, depending on the presence and type of existing drainage infrastructure in the area. No single alternative will be appropriate for all locations, and various levels of implementation will need to be considered given space and other constraints.

In general, roads represent small high-traffic areas of the subwatershed. As such, the main focus is on providing water quality treatment for the runoff water. This may be done by providing direct cleaning of runoff through a stormwater management structure such as an oil and grit separator, and/or by implementing roadside LID techniques such as vegetated swales to provide additional treatment or storage. A list of possible stormwater management techniques which may be considered for road reconstruction projects is provided in **Table 11.2.2** below. Note that infiltration-based techniques such as Infiltration Trenches, Permeable Pavers/Pavement, and Pervious Pipes may only be appropriate for those areas mapped as esker (Garson area), and/or where conditions permit with a collection system.

Table 11.2.2: Water Quality Techniques for Road Reconstruction Projects

Road Reconstruction Project Water Quality Techniques	
Technique	**Function**
Oil & Grit Separator	A compact end-of-pipe technique for water quality treatment Provides removal of oil and sediment using gravity and centrifugal forces Maintenance required to clean out collected oil and sediment
Jellyfish Filter	Similar to an oil-grit separator, but provides additional membrane filtration

Road Reconstruction Project Water Quality Techniques	
Technique	**Function**
	J Much more efficient at removing small particles
Bio-retention Cell	J Vegetated technique for filtration of storm runoff J Stormwater quality control provided through filtration of runoff through soil medium and vegetation J Infiltration/water balance maintenance and additional erosion control may be achieved if no sub-drain provided
Grassed Swale	J Vegetated technique to provide stormwater quality control J Stormwater quality control provided by filtration through vegetated system J Runoff volume reduction may be achieved by supplementing with soil amendments
Rain Garden	J Vegetated technique for infiltration of storm runoff J Stormwater quality control provided through filtration of runoff through soil medium and vegetation J Infiltration/water balance maintenance and additional erosion control may be achieved if no subdrain provided
Soil Amendments	J Technique for reducing runoff volume through increased depth of topsoil J Stormwater quality control provided through increased soil storage and associated interception of storm runoff J Increases water balance compared to existing conditions when applied in areas with low permeability soils J Possible erosion control benefits
Infiltration Trench	J Infiltration technique to provide stormwater quality control and maintain water balance J Erosion controls may be achieved depending upon soil conditions
Permeable Pavers/Pavement	J Infiltration technique to reduce surface runoff volume J Benefits to stormwater quality and erosion control are informal
Pervious Pipes	J Technique to reduce storm runoff through the implementation of perforated pipes within storm sewers J Promotion of infiltration maintains water balance and provides stormwater quality and erosion control benefits

11.2.2.3 *Hydraulic Upgrades*

As described in **Section 7**, an updated HEC-RAS hydraulic model of Junction Creek was created for this Study. Hydraulic analyses of the watercourse crossings along Junction Creek was completed in **Section 7.5**. As described in that section, in order to gauge the relative priority to upgrade the culvert or otherwise hydraulically improve the crossing, each crossing was removed from the model in turn, and the resultant water surface at the upstream cross section was compared to the base model. Watercourse crossings with a resultant drop in water surface greater than 0.30 m were tabulated in **Table 7.5.7** and a rough relative cost-estimate was provided based on a simple Manning's formula pipe size calculation to suit the 25 year design flow from the HEC-RAS model (i.e. from the existing conditions hydrologic model). The overall hydraulic benefit, as well as the relative cost, of these high priority crossings are summarized based on the criteria in **Table 11.2.3** into **Table 11.2.4** below.

Table 11.2.3: Hydraulic Crossing Upgrade Summary Criteria

Metric	Summary Criteria		
	Low	Medium	High
1:25 Year Water Surface Reduction after Removal	<0.60 m	>0.60 m, <1.20 m	>1.20 m
Relative Cost Estimate	<$150,000	>$150,000, <$500,000	>$500,000

Table 11.2.4: Hydraulic Crossing Upgrade Cost-Benefit Summary

Reach	ID	Description	Hydraulic Benefit	Relative Cost
Upper 1	16351.52	Orell Street	High	High
Upper 1	16014.38	Margaret Street Trail	Medium	Low
Upper 1	14157.42	O'Neil Drive West	Low	Low
Upper 1	12617.83	Carr Avenue	Low	Low
Upper 1	11828.6	Matson Road	Low	Medium
Upper 1	11253.31	Old Falconbridge Railway	Medium	Low
Upper 1	10872.4	Robin Street	Medium	Medium
Nic	4882.635	Railway 1	Medium	Low
Nic	3521.141	Railway 2	Low	Medium
Nic	1519.694	Lasalle Boulevard	High	High
Nolin	2063.12	Nolin Railway 1	Medium	Low
Nolin	1766.62	Nolin Railway 2	Medium	Low
Nolin	1457.72	Ruisseau Nolin Creek Trail	Medium	Medium

11.3 Recommended Programs

11.3.1 Septic System Maintenance & Inspection

As discussed in this Study, many lakes within the Junction Creek subwatershed are susceptible to algal blooms due to abnormally high levels of nutrients such as phosphorus, of which septic systems are a contributor. Additionally, septic systems can introduce pathogens from human waste into aquatic systems (Greater Sudbury Source Water Protection Area Source Protection Plan 2014). Septic system BMPs include professional inspection of septic systems every 3 to 5 years, with pump-outs as required (Ontario Ministry of Agriculture, Food and Rural Affairs 2008).

There is currently no regular septic system maintenance program operating in Greater Sudbury, bar the administration of the mandatory on-site sewage system maintenance inspection program required under O. Reg. 332/12: Building Code, within vulnerable areas in close proximity to drinking water sources, as per the Greater Sudbury Source Water Protection Area Source Protection Plan Policy S1EF-SA (2014). As part of this plan, the CGS and Sudbury and District Health Unit were responsible for delivering an education and outreach program regarding septic systems (Policy S2EF-EO), which was held in May 2018. Policy S5F-LUP within the program dictates the prohibition of "severance of lots that would require the construction of new septic systems within the Wellhead Protection Area (WHPA) A and B and Intake Protection Zone[6] (IPZ) 1 areas with vulnerability scores of 10".

Numerous Municipalities have implemented mandatory re-inspection programs following the Ontario Building Code O. Reg. 315/10 amendment, requiring Principal Authorities to re-inspect septic systems within vulnerable areas, with some providing grant sources to assist home-owners in paying the associated fee (e.g. Lake Simcoe Region Conservation Authority and Nottawasaga Valley Conservation Authority). For example, the Town of Innisfil's Septic Re-Inspection Program consists of the following processes: (1) "Identify systems to be re-inspected", (2) "Determine if the site/system has a permit or any Health Unit Septic records on file", (3) "Review and assess any septic information on file OR if no information is on file then the homeowner will be contacted to collect information on their septic system", (4) "Conduct Septic Re-Inspection of the system for compliance with section 8.9 of the Ontario Building Code", (5) Enter site/system and field inspection results into database". Additionally, several Conservation Authorities outside of Greater Sudbury currently employ funding programs to assist home-owners with septic systems upgrades and replacements, including the Landowner Action Fund (Credit Valley Conservation), granting 50% up to $4,000, and; the Ottawa Rural Clean Water Program (Mississippi Valley Conservation Authority, Rideau Valley Conservation Authority and South Nation Conservation), granting 50% up to $1,000.

A program should be developed and implemented for the re-inspection of septic systems every five years within the Junction Creek subwatershed, as previously proposed by The Greater Sudbury Watershed Alliance. The program could include dispersing informative material and letters to home-owners; collecting information from home-owners; creating a database of local septic systems and inspection dates; conducting septic system re-inspections; collecting re-inspection fees; looking into grant opportunities for home-owners, and; informing home-owners what their next steps should be based on a passing or failing septic system.

Additionally, the CGS should study the feasibility of introducing a by-law requiring septic maintenance agreements between the installer and property owner, the latter of which is responsible for maintenance of their septic system, and potential grant opportunities for home-owners in need of re-inspection, upgrades, or new systems entirely. Furthermore, public outreach efforts should be continual, to educate the public regarding greener septic systems, BMPs, 'Do's and Don't's'. One central location containing provisional information electronically would be helpful in attaining this goal.

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[6] WHPAs and IPZs are areas surrounding drinking water wellheads and surface water intakes, respectively, which have a set of Source Protection Policies designed to eliminate the possibility of drinking water source contamination, as identified through Ontario's new Drinking Water Source Protection programs.

11.3.2 Stormwater Public Education & Outreach

Stormwater serves as a source of excessive nutrients, metals, ions and bacteria such as *E. coli*. for water courses and bodies. There are BMPs recommended specifically for private land-owners who wish to make a personal difference in their communities from use of rain barrels and LID measures to shoreline naturalization.

Greater Sudbury Watershed Advisory Panel, CS and the CGS websites share information related to stormwater and water quality. However, engagement opportunities with the public and incentive to actively decrease runoff from their properties are not currently available. There are currently few LID sites within Greater Sudbury and Junction Creek Subwatershed due to the natural geology, which means public education and outreach are especially important at this stage.

Numerous Conservation Authorities offer stormwater and LID public education from informative material and demonstration sites to grant programs. Toronto Region Conservation Authority holds workshops, webinars and training events and Credit Valley Conservation has created numerous guidance documents available to the public. The North Bay-Mattawa Conservation Authority runs the Restore Your Shore program, which provides native shoreline species to landowners who wish to naturalize their shorelines. The CGS has already participated in the in the Canadian Wildlife Federation's Love Your Lake Program, which offered shoreline plants to approved shoreline residents.

The CGS should implement a public awareness campaign to help citizens understand what stormwater is and why it is important to manage it. The public awareness campaign should inform residents of potential LID techniques specific to Sudbury and Stormwater Management BMPs that can be implemented on their property to reduce peak flow and nutrient runoff from their properties. Beaver management on private lands should be included in this outreach effort, encouraging private land-owners to implement management practises suggested by the MNRF as included in **Section 4.1.7**. Alternatively, the CGS could provide funds and resources for individual stewardship and community groups to lead public awareness campaigns. Public outreach events could be similar to the Greater Sudbury Watershed Advisory Panel's recently held 'Septic Social', or include site visits to local LID sites such as the Vale Living with Lakes Centre, to give examples of locally feasible practises. It is recommended that applicable CGS stormwater management plans, and potentially The Drainage Master Plan and Source Protection Plan, be presented formally to the public to explain how they relate to the general public.

11.3.3 Winter Maintenance

It has been proven that road salt negatively effects vegetation, aquatic life, water and soil quality, human health and the structural integrity of roads and associated structures, and that it causes rusting of cars. Salt is not an effective de-icing agent below approximately -20°C, which is when municipalities turn to sand or a mix of sand and salt. However, sand increases the amount of sediments entering waterbodies and watercourses. Numerous alternatives to road salt exist, however to date there has been little research into their environmental effects, none are as cost-efficient as road salt, and many others have known negative environmental impacts.

The CGS is currently using a mix of salt and sand on its roads during the winter months to create traction and melt ice. In total, approximately 25% of roads are salted, with the remaining 75% receiving sand. Roads that are heavily used and have higher posted speed limits are plowed to bare pavement conditions and treated with road salt, with icy sections sanded, while roads less heavily used and which hold lower posted speed limits are plowed to snow-packed conditions and then sanded. The CGS actively reviews the road salt industry BMPs, adjusts the Salt Management Plan accordingly, reviews alternatives, and educates the public and employees to minimize the environmental impact of road salt usage. The CGS has substantially reduced salt usage since 2007 and introduced the usage of some brines, enacting a continuous improvement philosophy including sending road staff to attend snow management training.

Municipalities across North America have been experimenting with alternative de-icing agents with products and compounds that naturally contain high levels of sat, including: beet juice, organic waste, pickle and cheese brine, brewing by-products, potato juice, and even fracking waste water. Additionally, 'green' de-icing products and salt alternatives are commercially produced, such as EcoTraction, which is manufactured from hydrothermal volcanic minerals (zeolites). This year, numerous Quebec municipalities began to use beet juice and wood chips as alternatives to road salt and sand for their roads (Rakobowchuk 2018). It is important to note that no de-icing agent is without drawbacks, which may include environmental effects, storage difficulties, and cost.

The CGS should continue their practice of continually reviewing their Winter Road Maintenance program activities within the Junction Creek subwatershed in order to reduce the potential influence of chloride runoff and addition of sediments to watercourses and waterbodies. This re-assessment should include assessing the feasibility of alternatives to road salt, including 'green' options.

11.3.4 Enhanced Lake Water Quality Program

The current Lake Water Quality Program consists of sampling a portion of the sixty-seven (67) lakes on a rotating basis in spring for phosphorus levels, as per the 2017 Lake Water Quality Program Annual Report (CGS). This program focuses on phosphorus levels, but has included numerous other efforts since its commencement in 2001: cyanobacteria watch; aquatic vegetation mapping; shoreline assessments through the Love Your Lake Program and Shoreline Home Visits Program; Sudbury Children's Water Festival, natural shoreline demonstration site in partnership with Science North; Lake Stewardship Grant Assistance Program; coordination and involvement with local stewardship committees; Native Aquatic Vegetation and Eurasian Water Milfoil Preliminary Survey, and; involvement with the Greater Sudbury Watershed Advisory Panel meetings.

In addition to educational programs, provision of incentives or grants that allow home-owners to naturalize their shorelines are occurring in other locations across Ontario. The North Bay-Mattawa Conservation Authority runs the Restore Your Shore program, which provides native shoreline species to landowners who wish to naturalize their shorelines. The CGS has already participated in the in the Canadian Wildlife Federation's Love Your Lake Program, which offered shoreline plants to approved shoreline residents. Alternatively, the Lake Partner Program has been employed at hundreds of lakes in Ontario, with total phosphorus, secchi depth and calcium data available online on the Ontario website.

It is suggested that the CGS amend the current Lake Water Quality Program to include analysis of a suite of water quality parameters of elements in addition to phosphorus. It is recognized that including additional chemicals in the analysis will increase program costs, however this cost can potentially be lowered by increasing the time between sampling efforts or a longer time period between sampling of the same lakes. Alternatively, installation of ambient water quality stations in locations of particular interest may be feasible if cost-sharing options exist. Potential additional water quality parameters include chloride, *E. coli*, algae and blue-green algae, calcium, turbidity, metals of interest, and lake sediment samples. Continuing to involve community members in this current program as 'citizen scientists' or through the Lake Partner Program may lower costing and increase community interest additionally. It is recommended that the Love Your Lake Program and Shoreline Home Visits Program continue to be incorporated into the Lake Water Quality Program as they increase awareness and educate the public on the importance of healthy shoreline systems and increase the shoreline data available within the CGS.

11.4 Recommended Future Studies

In addition to the recommendations above based on the results of this Study, it is recommended that additional study work be undertaken within the Junction Creek subwatershed to:

- Develop a Continuous Model of the Junction Creek subwatershed, based on the PCSWMM event model created for this study, which will allow for more detailed design criteria and analysis related to water balance and erosion control;
- Provide an updated assessment of the fish community within Junction Creek since 2004 and 2008 (currently unpublished) to determine effectiveness of local and future restoration and enhancement initiatives;
- Review to the Water Quality and Lake Health Assessment for the potential to consider contaminants in addition to phosphorus;
- Establish/audit the subwatershed's current salinity levels and impacts from application of road salt throughout the winter, especially as community interest and engagement surrounding this issue continues to grow;
- Explore the requirements for creation of a water quality model and phosphorus budget for the Junction Creek subwatershed or CGS to assess effectiveness of BMPs and retrofits in addition to effects that future development will have on water quality; and,
- Explore a Stormwater Management Financing Program or Action Complementary Strategy to implement stormwater retrofits.

12.0 MONITORING & IMPLEMENTATION PLAN

The purposes of monitoring plans are to:

- Develop mechanisms through which the performance of the Master Plan Management Approach may be evaluated with respect to overall subwatershed and subwatershed goals;
- Develop mechanisms to adjust and/or optimize the Management Approach and associated recommendations, based on results of monitoring and future advances in resource management; and,

- Holistically and comprehensively assess the full study area, accounting for cumulative effects associated with the proposed development.

It should be recognized that the monitoring plans are required to evaluate all components of the Master Plan including stormwater management, fluvial geomorphology, hydrogeology, and natural heritage systems, including aquatic and terrestrial biology, for the Annexed Lands.

12.1 Stormwater Management

Based on the issues related to hydrologic model calibration noted in **Section 6.3** of this report, the following monitoring recommendations have been explicitly advanced:

- Install an additional rain gauge near the headwaters of Junction Creek, such as in the Garson area;
- Install an additional rain gauge near the end of Junction Creek, such as in Lively.
- Install an addition flow monitoring gauge along Junction Creek upstream and east of the Ponderosa at Arthur Street;
- Install an additional flow monitoring gauge along Junction Creek upstream and north of the Ponderosa at Lasalle Boulevard;
- Install an additional flow monitoring gauge along Junction Creek downstream and south of the Ponderosa at the Perrault Street trail bridge;
- Re-establish the flow monitoring gauge (station 02CF005) downstream of the Box Culvert (but upstream of the incoming mine tailings water treatment plant flow) at McLeod Street; and,
- Install an additional flow monitoring gauge downstream of the incoming flow from the mine tailings water treatment plant. There are no crossings between this location and Kelly Lake, but Ceasar Road is nearby Junction Creek and may provide an opportunity.

Long term collection of observed precipitation and flow data is recommended in order to facilitate future calibration efforts that may improve the hydrologic and hydraulic models developed herein and update stormwater management criteria as deemed appropriate. Establishing permanent rain and flow monitoring gauges would allow for watershed and climatic trends to be established and analyzed over a number of years.

Furthermore, monitoring of stormwater management facilities to validate that performance conforms to the subject regulations for water quantity and quality is expected to be required by CS/MOE as part of the permitting process. The installation of additional rain gauges will increase the efficiency of the flood warning system currently employed by CS, as well as the Low Water Response Program. In Ontario, flood forecasting and warning is the shared responsibility of Conservation Authorities and the MNRF (where there is no local Conservation Authority), with consistent statements messages shared to the public: 'Normal', 'Water Safety Statement', 'Flood Outlook Statement', 'Flood Watch', and 'Flood Warning'. There are currently six stations solely or jointly owned by CS: Maley, Leslie Street, McLeod Street, Fielding Road, Simon Lake and Centennial Park. Additional monitoring stations that would fill current gaps and increase monitoring efficiency within the Junction Creek Subwatershed are:

- Garson headwaters
- Ponderosa Wetland- daily water level and flow data
- Nolin Creek
- Copper Cliff Creek

12.2 Fluvial Geomorphology

The collection of field data from similar sites over an extended period of time can provide great insight on channel processes and function. This monitoring can also yield information regarding the response of a channel to changes in upstream land use. Typically, these responses take the form of planform adjustment, bank erosion, changes in cross-sectional area and changes in substrate composition. These adjustments can, in turn, affect aquatic habitat and water quality.

Future work from a geomorphic perspective should consist of two components: long-term monitoring of existing control stations and additional geomorphic field work to confirm appropriate and relevant erosion thresholds on a more site-specific basis for proposed development. Long-term monitoring would entail the repetition of baseline efforts undertaken through this study, whereby control cross-sections, substrate composition and erosion pins would be re-measured on an annual basis at a similar time of year and documented through photographic record. A qualified fluvial geomorphologist must be retained in order to interpret the findings and assess whether substantial change has occurred and to recommend any potential mitigative efforts. Additional detailed geomorphic field work would remain consistent with efforts documented through this study (two [2] detailed field survey locations, substrate composition, bank properties and longitudinal survey) at the most sensitive/representative downstream reaches to be impacted by proposed land use modifications in order to establish the governing threshold for that drainage system.

12.3 Hydrogeology

Specific locations for groundwater related monitoring, the location-specific frequency of monitoring and the location-specific parameters would be determined based on the future refinement of the hydrogeologic sensitivity and ecological connections within the Junction Creek subwatershed. Future more site-specific groundwater studies integrated with any additional local scale terrestrial and aquatic assessment are expected to provide this refined characterization.

Future groundwater monitoring should consider the following:

- A spatially representative number of water table monitors will be needed to assess any potential change to the water table and larger scale groundwater flow direction;
- A number of multilevel piezometers should be included to assess vertical gradient trends;
- An increased spatial level of groundwater monitoring should be carried out where groundwater discharge provides a significant function;

- Spot baseflow measurements throughout reaches within and adjacent to Junction Creek. The spot baseflow measurements are to be taken during periods when only groundwater is expected to be providing flow to the stream such as in between rainfall events, or subsequent to spring runoff;
- Spatial discretization to represent functional linkages and potential hydrostratigraphic variation;
- Seasonal measurements are recommended with selected sites considered for the installation of data loggers to monitor more detailed short and long term trends; and,
- Annual water quality monitoring of selected well and spot baseflow sites. Chemical analysis should include inorganic parameters, nitrogen species, and metals.

Efforts should be made in obtaining and assessing historical and ongoing monitoring data from developed sites in a similar hydrogeologic setting for comparative purposes.

12.4 Water Quality

Specific Ecological monitoring should be anticipated as a condition of permit and/or design review and will be site and/or issue specific. Features that may be impacted by stormwater management, surface flow, and groundwater changes will need to be monitored, including Brook Trout spawning, fish community, and wetlands if it is found that a substantial change in flows has occurred.

The CGS should implement a Construction Management and Siltation Control Best Management Practices Program to guide the use of silt fences, check dams, sumps, and other siltation control techniques during construction. Techniques and guidelines may be based on the *Erosion & Sediment Control Guideline for Urban Construction*, published by the Greater Golden Horseshoe Area Conservation Authorities, dated December 2006, and on Section 8 of the *Draft LID Stormwater Management Guidance Manual* (MOE, April 2017).

Future surface water quality monitoring should consider the following:

- Including upstream and downstream, and before and after assessments of construction sites;
- Sampling and analyzing numerous biotic and chemical parameters;
- Filling in any current gaps in water quality knowledge within the Junction Creek Subwatershed, such as e.coli sampling;
- Continuing sampling programs at established study sites to obtain long-term datasets;
- Expanding the current water quality monitoring programs to include monitoring and assessing ecosystem functions and productivity; and,
- Including monitoring of active erosion sites and sediment transport within the system.

13.0 REFERENCES

Bird Studies Canada, Environment Canada's Canadian Wildlife Service, Ontario Nature, Ontario Field Ornithologists and Ontario Ministry of Natural Resources. 2008. Ontario Breeding Bird Atlas Database. Accessed August 19, 2016. Available at: http://www.birdsontario.org/atlas/aboutdata.jsp?lang=en

Brierley, G. J. and Fryirs, K. A. 2005. Geomorphology and River Management: Applications of the River Styles Framework. Blackwell Publishing, Oxford, UK, 398pp. ISBN 1-4051-1516-5.

British Columbia Ministry of Water, Land and Air Protection (MWLAP). 2004. Standards and Best Practices: Beaver and Beaver Dam Management. Ecosystem Standards and Planning Biodiversity Branch. March, 2004.

Brown, S., D. Shafer, and S. Anderson. 2001. Control of beaver flooding at restoration projects. WRAP Technical Notes Collection (ERDC TN-WRAP-01-01), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

City of Greater Sudbury. 2006. Official Plan: Stormwater Background Study. Available at: https://www.greatersudbury.ca/linkservid/D0886D42-CD5D-42FB-250A508C19F8C0C4/showMeta/0/

City of Greater Sudbury. 2013. Greater Sudbury Natural Heritage Report, May 2013. Revised and Updated from 2005 Edition. 67 pp.

City of Greater Sudbury. 2016a. Greater Sudbury Official Plan. Office consolidation including all amendments in effect up to April 2016. Available at: https://www.greatersudbury.ca/inside-city-hall/official-plan/

City of Greater Sudbury. 2016b. Regreening Program 5 Year Plan: 2016-2020. 27pp.

City of Greater Sudbury. 2016c. Lake Water Quality Program Environmental Planning Initiatives. 2016 Annual Report Draft. Available at: https://www.greatersudbury.ca/live/environment-and-sustainability1/lake-health/pdf-documents/2016-annual-report/

City of Greater Sudbury. 2017a. Regreening Program: Program Operation. Available at: https://www.greatersudbury.ca/live/environment-and-sustainability1/initiatives/regreening-program/program-operation/#The Liming Phase.

City of Greater Sudbury. 2017b. Lake Water Quality Program Environmental Initiatives 2017 Annual Report. Available at: https://www.greatersudbury.ca/live/environment-and-sustainability1/lake-health/pdf-documents/2017-annual-report-lake-water-quality-program/

Chu, Cindy, Nicholas E. Jones, Andrew R. Piggott, James, M. Buttle. 2009. Evaluation of a Simple Method to Classify the Thermal Characteristics of Streams Using a Nomogram of Daily Maximum Air Temperatures and Water Temperatures. North American Journal of Fisheries Management 29: 1605-1619.

Conservation Ontario. 2015. Website. http://www.conservation-ontario.on.ca/
Accessed October 7, 2015.

Conservation Sudbury. 2017. Vermillion River Watershed Surface Water Quality Report on Current Conditions. Available at: http://vermilionriverstewards.ca/wp-content/uploads/2016/03/2016-03-29-CS-Report.pdf

Crombie, D., K. Currie, R. Horst, J. MacKenzie, L. Moore, D. Zimmerman. 2015. Planning for Health, Prosperity and Growth in the Greater Golden Horseshoe: 2015-2041. Queen’s Printer for Ontario. December 2015. http://www.mah.gov.on.ca/Asset11110.aspx?method=1

Davidson, J. and J. Gunn. 2012. Environmental Fate Assessment Article: Effects of land Cover Disturbance on Stream Invertebrate Diversity and Metal Concentrations in a Small Urban Industrial Watershed. Human and Ecological Risk Assessment. 18: 1078-1095.

Dewit and Castellan Architects Inc. 1988. The Ponderosa.

Dobbyn, J.S. 1994. Atlas of the Mammals of Ontario. Don Mills, Federation of Ontario Naturalists.

Downs, P.W. 1995. Estimating the Probability of River Channel Adjustment. Earth Surface Processes and Landforms, 20: 687-705.

Eakins, R.J. 2017. Ontario Freshwater Fishes Life History Database. Version 4.75. Online database. Available at: http://www.ontariofishes.ca (Accessed July 5, 2017).

Environment Canada. Historical Climate Data. Available at: http://climate.weather.gc.ca/

Galli, J. 1996. Rapid Stream Assessment Technique, Field Methods. Metropolitan Washington Council of Governments.

Fischenich, C. 2001. Stability Thresholds for Stream Restoration Materials. EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-29), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Gorynski, R. 2000. The Temperature Effects of Urban Runoff and In-stream Impoundments on an Urban Brook Trout Creek; Junction Creek, Sudbury, Ontario, Canada. Thesis. Environmental Earth Science Programme. Laurentian University.

Gunn J., C. Sarrazin-Delay, B. Wesolek, A. Stasko and E. Szkokan-Emilson. 2010. Delayed Recovery of Benthic Macroinvertebrate Communities in Junction Creek, Sudbury, Ontario, after the Diversion of Acid Mine Drainage. Human and Ecological Risk Assessment. 16: 901-912.

Greater Sudbury Source Protection Committee. 2014. Greater Sudbury Source Water Protection Area: Source Protection Plan. Available at: http://www.sourcewatersudbury.ca/images/uploaded_files/2018update/Greater_Sudbury_Source_Protection_Area_Updated_SPP_March-2018.pdf

Greater Sudbury Watershed Alliance. 2018. Road Salt Discussion Summary Report. Available at: http://gswa.ca/category/concerns/road-salt/

Hutchinson Environmental Sciences Ltd. 2013. Development and Application of a Water Quality Model for Lakes in the City of Greater Sudbury. Available at: https://www.greatersudbury.ca/live/environment-and-sustainability1/lake-health/pdf-documents/2016-annual-report/

Jones, C., Layberry,R. and MacNaughton, A. 2016. Ontario Butterfly Atlas Online. Toronto Entomologists' Association. Last updated January 16, 2016. Available at: http://www.ontarioinsects.org/atlas_online.htm (Accessed June 29, 2017).

Jones, S. 2001. Planning for Wildlife: Evaluating Creek Daylighting as a means of Urban Conservation. Dalhousie University, Halifax, NS.

Johnson M.G. and G.E. Owen. 1966. Biological Survey of the Streams and Lakes of the Sudbury Area: 1966. Ontario Waters Resource Commission. Biology Branch.Julien, P. Y. 1998. Erosion and Sedimentation (1st ed.). Cambridge University Press.

Junction Creek Stewardship Committee (JCSC). 2009. Junction Creek Restoration. Other Fish in Junction Creek. Available at http://www.junctioncreek.com/PDF%20files/fishpics.pdf. Accessed 24 January 2017.

Keller, W.B. and J.M. Gunn. Undated. Chemical and Biological Recovery of Sudbury Area Lakes: Responses to Smelter Emission Controls.

Kelly, V.R., Findlay, S.E.G., Schlesinger, W.H., Chatrchyan, A.M., and Menking, K. 2010. Road Salt: Moving Toward the Solution. The Cary Institute of Ecosystem Studies.

Kilborn Limited. 1980. Floodplain Mapping of Junction Creek Summary Report. Prepared for the Nickel District Conservation Authority.

Lautenbach, W.E. 1985. Land Reclamation Program 1978-1984. Regional Municipality of Sudbury. Vegetation Enhancement Technical Advisory Committee. April 15, 1985.

Lemieux, E.S., Gunn, J.M., and Sheardown, J. 2004. Fish Community Assessment of Junction Creek 2004.

M.M. Dillon Limited. 1969. Junction Creek Watershed Report. Prepared for Junction Creek Conservation Authority.

Ministry of the Environment (MOE). 2015. Fish Community Survey Results.

Ministry of the Environment (MOE). 2003. Ontario Ministry of Environment. Stormwater Management Guidelines.

Ministry of Natural Resources and Forestry (MNRF). 2016. Fish ON-Line. Available at: https://www.gisapplication.lrc.gov.on.ca/FishONLine/Index.html?site=FishONLine&viewer=FishONLine&locale=en-US

Ministry of Natural Resources and Forestry (MNRF). 2015a. Inland Ontario Lakes Designated for Lake Trout Management.

Ministry of Natural Resources and Forestry (MNRF). 2016. Land Information Ontario Base Mapping for the Junction Creek Subwatershed. Dated June 20, 2016.

Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). 2008. Septic Smart! Understanding Your Home's Septic System.

Ontario Ministry of Natural Resources (OMNR). 2010. Natural Heritage Reference Manual for Policies of the Provincial Policy Statement, Second Edition. March 18, 2010.

Ministry of Natural Resources and Forestry (MNRF). 2014. Ontario Wetland Evaluation System Northern Manual. 1st Edition, Version 1.3.

Ministry of Natural Resources and Forestry (MNRF). 2015b. Significant Wildlife Habitat Criteria Schedules for Ecoregion 5E. Dated January 2015.

Ministry of Natural Resources and Forestry (MNRF). 2015c. Preventing Conflicts with Beavers. https://www.ontario.ca/page/preventing-conflicts-beavers.

Ontario Ministry of Natural Resources (OMNR). 2000. Significant Wildlife Habitat Technical Guide. July 2014.

Montgomery, D.R. and Buffington, J.M. 1997. Channel-reach Morphology in Mountain Drainage Basins. Geological Society of America Bulletin, 109 (5): 596-611.

Natho, S. and J. Freeman. 2006. The Restoration of Junction Creek: An Overview . Laurentian University Department of Biology. WS 2006-07-21

Nickel District Conservation Authority (NDCA). 1980. Watershed Inventory.

Northland Engineering Limitied. 1982. Junction Creek Watershed Management Study. Prepared for the Nickel District Conservation Authority.

Ontario Centre for Climate Impacts and Adaptation Resources. Climate Change Adaptation in the City of Greater Sudbury, Case Study. Available at: http://www.climateontario.ca/doc/casestudies/Sudbury%20Case%20Study%20-%20Final1.pdf

Ontario Geological Survey (OGS). 2003. Surficial Geology of Southern Ontario.

Ontario Ministry of Municipal Affairs and Housing (OMMAH). 2014. Provincial Policy Statement. 56pp.

Ontario Ministry of Natural Resources (MNR). 2001. Technical Guide–River & Stream Systems: Erosion Hazard Limit.

Ontario Ministry of Natural Resources (OMNR). 2005. Ontario Odonata Atlas. Natural Heritage Information Center. Last updated February 15, 2005. Available at: (http://nhic.mnr.gov.on.ca/MNR/nhic/odonates/atlas.html).

Ontario Ministry of Natural Resources and Forestry (MNRF). 2017. Natural Heritage Information Centre (NHIC) Database. Accessed: June 29, 2017.

Ontario Nature. 2017. Ontario Reptile and Amphibian Atlas. Accessed June 29, 2017. Available at: (http://www.ontarioinsects.org/herpatlas/herp_draw_map.html?spIndex=0&view=47.5Q-83.5Q6).

Ontario Ministry of Natural Resources and Forestry (MNRF) - Land Information Ontario (LIO). Land Information Ontario Metadata Management Tool. Available at: www.javacoeapp.lrc.gov.on.ca/geonetwork/srv/en/main.home

Ouranos. 2008. Climate Change in Canada: Climate Scenarios for the Public Infrastructure Vulnerability Assessment. In First National Engineering Vulnerability Assessment Report: Roads and Associated Infrastructure, prepared by Dennis Consultants for the City of Greater Sudbury, March 2008. Available at: http://www.greatersudbury.ca/content/div_wastemanagement/documents/FInal-consolidated-FirstNationalReport.pdf

Pearson, D.A.B., Gunn, J.M. and Keller, W. 2002. Chapter 9: The Past, Present and Future of Sudbury's Lakes. Physical Environment – Sudbury; OGS Special Volume 6.

Poulin D.J., J.M. Gunn and K.M. Laws. 1991. Fish Species Present in Sudbury Lakes: Results of the 1989 and 1990 Urban Lakes Survey. Unpublished report. Cooperative Freshwater Ecology Unit (CFEU), Laurentian University, Sudbury, Ontario.

Rakobowchuk, Peter. January 23 2018. "Quebec Municipalities Using Environmentally Friendly Options to Road Salt". CTV [Montreal]. Available at: https://montreal.ctvnews.ca/quebec-municipalities-using-environmentally-friendly-options-to-road-salt-1.3772473

Richards, C., Haro, R.J., Johnson, L.B. and Host, G.E. 1997. Catchment and Reach-scale Properties as Indicators of Macroinvertebrate Species Traits. Freshwater Biology, 37: 219- 230.

S.A. Kirchhefer Limited. 2000. Engineering Report on Junction Creek Water Management, City of Sudbury. Prepared for the Nickel District Conservation Authority and City of Sudbury.

Sein, R. 1993. Physical, Chemical and Biological Assessment of Junction Creek 1993. Environmental Youth Corps Project # 3109. Cooperative Freshwater Ecology Unit. Aquatic Ecosystems Research Section. OMNR/Laurentian University.

Scott, W.B. and E.J. Crossman. 1998. Freshwater Fishes of Canada. Galt House Publications Ltd. Oakville, Ontario, Canada.

Taylor, J.D., and R.D. Singleton. 2014. The Evolution of Flow Devices Used to Reduce Flooding by Beavers: A Review. Published in USDA National Wildlife Research Centre – Staff Publications 1402.

Toronto and Region Conservation Authority. 2004. Belt Width Delineation Procedures. Vasseur, L., Léger and partners. 2007. Promoting Community Sustainability through Adaptive Responses to Socio-Economic and Risk Assessments of the Potential of Climate Change Scenarios in a Natural Resource-based Mid-Sized Canadian Shield Community: Greater Sudbury, Ontario. Project # A1241. Final report to Natural Resources Canada, 45 pp. Available at: http://climateontario.ca/doc/casestudies/Sudbury%20Case%20Study%20%20Final1.pdf

Vale Living with Lakes Centre. 2016. Sudbury Environmental Study (SES). Available at: http://www3.laurentian.ca/livingwithlakes/programs/sudbury-environmental-study/

Vasseur, L. and McMilan, E. 2009. Climate Change Position Paper. Positioning the Nickel District Conservation Authority within the City of Greater Sudbury in a Future Climate. Presented To and approved by the Nickel District Conservation Authority and the City of Greater Sudbury in March 2009, 20 pp.

Vermont Agency of Natural Resources (VANR). 2007. Step 7: Rapid Geomorphic Assessment (RGA). Phase 2 Stream Geomorphic Assessment.Waberi, H.A. 2002. The Effects of AMD (Acid Mine Drainage) Diversion on the Chemistry and Biology of Frood-Stobie Tributaries. Laurentian University, Sudbury, Ontario. Department of Earth Science Thesis.

Williams, G.P. 1986. River Meanders and Channel Size. Journal of Hydrology, 88 (1-2): 147-164.

Wolman, M.G. 1954. A Method of Sampling Coarse River-Bed Material. Transactions of the American Geophysical Union, 35: 951-956.

Appendix A

Background Data / Information

- Study Area
- Tracking Chart

Appendix B

Natural Heritage System and Aquatics

- Bird Species
- Reptile and Amphibian Species
- Butterfly Spec`ies
- Mammal Species
- Dragonfly and Damselfly Species
- Known Fish Species
- Species at Risk

Appendix C

Hydrology and Hydraulics

- Subwatershed Major Delineation
- Flow Schematic
- Subwatershed Areas
- Ponderosa Natural Storage Areas
- Major Road Crossing
- Floodplain Delineation
- Modeled Truck Sewers
- Stormwater Master Plan Options

Appendix D

Water Quality

- Surface Water Sampling Sites
- Pearson Correlation Results
- Water Quality Parameter Concentrations

Appendix E

Groundwater

- Boreholes Cross-sections Locations
- Land Cover
- Surface Elevation
- Bedrock Geology
- Wanapitei Esker and Bedrock Outcrops
- Potentiometric Surface and Areas of Groundwater Discharge
- Stratigraphy

Appendix F

Stream Morphology

- Historical Aerials
- Photographic Record
- Field Sheets
- Detailed Summaries

Appendix G

Future Land Use

- Future Land Use Mapping