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# APPENDIX 'A'

## Detailed Soil Chart

# APPENDIX A
## Soils Chart

## Grey County

| Symbol | Series-texture | Materials | Drainage | Topography |
|---|---|---|---|---|
| Bc | Brookston clay loam | Fine-textured derived from limestone till | Poor | Smooth, very gently sloping |
| Bp | Breypen variable | Shallow soils over bedrock | Variable | Nearly level with numerous rock outcrops |
| Brs | Brighton sand | Well sorted sandy outwash | Good | Gently sloping |
| Dc | Dunedin clay | Fine-textured derived from red shale | Good | Smooth, moderately sloping to irregular steeply sloping |
| Gs | Granby sand | Well sorted sandy outwash | Poor | Smooth, very gently sloping |
| Hal | Harkaway loam | Medium-textured derived from dolomitic, limestone till | Good | Smooth, gently sloping to moderately sloping |
| Ksc | Kemble silty clay | Fine-textured derived from limestone till | Imperfect | Smooth, very gently sloping to smooth, gently sloping |
| Ll | Listowel loam | Medium-textured derived from dolomitic, limestone till | Imperfect | Smooth, gently sloping |
| Lyl | Lily loam | Medium-textured stony derived from dolomitic, limestone till | Poor | Undrained basins to nearly level |
| M | Muck | Well decomposed organic material mostly derived from fan vegetation | Poor | Level undrained basin |
| Mc | Morley clay | Fine-textured derived from red shale | Poor | Smooth, very gently sloping |
| Ol | Osprey loam | Medium-textured derived from dolomitic, limestone till | Good | Irregular moderately sloping to irregular steeply sloping |
| Vsc | Vincent silty clay loam | Fine-textured limestone till | Good | Smooth, gently sloping to smooth, steeply sloping |
| Wsl | Waterloo sandy loam | Poorly sorted outwash | Good | Irregular moderately sloping to irregular steeply sloping |

**Simcoe County**

| Symbol | Series-texture | Materials | Drainage | Topography |
|---|---|---|---|---|
| Ans | Alliston sandy loam | Grey, calcareous outwash sand | Imperfect | Smooth, very gently sloping |
| Bef | Berrien fine sandy loam | Outwash sand underlain by calcareous clay or silty clay loam at depths of 3' or less | Imperfect | Smooth, gently sloping |
| Bes | Berrien sandy loam | Outwash sand underlain by calcareous clay or silty clay loam at depths of 3' or less | Imperfect | Smooth, gently sloping |
| Bos | Bookton sandy loam | Outwash sand underlain by calcareous clay or silty clay loam at depths of 3' or less | Good | Smooth, moderately sloping |
| Duc | Dunedin clay | Dark reddish brown, calcareous clay till | Good | Irregular, steeply sloping |
| Es | Edenvale sandy loam | Outwash sand underlain by grey calcareous loam or sandy loam till at depths of 3' or less | Imperfect | Smooth, very gently sloping |
| Gg | Gwillimbury gravelly sandy loam | Pale brown, calcareous outwash gravel | Imperfect | Smooth, very gently sloping |
| Gsl | Granby sandy loam | Grey, calcareous outwash sand | Poor | Level |
| Hal | Harkaway loam | Pale yellow, calcareous, loam and silt loam till | Good | Smooth, steeply sloping |
| Hl | Harriston loam | Pale yellow, calcareous, loam and silt loam till | Good | Smooth, moderately to steeply sloping |
| Kc | Kemble clay loam | Light brown, calcareous clay loam till | Imperfect | Smooth, gently sloping |
| Kc-sh | Kemble clay loam, shallow phase | Light brown, calcareous clay loam till | Imperfect | Smooth, gently sloping |
| M | Muck | Well, decomposed organic material over 1' deep underlain by rock, sand, silt or clay | Very Poor | Depressional |
| Mmc | Minesing marly clay | Lacustrine, marl, silt, loam and clay | Poor | Level |
| Pal | Parkhill loam | Pale yellow, calcareous, loam and silt loam till | Poor | Smooth, very gently sloping |
| Pfs | Percy fine sandy loam | Pale brown, calcareous outwash, fine loamy sand or fine sandy loam | Good | Smooth, gently sloping |
| Shsc | Schomberg sitly clay loam | Calcareous, lacustrine, varved silt loam clay | Good | Smooth, moderately to steeply sloping |
| Smsc | Smithfield silty clay loam | Calcareous, lacustrine, varved silt loam and clay | Imperfect | Smooth, gently sloping |
| Stsl | Sargent gravelly sandy loam | Pale brown, calcareous outwash gravel | Good | Smooth, gently sloping |
| Tif | Tioga fine sandy loam | Grey, calcareous outwash sand | Good | Smooth, gently to irregular, steeply sloping |
| Tis | Tioga loamy sand | Grey, calcareous outwash sand | Good | Smooth, gently to irregular, steeply sloping |
| Tisl | Tioga sandy loam | Grey, calcareous outwash sand | Good | Smooth, gently to irregular, steeply sloping |
| Vc | Vincent clay loam | Light brown, calcareous clay loam till | Good | Smooth, moderately sloping |
| Wl | Wiarton loam | Pale yellow, calcareous, loam and silt loam till | Imperfect | Smooth, gently sloping |

# APPENDIX B

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# HYDROLOGY

Return to Water Management

## B.1 INTRODUCTION

To ensure the successful integration of any new development within a subwatershed, a means is necessary to assess the impact of the urbanization on downstream flooding and erosion, and to evaluate the effectiveness of mitigative works to maintain flooding/erosion indices (i.e. SWM "targets") to acceptable levels. Therefore, development within Collingwood's sub-catchments of the Black Ash Creek system will result in a change to the rainfall-runoff characteristics of the subwatershed. The impacts would include changes to peak flows and volumes of runoff and response times to a given rainfall and/or rainfall plus snowmelt event.

In any hydrologic analysis, quantitative data on the rainfall-runoff relationships of the study area is of prime importance. Natural precipitation varies greatly in time and space – methods for quantifying it are dependent upon the runoff estimation technique employed. In applying any runoff estimation technique, major difficulties lie in considering regional climatological, hydrophysiographical and geological differences; availability of continuous data (precipitation and streamflow); and, differences in basin characteristics. For example, hydrologic models require:

1) A storm hyetograph (event or continuous record) showing the complete variation of rainfall intensity during the period; duration; frequency; and as-required temporal and/or aerial distributions;
2) Basin physiographic factors such as geomorphology (size, shape, slope, elevation, stream pattern orientation) and physiology (land use, cover, soils, geology); and,
3) Channel physiographic features such as transmission capacity (size, shape, slope, and roughness) and storage capacity (size, slope).

Although all of these factors play a role in determining the volume and rate of surface water runoff from an area and its frequency of occurrence, no one hydrologic simulation model incorporates all of them. Further, the effects of many factors have not been thoroughly quantified. There are a number of approaches, which are currently in use for estimating flows at various points in a watershed. Some of these are based upon runoff record and rely on statistical analyses of measurable parameters, while others are based upon rainfall records, which are usually more readily available in the area under examination.

## B.2 HYDROLOGIC MODELS

### *B.2.1 Overview*

For the Black Ash Creek Subwatershed study area, the **I**ntegrated **S**tormwater and **W**atershed **M**anagement **S**ystem (**ISWMS™**) by Greenland International was utilized to develop hydrologic computer models for pre-development and post-development conditions – including multiple stormwater management alternatives. The initial phase (i.e. flood forecasting) of the new software system was developed for the Nottawasaga Valley Conservation Authority in 1999 and combines the usefulness of both unit hydrograph runoff generation methods from OTTHYMO and U.S. EPA's SWMM based software programs. The ISWMS models for Black Ash Creek also include a powerful database that will allow (if required after this study) other different modules to be "plugged in" as required by the user, including modules for groundwater systems, water balance, water quality, etc. This study's models for stormwater management and flood control has applied the unit hydrograph runoff generation methods, typically used in similar subwatershed planning studies across Ontario, to model the hydrology of the Black Ash Creek Subwatershed. In addition, duplicate models were developed using Visual OTTHYMO© to verify the results of the ISWMS models. For the subject study area, our Visual OTTHYMO (existing condition) peak flows were substantiated and compared well with the results from the ISWMS models. Therefore, it was concluded that our ISWMS modelling approach was reasonable and representative of pre-development (June 2000) conditions for the study area.

The use of ISWMS™ to model the hydrology of the Black Ash Creek Subwatershed facilitates the required updating of the model based on ever-changing land use and development patterns within the subwatershed. For example, the “pre-development” or existing condition model was based on an interpretation of aerial topography of the study area, digital soils reports and existing land use schedules from the Official Plans of the three municipalities (Town of Collingwood, Springwater Township and Town of The Blue Mountains). Our ISWMS hydrologic models also accounted for flow attenuation affects from channel routing sections that were field surveyed in November 1999.

The following sections describe the steps taken towards the development of the existing condition and post-development (i.e. un-controlled and controlled scenarios only for Collingwood) hydrologic models for the Black Ash Creek Subwatershed.

### *B.2.2 Pre-development (June 2000) and Post-development (Collingwood) Models*

<u>Subwatershed Discretization</u>

The total Black Ash Creek Subwatershed area of 3,258 hectares was broken down into smaller sub-catchment areas to ensure that the ISWMS and Visual OTTYMO models accurately reflected the response characteristics of the watercourse systems. Figure 6 (overleaf) from the Main Report illustrates our delineation of the subwatershed. A topographic field survey, site reconnaissance and review of municipal base mapping were undertaken to verify/update the overall subwatershed boundary. Previous water resources engineering reports for surrounding areas were also reviewed to eliminate the overlap of subwatershed boundaries. Specifically, the drainage area of Cranberry Resort (C.C. Tatham and Associates, 1995) was incorporated to modify the boundary at the north end and other sub-watershed mapping of the Silver Creek and Pretty River systems to the north and south, respectively, were also used. As shown in Figure 6, flow nodes were established at key locations within the subwatershed for developing stormwater management targets within the Town of Collingwood.

<u>Modelling Parameters</u>

The tables at the end of this appendix summarize our ISWMS and Visual OTTHYMO modelling parameters for existing or pre-development (June 2000) conditions. Post-development modelling parameters for sub-catchments within the Town of Collingwood are also tabulated at the end of Appendix ‘B’. All parameters were measured or calculated using current protocols and procedures. Finally, hydrologic modelling schematics for ISWMS™ and Visual OTTHYMO© are also provided at the end of this appendix.

Specific comments about our hydrologic modelling approach using the ISWMS™ and Visual OTTHYMO© computer programs include the following:

1) Total imperviousness (TIMP) ratios for each sub-catchment for the post-development hydrologic models were assumed equal to the directly connected imperviousness (XIMP) ratio. This assumption will provide conservative peak flow targets and SWM facility storage volumes to develop a master

SWM strategy for only sub-catchments within Collingwood. However, these parameters should be confirmed at the functional servicing stage, and appropriate SWM facility sizing adjustments made, once detailed land use information is available for each development block or phase;

2) Initial abstraction (IA) parameters for all sub-catchments within the study area were estimated using the based on the assigned SCS runoff curve number (CN). This is documented further in the Visual OTTHYMO© program manual by Greenland International Consulting Inc.;

3) For pre-development conditions, modified SCS-II runoff curve numbers (CN*) were estimated for each sub-catchment of the study area. Hydrologic soil group classifications for each basin, using digital surficial soil data and observed land use characteristics, were determined using the protocols from the MTO Drainage Manual. Composite SCS curve numbers (CN) for each sub-catchment were then estimated using the above information and finally converted to CN* values. Our calculations are included at the end of Appendix ‘B’;

4) The CN* method was used for post-development conditions. The CN* numbers were based on the pre-development models and calculations are provided at the end of this appendix;

5) It should be noted that sub-catchment ‘190’ shown on Figure 6 is not part of the Black Ash Creek Subwatershed but represents the a headwater basin of the Cranberry Resort area. This sub-catchment was considered in our investigations in the event of any flood flows spilling into the subject study area during our November 1999 to May 2000 streamflow monitoring period. That is, the various Georgian Trail culverts within sub-catchment ‘190’ that convey riparian flows to the Cranberry Resort area have a 2 year flood capacity. In the event of a major flood, excess drainage from the affected 127 ha basin would cascade in southeasterly direction along the south side of the Georgian Trail. Any spills to the Black Ash Creek system would occur at the Main Branch, at the northwest corner of the Blue Mountain Mall.

Meteorological Data

Continuous rainfall and temperature data from November 1999 to May 2000 was collected from a network of climate station. Further station details are provided later on and suitable data was used with the ISWMS models for calibration purposes. Single event design storm intensities were also derived from total precipitation volumes measured from the Owen Sound climate station. In particular, pre-development (June 2000) conditions were evaluated using the SCS-II 24 hour distribution storms for the 25 mm storm, 2 year, 5 year, 10 year, 25 year, 50 year and 100 year storm events. The Regional Storm (Timmins flood event) 12 hour distribution was used to determine the Regulatory Flood hazard areas, while the 25 mm (CHICAGO and SCS-II rainfall distributions) were used to assess the need for any erosion controls for the Black Ash Creek system within Collingwood. That is, the 25 mm rainfall distributions were used to size extended detention storage requirements for stormwater management (SWM) facilities in order to address the erosion control objective for the study area. Our selection of 2 year through 100 year SCS-II (24 hour) and 25 mm design storms are consistent with methodologies used in recent hydrotechnical investigations within the region and across Ontario.

Existing Structural Crossings, Floodplain Spill Areas and SWM Facilities

The study reaches cross beneath a number of roads. Crossings at Highway 26 and Old Mountain Road have been reconstructed (as part of the proposed Black Ash Creek Flood Control Project) and some watercourse sections appear to have been enlarged during drainage maintenance by municipalities. An inventory of all road crossing structures, including the type, size, etc., and channel reach forms/features were documented during our field reconnaissance visits. Relevant data was incorporated into our hydrotechnical computer models to represent flow-water level rating curves and channel routing characteristics. Channel routing sections are included at the end of Appendix ‘B’.

Just south of the Sixth Street crossing, along the Black Ash Creek South Branch, a 600-metre section of the west streambank acts as “natural” levee. As a result of the adjacent topography, flood discharges greater than the 25 year flood peak flow (assuming no channel blockage) will spill north-easterly across High Street, in the vicinity of the Sixth Street intersection. Also, a smaller spill area along the North Branch and upstream of Sixth Street would also occur during a 25 year event. During this study, both spill areas were examined in detail. Appendix ‘C’ includes our analysis about the North Branch spill zone, just upstream of the Dunn Property development lands at Sixth Street and Tenth Line. Please note, however, that our calculations during the mid-way point of the study assumed a Regional Storm flow of 22.7 $m^3/s$ – based on the flood flow database used by the NVCA and documented in the report titled: *“Black Ash Creek Environmental Study Report; Ainley and Associates Limited, February 1988 “*, In fact, it was concluded from our investigations that the Regulatory flood discharge at this point is actually 30.0 $m^3/s$. The previous hydrologic model by Ainley’s may have under-estimated the North Branch catchment area and runoff coefficients to Sixth Street. The greater discharge calculated during the subject study is due not only to the greater drainage area of about 75 ha, but also a slightly greater CN-II for the affected basin. Nevertheless, the spill flow rating curve relationships included with Appendix ‘C’ should be used by any affected developer to assess potential impacts and any required mitigative works – subject to the approval of the Nottawasaga Valley Conservation Authority.

With the exception of snowmaking facilities servicing the Osler Bluff Ski Club, there are no SWM ponds within the Black Ash Creek system. However, the recent construction of the commercial A & P development has implemented On-Site Detention (OSD) works, including parking lot surface storage and underground storage pipes to maintain pre-development runoff flows from each site. In our hydrologic analysis of the Black Ash Creek system, any existing and future OSD facilities for commercial areas within Collingwood lands previously known as “OPA 37” were assumed part of our pre-development hydrologic computer models. That is, our pre-development (June 2000) land use scenario for the entire subwatershed was the basis for flood frequency flow targets that are documented herein. These management flow targets, for various flood frequency events, were adopted in our investigations.

Model Calibration Approach

In order to improve the accuracy of our modelling techniques, actual rainfall, streamflow, snow and temperature data was collected from November 1999 to May 2000. The following table describes the types and locations of the monitoring equipment. Locations of the monitoring stations are shown in Figure 7 (overleaf) of the Main Report.

***Monitoring Equipment and Locations***

| Station No. | Description | Location |
|---|---|---|
| 1 | Model PS 9000 Pressure Transducer, supplied by Instrumentation Northwest Inc. Measures depth, readings taken every 15 minutes. | Main Branch at concrete weir, next to Blue Mountain Mall parking lot |
| 2 | Model 1000 Portable Flow Meter, supplied by Rocky Mountain Instruments Inc. Unit includes 3 separate sensors: a pressure transducer to measure depth, an ultrasonic Doppler unit to measure velocity, and a temperature probe. Readings taken | South Branch, within the Sixth Street SPCSPA culvert at Sixth Street |

| | | |
|---|---|---|
| | every 15 minutes. | |
| 3 | Ultrasonic Probe, supplied by Milltronics. Instrument is suspended above channel to measure distance from instrument to water surface. Readings taken every 15 minutes. | North Branch, within the Sixth Street CSP culvert at Sixth Street |
| 4 | Manual streamflow recording station. Measurements of stream velocity, depth, and top width made during high flow events. | CSP outlet along South Branch at Tenth Line |
| 5 | Manual streamflow recording station. Measurements of stream velocity, depth, and top width made during high flow events. | South Branch at Nottawa Side Road CSP |
| 6 | Manual streamflow recording station. Measurements of stream velocity, depth, and top width made during high flow events. | North Branch at County Road 19 (Osler Bluff Road) CSPA |
| 7 | Flow Monitoring Station at Osler Bluff Ski Club (operated by the Club for snowmaking, as part of Permit to Take Water requirements). | North Branch, west of County Road 19 |
| 8 | Manual streamflow recording station. Measurements of stream velocity, depth, and top width made during high flow events. | South Branch Tributary at Poplar Side Road |
| 9 | Davis EZ-Mount Weather Station. Measures precipitation, wind speed/direction, air temperature, soil temperature, degree-days, solar radiation/energy, barometric pressure, wind chill, humidity, dew point, and the T.H. index. | At Petun Conservation Area (i.e. on the Escarpment crest) |
| 10 | Snow Course Station. Manual measurement of the water equivalent of snow-pack. | At Petun Conservation Area |
| 11 | Davis EZ-Mount Weather Station. Measures precipitation, wind speed/direction, air temperature, soil temperature, degree-days, solar radiation/energy, barometric pressure, wind chill, humidity, dew point, and the T.H. index. | On the roof of the Zubek Emo Patten office on Stewart Street (i.e. below the Escarpment crest) |
| 12 | Town Rain Gauge – provides daily total rainfall volumes | Located at the Sewage Treatment Plant, north of First Street. |
| 13 | Snow Course Station. Manual measurement of the water equivalent of snow-pack. | Located west of Tenth Line, north of Sixth Street at Fisher Field |
| 14 | Delphi Point Rain Gauge – operated by Ontario Hydro | Located at Delphi Point |

Unfortunately, conditions during this time of year were not ideal to collect sufficient streamflow data (at the three Collingwood monitoring gauges) from a suitable number of events for flood calibration purposes. Also, observed snow pack conditions at the Petun Conservation Area and Fisher Field snow course stations were well below seasonal norms. Finally, since there was no climate data collected during a summer-fall period (to estimate local evapotranspiration) and no monitoring of groundwater wells, an accurate water balance of the subwatershed study area could not be completed. However, this did not affect the project's "scoped" study purpose regarding stormwater management and flood control within sub-catchments of the Town of Collingwood.

With the exception of the Sixth Street-North Branch streamflow gauge (Station '3'; refer to Figure 7) channel freeze-up and break-up factors from December 22, 1999 through March 2, 2000 also prevented collecting a suitable amount of flow data within Collingwood. However, data collected at the Sixth Street-North Branch gauge (i.e. for almost the entire November 1999 through May 2000 monitoring period) and manual headwater basin gauging stations provided very important information about headwater baseflow volumes, potential groundwater system underflow to the affected sub-catchments '130' and '150' and flood flows from rainfall/snowmelt events. In fact, our highest observed flow of about 2.5 $m^3/s$ at the North Branch CSP culvert beneath Sixth Street occurred on April 21-22, 2000 whereby the culvert may have surcharged or flowed "full for a short period of time. In conjunction with a measured peak flow of over 10 $m^3/s$ at the Sixth Street-South Branch streamflow gauge (Station '2': refer to Figure 7), the flood recurrence interval of this rainfall (i.e. over 50 mm during 24 hours) plus snowmelt (i.e. remaining snowpack from runs at the Osler Bluff Ski Club) event was between 5-10 years.

Since snowmaking data from the Osler Bluff Ski Club was not provided for this and other freshet flood events, an estimation of the snowpack conditions at the Ski Club could not be made. Therefore, this one event could not be used to calibrate our ISWMS and Visual OTTHYMO models. Ideally, however, 3-4 significant events are required typically to properly calibrate and verify a hydrologic computer model. Nevertheless, the observed flood conditions plus other "smaller" freshet flows between February 24-27, 2000 and March 30-April 2, 2000 were very useful to prepare our hydraulic computer models. Measured flows, velocities and water levels at the continuous streamflow gauges in Collingwood were compared to simulated parameters based on field survey channel cross-sections and culvert opening sizes. Details of our hydraulic analysis are discussed further in Appendix 'C'.

### *B.2.3 Modeling Simulation Results*

Upon completion of the pre-development ISWMS and Visual OTTHYMO models, peak flow values were noted for selected nodes within the subwatershed (Figure 6) to establish the stormwater management targets to be applied in the post-development model – which incorporated multiple SWM alternatives for water quality, erosion and flood control. These flows were also used in the preparation of the pre-development hydraulic model.

Tables 1 through 4, respectively, summarizes our Visual OTTHYMO peak flow results at various nodes of interest in the subwatershed for 1) pre-development conditions, 2) "un-controlled" post-development conditions, 3) "controlled" post-development conditions to pre-development release rates, and 4) "over-controlled" post-development conditions to 50% pre-development peak flows.

Please note that total pre-development flow spill from the North Branch (across High Street and assuming no channel blockage) during a Regional Storm event was calculated to be about 27.2 $m^3/s$ from our hydraulic computer modelling Appendix 'C'). However, this flow has been included with the total peak flows that are tabulated below for nodes 1 through 3. Comparative ISWMS model discharges for the 100 year and Regional Storm floods are also presented below to demonstrate the very close findings with our initial Visual OTTHYMO models. Finally, flow nodes 1 through 8 in the tables correspond to those shown in Figure 8. Summary output data of the hydrologic models is also appended herewith.

### *Table 1*
### *Pre-Development Peak Flows ($m^3/s$)*

| Node | Description | Visual OTTHYMO | | | | | | | ISWMS | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2 Year | 5 Year | 10 Year | 25 Year | 50 Year | 100 Year | Regional Storm | 100 year | Regional Storm |
| 1 | Outlet to Collingwood Harbour | 9.7 | 15.5 | 19.6 | 25.2 | 30.0 | 34.6 | 109.4 | 35.0 | 108.1 |
| 2 | Main Channel – West Tributary Confluence, South of Old Mountain Road | 9.3 | 15.0 | 18.9 | 24.4 | 28.9 | 33.4 | 104.7 | 33.7 | 103.3 |
| 3 | Confluence of North and South Branches, North of Sixth Street | 8.7 | 13.8 | 17.4 | 22.6 | 26.7 | 30.8 | 95.4 | 31.1 | 94.6 |
| 4 | South Branch – West Tributary Confluence, West of Campbell Street | 7.2 | 11.3 | 14.4 | 18.7 | 22.0 | 25.4 | 72.3 | 25.7 | 72.0 |
| 5 | South Branch Tributary Confluence, North of Poplar Sideroad | 6.0 | 9.4 | 12.0 | 15.4 | 18.1 | 20.8 | 53.1 | 21.3 | 53.2 |
| 6 | South Branch @ Tenth Line | 5.6 | 8.7 | 11.1 | 14.2 | 16.7 | 19.2 | 45.6 | 19.7 | 47.2 |
| 7 | South Branch @ Osler Bluff Ski Club | 1.4 | 2.3 | 3.0 | 3.9 | 4.6 | 5.4 | 14.9 | 5.5 | 14.8 |
| 8 | North Branch @ Grey County Road 19 | 2.0 | 3.1 | 3.9 | 5.0 | 5.9 | 6.8 | 21.0 | 6.8 | 21.0 |
| 9 | North Branch Outlet @ South Branch Confluence | 2.6 | 4.2 | 5.3 | 6.8 | 8.0 | 9.3 | 29.6 | 9.5 | 30.0 |
| 10 | West Tributary to Main Channel, South of Old Mountain | 0.8 | 1.2 | 1.6 | 2.1 | 2.5 | 2.9 | 9.8 | 2.9 | 9.8 |

### *Table 2*
### *"Un-controlled" Post-Development Peak Flows ($m^3/s$)*

| Node | Description | Visual OTTHYMO | | | | | | | ISWMS | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2 Year | 5 Year | 10 Year | 25 Year | 50 Year | 100 Year | Regional Storm | 100 year | Regional Storm |
| 1 | Outlet to Collingwood Harbour | 10.6 | 16.7 | 21.1 | 27.1 | 31.3 | 36.2 | 112.7 | 38.1 | 112.7 |
| 2 | Main Channel – West Tributary Confluence, South of Old Mountain Road | 9.9 | 15.6 | 19.7 | 25.6 | 30.1 | 34.8 | 107.7 | 35.3 | 106.7 |
| 3 | Confluence of North and South Branches, North of Sixth Street | 8.9 | 14.1 | 17.9 | 23.1 | 27.2 | 31.4 | 96.8 | 31.9 | 95.9 |
| 4 | South Branch – West Tributary Confluence, West of Campbell Street | 7.3 | 11.5 | 14.6 | 18.9 | 22.1 | 25.5 | 72.1 | 25.9 | 71.8 |
| 5 | South Branch Tributary Confluence, North of Poplar Sideroad | 6.0 | 9.4 | 12.0 | 15.4 | 18.1 | 20.8 | 53.1 | 21.3 | 53.2 |
| 6 | South Branch @ Tenth Line | 5.6 | 8.7 | 11.1 | 14.2 | 16.7 | 19.2 | 45.6 | 19.7 | 47.2 |
| 7 | South Branch @ Osler Bluff Ski Club | 1.4 | 2.3 | 3.0 | 3.9 | 4.6 | 5.4 | 14.9 | 5.5 | 14.8 |
| 8 | North Branch @ Grey County Road 19 | 2.0 | 3.1 | 3.9 | 5.0 | 5.9 | 6.8 | 21.0 | 6.8 | 21.0 |
| 9 | North Branch Outlet @ South Branch Confluence | 2.7 | 4.2 | 5.4 | 7.0 | 8.2 | 9.3 | 29.7 | 9.7 | 30.3 |
| 10 | West Tributary to Main Channel, South of Old Mountain | 1.0 | 1.5 | 1.9 | 2.5 | 2.9 | 3.4 | 11.0 | 3.4 | 11.0 |

### *Table 3*
### *"Controlled" Post-Development Peak Flows to Pre-development Discharges ($m^3/s$)*

| Node | Description | Visual OTTHYMO | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **2 Year** | **5 Year** | **10 Year** | **25 Year** | **50 Year** | **100 Year** | **Regional Storm** |
| 1 | Outlet to Collingwood Harbour | 10.1 | 16.1 | 20.4 | 26.3 | 31.0 | 35.9 | 112.8 |
| 2 | Main Channel – West Tributary Confluence, South of Old Mountain Road | 9.7 | 15.4 | 19.5 | 25.2 | 29.9 | 34.5 | 107.7 |
| 3 | Confluence of North and South Branches, North of Sixth Street | 8.8 | 14.0 | 17.7 | 22.9 | 27.0 | 31.2 | 96.7 |
| 4 | South Branch – West Tributary Confluence, West of Campbell Street | 7.2 | 11.3 | 14.4 | 18.7 | 21.9 | 25.3 | 72.2 |
| 5 | South Branch Tributary Confluence, North of Poplar Sideroad | 6.0 | 9.4 | 12.0 | 15.4 | 18.1 | 20.8 | 53.1 |
| 6 | South Branch @ Tenth Line | 5.6 | 8.7 | 11.1 | 14.2 | 16.7 | 19.2 | 45.6 |
| 7 | South Branch @ Osler Bluff Ski Club | 1.4 | 2.3 | 3.0 | 3.9 | 4.6 | 5.4 | 14.9 |
| 8 | North Branch @ Grey County Road 19 | 2.0 | 3.1 | 3.9 | 5.0 | 5.9 | 6.8 | 21.0 |
| 9 | North Branch Outlet @ South Branch Confluence | 2.7 | 4.2 | 5.4 | 7.0 | 8.2 | 9.5 | 29.8 |
| 10 | West Tributary to Main Channel, South of Old Mountain | 0.9 | 1.4 | 1.9 | 2.4 | 2.9 | 3.3 | 11.0 |

### *Table 4*
### *"Over-controlled" Post-Development Peak Flows to 50% Pre-development Discharges ($m^3/s$)*

| Node | Description | Visual OTTHYMO | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **2 Year** | **5 Year** | **10 Year** | **25 Year** | **50 Year** | **100 Year** | **Regional Storm** |
| 1 | Outlet to Collingwood Harbour | 10.0 | 15.8 | 19.9 | 25.6 | 30.2 | 34.9 | 112.8 |
| 2 | Main Channel – West Tributary Confluence, South of Old Mountain Road | 9.6 | 15.3 | 19.3 | 25.0 | 29.6 | 34.2 | 107.7 |
| 3 | Confluence of North and South Branches, North of Sixth Street | 8.8 | 13.9 | 17.6 | 22.8 | 26.9 | 31.1 | 96.8 |
| 4 | South Branch – West Tributary Confluence, West of Campbell Street | 7.2 | 11.3 | 14.3 | 18.6 | 21.8 | 25.2 | 72.2 |
| 5 | South Branch Tributary Confluence, North of Poplar Sideroad | 6.0 | 9.4 | 12.0 | 15.4 | 18.1 | 20.8 | 53.1 |
| 6 | South Branch @ Tenth Line | 5.6 | 8.7 | 11.1 | 14.2 | 16.7 | 19.2 | 45.6 |
| 7 | South Branch @ Osler Bluff Ski Club | 1.4 | 2.3 | 3.0 | 3.9 | 4.6 | 5.4 | 14.9 |
| 8 | North Branch @ Grey County Road 19 | 2.0 | 3.1 | 3.9 | 5.0 | 5.9 | 6.8 | 21.0 |

| Node | Description | Visual OTTHYMO | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 Year | 5 Year | 10 Year | 25 Year | 50 Year | 100 Year | Regional Storm |
| 9 | North Branch Outlet @ South Branch Confluence | 2.7 | 4.2 | 5.4 | 7.0 | 8.2 | 9.5 | 29.8 |
| 10 | West Tributary to Main Channel, South of Old Mountain | 0.9 | 1.4 | 1.8 | 2.3 | 2.7 | 3.2 | 11.0 |

Tables 5 and 6 present the final hydrologic peak flow findings from our ISWMS hydrologic models. Output data presented in Table 6 incorporates the proposed water quality and 25 mm rainfall (48 hour detention) erosion control facilities but does not include flood control storage for 2 year through 100 year design storm events.

***Table 5***
***ISWMS Pre-Development Peak Flows (m³/s)***

| Node | Description | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 Year | 5 Year | 10 Year | 25 Year | 50 Year | 100 Year | Regional Storm |
| 1 | Outlet to Collingwood Harbour | 10.0 | 15.7 | 20.1 | 25.7 | 30.3 | 35.0 | 108.1 |
| 2 | Main Channel – West Tributary Confluence, South of Old Mountain Road | 9.7 | 15.1 | 19.3 | 24.8 | 29.1 | 33.7 | 103.3 |
| 3 | Confluence of North and South Branches, North of Sixth Street | 9.0 | 14.1 | 17.9 | 22.9 | 26.9 | 31.1 | 94.6 |
| 4 | South Branch – West Tributary Confluence, West of Campbell Street | 7.3 | 11.5 | 14.7 | 18.9 | 22.2 | 25.7 | 72.0 |
| 5 | South Branch Tributary Confluence, North of Poplar Sideroad | 6.1 | 9.6 | 12.2 | 15.7 | 18.5 | 21.3 | 53.2 |
| 6 | South Branch @ Tenth Line | 5.7 | 9.0 | 11.4 | 14.6 | 17.1 | 19.7 | 47.2 |
| 7 | South Branch @ Osler Bluff Ski Club | 1.5 | 2.4 | 3.0 | 4.0 | 4.7 | 5.5 | 14.8 |
| 8 | North Branch @ Grey County Road 19 | 2.0 | 3.1 | 3.9 | 5.0 | 5.9 | 6.8 | 21.0 |
| 9 | North Branch Outlet @ South Branch Confluence | 2.7 | 4.3 | 5.4 | 7.0 | 8.2 | 9.5 | 30.0 |
| 10 | West Tributary to Main Channel, South of Old Mountain | 0.8 | 1.2 | 1.6 | 2.1 | 2.5 | 2.9 | 9.8 |

***Table 6***
***ISWMS™” Un-controlled” Post-Development Peak Flows (m³/s)***

| Node | Description | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 Year | 5 Year | 10 Year | 25 Year | 50 Year | 100 Year | Regional Storm |
| 1 | Outlet to Collingwood Harbour | 11.3 | 17.5 | 22.1 | 28.2 | 33.1 | 38.1 | 112.7 |
| 2 | Main Channel – West Tributary Confluence, South of Old Mountain Road | 10.2 | 15.9 | 20.2 | 26.0 | 30.5 | 35.3 | 106.7 |
| 3 | Confluence of North and South Branches, North of Sixth Street | 9.2 | 14.4 | 18.3 | 23.5 | 27.6 | 31.9 | 95.9 |
| 4 | South Branch – West Tributary Confluence, West of Campbell Street | 7.5 | 11.7 | 14.8 | 19.1 | 22.4 | 25.9 | 71.8 |

| Node | Description | 2 Year | 5 Year | 10 Year | 25 Year | 50 Year | 100 Year | Regional Storm |
|---|---|---|---|---|---|---|---|---|
| 5 | South Branch Tributary Confluence, North of Poplar Sideroad | 6.1 | 9.6 | 12.2 | 15.7 | 18.5 | 21.3 | 53.2 |
| 6 | South Branch @ Tenth Line | 5.7 | 9.0 | 11.4 | 14.6 | 17.1 | 19.7 | 47.2 |
| 7 | South Branch @ Osler Bluff Ski Club | 1.5 | 2.4 | 3.0 | 4.0 | 4.7 | 5.5 | 14.8 |
| 8 | North Branch @ Grey County Road 19 | 2.0 | 3.1 | 3.9 | 5.0 | 5.9 | 6.8 | 21.0 |
| 9 | North Branch Outlet @ South Branch Confluence | 2.8 | 4.4 | 5.6 | 7.2 | 8.4 | 9.7 | 30.3 |
| 10 | West Tributary to Main Channel, South of Old Mountain | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.4 | 11.0 |

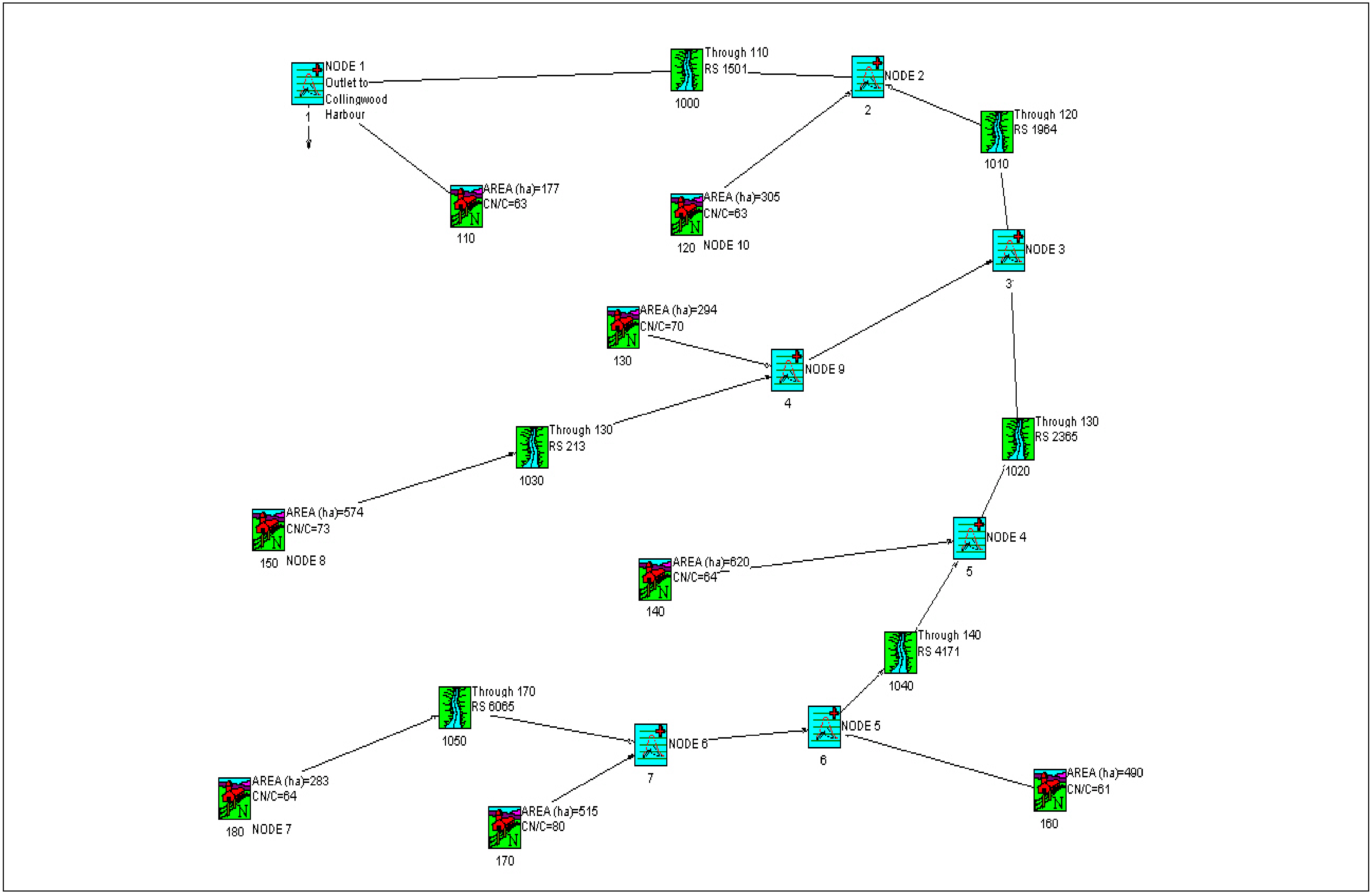
During our hydrologic analysis, a comparison with previously approved flow databases was also undertaken. For example, results from our pre-development ISWMS model were compared with the flood frequency flow values documented in two reports, namely: 1) *"Black Ash Creek Environmental Study Report; Ainley and Associates Limited, February 1988 "*, and 2) *Watershed, Hydrology Study for the Nottawasaga, Pretty and Batteaux Rivers, Black Ash, Silver and Sturgeon Creeks; MacLaren Plansearch, May 1988.* The following table compares the flows from these 1988 reports with those generated as part of this study at similar nodes of interest.

### *Table 7: Comparison of Flow Rates*

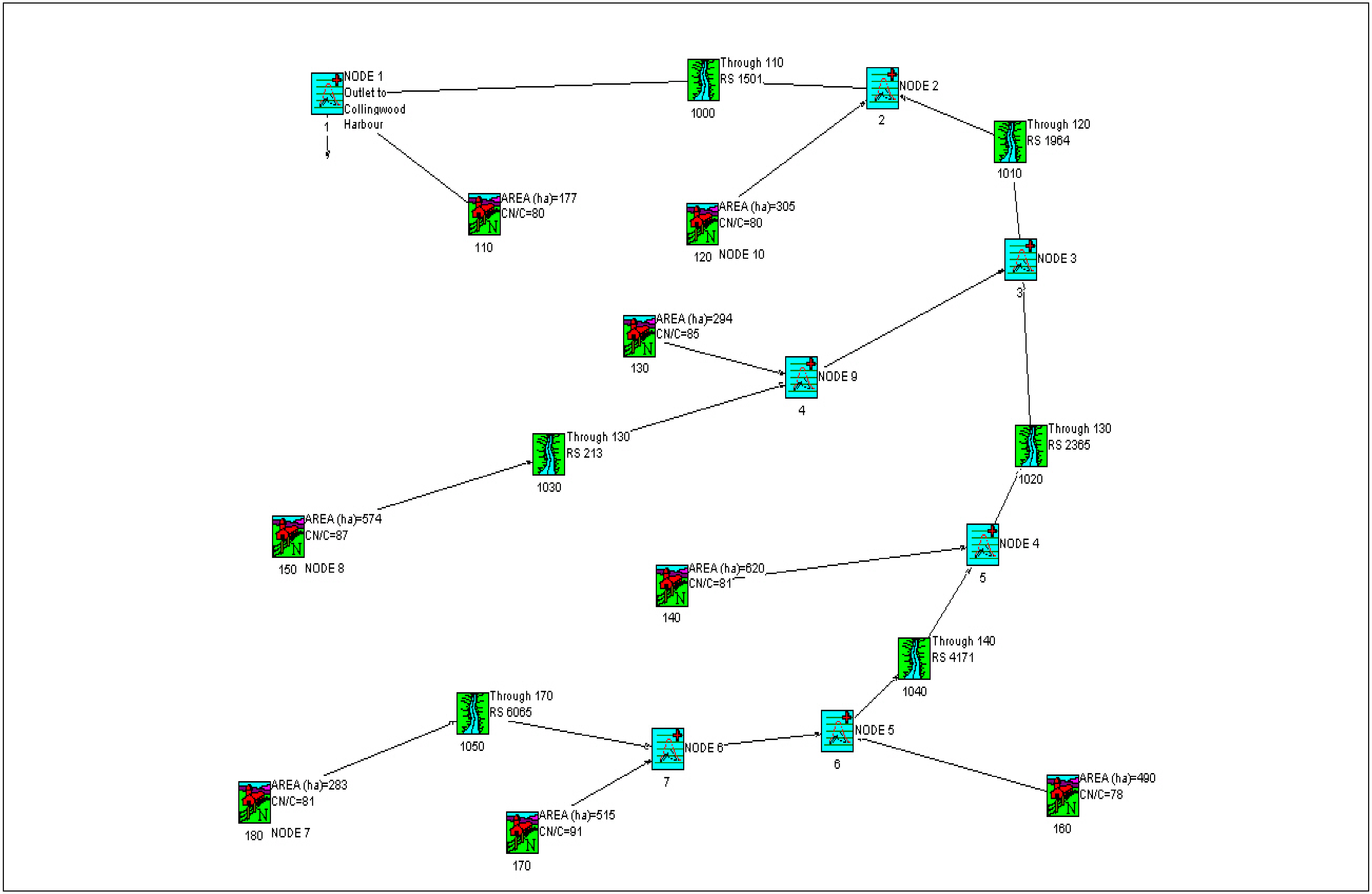
| Node | Description | 5 Year | | | 100 Year | | | Regional Storm (Timmins) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | MacLaren (1988) | Ainley (1988) | NVCA & Greenland (2000) | MacLaren (1988) | Ainley (1988) | NVCA & Greenland (2000) | MacLaren (1988) | Ainley (1988) | NVCA & Greenland (2000) |
| 1[1] | Outlet to Collingwood Harbour | 28.8 | 44.6 | **15.7** | 51.5 | 75.6 | **35.0** | 115.4 | 132.3 | **108.1** |
| 3[2] | Confluence of North and South Branches, North of Sixth Street | 27.7 | 30.9 | **14.1** | 43.9 | 52.4 | **31.1** | 112.5 | 86.7 | **94.6** |
| 4[3] | South Branch – West Tributary Confluence, West of Campbell Street | 11.1 | 21.8 | **11.5** | 19.6 | 37.0 | **25.7** | 51.1 | 60.2 | **72.0** |

NOTES: 1. Drainage Areas: MacLaren (2,914 ha), Ainley (3,033 ha) and NVCA/Greenland (3,258 ha)
2. Drainage Areas: MacLaren (2,685 ha), Ainley (2,505 ha) and NVCA/Greenland (2,776 ha)
3. Drainage Areas: MacLaren (1,110 ha), Ainley (1,709 ha) and NVCA/Greenland (1,908 ha)

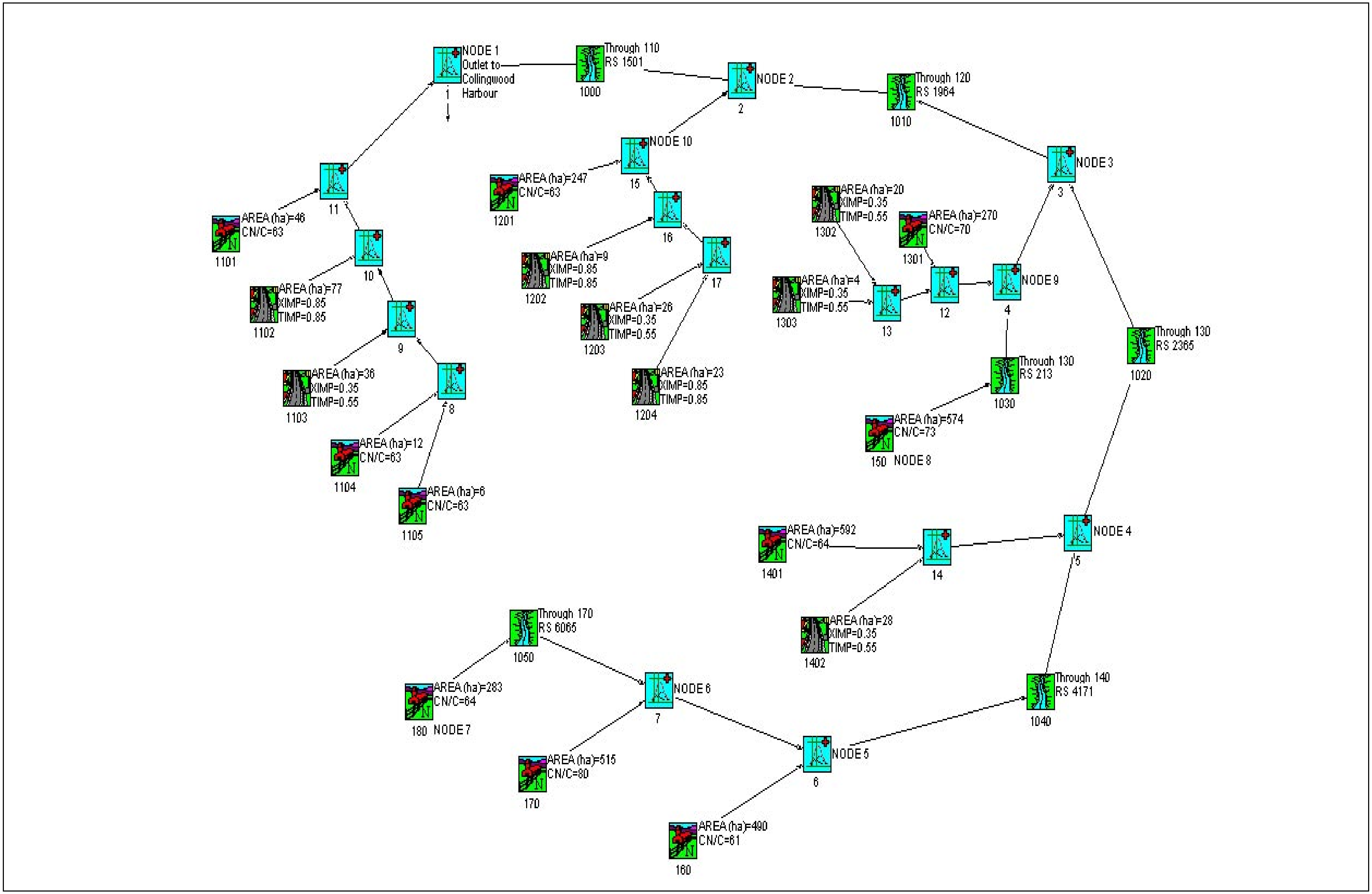
## ISWMS and Visual OTTHYMO Schematics – Pre-Development Conditions (June 2000): 2 through 100 Year Storms



**ISWMS and Visual OTTHYMO Schematics – Pre-Development Conditions (June 2000): Regional Storm – Timmins (AMC II) . . . SPILL NOT CONSIDERED**



**ISWMS and Visual OTTHYMO Schematics – "Un-controlled" Post-Development Conditions: 2-100 Year & Regional Storms (NO CHANNELIZATION)**



**Summary of Subcatchment Properties: Pre-development Conditions (June 2000)**

| Subcatchment | Urban/Rural | Command | (uncalibrated) CN (II) | CN* (II) | CN* (III) | Area (ha) | L (m) | Tp(hr) |
|---|---|---|---|---|---|---|---|---|
| 110 | Rural | Nashyd | 67 | 63 | 80 | 177 | -- | 3.81 |
| 120 | Rural | Nashyd | 67 | 63 | 80 | 305 | -- | 3.49 |
| 130 | Rural | Nashyd | 73 | 70 | 85 | 294 | -- | 4.69 |
| 140 | Rural | Nashyd | 69 | 64 | 81 | 620 | -- | 2.98 |
| 150 | Rural | Nashyd | 74 | 73 | 87 | 574 | -- | 3.76 |
| 160 | Rural | Nashyd | 66 | 61 | 78 | 490 | -- | 4.08 |
| 170 | Rural | Nashyd | 79 | 80 | 91 | 515 | -- | 1.21 |
| 180 | Rural | Nashyd | 68 | 64 | 81 | 283 | -- | 0.97 |

* L is derived from $A= 1.5L^2$, applies to urban catchments only

**Hydrologic Soils Groups and Corresponding CN-II Parameters**

| Soil | | HSG | CN's Crop | CN's Pasture | CN's Woodlot | Areas (as percentages) Crop | Areas (as percentages) Pasture | Areas (as percentages) Woodlot | CN by Soil Group |
|---|---|---|---|---|---|---|---|---|---|
| Ans | Alliston Sandy Loam | AB | 68 | 51 | 44 | 0.54 | 0.36 | 0.10 | 59 |
| Bes | Berrien Sandy Loam | AB | 68 | 51 | 44 | 0.54 | 0.36 | 0.10 | 59 |
| Bp | Breypen Variable | B | 74 | 65 | 58 | 0.43 | 0.42 | 0.15 | 68 |
| Duc | Dunedin Clay | D | 86 | 81 | 77 | 0.43 | 0.42 | 0.15 | 83 |
| Hal | Harkaway Loam | B | 74 | 65 | 58 | 0.43 | 0.42 | 0.15 | 68 |
| Kc | Kemble Clay Loam | D | 86 | 81 | 77 | 0.54 | 0.36 | 0.10 | 83 |
| Ksc | Kemble Silty Clay | C | 82 | 76 | 71 | 0.43 | 0.42 | 0.15 | 78 |
| Lyl | Lily Loam | B | 74 | 65 | 58 | 0.43 | 0.42 | 0.15 | 68 |
| Mmc | Minesing Marly Clay | C | 82 | 76 | 71 | 0.54 | 0.36 | 0.10 | 79 |
| Ol | Osprey Loam | B | 74 | 65 | 58 | 0.43 | 0.42 | 0.15 | 68 |
| Pal | Parkhill Loam | BC | 78 | 71 | 65 | 0.54 | 0.36 | 0.10 | 74 |
| Pfs | Percy Fine Sandy Loam | B | 74 | 65 | 58 | 0.54 | 0.36 | 0.10 | 69 |
| Smsc | Smithfield Silt Clay Loam | C | 82 | 76 | 71 | 0.54 | 0.36 | 0.10 | 79 |
| Stsl | Sargent Gravelly Sandy Loam | AB | 68 | 51 | 44 | 0.54 | 0.36 | 0.10 | 59 |
| Tis | Tioga Loamy Sand | A | 62 | 38 | 30 | 0.54 | 0.36 | 0.10 | 50 |
| Tisl | Tioga Sandy Loam | A | 62 | 38 | 30 | 0.54 | 0.36 | 0.10 | 50 |
| Vc | Vincent Clay Loam | D | 86 | 81 | 77 | 0.54 | 0.36 | 0.10 | 83 |
| Vsc | Vincent Silty Clay Loam | C | 82 | 76 | 71 | 0.43 | 0.42 | 0.15 | 78 |
| Wl | Wiarton Loam | B | 74 | 65 | 58 | 0.54 | 0.36 | 0.10 | 69 |

**CN-II Parameters by Sub-catchment: Pre-development Conditions (June 2000)**

| Subcatchment | Subwatershed Area (ha) | Soil Desc. | Percentage of Area (%) | Soil Sub Area (ha) | CN | A x CN | Total A x CN | Final CN |
|---|---|---|---|---|---|---|---|---|
| 110 | 177 | Stsl | 0.13 | 23.0 | 59 | 1369 | | |
| | | Bes | 0.02 | 3.5 | 59 | 211 | | |
| | | Hal | 0.06 | 10.6 | 68 | 720 | | |
| | | Smsc | 0.02 | 3.5 | 79 | 279 | | |
| | | Tis | 0.02 | 3.5 | 50 | 178 | | |
| | | Wl | 0.75 | 132.8 | 69 | 9181 | 11937 | 67 |
| | | | *1.00* | *177.0* | | | | |
| 120 | 305 | Mmc | 0.02 | 6.1 | 79 | 480 | | |
| | | Kc | 0.27 | 82.4 | 83 | 6860 | | |
| | | Stsl | 0.17 | 51.9 | 59 | 3084 | | |
| | | Tisl | 0.05 | 15.3 | 50 | 765 | | |
| | | Bes | 0.07 | 21.4 | 59 | 1270 | | |
| | | Hal | 0.06 | 18.3 | 68 | 1241 | | |
| | | Tis | 0.18 | 54.9 | 50 | 2754 | | |
| | | Wl | 0.05 | 15.3 | 69 | 1055 | | |
| | | Smsc | 0.09 | 27.5 | 79 | 2161 | | |
| | | Pal | 0.01 | 3.1 | 74 | 226 | | |
| | | Pfs | 0.03 | 9.2 | 69 | 633 | 20529 | 67 |
| | | | *1.00* | *305.0* | | | | |
| 130 | 294 | Vc | 0.14 | 41.2 | 83 | 3429 | | |
| | | Mmc | 0.04 | 11.8 | 79 | 926 | | |
| | | Kc | 0.22 | 64.7 | 83 | 5388 | | |
| | | Stsl | 0.23 | 67.6 | 59 | 4022 | | |
| | | Pfs | 0.28 | 82.3 | 69 | 5693 | | |
| | | Smsc | 0.09 | 26.5 | 79 | 2083 | 21541 | 73 |
| | | | *1.00* | *294.0* | | | | |
| 140 | 620 | Duc | 0.05 | 31.0 | 83 | 2559 | | |
| | | Vsc | 0.24 | 148.8 | 78 | 11581 | | |
| | | Kc | 0.04 | 24.8 | 83 | 2066 | | |
| | | Pal | 0.08 | 49.6 | 74 | 3679 | | |
| | | Wl | 0.20 | 124.0 | 69 | 8576 | | |
| | | Tisl | 0.20 | 124.0 | 50 | 6220 | | |
| | | Pfs | 0.19 | 117.8 | 69 | 8147 | 42828 | 69 |
| | | | *1.00* | *620.0* | | | | |
| 150 | 574 | Vsc | 0.20 | 114.8 | 78 | 8935 | | |
| | | Ksc | 0.05 | 28.7 | 78 | 2234 | | |
| | | Duc | 0.27 | 155.0 | 83 | 12794 | | |
| | | Ol | 0.42 | 241.1 | 68 | 16350 | | |
| | | Bp | 0.06 | 34.4 | 68 | 2336 | 42648 | 74 |
| | | | *1.00* | *574.0* | | | | |
| 160 | 490 | Vc | 0.23 | 112.7 | 83 | 9388 | | |
| | | Wl | 0.37 | 181.3 | 69 | 12539 | | |
| | | Ans | 0.18 | 88.2 | 59 | 5246 | | |
| | | Tisl | 0.22 | 107.8 | 50 | 5407 | 32580 | 66 |
| | | | *1.00* | *490.0* | | | | |
| 170 | 515 | Duc | 0.12 | 61.8 | 83 | 5102 | | |
| | | Vc | 0.54 | 278.1 | 83 | 23166 | | |
| | | Pal | 0.02 | 10.3 | 74 | 764 | | |
| | | Wl | 0.32 | 164.8 | 69 | 11398 | 40429 | 79 |
| | | | *1.00* | *515.0* | | | | |
| 180 | 283 | Lyl | 0.13 | 36.8 | 68 | 2495 | | |
| | | Bp | 0.03 | 8.5 | 68 | 576 | | |
| | | Ol | 0.84 | 237.7 | 68 | 16122 | 19193 | 68 |
| | | | *1.00* | *283.0* | | | | |

**Converting CN to CN***

*Total Rainfall, P (mm) =* 88.5
*Standard Abstraction, Ia (mm) =* 5

| Subcatchment | CN (AMC II) | CN (AMC III) | S (mm) | Ia | Q | S* | CN* (AMC III) | CN* (AMC II) |
|---|---|---|---|---|---|---|---|---|
| 110 | 67 | 83 | 52.0 | 10.4 | 46.9 | 65.3 | 80 | 63 |
| 120 | 67 | 83 | 52.0 | 10.4 | 46.9 | 65.3 | 80 | 63 |
| 130 | 73 | 87 | 38.0 | 7.6 | 55.1 | 43.1 | 85 | 70 |
| 140 | 69 | 84 | 48.4 | 9.7 | 48.8 | 59.2 | 81 | 64 |
| 150 | 74 | 88 | 34.6 | 6.9 | 57.3 | 38.3 | 87 | 73 |
| 160 | 66 | 82 | 55.8 | 11.2 | 44.9 | 71.6 | 78 | 61 |
| 170 | 79 | 91 | 25.1 | 5.0 | 64.2 | 25.2 | 91 | 80 |
| 180 | 68 | 84 | 48.4 | 9.7 | 48.8 | 59.2 | 81 | 64 |

Procedure used:
1. CN(AMC III) = 25400 / (254 + S) -> used to determine S
2. Ia = 0.2 x S --> calculated Ia
3. Q = $(P - Ia)^2$ / (P - Ia + S) --> determine Q using calculated Ia
4. With calculated Q, above, substitue calculated Ia with Standard Ia = 5mm. Determine S* using Q = (P - Ia)2 / (P - Ia + S*)
5. CN*(AMC III) = 25400 / (254 + S*) --> determine CN*

**Lookup Table for Converting CN Values**

| AMC II | AMC III | AMC I |
|---|---|---|
| 0 | 0 | 0 |
| 5 | 13 | 2 |
| 10 | 22 | 4 |
| 15 | 30 | 6 |
| 20 | 37 | 9 |
| 25 | 43 | 12 |
| 30 | 50 | 15 |
| 31 | 51 | 16 |
| 32 | 52 | 16 |
| 33 | 53 | 17 |
| 34 | 54 | 18 |
| 35 | 55 | 18 |
| 36 | 56 | 19 |
| 37 | 57 | 20 |
| 38 | 58 | 21 |
| 39 | 59 | 21 |
| 40 | 60 | 22 |
| 41 | 61 | 23 |
| 42 | 62 | 24 |
| 43 | 63 | 25 |
| 44 | 64 | 25 |
| 45 | 65 | 26 |
| 46 | 66 | 27 |
| 47 | 67 | 28 |
| 48 | 68 | 29 |
| 49 | 69 | 30 |
| 50 | 70 | 31 |
| 51 | 70 | 31 |
| 52 | 71 | 32 |
| 53 | 72 | 33 |
| 54 | 73 | 34 |
| 55 | 74 | 35 |
| 56 | 75 | 36 |
| 57 | 75 | 37 |
| 58 | 76 | 38 |
| 59 | 77 | 39 |
| 60 | 78 | 40 |
| 61 | 78 | 41 |
| 62 | 79 | 42 |
| 63 | 80 | 43 |
| 64 | 81 | 44 |
| 65 | 82 | 45 |
| 66 | 82 | 46 |
| 67 | 83 | 47 |
| 68 | 84 | 48 |
| 69 | 84 | 50 |
| 70 | 85 | 51 |
| 71 | 86 | 52 |
| 72 | 86 | 53 |
| 73 | 87 | 54 |
| 74 | 88 | 55 |
| 75 | 88 | 57 |
| 76 | 89 | 58 |
| 77 | 89 | 59 |
| 78 | 90 | 60 |
| 79 | 91 | 62 |
| 80 | 91 | 63 |
| 81 | 92 | 64 |
| 82 | 92 | 66 |
| 83 | 93 | 67 |
| 84 | 93 | 68 |
| 85 | 94 | 70 |
| 86 | 94 | 72 |
| 87 | 95 | 73 |
| 88 | 95 | 75 |
| 89 | 96 | 76 |
| 90 | 96 | 78 |
| 91 | 97 | 80 |
| 92 | 97 | 81 |
| 93 | 98 | 83 |
| 94 | 98 | 85 |
| 95 | 98 | 87 |
| 96 | 99 | 89 |
| 97 | 99 | 91 |
| 98 | 99 | 94 |
| 99 | 100 | 97 |
| 100 | 100 | 100 |

**Time to Peak Calculations**

| Subcatchment | Urban/Rural | Command | Area (ha) | $\Delta$h (m) | Length (m) | Slope (%) | V* (m/s) | Tc(hr) | Tp(hr) |
|---|---|---|---|---|---|---|---|---|---|
| 110 | Rural | Nashyd | 177 | 18 | 2883 | 0.6 | 0.14 | 5.72 | 3.81 |
| 120 | Rural | Nashyd | 305 | 28 | 3395 | 0.8 | 0.18 | 5.24 | 3.49 |
| 130 | Rural | Nashyd | 294 | 38 | 4556 | 0.8 | 0.18 | 7.03 | 4.69 |
| 140 | Rural | Nashyd | 620 | 145 | 5469 | 2.7 | 0.34 | 4.47 | 2.98 |
| 150 | Rural | Nashyd | 574 | 158 | 6500 | 2.4 | 0.32 | 5.64 | 3.76 |
| 160 | Rural | Nashyd | 490 | 45 | 4410 | 1.0 | 0.20 | 6.13 | 4.08 |
| 170 | Rural | Nashyd | 515 | 103 | 2689 | 3.8 | 0.41 | 1.82 | 1.21 |
| 180 | Rural | Nashyd | 283 | 138 | 2630 | 5.2 | 0.50 | 1.46 | 0.97 |

* Velocity determined with Uplands Method

**Route Channel Parameters**

| NHYD | 1000 | | 1010 | | 1020 | | 1030 | | 1040 | | 1050 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Length (for slope calc) | 970.0 | | 405.0 | | 1330.0 | | 1340.0 | | 2560.0 | | 2560.0 | |
| Actual Length (m) | 1400.0 | | 600.0 | | 800.0 | | 5000.0 | | 2200.0 | | 3200.0 | |
| Typical Section No. | *1501* | | *1964* | | *2365* | | *213* | | *4171* | | *6065* | |
| *RAS Sections* | *U/S* | *D/S* | *U/S* | *D/S* | *U/S* | *D/S* | *U/S* | *D/S* | *U/S* | *D/S* | *U/S* | *D/S* |
| Section No. | 104 | 101 | 2165 | 1760 | 3570 | 2265 | 223 | 201 | 6065 | 3528 | 6065 | 3528 |
| Inverts (m) | 191.6 | 188.0 | 186.6 | 183.6 | 190.2 | 187.4 | 198.9 | 187.8 | 216.7 | 190.0 | 216.7 | 190.0 |
| Ch Slope (%) | 0.4 | | 0.7 | | 0.2 | | 0.8 | | 1.0 | | 1.0 | |
| FP Slope (%) | 0.4 | | 0.7 | | 0.2 | | 0.8 | | 1.0 | | 1.0 | |
| VSN | | | | | | | | | | | | |
| NSEG | 3 | | 3 | | 3 | | 3 | | 3 | | 3 | |
| *Roughness (metres)* | *n* | *Stn* | *n* | *Stn* | *n* | *Stn* | *n* | *Stn* | *n* | *Stn* | *n* | *Stn* |
| (by section length) | 0.050 | 516.5 | 0.050 | 510.2 | 0.050 | 510.2 | 0.070 | 530.0 | 0.060 | 516.0 | 0.050 | 504.0 |
| | -0.030 | 534.0 | -0.030 | 526.0 | -0.030 | 526.0 | -0.035 | 535.0 | -0.040 | 528.9 | -0.030 | 510.8 |
| | 0.050 | 1000.0 | 0.050 | 1000.0 | 0.050 | 1000.0 | 0.070 | 1000.0 | 0.060 | 1000.0 | 0.050 | 1000.0 |
| Section Station | 1501 | | 1964 | | 2365 | | 213 | | 4171 | | 6065 | |
| *Dist/Elev (metres)* | *Stn* | *Elev* | *Stn* | *Elev* | *Stn* | *Elev* | *Stn* | *Elev* | *Stn* | *Elev* | *Stn* | *Elev* |
| *Note: Sections* | 0.0 | *184.5* | 0.0 | *189.4* | 0.0 | *191.2* | 0.0 | *198.3* | 0.0 | *205.1* | 0.0 | *219.9* |
| *expanded to 1000m* | 500.0 | 182.9 | 500.0 | 187.2 | 500.0 | 190.1 | 500.0 | 196.5 | 500.0 | 202.0 | 500.0 | 217.6 |
| | 508.7 | 183.2 | 505.0 | 187.7 | 505.0 | 190.6 | 517.4 | 193.9 | 507.0 | 201.1 | **504.0** | **217.5** |
| *(500m before & after,* | 512.5 | 183.9 | **510.2** | **188.0** | **510.2** | **190.8** | **530.0** | **193.2** | **516.0** | **198.0** | 505.0 | 216.9 |
| *using calculated* | **516.5** | **183.1** | 513.8 | 185.5 | 513.8 | 188.3 | 530.3 | 192.7 | 517.4 | 196.5 | 507.0 | 216.7 |
| *channel slope to* | 516.5 | 182.1 | 516.3 | 184.9 | 516.3 | 187.7 | 531.4 | 192.6 | 519.3 | 196.2 | 510.3 | 216.9 |
| *determine end* | 517.2 | 181.7 | 519.8 | 184.7 | 519.8 | 187.6 | 532.6 | 192.8 | 522.1 | 195.9 | **510.8** | **217.3** |
| *elevations)* | 517.3 | 181.7 | 523.1 | 185.5 | 523.1 | 188.3 | **535.0** | **193.2** | 524.7 | 196.1 | 515.5 | 217.4 |
| | 520.0 | 181.5 | **526.0** | **187.7** | **526.0** | **190.5** | 537.0 | 194.3 | **528.9** | **196.9** | 525.0 | 217.4 |
| | 522.7 | 181.7 | 527.0 | 187.7 | 527.0 | 190.6 | 545.0 | 195.4 | 542.7 | 196.9 | 1000.0 | *219.9* |
| | 528.0 | 182.4 | 540.9 | 187.7 | 540.9 | 190.6 | 565.9 | 196.7 | 562.9 | 202.2 | | |
| | 529.0 | 182.8 | 1000.0 | *189.4* | 1000.0 | *191.2* | 1000.0 | *198.3* | 596.6 | 203.0 | | |
| | **534.0** | **183.1** | | | | | | | 1000.0 | *205.1* | | |
| | 540.0 | 183.1 | | | | | | | | | | |
| | 1000.0 | *184.5* | | | | | | | | | | |

**Summary of Subcatchment Properties: Post-development Conditions for Town of Collingwood (As per new Official Plan land use)**

(uncalibrated)

| Subcatchment | Urban/Rural | Landuse | Command | CN (II) | CN* (II) | CN* (III) | Area (ha) | XIMP | TIMP | L (m) | Tp(hr) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1101 | Rural | Recreation | Nashyd | 67 | 63 | 80 | 46 | -- | -- | -- | 1.05 |
| 1102 | Urban | Industrial | Standhyd | 67 | 63 | 80 | 77 | 0.85 | 0.85 | 716 | -- |
| 1103 | Urban | Residential | Standhyd | 67 | 63 | 80 | 36 | 0.35 | 0.55 | 490 | -- |
| 1104 | Rural | EPA | Nashyd | 67 | 63 | 80 | 12 | -- | -- | -- | 0.25 |
| 1105 | Rural | EPA | Nashyd | 67 | 63 | 80 | 6 | -- | -- | -- | 0.17 |
| 1201 | Rural | Recreation/Rural | Nashyd | 67 | 63 | 80 | 247 | -- | -- | -- | 2.65 |
| 1202 | Urban | Industrial | Standhyd | 67 | 63 | 80 | 9 | 0.85 | 0.85 | 245 | -- |
| 1203 | Urban | Residential | Standhyd | 67 | 63 | 80 | 26 | 0.35 | 0.55 | 416 | -- |
| 1204 | Urban | Industrial | Standhyd | 67 | 63 | 80 | 23 | 0.85 | 0.85 | 392 | -- |
| 1301 | Rural | Recreation/Rural | Nashyd | 73 | 70 | 85 | 270 | -- | -- | -- | 4.00 |
| 1302 | Urban | Residential | Standhyd | 73 | 70 | 85 | 20 | 0.35 | 0.55 | 365 | -- |
| 1303 | Urban | Residential | Standhyd | 73 | 70 | 85 | 4 | 0.35 | 0.55 | 163 | -- |
| 1401 | Rural | Rural | Nashyd | 69 | 64 | 81 | 592 | -- | -- | -- | 3.01 |
| 1402 | Urban | Residential | Standhyd | 69 | 64 | 81 | 28 | 0.35 | 0.55 | 432 | -- |
| 150 | Rural | Rural | Nashyd | 74 | 73 | 87 | 574 | -- | -- | -- | 3.76 |
| 160 | Rural | Rural | Nashyd | 66 | 61 | 78 | 490 | -- | -- | -- | 4.08 |
| 170 | Rural | Rural | Nashyd | 79 | 80 | 91 | 515 | -- | -- | -- | 1.21 |
| 180 | Rural | Rural | Nashyd | 68 | 64 | 81 | 283 | -- | -- | -- | 0.97 |

* L is derived from $A = 1.5L^2$, applies to urban catchments only

*Additional Urban Parameters:*

| | | |
|---|---|---|
| SLPP (%) | Pervious Area Slope | 2 |
| LGP (m) | Pervious Area Overland Flow Length | 40 |
| MNP | Pervious Area Manning's n | 0.25 |
| DPSI (mm) | Depression Storage | 1 |
| SLPI (%) | Impervious Area Slope | 1 |
| MNI | Impervious Area Manning's n | 0.013 |

**Hydrologic Soils Groups and Corresponding CN-II Parameters**

| Soil | | HSG | CN's Crop | CN's Pasture | CN's Woodlot | Areas (as percentages) Crop | Areas (as percentages) Pasture | Areas (as percentages) Woodlot | CN by Soil Group |
|---|---|---|---|---|---|---|---|---|---|
| Ans | Alliston Sandy Loam | AB | 68 | 51 | 44 | 0.54 | 0.36 | 0.10 | 59 |
| Bes | Berrien Sandy Loam | AB | 68 | 51 | 44 | 0.54 | 0.36 | 0.10 | 59 |
| Bp | Breypen Variable | B | 74 | 65 | 58 | 0.43 | 0.42 | 0.15 | 68 |
| Duc | Dunedin Clay | D | 86 | 81 | 77 | 0.43 | 0.42 | 0.15 | 83 |
| Hal | Harkaway Loam | B | 74 | 65 | 58 | 0.43 | 0.42 | 0.15 | 68 |
| Kc | Kemble Clay Loam | D | 86 | 81 | 77 | 0.54 | 0.36 | 0.10 | 83 |
| Ksc | Kemble Silty Clay | C | 82 | 76 | 71 | 0.43 | 0.42 | 0.15 | 78 |
| Lyl | Lily Loam | B | 74 | 65 | 58 | 0.43 | 0.42 | 0.15 | 68 |
| Mmc | Minesing Marly Clay | C | 82 | 76 | 71 | 0.54 | 0.36 | 0.10 | 79 |
| Ol | Osprey Loam | B | 74 | 65 | 58 | 0.43 | 0.42 | 0.15 | 68 |
| Pal | Parkhill Loam | BC | 78 | 71 | 65 | 0.54 | 0.36 | 0.10 | 74 |
| Pfs | Percy Fine Sandy Loam | B | 74 | 65 | 58 | 0.54 | 0.36 | 0.10 | 69 |
| Smsc | Smithfield Silt Clay Loam | C | 82 | 76 | 71 | 0.54 | 0.36 | 0.10 | 79 |
| Stsl | Sargent Gravelly Sandy Loam | AB | 68 | 51 | 44 | 0.54 | 0.36 | 0.10 | 59 |
| Tis | Tioga Loamy Sand | A | 62 | 38 | 30 | 0.54 | 0.36 | 0.10 | 50 |
| Tisl | Tioga Sandy Loam | A | 62 | 38 | 30 | 0.54 | 0.36 | 0.10 | 50 |
| Vc | Vincent Clay Loam | D | 86 | 81 | 77 | 0.54 | 0.36 | 0.10 | 83 |
| Vsc | Vincent Silty Clay Loam | C | 82 | 76 | 71 | 0.43 | 0.42 | 0.15 | 78 |
| Wl | Wiarton Loam | B | 74 | 65 | 58 | 0.54 | 0.36 | 0.10 | 69 |

**CN-II Parameters by Sub-catchment: Post-development Conditions for Town of Collingwood (As per new Offic**

| Subcatchment | Subwatershed Area (ha) | Soil Desc. | Percentage of Area (%) | Soil Sub Area (ha) | CN | A x CN | Total A x CN | Final CN |
|---|---|---|---|---|---|---|---|---|
| 110 | 177 | Stsl | 0.13 | 23.0 | 59 | 1369 | | |
| | | Bes | 0.02 | 3.5 | 59 | 211 | | |
| | | Hal | 0.06 | 10.6 | 68 | 720 | | |
| | | Smsc | 0.02 | 3.5 | 79 | 279 | | |
| | | Tis | 0.02 | 3.5 | 50 | 178 | | |
| | | Wl | 0.75 | 132.8 | 69 | 9181 | 11937 | 67 |
| | | | *1.00* | *177.0* | | | | |
| 120 | 305 | Mmc | 0.02 | 6.1 | 79 | 480 | | |
| | | Kc | 0.27 | 82.4 | 83 | 6860 | | |
| | | Stsl | 0.17 | 51.9 | 59 | 3084 | | |
| | | Tisl | 0.05 | 15.3 | 50 | 765 | | |
| | | Bes | 0.07 | 21.4 | 59 | 1270 | | |
| | | Hal | 0.06 | 18.3 | 68 | 1241 | | |
| | | Tis | 0.18 | 54.9 | 50 | 2754 | | |
| | | Wl | 0.05 | 15.3 | 69 | 1055 | | |
| | | Smsc | 0.09 | 27.5 | 79 | 2161 | | |
| | | Pal | 0.01 | 3.1 | 74 | 226 | | |
| | | Pfs | 0.03 | 9.2 | 69 | 633 | 20529 | 67 |
| | | | *1.00* | *305.0* | | | | |
| 130 | 294 | Vc | 0.14 | 41.2 | 83 | 3429 | | |
| | | Mmc | 0.04 | 11.8 | 79 | 926 | | |
| | | Kc | 0.22 | 64.7 | 83 | 5388 | | |
| | | Stsl | 0.23 | 67.6 | 59 | 4022 | | |
| | | Pfs | 0.28 | 82.3 | 69 | 5693 | | |
| | | Smsc | 0.09 | 26.5 | 79 | 2083 | 21541 | 73 |
| | | | *1.00* | *294.0* | | | | |
| 140 | 620 | Duc | 0.05 | 31.0 | 83 | 2559 | | |
| | | Vsc | 0.24 | 148.8 | 78 | 11581 | | |
| | | Kc | 0.04 | 24.8 | 83 | 2066 | | |
| | | Pal | 0.08 | 49.6 | 74 | 3679 | | |
| | | Wl | 0.20 | 124.0 | 69 | 8576 | | |
| | | Tisl | 0.20 | 124.0 | 50 | 6220 | | |
| | | Pfs | 0.19 | 117.8 | 69 | 8147 | 42828 | 69 |
| | | | *1.00* | *620.0* | | | | |
| 150 | 574 | Vsc | 0.20 | 114.8 | 78 | 8935 | | |
| | | Ksc | 0.05 | 28.7 | 78 | 2234 | | |
| | | Duc | 0.27 | 155.0 | 83 | 12794 | | |
| | | Ol | 0.42 | 241.1 | 68 | 16350 | | |
| | | Bp | 0.06 | 34.4 | 68 | 2336 | 42648 | 74 |
| | | | *1.00* | *574.0* | | | | |
| 160 | 490 | Vc | 0.23 | 112.7 | 83 | 9388 | | |
| | | Wl | 0.37 | 181.3 | 69 | 12539 | | |
| | | Ans | 0.18 | 88.2 | 59 | 5246 | | |
| | | Tisl | 0.22 | 107.8 | 50 | 5407 | 32580 | 66 |
| | | | *1.00* | *490.0* | | | | |
| 170 | 515 | Duc | 0.12 | 61.8 | 83 | 5102 | | |
| | | Vc | 0.54 | 278.1 | 83 | 23166 | | |
| | | Pal | 0.02 | 10.3 | 74 | 764 | | |
| | | Wl | 0.32 | 164.8 | 69 | 11398 | 40429 | 79 |
| | | | *1.00* | *515.0* | | | | |
| 180 | 283 | Lyl | 0.13 | 36.8 | 68 | 2495 | | |
| | | Bp | 0.03 | 8.5 | 68 | 576 | | |
| | | Ol | 0.84 | 237.7 | 68 | 16122 | 19193 | 68 |
| | | | *1.00* | *283.0* | | | | |

**Converting CN to CN***

| | |
|---|---|
| *Total Rainfall, P (mm) =* | 88.5 |
| *Standard Abstraction, Ia (mm) =* | 5 |

| Subcatchment | CN (AMC II) | CN (AMC III) | S (mm) | Ia | Q | S* | CN* (AMC III) | CN* (AMC II) |
|---|---|---|---|---|---|---|---|---|
| 110 | 67 | 83 | 52.0 | 10.4 | 46.9 | 65.3 | 80 | 63 |
| 120 | 67 | 83 | 52.0 | 10.4 | 46.9 | 65.3 | 80 | 63 |
| 130 | 73 | 87 | 38.0 | 7.6 | 55.1 | 43.1 | 85 | 70 |
| 140 | 69 | 84 | 48.4 | 9.7 | 48.8 | 59.2 | 81 | 64 |
| 150 | 74 | 88 | 34.6 | 6.9 | 57.3 | 38.3 | 87 | 73 |
| 160 | 66 | 82 | 55.8 | 11.2 | 44.9 | 71.6 | 78 | 61 |
| 170 | 79 | 91 | 25.1 | 5.0 | 64.2 | 25.2 | 91 | 80 |
| 180 | 68 | 84 | 48.4 | 9.7 | 48.8 | 59.2 | 81 | 64 |

Procedure used:

1 CN(AMC III) = 25400 / (254 + S) -> used to determine S
2 Ia = 0.2 x S --> calculated Ia
3 $Q = (P - Ia)^2 / (P - Ia + S)$ --> determine Q using calculated Ia
4 With calculated Q, above, substitue calculated Ia with Standard Ia = 5mm. Determine S* using Q = (P - Ia)2 / (P - Ia + S*)
6 CN*(AMC III) = 25400 / (254 + S*) --> determine CN*

**Lookup Table for Converting CN Values**

| AMC II | AMC III | AMC I |
|---|---|---|
| 0 | 0 | 0 |
| 5 | 13 | 2 |
| 10 | 22 | 4 |
| 15 | 30 | 6 |
| 20 | 37 | 9 |
| 25 | 43 | 12 |
| 30 | 50 | 15 |
| 31 | 51 | 16 |
| 32 | 52 | 16 |
| 33 | 53 | 17 |
| 34 | 54 | 18 |
| 35 | 55 | 18 |
| 36 | 56 | 19 |
| 37 | 57 | 20 |
| 38 | 58 | 21 |
| 39 | 59 | 21 |
| 40 | 60 | 22 |
| 41 | 61 | 23 |
| 42 | 62 | 24 |
| 43 | 63 | 25 |
| 44 | 64 | 25 |
| 45 | 65 | 26 |
| 46 | 66 | 27 |
| 47 | 67 | 28 |
| 48 | 68 | 29 |
| 49 | 69 | 30 |
| 50 | 70 | 31 |
| 51 | 70 | 31 |
| 52 | 71 | 32 |
| 53 | 72 | 33 |
| 54 | 73 | 34 |
| 55 | 74 | 35 |
| 56 | 75 | 36 |
| 57 | 75 | 37 |
| 58 | 76 | 38 |
| 59 | 77 | 39 |
| 60 | 78 | 40 |
| 61 | 78 | 41 |
| 62 | 79 | 42 |
| 63 | 80 | 43 |
| 64 | 81 | 44 |
| 65 | 82 | 45 |
| 66 | 82 | 46 |
| 67 | 83 | 47 |
| 68 | 84 | 48 |
| 69 | 84 | 50 |
| 70 | 85 | 51 |
| 71 | 86 | 52 |
| 72 | 86 | 53 |
| 73 | 87 | 54 |
| 74 | 88 | 55 |
| 75 | 88 | 57 |
| 76 | 89 | 58 |
| 77 | 89 | 59 |
| 78 | 90 | 60 |
| 79 | 91 | 62 |
| 80 | 91 | 63 |
| 81 | 92 | 64 |
| 82 | 92 | 66 |
| 83 | 93 | 67 |
| 84 | 93 | 68 |
| 85 | 94 | 70 |
| 86 | 94 | 72 |
| 87 | 95 | 73 |
| 88 | 95 | 75 |
| 89 | 96 | 76 |
| 90 | 96 | 78 |
| 91 | 97 | 80 |
| 92 | 97 | 81 |
| 93 | 98 | 83 |
| 94 | 98 | 85 |
| 95 | 98 | 87 |
| 96 | 99 | 89 |
| 97 | 99 | 91 |
| 98 | 99 | 94 |
| 99 | 100 | 97 |
| 100 | 100 | 100 |

**Time to Peak Calculations**

| Subcatchment | Urban/Rural | Command | Area (ha) | Δh (m) | Length (m) | Slope (%) | V* (m/s) | Tc(hr) | Tp(hr) |
|---|---|---|---|---|---|---|---|---|---|
| 1101 | Rural | Nashyd | 46 | 6 | 961 | 0.6 | 0.17 | 1.57 | 1.05 |
| 1102 | Urban | Standhyd | 77 | | | | | | |
| 1103 | Urban | Standhyd | 36 | | | | | | |
| 1104 | Rural | Nashyd | 12 | 3 | 288 | 1.0 | 0.21 | 0.38 | 0.25 |
| 1105 | Rural | Nashyd | 6 | 2 | 192 | 1.0 | 0.21 | 0.25 | 0.17 |
| 1201 | Rural | Nashyd | 247 | 22 | 2716 | 0.8 | 0.19 | 3.97 | 2.65 |
| 1202 | Urban | Standhyd | 9 | | | | | | |
| 1203 | Urban | Standhyd | 26 | | | | | | |
| 1204 | Urban | Standhyd | 23 | | | | | | |
| 1301 | Rural | Nashyd | 270 | 34 | 4100 | 0.8 | 0.19 | 5.99 | 4.00 |
| 1302 | Urban | Standhyd | 20 | | | | | | |
| 1303 | Urban | Standhyd | 4 | | | | | | |
| 1401 | Rural | Nashyd | 592 | 138 | 5200 | 2.7 | 0.32 | 4.51 | 3.01 |
| 1402 | Urban | Standhyd | 28 | | | | | | |
| 150 | Rural | Nashyd | 574 | 158 | 6500 | 2.4 | 0.32 | 5.64 | 3.76 |
| 160 | Rural | Nashyd | 490 | 45 | 4410 | 1.0 | 0.20 | 6.13 | 4.08 |
| 170 | Rural | Nashyd | 515 | 103 | 2689 | 3.8 | 0.41 | 1.82 | 1.21 |
| 180 | Rural | Nashyd | 283 | 138 | 2630 | 5.2 | 0.50 | 1.46 | 0.97 |

* Velocity determined with Uplands Method

**Route Channel Parameters**

| NHYD | 1000 | | 1010 | | 1020 | | 1030 | | 1040 | | 1050 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Length (for slope calc) | 970.0 | | 405.0 | | 1330.0 | | 1340.0 | | 2560.0 | | 2560.0 | |
| Actual Length (m) | 1400.0 | | 600.0 | | 800.0 | | 5000.0 | | 2200.0 | | 3200.0 | |
| Typical Section No. | *1501* | | *1964* | | *2365* | | *213* | | *4171* | | *6065* | |
| *RAS Sections* | *U/S* | *D/S* | *U/S* | *D/S* | *U/S* | *D/S* | *U/S* | *D/S* | *U/S* | *D/S* | *U/S* | *D/S* |
| Section No. | 104 | 101 | 2165 | 1760 | 3570 | 2265 | 223 | 201 | 6065 | 3528 | 6065 | 3528 |
| Inverts (m) | 191.6 | 188.0 | 186.6 | 183.6 | 190.2 | 187.4 | 198.9 | 187.8 | 216.7 | 190.0 | 216.7 | 190.0 |
| Ch Slope (%) | 0.4 | | 0.7 | | 0.2 | | 0.8 | | 1.0 | | 1.0 | |
| FP Slope (%) | 0.4 | | 0.7 | | 0.2 | | 0.8 | | 1.0 | | 1.0 | |
| VSN | | | | | | | | | | | | |
| NSEG | 3 | | 3 | | 3 | | 3 | | 3 | | 3 | |
| *Roughness (metres)* | *n* | *Stn* | *n* | *Stn* | *n* | *Stn* | *n* | *Stn* | *n* | *Stn* | *n* | *Stn* |
| (by section length) | 0.050 | 516.5 | 0.050 | 510.2 | 0.050 | 510.2 | 0.070 | 530.0 | 0.060 | 516.0 | 0.050 | 504.0 |
| | -0.030 | 534.0 | -0.030 | 526.0 | -0.030 | 526.0 | -0.035 | 535.0 | -0.040 | 528.9 | -0.030 | 510.8 |
| | 0.050 | 1000.0 | 0.050 | 1000.0 | 0.050 | 1000.0 | 0.070 | 1000.0 | 0.060 | 1000.0 | 0.050 | 1000.0 |
| Section Station | 1501 | | 1964 | | 2365 | | 213 | | 4171 | | 6065 | |
| *Dist/Elev (metres)* | *Stn* | *Elev* | *Stn* | *Elev* | *Stn* | *Elev* | *Stn* | *Elev* | *Stn* | *Elev* | *Stn* | *Elev* |
| *Note: Sections* | 0.0 | *184.5* | 0.0 | *189.4* | 0.0 | *191.2* | 0.0 | *198.3* | 0.0 | *205.1* | 0.0 | *219.9* |
| *expanded to 1000m* | 500.0 | 182.9 | 500.0 | 187.2 | 500.0 | 190.1 | 500.0 | 196.5 | 500.0 | 202.0 | 500.0 | 217.6 |
| | 508.7 | 183.2 | 505.0 | 187.7 | 505.0 | 190.6 | 517.4 | 193.9 | 507.0 | 201.1 | **504.0** | **217.5** |
| *(500m before & after,* | 512.5 | 183.9 | **510.2** | **188.0** | **510.2** | **190.8** | **530.0** | **193.2** | **516.0** | **198.0** | 505.0 | 216.9 |
| *using calculated* | **516.5** | **183.1** | 513.8 | 185.5 | 513.8 | 188.3 | 530.3 | 192.7 | 517.4 | 196.5 | 507.0 | 216.7 |
| *channel slope to* | 516.5 | 182.1 | 516.3 | 184.9 | 516.3 | 187.7 | 531.4 | 192.6 | 519.3 | 196.2 | 510.3 | 216.9 |
| *determine end* | 517.2 | 181.7 | 519.8 | 184.7 | 519.8 | 187.6 | 532.6 | 192.8 | 522.1 | 195.9 | **510.8** | **217.3** |
| *elevations)* | 517.3 | 181.7 | 523.1 | 185.5 | 523.1 | 188.3 | **535.0** | **193.2** | 524.7 | 196.1 | 515.5 | 217.4 |
| | 520.0 | 181.5 | **526.0** | **187.7** | **526.0** | **190.5** | 537.0 | 194.3 | **528.9** | **196.9** | 525.0 | 217.4 |
| | 522.7 | 181.7 | 527.0 | 187.7 | 527.0 | 190.6 | 545.0 | 195.4 | 542.7 | 196.9 | 1000.0 | *219.9* |
| | 528.0 | 182.4 | 540.9 | 187.7 | 540.9 | 190.6 | 565.9 | 196.7 | 562.9 | 202.2 | | |
| | 529.0 | 182.8 | 1000.0 | *189.4* | 1000.0 | *191.2* | 1000.0 | *198.3* | 596.6 | 203.0 | | |
| | **534.0** | **183.1** | | | | | | | 1000.0 | *205.1* | | |
| | 540.0 | 183.1 | | | | | | | | | | |
| | 1000.0 | *184.5* | | | | | | | | | | |

# APPENDIX C

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# HYDRAULICS

Return to Water Management

## C.1 INTRODUCTION

For this study, the HEC-RAS (River Analysis System) computer model was used for the open channel hydraulic analysis, in combination with BOSS-RMS (River Modelling System) for the plotting of the revised floodlines. HEC-RAS is the most recent instalment of the U.S. Army Corps of Engineers series of hydraulic simulation software packages, and is the successor to HEC-2. BOSS-RMS is a program designed to integrate the hydraulic modelling capabilities of HEC-RAS with the plotting features of AutoCAD.

The HEC-RAS program calculates water surface profiles for flow in natural or man-made channels, assuming that such flow is steady and gradually varied. The one-dimensional equations of continuity and motion are solved using the standard step method, with energy losses due to friction evaluated by the Manning's equation. The HEC-RAS program can also calculate critical depth at each cross-section of the reach under investigation, and compute profiles for subcritical or supercritical flow, where required. Backwater profiles can be run for subcritical flow conditions by specifying a starting water level at the downstream end of the reach being simulated. Hydraulic models prepared for use with the HEC-RAS program can take into account the following factors:

- Channel roughness;
- Floodplain roughness;
- Islands or flow diversions
- Bends in the rivers or floodplain;
- Cross-sectional areas of the river channel and floodplain or overbank zones;
- Slope of the channel and floodplain;
- Energy losses at hydraulic structures such as culverts, bridges, weirs, dams, etc.;
- Channel and floodplain expansion and contraction losses;
- Variation in discharge along the reach, due to tributary inflows; and,
- The effect of ice/debris cover on the river or floodplain.

## C.2 HYDRAULIC MODELS

### *C.2.1 Overview*

General

The following briefly outlines the main assumptions in the application of our HEC-RAS model for the study reaches shown in Figure 8 (overleaf) from the Main Report. These assumptions are typical requirements (where applicable) of the Province in the determination of Regulatory Floodlines.

- Water levels were computed assuming subcritical flow conditions;
- All culverts, bridges, and hydraulic constraints were assumed free of any temporary obstruction which may reduce the hydraulic discharge capacities; and,
- Peak flows were used in determining the flood profiles.

All hydraulic parameters used to update the HEC-RAS model were initially measured or calculated using current protocols and procedures and based on SI (metric) units. Thereafter, roughness coefficients within the Town of Collingwood reaches were calibrated, wherever possible, using field collected streamflow, velocity, and depth data.

During our analysis of existing channel conditions, the geometric component of the HEC-RAS model was used to import HEC-2 data for reaches shown in Figure 8, as well as field surveyed cross-sections and bridge/culvert data collected as part of this study. The existing HEC-2 models were obtained from the NVCA, and were updated to include recent bridge replacements at Highway 26 and Mountain Road, as part of the Black Ash Creek Flood Control Project. For the proposed Black Ash Creek Flood Control Project conditions, the HEC-2 model from the report titled: *"Black Ash Creek Channelization Project – ESR Addendum; Nottawasaga Valley Conservation Authority and Ainley and Associates Limited, June 1995"* was incorporated into HEC-RAS with other existing reach modelling data from the existing channel condition model, such as the North Branch. This future condition model was then used to assess potential water level impacts from any phasing of the proposed flood control works. Cross-section chainage for the future channel condition model was consistent with the reference system used in the 1995 ESR document plus our filed survey sections of connecting tributaries and the North Branch. At the end of Appendix 'C', HEC-RAS section schematics are included for existing and future Black Ash Creek channel conditions in the Town of Collingwood.

Spill Areas within Collingwood

It should be noted that HEC-RAS is not currently capable of modelling spills or flow diversions between cross-sections and away from the channel/floodplain. As a result, a section of the main channel of Black Ash Creek, extending from its mouth at Collingwood Harbour to Campbell Street, was modelled simultaneously in HEC-2 to determine the magnitude of split flows occurring within this reach. The results of this analysis were incorporated into the HEC-RAS model to reduce the flows in the channel at the spill nodes (Figure 8). In particular, just south of the Sixth Street crossing and along the Black Ash Creek South Branch, a 600-metre section of the west streambank acts as "natural" levee. As a result of the adjacent topography, flood discharges greater than the 25 year flood peak flow (assuming no channel blockage) will spill north-easterly across High Street, in the vicinity of the Sixth Street intersection. In total, a Regional Storm spill of about 30 $m^3/s$ will spill across High Street and beginning just upstream of the Underwood Creek confluence with the South Branch. Previous spill calculations by Ainley and Associates Limited for this reach of Black Ash Creek estimated that the total Regional Storm flow spill would be over 50 $m^3/s$.

Also, a smaller spill area along the North Branch and upstream of Sixth Street would also occur during a 25 year event. At the end of Appendix 'C', our earlier analysis during the study about the North Branch spill zone, just upstream of the Dunn Property development lands at Sixth Street and Tenth Line, is included. Please note, however, that our calculations during the mid-way point of the study assumed a Regional Storm flow of 22.7 $m^3/s$ – based on the flood flow database used by the NVCA and documented in the report titled: "Black Ash Creek Environmental Study Report; Ainley and Associates Limited, February 1988 ", In fact, it was concluded from our investigations that the Regulatory flood discharge at this point is actually 30.0 $m^3/s$. The previous hydrologic model by Ainley's may have under-estimated the North Branch catchment area and runoff coefficients to Sixth Street. The greater discharge calculated during the subject study is due not only to the greater drainage area of about 75 ha, but also a slightly greater CN-II for the affected basin. Nevertheless, the spill flow rating curve relationships included at the end of Appendix 'C' should be used by any affected developer to assess potential impacts and any required mitigative works – subject to the approval of the Nottawasaga Valley Conservation Authority.

### *C.2.2 Modelling Simulation Results*

Utilizing our Visual OTTHYMO and ISWMS pre-development and post-development condition models (refer to Appendix 'B' for schematics) surface water runoff simulations were undertaken for the 25 mm (first-flush), 2 year, 5 year, 10 year, 25 year, 50 year, 100 year and Regional Storm events. Initial conditions for the "controlled" and "over-controlled" post-development SWM models assumed empty detention storage facilities.

Results of our stormwater management modelling analysis are presented in Section 6.2 of the Main Report. For the 2 through 100 hydrologic models, the SCS-II (24-hour duration) design storm distributions were used. Appendix 'B' includes the hydrologic modelling output data for the Black Ash Creek system (i.e. existing and post-development (un-controlled) conditions).

Tables 1 and 2 below present the HEC-RAS modelling results using the ISWMS pre-development Regional Storm and 100 year peak flow database for existing and future Black Ash Creek Flood Control Project conditions.

**HEC-RAS Model Schematic for Existing (June 2000) Black Ash Creek Conditions within the Town of Collingwood**

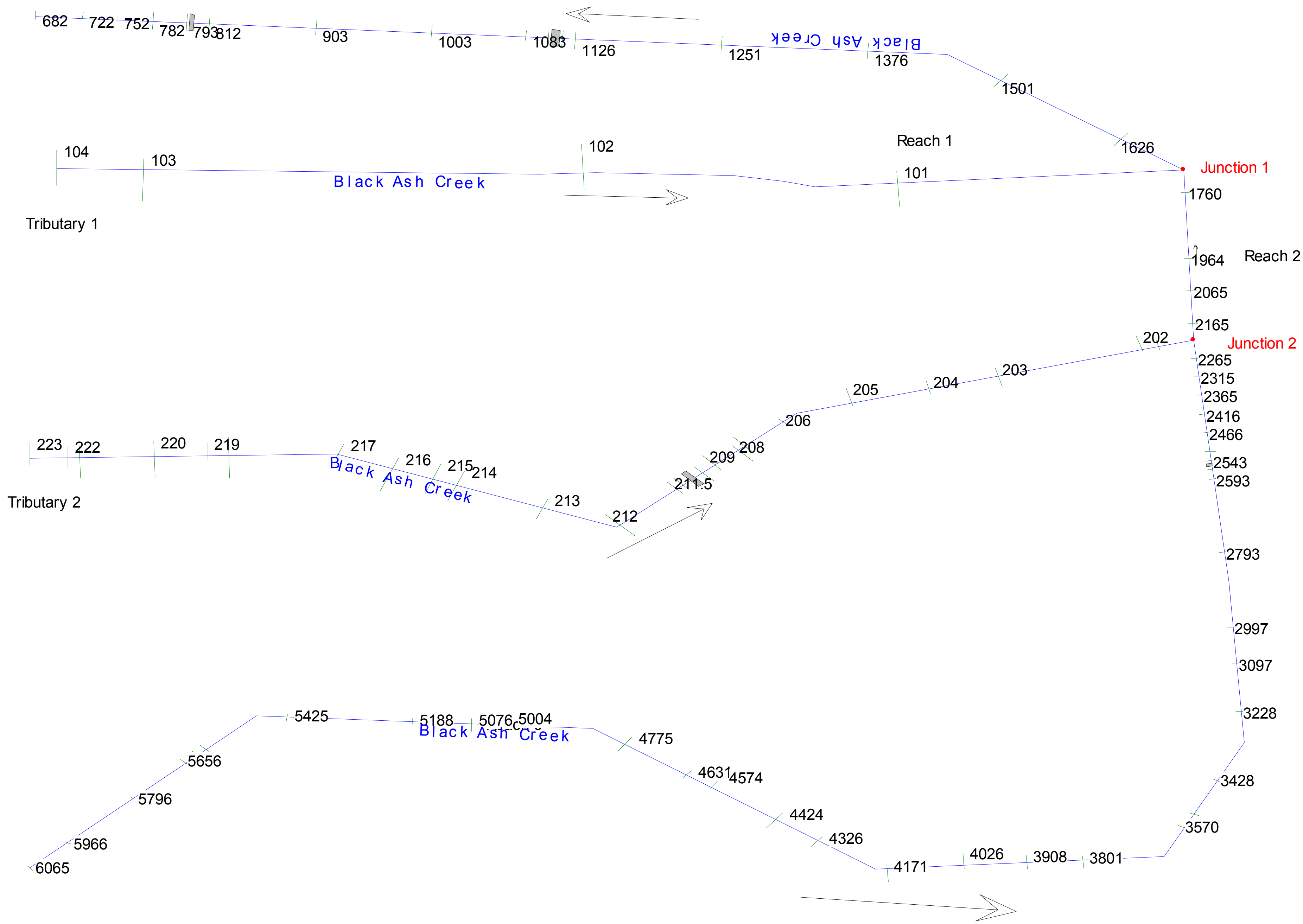
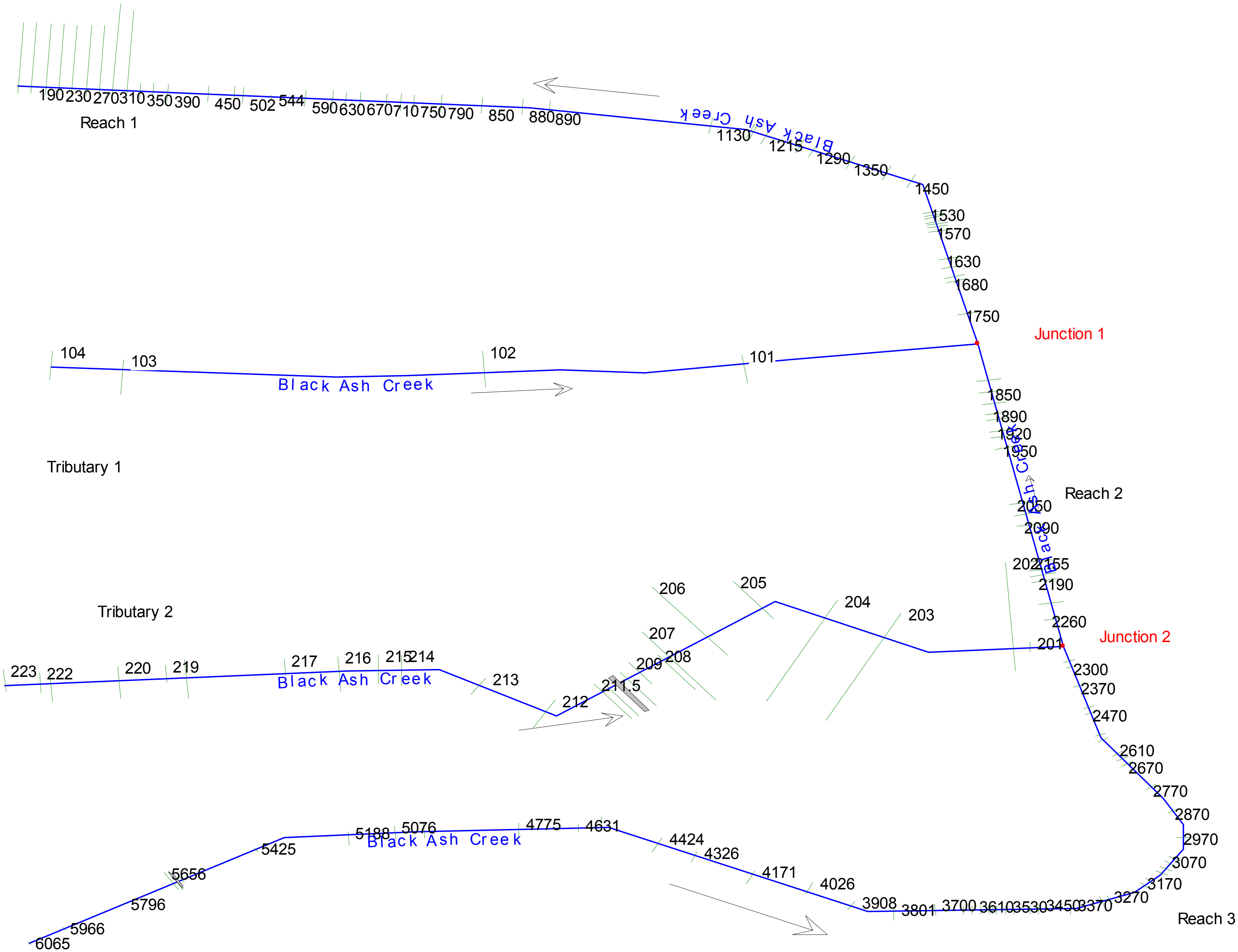


**TABLE 1: HEC-RAS Flood Water Levels (Regional Storm & 100 Year) Using Pre-development Hydrology ISWMS Results with Existing Channel Conditions (i.e. November 1999 Field Survey by the NVCA and Greenland International)**

| Regional Storm Flood (With Spill from Main Branch) | | | | | 100 Year Flood (No Spill from Main Branch) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| HEC-RAS Model Reach | River Station | Peak Flow (m3/s) | Min Ch El (m) | W.S. Elev (m) | HEC-RAS Model Reach | River Station | Peak Flow (m3/s) | Min Ch El (m) | W.S. Elev (m) |
| Reach 1 (Main Branch) | 682 | 76.08 | 177.48 | 179.29 | Reach 1 (Main Branch) | 682 | 33.7 | 177.48 | 178.62 |
| Reach 1 (Main Branch) | 722 | 76.08 | 177.61 | 179.46 | Reach 1 (Main Branch) | 722 | 33.7 | 177.61 | 179.10 |
| Reach 1 (Main Branch) | 752 | 76.08 | 177.81 | 179.49 | Reach 1 (Main Branch) | 752 | 33.7 | 177.81 | 179.19 |
| Reach 1 (Main Branch) | 782 | 76.08 | 177.79 | 179.54 | Reach 1 (Main Branch) | 782 | 33.7 | 177.79 | 179.52 |
| Reach 1 (Main Branch) | 793 | 76.08 | 177.81 | 179.83 | Reach 1 (Main Branch) | 793 | 33.7 | 177.81 | 179.43 |
| Reach 1 (Main Branch) | 798.5 | Georgian Trail Culvert | | | Reach 1 (Main Branch) | 798.5 | Georgian Trail Culvert | | |
| Reach 1 (Main Branch) | 799 | 76.08 | 177.81 | 179.86 | Reach 1 (Main Branch) | 799 | 33.7 | 177.81 | 179.46 |
| Reach 1 (Main Branch) | 812 | 76.08 | 177.85 | 179.77 | Reach 1 (Main Branch) | 812 | 33.7 | 177.85 | 179.64 |
| Reach 1 (Main Branch) | 903 | 76.08 | 178.16 | 180.36 | Reach 1 (Main Branch) | 903 | 33.7 | 178.16 | 179.85 |
| Reach 1 (Main Branch) | 1003 | 76.08 | 178.55 | 180.9 | Reach 1 (Main Branch) | 1003 | 33.7 | 178.55 | 180.28 |
| Reach 1 (Main Branch) | 1083 | 76.08 | 178.88 | 180.96 | Reach 1 (Main Branch) | 1083 | 33.7 | 178.88 | 180.71 |
| Reach 1 (Main Branch) | 1103 | 76.08 | 178.88 | 180.77 | Reach 1 (Main Branch) | 1103 | 33.7 | 178.88 | 180.68 |
| Reach 1 (Main Branch) | 1114.5 | Old Mountain Road Bridge | | | Reach 1 (Main Branch) | 1114.5 | Old Mountain Road Bridge | | |
| Reach 1 (Main Branch) | 1115 | 76.08 | 179 | 181 | Reach 1 (Main Branch) | 1115 | 33.7 | 179.00 | 180.69 |
| Reach 1 (Main Branch) | 1126 | 76.08 | 179.12 | 181.45 | Reach 1 (Main Branch) | 1126 | 33.7 | 179.12 | 180.72 |
| Reach 1 (Main Branch) | 1251 | 76.08 | 179.72 | 181.7 | Reach 1 (Main Branch) | 1251 | 33.7 | 179.72 | 181.14 |
| Reach 1 (Main Branch) | 1376 | 76.08 | 180.4 | 182.54 | Reach 1 (Main Branch) | 1376 | 33.7 | 180.40 | 182.15 |
| Reach 1 (Main Branch) | 1501 | 76.08 | 181.5 | 183.53 | Reach 1 (Main Branch) | 1501 | 33.7 | 181.50 | 182.77 |
| Reach 1 (Main Branch) | 1626 | 76.08 | 182.61 | 184.44 | Reach 1 (Main Branch) | 1626 | 33.7 | 182.61 | 183.94 |
| Reach 2 (Main Branch) | 1760 | 67.38 | 183.15 | 185.5 | Reach 2 (Main Branch) | 1760 | 31.1 | 183.15 | 184.72 |
| Reach 2 (Main Branch) | 1964 | 67.38 | 184.72 | 186.7 | Reach 2 (Main Branch) | 1964 | 31.1 | 184.72 | 186.04 |
| Reach 2 (Main Branch) | 2065 | 67.38 | 185.63 | 187.61 | Reach 2 (Main Branch) | 2065 | 31.1 | 185.63 | 187.00 |
| Reach 2 (Main Branch) | 2165 | 67.38 | 186.55 | 188.53 | Reach 2 (Main Branch) | 2165 | 31.1 | 186.55 | 187.87 |
| Reach 3 (South Branch) | 2265 | 44.78 | 187.35 | 189.55 | Reach 3 (South Branch) | 2265 | 25.7 | 187.35 | 188.79 |
| Reach 3 (South Branch) | 2315 | 44.78 | 187.45 | 189.68 | Reach 3 (South Branch) | 2315 | 25.7 | 187.45 | 189.05 |
| Reach 3 (South Branch) | 2365 | 44.78 | 187.55 | 189.81 | Reach 3 (South Branch) | 2365 | 25.7 | 187.55 | 189.21 |
| Reach 3 (South Branch) | 2416 | 44.78 | 187.65 | 189.93 | Reach 3 (South Branch) | 2416 | 25.7 | 187.65 | 189.35 |
| Reach 3 (South Branch) | 2466 | 44.78 | 187.75 | 190.04 | Reach 3 (South Branch) | 2466 | 25.7 | 187.75 | 189.47 |
| Reach 3 (South Branch) | 2518 | 44.78 | 187.85 | 190.16 | Reach 3 (South Branch) | 2518 | 25.7 | 187.85 | 189.59 |
| Reach 3 (South Branch) | 2543 | 44.78 | 187.9 | 190.95 | Reach 3 (South Branch) | 2543 | 25.7 | 187.90 | 189.47 |
| Reach 3 (South Branch) | 2555 | Sixth Street SPCSPA Culvert | | | Reach 3 (South Branch) | 2555 | Sixth Street SPCSPA Culvert | | |
| Reach 3 (South Branch) | 2568 | 44.78 | 187.95 | 191.64 | Reach 3 (South Branch) | 2568 | 25.7 | 187.95 | 190.89 |
| Reach 3 (South Branch) | 2593 | 44.78 | 188 | 191.64 | Reach 3 (South Branch) | 2593 | 25.7 | 188.00 | 191.15 |
| Reach 3 (South Branch) | 2793 | 69.34 | 188.42 | 191.71 | Reach 3 (South Branch) | 2793 | 25.7 | 188.42 | 191.19 |
| Reach 3 (South Branch) | 2997 | 70.23 | 188.83 | 191.76 | Reach 3 (South Branch) | 2997 | 25.7 | 188.83 | 191.27 |
| Reach 3 (South Branch) | 3097 | 70.58 | 189.04 | 191.96 | Reach 3 (South Branch) | 3097 | 25.7 | 189.04 | 191.32 |
| Reach 3 (South Branch) | 3228 | 70.63 | 189.31 | 192.22 | Reach 3 (South Branch) | 3228 | 25.7 | 189.31 | 191.42 |
| Reach 3 (South Branch) | 3428 | 71.7 | 189.73 | 192.64 | Reach 3 (South Branch) | 3428 | 25.7 | 189.73 | 191.64 |
| Reach 3 (South Branch) | 3528 | 72 | 189.95 | 192.85 | Reach 3 (South Branch) | 3528 | 25.7 | 189.95 | 191.79 |
| Reach 3 (South Branch) | 3570 | 47.2 | 190.16 | 193 | Reach 3 (South Branch) | 3570 | 21.3 | 190.16 | 191.84 |
| Reach 3 (South Branch) | 3801 | 47.2 | 192.67 | 194.32 | Reach 3 (South Branch) | 3801 | 21.3 | 192.67 | 193.82 |
| Reach 3 (South Branch) | 3908 | 47.2 | 193.25 | 195.44 | Reach 3 (South Branch) | 3908 | 21.3 | 193.25 | 195.02 |
| Reach 3 (South Branch) | 4026 | 47.2 | 194.27 | 196.02 | Reach 3 (South Branch) | 4026 | 21.3 | 194.27 | 195.71 |
| Reach 3 (South Branch) | 4171 | 47.2 | 195.89 | 197.37 | Reach 3 (South Branch) | 4171 | 21.3 | 195.89 | 197.00 |
| Reach 3 (South Branch) | 4326 | 47.2 | 197.05 | 198.81 | Reach 3 (South Branch) | 4326 | 21.3 | 197.05 | 198.35 |
| Reach 3 (South Branch) | 4424 | 47.2 | 197.96 | 199.55 | Reach 3 (South Branch) | 4424 | 21.3 | 197.96 | 199.04 |
| Reach 3 (South Branch) | 4574 | 47.2 | 199.04 | 200.55 | Reach 3 (South Branch) | 4574 | 21.3 | 199.04 | 200.08 |
| Reach 3 (South Branch) | 4631 | 47.2 | 200.1 | 202.35 | Reach 3 (South Branch) | 4631 | 21.3 | 200.10 | 201.80 |
| Reach 3 (South Branch) | 4775 | 47.2 | 201.17 | 203.57 | Reach 3 (South Branch) | 4775 | 21.3 | 201.17 | 202.94 |
| Reach 3 (South Branch) | 5004 | 47.2 | 202.38 | 204.3 | Reach 3 (South Branch) | 5004 | 21.3 | 202.38 | 203.79 |
| Reach 3 (South Branch) | 5076 | 47.2 | 202.3 | 204.88 | Reach 3 (South Branch) | 5076 | 21.3 | 202.30 | 204.31 |
| Reach 3 (South Branch) | 5188 | 47.2 | 202.9 | 204.84 | Reach 3 (South Branch) | 5188 | 21.3 | 202.90 | 204.46 |
| Reach 3 (South Branch) | 5425 | 47.2 | 205.2 | 206.96 | Reach 3 (South Branch) | 5425 | 21.3 | 205.20 | 206.32 |
| Reach 3 (South Branch) | 5614 | 47.2 | 208.6 | 210.67 | Reach 3 (South Branch) | 5614 | 21.3 | 208.60 | 209.96 |
| Reach 3 (South Branch) | 5634 | 47.2 | 209.28 | 211.72 | Reach 3 (South Branch) | 5634 | 21.3 | 209.28 | 211.72 |
| Reach 3 (South Branch) | 5637 | Tenth Line CSP Culvert | | | Reach 3 (South Branch) | 5637 | Tenth Line CSP Culvert | | |
| Reach 3 (South Branch) | 5648 | 47.2 | 209.75 | 213.03 | Reach 3 (South Branch) | 5648 | 21.3 | 209.75 | 212.82 |
| Reach 3 (South Branch) | 5656 | 47.2 | 210.02 | 213.02 | Reach 3 (South Branch) | 5656 | 21.3 | 210.02 | 212.82 |
| Reach 3 (South Branch) | 5796 | 47.2 | 212.9 | 215.03 | Reach 3 (South Branch) | 5796 | 21.3 | 212.90 | 214.49 |
| Reach 3 (South Branch) | 5966 | 47.2 | 214.9 | 216.69 | Reach 3 (South Branch) | 5966 | 21.3 | 214.90 | 216.28 |
| Reach 3 (South Branch) | 6065 | 47.2 | 216.7 | 218.14 | Reach 3 (South Branch) | 6065 | 21.3 | 216.70 | 217.79 |
| Tributary 1 (West Tributary) | 101 | 9.8 | 188.04 | 188.96 | Tributary 1 (West Tributary) | 101 | 2.9 | 188.04 | 188.71 |
| Tributary 1 (West Tributary) | 102 | 9.8 | 189.81 | 190.53 | Tributary 1 (West Tributary) | 102 | 2.9 | 189.81 | 190.36 |
| Tributary 1 (West Tributary) | 103 | 9.8 | 191.27 | 192.39 | Tributary 1 (West Tributary) | 103 | 2.9 | 191.27 | 192.02 |
| Tributary 1 (West Tributary) | 104 | 9.8 | 191.57 | 192.83 | Tributary 1 (West Tributary) | 104 | 2.9 | 191.57 | 192.37 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Tributary 2 (North Branch) | 201 | 30 | 187.75 | 189.55 | Tributary 2 (North Branch) | 201 | 9.5 | 187.75 | 188.89 |
| Tributary 2 (North Branch) | 202 | 30 | 187.79 | 189.74 | Tributary 2 (North Branch) | 202 | 9.5 | 187.79 | 188.96 |
| Tributary 2 (North Branch) | 203 | 30 | 188.84 | 190.62 | Tributary 2 (North Branch) | 203 | 9.5 | 188.84 | 190.27 |
| Tributary 2 (North Branch) | 204 | 30 | 189.37 | 190.71 | Tributary 2 (North Branch) | 204 | 9.5 | 189.37 | 190.54 |
| Tributary 2 (North Branch) | 205 | 30 | 190.06 | 191.03 | Tributary 2 (North Branch) | 205 | 9.5 | 190.06 | 190.72 |
| Tributary 2 (North Branch) | 206 | 30 | 189.94 | 191.45 | Tributary 2 (North Branch) | 206 | 9.5 | 189.94 | 191.30 |
| Tributary 2 (North Branch) | 207 | 30 | 190.44 | 192.04 | Tributary 2 (North Branch) | 207 | 9.5 | 190.44 | 191.33 |
| Tributary 2 (North Branch) | 208 | 30 | 190.57 | 191.82 | Tributary 2 (North Branch) | 208 | 9.5 | 190.57 | 191.63 |
| Tributary 2 (North Branch) | 209 | 30 | 190.52 | 192.3 | Tributary 2 (North Branch) | 209 | 9.5 | 190.52 | 191.66 |
| Tributary 2 (North Branch) | 210 | 30 | 190.61 | 192.53 | Tributary 2 (North Branch) | 210 | 9.5 | 190.61 | 192.12 |
| Tributary 2 (North Branch) | 210.2 | Sixth Street CSP Culvert | | | Tributary 2 (North Branch) | 210.2 | Sixth Street CSP Culvert | | |
| Tributary 2 (North Branch) | 211 | 30 | 190.94 | 193.25 | Tributary 2 (North Branch) | 211 | 9.5 | 190.94 | 192.95 |
| Tributary 2 (North Branch) | 211.5 | 30 | 191 | 193.27 | Tributary 2 (North Branch) | 211.5 | 9.5 | 191.00 | 194.23 |
| Tributary 2 (North Branch) | 212 | 30 | 191.54 | 193.25 | Tributary 2 (North Branch) | 212 | 9.5 | 191.54 | 194.23 |
| Tributary 2 (North Branch) | 213 | 30 | 192.61 | 194.2 | Tributary 2 (North Branch) | 213 | 9.5 | 192.61 | 194.20 |
| Tributary 2 (North Branch) | 214 | 30 | 194.57 | 195.64 | Tributary 2 (North Branch) | 214 | 9.5 | 194.57 | 195.19 |
| Tributary 2 (North Branch) | 215 | 30 | 194.93 | 196.85 | Tributary 2 (North Branch) | 215 | 9.5 | 194.93 | 196.07 |
| Tributary 2 (North Branch) | 216 | 30 | 195.05 | 197.32 | Tributary 2 (North Branch) | 216 | 9.5 | 195.05 | 196.55 |
| Tributary 2 (North Branch) | 217 | 30 | 195.47 | 197.47 | Tributary 2 (North Branch) | 217 | 9.5 | 195.47 | 196.74 |
| Tributary 2 (North Branch) | 218 | 30 | 197.28 | 199.02 | Tributary 2 (North Branch) | 218 | 9.5 | 197.28 | 198.29 |
| Tributary 2 (North Branch) | 219 | 30 | 197.41 | 199.51 | Tributary 2 (North Branch) | 219 | 9.5 | 197.41 | 198.65 |
| Tributary 2 (North Branch) | 220 | 30 | 197.69 | 199.59 | Tributary 2 (North Branch) | 220 | 9.5 | 197.69 | 198.99 |
| Tributary 2 (North Branch) | 221 | 30 | 198.4 | 200.38 | Tributary 2 (North Branch) | 221 | 9.5 | 198.40 | 199.67 |
| Tributary 2 (North Branch) | 222 | 30 | 198.81 | 200.74 | Tributary 2 (North Branch) | 222 | 9.5 | 198.81 | 200.01 |
| Tributary 2 (North Branch) | 223 | 30 | 198.86 | 200.86 | Tributary 2 (North Branch) | 223 | 9.5 | 198.86 | 200.14 |




HEC-RAS Model Schematic for Future “Black Ash Creek Flood Control Project” Conditions within the Town of Collingwood

**TABLE 2: HEC-RAS Flood Water Levels (Regional Storm & 100 Year) Using Pre-development Hydrology ISWMS Results with Proposed Flood Control Design Conditions by Ainley & Associates Limited**

| Regional Storm Flood (No Spill from Channelization) | | | | | 100 Year Flood (No Spill from Channelization) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| HEC-RAS Model Reach | River Station | Peak Flow (m3/s) | Min Ch El (m) | W.S. Elev (m) | HEC-RAS Model Reach | River Station | Peak Flow (m3/s) | Min Ch El (m) | W.S. Elev (m) |
| Reach 1 (Main Branch) | 170 | 103.3 | 175.00 | 176.67 | Reach 1 (Main Branch) | 170 | 33.7 | 175 | 176.67 |
| Reach 1 (Main Branch) | 190 | 103.3 | 174.99 | 177.23 | Reach 1 (Main Branch) | 190 | 33.7 | 174.99 | 176.98 |
| Reach 1 (Main Branch) | 210 | 103.3 | 175.01 | 177.28 | Reach 1 (Main Branch) | 210 | 33.7 | 175.01 | 177.49 |
| Reach 1 (Main Branch) | 230 | 103.3 | 175.01 | 177.29 | Reach 1 (Main Branch) | 230 | 33.7 | 175.01 | 177.49 |
| Reach 1 (Main Branch) | 250 | 103.3 | 175.02 | 177.67 | Reach 1 (Main Branch) | 250 | 33.7 | 175.02 | 177.39 |
| Reach 1 (Main Branch) | 270 | 103.3 | 175.02 | 177.71 | Reach 1 (Main Branch) | 270 | 33.7 | 175.02 | 177.55 |
| Reach 1 (Main Branch) | 290 | 103.3 | 175.02 | 177.78 | Reach 1 (Main Branch) | 290 | 33.7 | 175.02 | 177.57 |
| Reach 1 (Main Branch) | 310 | 103.3 | 175.03 | 177.82 | Reach 1 (Main Branch) | 310 | 33.7 | 175.03 | 177.58 |
| Reach 1 (Main Branch) | 330 | 103.3 | 175.03 | 177.87 | Reach 1 (Main Branch) | 330 | 33.7 | 175.03 | 177.59 |
| Reach 1 (Main Branch) | 350 | 103.3 | 175.04 | 177.85 | Reach 1 (Main Branch) | 350 | 33.7 | 175.04 | 177.62 |
| Reach 1 (Main Branch) | 370 | 103.3 | 175.04 | 177.88 | Reach 1 (Main Branch) | 370 | 33.7 | 175.04 | 177.62 |
| Reach 1 (Main Branch) | 390 | 103.3 | 175.05 | 177.91 | Reach 1 (Main Branch) | 390 | 33.7 | 175.05 | 177.63 |
| Reach 1 (Main Branch) | 450 | 103.3 | 175.06 | 177.98 | Reach 1 (Main Branch) | 450 | 33.7 | 175.06 | 177.64 |
| Reach 1 (Main Branch) | 490 | 103.3 | 175.07 | 178.03 | Reach 1 (Main Branch) | 490 | 33.7 | 175.07 | 177.64 |
| Reach 1 (Main Branch) | 502 | 103.3 | 175.07 | 178.04 | Reach 1 (Main Branch) | 502 | 33.7 | 175.07 | 177.65 |
| Reach 1 (Main Branch) | 544 | Highway 26 Bridge | | | Reach 1 (Main Branch) | 544 | Highway 26 Bridge | | |
| Reach 1 (Main Branch) | 574 | 103.3 | 175.36 | 178.02 | Reach 1 (Main Branch) | 574 | 33.7 | 175.36 | 177.64 |
| Reach 1 (Main Branch) | 590 | 103.3 | 175.43 | 178.04 | Reach 1 (Main Branch) | 590 | 33.7 | 175.43 | 177.64 |
| Reach 1 (Main Branch) | 630 | 103.3 | 175.51 | 178.10 | Reach 1 (Main Branch) | 630 | 33.7 | 175.51 | 177.65 |
| Reach 1 (Main Branch) | 650 | 103.3 | 175.55 | 178.13 | Reach 1 (Main Branch) | 650 | 33.7 | 175.55 | 177.66 |
| Reach 1 (Main Branch) | 670 | 103.3 | 175.65 | 178.18 | Reach 1 (Main Branch) | 670 | 33.7 | 175.65 | 177.67 |
| Reach 1 (Main Branch) | 710 | 103.3 | 175.84 | 178.22 | Reach 1 (Main Branch) | 710 | 33.7 | 175.84 | 177.68 |
| Reach 1 (Main Branch) | 730 | 103.3 | 175.94 | 178.24 | Reach 1 (Main Branch) | 730 | 33.7 | 175.94 | 177.68 |
| Reach 1 (Main Branch) | 750 | 103.3 | 176.03 | 178.27 | Reach 1 (Main Branch) | 750 | 33.7 | 176.03 | 177.69 |
| Reach 1 (Main Branch) | 790 | Old Mountain Road Bridge | | | Reach 1 (Main Branch) | 790 | Old Mountain Road Bridge | | |
| Reach 1 (Main Branch) | 850 | 103.3 | 176.51 | 178.46 | Reach 1 (Main Branch) | 850 | 33.7 | 176.51 | 177.76 |
| Reach 1 (Main Branch) | 880 | 103.3 | 176.65 | 178.65 | Reach 1 (Main Branch) | 880 | 33.7 | 176.65 | 177.85 |
| Reach 1 (Main Branch) | 890 | 103.3 | 176.70 | 178.78 | Reach 1 (Main Branch) | 890 | 33.7 | 176.7 | 177.92 |
| Reach 1 (Main Branch) | 1130 | 103.3 | 177.92 | 179.52 | Reach 1 (Main Branch) | 1130 | 33.7 | 177.92 | 178.61 |
| Reach 1 (Main Branch) | 1190 | 103.3 | 178.36 | 179.88 | Reach 1 (Main Branch) | 1190 | 33.7 | 178.36 | 179.19 |
| Reach 1 (Main Branch) | 1195 | 103.3 | 178.39 | 179.92 | Reach 1 (Main Branch) | 1195 | 33.7 | 178.39 | 179.22 |
| Reach 1 (Main Branch) | 1215 | 103.3 | 178.52 | 180.09 | Reach 1 (Main Branch) | 1215 | 33.7 | 178.52 | 179.34 |
| Reach 1 (Main Branch) | 1241 | Sixth Street SPCSPA Culvert | | | Reach 1 (Main Branch) | 1241 | Sixth Street SPCSPA Culvert | | |
| Reach 1 (Main Branch) | 1253 | 103.3 | 178.60 | 180.53 | Reach 1 (Main Branch) | 1253 | 33.7 | 178.6 | 179.51 |
| Reach 1 (Main Branch) | 1270 | 103.3 | 178.64 | 180.62 | Reach 1 (Main Branch) | 1270 | 33.7 | 178.64 | 179.76 |
| Reach 1 (Main Branch) | 1290 | 103.3 | 178.79 | 181.10 | Reach 1 (Main Branch) | 1290 | 33.7 | 178.79 | 179.93 |
| Reach 1 (Main Branch) | 1350 | 103.3 | 179.25 | 181.69 | Reach 1 (Main Branch) | 1350 | 33.7 | 179.25 | 180.38 |
| Reach 1 (Main Branch) | 1410 | 103.3 | 179.71 | 181.84 | Reach 1 (Main Branch) | 1410 | 33.7 | 179.71 | 180.73 |
| Reach 1 (Main Branch) | 1450 | 103.3 | 180.01 | 182.04 | Reach 1 (Main Branch) | 1450 | 33.7 | 180.01 | 181.05 |
| Reach 1 (Main Branch) | 1530 | 103.3 | 180.62 | 182.57 | Reach 1 (Main Branch) | 1530 | 33.7 | 180.62 | 181.65 |
| Reach 1 (Main Branch) | 1535 | 103.3 | 180.65 | 182.61 | Reach 1 (Main Branch) | 1535 | 33.7 | 180.65 | 181.69 |
| Reach 1 (Main Branch) | 1540 | 103.3 | 180.69 | 182.65 | Reach 1 (Main Branch) | 1540 | 33.7 | 180.69 | 181.73 |
| Reach 1 (Main Branch) | 1550 | 103.3 | 180.77 | 182.73 | Reach 1 (Main Branch) | 1550 | 33.7 | 180.77 | 181.8 |
| Reach 1 (Main Branch) | 1555 | 103.3 | 180.81 | 182.77 | Reach 1 (Main Branch) | 1555 | 33.7 | 180.81 | 181.84 |
| Reach 1 (Main Branch) | 1560 | 103.3 | 180.84 | 182.80 | Reach 1 (Main Branch) | 1560 | 33.7 | 180.84 | 181.88 |
| Reach 1 (Main Branch) | 1570 | 103.3 | 180.92 | 182.88 | Reach 1 (Main Branch) | 1570 | 33.7 | 180.92 | 181.96 |
| Reach 1 (Main Branch) | 1630 | 103.3 | 181.38 | 183.34 | Reach 1 (Main Branch) | 1630 | 33.7 | 181.38 | 182.41 |
| Reach 1 (Main Branch) | 1650 | 103.3 | 181.53 | 183.49 | Reach 1 (Main Branch) | 1650 | 33.7 | 181.53 | 182.56 |
| Reach 1 (Main Branch) | 1670 | 103.3 | 181.68 | 183.64 | Reach 1 (Main Branch) | 1670 | 33.7 | 181.68 | 182.71 |
| Reach 1 (Main Branch) | 1680 | 103.3 | 181.76 | 183.72 | Reach 1 (Main Branch) | 1680 | 33.7 | 181.76 | 182.79 |
| Reach 1 (Main Branch) | 1750 | 103.3 | 182.29 | 184.25 | Reach 1 (Main Branch) | 1750 | 33.7 | 182.29 | 183.32 |
| | | | | | | | | | |
| Reach 2 (Main Branch) | 1830 | 94.6 | 182.89 | 185.25 | Reach 2 (Main Branch) | 1830 | 31.1 | 182.89 | 184.13 |
| Reach 2 (Main Branch) | 1850 | 94.6 | 183.03 | 185.30 | Reach 2 (Main Branch) | 1850 | 31.1 | 183.03 | 184.19 |
| Reach 2 (Main Branch) | 1870 | 94.6 | 183.15 | 185.36 | Reach 2 (Main Branch) | 1870 | 31.1 | 183.15 | 184.27 |
| Reach 2 (Main Branch) | 1890 | 94.6 | 183.29 | 185.42 | Reach 2 (Main Branch) | 1890 | 31.1 | 183.29 | 184.36 |
| Reach 2 (Main Branch) | 1900 | 94.6 | 183.35 | 185.46 | Reach 2 (Main Branch) | 1900 | 31.1 | 183.35 | 184.42 |
| Reach 2 (Main Branch) | 1920 | 94.6 | 183.48 | 185.54 | Reach 2 (Main Branch) | 1920 | 31.1 | 183.48 | 184.53 |
| Reach 2 (Main Branch) | 1930 | 94.6 | 183.54 | 185.59 | Reach 2 (Main Branch) | 1930 | 31.1 | 183.54 | 184.59 |
| Reach 2 (Main Branch) | 1950 | 94.6 | 183.67 | 185.69 | Reach 2 (Main Branch) | 1950 | 31.1 | 183.67 | 184.72 |
| Reach 2 (Main Branch) | 2050 | 94.6 | 184.25 | 186.27 | Reach 2 (Main Branch) | 2050 | 31.1 | 184.25 | 185.33 |
| Reach 2 (Main Branch) | 2070 | 94.6 | 184.36 | 186.39 | Reach 2 (Main Branch) | 2070 | 31.1 | 184.36 | 185.44 |
| Reach 2 (Main Branch) | 2090 | 94.6 | 184.46 | 186.51 | Reach 2 (Main Branch) | 2090 | 31.1 | 184.46 | 185.55 |
| Reach 2 (Main Branch) | 2155 | 94.6 | 184.78 | 186.89 | Reach 2 (Main Branch) | 2155 | 31.1 | 184.78 | 185.9 |
| Reach 2 (Main Branch) | 2170 | 94.6 | 184.85 | 186.96 | Reach 2 (Main Branch) | 2170 | 31.1 | 184.85 | 185.98 |
| Reach 2 (Main Branch) | 2180 | 94.6 | 184.90 | 187.01 | Reach 2 (Main Branch) | 2180 | 31.1 | 184.9 | 186.03 |
| Reach 2 (Main Branch) | 2190 | 94.6 | 184.94 | 187.07 | Reach 2 (Main Branch) | 2190 | 31.1 | 184.94 | 186.08 |
| Reach 2 (Main Branch) | 2230 | 94.6 | 185.11 | 187.27 | Reach 2 (Main Branch) | 2230 | 31.1 | 185.11 | 186.27 |
| Reach 2 (Main Branch) | 2260 | 94.6 | 185.23 | 187.46 | Reach 2 (Main Branch) | 2260 | 31.1 | 185.23 | 186.46 |
| | | | | | | | | | |
| Reach 3 (South Branch) | 2280 | 72 | 185.31 | 188.38 | Reach 3 (South Branch) | 2280 | 25.7 | 185.31 | 187.15 |
| Reach 3 (South Branch) | 2300 | 72 | 185.38 | 188.40 | Reach 3 (South Branch) | 2300 | 25.7 | 185.38 | 187.17 |
| Reach 3 (South Branch) | 2370 | 72 | 185.62 | 188.47 | Reach 3 (South Branch) | 2370 | 25.7 | 185.62 | 187.27 |
| Reach 3 (South Branch) | 2450 | 72 | 185.85 | 188.59 | Reach 3 (South Branch) | 2450 | 25.7 | 185.85 | 187.43 |
| Reach 3 (South Branch) | 2470 | 72 | 185.89 | 188.63 | Reach 3 (South Branch) | 2470 | 25.7 | 185.89 | 187.48 |
| Reach 3 (South Branch) | 2550 | 72 | 186.06 | 188.78 | Reach 3 (South Branch) | 2550 | 25.7 | 186.06 | 187.67 |
| Reach 3 (South Branch) | 2570 | 72 | 186.10 | 188.82 | Reach 3 (South Branch) | 2570 | 25.7 | 186.1 | 187.71 |
| Reach 3 (South Branch) | 2593 | 72 | 186.12 | 188.65 | Reach 3 (South Branch) | 2593 | 25.7 | 186.12 | 187.73 |
| Reach 3 (South Branch) | 2610 | 72 | 186.13 | 188.89 | Reach 3 (South Branch) | 2610 | 25.7 | 186.13 | 187.81 |
| Reach 3 (South Branch) | 2630 | 72 | 186.15 | 189.58 | Reach 3 (South Branch) | 2630 | 25.7 | 186.15 | 187.97 |
| Reach 3 (South Branch) | 2650 | 72 | 186.17 | 189.59 | Reach 3 (South Branch) | 2650 | 25.7 | 186.17 | 188.01 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Reach 3 (South Branch) | 2670 | 72 | 186.18 | 189.61 | Reach 3 (South Branch) | 2670 | 25.7 | 186.18 | 188.04 |
| Reach 3 (South Branch) | 2770 | 72 | 186.31 | 189.68 | Reach 3 (South Branch) | 2770 | 25.7 | 186.31 | 188.19 |
| Reach 3 (South Branch) | 2870 | 72 | 186.63 | 189.75 | Reach 3 (South Branch) | 2870 | 25.7 | 186.63 | 188.34 |
| Reach 3 (South Branch) | 2970 | 72 | 186.96 | 189.85 | Reach 3 (South Branch) | 2970 | 25.7 | 186.96 | 188.57 |
| Reach 3 (South Branch) | 3050 | 72 | 187.21 | 189.97 | Reach 3 (South Branch) | 3050 | 25.7 | 187.21 | 188.79 |
| Reach 3 (South Branch) | 3070 | 72 | 187.28 | 190.01 | Reach 3 (South Branch) | 3070 | 25.7 | 187.28 | 188.85 |
| Reach 3 (South Branch) | 3090 | 72 | 187.34 | 190.04 | Reach 3 (South Branch) | 3090 | 25.7 | 187.34 | 188.92 |
| Reach 3 (South Branch) | 3110 | 72 | 187.41 | 190.08 | Reach 3 (South Branch) | 3110 | 25.7 | 187.41 | 188.98 |
| Reach 3 (South Branch) | 3150 | 72 | 187.53 | 190.17 | Reach 3 (South Branch) | 3150 | 25.7 | 187.53 | 189.1 |
| Reach 3 (South Branch) | 3170 | 72 | 187.60 | 190.22 | Reach 3 (South Branch) | 3170 | 25.7 | 187.6 | 189.16 |
| Reach 3 (South Branch) | 3270 | 72 | 187.92 | 190.47 | Reach 3 (South Branch) | 3270 | 25.7 | 187.92 | 189.48 |
| Reach 3 (South Branch) | 3290 | 72 | 187.99 | 190.53 | Reach 3 (South Branch) | 3290 | 25.7 | 187.99 | 189.55 |
| Reach 3 (South Branch) | 3370 | 53.2 | 188.26 | 190.87 | Reach 3 (South Branch) | 3370 | 21.3 | 188.26 | 189.83 |
| Reach 3 (South Branch) | 3450 | 53.2 | 188.57 | 190.97 | Reach 3 (South Branch) | 3450 | 21.3 | 188.57 | 190.01 |
| Reach 3 (South Branch) | 3470 | 53.2 | 188.65 | 191.00 | Reach 3 (South Branch) | 3470 | 21.3 | 188.65 | 190.07 |
| Reach 3 (South Branch) | 3510 | 53.2 | 188.83 | 191.08 | Reach 3 (South Branch) | 3510 | 21.3 | 188.83 | 190.2 |
| Reach 3 (South Branch) | 3530 | 53.2 | 188.92 | 191.13 | Reach 3 (South Branch) | 3530 | 21.3 | 188.92 | 190.27 |
| Reach 3 (South Branch) | 3550 | 53.2 | 189.01 | 191.18 | Reach 3 (South Branch) | 3550 | 21.3 | 189.01 | 190.35 |
| Reach 3 (South Branch) | 3560 | 53.2 | 189.06 | 191.20 | Reach 3 (South Branch) | 3560 | 21.3 | 189.06 | 190.39 |
| Reach 3 (South Branch) | 3570 | 53.2 | 189.11 | 191.23 | Reach 3 (South Branch) | 3570 | 21.3 | 189.11 | 190.43 |
| Reach 3 (South Branch) | 3590 | 53.2 | 189.20 | 191.29 | Reach 3 (South Branch) | 3590 | 21.3 | 189.2 | 190.52 |
| Reach 3 (South Branch) | 3610 | 53.2 | 189.31 | 191.36 | Reach 3 (South Branch) | 3610 | 21.3 | 189.31 | 190.61 |
| Reach 3 (South Branch) | 3630 | 53.2 | 189.40 | 191.44 | Reach 3 (South Branch) | 3630 | 21.3 | 189.4 | 190.7 |
| Reach 3 (South Branch) | 3700 | 53.2 | 191.60 | 192.74 | Reach 3 (South Branch) | 3700 | 21.3 | 191.6 | 192.4 |
| Reach 3 (South Branch) | 3801 | 53.2 | 192.67 | 194.46 | Reach 3 (South Branch) | 3801 | 21.3 | 192.67 | 193.91 |
| Reach 3 (South Branch) | 3908 | 53.2 | 193.25 | 195.49 | Reach 3 (South Branch) | 3908 | 21.3 | 193.25 | 195.02 |
| Reach 3 (South Branch) | 4026 | 53.2 | 194.27 | 196.09 | Reach 3 (South Branch) | 4026 | 21.3 | 194.27 | 195.71 |
| Reach 3 (South Branch) | 4171 | 53.2 | 195.89 | 197.44 | Reach 3 (South Branch) | 4171 | 21.3 | 195.89 | 197 |
| Reach 3 (South Branch) | 4326 | 53.2 | 197.05 | 198.89 | Reach 3 (South Branch) | 4326 | 21.3 | 197.05 | 198.35 |
| Reach 3 (South Branch) | 4424 | 53.2 | 197.96 | 199.64 | Reach 3 (South Branch) | 4424 | 21.3 | 197.96 | 199.04 |
| Reach 3 (South Branch) | 4574 | 53.2 | 199.04 | 200.64 | Reach 3 (South Branch) | 4574 | 21.3 | 199.04 | 200.08 |
| Reach 3 (South Branch) | 4631 | 53.2 | 200.10 | 202.45 | Reach 3 (South Branch) | 4631 | 21.3 | 200.1 | 201.8 |
| Reach 3 (South Branch) | 4775 | 53.2 | 201.17 | 203.69 | Reach 3 (South Branch) | 4775 | 21.3 | 201.17 | 202.94 |
| Reach 3 (South Branch) | 5004 | 53.2 | 202.38 | 204.40 | Reach 3 (South Branch) | 5004 | 21.3 | 202.38 | 203.79 |
| Reach 3 (South Branch) | 5076 | 53.2 | 202.30 | 204.97 | Reach 3 (South Branch) | 5076 | 21.3 | 202.3 | 204.31 |
| Reach 3 (South Branch) | 5188 | 53.2 | 202.90 | 204.88 | Reach 3 (South Branch) | 5188 | 21.3 | 202.9 | 204.46 |
| Reach 3 (South Branch) | 5425 | 47.2 | 205.20 | 207.03 | Reach 3 (South Branch) | 5425 | 19.7 | 205.2 | 206.28 |
| Reach 3 (South Branch) | 5614 | 47.2 | 208.60 | 210.67 | Reach 3 (South Branch) | 5614 | 19.7 | 208.6 | 209.9 |
| Reach 3 (South Branch) | 5634 | 47.2 | 209.28 | 211.72 | Reach 3 (South Branch) | 5634 | 19.7 | 209.28 | 211.72 |
| Reach 3 (South Branch) | 5637 | Tenth Line CSP Culvert | | | Reach 3 (South Branch) | 5637 | Tenth Line CSP Culvert | | |
| Reach 3 (South Branch) | 5648 | 47.2 | 209.75 | 213.03 | Reach 3 (South Branch) | 5648 | 19.7 | 209.75 | 212.79 |
| Reach 3 (South Branch) | 5656 | 47.2 | 210.02 | 213.02 | Reach 3 (South Branch) | 5656 | 19.7 | 210.02 | 212.79 |
| Reach 3 (South Branch) | 5796 | 47.2 | 212.90 | 215.03 | Reach 3 (South Branch) | 5796 | 19.7 | 212.9 | 214.45 |
| Reach 3 (South Branch) | 5966 | 47.2 | 214.90 | 216.69 | Reach 3 (South Branch) | 5966 | 19.7 | 214.9 | 216.25 |
| Reach 3 (South Branch) | 6065 | 47.2 | 216.70 | 218.14 | Reach 3 (South Branch) | 6065 | 19.7 | 216.7 | 217.77 |
| | | | | | | | | | |
| Tributary 1 (West Tributar | 101 | 9.8 | 188.04 | 188.95 | Tributary 1 (West Tributary | 101 | 2.9 | 188.04 | 188.71 |
| Tributary 1 (West Tributar | 102 | 9.8 | 189.81 | 190.53 | Tributary 1 (West Tributary | 102 | 2.9 | 189.81 | 190.35 |
| Tributary 1 (West Tributar | 103 | 9.8 | 191.27 | 192.39 | Tributary 1 (West Tributary | 103 | 2.9 | 191.27 | 192.03 |
| Tributary 1 (West Tributar | 104 | 9.8 | 191.57 | 192.83 | Tributary 1 (West Tributary | 104 | 2.9 | 191.57 | 192.37 |
| | | | | | | | | | |
| Tributary 2 (North Branch | 201 | 30 | 187.75 | 189.39 | Tributary 2 (North Branch) | 201 | 9.5 | 187.75 | 188.64 |
| Tributary 2 (North Branch | 202 | 30 | 187.79 | 189.74 | Tributary 2 (North Branch) | 202 | 9.5 | 187.79 | 188.94 |
| Tributary 2 (North Branch | 203 | 30 | 188.84 | 190.68 | Tributary 2 (North Branch) | 203 | 9.5 | 188.84 | 190.26 |
| Tributary 2 (North Branch | 204 | 30 | 189.37 | 190.79 | Tributary 2 (North Branch) | 204 | 9.5 | 189.37 | 190.56 |
| Tributary 2 (North Branch | 205 | 30 | 190.06 | 191.18 | Tributary 2 (North Branch) | 205 | 9.5 | 190.06 | 190.85 |
| Tributary 2 (North Branch | 206 | 30 | 189.94 | 191.61 | Tributary 2 (North Branch) | 206 | 9.5 | 189.94 | 191.25 |
| Tributary 2 (North Branch | 207 | 30 | 190.44 | 191.70 | Tributary 2 (North Branch) | 207 | 9.5 | 190.44 | 191.35 |
| Tributary 2 (North Branch | 208 | 30 | 190.57 | 191.74 | Tributary 2 (North Branch) | 208 | 9.5 | 190.57 | 191.22 |
| Tributary 2 (North Branch | 209 | 30 | 190.52 | 192.30 | Tributary 2 (North Branch) | 209 | 9.5 | 190.52 | 191.63 |
| Tributary 2 (North Branch | 210 | 30 | 190.61 | 192.62 | Tributary 2 (North Branch) | 210 | 9.5 | 190.61 | 192.12 |
| Tributary 2 (North Branch | 210.2 | Sixth Street CSP Culvert | | | Tributary 2 (North Branch) | 210.2 | Sixth Street CSP Culvert | | |
| Tributary 2 (North Branch | 211 | 30 | 190.94 | 193.25 | Tributary 2 (North Branch) | 211 | 9.5 | 190.94 | 192.95 |
| Tributary 2 (North Branch | 211.5 | 30 | 190.94 | 193.26 | Tributary 2 (North Branch) | 211.5 | 9.5 | 190.94 | 194.23 |
| Tributary 2 (North Branch | 212 | 30 | 191.54 | 193.31 | Tributary 2 (North Branch) | 212 | 9.5 | 191.54 | 194.23 |
| Tributary 2 (North Branch | 213 | 30 | 192.61 | 194.20 | Tributary 2 (North Branch) | 213 | 9.5 | 192.61 | 194.21 |
| Tributary 2 (North Branch | 214 | 30 | 194.57 | 195.64 | Tributary 2 (North Branch) | 214 | 9.5 | 194.57 | 195.19 |
| Tributary 2 (North Branch | 215 | 30 | 194.93 | 196.86 | Tributary 2 (North Branch) | 215 | 9.5 | 194.93 | 196.07 |
| Tributary 2 (North Branch | 216 | 30 | 195.05 | 197.32 | Tributary 2 (North Branch) | 216 | 9.5 | 195.05 | 196.55 |
| Tributary 2 (North Branch | 217 | 30 | 195.47 | 197.47 | Tributary 2 (North Branch) | 217 | 9.5 | 195.47 | 196.74 |
| Tributary 2 (North Branch | 218 | 30 | 197.28 | 198.96 | Tributary 2 (North Branch) | 218 | 9.5 | 197.28 | 198.29 |
| Tributary 2 (North Branch | 219 | 30 | 197.41 | 199.54 | Tributary 2 (North Branch) | 219 | 9.5 | 197.41 | 198.65 |
| Tributary 2 (North Branch | 220 | 30 | 197.69 | 199.62 | Tributary 2 (North Branch) | 220 | 9.5 | 197.69 | 198.99 |
| Tributary 2 (North Branch | 221 | 30 | 198.40 | 200.38 | Tributary 2 (North Branch) | 221 | 9.5 | 198.4 | 199.67 |
| Tributary 2 (North Branch | 222 | 30 | 198.81 | 200.74 | Tributary 2 (North Branch) | 222 | 9.5 | 198.81 | 200.01 |
| Tributary 2 (North Branch | 223 | 30 | 198.86 | 200.86 | Tributary 2 (North Branch) | 223 | 9.5 | 198.86 | 200.11 |

# Memorandum

GREENLAND

DATE: May 25, 2000 FILE NO.: 99-G-1290

TO: Bob Law, NVCA
Jeff Langlois, R.J.B.

FROM: Abe Khademi, P.Eng.

CC: Mark Palmer, Greenland

**RE: Black Ash Creek Tributary – Spill Analysis at Sixth Street**

This analysis has identified the Regional spill conditions of Tributary 2 of Black Ash Creek at Sixth Street. The flow in the tributary upstream of Sixth Street was divided into 3 components:

(i) flow through the Sixth Street culvert;

(ii) flow over the berm on the east side of the channel, immediately upstream of Sixth Street; and,

(iii) flow over Sixth Street.

Rating curves of flow versus depth were developed for each component. The combined rating curve is the sum of the flow ordinates for each component across the range of elevations (refer to attached figure). The relative contribution of each component was determined by identifying the elevation of the combined rating curve at the Regional flow of 22.7 $m^3/s$.

The Regional flow was determined to split as follows:

| Spill Component | Spill Magnitude ($m^3/s$) |
|---|---|
| Flow through the Sixth Street culvert | 2.9 |
| Flow over the berm on the east side of the channel, immediately upstream of Sixth Street | 12.0 |
| Flow over Sixth Street | 7.8 |

The attached drawing shows the direction and magnitude of the spill components. The flow crossing Sixth Street of 10.7 $m^3/s$ (i.e. sum of flow through culvert and flow over Sixth Street) was included in the HEC-RAS model to determine the change in flood elevations downstream of Sixth Street. The following table compares the flood elevations between the two models.



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| River Station | Water Surface Elevation (m) | | |
|---|---|---|---|
| | at 22.7 $m^3/s$ | at 10.7 $m^3/s$ | Difference (m) |
| 201 | 189.3 | 189.4 | -0.1 |
| 202 | 189.7 | 189.4 | 0.3 |
| 203 | 190.6 | 190.2 | 0.4 |
| 204 | 190.9 | 190.7 | 0.2 |
| 205 | 191.3 | 191.0 | 0.3 |
| 206 | 191.6 | 191.3 | 0.3 |
| 207 | 192.0 | 191.6 | 0.4 |
| 208 | 192.1 | 191.7 | 0.4 |
| 209 | 192.0 | 191.7 | 0.3 |
| 210 | 192.5 | 192.1 | 0.4 |
| 211 | 193.7 | 193.5 | 0.2 |

From the above table, it can be seen that the change in flow results in marginal changes to the flood elevations across the subject property, causing a minor reduction in the top-width of the established floodline. However, for floodline mapping purposes, our previous analysis was consistent with current subwatershed modelling practices.

Prepared by,

**GREENLAND INTERNATIONAL CONSULTING INC.**

Abraham Khademi, P.Eng.



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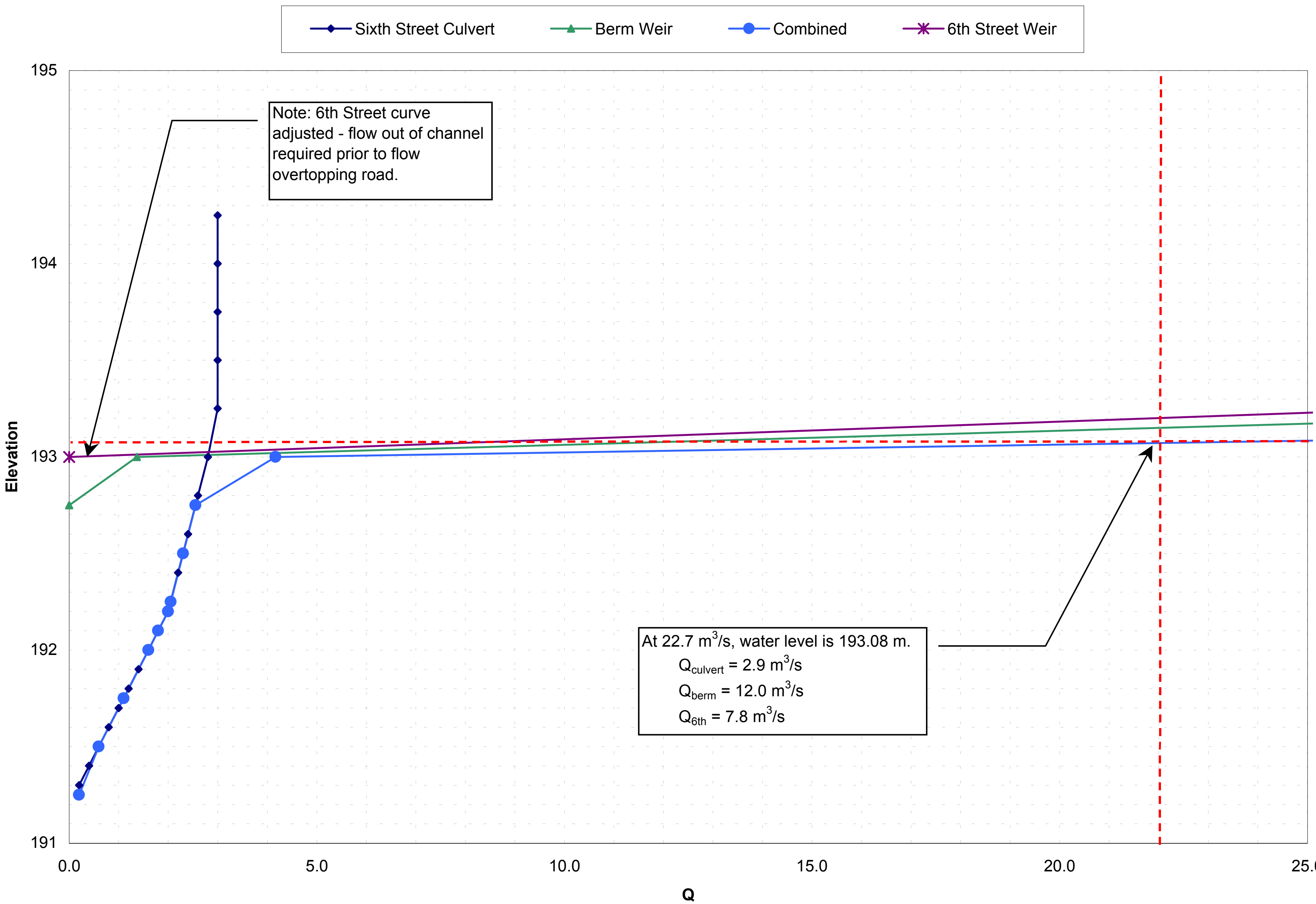
Sixth Street Spill Analysis



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# APPENDIX “D”

# STORMWATER MANAGEMENT, FLOOD CONTROL AND MONITORING

# APPENDIX D

## STORMWATER MANAGEMENT, FLOOD CONTROL AND MONITORING

## D.1 OPPORTUNITIES AND CONSTRAINTS

### *D.1.1 Constraints*

Based on existing conditions, any areas of constraint due to physical and ecological parameters were identified during Phase I to ensure that those features worthy of protection were noted. Constraints refer to the definition of boundary or existing conditions that affect the long-term management, maintenance and enhancement of the Black Ash Creek Subwatershed. Constraints were defined and quantified where feasible. They served as important considerations in establishing study area targets for water management.

Examples of identified constraints within the Black Ash Creek Subwatershed that effect the selection of stormwater management and flood control solution for the Town of Collingwood include:

- ✓ Maximum baseflow which can be sustained (particularly during drought periods) and potential influence of groundwater “underflow” discharge to the North Branch, from adjacent watercourse systems such as the Pretty River, Beaver River and/or Silver Creek basins;
- ✓ With the exception of the Blue Mountain Golf and Country Club, there could be an increasing demand for Permit to Take Water (PTTW) taking in the near future to address recreational and resort community needs in the headwater basins. In addition to current surface water taking for local businesses such the Osler Bluff Ski Club, this additional water use would be from either Black Ash Creek or local groundwater system;
- ✓ Vulnerability of baseflow from hydrogeologic characteristics and volumes that were measured previously by the NVCA during summer months and baseflow measured during this study to assimilate non-point and point source inputs, including treated stormwater discharge from new development in Collingwood;
- ✓ Limits on the biotic diversity and vulnerability due to the extent of natural areas and human interactions;
- ✓ Rural water supply requirements;
- ✓ Land use needs in the study area;
- ✓ The uncertainty of climate change;
- ✓ Further delays to the construction of the Black Ash Creek Flood Control Project that would cause financial impacts to Collingwood developers in terms of “interim” floodproofing requirements and/or loss of developable land; and,
- ✓ Potential flood damages and risk to life from flooding events before the Flood Control Project is constructed, including combined rainfall-runoff and snowmelt events and Regulatory Flood spills flows from the South Branch (south of Sixth Street). Significant floods would include spill from a Timmins storm event to the northeast across High Street and through a large urban area of Collingwood. Historical flooding due to ice blockage, that has already been incorporated in a floodplain special policy for lands in

the vicinity of Campbell Street and through the Ferracuti development site, also warrants attention in regulating developments within this area of the municipality.

### *D.1.2 Opportunities*

Opportunities for rehabilitation were also identified, however not only from a heritage perspective but also from within the social and physical context. These opportunities were assessed based on existing vegetation and wildlife (including fisheries) and the dependency of those attributes on the groundwater and surface water supply. Enhancement of those opportunities are proposed in the Subwatershed Plan and were evaluated using an ecosystem approach that integrated the context within which the study area lies in the province, in the region and relative to local neighbourhood uses.

Examples of opportunities, which exist in the study area to sustain or enhance the ecosystem, include:

- ✓ Terrestrial habitat and stream function;
- ✓ Vegetation community, function composition and diversity;
- ✓ Stability and sustainability of Black Ash Creek;
- ✓ Existing land use and planning designations;
- ✓ Recreational use, circulation and linkages and adjacent land use;
- ✓ Integration with adjacent land use and community;
- ✓ Aesthetics;
- ✓ Preservation and enhancement of significant natural and cultural heritage resources;
- ✓ Public education and interpretation; and,
- ✓ Community involvement in stewardship, monitoring and management.

Our initial assessment of development areas within Collingwood included large tracts of land. That is, at the completion of Phase I, sufficient information was only known about areas not suitable for development based on the presence of significant features (such as an ESA boundary or floodplain area). What was not fully known at the end of Phase I was the area of land that may not be suitable for development based on potential impacts to functions, processes and linkages. Therefore, our “vision plan” development during Phase II formed the basis for consideration of a proposed land use scenario (plus any modifications).

## D.2 STORMWATER MANAGEMENT AND FLOOD CONTROL ASSESSMENT

Based on our understanding of the subwatershed functions and attributes, concepts integrating development scenarios with natural heritage protection were generated. The alternatives together with a recommendation for the preferred option were presented to the Steering Committee near the end of the study.

### *D.2.1 Discussion of Alternatives*

From a stormwater management perspective for the Town of Collingwood, which assumed existing land use conditions for Clearview Township and Town of The Blue Mountains, four (4) scenarios within Collingwood were assessed for developing Subwatershed Plan alternatives. Hydrologic and hydraulic computer models from Appendices ‘B’ and ‘C’, respectively, were used and these scenarios included:

1) Complete development within Collingwood “without” the Black Ash Creek Flood Control Project;

2) Complete development "with" the proposed Black Ash Creek flood control and channelization works;
3) Phased development "without" the proposed Black Ash Creek works; and,
4) Phased development "with" the proposed Black Ash Creek works.

It should be noted "complete" development within Collingwood also refers to a specified number of development applications that were made known to the Study Team prior to our investigations. Proposed amendments to the municipality's Official Plan and future Secondary Plan areas at the time of the study were not considered.

### *D.2.2 Recommendation of Preferred Scenario*

Based on input from the Steering Committee and feedback from one Public Open House forum, the preferred Subwatershed Plan scenario will be a compromise between development within Collingwood and preservation for the balance of the study area. Specific details of the recommended plan for stormwater management, flood control and monitoring within the Town of Collingwood are provided later on.

In general terms, the recommended Subwatershed Plan is intended to provide broad direction to the Town of Collingwood and neighbouring municipalities. However, our "living document" approach recommends environmental monitoring after this study and future updates to our computer models so that any municipality can continue to assess potential subwatershed impacts from other development - not currently designated in Official Plans. Therefore, the recommended plan for the Black Ash Creek Subwatershed arising from this study identifies the following:

- Lands that should be protected or conserved as a Natural Heritage System;
- Criteria which should be used in the design of future urban development and stormwater management within the Town of Collingwood;
- Additional streamflow and climate monitoring to address fully, after this study, water balance properties and stormwater management requirements of headwater basins, as well as baseflow (groundwater discharge) sources to the North Branch. This information, in addition to the baseline data collected from November 1999 to May 2000 for this study, will be very important to address any recreational and resort development pressures in Clearview Township and Town of The Blue Mountains, as well as the potential for a new highway by-pass in the vicinity of Poplar Sideroad (i.e. through the Black Ash Creek Subwatershed) that would service new communities along the Niagara Escarpment;
- Construction of the "integrated" Black Ash Creek flood control and natural channel works through the Town of Collingwood;
- Conservation and management practices which address existing any impacts from land use activities; and,
- A series of projects and programs which seek to fix specific problems and increase awareness of needs of the environment.

The Natural Heritage System will identify the significant natural features for the affected municipalities. By retaining these areas and their functions, while allowing growth to occur that would not affect those functions, the framework for a healthy aquatic ecosystem will be preserved. Combined with the development criteria which will govern the environmental standards that future development should meet, the Natural Heritage System will ensure that growth will be sustainable in environmental, as well as social and economic terms.

The conservation and management elements of the Subwatershed Plan will, over the long term and where appropriate, introduce practices that reduce many of the impacts caused by agricultural, rural and municipal land uses. By reducing stress on the systems in this manner, and by implementing specific projects and programs to strengthen the key environments, the Black Ash Creek Subwatershed will become more resilient and able to support a diversity of life. The value of this will increase over time, producing a healthy natural environment, integrated into the rural and urban landscapes.

The recommended Subwatershed Plan is strategic in nature, as is an Official Plan. It deals with larger vegetation patches and broad landscapes in formulating the Natural Heritage System. It also indicates development criteria and environmental targets on a tributary basis. Also, the plan addresses the need for conservation practices on a sub-catchment basis.

With the exception of the Dunn Property development (at the northeast corner of Sixth Street and Tenth Line) which was examined concurrently by the proponent at an “Environmental Impact Study” level of detail, our recommended Subwatershed Plan does not get down to a “design” level of detail. Therefore, it is expected that subsequent “Functional Servicing Plan (FSP)” studies, as part of future Secondary Plan initiatives, will be undertaken for other properties within the Subwatershed to provide more specific information and data as growth proceeds. In terms of future FSP requirements (including stormwater management) for lands within Collingwood, section D.4.1 presents a summary that will refine municipal servicing details, while retaining the broader strategy and recommendations of the Subwatershed Plan.

## D.3 IMPACT ASSESSMENT AND MITIGATION

### *D.3.1 Future Land Use Assumptions*

The study area includes existing and future development lands, within the Town of Collingwood, as well as current land use designations within Clearview Township and Town of The Blue Mountains, to properly plan stormwater management facilities for urban growth within Collingwood. Figure 1 (refer to the Main Report) illustrates the location of the study area. Figure 9 of the Main Report presents the proposed land uses within Collingwood’s catchments of the Black Ash Creek Subwatershed - as per the municipality’s recent Official Plan.

Future development within the affected basins of Collingwood will include low and medium density residential areas (sub-catchments ‘1103’, ‘1203’, ‘1302’ and ‘1402’), as well as industrial and commercial lands in the vicinity of Old Mountain Road. Some of these developments will be dependent upon the construction of the municipal services, as outlined in the Town’s master servicing plan for lands acquired under County re-structuring (C.C. Tatham & Associates Ltd, 1994). Where necessary and as required by the municipality, separate Class Environmental Assessments will be required for major water supply, sanitary sewerage and roadway works. In general, future development within the Black Ash Creek Subwatershed will be integrated with the existing communities and resort areas, as well as surrounding rural landscapes to the south and greenspace/waterfront areas to the north. Motor vehicles may have to be accommodated on an expanded system of public roads.

Natural and open space elements, as specified in the Official Plans of the Town of Collingwood, Township of Clearview and Town of The Blue Mountains, have been incorporated into the Black Ash Creek Subwatershed Study and include (where applicable), but not be limited to, the following:

- The construction of new recreational trails and connections to existing pathways;
- Tree preservation of significant stands within open space blocks and linkages, which include steam/valley corridors and hazard (floodplain) lands; and,
- The integration of stormwater management (SWM) facilities within open space features or adjacent to proposed flood control works in order to promote efficient use of developable land, as well as provide for potential passive recreational use of the facilities.

In terms of our SWM investigations, five (5) land use planning issues were identified at the beginning of the study. The issues of concern for the Black Ash Creek Subwatershed are:

1. The preservation of floodplain (riparian) storage, as a result of filling of any new lots and constructing any on-line (i.e. flood control or “peak flow shaving”) or off-line (i.e. extended detention water quality/quantity) drainage/SWM facilities within a floodplain;

2. Stormwater quantity controls (i.e. flood/peak flow and erosion/runoff volume or duration) and water quality enhancement (i.e. Level ‘1’ fish habitat protection for all watercourses of the Black Ash Creek system) requirements;

3. Groundwater recharge/baseflow preservation and, if practical, enhancement;

4. Operation/maintenance responsibilities for the SWM plan; and,

5. Environmental protection, including the establishment of sufficient buffer widths between new lots/roadways and low flow channels of Black Ash Creek - as they relate to the protection of valley corridors and net environmental gains.

Consequently, the following objectives were satisfied to develop a SWM plan for development lands within Collingwood that will provide a practical and environmentally sound approach for developing the study area:

- Protect, conserve, and enhance (where practical) all relevant natural resources within the study area, including water, aquatic, and terrestrial;
- Identify potential flooding impacts within the study area as a result of urbanizing the Subwatershed and recommend mitigative flood control measures to minimize the threat to life and destruction of property from flooding;
- Confirm general development limits from the Official Plan in a manner that considers the natural environment as well as the hydrologic functions of the proposed development blocks and phases;
- Identify potential urbanization impacts from the development blocks/phases upon flooding, erosion, water quality, baseflow supplies, and the natural environment within the study area;
- Select environmentally compatible and practical storm water management practices (SWMPs), to be located within future development lands in order to mitigate any identified surface water impacts from the urbanization; and
- Identify land use requirements and any constraints (e.g. locations of future SWM facilities) that will be accommodated in future planning documents about the proposed development areas.

Final design details of the SWM plan are not required at this stage, in accordance with review submission procedures of the Town of Collingwood, Nottawasaga Valley Conservation Authority and other regulatory agencies. Detailed design drawings for the recommended works however must be submitted later on, in addition to required permit applications, to construct the recommended drainage/SWM works.

### *D.3.2 Hydrologic Impacts*

An ecosystem approach to subwatershed management is based on the fact the natural features and functions of a subwatershed are linked by the movement of water. Changes in the subwatershed that affect this movement of water may, in turn, affect the natural features and functions. Impact assessment of land use change in a subwatershed must consider these fundamental relationships. The hydrologic processes, aquatic resources and terrestrial resources of a subwatershed define the unique set of ecosystem functions, attributes and linkages and provide an overall framework for an assessment of the subwatershed ecosystem in a holistic manner. Management of a subwatershed from an ecosystem perspective must address these functional components. Maintenance of the subwatershed functions, attributes and linkages (including the basin's water budget) would typically maintain the existing environmental quality.

To ensure the successful integration of any new development within a subwatershed, a means is necessary to assess the impact of the urbanization on downstream flooding and erosion, and to evaluate the effectiveness of mitigative works to maintain flooding/erosion indices (i.e. SWM "targets") to acceptable levels. Development of the land uses shown on Figure 9 (Main Report) will result in a change to the hydrologic characteristics of the Black Ash Creek Subwatershed. The impacts would include changes to peak flows, infiltration and runoff volumes, as well as response times to a given rainfall and/or snowmelt event.

For the Black Ash Creek Subwatershed study area, ISWMS™ and Visual OTTHYMO© hydrologic computer programs were used to predict/compare "post-development" surface water impacts from the proposed concept land uses shown on Collingwood's Official Plan, relative to existing or "pre-development" conditions. Appendix 'B' presents our baseline findings for pre-development hydrologic conditions. The post-development hydrologic models were based on an interpretation of site specific aerial topography, soil reports, proposed land use schedules, etc. Our hydrologic models also accounted for flow attenuation affects from field-surveyed channel routing sections and required SWM facilities, as part of our stormwater management plan for the sub-catchments within the Town of Collingwood.

As shown on Figure 9, the same points of interest to establish pre-development peak flow targets (Figure 6 of the Main Report) within the Black Ash Creek Subwatershed were again used for our post-development hydrologic analysis. Visual OTTHYMO© and ISWMS™ peak flows were calculated at these locations for various return periods to compare uncontrolled and controlled post-development scenarios, relative to existing hydrologic conditions. Pre-development flow data was also used in our hydraulic analysis to determine flood hazard areas, potential spill flows from Black Ash Creek across High Street and as "peak flow" targets to design the subwatershed SWM plan. Section D.4.1 presents the results from our investigations.

### *D.3.3 Hydrogeologic Impacts*

D.3.3.1 General

Water balance is linked to the hydrologic cycle. It describes the process of water inflow from precipitation and the outflow of water by evapotranspiration, groundwater recharge and streamflow. This process forms a dynamic balance that can vary with time depending greatly upon climatic conditions – as evident over the past couple of years throughout Simcoe County. The water budget, or how much water is available in each stage of the cycle, is "critical" in that it dictates the conditions of an ecosystem. Human activities are part of this ecosystem and conflicts arise when water use exceeds the resources available in terms of the water budget conditions. These "baseline" conditions can only be determined utilizing existing data records and/or implementing a monitoring program.

Groundwater impact and surface water management are often key issues in the development of subwatershed management strategies. Concerns regarding water use and availability are often rooted in the following principals. All five principals apply to the Collingwood region:

- ✓ The potential depletion or degradation of water as a resource reducing availability for all users. This includes "cumulative impacts" from the issuance of Permits to Take Water by the Ontario Ministry of the Environment (MOE). Generally, a permit is easy to obtain and conditions sometime apply (such as monitoring) but are rare. Public hearings are also not necessary for these permits or direct notices to adjacent landowners. Permit issuance and details (i.e. quantity) are not based on "sustainable yield" through knowledge of local water budgets. However, this approach is gaining widespread acceptance - albeit information is not widely available.
- ✓ Potential conflicting uses and the distribution of equitable water "rights". In Ontario, water rights (other than for personal use, agricultural use, fire fighting, etc.) are based on Common Law – namely, a landowner has the right to a "reasonable" use of water on their property as long it does not have adverse impacts on adjacent landowners;
- ✓ Population growth, outstripping supply causing depletion and conflict amongst other users;
- ✓ Unequal distribution of water resources leading to pressures for diversions – and potentially, as a result, erosion and assimilation (e.g. phosphorus, ammonia, etc.) problems for receiving streams and rivers from wastewater effluent discharge; and,
- ✓ Groundwater availability and quality is inseparably linked with quality/quantity of surface water – especially, baseflow in headwater streams, fish habitat, etc.

The sensitivity of headwater basins within the Blue Mountain ecosystem (including Black Ash Creek) compounds these concerns since environmental characteristics are controlled by current water balance conditions. Depletion of groundwater tables and changes in streamflow patterns will change habitat conditions and alter species (including humans) distribution and perhaps reduce the number of species that can live in a municipality.

D.3.3.2 Black Ash Creek Subwatershed Study Requirements

The use of water or impact from human activities within as well as around the Black Ash Creek Subwatershed may not simply have localized impacts. These impacts could be widespread where land is linked to the stream network that drains to surface and groundwater. Typically, the boundary of watershed is almost always defined on the basis of the boundary of a surface water drainage basin. However, because groundwater flow systems typically occur within aquifers (local/shallow or regional/deep systems), which do not follow the surface water boundaries, the groundwater watershed can be considerably larger from the surface water basin.

A subwatershed management plan that includes a "groundwater management plan component" provides for the ability to investigate environmental processes on a broad scale within a reasonable (watershed or regional) boundary. There is still some cross boundary issues to deal with, such as the transfer of groundwater linkages between different municipalities. Watershed(s), however, can provide the geographical basis for analyzing and quantifying the environmental and social processes that govern its conditions.
The major connecting link in a watershed ecosystem is the flow of water. The flow pattern is part of the water balance. How and where the water flows determines the quality of the water, the shape and stability of streambanks, the health and diversity of vegetation, and the availability of fish and wildlife habitat. As human use of a watershed or region increases, all of these characteristics can change, altering the water budget. Changes to the water budget then cause changes to the above resources. These unintentional changes often reduce the ability of the human population to use and enjoy the resources of the watershed.

*Based on our streamflow monitoring results from November 1999 to May 2000 groundwater system(s) adjacent to the Black Ash Creek Subwatershed are contributing baseflow to the North and South Branches.* However, our "scoped" study approach for stormwater management and flood control within Collingwood prevented consecutive four-season climate and streamflow monitoring which is necessary to determine accurate water balance parameters – including evapotranspiration. In addition, an examination of existing wells and monitoring of local groundwater levels was also not required for the subject Terms of Reference.

Under the Planning Act, the provincial government downloaded the land use decision making process to the local municipal level. To ensure that provincial interests are not compromised by local decisions (including Zoning By-law amendments and, if applicable, any Permit to Take Water approvals by the MOE), provincial policies were enacted which require local municipalities to "measure" the effect of their decisions on the environment via standardized "Performance Indicators". As a consequence, municipalities must now show "due diligence" in managing their water resources. To accomplish this, there will be an increasing need for monitoring water quality and quantity data for their groundwater and surface water systems. As noted earlier, the watershed boundary for surface drainage is not generally the same as the groundwater boundary, particularly at regional groundwater levels. Water flow may be in or out of the surface watershed depending upon the direction of groundwater flow. This may be dependent upon groundwater extraction. Inter-basin transfers must be quantified for the Black Ash Creek Subwatershed through estimates of flow rates and hydrostatic levels in wells or piezometers.

Given the *"A-E-M-O-T Groundwater Management Plan Study"* will be completed by the summer of 2001, an ideal opportunity exists now for developing a groundwater management plan for headwater basins of the Black Ash Creek system. These investigations would also determine potential impacts from future development scenarios upon the water budget. At the municipal level, the resource management "partners" would include Clearview Township and Town of The Blue Mountains. However, the Town of Collingwood, Nottawasaga Valley Conservation Authority, Ministry of the Environment, public and local businesses should be consulted too so that targets from this scoped study are maintained. One or more of the following issues could be addressed in the preparation of a groundwater management plan for the Black Ash Creek headwater basins and this plan would then be incorporated into this document:

- Groundwater resource assessment;
- Contamination assessment;
- Current groundwater use;
- Economic evaluation; and/or,
- Groundwater management and protection measures.

By January 2001, a considerable amount of background information will exist from the on-going *"A-E-M-O-T Groundwater Management Plan Study"* for the Blue Mountain/Beaver Valley region to map local and regional groundwater systems – including those of the Black Ash Creek Subwatershed. Greenland International Consulting Inc. is undertaking the A-E-M-O-T study and the NVCA and Town of The Blue Mountains are members of the Steering Committee.

Since ISWMS®, ViewLog/DB™ and MODFLOW computer models are also being developed for the A-E-M-O-T study area, the completed database could eventually be integrated with other similar "living document" models of the Black Ash Creek system. This would then enable the NVCA to conduct long-term surface hydrology simulation during summer and winter conditions, as well as comprehensive surficial infiltration capabilities, both of which are essential for water balance analysis. Further calibration (after this study) would consist of continued stream flow monitoring and "wide-spread" baseflow measurements throughout the study area during the summer/fall periods. ISWMS® calculates infiltration from catchment pervious areas using a two-stage implementation of the physically based Green-Ampt infiltration approach. This Green-Ampt infiltration model utilizes Darcy's law of flow in porous media. With this approach, water is assumed to infiltrate into the soil as piston flow resulting in a well-defined wetting front. The first stage of these subsequent water balance investigations would predict infiltration under unsaturated soil conditions. In this case, the greater capillary suction is accounted for until complete saturation occurs. Once the surficial soil becomes saturated, infiltration is predicted using the Green-Ampt equation and this data can then be serve as input data for the groundwater computer program known as MODFLOW. ISWMS® uses a moisture depletion factor approach to regenerate the infiltration capacity of the soil. Regeneration occurs when there is no infiltration from rainfall or depression storage. This model also accounts for factors such as evaporation and transpiration based on vegetative community make-up.

<u>D.3.3.3 Potential for Recharge Enhancement within Collingwood</u>

Within urban development areas, storm water runoff carries increased quantities of pollutants. Rural development practices can also contribute significantly to point and non-point pollution source loads to the groundwater system - especially if the surficial soils are permeable. Unless properly designed and monitored, intentional (i.e. induced) or even non-intentional infiltrating water from both urban and rural land use practices can contaminate groundwater. Waters having elevated contaminant concentrations available for groundwater recharge within a permeable basin include effluent from domestic septic tank and tile bed systems, wastewater from percolation basins, infiltrating storm water, and infiltrating water from agricultural operations.

The natural recharge condition of a development site can sometimes be enhanced, using induced infiltration techniques. The existing conditions and the naturally occurring recharge function of the site affect the suitability of these techniques in question.

Within the Town of Collingwood, subcatchments of Black Ash Creek were screened from a hydrogeological perspective, based on existing albeit limited data, to determine the potential for enhancing the existing recharge capability of the subwatershed. Based on the scope of background information available, work documented by Schueler (1987) was used as the basis for evaluating infiltration potential. These studies suggest that a soil permeability of $2 \times 10^{-4}$ cm/s or higher is required for suitable infiltration. Clay content in the soils should be less than 20% - 30%. Based on this, the Black Ash Creek Subwatershed is unsuitable for induced infiltration techniques within the clay and clay-loam soil units shown Figure 10 (refer to the Main Report). Within the affected sub-catchments, the soil permeability is expected to be in the order of $6 \times 10^{-5}$ cm/s and could likely influenced by the groundwater system in low-lying areas. In addition, any flux of water through these soils is likely too low to allow for effective recharge of regional groundwater systems associated with the Black Ash Creek Subwatershed. On the other hand, the higher permeability of the sandy-loam and loam soils (Figure 10; Main Report) render infiltration via induced practices (e.g. exfiltration type SWMPs) feasible for these portions of the study area.

Previous consultant reports for developers about the Black Ash Creek system have proposed post-development water quality source controls using recharge practices. For example, roof drainage dry wells and perforated pipes with rock trenches (or exfiltration systems) were considered. It is recommended, however, that only source control (i.e. residential lots) practices fitted with an overflow pipe are acceptable. This would include roof drainage dry wells. However, sub-surface exfiltration and surface infiltration basins/swales are not acceptable because of potential maintenance concerns.

In order to maintain (or even enhance) the study area's existing water budget, findings from the "*A-E-M-O-T Groundwater Management Plan Study*" should initially be used as total "management targets" for each headwater basin. However, detailed hydrogeological investigations will still be necessary (and preferably at FSP stage) to confirm the most appropriate stormwater recharge techniques. In addition, baseline (pre-construction) data from the our recommended biophysical monitoring program after this study (refer to Section D.5) will also be very important to resolve the "actual recharge potential" for each development block or phase and avoid costly/ineffective source control practices.

### *D.3.4 Flooding*

Floodplains of the Black Ash Creek system are regulated in accordance with a *Policy Statement on Floodplain Planning* issued under Section 3 of the Planning Act, 1983, by the Ministries of Natural Resources and Municipal Affairs. For the study area, the Nottawasaga Valley Conservation Authority administers this policy. Floodplains are also regulated under Section 28 of the Conservation Authorities Act. Within the established regulatory floodplain (based on the Regional or "Timmins" Storm) all development is prohibited. This floodplain policy extends to the 125 ha catchment limit and this criterion was used to prepare the stormwater management plan for Collingwood's sub-catchments of the Black Ash Creek Subwatershed Plan.

The Nottawasaga Valley Conservation Authority (NVCA) also controls all hazard lands under *the Fill, Construction and Alternation to Waterways* regulation [Section 28(1)] of the Conservation Authorities Act. This section makes provisions for the Conservation Authority to pass regulations restricting and regulating alternation of waterways; construction within areas susceptible to flooding; placement of fill in fill regulated areas; etc. The regulations do not wholly prohibit these but rather require that the proponents of these activities obtain approval from the Conservation Authority.

Design flood profiles of the Black Ash Creek system, for the four land use scenarios discussed in Section D.2.1 and “controlled” post-to-pre development conditions, were calculated (along the watercourse reaches shown on Figure 8: Main Report) for the 2 year, 5 year, 10 year, 25 year, 50 year, 100 year and Regional Storm events. The calculated floodplain limits of the 100 year and Regional Storm events for existing and proposed Black Ash Creek channel conditions, as well as the flood water elevations, were superimposed on the Town’s 1:2,000 scale digital maps using the floodplain graphic module of the BOSS RMS computer program. Output data from our HEC RAS models (refer to Appendix ‘C’) were incorporated into BOSS RMS. The established floodlines were considered appropriate for use in the regulation of future development within the Town of Collingwood.

### *D.3.5 Water Quality and Quantity Controls*

D.3.5.1 Policies

The Ministry of Natural Resources, Ministry of the Environment, and the NVCA has policies that control the rate (peak flow and runoff volume) and quality of runoff from a developing area.

In terms of quantity control, the policies are designed to ensure that the post-development outflows do not exceed those of the predevelopment level and that any stream bank erosion is not exacerbated. However, this “blanket” policy of runoff controls for flood control purposes may be overly restrictive for Collingwood’s developments at the north end of the Black Ash Creek Subwatershed. That is, similar SWM studies for the Alliston Secondary Plan (Greenland International, 2000) in New Tecumseth and other large communities in the GTA concluded that post-development attenuation (for all storms) for some subwatersheds is not practical if these developments discharge near the subwatershed outlet. Therefore, different levels of storm water management controls for Collingwood’s development lands within the Black Ash Creek Subwatershed were examined in combination with the balance of the existing condition state of headwater basins. This analytical approach has been undertaken for the other communities within the Nottawasaga Valley Watershed.

In May 1991, the two provincial ministries (MNR and MOE) jointly issued the *Interim Stormwater Quality Guidelines for New Development*. The intent of this guideline was to ensure that stormwater runoff from new developments would not be discharged into any water body without first being treated. In June 1994 the MOE issued a document entitled *Stormwater Management Practices, Planning and Design Manual*. Although this manual provides guidance in the design of stormwater management facilities it is recognized that agencies must not discourage the efforts of innovative designers.

Alternations to watercourses are controlled under the Lakes and Rivers Improvement Act. The regulations are administered by the Ministry of Natural Resources and apply to dams, diversions, channelization, bridges, culverts, etc. The Conservation Authorities regulates alterations to watercourses. The Ministry of Natural Resources and NVCA also recommend a minimum development setback from all watercourses. It is this buffer area that is recognized as having a potential benefit for fish habitat enhancement and water quality improvement (i.e. sediment and nutrient retention).

Reference is also given to the NVCA’s *Interim Technical Standards for Development within the NVCA Watershed* (June 1997) document. In particular, the intent of these standards is to provide technical implementation procedures and criteria for development in concert with goals and objectives of the NVCA’s *Watershed Management Plan* (1995) and current provincial policies/standards. The NVCA's standards have been incorporated for the subject study, such as Level '1' water quality controls and off-line pond location policy; whereby SWM facilities must be located outside of the Regional Storm floodlines in the case of a One-Zone Floodplain Management Policy which applies to Black Ash Creek.

D.3.5.2 Design Guidelines

***General***

The stormwater management plan for Collingwood's sub-catchments of the study area is based on conceptual land use information. As the various draft plans proceed through the planning process, it is anticipated that the land use types, densities, road patterns, etc. will be finalized. This will require that, at the Functional Servicing Plan stage associated with a Secondary Plan application, the hydrologic calculations undertaken as part of this study be refined to better reflect the approved development plans. The recommended approach for the handling of surface runoff, as outlined in this report, would however, not change. The recommended approach considered the following guidelines.

***Water Quality Enhancement Criteria***

The Ministry of Natural Resources and Ministry of the Environment have both published specific criteria regarding water quality. For the study area, the water quality criteria are based on protection of aquatic life. The primary focus of the MNR guidelines is the reduction in total suspended solids (TSS) concentrations and adoption of setbacks to regulate development, encroachment and the maintenance of existing cover along stream banks (and shorelines), where possible. The MOE guidelines cover a wide variety of parameters with respect to aquatic habitat and human health objectives.

For the subject study, the primary concern of the agencies has been addressed in detail, namely the control of total suspended solids from a "first flush" event. Because the development plans are conceptual in nature, other concerns by the MNR and MOE, such as water temperatures, dissolved oxygen levels, lead and nutrients cannot be explicitly addressed at this time. Nevertheless, preliminary design objectives are included with our SWM plan. These other parameters would, however, be of interest when preparing the design details of each stormwater management facility. Current water quality requirements for the Black Ash Creek Subwatershed calls for Level '1' protection, as per the MOE's 1994 *Stormwater Management Practices Planning and Design Manual* – namely, an 80% total suspended solids removal efficiency for any SWM facility.

***Water Quantity Control Criteria***

For quantity control, our stormwater management plan was designed to ensure that there would be no impacts from peak outflows above that of the pre-development condition at all stream node locations shown on Figure 6 (Main Report). That includes all storms ranging from the frequent events (e.g. 2 year) to the infrequent events (e.g. 100 year event). Where possible after this study, for headwater basins within Clearview Township and Town of The Blue Mountains, other post-development flows may have to be over-controlled in order to reduce potential flood hazards that currently exist along some downstream study reaches. Following construction of Collingwood's flood control/channelization works, post-development flow attenuation within Clearview Township and Town of The Blue Mountains may still be necessary and will have to be confirmed using this study's hydrotechnical computer models. Where any landowner within the Black Ash Creek Subwatershed is required to over-control peak outflows from their SWM facility, in the interest of providing increased downstream flood hazard protection, then consideration should be given (at the functional servicing plan stage) to adjusting allowable pond depths as opposed to the pond area.

For future development areas within the Collingwood's sub-catchments of the Black Ash Creek Subwatershed and ultimate construction of the flood control/channelization works, storage of the first flush (associated with a 25 mm rainfall volume) for twenty-four hours is adequate as a base level for erosion control – and, where practical, induced infiltration for maintaining or enhancing stream baseflow. The NVCA and MNR require that the baseflow in the recipient watercourses not be impacted upon as a result of development. Also, in the event the flood control/channelization works are not constructed before the proposed Collingwood developments, "over-control" storage of the 2 year rainfall for forty-eight hours is also recommended as an interim measure to prevent erosion impacts within Collingwood reaches of the Black Ash Creek. For other development lands not considered in our investigations and that would outlet to other tributaries or stream branches (i.e. upstream of the Black Ash Creek Main Branch), erosion control requirements must be confirmed on case-by-case basis using this study's hydrotechnical models.

Finally, the NVCA has adopted, in accordance with the *Provincial Statement on Floodplain Planning*, the Timmins Storm (Regional) event as the regulatory storm for all watercourses. Their current regulations prohibit any new development within the flood hazard area unless the proponent of these activities obtains prior approval from the Conservation Authority. As part of the current investigation the flood hazard associated with the Timmins Storm event has been identified.

D.3.5.3 Functional Design Objectives

The selection process of the most appropriate stormwater management practices (SWMPs), for both water quantity and quality control, was undertaken in accordance with the current policies and design guidelines of the regulatory agencies. Commitments from these agencies about the conceptual SWM plan details were also discussed during our proactive consultations. In addition, our recommended SWM plan also addresses the following functional design objectives:

- Locate off-line SWM facilities outside of the Regional Storm floodplain;

- Retain the Regulatory Flood (Regional Storm) storage relationship for the study area's watercourses. This would apply to any road crossing structure that will be located within the Regional Storm floodplain. Any other locally significant floodplain storage improvements, such as stream rehabilitation/enlargement works within the same reach, should also be accounted for in preserving riparian storage relationships. A balanced cut-and-fill analysis may also be necessary to achieve this functional design objective;

- Sizing of off-line storm water quantity (runoff duration) erosion control facilities (i.e. for either a 25 mm or 2year rainfall event), should be exclusive of active storage needed for flood control (i.e. 5 year through 100 year events) but could incorporate the extended detention requirements for water quality enhancement;

- The sizing of a stormwater quality cell, to achieve the desired level of fish habitat protection for the watercourse receiver, must incorporate current storage requirements (permanent pool, active storage, etc.) of the MOE;

- The detention or “drawdown” time within any SWM flood control facility, to maintain pre-development peak flows along a reach, should be minimized. A maximum 48 hour drawdown time is recommended to prevent adverse (overtopping) impacts from "back-to-back" storm events and proper operation with all off-line SWM facilities along the same reach;

- Ensure overtopping of any SWM facility, from excess design flood flows, are safely conveyed to a watercourse via erosion resistant emergency spillways. A freeboard allowance should also be included in the design;

- Quality control structures must incorporate a “bottom-draw” outlet or "cooling" conduit outlet to prevent thermal impacts to any cold water stream discharge. The MOE (1994) temperature mass balance criteria should be used at the Functional Servicing Plan stage. In addition, outflow temperature design parameters should consider any net-temperature reductions from future riparian cover improvements within stream/valley corridors of the Black Ash Creek system. Finally, the design configuration must consider, if applicable, how the outlet will be integrated with the Black Ash Creek Flood Control Project works in order to prevent surcharging of the off-line SWM facility, etc.;

- For groundwater recharge maintenance/baseflow preservation and to achieve (as a minimum) pre-development sub-catchment infiltration targets calculated from the ISWMS™ hydrologic models, these outlet structures should also be fitted with an infiltration trench gallery or filtration pit device. This will obviously depend upon the in situ soil permeability and groundwater table depth. These recharge devices would also reduce nutrient loading (i.e. phosphorus) beyond the proposed suspended solids treatment efficiency of 80% (i.e. Level ‘1’ criterion for the Black Ash Creek system). Nevertheless, detailed hydrogeological investigations will be necessary at each quality SWM facility location in order to confirm if a stormwater recharge outlet device is practical. Outflow structure design parameters for each water quality SWM facility must also consider findings from the NVCA’s stream health monitoring program of the Black Ash Creek Subwatershed;

- Optimize suspended solids and heavy metal removal efficiencies by efficiently locating minor system inlet(s) and SWM facility outlet(s). This will prevent short-circuiting;

- Optimize nutrient uptake potential and diversity of plantings to enhance local aquatic and wildlife habitats. This includes littoral zone considerations for any facility that incorporates a wet pond component and incorporation of wetland pocket features. The NVCA promotes the use of “hybrid” wet pond/wetland cell SWM facilities for reducing phosphorus loading to Black Ash Creek;

- Consider operation and maintenance (requirements and frequency) aspects and include these as part of the design process;

- Address municipality and regulatory agency comments from earlier consultation meetings/discussions;

- Consider re-suspension impacts of retained sediments within each facility, from any major system flows discharging to a facility; and,

- Identify a post-construction monitoring program to assess storm water quality control performance/compliance for each SWM facility - as part of the work permitting stage and in conjunction with the issuance of Certificates of Approval under the Ontario Water Resources Act.

Section D.4 includes preliminary design details for the recommended SWM plan in order to secure planning approvals for various development blocks and phases within the Town of Collingwood. Functional servicing plan (detailed design) information will be necessary later on to secure timely approvals and confirm or amend the recommended design storage/controlled outflows and induced infiltration practices presented in this report.

D.3.5.4 Modelling Simulation Results

Utilizing our Visual OTTHYMO© and ISWMS™ pre-development and post-development condition models (refer to Appendix 'B' for schematics) surface water runoff simulations were undertaken for the 25 mm (first-flush), 2 year, 5 year, 10 year, 25 year, 50 year, 100 year and Regional Storm events. Initial conditions for the "controlled" and "over-controlled" post-development SWM models assumed empty detention storage facilities.

Results of our stormwater management modelling analysis are presented in Section D.4. For the 2 through 100 hydrologic models, the SCS-II (24-hour duration) design storm distributions were used. Appendix 'B' includes the hydrologic modelling output data for the Black Ash Creek system (i.e. existing and post-development (un-controlled) conditions). Tables 1 and 2 present the HEC-RAS modelling results using the ISWMS™ pre-development Regional Storm and 100 year peak flow database for existing and future Black Ash Creek Flood Control Project conditions.

## D.4 SUBWATERSHED MANAGEMENT PLAN

### *D.4.1 Development Controls*

D.4.1.1 General

Subwatershed management plans are prepared as an integral part of the municipal land use planning process. The methodology used for addressing stormwater drainage recognizes that when development is to occur within an area (whether it is on a watershed or subwatershed level) an *ecosystem approach* should be followed for mitigating environmental impacts from post-development stormwater runoff and snowmelt upon surface water and groundwater resources. The relationship between surface-groundwater regimes and the aquatic/terrestrial communities is also considered when assessing the potential for new development within a specified study area.

The goal of a stormwater management (SWM) plan, that forms part of subwatershed management plan, is to establish an environmentally sensitive approach, prior to the approval of any plan of subdivision, for the handling of stormwater runoff/snowmelt from an urbanizing area. It defines practical and environmentally sound source and/or end-of-pipe mitigative controls and provides conceptual design details which, when refined at the "functional servicing plan" or final design stage and implemented thereafter, will prevent adverse environmental impacts on the quantity/quality of both surface waters and groundwater.

**TABLE 1: HEC-RAS Flood Water Levels (Regional Storm & 100 Year) Using Pre-development Hydrology ISWMS Results with Existing Channel Conditions (i.e. November 1999 Field Survey by the NVCA and Greenland International)**

| Regional Storm Flood (With Spill from Main Branch) | | | | | 100 Year Flood (No Spill from Main Branch) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| HEC-RAS Model Reach | River Station | Peak Flow (m3/s) | Min Ch El (m) | W.S. Elev (m) | HEC-RAS Model Reach | River Station | Peak Flow (m3/s) | Min Ch El (m) | W.S. Elev (m) |
| Reach 1 (Main Branch) | 682 | 76.08 | 177.48 | 179.29 | Reach 1 (Main Branch) | 682 | 33.7 | 177.48 | 178.62 |
| Reach 1 (Main Branch) | 722 | 76.08 | 177.61 | 179.46 | Reach 1 (Main Branch) | 722 | 33.7 | 177.61 | 179.10 |
| Reach 1 (Main Branch) | 752 | 76.08 | 177.81 | 179.49 | Reach 1 (Main Branch) | 752 | 33.7 | 177.81 | 179.19 |
| Reach 1 (Main Branch) | 782 | 76.08 | 177.79 | 179.54 | Reach 1 (Main Branch) | 782 | 33.7 | 177.79 | 179.52 |
| Reach 1 (Main Branch) | 793 | 76.08 | 177.81 | 179.83 | Reach 1 (Main Branch) | 793 | 33.7 | 177.81 | 179.43 |
| Reach 1 (Main Branch) | 798.5 | Georgian Trail Culvert | | | Reach 1 (Main Branch) | 798.5 | Georgian Trail Culvert | | |
| Reach 1 (Main Branch) | 799 | 76.08 | 177.81 | 179.86 | Reach 1 (Main Branch) | 799 | 33.7 | 177.81 | 179.46 |
| Reach 1 (Main Branch) | 812 | 76.08 | 177.85 | 179.77 | Reach 1 (Main Branch) | 812 | 33.7 | 177.85 | 179.64 |
| Reach 1 (Main Branch) | 903 | 76.08 | 178.16 | 180.36 | Reach 1 (Main Branch) | 903 | 33.7 | 178.16 | 179.85 |
| Reach 1 (Main Branch) | 1003 | 76.08 | 178.55 | 180.9 | Reach 1 (Main Branch) | 1003 | 33.7 | 178.55 | 180.28 |
| Reach 1 (Main Branch) | 1083 | 76.08 | 178.88 | 180.96 | Reach 1 (Main Branch) | 1083 | 33.7 | 178.88 | 180.71 |
| Reach 1 (Main Branch) | 1103 | 76.08 | 178.88 | 180.77 | Reach 1 (Main Branch) | 1103 | 33.7 | 178.88 | 180.68 |
| Reach 1 (Main Branch) | 1114.5 | Old Mountain Road Bridge | | | Reach 1 (Main Branch) | 1114.5 | Old Mountain Road Bridge | | |
| Reach 1 (Main Branch) | 1115 | 76.08 | 179 | 181 | Reach 1 (Main Branch) | 1115 | 33.7 | 179.00 | 180.69 |
| Reach 1 (Main Branch) | 1126 | 76.08 | 179.12 | 181.45 | Reach 1 (Main Branch) | 1126 | 33.7 | 179.12 | 180.72 |
| Reach 1 (Main Branch) | 1251 | 76.08 | 179.72 | 181.7 | Reach 1 (Main Branch) | 1251 | 33.7 | 179.72 | 181.14 |
| Reach 1 (Main Branch) | 1376 | 76.08 | 180.4 | 182.54 | Reach 1 (Main Branch) | 1376 | 33.7 | 180.40 | 182.15 |
| Reach 1 (Main Branch) | 1501 | 76.08 | 181.5 | 183.53 | Reach 1 (Main Branch) | 1501 | 33.7 | 181.50 | 182.77 |
| Reach 1 (Main Branch) | 1626 | 76.08 | 182.61 | 184.44 | Reach 1 (Main Branch) | 1626 | 33.7 | 182.61 | 183.94 |
| Reach 2 (Main Branch) | 1760 | 67.38 | 183.15 | 185.5 | Reach 2 (Main Branch) | 1760 | 31.1 | 183.15 | 184.72 |
| Reach 2 (Main Branch) | 1964 | 67.38 | 184.72 | 186.7 | Reach 2 (Main Branch) | 1964 | 31.1 | 184.72 | 186.04 |
| Reach 2 (Main Branch) | 2065 | 67.38 | 185.63 | 187.61 | Reach 2 (Main Branch) | 2065 | 31.1 | 185.63 | 187.00 |
| Reach 2 (Main Branch) | 2165 | 67.38 | 186.55 | 188.53 | Reach 2 (Main Branch) | 2165 | 31.1 | 186.55 | 187.87 |
| Reach 3 (South Branch) | 2265 | 44.78 | 187.35 | 189.55 | Reach 3 (South Branch) | 2265 | 25.7 | 187.35 | 188.79 |
| Reach 3 (South Branch) | 2315 | 44.78 | 187.45 | 189.68 | Reach 3 (South Branch) | 2315 | 25.7 | 187.45 | 189.05 |
| Reach 3 (South Branch) | 2365 | 44.78 | 187.55 | 189.81 | Reach 3 (South Branch) | 2365 | 25.7 | 187.55 | 189.21 |
| Reach 3 (South Branch) | 2416 | 44.78 | 187.65 | 189.93 | Reach 3 (South Branch) | 2416 | 25.7 | 187.65 | 189.35 |
| Reach 3 (South Branch) | 2466 | 44.78 | 187.75 | 190.04 | Reach 3 (South Branch) | 2466 | 25.7 | 187.75 | 189.47 |
| Reach 3 (South Branch) | 2518 | 44.78 | 187.85 | 190.16 | Reach 3 (South Branch) | 2518 | 25.7 | 187.85 | 189.59 |
| Reach 3 (South Branch) | 2543 | 44.78 | 187.9 | 190.95 | Reach 3 (South Branch) | 2543 | 25.7 | 187.90 | 189.47 |
| Reach 3 (South Branch) | 2555 | Sixth Street SPCSPA Culvert | | | Reach 3 (South Branch) | 2555 | Sixth Street SPCSPA Culvert | | |
| Reach 3 (South Branch) | 2568 | 44.78 | 187.95 | 191.64 | Reach 3 (South Branch) | 2568 | 25.7 | 187.95 | 190.89 |
| Reach 3 (South Branch) | 2593 | 44.78 | 188 | 191.64 | Reach 3 (South Branch) | 2593 | 25.7 | 188.00 | 191.15 |
| Reach 3 (South Branch) | 2793 | 69.34 | 188.42 | 191.71 | Reach 3 (South Branch) | 2793 | 25.7 | 188.42 | 191.19 |
| Reach 3 (South Branch) | 2997 | 70.23 | 188.83 | 191.76 | Reach 3 (South Branch) | 2997 | 25.7 | 188.83 | 191.27 |
| Reach 3 (South Branch) | 3097 | 70.58 | 189.04 | 191.96 | Reach 3 (South Branch) | 3097 | 25.7 | 189.04 | 191.32 |
| Reach 3 (South Branch) | 3228 | 70.63 | 189.31 | 192.22 | Reach 3 (South Branch) | 3228 | 25.7 | 189.31 | 191.42 |
| Reach 3 (South Branch) | 3428 | 71.7 | 189.73 | 192.64 | Reach 3 (South Branch) | 3428 | 25.7 | 189.73 | 191.64 |
| Reach 3 (South Branch) | 3528 | 72 | 189.95 | 192.85 | Reach 3 (South Branch) | 3528 | 25.7 | 189.95 | 191.79 |
| Reach 3 (South Branch) | 3570 | 47.2 | 190.16 | 193 | Reach 3 (South Branch) | 3570 | 21.3 | 190.16 | 191.84 |
| Reach 3 (South Branch) | 3801 | 47.2 | 192.67 | 194.32 | Reach 3 (South Branch) | 3801 | 21.3 | 192.67 | 193.82 |
| Reach 3 (South Branch) | 3908 | 47.2 | 193.25 | 195.44 | Reach 3 (South Branch) | 3908 | 21.3 | 193.25 | 195.02 |
| Reach 3 (South Branch) | 4026 | 47.2 | 194.27 | 196.02 | Reach 3 (South Branch) | 4026 | 21.3 | 194.27 | 195.71 |
| Reach 3 (South Branch) | 4171 | 47.2 | 195.89 | 197.37 | Reach 3 (South Branch) | 4171 | 21.3 | 195.89 | 197.00 |
| Reach 3 (South Branch) | 4326 | 47.2 | 197.05 | 198.81 | Reach 3 (South Branch) | 4326 | 21.3 | 197.05 | 198.35 |
| Reach 3 (South Branch) | 4424 | 47.2 | 197.96 | 199.55 | Reach 3 (South Branch) | 4424 | 21.3 | 197.96 | 199.04 |
| Reach 3 (South Branch) | 4574 | 47.2 | 199.04 | 200.55 | Reach 3 (South Branch) | 4574 | 21.3 | 199.04 | 200.08 |
| Reach 3 (South Branch) | 4631 | 47.2 | 200.1 | 202.35 | Reach 3 (South Branch) | 4631 | 21.3 | 200.10 | 201.80 |
| Reach 3 (South Branch) | 4775 | 47.2 | 201.17 | 203.57 | Reach 3 (South Branch) | 4775 | 21.3 | 201.17 | 202.94 |
| Reach 3 (South Branch) | 5004 | 47.2 | 202.38 | 204.3 | Reach 3 (South Branch) | 5004 | 21.3 | 202.38 | 203.79 |
| Reach 3 (South Branch) | 5076 | 47.2 | 202.3 | 204.88 | Reach 3 (South Branch) | 5076 | 21.3 | 202.30 | 204.31 |
| Reach 3 (South Branch) | 5188 | 47.2 | 202.9 | 204.84 | Reach 3 (South Branch) | 5188 | 21.3 | 202.90 | 204.46 |
| Reach 3 (South Branch) | 5425 | 47.2 | 205.2 | 206.96 | Reach 3 (South Branch) | 5425 | 21.3 | 205.20 | 206.32 |
| Reach 3 (South Branch) | 5614 | 47.2 | 208.6 | 210.67 | Reach 3 (South Branch) | 5614 | 21.3 | 208.60 | 209.96 |
| Reach 3 (South Branch) | 5634 | 47.2 | 209.28 | 211.72 | Reach 3 (South Branch) | 5634 | 21.3 | 209.28 | 211.72 |
| Reach 3 (South Branch) | 5637 | Tenth Line CSP Culvert | | | Reach 3 (South Branch) | 5637 | Tenth Line CSP Culvert | | |
| Reach 3 (South Branch) | 5648 | 47.2 | 209.75 | 213.03 | Reach 3 (South Branch) | 5648 | 21.3 | 209.75 | 212.82 |
| Reach 3 (South Branch) | 5656 | 47.2 | 210.02 | 213.02 | Reach 3 (South Branch) | 5656 | 21.3 | 210.02 | 212.82 |
| Reach 3 (South Branch) | 5796 | 47.2 | 212.9 | 215.03 | Reach 3 (South Branch) | 5796 | 21.3 | 212.90 | 214.49 |
| Reach 3 (South Branch) | 5966 | 47.2 | 214.9 | 216.69 | Reach 3 (South Branch) | 5966 | 21.3 | 214.90 | 216.28 |
| Reach 3 (South Branch) | 6065 | 47.2 | 216.7 | 218.14 | Reach 3 (South Branch) | 6065 | 21.3 | 216.70 | 217.79 |
| Tributary 1 (West Tributary) | 101 | 9.8 | 188.04 | 188.96 | Tributary 1 (West Tributary) | 101 | 2.9 | 188.04 | 188.71 |
| Tributary 1 (West Tributary) | 102 | 9.8 | 189.81 | 190.53 | Tributary 1 (West Tributary) | 102 | 2.9 | 189.81 | 190.36 |
| Tributary 1 (West Tributary) | 103 | 9.8 | 191.27 | 192.39 | Tributary 1 (West Tributary) | 103 | 2.9 | 191.27 | 192.02 |
| Tributary 1 (West Tributary) | 104 | 9.8 | 191.57 | 192.83 | Tributary 1 (West Tributary) | 104 | 2.9 | 191.57 | 192.37 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Tributary 2 (North Branch) | 201 | 30 | 187.75 | 189.55 | Tributary 2 (North Branch) | 201 | 9.5 | 187.75 | 188.89 |
| Tributary 2 (North Branch) | 202 | 30 | 187.79 | 189.74 | Tributary 2 (North Branch) | 202 | 9.5 | 187.79 | 188.96 |
| Tributary 2 (North Branch) | 203 | 30 | 188.84 | 190.62 | Tributary 2 (North Branch) | 203 | 9.5 | 188.84 | 190.27 |
| Tributary 2 (North Branch) | 204 | 30 | 189.37 | 190.71 | Tributary 2 (North Branch) | 204 | 9.5 | 189.37 | 190.54 |
| Tributary 2 (North Branch) | 205 | 30 | 190.06 | 191.03 | Tributary 2 (North Branch) | 205 | 9.5 | 190.06 | 190.72 |
| Tributary 2 (North Branch) | 206 | 30 | 189.94 | 191.45 | Tributary 2 (North Branch) | 206 | 9.5 | 189.94 | 191.30 |
| Tributary 2 (North Branch) | 207 | 30 | 190.44 | 192.04 | Tributary 2 (North Branch) | 207 | 9.5 | 190.44 | 191.33 |
| Tributary 2 (North Branch) | 208 | 30 | 190.57 | 191.82 | Tributary 2 (North Branch) | 208 | 9.5 | 190.57 | 191.63 |
| Tributary 2 (North Branch) | 209 | 30 | 190.52 | 192.3 | Tributary 2 (North Branch) | 209 | 9.5 | 190.52 | 191.66 |
| Tributary 2 (North Branch) | 210 | 30 | 190.61 | 192.53 | Tributary 2 (North Branch) | 210 | 9.5 | 190.61 | 192.12 |
| Tributary 2 (North Branch) | 210.2 | Sixth Street CSP Culvert | | | Tributary 2 (North Branch) | 210.2 | Sixth Street CSP Culvert | | |
| Tributary 2 (North Branch) | 211 | 30 | 190.94 | 193.25 | Tributary 2 (North Branch) | 211 | 9.5 | 190.94 | 192.95 |
| Tributary 2 (North Branch) | 211.5 | 30 | 191 | 193.27 | Tributary 2 (North Branch) | 211.5 | 9.5 | 191.00 | 194.23 |
| Tributary 2 (North Branch) | 212 | 30 | 191.54 | 193.25 | Tributary 2 (North Branch) | 212 | 9.5 | 191.54 | 194.23 |
| Tributary 2 (North Branch) | 213 | 30 | 192.61 | 194.2 | Tributary 2 (North Branch) | 213 | 9.5 | 192.61 | 194.20 |
| Tributary 2 (North Branch) | 214 | 30 | 194.57 | 195.64 | Tributary 2 (North Branch) | 214 | 9.5 | 194.57 | 195.19 |
| Tributary 2 (North Branch) | 215 | 30 | 194.93 | 196.85 | Tributary 2 (North Branch) | 215 | 9.5 | 194.93 | 196.07 |
| Tributary 2 (North Branch) | 216 | 30 | 195.05 | 197.32 | Tributary 2 (North Branch) | 216 | 9.5 | 195.05 | 196.55 |
| Tributary 2 (North Branch) | 217 | 30 | 195.47 | 197.47 | Tributary 2 (North Branch) | 217 | 9.5 | 195.47 | 196.74 |
| Tributary 2 (North Branch) | 218 | 30 | 197.28 | 199.02 | Tributary 2 (North Branch) | 218 | 9.5 | 197.28 | 198.29 |
| Tributary 2 (North Branch) | 219 | 30 | 197.41 | 199.51 | Tributary 2 (North Branch) | 219 | 9.5 | 197.41 | 198.65 |
| Tributary 2 (North Branch) | 220 | 30 | 197.69 | 199.59 | Tributary 2 (North Branch) | 220 | 9.5 | 197.69 | 198.99 |
| Tributary 2 (North Branch) | 221 | 30 | 198.4 | 200.38 | Tributary 2 (North Branch) | 221 | 9.5 | 198.40 | 199.67 |
| Tributary 2 (North Branch) | 222 | 30 | 198.81 | 200.74 | Tributary 2 (North Branch) | 222 | 9.5 | 198.81 | 200.01 |
| Tributary 2 (North Branch) | 223 | 30 | 198.86 | 200.86 | Tributary 2 (North Branch) | 223 | 9.5 | 198.86 | 200.14 |

**TABLE 2: HEC-RAS Flood Water Levels (Regional Storm & 100 Year) Using Pre-development Hydrology ISWMS Results with Proposed Flood Control Design Conditions by Ainley & Associates Limited**

| Regional Storm Flood (No Spill from Channelization) | | | | | 100 Year Flood (No Spill from Channelization) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| HEC-RAS Model Reach | River Station | Peak Flow (m3/s) | Min Ch El (m) | W.S. Elev (m) | HEC-RAS Model Reach | River Station | Peak Flow (m3/s) | Min Ch El (m) | W.S. Elev (m) |
| Reach 1 (Main Branch) | 170 | 103.3 | 175.00 | 176.67 | Reach 1 (Main Branch) | 170 | 33.7 | 175 | 176.67 |
| Reach 1 (Main Branch) | 190 | 103.3 | 174.99 | 177.23 | Reach 1 (Main Branch) | 190 | 33.7 | 174.99 | 176.98 |
| Reach 1 (Main Branch) | 210 | 103.3 | 175.01 | 177.28 | Reach 1 (Main Branch) | 210 | 33.7 | 175.01 | 177.49 |
| Reach 1 (Main Branch) | 230 | 103.3 | 175.01 | 177.29 | Reach 1 (Main Branch) | 230 | 33.7 | 175.01 | 177.49 |
| Reach 1 (Main Branch) | 250 | 103.3 | 175.02 | 177.67 | Reach 1 (Main Branch) | 250 | 33.7 | 175.02 | 177.39 |
| Reach 1 (Main Branch) | 270 | 103.3 | 175.02 | 177.71 | Reach 1 (Main Branch) | 270 | 33.7 | 175.02 | 177.55 |
| Reach 1 (Main Branch) | 290 | 103.3 | 175.02 | 177.78 | Reach 1 (Main Branch) | 290 | 33.7 | 175.02 | 177.57 |
| Reach 1 (Main Branch) | 310 | 103.3 | 175.03 | 177.82 | Reach 1 (Main Branch) | 310 | 33.7 | 175.03 | 177.58 |
| Reach 1 (Main Branch) | 330 | 103.3 | 175.03 | 177.87 | Reach 1 (Main Branch) | 330 | 33.7 | 175.03 | 177.59 |
| Reach 1 (Main Branch) | 350 | 103.3 | 175.04 | 177.85 | Reach 1 (Main Branch) | 350 | 33.7 | 175.04 | 177.62 |
| Reach 1 (Main Branch) | 370 | 103.3 | 175.04 | 177.88 | Reach 1 (Main Branch) | 370 | 33.7 | 175.04 | 177.62 |
| Reach 1 (Main Branch) | 390 | 103.3 | 175.05 | 177.91 | Reach 1 (Main Branch) | 390 | 33.7 | 175.05 | 177.63 |
| Reach 1 (Main Branch) | 450 | 103.3 | 175.06 | 177.98 | Reach 1 (Main Branch) | 450 | 33.7 | 175.06 | 177.64 |
| Reach 1 (Main Branch) | 490 | 103.3 | 175.07 | 178.03 | Reach 1 (Main Branch) | 490 | 33.7 | 175.07 | 177.64 |
| Reach 1 (Main Branch) | 502 | 103.3 | 175.07 | 178.04 | Reach 1 (Main Branch) | 502 | 33.7 | 175.07 | 177.65 |
| Reach 1 (Main Branch) | 544 | Highway 26 Bridge | | | Reach 1 (Main Branch) | 544 | Highway 26 Bridge | | |
| Reach 1 (Main Branch) | 574 | 103.3 | 175.36 | 178.02 | Reach 1 (Main Branch) | 574 | 33.7 | 175.36 | 177.64 |
| Reach 1 (Main Branch) | 590 | 103.3 | 175.43 | 178.04 | Reach 1 (Main Branch) | 590 | 33.7 | 175.43 | 177.64 |
| Reach 1 (Main Branch) | 630 | 103.3 | 175.51 | 178.10 | Reach 1 (Main Branch) | 630 | 33.7 | 175.51 | 177.65 |
| Reach 1 (Main Branch) | 650 | 103.3 | 175.55 | 178.13 | Reach 1 (Main Branch) | 650 | 33.7 | 175.55 | 177.66 |
| Reach 1 (Main Branch) | 670 | 103.3 | 175.65 | 178.18 | Reach 1 (Main Branch) | 670 | 33.7 | 175.65 | 177.67 |
| Reach 1 (Main Branch) | 710 | 103.3 | 175.84 | 178.22 | Reach 1 (Main Branch) | 710 | 33.7 | 175.84 | 177.68 |
| Reach 1 (Main Branch) | 730 | 103.3 | 175.94 | 178.24 | Reach 1 (Main Branch) | 730 | 33.7 | 175.94 | 177.68 |
| Reach 1 (Main Branch) | 750 | 103.3 | 176.03 | 178.27 | Reach 1 (Main Branch) | 750 | 33.7 | 176.03 | 177.69 |
| Reach 1 (Main Branch) | 790 | Old Mountain Road Bridge | | | Reach 1 (Main Branch) | 790 | Old Mountain Road Bridge | | |
| Reach 1 (Main Branch) | 850 | 103.3 | 176.51 | 178.46 | Reach 1 (Main Branch) | 850 | 33.7 | 176.51 | 177.76 |
| Reach 1 (Main Branch) | 880 | 103.3 | 176.65 | 178.65 | Reach 1 (Main Branch) | 880 | 33.7 | 176.65 | 177.85 |
| Reach 1 (Main Branch) | 890 | 103.3 | 176.70 | 178.78 | Reach 1 (Main Branch) | 890 | 33.7 | 176.7 | 177.92 |
| Reach 1 (Main Branch) | 1130 | 103.3 | 177.92 | 179.52 | Reach 1 (Main Branch) | 1130 | 33.7 | 177.92 | 178.61 |
| Reach 1 (Main Branch) | 1190 | 103.3 | 178.36 | 179.88 | Reach 1 (Main Branch) | 1190 | 33.7 | 178.36 | 179.19 |
| Reach 1 (Main Branch) | 1195 | 103.3 | 178.39 | 179.92 | Reach 1 (Main Branch) | 1195 | 33.7 | 178.39 | 179.22 |
| Reach 1 (Main Branch) | 1215 | 103.3 | 178.52 | 180.09 | Reach 1 (Main Branch) | 1215 | 33.7 | 178.52 | 179.34 |
| Reach 1 (Main Branch) | 1241 | Sixth Street SPCSPA Culvert | | | Reach 1 (Main Branch) | 1241 | Sixth Street SPCSPA Culvert | | |
| Reach 1 (Main Branch) | 1253 | 103.3 | 178.60 | 180.53 | Reach 1 (Main Branch) | 1253 | 33.7 | 178.6 | 179.51 |
| Reach 1 (Main Branch) | 1270 | 103.3 | 178.64 | 180.62 | Reach 1 (Main Branch) | 1270 | 33.7 | 178.64 | 179.76 |
| Reach 1 (Main Branch) | 1290 | 103.3 | 178.79 | 181.10 | Reach 1 (Main Branch) | 1290 | 33.7 | 178.79 | 179.93 |
| Reach 1 (Main Branch) | 1350 | 103.3 | 179.25 | 181.69 | Reach 1 (Main Branch) | 1350 | 33.7 | 179.25 | 180.38 |
| Reach 1 (Main Branch) | 1410 | 103.3 | 179.71 | 181.84 | Reach 1 (Main Branch) | 1410 | 33.7 | 179.71 | 180.73 |
| Reach 1 (Main Branch) | 1450 | 103.3 | 180.01 | 182.04 | Reach 1 (Main Branch) | 1450 | 33.7 | 180.01 | 181.05 |
| Reach 1 (Main Branch) | 1530 | 103.3 | 180.62 | 182.57 | Reach 1 (Main Branch) | 1530 | 33.7 | 180.62 | 181.65 |
| Reach 1 (Main Branch) | 1535 | 103.3 | 180.65 | 182.61 | Reach 1 (Main Branch) | 1535 | 33.7 | 180.65 | 181.69 |
| Reach 1 (Main Branch) | 1540 | 103.3 | 180.69 | 182.65 | Reach 1 (Main Branch) | 1540 | 33.7 | 180.69 | 181.73 |
| Reach 1 (Main Branch) | 1550 | 103.3 | 180.77 | 182.73 | Reach 1 (Main Branch) | 1550 | 33.7 | 180.77 | 181.8 |
| Reach 1 (Main Branch) | 1555 | 103.3 | 180.81 | 182.77 | Reach 1 (Main Branch) | 1555 | 33.7 | 180.81 | 181.84 |
| Reach 1 (Main Branch) | 1560 | 103.3 | 180.84 | 182.80 | Reach 1 (Main Branch) | 1560 | 33.7 | 180.84 | 181.88 |
| Reach 1 (Main Branch) | 1570 | 103.3 | 180.92 | 182.88 | Reach 1 (Main Branch) | 1570 | 33.7 | 180.92 | 181.96 |
| Reach 1 (Main Branch) | 1630 | 103.3 | 181.38 | 183.34 | Reach 1 (Main Branch) | 1630 | 33.7 | 181.38 | 182.41 |
| Reach 1 (Main Branch) | 1650 | 103.3 | 181.53 | 183.49 | Reach 1 (Main Branch) | 1650 | 33.7 | 181.53 | 182.56 |
| Reach 1 (Main Branch) | 1670 | 103.3 | 181.68 | 183.64 | Reach 1 (Main Branch) | 1670 | 33.7 | 181.68 | 182.71 |
| Reach 1 (Main Branch) | 1680 | 103.3 | 181.76 | 183.72 | Reach 1 (Main Branch) | 1680 | 33.7 | 181.76 | 182.79 |
| Reach 1 (Main Branch) | 1750 | 103.3 | 182.29 | 184.25 | Reach 1 (Main Branch) | 1750 | 33.7 | 182.29 | 183.32 |
| | | | | | | | | | |
| Reach 2 (Main Branch) | 1830 | 94.6 | 182.89 | 185.25 | Reach 2 (Main Branch) | 1830 | 31.1 | 182.89 | 184.13 |
| Reach 2 (Main Branch) | 1850 | 94.6 | 183.03 | 185.30 | Reach 2 (Main Branch) | 1850 | 31.1 | 183.03 | 184.19 |
| Reach 2 (Main Branch) | 1870 | 94.6 | 183.15 | 185.36 | Reach 2 (Main Branch) | 1870 | 31.1 | 183.15 | 184.27 |
| Reach 2 (Main Branch) | 1890 | 94.6 | 183.29 | 185.42 | Reach 2 (Main Branch) | 1890 | 31.1 | 183.29 | 184.36 |
| Reach 2 (Main Branch) | 1900 | 94.6 | 183.35 | 185.46 | Reach 2 (Main Branch) | 1900 | 31.1 | 183.35 | 184.42 |
| Reach 2 (Main Branch) | 1920 | 94.6 | 183.48 | 185.54 | Reach 2 (Main Branch) | 1920 | 31.1 | 183.48 | 184.53 |
| Reach 2 (Main Branch) | 1930 | 94.6 | 183.54 | 185.59 | Reach 2 (Main Branch) | 1930 | 31.1 | 183.54 | 184.59 |
| Reach 2 (Main Branch) | 1950 | 94.6 | 183.67 | 185.69 | Reach 2 (Main Branch) | 1950 | 31.1 | 183.67 | 184.72 |
| Reach 2 (Main Branch) | 2050 | 94.6 | 184.25 | 186.27 | Reach 2 (Main Branch) | 2050 | 31.1 | 184.25 | 185.33 |
| Reach 2 (Main Branch) | 2070 | 94.6 | 184.36 | 186.39 | Reach 2 (Main Branch) | 2070 | 31.1 | 184.36 | 185.44 |
| Reach 2 (Main Branch) | 2090 | 94.6 | 184.46 | 186.51 | Reach 2 (Main Branch) | 2090 | 31.1 | 184.46 | 185.55 |
| Reach 2 (Main Branch) | 2155 | 94.6 | 184.78 | 186.89 | Reach 2 (Main Branch) | 2155 | 31.1 | 184.78 | 185.9 |
| Reach 2 (Main Branch) | 2170 | 94.6 | 184.85 | 186.96 | Reach 2 (Main Branch) | 2170 | 31.1 | 184.85 | 185.98 |
| Reach 2 (Main Branch) | 2180 | 94.6 | 184.90 | 187.01 | Reach 2 (Main Branch) | 2180 | 31.1 | 184.9 | 186.03 |
| Reach 2 (Main Branch) | 2190 | 94.6 | 184.94 | 187.07 | Reach 2 (Main Branch) | 2190 | 31.1 | 184.94 | 186.08 |
| Reach 2 (Main Branch) | 2230 | 94.6 | 185.11 | 187.27 | Reach 2 (Main Branch) | 2230 | 31.1 | 185.11 | 186.27 |
| Reach 2 (Main Branch) | 2260 | 94.6 | 185.23 | 187.46 | Reach 2 (Main Branch) | 2260 | 31.1 | 185.23 | 186.46 |
| | | | | | | | | | |
| Reach 3 (South Branch) | 2280 | 72 | 185.31 | 188.38 | Reach 3 (South Branch) | 2280 | 25.7 | 185.31 | 187.15 |
| Reach 3 (South Branch) | 2300 | 72 | 185.38 | 188.40 | Reach 3 (South Branch) | 2300 | 25.7 | 185.38 | 187.17 |
| Reach 3 (South Branch) | 2370 | 72 | 185.62 | 188.47 | Reach 3 (South Branch) | 2370 | 25.7 | 185.62 | 187.27 |
| Reach 3 (South Branch) | 2450 | 72 | 185.85 | 188.59 | Reach 3 (South Branch) | 2450 | 25.7 | 185.85 | 187.43 |
| Reach 3 (South Branch) | 2470 | 72 | 185.89 | 188.63 | Reach 3 (South Branch) | 2470 | 25.7 | 185.89 | 187.48 |
| Reach 3 (South Branch) | 2550 | 72 | 186.06 | 188.78 | Reach 3 (South Branch) | 2550 | 25.7 | 186.06 | 187.67 |
| Reach 3 (South Branch) | 2570 | 72 | 186.10 | 188.82 | Reach 3 (South Branch) | 2570 | 25.7 | 186.1 | 187.71 |
| Reach 3 (South Branch) | 2593 | 72 | 186.12 | 188.65 | Reach 3 (South Branch) | 2593 | 25.7 | 186.12 | 187.73 |
| Reach 3 (South Branch) | 2610 | 72 | 186.13 | 188.89 | Reach 3 (South Branch) | 2610 | 25.7 | 186.13 | 187.81 |
| Reach 3 (South Branch) | 2630 | 72 | 186.15 | 189.58 | Reach 3 (South Branch) | 2630 | 25.7 | 186.15 | 187.97 |
| Reach 3 (South Branch) | 2650 | 72 | 186.17 | 189.59 | Reach 3 (South Branch) | 2650 | 25.7 | 186.17 | 188.01 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Reach 3 (South Branch) | 2670 | 72 | 186.18 | 189.61 | Reach 3 (South Branch) | 2670 | 25.7 | 186.18 | 188.04 |
| Reach 3 (South Branch) | 2770 | 72 | 186.31 | 189.68 | Reach 3 (South Branch) | 2770 | 25.7 | 186.31 | 188.19 |
| Reach 3 (South Branch) | 2870 | 72 | 186.63 | 189.75 | Reach 3 (South Branch) | 2870 | 25.7 | 186.63 | 188.34 |
| Reach 3 (South Branch) | 2970 | 72 | 186.96 | 189.85 | Reach 3 (South Branch) | 2970 | 25.7 | 186.96 | 188.57 |
| Reach 3 (South Branch) | 3050 | 72 | 187.21 | 189.97 | Reach 3 (South Branch) | 3050 | 25.7 | 187.21 | 188.79 |
| Reach 3 (South Branch) | 3070 | 72 | 187.28 | 190.01 | Reach 3 (South Branch) | 3070 | 25.7 | 187.28 | 188.85 |
| Reach 3 (South Branch) | 3090 | 72 | 187.34 | 190.04 | Reach 3 (South Branch) | 3090 | 25.7 | 187.34 | 188.92 |
| Reach 3 (South Branch) | 3110 | 72 | 187.41 | 190.08 | Reach 3 (South Branch) | 3110 | 25.7 | 187.41 | 188.98 |
| Reach 3 (South Branch) | 3150 | 72 | 187.53 | 190.17 | Reach 3 (South Branch) | 3150 | 25.7 | 187.53 | 189.1 |
| Reach 3 (South Branch) | 3170 | 72 | 187.60 | 190.22 | Reach 3 (South Branch) | 3170 | 25.7 | 187.6 | 189.16 |
| Reach 3 (South Branch) | 3270 | 72 | 187.92 | 190.47 | Reach 3 (South Branch) | 3270 | 25.7 | 187.92 | 189.48 |
| Reach 3 (South Branch) | 3290 | 72 | 187.99 | 190.53 | Reach 3 (South Branch) | 3290 | 25.7 | 187.99 | 189.55 |
| Reach 3 (South Branch) | 3370 | 53.2 | 188.26 | 190.87 | Reach 3 (South Branch) | 3370 | 21.3 | 188.26 | 189.83 |
| Reach 3 (South Branch) | 3450 | 53.2 | 188.57 | 190.97 | Reach 3 (South Branch) | 3450 | 21.3 | 188.57 | 190.01 |
| Reach 3 (South Branch) | 3470 | 53.2 | 188.65 | 191.00 | Reach 3 (South Branch) | 3470 | 21.3 | 188.65 | 190.07 |
| Reach 3 (South Branch) | 3510 | 53.2 | 188.83 | 191.08 | Reach 3 (South Branch) | 3510 | 21.3 | 188.83 | 190.2 |
| Reach 3 (South Branch) | 3530 | 53.2 | 188.92 | 191.13 | Reach 3 (South Branch) | 3530 | 21.3 | 188.92 | 190.27 |
| Reach 3 (South Branch) | 3550 | 53.2 | 189.01 | 191.18 | Reach 3 (South Branch) | 3550 | 21.3 | 189.01 | 190.35 |
| Reach 3 (South Branch) | 3560 | 53.2 | 189.06 | 191.20 | Reach 3 (South Branch) | 3560 | 21.3 | 189.06 | 190.39 |
| Reach 3 (South Branch) | 3570 | 53.2 | 189.11 | 191.23 | Reach 3 (South Branch) | 3570 | 21.3 | 189.11 | 190.43 |
| Reach 3 (South Branch) | 3590 | 53.2 | 189.20 | 191.29 | Reach 3 (South Branch) | 3590 | 21.3 | 189.2 | 190.52 |
| Reach 3 (South Branch) | 3610 | 53.2 | 189.31 | 191.36 | Reach 3 (South Branch) | 3610 | 21.3 | 189.31 | 190.61 |
| Reach 3 (South Branch) | 3630 | 53.2 | 189.40 | 191.44 | Reach 3 (South Branch) | 3630 | 21.3 | 189.4 | 190.7 |
| Reach 3 (South Branch) | 3700 | 53.2 | 191.60 | 192.74 | Reach 3 (South Branch) | 3700 | 21.3 | 191.6 | 192.4 |
| Reach 3 (South Branch) | 3801 | 53.2 | 192.67 | 194.46 | Reach 3 (South Branch) | 3801 | 21.3 | 192.67 | 193.91 |
| Reach 3 (South Branch) | 3908 | 53.2 | 193.25 | 195.49 | Reach 3 (South Branch) | 3908 | 21.3 | 193.25 | 195.02 |
| Reach 3 (South Branch) | 4026 | 53.2 | 194.27 | 196.09 | Reach 3 (South Branch) | 4026 | 21.3 | 194.27 | 195.71 |
| Reach 3 (South Branch) | 4171 | 53.2 | 195.89 | 197.44 | Reach 3 (South Branch) | 4171 | 21.3 | 195.89 | 197 |
| Reach 3 (South Branch) | 4326 | 53.2 | 197.05 | 198.89 | Reach 3 (South Branch) | 4326 | 21.3 | 197.05 | 198.35 |
| Reach 3 (South Branch) | 4424 | 53.2 | 197.96 | 199.64 | Reach 3 (South Branch) | 4424 | 21.3 | 197.96 | 199.04 |
| Reach 3 (South Branch) | 4574 | 53.2 | 199.04 | 200.64 | Reach 3 (South Branch) | 4574 | 21.3 | 199.04 | 200.08 |
| Reach 3 (South Branch) | 4631 | 53.2 | 200.10 | 202.45 | Reach 3 (South Branch) | 4631 | 21.3 | 200.1 | 201.8 |
| Reach 3 (South Branch) | 4775 | 53.2 | 201.17 | 203.69 | Reach 3 (South Branch) | 4775 | 21.3 | 201.17 | 202.94 |
| Reach 3 (South Branch) | 5004 | 53.2 | 202.38 | 204.40 | Reach 3 (South Branch) | 5004 | 21.3 | 202.38 | 203.79 |
| Reach 3 (South Branch) | 5076 | 53.2 | 202.30 | 204.97 | Reach 3 (South Branch) | 5076 | 21.3 | 202.3 | 204.31 |
| Reach 3 (South Branch) | 5188 | 53.2 | 202.90 | 204.88 | Reach 3 (South Branch) | 5188 | 21.3 | 202.9 | 204.46 |
| Reach 3 (South Branch) | 5425 | 47.2 | 205.20 | 207.03 | Reach 3 (South Branch) | 5425 | 19.7 | 205.2 | 206.28 |
| Reach 3 (South Branch) | 5614 | 47.2 | 208.60 | 210.67 | Reach 3 (South Branch) | 5614 | 19.7 | 208.6 | 209.9 |
| Reach 3 (South Branch) | 5634 | 47.2 | 209.28 | 211.72 | Reach 3 (South Branch) | 5634 | 19.7 | 209.28 | 211.72 |
| Reach 3 (South Branch) | 5637 | Tenth Line CSP Culvert | | | Reach 3 (South Branch) | 5637 | Tenth Line CSP Culvert | | |
| Reach 3 (South Branch) | 5648 | 47.2 | 209.75 | 213.03 | Reach 3 (South Branch) | 5648 | 19.7 | 209.75 | 212.79 |
| Reach 3 (South Branch) | 5656 | 47.2 | 210.02 | 213.02 | Reach 3 (South Branch) | 5656 | 19.7 | 210.02 | 212.79 |
| Reach 3 (South Branch) | 5796 | 47.2 | 212.90 | 215.03 | Reach 3 (South Branch) | 5796 | 19.7 | 212.9 | 214.45 |
| Reach 3 (South Branch) | 5966 | 47.2 | 214.90 | 216.69 | Reach 3 (South Branch) | 5966 | 19.7 | 214.9 | 216.25 |
| Reach 3 (South Branch) | 6065 | 47.2 | 216.70 | 218.14 | Reach 3 (South Branch) | 6065 | 19.7 | 216.7 | 217.77 |
| | | | | | | | | | |
| Tributary 1 (West Tributar | 101 | 9.8 | 188.04 | 188.95 | Tributary 1 (West Tributary | 101 | 2.9 | 188.04 | 188.71 |
| Tributary 1 (West Tributar | 102 | 9.8 | 189.81 | 190.53 | Tributary 1 (West Tributary | 102 | 2.9 | 189.81 | 190.35 |
| Tributary 1 (West Tributar | 103 | 9.8 | 191.27 | 192.39 | Tributary 1 (West Tributary | 103 | 2.9 | 191.27 | 192.03 |
| Tributary 1 (West Tributar | 104 | 9.8 | 191.57 | 192.83 | Tributary 1 (West Tributary | 104 | 2.9 | 191.57 | 192.37 |
| | | | | | | | | | |
| Tributary 2 (North Branch | 201 | 30 | 187.75 | 189.39 | Tributary 2 (North Branch) | 201 | 9.5 | 187.75 | 188.64 |
| Tributary 2 (North Branch | 202 | 30 | 187.79 | 189.74 | Tributary 2 (North Branch) | 202 | 9.5 | 187.79 | 188.94 |
| Tributary 2 (North Branch | 203 | 30 | 188.84 | 190.68 | Tributary 2 (North Branch) | 203 | 9.5 | 188.84 | 190.26 |
| Tributary 2 (North Branch | 204 | 30 | 189.37 | 190.79 | Tributary 2 (North Branch) | 204 | 9.5 | 189.37 | 190.56 |
| Tributary 2 (North Branch | 205 | 30 | 190.06 | 191.18 | Tributary 2 (North Branch) | 205 | 9.5 | 190.06 | 190.85 |
| Tributary 2 (North Branch | 206 | 30 | 189.94 | 191.61 | Tributary 2 (North Branch) | 206 | 9.5 | 189.94 | 191.25 |
| Tributary 2 (North Branch | 207 | 30 | 190.44 | 191.70 | Tributary 2 (North Branch) | 207 | 9.5 | 190.44 | 191.35 |
| Tributary 2 (North Branch | 208 | 30 | 190.57 | 191.74 | Tributary 2 (North Branch) | 208 | 9.5 | 190.57 | 191.22 |
| Tributary 2 (North Branch | 209 | 30 | 190.52 | 192.30 | Tributary 2 (North Branch) | 209 | 9.5 | 190.52 | 191.63 |
| Tributary 2 (North Branch | 210 | 30 | 190.61 | 192.62 | Tributary 2 (North Branch) | 210 | 9.5 | 190.61 | 192.12 |
| Tributary 2 (North Branch | 210.2 | Sixth Street CSP Culvert | | | Tributary 2 (North Branch) | 210.2 | Sixth Street CSP Culvert | | |
| Tributary 2 (North Branch | 211 | 30 | 190.94 | 193.25 | Tributary 2 (North Branch) | 211 | 9.5 | 190.94 | 192.95 |
| Tributary 2 (North Branch | 211.5 | 30 | 190.94 | 193.26 | Tributary 2 (North Branch) | 211.5 | 9.5 | 190.94 | 194.23 |
| Tributary 2 (North Branch | 212 | 30 | 191.54 | 193.31 | Tributary 2 (North Branch) | 212 | 9.5 | 191.54 | 194.23 |
| Tributary 2 (North Branch | 213 | 30 | 192.61 | 194.20 | Tributary 2 (North Branch) | 213 | 9.5 | 192.61 | 194.21 |
| Tributary 2 (North Branch | 214 | 30 | 194.57 | 195.64 | Tributary 2 (North Branch) | 214 | 9.5 | 194.57 | 195.19 |
| Tributary 2 (North Branch | 215 | 30 | 194.93 | 196.86 | Tributary 2 (North Branch) | 215 | 9.5 | 194.93 | 196.07 |
| Tributary 2 (North Branch | 216 | 30 | 195.05 | 197.32 | Tributary 2 (North Branch) | 216 | 9.5 | 195.05 | 196.55 |
| Tributary 2 (North Branch | 217 | 30 | 195.47 | 197.47 | Tributary 2 (North Branch) | 217 | 9.5 | 195.47 | 196.74 |
| Tributary 2 (North Branch | 218 | 30 | 197.28 | 198.96 | Tributary 2 (North Branch) | 218 | 9.5 | 197.28 | 198.29 |
| Tributary 2 (North Branch | 219 | 30 | 197.41 | 199.54 | Tributary 2 (North Branch) | 219 | 9.5 | 197.41 | 198.65 |
| Tributary 2 (North Branch | 220 | 30 | 197.69 | 199.62 | Tributary 2 (North Branch) | 220 | 9.5 | 197.69 | 198.99 |
| Tributary 2 (North Branch | 221 | 30 | 198.40 | 200.38 | Tributary 2 (North Branch) | 221 | 9.5 | 198.4 | 199.67 |
| Tributary 2 (North Branch | 222 | 30 | 198.81 | 200.74 | Tributary 2 (North Branch) | 222 | 9.5 | 198.81 | 200.01 |
| Tributary 2 (North Branch | 223 | 30 | 198.86 | 200.86 | Tributary 2 (North Branch) | 223 | 9.5 | 198.86 | 200.11 |

The recommended drainage and SWM infrastructure must also be of sufficient detail for use in the formulation of the master concept (land use) plan for each development block or phase.

Once the master concept plan is approved, its details are then used as a guide to regulate the municipal servicing and SWM requirements associated with each development of the new community. It also forms the basis on which the final SWM plans for each block/phase are generated as part of an overall functional servicing plan. Final SWM plans should provide specific details of location and design requirements, and conform with the master SWM plan's design objectives, prior to the approval of any site plan.

With the exception of the Dunn Property and other already zoned development lands, a Functional Servicing Plan report will be required for all future development blocks and as part of an overall Secondary Plan. These reports will be submitted to the affected municipality, Nottawasaga Valley Conservation Authority and other regulatory agencies in support of each draft plan or site plan application. The purpose of the FSP will be to demonstrate that the proposed plan meets the general intent of the Subwatershed Plan, and any other Master Servicing Plan requirements of the municipality, with respect to servicing, grading and stormwater management. In addition, each FSP must be integrated with the natural heritage system.

We have compiled a list of objectives to be satisfied by each FSP. While this list is not exhaustive for every site, it will give each proponent the minimum amount of information that must be supplied to the municipality and Conservation Authority for review.

Servicing Information to be Provided

1. The site should be identified within the context of the SWM facility catchment that it is located.
2. Upstream storm drainage areas should be identified and the assumed design criteria for the upstream lands should be clearly stated.
3. All storm outlets should be identified, including size and invert elevation, and how (if applicable) they will be integrated with the Black Ash Creek Flood Control Project.
4. If there are external areas it should be demonstrated that the proposed inverts within the proponent's site can adequately service upstream lands, without adverse filling being required.
5. External servicing requirements and improvements should be identified.
6. Temporary servicing schemes that are required to service the proponent's lands should be identified.
7. The limits of any 100 year storm sewers should be identified as well as the hydraulic implications to upstream lands.

Grading Information to be Provided

1. A Conceptual Grading Plan should be prepared for the site.
2. This plan should demonstrate that continuous major system flow routes have been provided and that they have sufficient capacity for the expected 100 year flows.
3. This plan should also highlight any areas where retaining walls or significant sloping is required to match existing grades.
4. Where the development abuts an existing residence, sufficient details should be provided to demonstrate that existing drainage patterns would not be impacted.
5. Where the development abuts a Supporting Area, as identified in the Subwatershed Plan report, it should be demonstrated how the grading ties into the grades of the Supporting Area. All proposed alterations should be identified.
6. Where the development contains a channel that is designated for municipal drainage, a Conceptual Grading Plan should be prepared that confirms the channel geometry.
7. Where a development contains a SWM facility, a Conceptual Grading Plan should be prepared that confirms the pond block area required to meet the discharge-storage curve given in the Subwatershed Plan report, as well as confirm that the Town's SWM pond design criteria have been met.
8. The SWM facility Grading Plan should also show all side slopes and demonstrate that adequate maintenance access has been provided. More details on the SWM facility requirements are given below.

Stormwater Management Information to be Provided

1. If the site soils are adequate for soakaway pits or similar induced infiltration practices, then the design criteria for the soakaway pits should be specified. The design criteria should be consistent with MOE and Town of Collingwood requirements.
2. Release rates for external areas should be specified.
3. It should be demonstrated that the release rates at the site outlet are consistent with the release rates given in the Subwatershed Plan report.
4. For industrial or commercial sites within the Town of Collingwood, a conceptual orifice tube detail should be included showing that the orifice tube is located at the site property boundary and is entirely within municipal property.

5. Sufficient detail should be provided to demonstrate that all water quality control obligations have been met, as per the requirements of the Subwatershed Plan report. A conceptual post-construction monitoring plan should also be presented.
6. The conceptual design of the SWM facility should include: storage volumes, water levels, water level fluctuations, inverts of inlets and outlets, berm elevations, slope information and any easement requirements. Also the relationship between the pond components (i.e. permanent pool, flood storage) should be identified.
7. The original assumptions in the Subwatershed Plan report pertaining to drainage area and land imperviousness should be checked to confirm whether the SWM facility volume requirements are valid.
8. Any fencing requirements for the SWM facilities should be identified as well as screening requirements adjacent to existing residences.
9. The location of the 100 year and Regional Storm floodlines from the Subwatershed Plan report, in relation to the SWM facility, should be indicated.
10. Where the existing riparian storage has been altered, it should be demonstrated that these alterations satisfy Floodplain Management Policies established by the Province of Ontario.
11. Water levels within channels conveying municipal drainage should be presented and any impacts to upstream lands should be clarified.
12. Preliminary sizing of all road crossings of all channels should be provided in the FSP.

D.4.1.2 Evaluation of Stormwater Management Plan Options

***Selection of SWMPs for Water Quality Enhancement***

Rainwater falling over an urban area scavenges chemicals from the atmosphere and upon reaching the catchment surface comes into contact with other pollutants already accumulated on the surface. Stormwater runoff mobilizes such pollutants and transports them off site as dissolved loads, suspended loads and bed loads.

Each of the above three loads is typified by certain pollutants, which are transported in that particular mode. For example, soluble nutrients, bacteria, and chlorides are preferentially transported as dissolved loads. Fine-grained sediment and associated hydrophobic contaminants (e.g. metals, toxic organics, and hydrocarbons) are transported as the suspended load. Coarser sediment and associated contaminants (bound not just by sorption, but also by surficial films or coatings) may be transported as bed load. The distinction between suspended or bed load transport is given by the particle properties (size, specific weight) and flow characteristics (flow velocity and turbulence).

Finally, it should also be noted that light materials (oil and other hydrocarbons, and particulate debris) may be transported on the flow surface and these loads are typically associated with spills from commercial, industrial, and/or high density residential (i.e. parking lot) areas. For the study area, all four loading scenarios are possible and were considered in the development of the SWM plan.

Even though the probability of spills from the proposed low/medium residential may be low, any spill from industrial sites may involve a variety of chemicals of various elements and denismetic properties. The most common spills from any area would likely involve oil or various types of fuels. In general, these materials do not mix with water and, being lighter than water, float on the surface. Motor oil is a typical substance in this group. A spill onto a parking lot area would accumulate within the depressions and voids of the asphalt surface. If there is ponded stormwater on the ground during the spill, oil may form a slick, floating on the water surface and moving in the direction of flow. Without containment, the spill would eventually be conveyed to Black Ash Creek.

All classes of SWMPs for water quality enhancement were considered in the initial screening stage. Table 3 presents the long list of general classes, which were examined. In the steps that followed, unsuitable SWMPs were eliminated and the SWMPs, which remained, were prioritized into a short-list for each general class.

Since no single SWMP can alleviate all concerns about the protection of receiving waters, it is necessary to determine the capabilities of individual structures and then search for combinations of SWMPs that can provide the desired water quality protection. The removal effectiveness of any treatment device depends on the characteristics of the media treated. In this particular case, two types of medium treated can be envisaged - storm water flows during wet weather and oil/fuel spills occurring mostly during dry weather.

***Table 3***
***Initial Screening of SWMPs for Water Quality Enhancement***

| ***CLASSIFICATION*** | ***APPLICABLE*** | ***COMMENTS*** |
|---|---|---|
| **SURFACE STORAGE** | **YES** | End-of-pipe wet ponds, hybrid wet pond/wetland facilities, etc., with cool water outflows are practical. Outlet recharge devices may also be suitable for some of the development sites, depending upon soil and groundwater table conditions.<br><br>Given the anticipated Plan of Subdivision sizes within Collingwood, minimum drainage area constraints do not limit the on-site use of these facilities. However, a maximum drainage area of 65 ha was considered to assess the number of facilities and to minimize storm sewer oversizing from 100 year flows. Optimum design drainage areas were also selected to minimize the number of facilities, as well as to address operation and maintenance concerns of the municipality. If larger drainage catchments are required, the conveyance capacity of internal storm sewers and roads, in excess of a minimum 65 hectare criterion during a 100 year storm event, must be approved at the detailed design stage – especially in the case of multiple landowners and potential cost-sharing implications. |

| CLASSIFICATION | APPLICABLE | COMMENTS |
|---|---|---|
| **INFILTRATION** | **LIMITED** | Not practical for all future development areas due to the low permeability of some underlying soils and potential effect of the groundwater system.<br><br>However, these practices are applicable in terms of lot level (source) controls for roof drainage from residential units such as groundwater recharge devices (fitted with overflow devices) connected to roof downspouts. |
| **VEGETATIVE** | **YES** | Applicable to lots draining to open space areas and stream/valley corridors, as well as side-yard and rear-yard functional drainage designs.<br><br>Surface swales are an effective drainage method for conveying major system (overland) flows to the watercourse receivers and as an auxiliary method for enhancing storm water runoff by the filtering of pre-treatment sediment before conveyance and/or end-of-pipe controls. |
| **SOFT MEASURES** | **YES** | Applicable as an auxiliary solution in combination with other facilities. Measures would include the use of environmentally friendly fertilizers and limited use of pesticides/herbicides on parks within the development site. Public education may also lead to residential participation in implementing such measures as well. |
| **CONSERVATION AND/OR RESTORATION** | **YES** | Buffer/filter strip zones and setback required along cool water or cold water reaches. These will provide a high degree of aquatic food source protection, thermal control (i.e. shading of watercourses), terrestrial habitat and natural appearance preservation (or in some cases enhancement). |

The results of our short-list assessment indicated that the preferred "end-of-pipe" solution should take the form of retention (wet) ponds, or variations thereof such as hybrid/wetland type facilities, as the ultimate on-site servicing solution. Full constructed wetlands may be practical for some developments but should address at the detailed design stage, surface area requirements and potential cool water or cold water stream constraints. In addition, the proposed natural channel features of the Black Ash Creek flood control/channelization works would also provide a major benefit to water quality enhancement. Table 4 summarizes the Level '1' quality and ultimate 25mm rainfall erosion control requirements for Collingwood's sub-catchments of the Black Ash Creek system. Figure 9 of the Main report presents subcatchment locations of these SWM control requirements.

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***Table 4***
***Extended Detention (Water Quality and Erosion Control) Requirements***

| Watercourse | Proposed SWM Control Facility(ies) | Subcatchment No(s). | Contributing Drainage Area (ha) | Proposed Land Use | Runoff Coefficient | Impervious Level (%) | Total Water Quality Storage Volume Required ($m^3$/ha) | Total Water Quality Storage Volume Required ($m^3$) | Permanent Storage Volume (PV) Required ($m^3$) | Extended Detention Storage Volume (EV) 25mm Rainfall (from ISWMS™ models) ($m^3$) | Total Quality & Erosion Control Storage Required ($m^3$) | Maximum Release Rate ($m^3$/s) for 25mm Rainfall Erosion Control Storage ($m^3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Main Branch** | **'A'** | **1102, 1103, 1104 & 1105** | 18.00 | Hazard Land | N/A | N/A | N/A | N/A | N/A | N/A | N/A | |
| | | | 77.00 | Industrial | 0.75 | 79 | 240 | 18,480 | 15,400 | 20,400 | 34,980 | |
| | | | 0.0 | Institutional | 0.65 | 65 | 215 | 0 | 0 | 0 | 0 | |
| | | | 36.00 | Low Density Res. | 0.45 | 35 | 140 | N/A (See Facility D) | N/A (See Facility D) | N/A (See Facility D) | N/A (See Facility D) | |
| | | | 0.00 | Medium Density Res. | 0.55 | 50 | 180 | 0 | 0 | 0 | 0 | |
| | | | 0.00 | High Density Res. | 0.65 | 65 | 215 | 0 | 0 | 0 | 0 | |
| | | | 0.00 | Commercial | 0.70 | 70 | 225 | 0 | 0 | 0 | 0 | |
| | | | 0.00 | Park/Woodlot/ SWM | 0.25 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | | Total | 131.00 | | | | Total: | 18,480 | N/A | 20,400 | 34,900 | 0.290 |
| **Main Branch** | **'B'** | **1203** | 0.00 | Hazard Land | N/A | N/A | N/A | N/A | N/A | N/A | N/A | |
| | | | 0.00 | Industrial | 0.75 | 79 | 240 | 0 | 0 | 0 | 0 | |
| | | | 0.00 | Institutional | 0.65 | 65 | 215 | 0 | 0 | 0 | 0 | |
| | | | 26.00 | Low Density Res. | 0.45 | 35 | 140 | 3,640 | 2,600 | 2,900 | 6,540 | |
| | | | 0.00 | Medium Density Res. | 0.55 | 50 | 180 | 0 | 0 | 0 | 0 | |
| | | | 0.00 | High Density Res. | 0.65 | 65 | 215 | 0 | 0 | 0 | 0 | |
| | | | 0.00 | Existing Residential | 0.45 | 35 | 225 | 0 | 0 | 0 | 0 | |
| | | | 0.00 | Park/Woodlot/ SWM | 0.25 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | | Total | 26.00 | | | | Total: | 3,640 | N/A | 2,900 | 6,540 | 0.030 |
| **North Branch** | **'C' (Facility to be located within catchment** | **1302 & 1303** | 0.00 | Hazard Land | N/A | N/A | N/A | N/A | N/A | N/A | N/A | |
| | | | 0.00 | Industrial | 0.75 | 79 | 240 | 0 | 0 | 0 | 0 | |
| | | | 0.00 | Institutional | 0.65 | 65 | 215 | 0 | 0 | 0 | 0 | |
| | | | 20.00 | Low Density Res. | 0.45 | 35 | 140 | 2,800 | 2,000 | 2,000 | 4,800 | |

| Watercourse | Proposed SWM Control Facility(ies) | Subcatchment No(s). | Contributing Drainage Area (ha) | Proposed Land Use | Runoff Coefficient | Impervious Level (%) | Total Water Quality Storage Volume Required ($m^3$/ha) | Total Water Quality Storage Volume Required ($m^3$) | Permanent Storage Volume (PV) Required ($m^3$) | Extended Detention Storage Volume (EV) 25mm Rainfall (from ISWMS™ models) ($m^3$) | Total Quality & Erosion Control Storage Required ($m^3$) | Maximum Release Rate ($m^3$/s) for 25mm Rainfall Erosion Control Storage ($m^3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **catchment 1302)** | | 2.00 | Medium Density Res. | 0.55 | 50 | 180 | 360 | 280 | 300 | 1,020 | |
| | | | 0.00 | High Density Res. | 0.65 | 65 | 215 | 0 | 0 | 0 | 0 | |
| | | | 0.00 | Commercial | 0.70 | 70 | 225 | 0 | 0 | 0 | 0 | |
| | | | 2.00 | Park/Woodlot/ SWM | 0.25 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | | Total | 24.00 | | | | Total: | 3,160 | N/A | 2,300 | 5,460 | 0.025 |
| **Main Branch** | **'D'** | **1103** | 0.00 | Hazard Land | N/A | N/A | N/A | N/A | N/A | N/A | N/A | |
| | | | 0.00 | Industrial | 0.75 | 79 | 240 | 0 | 0 | 0 | 0 | |
| | | | 0.00 | Institutional | 0.65 | 65 | 215 | 0 | 0 | 0 | 0 | |
| | | | 36.00 | Low Density Res. | 0.45 | 35 | 140 | 5,040 | 3,600 | 3,900 | 8,940 | |
| | | | 0.00 | Medium Density Res. | 0.55 | 50 | 180 | 0 | 0 | 0 | 0 | |
| | | | 0.00 | High Density Res. | 0.65 | 65 | 215 | 0 | 0 | 0 | 0 | |
| | | | 0.00 | Commercial | 0.70 | 70 | 225 | 0 | 0 | 0 | 0 | |
| | | | 0.00 | Park/Woodlot/ SWM | 0.25 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | | Total | 36.00 | | | | Total: | 5,040 | N/A | 3,900 | 8,940 | 0.039 |
| **South Branch** | **'E'** | **1402** | 0.00 | Hazard Land | N/A | N/A | N/A | N/A | N/A | N/A | N/A | |
| | | | 0.00 | Industrial | 0.75 | 79 | 240 | 0 | 0 | 0 | 0 | |
| | | | 0.00 | Institutional | 0.65 | 65 | 215 | 0 | 0 | 0 | 0 | |
| | | | 28.00 | Low Density Res. | 0.45 | 35 | 140 | 3,920 | 2,800 | 3,100 | 7,020 | |
| | | | 0.00 | Medium Density Res. | 0.55 | 50 | 180 | 0 | 0 | 0 | 0 | |
| | | | 0.00 | High Density Res. | 0.65 | 65 | 215 | 0 | 0 | 0 | 0 | |
| | | | 0.00 | Commercial | 0.70 | 70 | 225 | 0 | 0 | 0 | 0 | |
| | | | 0.00 | Park/Woodlot/ SWM | 0.25 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | | Total | 28.00 | | | | Total: | 3,920 | N/A | 3,100 | 7,020 | 0.030 |
| **Main Branch** | **'F'** | **1202** | 0.00 | Hazard Land | N/A | N/A | N/A | N/A | N/A | N/A | N/A | |
| | | | 9.00 | Industrial | 0.75 | 79 | 240 | 2,160 | 1,800 | 1,900 | 4,060 | |
| | | | 0.00 | Institutional | 0.65 | 65 | 215 | 0 | 0 | 0 | 0 | |
| | | | 0.00 | Low Density Res. | 0.45 | 35 | 140 | 0 | 0 | 0 | 0 | |
| | | | 0.00 | Medium Density Res. | 0.55 | 50 | 180 | 0 | 0 | 0 | 0 | |
| | | | 0.00 | High Density Res. | 0.65 | 65 | 215 | 0 | 0 | 0 | 0 | |
| | | | 0.00 | Commercial | 0.70 | 70 | 225 | 0 | 0 | 0 | 0 | |
| | | | 0.00 | Park/Woodlot/ SWM | 0.25 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | | Total | 9.00 | | | | Total: | 2,160 | N/A | 1,900 | 4,060 | 0.020 |

Since SWM facilities 'A' and 'D' may be "in-series" and ultimately connected to a common storm sewer system (i.e. perhaps running easterly along the Georgian Trail and outletting to the Main Branch reach), our SWM storage calculations have incorporated this design constraint. As such, SWM facility 'D" would require a greater volume that normally would result from servicing only the 77 ha industrial lands. At the Secondary Plan stage, the proposed SWM plan for future development lands within subcatchment '1102' should be investigated in greater detail.

Also, the above design parameters for the industrial subcatchment ‘1102’ and ‘1202’ have assumed SWM “retrofitting” opportunities for existing businesses such as Goodyear and Reynolds-Lemmerz. This is discussed further in Section D.4.3. Future industrial blocks or re-construction within sub-catchments ‘1102’ and ‘1202’ would implement on-site detention (OSD) as part of the overall stormwater management scheme. Water quality and quantity control could then be provided for each individual site. Both the Town of Collingwood and NVCA are concerned how OSD will be implemented and remain effective over the life of each individual site. Therefore, it is recommended that orifice tubes should be used instead of inlet control devices (ICDs) to control individual site release rates to the above values. These orifice tubes would be placed at the site property limit, within municipal property.

### D.4.1.3 Selection of SWMPs for Water Quantity Control

**Overview**

The main criterion for conventional SWM to mitigate hydrologic changes has typically been detention. A specified design storm occurring after development should produce no higher peak flow rate that occurs from the same storm prior to development measured at the site itself. This policy of prevention, when detention ponds are used with no evaluation at the watershed or subwatershed level has sometimes proven not effective. That is, in some cases it has been shown that the effect of such mitigative plans controlling floods rapidly disappears the further downstream.

However, if such a policy is examined at the subwatershed level, such an occurrence can be avoided by way of various structural and/or non-structural mitigative measures. “Multi-criterion” SWM strategies are now required in the Province in the context of scoped subwatershed studies which consider prevention of increased flooding, erosion, water balance impacts and runoff pollution from new development within a specified study area. Our assessment of the Black Ash Creek Subwatershed’s hydrology, hydraulic, erosion and groundwater recharge changes in terms of “uncontrolled” post-development flow/runoff volume regimes, relative to existing conditions, clearly indicated the need for a multi-criterion master SWM approach. Earlier it was recommended that 25mm rainfall/runoff-24 hour detention control be required ultimately to prevent future stream erosion and flooding downstream of the proposed areas of urbanization. In the interim, however, and prior to construction of the flood control/channelization works, over-controlling the 2 year design storm event for 48 hours is necessary to protect the Black Ash Creek Main Branch.

A number of potential SWM quantity control alternatives were evaluated based on the following criteria:

- Land requirements;
- Construction costs;
- Anticipated maintenance requirements;
- Aesthetics;
- Environmental benefits in terms of controlling erosion downstream, increased flood discharges and higher water levels along the Black Ash Creek system;

- Maintain or improve current hydraulic capacity or "flood frequency levels of service" at downstream structural crossings; and,
- Any roadway culvert or bridge replacement must satisfy MTO directives in terms of the design flow return period opening of the new structure.

Our analytical process of developing SWM quantity control alternatives for the Black Ash Creek Subwatershed Plan began by outlining the concepts on a broad scale and eventually developing schemes specific to each headwater basin – in terms of type and location.

### Flooding (Peak Flow) Control

The objectives for the implementation of peak flow or flood controls for the study area relate in part to the following:

- Optimizing a cost-effective and practical, yet environmentally sound, approach to functional drainage at the subcatchment level; and,
- Maximizing the development potential of future urbanization provided drainage, topographical, ecological and other constraints imposed by the Subwatershed Plan are adhered to.

Given this general perspective, a "long-list" of potential options and combinations thereof were formulated, which upon further analysis, was refined to a "short-list", indicative of the overall study objectives. A number of flood control alternatives, consisting of non-structural and structural options, were then investigated. The following summarizes the options considered and findings from our long-list assessment:

***1. Non-structural Options:***

1.1 ***Do-Nothing*: ** Essentially, this option includes letting future development flows to discharge uncontrolled by accepting changes in hydrologic, hydraulic and erosion properties of the watercourses. This option would only be acceptable for negligible flow increases (i.e. both minor and major drainage systems) and if no additional on-site or off-site flooding and potential erosion will occur. This option was only considered on a "subcatchment-by-subcatchment basis" for the study area. Existing development peak flow targets along the Black Ash Creek system would of course have to be maintained.

1.2 ***Do-Nothing Plus Post-Construction Monitoring*:** This approach would be implemented at the same time as the Do-Nothing option. That is, let minor or major system flows from specific development blocks proceed unchecked but monitor, over a specified time period, erosion and/or flooding conditions so that measures can be implemented (if conditions warrant) before a serious problem arises. This approach would include a "sinking fund"; whereby monies would be set aside over the monitoring period for any mitigative works (e.g. natural or bioengineering reinforcement measures). This option would apply to uncontrolled major system flows in terms of preventing erosion impacts to valley sections receiving the overland flows.

## *2. Structural Options:*

2.1 ***Watercourse Improvements:*** In addition to floodplain widening/enlargement works, this option would be associated with valley storage and low flow channel modifications to minimize potential flooding of public/private properties. However, given the length of the watercourses, this alternative would be extremely costly to maintain floodwaters upstream of all existing structural crossings current flow frequency levels and not practical for off-site containment of flood flows. Therefore, any major channelization works within the study area would have to be integrated with culvert/bridge improvement options or recommended stream corridor rehabilitation works such as the Black Ash Creek Flood Control project.

2.2 ***Culvert/Bridge Inlet Improvements:*** This option includes improvements to the inlet(s) of structural crossings in order to reduce headlosses and increase hydraulic capacities. The existing inlets of the majority of hydraulic structures within the Town of Collingwood were considered efficient for reducing entrance headlosses from existing development condition flows relative to the current roadway use.

2.3 ***Culvert/Bridge Improvements:*** This option includes the enlargement or replacement of existing structures to reduce flooding. This option would be necessary in conjunction with future roadway capacity upgrades such as Sixth Street to service future developments and in light of somewhat higher flood frequency peak flows along the North Branch relative to earlier hydrologic modelling by MacLaren Plansearch (1984). Our updated HEC-RAS computer model of existing culvert/bridge crossing structures was deemed acceptable to establish existing condition floodlines through the Town of Collingwood. However, at the Functional Servicing Plan stage for developments that need rezoning, this option should be examined if the reduction of floodlines is necessary upstream of any new crossing structures.

2.4 ***SWM Storage Facilities:*** Dry detention pond structures (off-line), in accordance with the NVCA's policy document, were considered for this quantity control option. The flood storage option was also examined with other viable non-structural and structural options to achieve an economical solution that optimizes the balance of detention storage facilities (centralized or dispersed) with other improvements.

One detention storage scenario includes the "dispersed" locations of all SWM control facilities as off-line, with separate quality and any required quantity (flood) control ponds. This approach is typically preferred by the NVCA. However, this scenario may be of concern to the Town of Collingwood in terms of not utilizing instead potential "centralized" on-line/dry ponds within headwater open space/valley systems, while respecting environmentally sensitive areas. However, until development pressures heighten within basins upstream of Collingwood, this option cannot be examined at this stage. For example, this option could be feasible for potential resort-related developments in Clearview Township and stream reaches with suitable valley storage. In response the NVCA would have to revise their SWM pond policies by relaxing its prohibition of on-line facilities. This would include recognizing topographical constraints for the construction of off-line cells; a municipality's desire to minimize the number of facilities; and, the municipality's other concern in terms of long-term maintenance costs. As such, existing valley cross-sections/stage-storage relationships and potential embankment configurations would have to be determined for headwater subcatchments to confirm feasible on-line dry flood control sites.

Based on the above, we could only examine a "limited" number of SWM storage facility scenarios with off-line flood control cell configurations - as per the NVCA's current policy conditions. The first step of this assessment involved an integrated review of valley topography for each watercourse system, relative to potential structural crossing sites, and proposed establishment of core, supporting and restoration vegetated areas from our natural science investigations. Other off-line pond storage requirements (if necessary) further downstream were then determined to maintain pre-development peak flow targets at various points of interest.

2.5 ***Inter-catchment Diversions*****:** Diversion of a development's stormwater flows, to reduce the actual discharge in a given reach, is a potential solution when the following are satisfied:

- The receiving watercourse can accommodate the increased flows without, in turn, increasing its susceptibility to flooding and erosion;
- The receiving stream is relatively close to the problem watercourse;
- The receiving watercourse is at a suitable elevation (i.e. sufficient fall for gravity drainage);
- The divide between the two watercourses is suitable for construction of a diversion structure; and,
- There will be no detrimental impacts to aquatic habitat of the receiving stream.

On the basis of the above, it was concluded that this alternative should not be considered for the Black Ash Creek Subwatershed until a complete subwatershed water balance analysis is completed using data from the "*A-E-M-O-T Groundwater Management Plan Study"* (Greenland International, ongoing). At that time, our hydrologic computer models could then incorporate any drainage diversion proposal for sizing SWM storage volume requirements. Nevertheless, existing water balance relationships (i.e. groundwater recharge volumes) for each basin should be maintained by incorporating appropriate induced infiltration practices for the affected area.

2.6 ***On-site Detention (OSD) Control:*** Generally, the most cost-effective means of storm water quantity control can be achieved by controlling surface water run-off before it enters the minor or storm sewer system. These OSD methods can include the use of inlet control devices (ICDs) for the temporary ponding or storage of storm water within parking lots, roadway sags and roofs. These devices are intended to reduce the rate of run-off by taking advantage of natural and/or man-made elements of the major drainage system. Alternatively, on-line or off-line storage structure(s) can be added to the underground storm sewer or minor system as part of this flood control option.

Recent trends in watershed management, however, have discouraged the intense use of ICD controls where alternative means are available. The primary reason for this is the maintenance and administrative difficulties associated with implementation and on-going regulation (i.e. private versus public ownership of lands where ICDs are in place).

Tables 5 through 8, respectively, summarizes our Visual OTTHYMO© peak flow results at various nodes of interest in the subwatershed for 1) pre-development conditions, 2) "un-controlled" post-development conditions, 3) "controlled" post-development conditions to pre-development release rates, and 4) "over-controlled" post-development conditions to 50% pre-development peak flows. Please note, that total pre-development flow spill from the North Branch (across High Street) during a Regional Storm event was calculated to be about 27.2 $m^3/s$ from our hydraulic computer modelling. However, this flow has been included with the total peak flows that are tabulated below for nodes 1 through 3. Comparative ISWMS™ model discharges for the 100 year and Regional Storm floods are also presented below to demonstrate the very close findings with our initial Visual OTTHYMO© models. Finally, flow nodes 1 through 8 in the tables correspond to those shown in Figure 8 of the Main Report.

***Table 5***
***Pre-Development Peak Flows ($m^3/s$)***

| Node | Description | Visual OTTHYMO | | | | | | | ISWMS | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2 Year | 5 Year | 10 Year | 25 Year | 50 Year | 100 Year | Regional Storm | 100 year | Regional Storm |
| 1 | Outlet to Collingwood Harbour | 9.7 | 15.5 | 19.6 | 25.2 | 30.0 | 34.6 | 109.4 | 35.0 | 108.1 |
| 2 | Main Channel – West Tributary Confluence, South of Old Mountain Road | 9.3 | 15.0 | 18.9 | 24.4 | 28.9 | 33.4 | 104.7 | 33.7 | 103.3 |
| 3 | Confluence of North and South Branches, North of Sixth Street | 8.7 | 13.8 | 17.4 | 22.6 | 26.7 | 30.8 | 95.4 | 31.1 | 94.6 |
| 4 | South Branch – West Tributary Confluence, West of Campbell Street | 7.2 | 11.3 | 14.4 | 18.7 | 22.0 | 25.4 | 72.3 | 25.7 | 72.0 |
| 5 | South Branch Tributary Confluence, North of Poplar Sideroad | 6.0 | 9.4 | 12.0 | 15.4 | 18.1 | 20.8 | 53.1 | 21.3 | 53.2 |
| 6 | South Branch @ Tenth Line | 5.6 | 8.7 | 11.1 | 14.2 | 16.7 | 19.2 | 45.6 | 19.7 | 47.2 |
| 7 | South Branch @ Osler Bluff Ski Club | 1.4 | 2.3 | 3.0 | 3.9 | 4.6 | 5.4 | 14.9 | 5.5 | 14.8 |
| 8 | North Branch @ Grey County Road 19 | 2.0 | 3.1 | 3.9 | 5.0 | 5.9 | 6.8 | 21.0 | 6.8 | 21.0 |
| 9 | North Branch Outlet @ South Branch Confluence | 2.6 | 4.2 | 5.3 | 6.8 | 8.0 | 9.3 | 29.6 | 9.5 | 30.0 |
| 10 | West Tributary to Main Channel, South of Old Mountain | 0.8 | 1.2 | 1.6 | 2.1 | 2.5 | 2.9 | 9.8 | 2.9 | 9.8 |

## *Table 6*
## *"Un-controlled" Post-Development Peak Flows ($m^3/s$)*

| Node | Description | Visual OTTHYMO | | | | | | | ISWMS | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2 Year | 5 Year | 10 Year | 25 Year | 50 Year | 100 Year | Regional Storm | 100 year | Regional Storm |
| 1 | Outlet to Collingwood Harbour | 10.6 | 16.7 | 21.1 | 27.1 | 31.3 | 36.2 | 112.7 | 38.1 | 112.7 |
| 2 | Main Channel – West Tributary Confluence, South of Old Mountain Road | 9.9 | 15.6 | 19.7 | 25.6 | 30.1 | 34.8 | 107.7 | 35.3 | 106.7 |
| 3 | Confluence of North and South Branches, North of Sixth Street | 8.9 | 14.1 | 17.9 | 23.1 | 27.2 | 31.4 | 96.8 | 31.9 | 95.9 |
| 4 | South Branch – West Tributary Confluence, West of Campbell Street | 7.3 | 11.5 | 14.6 | 18.9 | 22.1 | 25.5 | 72.1 | 25.9 | 71.8 |
| 5 | South Branch Tributary Confluence, North of Poplar Sideroad | 6.0 | 9.4 | 12.0 | 15.4 | 18.1 | 20.8 | 53.1 | 21.3 | 53.2 |
| 6 | South Branch @ Tenth Line | 5.6 | 8.7 | 11.1 | 14.2 | 16.7 | 19.2 | 45.6 | 19.7 | 47.2 |
| 7 | South Branch @ Osler Bluff Ski Club | 1.4 | 2.3 | 3.0 | 3.9 | 4.6 | 5.4 | 14.9 | 5.5 | 14.8 |
| 8 | North Branch @ Grey County Road 19 | 2.0 | 3.1 | 3.9 | 5.0 | 5.9 | 6.8 | 21.0 | 6.8 | 21.0 |
| 9 | North Branch Outlet @ South Branch Confluence | 2.7 | 4.2 | 5.4 | 7.0 | 8.2 | 9.3 | 29.7 | 9.7 | 30.3 |
| 10 | West Tributary to Main Channel, South of Old Mountain | 1.0 | 1.5 | 1.9 | 2.5 | 2.9 | 3.4 | 11.0 | 3.4 | 11.0 |

## *Table 7*
## *"Controlled" Post-Development Peak Flows to Pre-development Discharges ($m^3/s$)*

| Node | Description | Visual OTTHYMO | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 Year | 5 Year | 10 Year | 25 Year | 50 Year | 100 Year | Regional Storm |
| 1 | Outlet to Collingwood Harbour | 10.1 | 16.1 | 20.4 | 26.3 | 31.0 | 35.9 | 112.8 |
| 2 | Main Channel – West Tributary Confluence, South of Old Mountain Road | 9.7 | 15.4 | 19.5 | 25.2 | 29.9 | 34.5 | 107.7 |
| 3 | Confluence of North and South Branches, North of Sixth Street | 8.8 | 14.0 | 17.7 | 22.9 | 27.0 | 31.2 | 96.7 |
| 4 | South Branch – West Tributary Confluence, West of Campbell Street | 7.2 | 11.3 | 14.4 | 18.7 | 21.9 | 25.3 | 72.2 |
| 5 | South Branch Tributary Confluence, North of Poplar Sideroad | 6.0 | 9.4 | 12.0 | 15.4 | 18.1 | 20.8 | 53.1 |
| 6 | South Branch @ Tenth Line | 5.6 | 8.7 | 11.1 | 14.2 | 16.7 | 19.2 | 45.6 |
| 7 | South Branch @ Osler Bluff Ski Club | 1.4 | 2.3 | 3.0 | 3.9 | 4.6 | 5.4 | 14.9 |
| 8 | North Branch @ Grey County Road 19 | 2.0 | 3.1 | 3.9 | 5.0 | 5.9 | 6.8 | 21.0 |
| 9 | North Branch Outlet @ South Branch Confluence | 2.7 | 4.2 | 5.4 | 7.0 | 8.2 | 9.5 | 29.8 |
| 10 | West Tributary to Main Channel, South of Old Mountain | 0.9 | 1.4 | 1.9 | 2.4 | 2.9 | 3.3 | 11.0 |

***Table 8***
***"Over-controlled" Post-Development Peak Flows to 50% Pre-development Discharges (m³/s)***

| Node | Description | Visual OTTHYMO | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **2 Year** | **5 Year** | **10 Year** | **25 Year** | **50 Year** | **100 Year** | **Regional Storm** |
| 1 | Outlet to Collingwood Harbour | 10.0 | 15.8 | 19.9 | 25.6 | 30.2 | 34.9 | 112.8 |
| 2 | Main Channel – West Tributary Confluence, South of Old Mountain Road | 9.6 | 15.3 | 19.3 | 25.0 | 29.6 | 34.2 | 107.7 |
| 3 | Confluence of North and South Branches, North of Sixth Street | 8.8 | 13.9 | 17.6 | 22.8 | 26.9 | 31.1 | 96.8 |
| 4 | South Branch – West Tributary Confluence, West of Campbell Street | 7.2 | 11.3 | 14.3 | 18.6 | 21.8 | 25.2 | 72.2 |
| 5 | South Branch Tributary Confluence, North of Poplar Sideroad | 6.0 | 9.4 | 12.0 | 15.4 | 18.1 | 20.8 | 53.1 |
| 6 | South Branch @ Tenth Line | 5.6 | 8.7 | 11.1 | 14.2 | 16.7 | 19.2 | 45.6 |
| 7 | South Branch @ Osler Bluff Ski Club | 1.4 | 2.3 | 3.0 | 3.9 | 4.6 | 5.4 | 14.9 |
| 8 | North Branch @ Grey County Road 19 | 2.0 | 3.1 | 3.9 | 5.0 | 5.9 | 6.8 | 21.0 |
| 9 | North Branch Outlet @ South Branch Confluence | 2.7 | 4.2 | 5.4 | 7.0 | 8.2 | 9.5 | 29.8 |
| 10 | West Tributary to Main Channel, South of Old Mountain | 0.9 | 1.4 | 1.8 | 2.3 | 2.7 | 3.2 | 11.0 |

## D.4.1.4 Recommended Stormwater Management Plan

### General

The stormwater drainage infrastructure for the Town of Collingwood will be designed according to the dual drainage principle - with major and minor storm water drainage systems. Frequent flows up to that which is generated by the 5 year storm will be collected by the minor storm sewer system in accordance with Collingwood's design criteria. Streets and lots should be designed, where feasible, with continuous slopes to convey the major (overland) flows to the stream outlets, and basically consistent with the existing topographical relief. However, in some, as a result of grading constraints, a cascading road system (saw-tooth grading) could be implemented to subdivision design and must be consistent with accepted design practices (e.g. maximum allowable depth of ponding water within road sag areas, etc.).

The recommended SWMPs include the general surface storage, vegetative, soft measures, special purpose and conservation/restoration classes discussed earlier to address storm water quality concerns. They also address the other management concerns to mitigate storm water quantity (i.e. erosion and flooding) and groundwater recharge impacts. Further details of the recommended SWM plan are discussed next in terms of the proposed source and end-of-pipe controls.

### Lot Level Controls

Lot level SWMPs that can be incorporated into the residential lots of each development are presented below. These types of "source" controls have several advantages. By maximizing the use of naturalized overland flow paths, they enhance storm water infiltration and permit peak flow reductions, as well as partial pollutant removal. However, their efficiency is limited and seasonal.

For example, source control measures are ineffective with frozen ground. Also, they rapidly loose their effectiveness when not properly maintained. The recommended lot level controls do not replace the need for other SWMP facilities.

| ***Lot Level (Source) Control*** | ***Description of Recommended Lot Level Controls*** |
|---|---|
| **Drainage Swales** | Surface swales are an effective method for draining overland flow and enhancing infiltration. For example, swales provide resistance to flow during conveyance and enhance infiltration. The effectiveness of the swales is related to physical constraints such as side and longitudinal slopes, soil type, water table elevations, storm volume, duration, and the interval between storms. |
| ***Lot Level (Source) Control*** | ***Description of Recommended Lot Level Controls*** |
| **Dry Wells** | Dry wells are small rock trenches designed to accept rooftop run-off. They permit infiltration of the run-off until the dry well capacity is exceeded.<br><br>Based on the anticipated soil permeability for most development sites within Collingwood, dry wells are only practical for sandy-loam and loam soil areas. At the functional servicing plan stage, detailed soil investigations will be needed for all development areas to confirm the feasibility of induced infiltration practices. |
| **Reduced Lot Grading to Maximize Depression Storage for Groundwater Recharge** | Depression storage should be maximized by incorporating, where applicable, 2% grades around each residence, and somewhat flatter grades for the balance of the lot. Confirmation of lot grading will be done during the functional servicing or final design stage. However, given the predominantly sloping topography of most development lands in Collingwood, this source control practice will be limited and should be examined on a "lot-by-lot" basis. |

## End-of-Pipe Controls

*Off-line Facilities – Extended Detention Control Only or Water Quality/Quantity Controls*

Complete design details for each off-line pond (i.e. conceptual locations) shown on Figure 12 (Main Report) is not available at this time. The extended detention (i.e. water quality and erosion control) requirements are referred to as facilities 'A', "B', 'C', 'D', 'E' and 'F'. Table 2 summarized our preliminary water quality pond calculations. Based on our hydrologic modelling assessment (Tables 3 through 5), flood control storage is not recommended for the affected Collingwood development lands given potential timing impacts with headwater basin runoff. This applies to Black Ash Creek conditions with and without the proposed flood control/channelization works.

The preferred single cell configuration of any off-line facilities for water quality and erosion control will include: 1) a sediment forebay within the dual purpose water quality/erosion control cell, 2) outlet control structure(s) from the cell to the watercourse receiver via a bio-engineered outlet channel, 3) an emergency spillway to safely convey excess flows to the watercourse from "back-to-back" storm events, and 4) a sediment storage area within each facility for maintenance purposes. The maximum water level depth in the water quality/25 mm storm extended detention cell should be limited to 1.2 m in order to sustain a bio-diverse vegetative community.

The landscape design for any SWM facility should create a cost-effective/functional cell that look as natural as possible. The detailed design should go beyond the aesthetics of form and the screening of manufactured structures. The ultimate goal should be to develop a naturally functioning ecosystem through the incorporation of sustainable design and maintenance practices.

The key to developing a more naturally functioning ecosystem within each facility will be the creation of bio-diversity, which will provide each system with the resilience to withstand a variety of flow conditions and water levels.

The creation of bio-diversity is based on the design of a more organic or "natural" shape for a single cell configuration within an open space area. This will lead to the development of wet and dry pockets within each facility that will, in turn, allow the growth of a variety of upland and wetland plants. The proposed plants should be native to the area and located in areas that replicate their natural habitat. While all of the species chosen should be able to withstand some flooding, those that are habituated to large scale fluctuations must be placed in the bottom of the facility, while those more susceptible to flood conditions should be placed up the slopes at the edge of the SWM cell(s). A wide variety of species initially planted will allow natural selection to help create an ecosystem in which those species best suited to the conditions of the site will flourish, while other less suitable species will not do so well. Larger numbers of smaller stock should be planted in order to have a greater impact over a wider area. As the younger plants mature they will become habituated to affected local valleyland micro-conditions and will, as mature plants, be better able to survive the future conditions of the facility.

Existing plants within the proposed pond areas should be "salvaged" during construction by removing them with their root masses intact, and heeling them in to preserve them until cuttings can be taken to be used for the creation of fascines and live stakes. The fascines could then be placed to stabilize the edges of the water quality/25 mm storm extended detention cell and to encourage the growth of vegetation on the basin floor. The live stakes must be used to fasten the fascines in place and to help stabilize the forebay and outflow weirs. Additional cuttings may be required from off-site.

Maintenance of each SWM facility should be minimal. Mowing will be eliminated throughout the basin after an initial establishment period. The forebay and SWM facility floor areas will be cleaned out on an as-needed basis. The permanent wetland areas and vegetation clumps should be left undisturbed. This will allow the plant clumps to act as a seed source for the naturalization of the rest of the basin through natural succession processes. With the elimination of regular mowing, the seeds and suckers of these plants will be able to spread out from the clumps and eventually create a natural cover over the entire SWM facility floor. The soil along the existing channel should be stockpiled and redistributed on any proposed vegetation islands. This soil will contain the seeds and root mass of plants that have been able to survive the existing conditions of the pond and will also act as a seed source of plants habituated to local conditions.

The required forebay will act as a settling basin to remove some of the suspended sediments in the water before it reaches the water quality treatment cell. This will reduce the likelihood of the plants in this cell being smothered. The forebay will also experience a variety of water levels.

Willows should be planted on the forebay weirs to help hold the chosen erosion resistant liner and soil in place, as well as soften the form of the weirs to mitigate their visual impact. Overall, this landscape design concept also seeks to incorporate naturalization techniques within accepted engineering practices to create a multi-functional facility. The recommended sustainable landscape approach for each open space SWM facility will be a cost-effective means to allow the ponds to grow into a fully functional facility in which natural processes are allowed to occur with minimum human interference.

Tables 9 and 10 present the final hydrologic peak flow findings from the ISWMS™ models developed during this study. The model output data presented in Table 10 incorporates the proposed water quality and 25mm rainfall erosion control facilities but does not include flood control storage for 2 year through 100 year design storm events.

***Table 9***
***ISWMS™Pre-Development Peak Flows (m³/s)***

| Node | Description | 2 Year | 5 Year | 10 Year | 25 Year | 50 Year | 100 Year | Regional Storm |
|---|---|---|---|---|---|---|---|---|
| 1 | Outlet to Collingwood Harbour | 10.0 | 15.7 | 20.1 | 25.7 | 30.3 | 35.0 | 108.1 |
| 2 | Main Channel – West Tributary Confluence, South of Old Mountain Road | 9.7 | 15.1 | 19.3 | 24.8 | 29.1 | 33.7 | 103.3 |
| 3 | Confluence of North and South Branches, North of Sixth Street | 9.0 | 14.1 | 17.9 | 22.9 | 26.9 | 31.1 | 94.6 |
| 4 | South Branch – West Tributary Confluence, West of Campbell Street | 7.3 | 11.5 | 14.7 | 18.9 | 22.2 | 25.7 | 72.0 |
| 5 | South Branch Tributary Confluence, North of Poplar Sideroad | 6.1 | 9.6 | 12.2 | 15.7 | 18.5 | 21.3 | 53.2 |
| 6 | South Branch @ Tenth Line | 5.7 | 9.0 | 11.4 | 14.6 | 17.1 | 19.7 | 47.2 |
| 7 | South Branch @ Osler Bluff Ski Club | 1.5 | 2.4 | 3.0 | 4.0 | 4.7 | 5.5 | 14.8 |
| 8 | North Branch @ Grey County Road 19 | 2.0 | 3.1 | 3.9 | 5.0 | 5.9 | 6.8 | 21.0 |
| 9 | North Branch Outlet @ South Branch Confluence | 2.7 | 4.3 | 5.4 | 7.0 | 8.2 | 9.5 | 30.0 |
| 10 | West Tributary to Main Channel, South of Old Mountain | 0.8 | 1.2 | 1.6 | 2.1 | 2.5 | 2.9 | 9.8 |

***Table 10***
***ISWMS™"Un-controlled" Post-Development Peak Flows (m³/s)***

| Node | Description | 2 Year | 5 Year | 10 Year | 25 Year | 50 Year | 100 Year | Regional Storm |
|---|---|---|---|---|---|---|---|---|
| 1 | Outlet to Collingwood Harbour | 11.3 | 17.5 | 22.1 | 28.2 | 33.1 | 38.1 | 112.7 |
| 2 | Main Channel – West Tributary Confluence, South of Old Mountain Road | 10.2 | 15.9 | 20.2 | 26.0 | 30.5 | 35.3 | 106.7 |
| 3 | Confluence of North and South Branches, North of Sixth Street | 9.2 | 14.4 | 18.3 | 23.5 | 27.6 | 31.9 | 95.9 |
| 4 | South Branch – West Tributary Confluence, West of Campbell Street | 7.5 | 11.7 | 14.8 | 19.1 | 22.4 | 25.9 | 71.8 |

| Node | Description | 2 Year | 5 Year | 10 Year | 25 Year | 50 Year | 100 Year | Regional Storm |
|---|---|---|---|---|---|---|---|---|
| 5 | South Branch Tributary Confluence, North of Poplar Sideroad | 6.1 | 9.6 | 12.2 | 15.7 | 18.5 | 21.3 | 53.2 |
| 6 | South Branch @ Tenth Line | 5.7 | 9.0 | 11.4 | 14.6 | 17.1 | 19.7 | 47.2 |
| 7 | South Branch @ Osler Bluff Ski Club | 1.5 | 2.4 | 3.0 | 4.0 | 4.7 | 5.5 | 14.8 |
| 8 | North Branch @ Grey County Road 19 | 2.0 | 3.1 | 3.9 | 5.0 | 5.9 | 6.8 | 21.0 |
| 9 | North Branch Outlet @ South Branch Confluence | 2.8 | 4.4 | 5.6 | 7.2 | 8.4 | 9.7 | 30.3 |
| 10 | West Tributary to Main Channel, South of Old Mountain | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.4 | 11.0 |

*<u>On-line Facilities – Peak Flow Shaving or Flood Control</u>*

At this point in subwatershed planning process for the Black Ash Creek, on-line SWM facilities were not considered for peak flow shaving and flood control within the Town of Collingwood. These types of facilities are now recommended for Lake Simcoe subwatersheds to service Secondary Plan areas within East Gwillimbury, Newmarket and Aurora. As highlighted earlier, however, this option could be considered in the future for potential developments in Clearview Township and Town of the Blue Mountains.

In general, each facility would be designed to withhold stormwater runoff from a 100 year event less the runoff detained in any off-line extended detention pond(s) at the facility. At the downstream road embankment structure, a control structure would be constructed immediately upstream of the road crossing's culvert or bridge to safely pass the 100 year design flow target (specified herein) and Regional Storm flows. To limit flow from less frequent events (such as a 10 year storm), as per the recommended SWM strategies target flow indices, a stepped weir control structure (or multi-inlet box structure with orifices and slotted weirs) would be necessary. Whatever design is proposed, the control structure must also maintain a terrestrial corridor linkage with the downstream stream and valley corridor via the low channel section. In addition, front-end construction of each facility may be necessary before any development occurs.

**Maintenance and Operational Considerations**

Inspections of each SWMP will determine the frequency of maintenance required. Inspections should be made by the developer after every significant storm during the first two years of operation to ensure that each SWMP is operating properly. It is anticipated that this will translate into an average of four inspections per year. After this maintenance period, when the operation of each SWMP has been confirmed, inspections are recommended every three years thereafter.

Off-line SWM facilities should be fenced and signs posted to advise of their intended functions. SWM facility slope criteria should be confirmed with the Town at the FSP stage. It is recommended that a 5:1 slope be used in the vicinity of the permanent pool for at least 3 m horizontally, on either side of the permanent pool, in order to provide a sufficient safety factor and if the facility will not be fenced.

Off-line SWM facilities will require periodic maintenance activities. All facilities should be inspected after significant rainfall events, (a minimum of one inspection every three years) and spill occurrences, and any large pieces of debris and/or spill contaminants should be removed. Beyond this, each facility will require monitoring for sediment accumulation. It is estimated that each sediment forebay for the off-line facilities will require maintenance once every 8-10 years in order to remain efficient. This would entail draining the forebay and using a front-end loader to scrape up the sediments. These sediments could be disposed of in the short term, within a landfill facility of the municipality. Alternatively, areas could be designated within each facility, but outside of the quality and quantity (runoff duration control) active volumes, for the storage of sediments. The topsoil would be stripped from these storage areas, the sediments from the forebay deposited, and the topsoil replaced and revegetated. All maintenance activity would be scheduled to occur during dry weather conditions. This work would take roughly one or two days to complete.

As each facility will accumulate sediment, it is anticipated that each off-line pond will require a full scale clean out every 25 years. At that time, each facility will be restored to the final design grades. The sediments from the forebay clean outs would also be removed and all sediments would be disposed of off site. Based upon current standards, the sediments should be disposable as normal fill material.

To confirm anticipated sediment removal requirements at the detailed design stage, the "*Stormwater Sediment Management Manual (1999)"* by Greenland International Consulting Inc. should be used. This manual was developed through a joint committee that was formed/funded by the Ontario Ministry of the Environment (SWAMP program), Toronto and Region Conservation Authority, Credit Valley Conservation and several GTA municipalities, to investigate alternative methods for removing accumulated sediments from stormwater management facilities. The work completed by Greenland is an important step towards optimizing the long-term maintenance of SWM facilities. Its contents and the information from pilot studies measuring sediment accumulation, plus experience with new sediment removal projects, forms the basis of his practical guidance manual for consultants and municipal maintenance departments.

### Final Design and Post-Construction Monitoring Requirements

This section discusses the requirements for technical approvals, the future needs of the facilities and suggests a post-construction monitoring strategy to ensure that the proposed facilities will continue to function as designed. It is anticipated that as the SWM facilities and development matures, the monitoring and maintenance programs would require refinements. Any changes would be dictated by the observations noted during regular monitoring.

<u>Final Design Requirements</u>

The information presented in the previous sections of this report provides the basis for the implementation of a recommended stormwater management plan for the Black Ash Creek Subwatershed Plan. Although the findings from our natural heritage and hydrogeological analyses were used in the development of a mitigative plan, detailed site specific information will be required to complete the final design at the functional servicing plan and Environmental Impact Statement stages.

Our recommended SWM plan, as identified on Figure 12 of the Main Report, has identified facilities where costs could be shared by more than one stakeholder. Prior to the final design, the Town of Collingwood, in conjunction with the appropriate stakeholders, must resolve all land requirements associated with implementation of the preferred scheme. This will require the undertaking of land appraisals as well as legal surveys.

The following identifies a number of other final SWM facility design requirements:

- Geotechnical investigations to confirm foundation conditions in the area of the proposed SWM facilities;
- Topographic surveys to confirm grades and establish proper alignment of road patterns and storm sewer outlets.
- Confirmation and completion, if required, of fish habitat compensation pursuant to the *Federal Fisheries Act*. The need for, and suitability of, compensation and the scope of the compensation program would be completed in the early stages of the design process;
- Refinement of our Visual OTTHYMO hydrologic models to suit approved subdivision draft plans. Thereafter, the NVCA will incorporate this design data into the ISWMS models of the overall Black Ash Creek Subwatershed;
- Land easement requirements to facilitate the proposed SWM facilities;
- Detailed site grading plan to achieve the required storage volumes within the proposed off-line and/or on-line SWM facilities, as identified in our report;
- Detailed design of the inlet and outlet structures associated with the SWM facility proposals;
- A naturalization/landscaping plan designed to achieve environmental targets specified in the Subwatershed Plan;
- Specifications identifying details of the design, method of implementation and erosion and sediment control during construction; and,
- A manual of Operations, Maintenance and Monitoring requirements associated with the proposed SWM facility (ies).

Proactive consultations with the municipality and regulatory agencies, to avoid delays in the review/ approval process, should be a priority. Although the final design will be based on the details in this report, subsequent approvals will be required from the various regulatory agencies.

Post-Construction Monitoring Strategy

In accordance with the Ontario Water Resources Act, as administered by the Ministry of the Environment, the approval process for each SWM facility would result in a “Certificate of Approval”. This would include the operation of each facility, according to specific conditions regarding operational methods, required effluent quality, and required “performance” monitoring reporting. The monitoring locations should be established at both the inlet to and outlet(s) from each facility. This type of approach will allow determination of the pollutant contribution from the development area draining to each facility, while at the same time determine the pollutant removal efficiency of the facility.

The monitoring of the water quality itself can be done by means of either grab samples or continuous sampling protocols/procedures, and must be taken during wet weather flow conditions to establish the increase in pollutant concentrations. The monitoring of rainfall will be essential to relate the increase in pollutants and flows in order to approximate mass loading rates. Instantaneous flow measurements will be necessary at the time of collecting the water quality samples. The following brief synopsis will serve as a "skeleton format" to later develop a step-by-step monitoring schedule at the time of the final design. The Town of Collingwood, NVCA and MOE should be consulted at the functional servicing plan stage to determine if the monitoring program must be reviewed and approved prior to the issuance of the Certificate of Approval:

1) Finalize the monitoring objectives and relative importance of each and incorporate data from the long-term stream health monitoring program (including the use of NVCA technical staff to measure BioMAP parameters for the affected stream reach).
2) Express the objectives in statistical form. Each objective should be expressed as an average with an associated level of statistical significance. Often neglected, water quality monitoring is a statistical process with uncertainty associated with the final results.
3) Assign monitoring budget and fractions allocated to each objective. Realistic economic limits will be established on the number of samples, stations and parameters to be analyzed according to the monitoring objectives.
4) Monitoring parameters. Parameter selection must reflect the desired water enhancement purpose. Selection of the monitoring parameters must reflect seasonal relevance and applicability.
5) Finalize sampling times and frequencies. Sampling should be undertaken between April and November (and at the earliest in March if snow melt occurs earlier) in order to coincide with the critical periods of spring melt and wet weather flow. Measurements during these periods would give an indication of the critical water quality conditions in the serviced drainage area.
6) Recommend an operating plan and procedures. Sample collection procedures and schedule will be defined for co-ordination with laboratory, and other field operations (e.g. flow monitoring, data retrieval, etc.)
7) Recommend a reporting format. Data should be summarized and presented in a clear and concise manner to facilitate impact assessment.

### *D.4.2 Construction Controls*

Erosion and sediment control should be implemented for all construction activities within areas, including topsoil stripping, parking lot construction, foundation excavation and stockpiling of materials. The basic principles considered to minimize erosion and sedimentation and resultant negative environmental impacts include:

- Minimize local disturbance activities (e.g. grading);
- Expose the smallest possible land area to erosion for the shortest possible time;
- Institute erosion control measures where needed and as required immediately;
- Implement sediment control measures before the outset of construction activities; and,
- Carry out regular inspections of erosion/sediment control measures and repair or maintain as necessary.

The proposed grading, servicing and building construction should be carried out in such a manner that a minimum amount of erosion occurs and such that sedimentation facilities control any erosion that does occur.

Erosion and sediment control measures should include but not be limited to the following:

- Pre-grading of off-line SWM facilities for use as a siltation control pond. The MNR criteria requires siltation/erosion control for 125 m≥/ha of dry run-off storage for each facility. However, given the environmentally sensitive nature of Black Ash Creek, siltation control ponds should also include, where appropriate, a permanent pool volume. For example, a criterion used by the Grand River Conservation Authority in the Kitchener/ Waterloo area includes 100 m≥/ha of both dry and wet storage volumes for each facility. An appropriate level of control should be agreed upon with the Town of Collingwood and NVCA. Once the construction site has stabilized, each pond must then be cleaned out and restored to the final grades, plantings, etc. for its post-construction use.

- Erection of silt fences around all construction sites;
- Provide sediment traps (e.g. berms, geotextile stone barriers in swales);
- Provide gravel "mud matts" at construction vehicle access points to minimize off-site tracking of sediments; and,
- Confine refuelling/servicing equipment to areas well away from inlets to the minor system or major system elements.

The location and types of all erosion/sediment control measures will be illustrated on the final design drawings. Removal of the erosion/sediment controls should be done once construction is completed and sediment run-off from the construction activities has stabilized.

### *D.4.3 Improvements to Current Land Use Practices*

<u>D.4.3.1 Urban Areas</u>

The restoration of “stressed” or degraded stream systems is perhaps the most challenging watershed management objective for achieving sustainable targets such as water quality enhancement and erosion control. The restoration, rehabilitation or enhancement of watercourses within urbanized watersheds, to any meaningful degree, can be economically achieved by taking advantage of opportunities such as the retrofitting of Best Management Practices (BMPs) in the drainage network.

Opportunities for urban retrofitting are limited in developed watersheds, but they can be revealed through detailed evaluations. For example, stormwater management pond retrofitting has been the primary focus of restoration efforts in the Greater Toronto Area and has typically involved converting older dry SWM facilities into extended detention, hybrid wet pond-wetland systems. Typically, the best sites for urban retrofits for water quality enhancement, erosion protection and/or water quantity control are found: 1) at the “end of pipe of a storm drainage system, 2) across or within an open engineered channel, 3) adjacent to a natural or open engineered channel, or 4) within an older BMP system, such as stormwater detention ponds or surface water retention facilities.

Our retrofit assessment of stormwater management opportunities within the Town of Collingwood revealed no practical/cost-effective “end-of-pipe”’ or “conveyance” options for enhancing existing stormwater runoff from a water quality and quantity (erosion control) perspective. However, the future implementation of a community-wide “at-source” control program would ensure achieving water resource management targets specified in the Subwatershed Plan. Potential benefits would include the moderation of more frequent flood flows and mitigation of urban runoff pollution – with or without potential improvements to upstream rural areas. These other potential land use improvements are discussed later on.

Potential at-source control options would be limited to existing industrial and recreation (including the Blue Mountain Golf and Country Club) lands within the Town of Collingwood.

D.4.3.2 Rural Areas

Agricultural land uses (within headwater basins of the Black Ash Creek Subwatershed) have gradually intensified as narrow economic margins have pushed farmers to utilize as much land as possible and increase production per hectare by increasing herd size, intensifying cultivation and fertilizer/pesticide use, and by growing crops with greater nutrient requirements. While this land use change is more subtle than rural to urban change, environmental impacts along the Black Ash Creek system may be significant.

Some impacts, such as tile drainage and watercourse alterations, have caused stream instability and aquatic habitat deterioration over several decades. While these practices may have extended the defined channel of some streams by deepening watercourses and concentrating flows via tile drainage, they have also eliminated natural channel characteristics and reduced the former extent of natural floodplains. More efficient drainage along the Black Ash Creek system has also caused headwater reaches to dry up more quickly and the concentration of flood flows within the drainage channels combined with sedimentation from soil erosion has increased streambank erosion further downstream. Other impacts from rural land use practices, such as soil erosion and nutrient loading, are more recent activities affecting stream habitat conditions. These degrading effects have been subtle, yet cumulative, resulting in streams, which are capable of supporting only the hardiest of fish and invertebrates. Likewise, extensive drainage practices, clearing of marginal lands, removal of fencerows and streamside vegetation and depletion of woodland reserves has left limited areas of natural vegetation on the landscape. Correcting these problems and restoring natural stream functions and natural vegetation features should be viewed as a long term, but critical goal, which should proceed on a priority basis.

Current trends in agricultural land use is toward larger, more productive farms resulting in fewer farmers and an increase in lands farmed under lease agreements. In some cases, this would threaten the continued enhancement of natural areas, since the renter's interest in the land is short term and most conservation initiatives require a long-term view. On farmlands closer to urban centres, this concern can be intensified since more lands are held by non-farming owners and individual farm sizes have tended to remain smaller. Another current trend is an increase in the number of farm operators who do custom work, such as planting and harvesting services to other farmers on a fee for service basis. These custom operators, some of whom utilize conservation tillage equipment, represent an important opportunity for implementing some rural Best Management Practices for the large land areas that they work.

The Nottawasaga Valley Conservation Authority has actively promoted programs within rural portions of its jurisdictional watershed. Over the years, the NVCA has served as the implementation mechanism for a variety of incentives provided by all levels of government. Currently, however, the NVCA has a very limited capital works budget to correct major sources of stream bank erosion, which contributes to sedimentation of the Black Ash Creek system. Funding support is also available through the NVCA for tree planting on marginal lands and for the purposes of providing windbreaks, shelterbelts and streamside vegetation.

The NVCA has a strong presence in rural communities of the Nottawasaga Valley Watershed and has fostered a number of partnership arrangements with conservation clubs, soil and crop improvement associations, etc. As a result, the NVCA is well positioned to implement rural programs associated with the Black Ash Creek Subwatershed Plan. Incentives, combined with education/awareness and technical assistance programs, are clearly effective in rural implementation. However, incentive programs have traditionally been under-funded or too inflexible to address the broad range of rural issues.

D.4.3.3 Recommendations

***Urban (Industrial) Areas***

As alluded too earlier, the recommended SWM plan for developments within Collingwood will ultimately include water quality (Level'1') and 25mm rainfall-24 hour detention controls – in the event the Flood Control Project is constructed. If the channelization is not in place prior to a site being developed, 2 year storm-48 hour detention erosion controls will be necessary. Flood control storage for design storms greater than a 2 year event are not necessary for the Collingwood developments examined during this study (refer to Figure 9; Main Report). Subwatershed location and headwater basin flow attenuation effects are important factors to ensure that urban flood discharges near the subwatershed outlet are discharged as quickly as possible to the watercourse. These findings are supported from our Visual OTTHYMO©, ISWMS™ and HEC-RAS computer models. Nevertheless, in light of the limited streamflow monitoring data (i.e. due to the study length and insufficient number of significant rainfall and/or snowmelt/runoff to ensure a proper calibration of the hydrologic models), it is also recommended that the monitoring program be maintained until December 2001 for model calibration purposes. In the event that other groundwater modelling work is required for the headwater basins, this data would also be valuable for undertaking water balance analysis of the entire subwatershed. Any future SWM retrofit projects by local industry/businesses should also be considered in these investigations. In the meantime, the Town of Collingwood and developers should use the computer modelling database from this study.

In terms of confirming "at-source" retrofit control opportunities for industrialized areas of the Black Ash Creek Subwatershed Plan, the percentage of businesses interested to explore innovative "smart" BMPs must be determined first. The Nottawasaga Valley Conservation Authority could undertake this preliminary assessment of at-source control retrofit opportunities for the Town of Collingwood, with any required technical support. The "smart" use of Best Management Practices combines "conventional" stormwater management works with "non-conventional" conservation technologies. For example this would include, for large industrial sites, the collection/storage of surface water, treatment if necessary and converting the surface water for local plant needs – such as equipment washing, process and/or product water. Wastewater from the re-used surface water could then be discharged to the municipal sanitary system – at the desired compliance targets and at the same (i.e. potable water source) volume as before. This diversion of wet-weather runoff (i.e. not natural baseflow) from the storm drainage network would be acceptable as long as downstream stream health is not adversely affected and if the solution helps to maximize erosion control benefits. Alternatively, re-used surface water for an industry's process water (cooling) needs could be discharged back to the storm drainage network following as-required thermal treatment (e.g. via a cooling trench outlet) in the case of a coldwater receiver. This other discharge approach would therefore help to augment stream baseflow but would not be as helpful to reduce downstream erosion shear stress along the stream receiver.

A smart use of BMPs for large industrial/commercial settings can be undertaken when older plants or businesses need to upgrade storm and sanitary sewer collection/treatment systems to ensure full and consistent sewer use by-law compliance. Typically, at-source controls for industrial/commercial settings can include: 1) the collection/storage/treatment of contaminated runoff from wet-weather events, 2) the containment of potential dry-weather spills from chemical tanks farms, loading/shipping areas and rail tanker yards, and 3) routine site management operations such as snow removal/storage. Prior to the detailed design of "site specific" at-source controls, a comprehensive sewershed-wide water balance is needed to review industry operation/production water needs, to maximize the conservation or re-use of surface water from roof and/or paved surfaces and to optimize local wastewater collection/treatment systems. This integrated water balance and surface water management approach would be based on computer modelling with historical rainfall data, as well as water use and sewage records (i.e. via an audit process) for the affected industry (ies).

Finally, Greenland International in partnership with the Toronto Region Conservation Authority, Seneca College, University of York, City of Toronto, CRESTech and Public Works Canada, initiated in March 2000 "combined natural systems" research for runoff source control, air purification and energy reduction at various pilot sites in the Greater Toronto Area. The "system" will combine new but proven technologies for precipitation-runoff water capture, flow attenuation, storage and re-use as well as air bio-filtration mechanisms (e.g. "green" wall and roof designs) and will integrate both with internal building water air/water uses. This system has immense potential to provide short and long term benefits for indoor and outdoor air quality, stormwater control and reductions in municipal potable water demand. Each site will be accurately monitored and carefully operated for at least four years to allow stabilization and performance optimization so as to demonstrate local, regional and global benefits. The technology arising from this research could have great potential for any "at-source" retrofit control initiative for industrialized areas of the Black Ash Creek Subwatershed Plan.

***Rural Areas***

Discussions with study participants, representing resort businesses (e.g. Osler Bluff Ski Club) and agricultural community have indicated that the short-term economic effects of restoring a natural heritage system within the headwater basins are perceived to be negative. Therefore, an on-going program of incentives is necessary to offset initial negative impacts, combined with an overhaul of provincial policies and legislation to provide clear direction on provincial priorities for environment and agriculture in the rural landscape. Fundamental to success of any rural program for the Black Ash Creek Subwatershed Plan is provision of the necessary staff and resources to continue an education/awareness program, provide technical assistance and monitor the effectiveness of programs in terms of usage by client groups and environmental improvement. Active participation (in terms of staff and financial support) by the Town of Collingwood and NVCA is also viewed as fundamental to success of any rural program implementation. The municipality should also acknowledge from the onset that agricultural and resort land uses are a permanent land use within the Black Ash Creek Subwatershed and a vital part of the local economy. Finally, a continued effort to establish partnerships between rural and urban (i.e. Town of Collingwood) constituents is needed to foster better understanding and joint participation in understanding environmental issues common to both groups.

In the long term, goals for sustaining natural systems and healthy streams by way of improving current rural land use practices will be achieved by changing landowner attitudes toward these areas from liabilities to assets. The continuation of the following initiatives is vital to championing this long-term attitudinal shift:

1) Education and awareness programs;
2) Technical assistance and demonstration projects;
3) Fostering stewardship through community groups/organizations; and,
4) Monitoring program effectiveness.

The implementation of a rural program for headwater basins of the Black Ash Creek Subwatershed should focus on the following:

- Correcting existing problems on a priority basis; and,
- Preventing future problems from occurring by strengthening and clarifying policies/legislation and providing services that are customer driven.

The priorities for addressing existing land use practice problems associated with agricultural practices are as follows:

1) Prevent overland soil erosion.
2) Reduce nutrient loading to streams.
3) Stabilize stream banks.
4) Restore stream morphology.

Staff resources, particularly in extension services of the NVCA and/or affected municipality, must be maintained or expanded to ensure that effective promotion of incentive programs and ongoing technical/monitoring support is ensured. Without this level of effort, an incentive program (for either urban or rural areas) associated with the Black Ash Creek Subwatershed Plan will fail.

### *D.4.4 Capital Works Projects*

The following summarizes required capital works projects associated with or affected by the recommended Subwatershed Plan:

1) Construction of the Black Ash Creek Flood Control Project.

### *D.4.5 Recommendations and Implementation Strategy Framework*

The Subwatershed Plan recommendations are outlined under the broad headings of: 1) Constraint Areas, 2) Development Criteria, and 3) Conservation and Management Practices. In order for the Plan to achieve its full potential, progress must be made under each of these categories. To facilitate this, Table 11 below has been prepared indicating the action to be taken, the lead agency (and support agencies), the recommended means or mechanism for completing the action, the time frame for implementation and the funding responsibility.

In many cases the time frame for the component action is “immediate and ongoing” or “ongoing”. The actions needed under the Subwatershed Plan are not simply reactive “fix and forget” type solutions. Rather they require an ongoing commitment and perseverance if they are ultimately successful. The Subwatershed Plan must change the way stakeholders develop and use the land if sustainable growth is to be achieved.

The lead agency for implementation varies from component to component but is always either the Town of Collingwood, Clearview Township, Town of the Blue Mountains or Nottawasaga Valley Conservation Authority. Provincial agencies and/or private sector partners are designated as supporting agencies in some cases and are assumed to be available for technical comment and support, as needed. The responsibility of implementation may require modifications or additions to both municipal and NVCA structures to allow for the most effective implementation. The greatest change will be needed within the Municipality because the implementation of the Subwatershed Plan represents a new mandate. Just as the development of the Subwatershed Plan brought together divergent viewpoints, it will be necessary for all three municipalities to form a structure that involves many of its departments and committees in the continuing implementation of the Plan. It is recommended that the municipalities undertake to form an

“Environmental Implementation Committee”, as part of its endorsement of this Subwatershed Plan, as well as potential others in the future.

The Conservation Authority is structured in a manner, which is consistent with the responsibilities assigned to them under the Subwatershed Plan. There may however be a need to reorient some efforts and programs in order to increase liaison or delivery within the Black Ash Creek Subwatershed.

Funding responsibility is predominantly assigned to either the municipality or the proponent, although in some cases this responsibility rests with the NVCA or landowner. It is recommended that discussion continue within the Implementation Committee to assess means of accessing provincial or federal sources of funding and reallocating resources to key areas such as agricultural land use improvement programs.

**TABLE 11**
**Implementation Strategy - Subwatershed Plan Recommendations and Responsibilities**

| Subwatershed Plan Component | Recommendations (Action) | Lead Agency (support agency and/or advisory municipality) | Mechanism | Proposed Time Frame | Funding Responsibility |
|---|---|---|---|---|---|
| ***Constraint Areas (Natural Features and Hazards) –*** | | | | | |
| Natural Heritage system | Identify and protect the Natural Heritage system within the Watershed. | Municipalities; Approval Authority; Review Agencies | Designate the Natural heritage System in Municipal Official Plans and outline policies for their protection in accordance with the Provincial Polity Statement. | Upon completion of the Subwatershed Plan; and ongoing | Municipalities and Proponents |
| Natural Heritage System rehabilitation | Promote the rehabilitation (tree planting) of priority sites | Interest groups, agencies(NVCA), and landowners | Promotion, through planting programs, and contacts with potential partners | Ongoing | Landowners and/or partner organizations |
| Areas within flood or fill lines<br><br>(Town of Collingwood reaches of Black Ash Creek and designated urban lands that were examined during this study) | Protect lands within flood and fill lines as no development lands | Town of Collingwood (NVCA) | Update and register flood and fill lines, based on HEC-RAS modelling from study. Delineate new hazard areas within OP land use schedules | Complete in 2000 | Municipality |
| Areas within flood or fill lines<br><br>(Other Collingwood developments requiring amendments to the OP and as-required areas for Township of Clearview and Town of The Blue Mountains) | Protect lands within flood and fill lines as no development lands | Town of Collingwood, Clearview Township and Town of The Blue Mountains (NVCA) | Update HEC-RAS computer models from this study and register flood and fill lines prior to development approvals. Delineate new hazard areas within OP land use schedules | Unknown at this time | Developers & Municipalities |

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| All significant headwater recharge and discharge areas within Black Ash Creek, as well as adjacent watercourse systems (e.g. Pretty River, etc.) that provide baseflow to Black Ash Creek via aquifer underflow connections | Protect lands subject to a detailed water balance and groundwater study that incorporates data from the *"A-E-M-O-T Groundwater Management Plan"* study. | Clearview Township and Town of The Blue Mountains (NVCA and Town of Collingwood) | Designate lands in Official Plans prior to consideration of development | Complete by December 2001 | MOE and Municipalities |
| ***Development Criteria*** | | | | | |
| Peak flow attenuation<br><br>(NOTE: Not necessary for the Collingwood developments examined during this study) | Provide quantity control storage to prevent increased flood damage as specified in the Subwatershed Plan | Clearview Township and Town of The Blue Mountains (NVCA and Town of Collingwood) | Update hydrologic models from this study prior to the preparation of individual stormwater management (SWM) reports by developers. Final design submission would also be in parallel with submissions for subdivision approvals. | Unknown at this time | Developers |
| Water Quality | Provide quality storage as specified in the Subwatershed Plan | Municipality | Submission of preliminary or "Stage 1" stormwater management (SWM) report to include pre-design of facility conformance with Plan. Final design submission in parallel with submissions for subdivision approvals. | Immediate and ongoing | Developers |
| Erosion/Stream Morphology<br><br>(Town of Collingwood reaches of Black Ash Creek and designated urban lands that were examined during this study) | Provide "interim" 2-year or "ultimate" 25mm storm quantity storage to prevent increased erosion potential from new urban development | Municipality (NVCA) | As above | Immediate and ongoing | Developers |
| Baseflow Augmentation | Refer to water quality/erosion requirements and proposed at-source control initiative | | | | |
| Infiltration | Provide lot level infiltration (5-10mm of roof runoff) on suitable soils (moderate recharge/discharge areas) if development approved | Municipality (NVCA) | Require detailed hydrogeologic studies of potential recharge or discharge areas in Plan. SWM report to include, if appropriate, infiltration techniques to be employed | Immediate and ongoing | Developers |
| Erosion control during construction | Require preparation of Sediment and Erosion Control Plan for all new developments | Municipality (NVCA) | Preparation of the Erosion and Sediment Control Plan to be included in the conditions of draft plan approval | Immediate and ongoing | Developers |

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| Two-Zone Flood Policy | Not examined during this study. This policy should be considered, however, by the NVCA on a "case-by-case" basis if Black Ash Creek Flood Control Project construction is not initiated in 2001. | | | | |
| Complete update of flood and fill lines | Undertake detailed floodplain mapping and prepare flood / fill line maps for remaining watercourses designated on OP land use schedules prior to consideration of development | NVCA, Clearview Township and Town of The Blue Mountains | N/A | Complete by December 2001 | NVCA and Municipalities |
| Construction inspection | Require regular inspection by a qualified environmental inspector during construction | Municipality (NVCA) | Agreement to provide an environmental inspector to be included in the conditions of draft plan approval | Immediate and ongoing | Developers |
| Erosion monitoring | Require regular inspection of receiving watercourse by a qualified environmental inspector during construction and for period of two years after completion of construction | Municipality (NVCA) | As above | Immediate and ongoing | Developers |
| Encourage environmentally sensitive site planning techniques | Promote the use of good site planning techniques which seeks to limit grading and retain smaller natural areas and watercourses | Municipality (NVCA) | Municipality to develop guidelines and encourage their use in subdivision design | Immediate and ongoing | Developers |
| ***Conservation and Management, Practices, Projects and Programs*** | | | | | |
| Floodproofing and Local Flood Protection (i.e. if the Black Ash Creek Flood Control Project construction is not initiated in 2001) | Provide local flood protection for structures identified from study's HEC-RAS modelling, as well as potential spill areas from the North and South Branch and affected lands of the Blue Mountain Mall | NVCA and Town of Collingwood | Evaluate feasibility, if the Black Ash Creek Flood Control will be delayed indefinitely. The spill hazard through Collingwood should be mapped using HEC-RAS and the Town's digital mapping database. | Complete in 2001 | Town of Collingwood and NVCA |
| "At-source" Control Retrofit Program for Industrialized Areas | Investigate feasibility of "smart" Best Management Practices that re-use stormwater for process water. Integrated water balance, SWM and "green-roof" system opportunities would also be identified. | Affected Industry, Town of Collingwood and On-going Public-Private Research Initiatives | Preparation of a report that could be incorporated with any Subwatershed Plan Addendum. This addendum would therefore incorporate detailed water balance and groundwater modelling calculations | Complete by December 2001 | Affected Industry, Town of Collingwood, Available Funding Grants from Government and Public-Private Research Sources |

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| Climate, Streamflow and Biological Monitoring | Maintain/operate continuous monitoring devices from this study for at least one year – beginning Sept 2000.<br><br>Continue biological monitoring of Black Ash Creek and the wetland at its mouth | Town of Collingwood and NVCA | Finalize calibration of hydrologic models prior to water balance and groundwater system modelling for the headwater basins. Data would be used to monitor potential impacts from future development within headwater basins and provide real-time flood forecasting capabilities for the NVCA. Real-time web-based data collection capabilities could be implemented (if approved) as part-of a 2000 *"Ontario GeoSmart"* research initiative .<br>Continue the Stream Health Monitoring Program established by NVCA, through the flood control project and include the wetland at its mouth. | Completed by 2001 (i.e. minimum one year data collection period for model calibration with the GeoSmart research initiative)<br><br>Ongoing, continue through the flood control monitoring program | Town of Collingwood, Developers, Local Industry and Environmental Groups, NVCA, and MOE |

## D.5 MONITORING AND ADAPTIVE ENVIRONMENTAL MANAGEMENT

### *D.5.1 Overview*

As discussed earlier, in the absence of human activities, the critical habitat characteristics for most biological communities are determined either directly or indirectly by physical features and processes whose magnitude and rates of change are determined largely by geology and climate. When human activities are introduced to natural areas, which were previously void of human activities, impacts can cover the range from being direct and obvious to being indirect and subtle.

Despite our best efforts to establish a subwatershed management plan for the study area to maintain and enhance the features and functions of the natural environment, the plan is based on a finite set of information and assumptions about development timing, build-out period and human activity. Consequently, it is important that a set of indicators be established that can be monitored over time to determine if the components of the Management Plan have been appropriately conceived, or if changes to the plan need to be made to adapt to a different set of conditions which have evolved in the area. For example, the stability of stream morphology could be monitored using a protocol based on the comparison of the statistics describing the pebble count data and hydraulic geometry parameters (bankfull channel area, depth and width, channel-top width, pool depth, and baseflow channel width and depth) are possible variables for consideration. If a decrease in particle size is found, which is determined to be statistically significant along with corroborative evidence of aggradation, the monitoring results could be interpreted as a sign of significant morphological alteration.

Such a change could have been brought about by economic factors that slowed the rate of build-out in a development area that resulted in the inadvertent oversizing and hence overcontrol of instream erosion potential resulting in destabilization of the channel and habitat impacts due to aggradation. The adaptive management approach would be to increase the rate of flow for the mid-bankfull and bankfull stages to increase scour potential. It is important, consequently, that any centralized SWM facilities and the respective flow control structures be designed such that they can be implemented in a phased manner. Ponds can be constructed in a multi-celled manner and flow control structures can be designed such that their hydraulic performance can be varied.

Conversely, if pebble counts indicated an increase in coarse material and/or a homogenizing of the bed materials is occurring along with corroborative evidence indicating that degradation was occurring, then the adaptive management strategy would be to decrease the rate of flow for the mid-bankfull and bankfull stages. Consequently, flexibility in the design and operation of centralized SWM facilities is required.

Therefore, particular effort will be made to finalize the implementation strategy shown in Table 11 to develop an appropriate monitoring plan, a set of indicators, and corresponding adaptive management measures to be employed if monitoring results indicate adjustments are required to be made to management measures already in place. Table 11 presented general details and final study requirements must be confirmed with the Town of Collingwood.