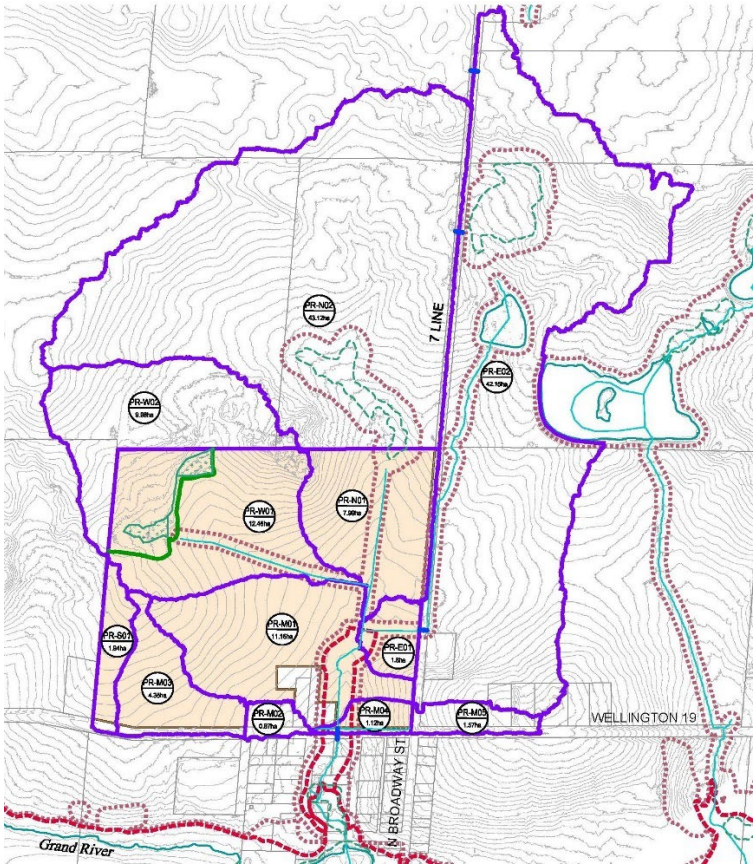
BELCAL INC

FUNCTIONAL SERVICING AND STORMWATER MANAGEMENT REPORT FOR BELCAL DEVELOPMENT

6640 SEVENTH LINE, BELWOOD, ONTARIO, LOT 12, CONCESSION 7



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6640 SEVENTH LINE, BELWOOD, ONTARIO, LOT 12, CONCESSION 7

BELCAL INC

PROJECT NO.: WW22011051

DATE: AUGUST 02, 2023

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QUALITY MANAGEMENT

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1 INTRODUCTION

1.1 LOCATION AND PLAN DETAILS

The proposed residential development is located west of Seventh Line and north of Wellington Rd 19 in the community of Belwood, part of the Township of Centre Wellington. The current proposal is to develop the lands into approximately 107 single family lots on private services (water and septic). The development site is located within a catchment of a local tributary flowing through the Community of Belwood into Belwood Lake which is a controlled section of the Grand River (Shand Dam).

1.2 PURPOSE OF REPORT

This Functional Servicing and Stormwater Management (SWM) Report has been prepared to provide details as to the proposed servicing and stormwater management works for the subject development, and specifically how these works are intended to address the governing criteria of the Township, Grand River Conservation Authority (GRCA) and the Province of Ontario. This report is intended to support the review of the application by the Township and GRCA.

1.3 SUPPORTING REPORTS/STUDIES AND CONTENT OVERVIEW

This report has been prepared in accordance with, and in consideration of, the information and recommendations provided in the following documents:

Standards and Guidelines:

- Development Manual, Township Centre Wellington, March 2018.
- Stormwater Management Planning and Design Manual, Ministry of Environment (MOE), March 2003.
- Low Impact Development Stormwater Management Guidance Manual, (Draft), January 2022, MECP

Site Specific Studies:

- Preliminary Geotechnical Characterization, Proposed Residential Subdivision, 6640 Wellington Road 19, Belwood, Ontario (Chung & Vander Doelen Engineering Limited, September 21, 2022)
- Draft Hydrogeologic Assessment BelCal Inc. Proposed Development 6640 7th Line Belwood ON (Groundwater Science Corp, March 2023)
- Environmental Impact Study (Stovel and Associates, 2023)
- Headwater Drainage Feature Assessment Fluvial Geomorphology Components & Meander Belt Analysis, Belwood Lake Tributary Township of Centre Wellington (Aqualogic May 24, 2023)
- Preliminary Onsite Sewage Servicing Assessment Proposed Residential Development 6640 Seventh Line in the Village of Belwood, Township of Centre Wellington (Crozier Consulting Engineers, January 24, 2023)

The report includes a description of the governing SWM Criteria, an overview of existing conditions and an outline of the proposed development and associated SWM works.

2 STORMWATER MANAGEMENT CRITERIA

2.1 OVERVIEW

The SWM plan needs to address specific criteria and requirements associated with the management of stormwater runoff (quantity and quality), as well as the treatment of open water features specific to watercourses and headwater drainage features (HDF). The following summarizes the respective criteria and guidance accordingly.

In addition, a Pre-consultation Meeting was held with Township staff (January 25, 2023) and the following matters were raised for consideration in the formulation of the SWM plan:

- Preferred source controls for public systems include linear systems with low maintenance needs and for private side systems infiltration galleries are preferred; enhanced/increased topsoil may be considered;
- Urban roadway standards are preferred however hybrid (urban/rural) can be considered;
- Township prefers the south SWMF location on Lots 1 and 2 rather than Lot 3;
- Discharge to County Road needs to meet its standards, including driveway upgrades;
- Preference to pipe western watercourse feature rather than incorporation into the roadside drainage system;
- Need to consider chloride infiltration in roadside works;
- Township not aware of any flooding issues downstream of the site but would be open to potential mitigation measures; and
- For maintained watercourse features Township noted a preference to ownership rather than easements

Pursuant to the Pre-consultation meeting, WSP/SAL engaged the Township Engineer (Colin Baker) regarding the roadway drainage approach; as part of that discussion, it was confirmed that the Township would consider a roadway drainage system comprised of shallow ditches on one side of the road with a sidewalk on the other. Ditch depths and lengths would be limited by having gutter outlets to capture roadway runoff and a roadway storm sewer, to capture treated runoff from the enhanced swales. This approach would address provincial requirements for a treatment train while also minimizing Township maintenance. Further details are outlined in this report.

2.2 QUANTITY AND QUALITY CONTROL

The stormwater management design criteria based on the Township of Centre Wellington, Grand River Conservation Authority Design Criteria, and the Ministry of the Environment, Conservation and Parks (MECP) Stormwater Management Guidelines include:

- Quality Control: Level 1 (Enhanced – 80% average annual removal of Total Suspended Solids (TSS))
- Erosion Control: 24-hour retention of 25 mm runoff event
- Peak Flow Control: Post- to Pre-Development Peak Flow Control for 2- through 100-year storm events
- Volume Control: between 28 and 29 mm per MECP 2022 (Draft)

2.3 WATERCOURSES AND HEADWATER DRAINAGE FEATURES (HDF)

Open water features with a drainage area greater than 50 ha can be considered as regulated watercourses by the GRCA. Based on available mapping and drainage area calculations this is considered limited to the Main watercourse flowing north to south to Belwood Lake (refer to Section 3).

In terms of all other open water features, these are all considered to be headwater drainage features (HDF) and their management is based on their classification per the TRCA/CVC Headwater Drainage Feature Guidelines, 2014, which is detailed in the Aqualogic Report provided in Appendix A.

3 EXISTING CONDITIONS

3.1 LAND USES

The proposed development site is currently under existing conditions comprised of agricultural uses with some residential properties along Wellington Road 19. There is an existing woodlot with wetland features in the northwest part of the site, and a small wetland feature at the top end on the Main watercourse (ref. EIS, Stovel and Associates).

3.2 DRAINAGE AREAS AND TOPOGRAPHY

The Belwood Lake Tributary generally drains from north to south; it has numerous sub-branches or reaches. It has a cumulative drainage area of approximately 137 ha at Wellington Road 19. Refer to Drawing 1 for estimated overall drainage boundaries.

As noted in the Stream Morphology Report (Aqualogic Report May 2023 – ref. Appendix A), the reaches all appear to be man-made drainage features, constructed to facilitate field drainage. Aqualogic set up a reach nomenclature reflecting the orientation of the various branches as follows:

- North
- West
- East
- West + North
- West + North + East (Main)

There is also another minor ditch which is man-made which flows from the west along the north side of a small woodlot to reach West + North + East, through a small culvert.

3.3 SOILS AND GROUNDWATER

Groundwater Science Corp (GWS) prepared a Hydrogeologic Assessment for the subject development site (March 2023). The purpose of the Hydrogeologic study was to characterize the Site using existing information sources, complemented by site-specific field investigation in order assess the feasibility of the proposed use of on-site sewage systems and private water supply wells to service the development.

The study was conducted such that it addressed the Ontario Ministry of the Environment, Conservation and Parks Procedure D-5-4: Technical Guideline for Individual On-Site Sewage Systems: Water Quality Impact Risk Assessment (August 1996); and Procedure D-5-5: Technical Guideline for Private Wells: Water Supply Assessment (August 1996).

The Study provides overall site characterization (i.e., high water table conditions) and impact analysis (e.g. water balance) to support the site design including grading and SWM. Key findings include:

- No Well Head Protection Area (WHPA) or Intake Protection Zone (IPZ) identified at the site or in the vicinity of the proposed development.
- The ice-contact sand/gravel deposit area is part of a Significant Groundwater Recharge area, however, given the presence of till at surface or (generally) near surface, actual recharge contribution to regional groundwater flow systems (i.e. that would potentially support municipal water taking) is marginal.

- The site is identified within an area of low intrinsic groundwater vulnerability and the site is also not within any identified Wellhead Water Quantity Zone.
- The high-water table condition measured at the site occurred in March 2022. A low water table condition at the site was observed in October/November 2022. The high-water table as defined in the GWS report should be used to plan the subdivision design.
- The sand and gravel at surface will likely result in locally enhanced infiltration, however, the sand and gravel deposit is relatively "thin" over most of the site.
- The nearby wetland areas likely contribute to the infiltration and availability of water in the shallow zone.
- The underlying till unit will limit deeper infiltration and regional/local groundwater recharge. The upper till unit is likely weathered/fractured such that some horizontal flow would occur, in both the sand/gravel unit and upper till layer. In the overall area, including the site, this shallow horizontal flow could reach the local channel system and/or any tile drains where they occur.

A Water balance analysis was also completed by GWS for existing site conditions to characterize targets for stormwater management LID source controls implementation. The assessments examined average annual conditions and were developed according to standard water balance input/output methodology. Monthly actual evapotranspiration (AET) estimates were calculated for the sand/gravel and till surficial soils and site setting (hilly landscape, primarily agricultural land cover).

- The AET estimates were developed according to a Soil Moisture Retention (SMR) value of 75 mm for the sand/gravel deposit (moderately deep-rooted crops on fine sand soil), and, 200 mm for the till soils (moderately deep rooted crops on silt loam).
- Annual average precipitation is estimated to be 945.9 mm/yr. The AET on sand/gravel and till soil types is estimated to be 551.29 mm/yr and 571.29 mm/yr respectively. The difference between precipitation falling on the assessment area (direct input) and evaporation/evapotranspiration (direct initial output) is termed the water "surplus".
- The site is generally open hilly lands in which it is assumed that natural runoff could occur. Surficial sand/gravel deposits areas of the site have open sandy loam type soils and can be considered "cultivated". Therefore, an IF of 0.6 (60%) is estimated. The remainder of the surplus (40%) in this area can become runoff. Similarly, the surficial till soils (cultivated medium clay + loam) have an estimated IF value of 0.4 (40%) and runoff of 0.6 (60%). The site is approximately 38.6 ha, of which approximately 19.8 ha (51%) is estimated to have sand/gravel at surface and 18.8 ha (49%) is estimated to have till soils at surface. Under existing conditions average on-site annual recharge is therefore estimated to occur at a rate of 0.195 m/yr.
- It is expected that in order to mitigate any water balance within the proposed development area deficit clean (roof and open land) runoff will be directed to LID lot level and/or conveyance control measures. In addition, end-of-pipe infiltration measures can also be considered.

3.4 ENVIRONMENTAL FEATURES

As noted, there are a few environmental features which need to be considered as part of the overall site development in terms of avoidance and protection as well as sustainability. Details on the various features and their significance and preferred management practices are in the Environmental Impact Study (EIS) which has been used in the preparation of the proposed SWM Plan to guide grading and water management activities.

Some key relevant details from the EIS include the following:

- The Environmental Impact Study (EIS) (Stovel and Associates (2023)) identified the natural heritage features located on and *adjacent* to the subject property, and conducted an assessment to demonstrate that there will be no negative impacts on the natural features or on the ecological functions based on the proposed development and associated mitigation/management recommendations.
- The EIS involved field studies which included: botanical inventories, wildlife inventories, and vegetation community mapping, completed in May to August 2022.
- The subject lands are primarily disturbed and/or used for agricultural purposes, with over two decades of cultivation for common field crop production. There are no natural or semi-natural vegetation communities located within the area proposed to be developed.
- The field investigations and vegetation community mapping focused on natural heritage features located adjacent to the proposed development area. Vegetation communities adjacent to the site were described using the Ecological Land Classification ("ELC") System. Vegetation community boundaries were established on an aerial photo-mosaic base map and field checked.
- The wetland limits and driplines of the adjacent deciduous forests were flagged and surveyed (where possible). Staff from the Grand River Conservation Authority ("GRCA") confirmed the wetland limits onsite. The surveyed wetland limits and driplines of adjacent deciduous forests are shown on the Vegetation Communities map and Development Concept in the EIS.

The EIS defined a series of environmental constraints and opportunities including:

- Northwest Woodlot (FODM5)
- Wetland (SWM3-1)
- Wetland (SWT/SWD)
- Northern Onsite Plantation (WOCM1)
- Southeastern Onsite Plantation
- Onsite Watercourses

The environmental constraints for the subject area are primarily associated with the woodland/wetland feature located northwest of the site. The proposed development does not encroach into any existing natural or semi-natural environmental systems. A portion of the coniferous plantation in the northern portion of the site, i.e., WOCM1, is proposed to be removed as part of the proposed development. To offset this impact, it is proposed that the northerly property limit (specifically the 7.5 m rear yard setback of the proposed residential lots in this portion of the site) be replanted with native trees and shrubs.

In Summary, the ecological recommendations for the proposed development include:

- No development in existing forest/wetland community located in the northwest portion of the site.
- 30 m setback from Wetland SWM3-1.
- 15 m setback from adjacent wetland SWT/SWD in the northwest portion of the site. The wetland in this area is demarcated by an existing agricultural drain that has been excavated along the edge of the wetland.
- 15 m setback from the wetland (SWT/SWD) in the northeast portion of the site. This wetland is in a highly disturbed portion of the site and a drain has been excavated through the middle of the wetland community.
- Removal of 0.2 ha of former plantation (WOCM1) in the north-central portion of the site. To offset the lost of these trees, ecological enhancements and tree-plantings are proposed.
- Maintenance of a 7.5 m setback from the dripline of adjacent woodlands.
- Ecological enhancements adjacent to natural/semi-natural woodlands.
- Rear yard setbacks of 7.5 m in the proposed residential zoning for the subdivision. In areas next to natural heritage features, this 7.5 m rear yard setback would be planted with native trees and shrubs.

- Maintenance of existing plantations in the southern portion of the site. The proposed lot fabric has been established to use these existing plantations as part of the rear yard setback/planting zone and/or used as part of the proposed onsite open space system.
- Public awareness education, and
- Erosion and sedimentation control per Township Standards.

Specific to water management (surface and ground), the EIS acknowledges the proposed SWM Plan which will address the following impacts:

- Disruption of Surface Water Flow to the Wetland Areas. The proposed stormwater design and associated grading plan proposed for the development largely replicate the existing drainage patterns, hence impacts to the wetland areas will be mitigated from a quantity and quality perspective through the use of distributed source controls and water quality treatment train measures in accordance with Provincial requirements.
- Surface Water Storage and Conveyance The proposed stormwater management plan includes at-source infiltration of surface water, limiting onsite grading through the use of a semi-urban/hybrid roadway cross-section for the internal road design. No significant impacts are anticipated on the existing surface water storage and conveyance functions on the site.
- Ground Water Recharge and Discharge. The ground water recharge functions of the site will be preserved and maintained through the use of at-source/distributed infiltration methods to control surface water runoff and thereby enhance this function. The discharge function is largely limited to the wetland and near wetland areas, and no impact on wetland systems or functions is anticipated with the proposed SWM plan in place.

3.5 WATERCOURSES AND HDFS

Aqualogic (2023) (refer to Appendix A) concludes that none of the reaches on the proposed development site are in historically natural alignments. That said, the man-made horizontal alignments have naturalized to a degree over time. The North Reach, the West + North Reach, and the Main (West + North + East) Branch, provide the most significant function through the development area in terms of flow conveyance and corridor linkage. The West Reach has the smallest drainage area and a nominal function with limited apparent aquatic habitat significance. The East Reach has minor functional significance in the development site, as it is bisected by Seventh Line and most of its drainage area is external to the development area which does however reinforce the need to maintain corridor linkages.

Aqualogic recommends that the West Reach can potentially be enclosed by future development with appropriate stormwater management (SWM) practices to ensure no adverse impacts at the confluence with the North Reach. It is recommended that the North Reach, West + North Reach, East Reach, and Main Branch all need to be retained as open features with appropriate setbacks to adjacent future development. Specifically, Aqualogic suggests that:

"*Given the lack of natural channel planform alignments, empirically derived meander belt limits were produced for each reach. The empricial meander belt limit approach has proven to be fair and reasonable for definition of new development limits over existing altered watercourses, for use in realignment natural channel designs, and for risk assessments of existing infrastructure. Future development options and scenarios are therefore recommended to apply meander belt limits of 16m, 19m, 16m, and 25m respectively, for the North, West + North, East, and Main Branch reaches.*"

Resulting meander belt limits are presented graphically on Drawing 2 (attached). AquaLogic also noted that:

"It is also recommended that the existing culvert crossing on the West Reach + North Reach be removed and localized channel restoration be implemented. It is also recommended that restoration works be implemented to replace the existing dam on the Main Branch with a barrier free channel profile".

4 PROPOSED CONDITIONS

4.1 LAND USE

The current plan for the development of 6640 Seventh Line Belwood, Lot 12, Concession 7 is for 107 residential lots which will generally range in size from approximately 0.2 ha to 0.4 ha. The site is proposed to be accessed from both Seventh Line and Wellington Rd 19. Other proposed features of the site include the two dedicated SWM facilities, re-aligned upper section of creek (North\Main Reach; expected to require a municipal easement) and enclosed section of the former western creek tributary (to be piped within municipal road right-of-way) and Open space for parkland, as well as protected natural areas. Refer to Drawing 4 for an overview of the proposed land uses.

4.2 WATER AND WASTEWATER SERVICING

As noted previously, the site is proposed to be serviced by private water and wastewater (i.e. septic) services. Supporting reports have been prepared by others to confirm the adequacy of this proposed approach.

Water services will be provided via private individual wells for each lot. Minimum separation distances from on site septic systems will be maintained; it is generally expected that wells will be proposed in front yards (while septic beds will be located in the rear yards).

Sanitary services will be provided by individual septic systems on each lot. Tertiary treatment is expected to be included as required. Detailed design of individual septic systems will be completed at the subsequent detailed design stage based on the specific soil conditions and development constraints of each lot.

4.3 GENERAL GRADING, DRAINAGE AND WATERCOURSE/HDF APPROACH

Watercourse Features:

The North, West+North, East, and West+North+East (Main) watercourses (per nomenclature of Aqualogic – see Appendix A) are recommended to remain open and as such will likely be contained within easements granted to the Municipality for operations and maintenance (Note: based on Pre-consultation Township has indicated a preference to ownership). Based on the recommendations of Aqualogic, the West watercourse can either be enclosed/piped or incorporated into the roadway drainage system, which is proposed to be comprised of a hybrid drainage system with roadside ditches and storm sewers (semi-urban drainage standard). The drainage from the West + North drainage feature is proposed to remain open. The proposed dimensions for these watercourse features have been established, based on a function of hydraulics, stream morphology requirements and environmental setbacks.

Stormwater Management:

From a Stormwater management perspective, the site has three (3) primary drainage basins based on area topography which need to be considered in terms of surface water management. The three basins include:

- East Area: lands between 7th Line and the North and West+North+East watercourse
- West Area: lands between North and West+North+East watercourse and property limits to the west, property limit to the north, and high point to the south

— South-West Area: lands between Wellington Rd 19 north to high point, west of North and West+North+East watercourse

West Area:

The largest of the drainage basins on the site is the West Area at about 14.4 ha of direct development area (excluding natural and external areas and the SWM facility block) as per Drawing 6. This parcel (comprised of residential groups A, C, D, and E; Street C generally) would be of sufficient size to support a SWM Facility (SWMF) either dry or wet. Rule of thumb sizing from an areal perspective is between 4 and 6 % of the developable area which would mean a facility of approximately 0.7 ha (at 5%). The subject SWMF is currently sized at 1.0 ha (+/-) which would represent approximately 7% of the currently assumed drainage area to the proposed facility.

East Area:

The East Area (development lands situated east of the Main watercourse) is comprised of two discrete development areas. This includes the frontage of properties from Group G (Street E; rear-yard areas expected to drain directly to the north watercourse) and Group H (Street D). Each of these areas would be serviced by its own street with access to 7th Line. The Lots are comparatively large and of low net imperviousness, and the number of lots is minimal (13 lots in Group G and 8 Lots in Group H). Due to these factors, it is proposed that each group (G and H) be managed with source and conveyance controls, along with subsurface storage systems under the roadways or in easements to the creek. Private source controls can be implemented for the residential properties and the roadway runoff can be treated for quality through conveyance controls (grassed swales) and an open bottom storage system can be sited near the discharge point to the Main watercourse to achieve volume controls. Furthermore, any excess runoff during more severe events can be offset through overcontrol in the two SWMFs proposed on the west side of the Main watercourse.

South-West Area:

The South-West Area (groups A, B and C; Street A) is slightly more complex, in that this area generally drains towards Wellington Rd 19, as well as the rear of existing private land holdings which front onto the north side of Wellington Rd 19. There is a man-made ditch and culvert system along the rear of those private parcels which drains easterly to the Main watercourse. It is proposed to use this man-made feature as the outlet for a SWMF to serve this area and put the outlet into some form of public control likely through an easement. As shown on the preliminary proposed drainage plan (refer to Drawing 5), the rear lots of the western most and southern most lots in this area would be graded to drain to Wellington Rd 19; some minor source controls would be expected to be required to mitigate the minor impacts in this area.

5 PROPOSED STORMWATER MANAGEMENT

5.1 OVERVIEW

The currently proposed SWM Plan is presented on Drawing 5. This has been prepared for consideration by the Township and GRCA, with the intent to provide input to each agencies' review of the proposed land use plan.

The SWM Plan has been established to address the criteria and requirements cited in Section 2 specific to the management of surface water related to quality and quantity. For quantity control this needs to consider the objectives associated with managing the impacts of the development on flooding, erosion and water balance (volume). The subsections below outline the approach currently considered preferred for the subject development.

5.2 QUALITY CONTROL

The MECP advocates for a treatment train approach to managing the impacts of urbanization on water quality (ref. MOE 2003 and MECP 2022 (Draft)). For the BelCal development, it is recommended that runoff quality be treated through a series of techniques. Runoff from the private residential development sites is proposed to be captured in part through on-lot source controls (see Sub-section 5.4). The runoff from the private properties will then combine with roadway runoff and be further treated with conveyance controls through the one-sided roadside ditch system (enhanced grassed swales). A typical roadway cross-section has been provided (refer to Drawing 5) which depicts the semi-urban/hybrid approach.

The combined residential and roadway runoff from the lands west of the Main reach will then discharge to one of two SWMFs, where the runoff can be controlled prior to discharge to the Main watercourse. For the lands east of the Main watercourse, no surface-based SWMF is proposed however two small sub-surface (open-bottom) storage systems are proposed at/near the discharge point to the Main watercourse (one for the north and one for the south development parcels) to promote peak flow and volume control for roadway runoff (see sub-section 5.4) and also assist in treating runoff for water quality objectives, prior to discharge to the Main watercourse.

5.3 PEAK FLOW CONTROL/EROSION CONTROL

The introduction of 107 residential lots and the associated roadways to provide access to the properties will increase the amount of impervious area which has the potential to increase peak flows and lead to flooding and erosion in the receiving system (Belwood Lake Tributary). As such, it is proposed to construct two (2) SWMFs along with two (2) subsurface systems to provide controls primarily for the management of flooding and secondarily for erosion control.

Also, as noted in sub-section 5.4, volume control is being recommended to meet the draft guidance from MECP which is expected to be in-place formally shortly. This amount of control for both the private and public lands is also expected to adequately meet the needs of the erosion criteria. That said, there may be opportunities to provide further controls through extended detention in each SWMF, however this has not been proposed at this time.

Lastly, the SWMF, as noted can be either "wet" or "dry". Based on the currently conceived SWM plan which advocates for distributed source controls, it is suggested that the SWMFs would be dry. This form of SWMF would have reduced maintenance and also provide informal open space for the area, hence is considered preferred.

5.4 VOLUME CONTROL

The Low Impact Development Stormwater Management Guidance Manual, (Draft), January 2022, MECP promotes the need for source controls through Low Impact Development Best Management Practices (LID BMPs). This is also consistent with the guidance in the Provincial Policy Statement (PPS) and the Township's Official Plan (OP).

The MECP recommends a three-tier assessment and implementation process whereby Tier 1 (preferred) provides volume controls using LID BMPs at source to capture and manage the 90th percentile runoff event which for Belwood would be between 28 and 29 mm.

Due to the large lots, and the largely unconstrained nature of the development site, it is considered that the MECP draft criteria can likely be attained through on-lot measures, such as rain gardens and infiltration pits (note: Pre-consultation with Township has indicated a preference to infiltration galleries). Further, volume controls can be achieved for the roadway system either through bioswales/infiltration trenches constructed in appropriate locations along the one-sided ditch system (not in areas with shallow groundwater or high bedrock) or through subsurface systems located within the SWMF.

The form of LID BMP and location will be reviewed further at the draft planning stage, using the input from the geotechnical and hydrogeological studies. The seasonally high depth of groundwater below surface in particular will impact the form and feasibility of infiltration measures.

6 HYDROLOGIC MODELLING

6.1 EXISTING CONDITIONS

Drainage Areas

As part of the model development process, points of interest corresponding to the drainage features noted in the Stream Morphology Report (Aqualogic 2023) have been identified. The publicly available LiDAR-based DTM h Lake Erie DTM 2016-2018 (Package W) has been used to determine the subcatchment boundaries and the overall drainage areas. A total of twelve (12) sub-catchments have been included in the simulation (average area of 11.5 ha +/-), including multiple subcatchments covering the proposed development site. Subcatchments have been delineated based on generally common land use and outlet locations, in order to reasonably estimate modelling results at key points of interest.

The drainage area includes lands on the north side of the 7th Line and County Road 19 intersection. A total of approximately 137 ha has been determined. In general, the drainage is from north to south towards the Belwood Lake Tributary. Drainage is facilitated by multiple man-made drainage features and a ditch.

Refer to Drawings 1 (existing and external areas) and 6 (proposed conditions) for overall drainage boundaries.

Parameterization

Drainage areas for modelled subcatchments have been calculated directly from the measured boundaries in GIS. Similarly, overland flow length and slope, which are used to determine subcatchments' time of concentration and infiltration, have been estimated from the available mapping. Flow lengths, based on the expected length of sheet flow, range from a minimum of 144 m to a maximum of 1,313 m. Overland slopes determined from the DEM have been applied, ranging from 3.2% to 9.6%.

Infiltration has been estimated using the SCS CN methodology. The SCS CN method is considered suitable for single event simulation. The land use parameters have been estimated based on the existing conditions aerial imagery corresponding to GRCA's Curve Number land use categories. The soil type has been identified from the Preliminary Geotechnical Characterization Report and Land Information Ontario. In instances with multiple land use types within a subcatchment, values have been areally weighted. The CN values range from 72 to 85 for AMC II conditions.

Initial abstraction values have been calculated based on estimated land use types and areally weighted for each subcatchment. Proposed values are included in Appendix B. The modelled time of concentration has been set at 10 minutes, in accordance with the requirements of the Township of Centre Wellington Development Manual for similar land use classes.

Time of concentration values have been calculated using the Airport Method and the Bransby-William's Formula. The runoff coefficient of each subcatchment has been areally weighted from estimated land use. The Airport Method has been used to calculate the time of concentration of subcatchments with runoff coefficients less than 0.4. Of the twelve (12) subcatchments modelled, only one (1) had a runoff coefficient greater than 0.4 thus requiring the use of the Bransby-William's Formula. Estimated values are included in Appendix B.

Design Storms

The model has been developed to run the 2 to 100 yr design storm events and the Regional Storm. IDF data have been taken from the Township of Centre Wellington Development Manual for the year 2010 for the development of the Chicago 6 hr, the SCS Type II 12 hr, and the SCS Type II 24hr distributions. Rainfall intensity data for each event are included in Appendix B.

For the Regional Storm, two scenarios have been modelled to determine which yields the most conservative results:

- CN values at AMC II (normal) conditions, and the full 48-hour version of Hurricane Hazel (36-hour pre-wetting period and 12-hour primary storm) applied
- CN values converted to AMC III (saturated) conditions, and the 12-hour version of Hurricane Hazel applied

Areal reduction factors have not been applied due to the small size of the development and contributing drainage area (less than 25 km^2).

6.2 PROPOSED CONDITIONS

For proposed conditions, there are changes in land use, land cover, as well as proposed drainage boundaries.

Table 6.1 summarizes the changes in land use, where the catchment with a NASHYD catchment type remains the same between existing and proposed, and the STANDHYD function represents those areas which would be urban land use in the future. The proposed land has been determined by the use of aerial imagery and the site plans provided by the development planner. The ground cover estimations have been established using the Centre Wellington development manual, which specifies that for detached residential units, assume an imperviousness value of 50%. The catchments that only consisted of rear yards have been assumed to have an imperviousness value of a small park (7% according to the manual).

The drainage boundaries would also be expected to change between existing and proposed land use to reflect proposed grading specifically towards two proposed SWM facilities (North and South). The North pond has two inlets, the north inlet contributes through PR-W02 (9.98 ha), PO-W01 (3.69 ha), and PO-W02 (10.50 ha). As for the South inlet, one contributing source is Street B (PO-W03, 391 ha) and the second is Pond Block (PO-SWM, 0.95 ha).

North of the Main creek, PR-N02 and the rear yards of PO-N01, directly discharge into the creek. Their combined flow then joins with PO-N02 (controlled flow from Street D and associated source controls) and PO-N03 (creek block), as well as the SWM facility discharge, which also flows into the creek. Furthermore, this combined flow would join with the eastern area, PR-E02, which ultimately reaches the common creek receiver.

On the southern side, a smaller SWM facility is proposed to drain flows from PO-M05 (6.91 ha), and its discharge is proposed to subsequently combine with the uncontrolled PO-M03 flow, followed by PO-M01 (rear yards and creek block) and PO-E01 (controlled flow from Street E).

The road drainage systems drain from the west, where PO-M07 and PO-M02 contribute to the creek's flow, while from the east, PR-M05 combines with PO-M04 before reaching the creek.

PO-M06 discharges into an existing ditch on the southwest of the development and would drain westerly, away from the primary creek of interest.

Table 6.1: Updated Land Use and Ground Cover under Proposed Conditions

Hydrologic Algorithm	Proposed Catchments	Proposed Land Use	Ground Cover
NASHYD	PR-W02	Agricultural	
	PR-N02	Agricultural	
	PR-E02	Agricultural	
	PR-M05	Agricultural	
	PR-M04	Agricultural	
	PR-M02	Agricultural	
	PO-W01	Wetland	
	PO-M01	Agricultural	
		Forest	
	PST_SWM	Agricultural	
STANDHYD	PO-W02	Residential Medium / Low Density	54%
	PO-W03	Residential Medium / Low Density	50%
	PO-N01	Residential Medium / Low Density	7%
	PO-N02	Residential Medium / Low Density	55%
	PO-N03	Residential Medium / Low Density	29%
	PO-E01	Agricultural	20%
		Forest	
	PO-M03	Residential Medium / Low Density	52%
	PO-M05	Residential Medium / Low Density	52%
	PO-M06	Residential Medium / Low Density	7%
	PO-M07	Residential Medium / Low Density	7%

6.3 SWM SIZING

The sizing of the Stormwater Management (SWM) facilities has involved a comparative analysis between pre-development and post-development conditions. The primary objective of these SWMF is to mitigate outflows in post-development scenarios, ensuring they matched the pre-development conditions for 2–100 year storms. To facilitate this analysis, Visual OTTHYMO (VO) software has been used, creating models for both existing and proposed conditions using site plans, native soil conditions, and land use proposals.

To assess the difference in outflow, a unitary discharge ($m^2/s/ha$) has been calculated based on peak flow at the outlet (m^3/s) and the drainage area (ha) for both existing and proposed conditions during 2-100 year SCS Type II 24-hour design storms. The unitary discharge has been assumed to apply at any node, by using the total drainage area at the node of interest. Modelling of the SWMF has been accomplished using the RouteResevoir tool in VO.

Sizing the SWMF required determining suitable discharge and storage values for each storm event. The discharge value has been obtained by considering the unitary discharge of the storm event and the total drainage area of the SWMF. Storage values have been derived using an estimated unitary storage value and the impervious drainage area.

The iterative process for SWMF sizing, involved an initial unitary storage estimate (m^3/impervious ha) starting with a 2-year storm event. Using this estimate, a storage value (ha-m) has been calculated based on the impervious drainage area and inputted into the model along with the 2-year storm discharge value.

The outflow at the SWMF has been compared to the outflow in pre-development conditions, which was determined by multiplying the drainage area of the SWMF with the pre-development 2-year unitary discharge. The percentage difference between the outflow in pre-development and post-development for the 2-year storm event has been assessed. Where the difference was too large (+/-), the initial unitary storage estimate was adjusted through iterations until the percentage difference was approximately 0% between existing and proposed conditions.

Once the SWMF was sized for a 2-year storm, a unitary storage estimate for a 5-year storm was made, and the same iterative process was followed. This procedure was repeated for storms of increasing intensity from 10 to 100 years. The sizing process continued until the outflow at the SWM pond location and the outlet of the development achieved a percentage difference of approximately 0% between existing and proposed conditions for all storm events.

Through the analysis, the required storage for the North SWMF is approximately 6,850m^3 and the South SWMF is approximately 1,400m^3. Furthermore, to meet the criteria for discharge at the outlet, storage tanks of volumes 1,300m^3 and 200m^3 are proposed to be provided in Streets D and E respectively. In addition, the outflow from catchment PST-M06 is proposed to be directed to a ditch in the southwest of the development, to control the outflow to pre-development flows a storage tank of volume of approximately 65m^3 is to be provided. Locations are presented on Drawing 5.

Detailed hydrologic modelling results are included in Appendix B.

7 HYDRAULIC MODELLING

7.1 TOPOGRAPHIC DATA

The LiDAR mapping shows elevations from vegetation, buildings, structures, roads and other features on the landscape. Topgraphic survey has been completed for the site for BelCal Inc for key elevations of hydraulic structures as well as selected open channel sections. The topographic survey points focused upon hydraulic structures have been considered under two (2) categories or zones for data type – namely the following:

- Channel Points (i.e., Centreline, Edge of Water, Orignal Ground)
- Hydraulic Structures (i.e. Inverts, Obverts, Headwalls, Wingwalls, etc.)

7.2 EXISTING CONDITIONS

1-Dimensional (1D) hydraulic modelling has been completed applying the most recent non-beta version of HEC-RAS, (version 6.3.1).

7.2.1 HYDRAULIC MODEL NAMING CONVENTION

The hydraulic modelling platform, HEC-RAS developed by the US Army Corps of Engineers, allows for an input for both a "river" and a "reach" naming convention. Reaches can be a subset of segments along the primary river being modelled. The river and reach naming for the development is outlined in Table 7.1.

Table 7.1. River and Reach Naming in HEC-RAS

River	Reach
River 1	West Trib
River 2	North Trib
River 3	North East Trib
River 4	East Trib
River 6	Main Trib

The cross-section naming has been based upon the cross-section's location along the modelled reach (distance based).

7.2.2 CROSS-SECTION ALIGNMENT, CENTRELINE AND OVERBANKS

The base watercourse centreline has been based upon the ArcHydro GIS analysis of subcatchments and drainage direction within the development. The watercourses layer has been reviewed against the DEM and the aerial imagery to simplify the shape and confirm the accurate centreline location.

The overbank lines have been delineated for each watercourse feature through review of the DEM and aerial imagery to establish bank lines along both the left and right banks of the system; this has been established based

upon the bank-full width. The overbank lines have been used as part of the subsequent model building stages to assign bank stations within each of the cross-sections.

The cross-section locations and extents have been established based upon a variety of information, including the watercourse centreline, topographic information (contours), aerial imagery, building footprints, and the existing floodplain. The cross-section cutting approach has been applied looking downstream, from left to right, stopping at the high point on either end of the cross-section. The cross-section lengths have been established based upon the topographic information and the existing floodplain limits, which can provide an indication of the flood limits expected within each section of the model; these cross-section extents have been subsequently refined as needed through the model development.

The cross-sections have been cut to ensure that there are 4 bounding cross-sections for each hydraulically significant structure to be included in the modelling (2 upstream and 2 downstream), representing the contraction and expansion zones approaching each hydraulic structure. Best efforts have also been made to ensure that cross-sections bounding the structures do not cross the road deck or embankment.

7.2.3 HYDRAULIC PARAMETERS

Initial estimation of Manning's roughness coefficients has been based upon field observation and review of aerial imagery. The roughness coefficients assumed are based on Table 3-1 « Mannings 'n' Values for Channelized Flow ». The chosen Manning's n values are listed in Table 7.2.

Table 7.2. Land Cover and Assumed Roughness Category

CHANNEL COMPONENT	EXISTING CONDITION	n
Channel	Vegetated or Natural Rock	0.035
Floodplain	Brush - Light Brush and Trees	0.06
	Cultivated Areas – Mature Field Crops	0.04

7.2.4 HYDRUALIC STRUCTURES

There is a total of two (2) structures identified within the study area for the development.

Under existing conditions, there is a farm crossing culvert on the North Trib. It is expected that this hydraulic structure would be removed under proposed conditions. A new hydraulic structure will ultimately be required to permit the crossing of Street C (connecting to Street C).

The other is the culvert for the main branch at County Road 19, which will remain under proposed conditions.

The information collected for the structures under existing conditions is based on field inventory, which was used to confirm the structure geometry (i.e., type, end treatments, opening width, span, distance from obvert to top of road, etc.) as well as identify any other pertinent observations such as low flow channel geometry, vegetation and formation of overbank zones, categorizing the road deck, among others. This information has been used as the primary source for hydraulic structure coding into the HEC-RAS models, which can be supplemented by topographic survey, as-built drawings, previous modelling and aerial imagery.

Structure coding in the HEC-RAS model has been completed. The hydraulic significance of structures has been determined based upon the opening type, the structure deck and the expected impact to flow conveyance and floodplain limits.

HEC-RAS provides two (2) methods for modelling hydraulic structures, namely culvert method or bridge method. Based upon review of the completed field inventory, all of the structures within the study area consist of culverts. If the culvert has been noted in the field inventory as open bottom, a natural channel Manning's n value (i.e., 0.035) has been applied to the bottom 0.1 m depth of the culvert.

Ineffective flow areas have been assigned at each hydraulic structure crossing, applied to both the upstream and downstream bounding cross-sections. The approach is consistent with the HEC-RAS methodology, where a 1:1 contraction rate has been applied for placing the ineffective flow areas on both sides of the structure face. On the upstream side, the ineffective flow area elevation has been assigned based upon the low point (spill point) in the roadway deck, whereas on the downstream side the elevation has been assigned based upon the midpoint between the bridge/culvert obvert and the deck low point, as WSP has applied in other floodplain mapping modelling.

7.2.5 STEADY STATE FLOW TABLE

The steady state flow table has been developed based upon the peak flows generated as part of the hydrologic modelling which has been completed in parallel to the hydraulic modelling. The hydraulic modelling has simulated the 100-year event and Regional Storm.

The flow change locations have been established based upon a review of all available flow nodes from the hydrologic models, noting key locations throughout the drainage area (i.e. upstream of confluences, at roadways, etc.). The flow changes have been applied at the upstream extent of the reach / subcatchment, which allows for the most conservative modelling approach for the subject reach. Best efforts have been made to locate flow change locations outside of the four (4) cross-sections bounding a hydraulic structure, to ensure that a consistent flow rate is applied throughout the structure.

Table 7.3: Steady Flow Table

River	Reach	RS	100 24H SCS (m^3/s)	Regional 12H (m^3/s)
River 1	West Trib	410	2.97	2.97
River 2	North Trib	279	5.8	6.42
River 3	Northwest Trib	85	8.49	9.32
River 4	East Trib	120	4.25	5.21
River 6	Main Trib	353	14.2	15.93
River 6	Main Trib	158	15.17	16.92

7.2.6 BOUNDARY CONDITIONS

A Normal Depth boundary condition has been used in the hydraulic model for this development. To calculate the value for normal depth an average value for slope of channel has been calculated using the terrain profile of the watercourse and contour lines. Using the calculated value of slope, a normal depth has been calculated for each profile.

7.3 PROPOSED CONDITIONS

7.3.1 MODELLING APPROACH

For the proposed conditions, River 1 – West Trib and the farm crossing on the North West Trib have been removed from the analysis for the reasons noted previously. The cross sections have also been adjusted with the proposed street C alignment.

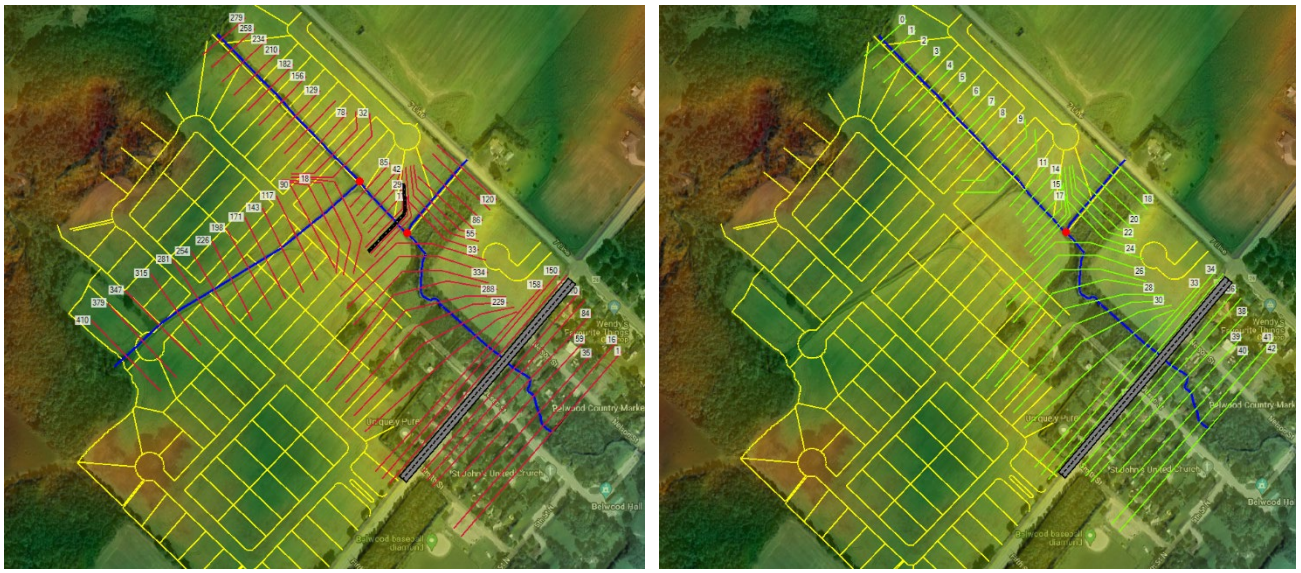


Figure 7.3: Hydraulic Model Set Up Existing (Left) vs Proposed (Right)

The RAS Mapper function in HEC-RAS has been used to plot the simulated inundation boundary for the 100 year, and 12-hour Regional Storm event, based upon the model terrain and the computed water surface elevations at each cross-section. This has been completed to enable an initial comparison between the initial (existing condition) draft models and existing floodlines.

7.3.2 FLOODPLAIN OF EXISTING VS PROPOSED CONDITIONS

The differences in floodplain between proposed and existing conditions has been assessed through a review of the inundation limits. As would be expected with the removal of River 1 – West Trib in proposed conditions, there is no floodplain in the west region of the development. The difference in floodplain between existing and proposed conditions appear relatively minor, which can be attributed to the no change in Manning's roughness coefficient values. That said it is acknowledged that the proposed development will regrade the Main North South channel at the limits of the meander belt and thereby contain the regulatory flows and protect proposed development with no upstream or downstream impacts. These components will be determined as part of future detailed design.

Figure 7.4: 100-year Storm Event Inundation Boundaries for Existing vs Proposed

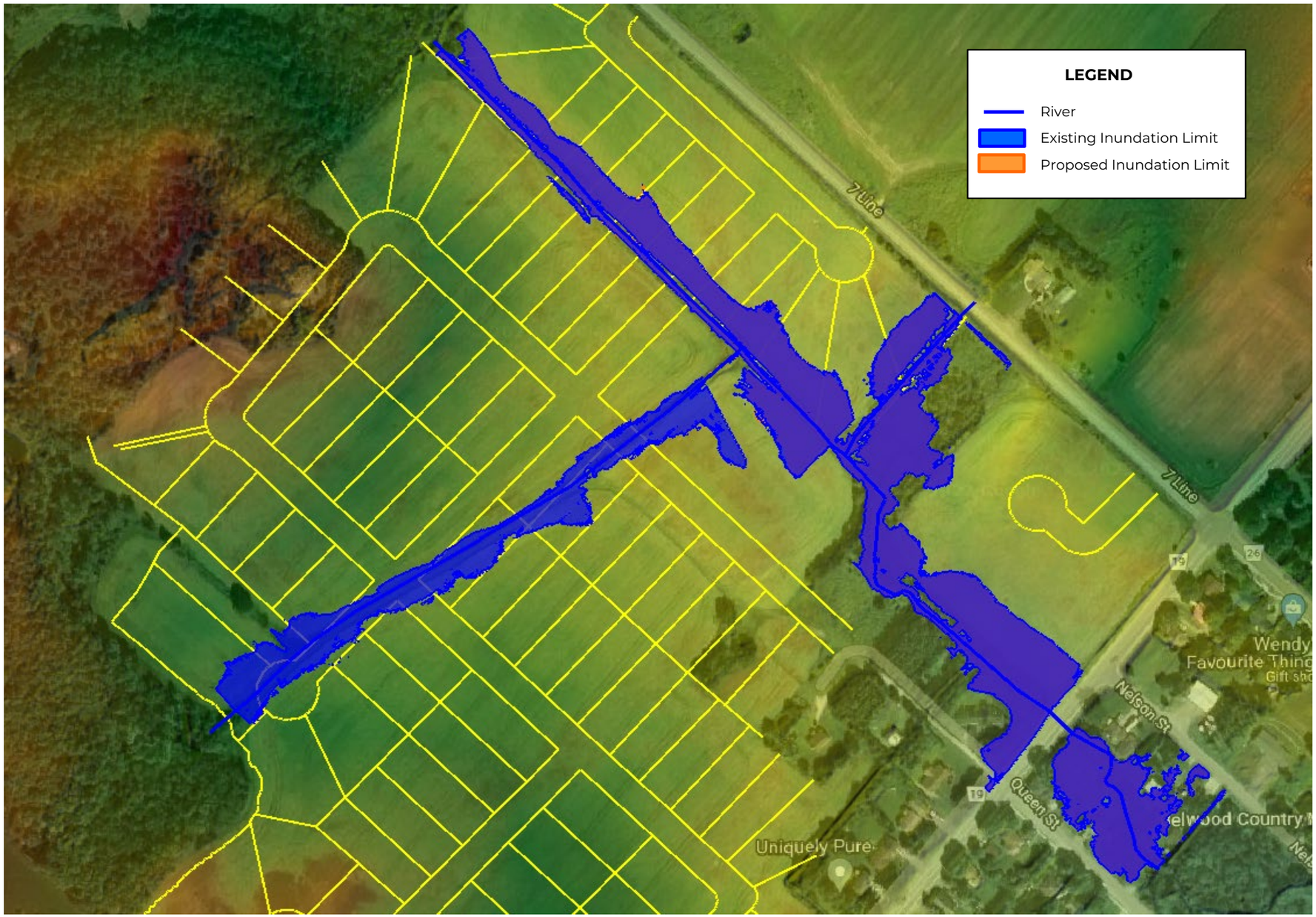


Figure 7.5: 12-hour Regional Storm Event Inundation Boundaries for Existing vs Proposed

8 SUMMARY AND CONCLUSIONS

The applicant proposes to develop 107 lots in Belwood located northwest of Seventh Line and Wellington Rd 19. The area is currently farmland with limited structures. Future development as currently planned will alter the landscape through the introduction of roads, buildings and associated re-grading.

Each individual residential lot will be serviced by private wells (water) and septic systems (sanitary).

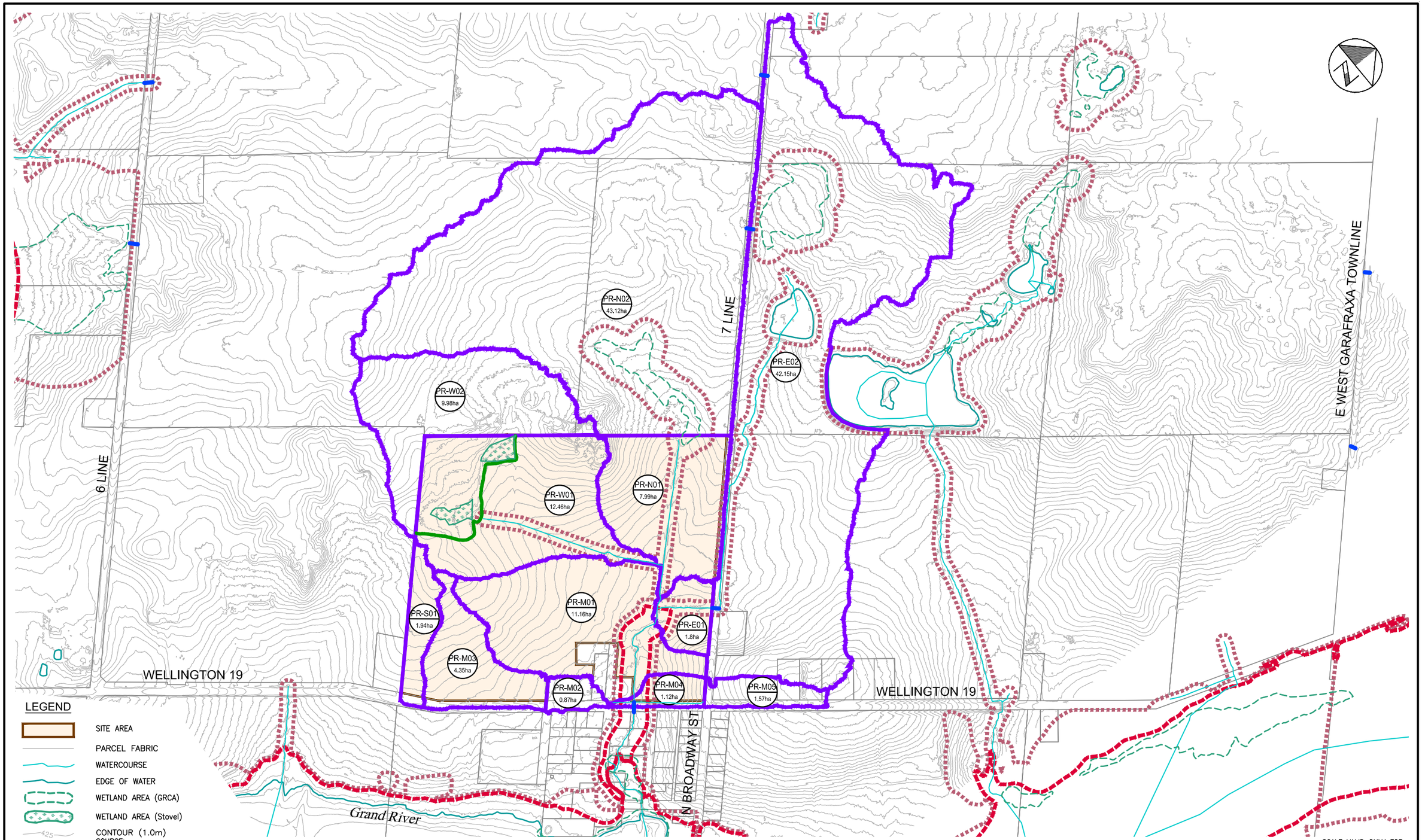
With respect to stormwater management, the proposed land use changes have the potential to alter the areas hydrology which can potentially impact flooding, erosion and water balance. As such, a comprehensive assessment has been completed to determine the current hydrologic conditions and use these as a target to meet the requirements of the Township, GRCA and Province in terms of stormwater management.

The proposed SWM plan addresses the specific criteria and requirements associated with the management of stormwater runoff (quantity and quality), as well as the management of open water features specific to watercourses and headwater drainage features (HDF). As part of the development of the overall SWM plan, AquaLogic conducted a complementary watercourse and headwater drainage feature assessment to support the planning and management of on-site drainage features, including meander belt limit determination.

As part of the proposed SWM plan, it is recommended that runoff quality be treated through a series of techniques, whereby a portion of the runoff from the private residential development sites could be captured through on-lot source controls, which could then combine with roadway runoff and be treated with conveyance controls through the roadside drainage system (enhanced grassed swales with gutter outlets). The roadway drainage system is proposed to be of a hybrid form, whereby the roadway would have short shallow ditches on one side, and a storm sewer and curbs/gutter outlets, to facilitate an "urban" feel while addressing the Provincial requirement for a treatment train of multiple best management practices. The combined treated residential and roadway runoff from the lands west of the Main reach will then discharge to one of two proposed Stormwater Management Facilities (SWMFs), where the runoff will be treated/detained. For the lands east of the Main watercourse, no SWMFs are proposed, however a subsurface storage system is proposed for both the north and south enclaves upstream of their discharge points to the Main watercourse (one for the north and one for the south development parcels) to promote peak flow and volume control for roadway runoff and also assist in treating runoff for water quality objectives, prior to discharge to the Main watercourse.

The previously noted two SWMFs are also proposed to provide controls primarily for the management of flooding and quantity control. The SWMF, as noted, can be either "wet" or "dry". Based on the currently proposed SWM plan which advocates for source and conveyance controls, it is suggested that the SWMFs would preferentially be dry. This form of SWMF would have reduced maintenance and also provide informal open space for the area residents, hence is considered preferred.

Volume control is being recommended to meet the "draft" guidance from MECP (2022). This amount of control for both the private and public lands is expected to adequately meet the needs of the site's erosion criteria. The MECP recommends a three-tier assessment and implementation process whereby Tier 1 (preferred) provides volume controls using measures at source, such as rain gardens and infiltration pits to capture and infiltrate the 90th percentile runoff event which for Belwood would be a 29 mm event. Further, volume controls can be achieved for the roadway system either through infiltration trenches constructed in appropriate locations along the roadside ditches (not in areas with shallow groundwater or high bedrock) or through subsurface systems located within the proposed SWMF.



NOTE:
GRCA REGULATORY LIMITS ARE SHOWN FOR INFORMATION PURPOSES ONLY. SPECIFIC REGULATORY LIMITS HAVE BEEN DETERMINED AND ARE SHOWN ON SUBSEQUENT PLANS.

SCALE VALID ONLY FOR 24"x36" VERSION

BELWOOD DEVELOPMENT BEL CAL INC.	SUBCATCHMENT BOUNDARY PLAN (EXISTING CONDITION)	wsp	Scale 1:4000 0 40 80 160 Consultant File No. WW22011051 Drawing No. 1

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Plotted: 2023-07-06
Last Saved: 2023-07-04

WEST TRIBUTARY FLOWS TO BE CONVEYED THROUGH PIPED (STORM SEWER) FEATURE; REFER TO DRAWINGS 5 AND 6

16.0m MEANDER BELT

16.0m MEANDER BELT

19.0m MEANDER BELT

19.0m MEANDER BELT

23.0m MEANDER BELT

QUEEN ST

7 LINE

WELLINGTON 19

LEGEND

- SITE AREA
- PARCEL FABRIC
- WATERCOURSE (LIDAR BASED)
- WATERCOURSE (PLANNER)
- WETLAND AREA (GRCA)
- WETLAND AREA (Stovel)
- CONTOUR (1.0m) SOURCE: LAKE ERIE DTM LIDAR ADJUSTED TO CGVD28:78 VERTICAL DATUM
- WOODLOT LIMIT
- CULVERT
- MEANDER BELT (SEE PLAN FOR WIDTH)
- GRCA EROSION HAZARD (15m SETBACK)

NOTE:
MEANDER BELTS HAVE BEEN BASED ON WATERCOURSE (LIDAR BASED) CENTRELINES.

SCALE VALID ONLY FOR 24"x36" VERSION

BELWOOD DEVELOPMENT
BEL CAL INC.

MEANDER BELT PLAN
(EXISTING CONDITION)

wsp

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Consultant File No.
WW22011051

Drawing No.
2

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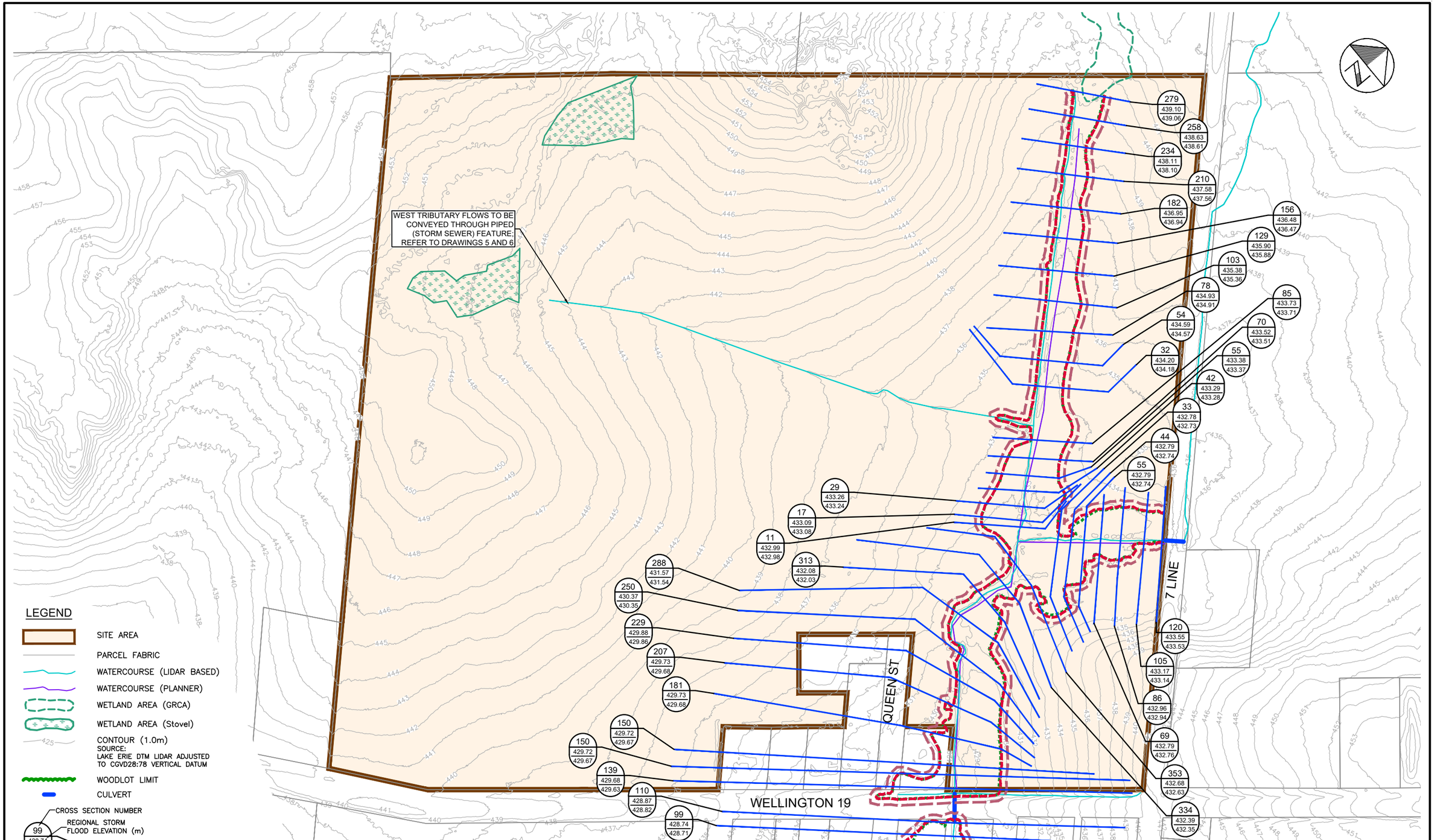

LEGEND

- SITE AREA
- PARCEL FABRIC
- WATERCOURSE (LIDAR BASED)
- WATERCOURSE (PLANNER)
- WETLAND AREA (GRCA)
- WETLAND AREA (Stovel)
- CONTOUR (1.0m) SOURCE: LAKE ERIE DTM LIDAR ADJUSTED TO CGVD28:78 VERTICAL DATUM
- WOODLOT LIMIT
- CULVERT
- CROSS SECTION NUMBER
- REGIONAL STORM FLOOD ELEVATION (m)
- CROSS SECTION LOCATION
- 100 YEAR STORM FLOOD ELEVATION (m)
- REGIONAL STORM FLOODPLAIN
- 100 YEAR STORM FLOODPLAIN
- GRCA FLOOD HAZARD BUFFER (5.0m SETBACK)

SCALE VALID ONLY FOR 24"x36" VERSION

BELWOOD DEVELOPMENT BEL CAL INC.	FLOOD HAZARD PLAN (EXISTING CONDITION)	wsp

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Drawing No. 3

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Plotted: 2023-07-10
Last Saved: 2023-07-10

LEGEND

- SITE AREA
- PARCEL FABRIC
- WATERCOURSE (LIDAR BASED)
- WETLAND AREA (GRCA)
- WETLAND AREA (Stovel)
- CONTOUR (1.0m) SOURCE: LAKE ERIE DTM LIDAR ADJUSTED TO CGVD28:78 VERTICAL DATUM
- WOODLOT LIMIT
- CULVERT
- PROPOSED REGULATORY LIMIT

NOTE:
FLOOD HAZARD LIMIT UNDER PROPOSED CONDITIONS TO BE MANAGED TO LESS THAN EROSION HAZARD LIMIT, WHICH IS ASSUMED TO BE REGULATORY LIMIT. CUT\FILL BALANCE AND DETAILED CREEK CORRIDOR GRADING TO BE CONFIRMED AS PART OF DETAILED DESIGN

SCALE VALID ONLY FOR 24"x36" VERSION

BELWOOD DEVELOPMENT
BEL CAL INC.

SITE PLAN
(PROPOSED CONDITION)

wsp

Scale 1:1500
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Consultant File No.
WW22011051

Drawing No.
4

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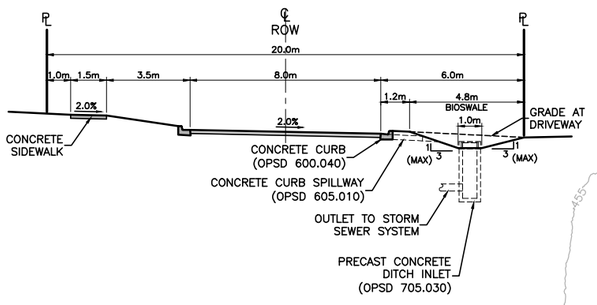

TYPICAL ROAD SECTION

SCALE 1 : 125

LEGEND

- SITE AREA
- PARCEL FABRIC
- WATERCOURSE (LIDAR BASED)
- WETLAND AREA (GRCA)
- WETLAND AREA (Stovel)
- CONTOUR (1.0m) SOURCE: LAKE ERIE DTM LIDAR ADJUSTED TO CGVD28:78 VERTICAL DATUM
- WOODLOT LIMIT
- CULVERT
- PROPOSED REGULATORY LIMIT
- SUBCATCHMENT BOUNDARY PLAN (REFER TO DRAWING 6)
- PROPOSED DITCH
- PROPOSED BIOSWALE
- PROPOSED STORM SEWER
- PROPOSED MAINTENANCE HOLE
- PROPOSED DITCH INLET MAINTENANCE HOLE
- PROPOSED DITCH INLET CATCHBASIN
- PROPOSED GRADE

NOTE:
FLOOD HAZARD LIMIT UNDER PROPOSED CONDITIONS TO BE MANAGED TO LESS THAN EROSION HAZARD LIMIT, WHICH IS ASSUMED TO BE REGULATORY LIMIT. CUT\FILL BALANCE AND DETAILED CREEK CORRIDOR GRADING TO BE CONFIRMED AS PART OF DETAILED DESIGN

SCALE VALID ONLY FOR 24"x36" VERSION

BELWOOD DEVELOPMENT BEL CAL INC.	SITE GRADING AND DRAINAGE PLAN (PROPOSED CONDITION)	wsp

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Consultant File No. WW22011051
Drawing No. 5

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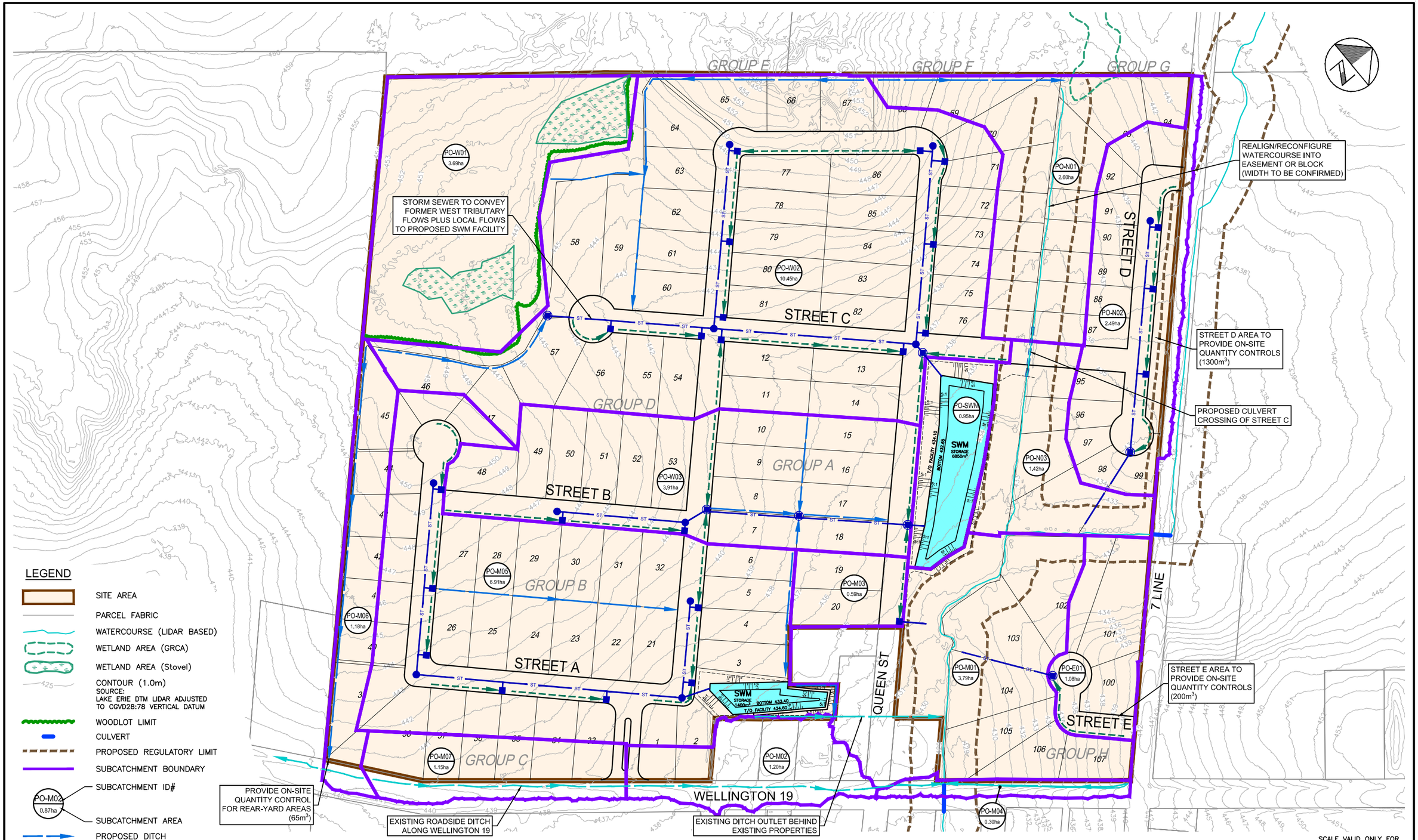

LEGEND

- SITE AREA
- PARCEL FABRIC
- WATERCOURSE (LIDAR BASED)
- WETLAND AREA (GRCA)
- WETLAND AREA (Stovel)
- CONTOUR (1.0m) SOURCE: LAKE ERIE DTM LIDAR ADJUSTED TO CGVD28:78 VERTICAL DATUM
- WOODLOT LIMIT
- CULVERT
- PROPOSED REGULATORY LIMIT
- SUBCATCHMENT BOUNDARY
- SUBCATCHMENT ID# (PO-M02)
- SUBCATCHMENT AREA (0.87ha)
- PROPOSED DITCH
- PROPOSED BIOSWALE
- PROPOSED STORM SEWER (ST)
- PROPOSED MAINTENANCE HOLE
- PROPOSED DITCH INLET MAINTENANCE HOLE
- PROPOSED DITCH INLET CATCHBASIN

NOTE:
FLOOD HAZARD LIMIT UNDER PROPOSED CONDITIONS TO BE MANAGED TO LESS THAN EROSION HAZARD LIMIT, WHICH IS ASSUMED TO BE REGULATORY LIMIT. CUT\FILL BALANCE AND DETAILED CREEK CORRIDOR GRADING TO BE CONFIRMED AS PART OF DETAILED DESIGN

SCALE VALID ONLY FOR 24"x36" VERSION

BELWOOD DEVELOPMENT
BEL CAL INC.

SUBCATCHMENT BOUNDARY PLAN
(PROPOSED CONDITION)

wsp

Scale 1:1500 (0 15 30 60)
Consultant File No. WW22011051
Drawing No. 6

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Plotted: 2023-07-06
Last Saved: 2023-07-04

APPENDIX

A AQUALOGIC REPORT

Headwater Drainage Feature Assessment
Fluvial Geomorphology Components
& Meander Belt Analysis
Belwood Lake Tributary
Township of Centre Wellington

Submitted to:

WSP E & I Canada Limited
3450 Harvester Road, Suite 100
Burlington, ON L7N 3W5

DRAFT August 30, 2022, December 13, 2022 / FINAL May 24, 2023

AquaLogic Consulting • 324 St. Paul Street, Burlington, ON L7R 3J9 • (905) 637-1862 • bill.degeus@sympatico.ca

Headwater Drainage Feature Assessment
Fluvial Geomorphology Components
& Meander Belt Analysis
Belwood Lake Tributary
Township of Centre Wellington

Headwater drainage feature assessment has been done for the fluvial geomorphology characteristics of five reaches of a Belwood Lake Tributary. Assessment has been done to help establish baseline constraints to future development opportunities on adjacent lands. Four qualitative assessment protocols have been undertaken, including Rapid Geomorphic Assessment (RGA) (MOEE 2003), Rapid Habitat Assessment (RHA) (USEPA 2004), the Rapid Stream Assessment Technique (RSAT) (Galli 1996), and the Hydrology Classification component of the Evaluation, Classification, and Management of Headwater Drainage Features Guidelines (HDFG) (TRCA & CVCA 2014).

Analysis of meander belt limits has also been done with regard to future development considerations. Lacking measurable historical planform patterning in the straightened reaches, an empirical approach has been used to define the meander belt component of integrated corridor constraints.

Watershed and Watercourse Characterization

The Belwood Lake Tributary is a 2nd order feature with a cumulative drainage area of approximately 1.27 km^2 to Wellington Road 19. An appended drainage area figure shows the five reaches and respective catchment area breakdown. The study area is in the Hillsburgh Sandhills physiographic region and land use within the site boundaries is dominantly tilled agricultural with some swamp and upland forest, and some legacy plantation forest. Historically the study site has been agricultural for at least several decades as seen in the appended 1937 mapping and 1954 air photo. The reaches all appear to be man-made drainage features, constructed to facilitate field drainage. The 1937 mapping only shows the Main Branch at Wellington Road 19 and the equivalent of the current East Reach downstream from 7th Line. The 1954 air photo suggests all reaches as they currently exist were likely in place at this time step. The alignments appear generally similar as present day except for the mid-point area of the West Reach which at some interim point has been more directly straightened.

In current times, zero order drainage features (as defined in/by TRCA 2007) are also seen in a few locations within and adjacent to the study site. On-site locations are, a) at the upstream end of the West Reach where it originates from the north in a study site woodlot, and b) just below the West Reach upstream end and perpendicular between fields to the north. The two off-site but adjacent locations are, a) on the East Reach perpendicular from 7th Line at the crossing, and b) from the upstream end of the North Reach westerly into the off-site woodlot. By typical characterization and definition, the two zero order connectors to the West Branch, within the site, are too minor in terms of drainage area and function to warrant further discussion.

An appended photo inventory shows a range of overview typical conditions and detailed features across the study site reaches. Example photos from both May and August are shown for Spring and Summer comparison. Photos from May show observed baseflow and post dormant vegetation. August photos show the advanced encroachment of growing season vegetation and typically no flow in any reach, with some standing water in the Main Branch. The majority of the length of all reaches, except for the Main Branch, have riparian conditions dominated by dense groundcover with varying degrees of shrub thicket density. The Main Branch enters a mix of natural and plantation forest cover, with resultant shading limiting groundcover growth in the area above Wellington Road 19. All features have relative swale type or man-made trapezoidal geometry, with the West Reach + North Reach and Main Branch showing more definition of active channel bed and banks and some low flow meandering and profiling of riffle features with coarser gravels and cobble. The North Reach specifically originates from a wetland area just above the northerly site boundary and thus appears to provide a continuum function with high value external systems. The upstream end of the North Reach has a short segment of steeper gradient and meandering over gravels and some cobble. Further downstream, wetland vegetation emerges along the North Reach in the form of cattail stands and dogwood thickets. The East Reach is seen in air photos to originate from an off-site man-made pond and may therefore be affected by some level of flow regulation. The East Reach lacks a well-defined low flow and discharge in Spring was seen flowing opportunistically through vegetation. The West Reach has a distinct knickpoint drop near its downstream end which thus creates a vertical barrier to any aquatic habitat consideration. The Main Branch has a man-made low head dam, made of large cobble grouted with concrete, approximately 25m above Wellington Road 19, which also creates a distinct aquatic habitat barrier. Concrete culverts exist in two locations on the West Reach and the West Reach + North Reach, that facilitate existing field access. Localized erosion scars exist on the West Reach + North Reach below the culvert crossing and extensive erosion scars are seen on the Main Branch.

Rapid Assessment Protocols

Rapid assessment inspections were done at two time points, early May and mid August, to confirm differences between typical seasonal conditions of Spring and Summer. Many individual variables in respective protocols will score the same between seasons, but there are some key differences. The RGA protocol is typically best done in the Spring when vegetation is not in leaf and obscuring observations that might otherwise bias Summer only scoring to be higher. In systems that are base flow challenged, the Summer inspection is typically more accurate with regard to observations of physical habitat performance. The RHA and RSAT protocols will typically score lower in Summer, as a result. A lack of base flow yield in Summer will also result in the Spring HDFG characterization typically identifying flow conveyance functions more accurately.

Analysis using Rapid Geomorphic Assessment (RGA) was done to rate feature stability and infrastructure impact, Rapid Habitat Assessment (RHA) was done for definition of in-stream and riparian habitat, and Rapid Stream Assessment Technique (RSAT) was done to test broad indicators of stability, aquatic habitat, and water quality. A weighted score out of 100 was transposed from the results of each protocol and a combined average score was determined from

the three tests. Four qualifying ranges of optimal, good, fair, and poor are maintained in the RHA and RSAT protocols, between the original scoring and weighted scoring out of 100, while the three original ranges in RGA scoring are reflected as optimal, good-fair, and fair-poor (urban vs. natural conditions considered). The combined average score is qualified by optimal to poor ranges designed as a best fit of the individual protocol ranges. The detailed results are appended. Scoring results are summarized in Table 1.

Table 1: Rapid Assessment Results Summary

	RGA	RHA	RSAT	combined
West Reach - May	87.9	58.0	60.0	68.0
West Reach - Aug.	87.9	52.5	60.0	66.8
North Reach - May	90.4	75.0	76.0	80.5
North Reach - Aug.	90.4	64.5	72.0	75.6
West + North - May	88.9	72.0	72.0	77.6
West + North - Aug.	88.9	61.5	68.0	72.8
East Reach - May	92.9	62.5	70.0	75.1
East Reach - Aug.	92.9	58.5	60.0	70.5
W + N + E, Main Branch - May	58.6	62.0	62.0	60.9
W + N + E, Main Branch - Aug.	58.6	53.5	60.0	57.4

RGA Rapid Geomorphic Assessment
RHA Rapid Habitat Assessment
RSAT Rapid Stream Assessment Technique

Combined Assessment
Optimal 100-80 / Good 80-56 / Fair 55-30 / Poor 29-0

The RGA results confirm that four reaches are dynamically stable but the Main Branch reach is unstable. Levels of confinement and entrenchment on the Main Branch have resulted in bank erosion scars. Widening is the dominant current channel evolution process on the Main Branch. The RHA and RSAT scoring are biased higher in Spring due to observed levels of flow in all reaches. The Summer inspection confirmed however that no observable tailwater flow was occurring in any reach. Standing water was seen sporadically, with nominal flow just at the study area downstream limit at Wellington Road 19. At the next Main Branch road crossing outside the study area and close to Belwood Lake, George Street, there was no observed flow in August. Some ponded standing water was seen in Summer specifically at the 7th Line culvert crossing of the East Reach which was also the only location upstream of Wellington Road 19 seen in Spring to have fish present. No fish were seen in the Summer at this location. Some fish were seen at both time step inspections in ponded water at Wellington Road 19. The permanent year-round presence of aquatic organisms does not appear viable over most of the study area, and seasonal presence at time of ephemeral Spring flow appears to be highly constrained.

The Hydrology Classification component of the Evaluation, Classification, and Management of Headwater Drainage Features Guidelines (HDFG) (TRCA & CVCA 2014) was done to add characterization detail of the physical form and function of each reach. Inspection was specifically undertaken to identify in greater detail the differences in flow conditions and flow classification. Results are shown on the appended scoring pages and are summarized in Table 2. The results show that Spring flow classification suggested perennial flow conditions might exist on all but the West Reach. The Summer inspection confirmed however that a significant lack of base flow yield occurs over the whole study area. The seasonal drop off leaves small pockets of standing water between rainfalls in some spots. Intermittent flow from larger rain events likely occurs with interstitial flow subsequently happening on the Main Branch during Summer. The presence of various observed tile drain outlets does not appear to add low flow yield enhancement in the Summer. The qualitative results of hydrology classification suggest that the West Reach has nominal in-situ function but that all other reaches have relatively significant seasonal conveyance performance, which increases in importance moving downstream as drainage areas become confluent. All reaches, except for the West, are therefore identified for some level of protection. The East Reach could be considered for conservation, versus strict protection management, which arguably would allow for physical realignment alteration if land use planning can benefit.

Table 2: Headwater Drainage Feature Hydrology Classification

	QC	FC	FT	RM
West Reach - May	C	3	1+5+7	F
West Reach - Aug.	E	1	1+5+7	F
North Reach - May	A	5	1+5	A
North Reach - Aug.	B+C	2	1+5	A
West + North - May	A	5	1+5	A
West + North - Aug.	B+C	2	1+5	A
East Reach - May	A	5	1+5	A
East Reach - Aug.	D	2	1+5	B
W + N + E, Main Branch - May	A	5	1+5	A
W + N + E, Main Branch - Aug.	B	3	1+5	A

QC Flow Classification: A - perennial, B - intermittent, C - ephemeral,
D - dry or standing water w/recharge, E - dry or standing water w/no recharge

FC Flow Condition: 1 - no surface water, 2 - standing water,
3 - interstitial flow, 4 - <0.5l/sec, 5 - >0.5l/sec

FT Feature Type: 1 - defined bed & banks, 2 - channelized historically, 3 - multi-thread,
4 - no defined feature, 5 - tile drain, 6 - wetland, 7 - swale, 8 - roadside ditch, 9 - online pond outlet

RM Recommended Management:
A - protection, B - conservation, C - mitigation, D - recharge protection,
E - maintain/replicate terrestrial linkage, F - no management

Meander Belt Analysis

Based on the history of past drainage feature alteration, there is a lack of measurable channel meander patterns in each study reach. An empirical calculation of meander belt is realistically the best way to provide supportable recommendations. Regional regression analysis of a variety of fluvial geomorphic variables is possible. It has been demonstrated that the best statistical correlation is typically a regression plot of meander belt limits as a function of drainage area (Howett 2017).

Plotting results are appended showing the full Ontario data record produced by AquaLogic over 20 years of past studies, with three more focussed sample plots that are specific to headwater features defined by 1st to 3rd stream order. The downstream drainage area of each Belwood Lake tributary reach was used in the power regression calculation from the comparative plots. The downstream drainage area node represents a conservative approach to represent the upstream reach length, because incremental drainage area decreases moving upstream.

Provincial guidelines for meander belt characterization do not require additional factors of safety or contingency allowances for features deemed to be unconfined by valley walls (OMNR 2002). Interpretation of confinement and unconfined conditions can vary depending on specific case circumstances. Some consideration of added buffers is in practice used and discussed in other guidelines (TRC 2004) relative to unconfined scenarios. For the current study, it is deemed that the reaches are all unconfined and fall across topography that lacks classic valley wall demarcation. Nonetheless, a factor of safety (FS) equal to 1.2, or 20% contingency, is deemed appropriate to be conservative, but also to not be biased unreasonably high. Based on the data cloud ranges shown in the regression plots, an FS=1.2 falls lower than upper data point outliers. The FS adjustment calculation is shown on the plotting summary. In turn, a ceiling function ($\mathrm{ceil}(x)$) whole number integer adjustment is made to each result to simplify the recommendations. All reaches are summarized, but the West Reach calculation is for context only due to the proposed potential enclosure. Meander belt limits of 16m, 19m, 16m, and 25m respectively, for the North, West + North, East, and Main Branches are recommended.

Plotting empirical meander belt limits on straightened watercourses is a simple exercise of splitting the width over the active channel centreline. The straightened channel is effectively coincident to the meander belt axis.

Conclusions and Recommendations

Headwater drainage feature assessment has been done for the fluvial geomorphology characteristics of five reaches of a Belwood Lake Tributary. Assessment has been done to help establish baseline constraints to future development opportunities on adjacent lands. None of the reaches are in historically natural alignments. The man-made planforms have nonetheless naturalized over time and currently supply flow conveyance functions in the Spring and intermittently at other times of the year. The North Reach, the West Reach + North Reach, and the Main Branch, provide the most significant cumulative function through the study site in terms

of flow conveyance and physical feature corridor linkage. The West Reach has the smallest drainage area and nominal function with limited apparent aquatic habitat significance. The East Reach has minor functional significance but most of its drainage area is external to the study site which thus influences the need to maintain corridor linkages.

It is recommended that the West Reach can be enclosed by future development with stormwater management practices implemented to maintain no adverse change at the confluence with the North Reach. It is recommended that the North Reach, West Reach + North Reach, East Reach, and Main Branch all need to be retained features with appropriate setbacks to adjacent future development. Stormwater targets and controls should also be established on a retained reach-by-reach basis to maintain or improve thresholds for channel stability. The East Reach could be retained through realignment that replicates or improves conditions; however, this may not be geometrically necessary or advantageous to development layout. It is also recommended that the existing culvert crossing on the West Reach + North Reach be removed and localized channel restoration be implemented. It is also recommended that restoration works be implemented to replace the existing dam on the Main Branch with a barrier free channel profile.

Given the lack of natural channel planform alignments, empirically derived meander belt limits were produced for each reach. The empirical meander belt limit approach has proven to be fair and reasonable for definition of new development limits over existing altered watercourses, for use in realignment natural channel designs, and for risk assessments of existing infrastructure. Future development options and scenarios are therefore recommended to apply meander belt limits of 16m, 19m, 16m, and 25m respectively, for the North, West + North, East, and Main Branch reaches.

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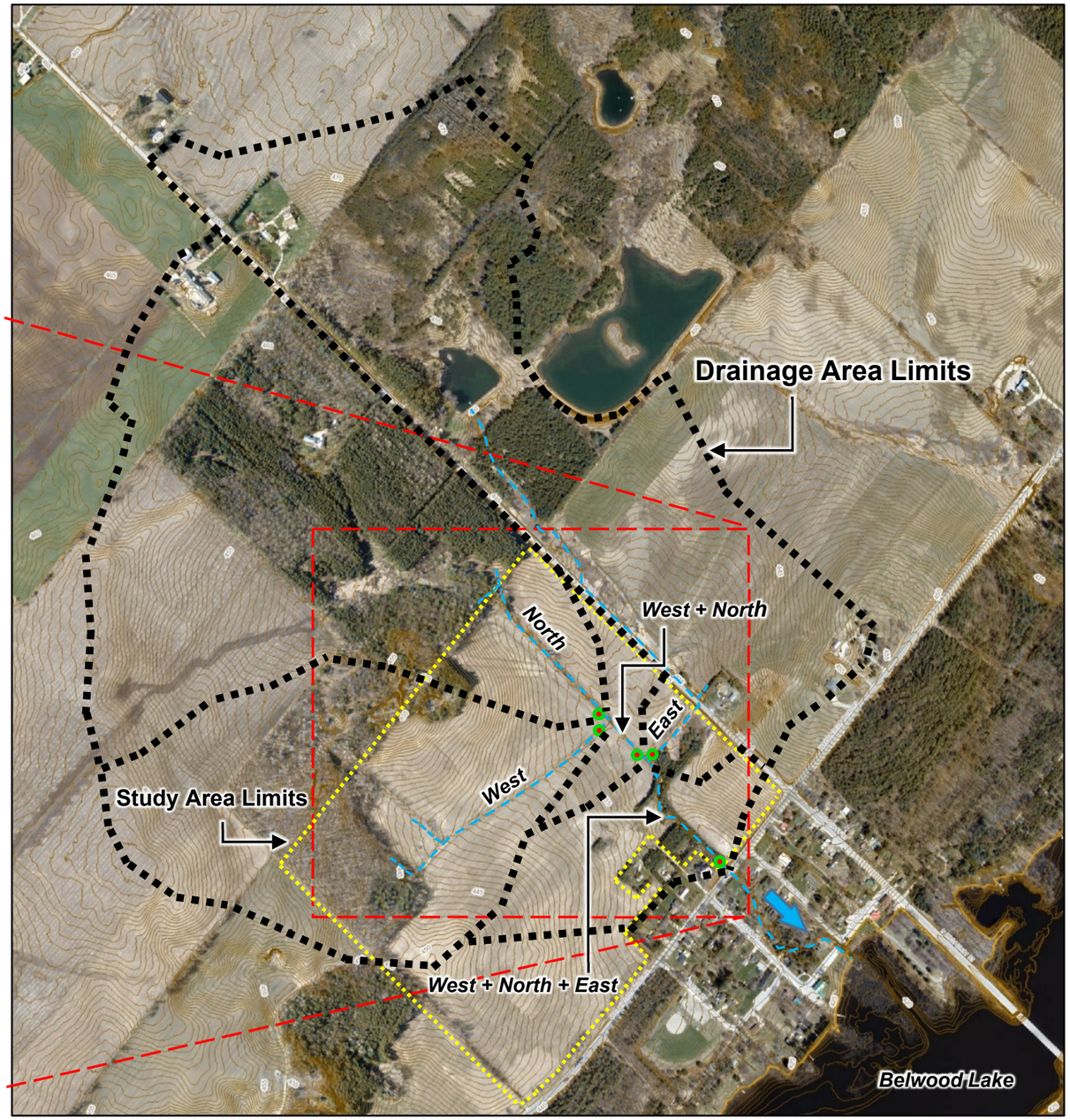
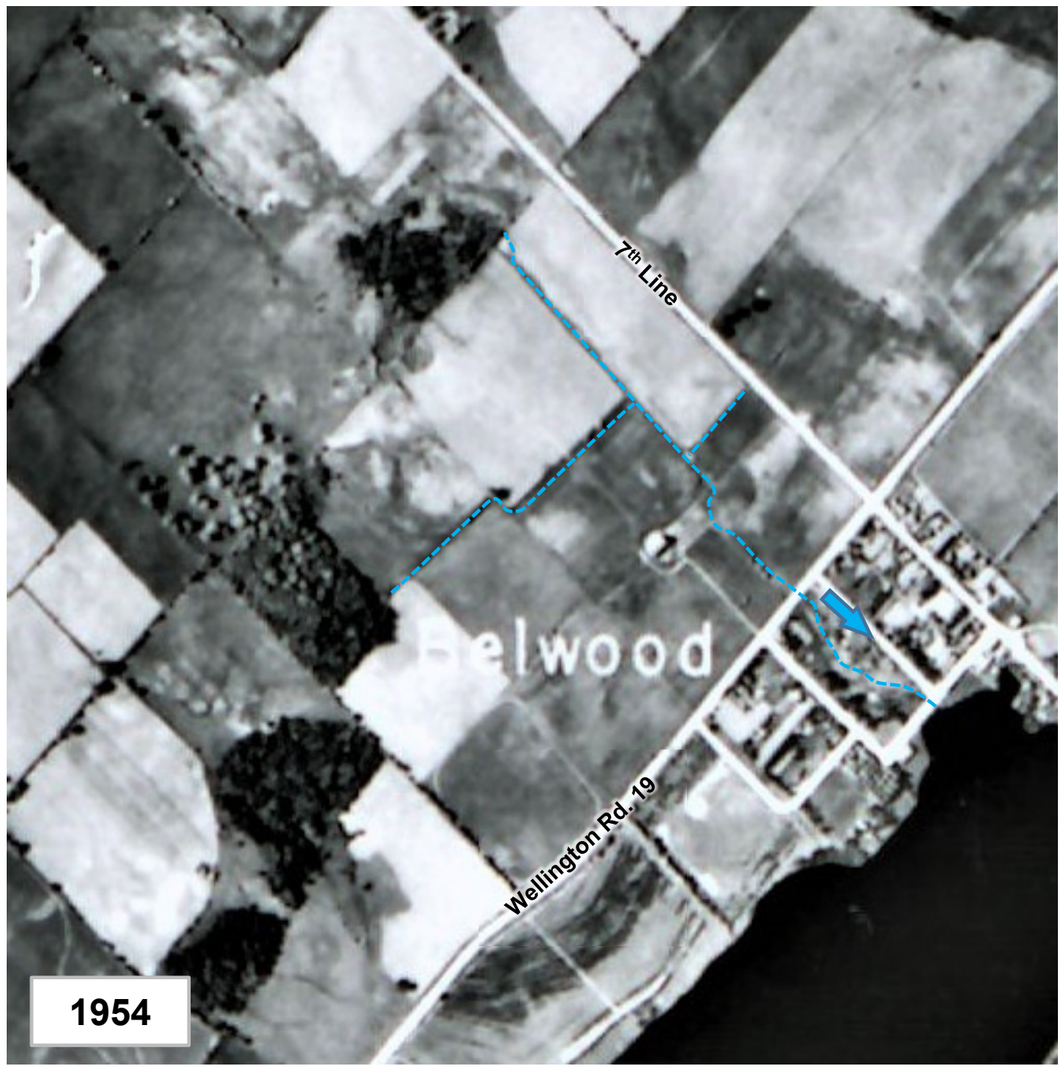
Drainage Areas
Belwood Lake Tributary

West Reach	0.27 km^2
North Reach	0.44 km^2
West Reach + North Reach	0.74 km^2
East Reach	0.44 km^2
West + North + East = Main Branch	1.27 km^2
Total at Belwood Lake	1.44 km^2

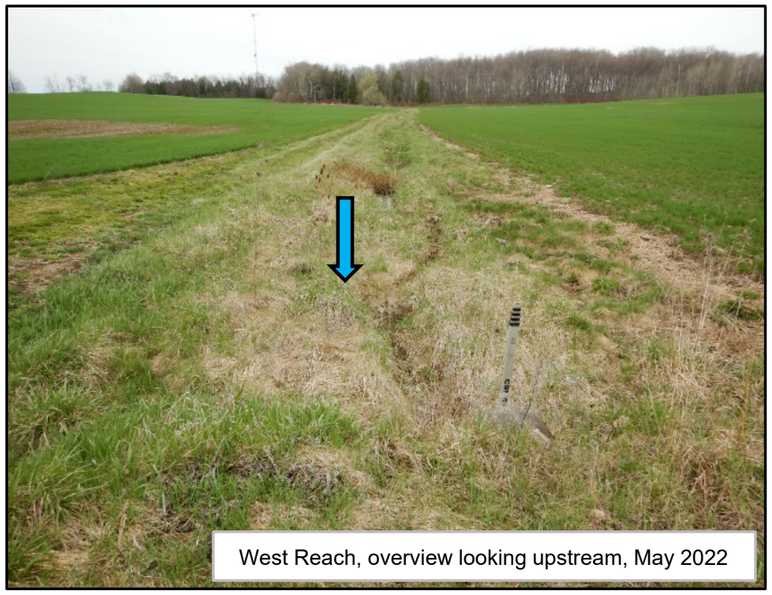


Historic Conditions
Belwood Lake Tributary

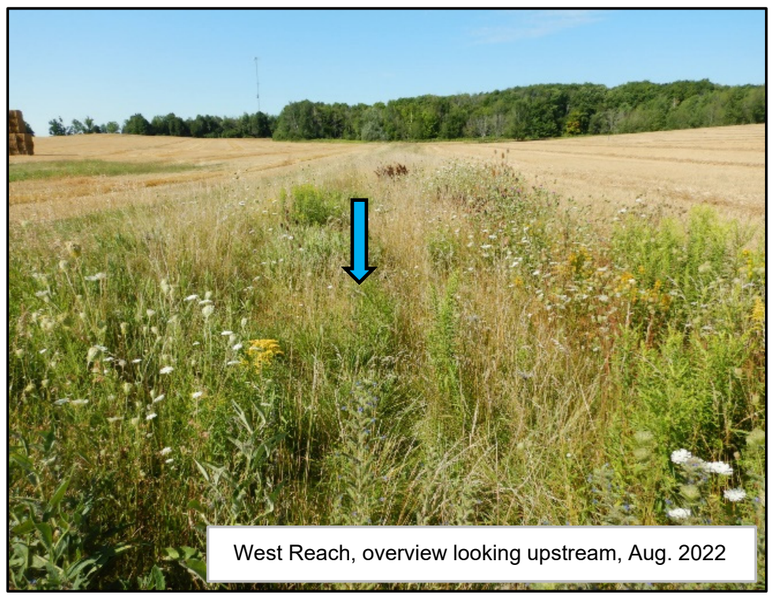
N▲ not to scale



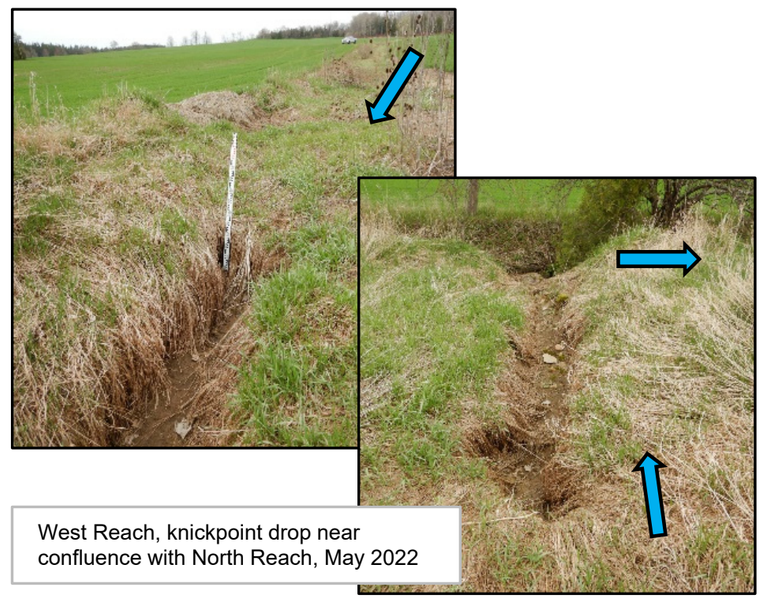
Belwood Lake Tributary, Photo Inventory



West Reach, overview looking upstream, May 2022

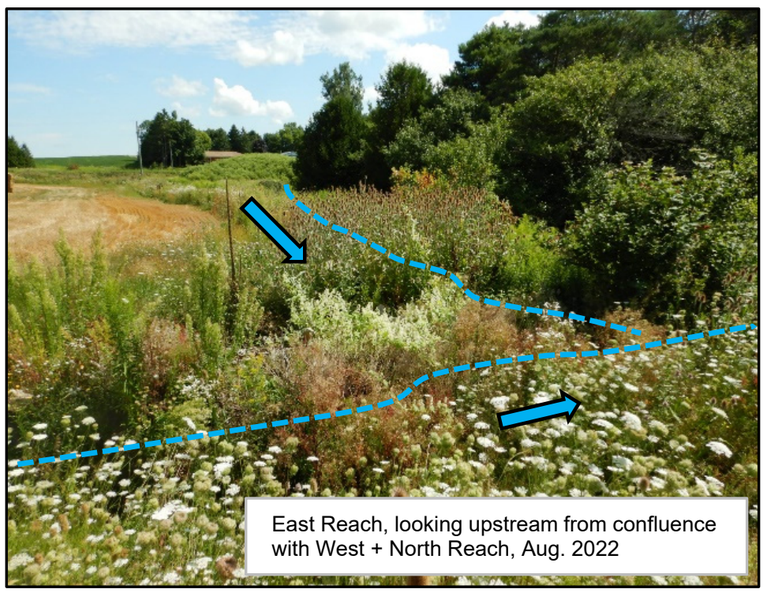


West Reach, overview looking upstream, Aug. 2022



West Reach, knickpoint drop near confluence with North Reach, May 2022

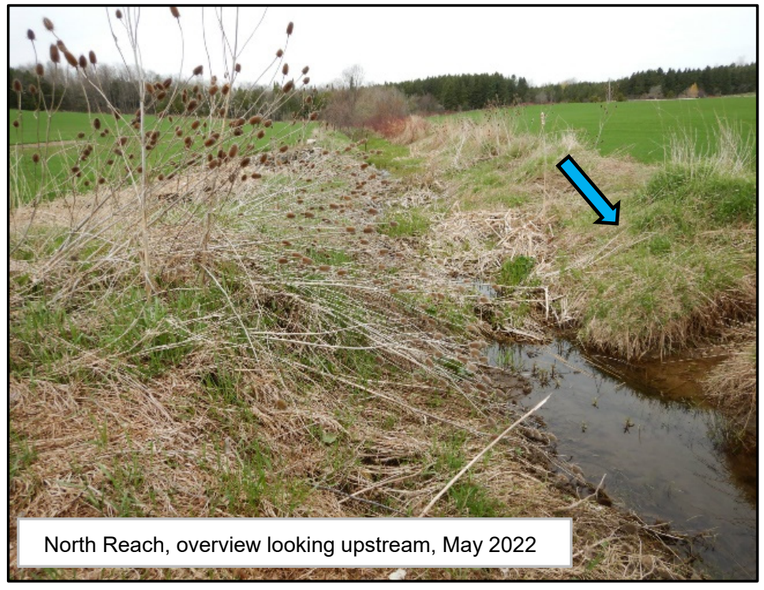
East Reach, looking downstream from near 7th Line, May 2022



East Reach, looking upstream from confluence with West + North Reach, Aug. 2022

East Reach, 7th Line, May 2022

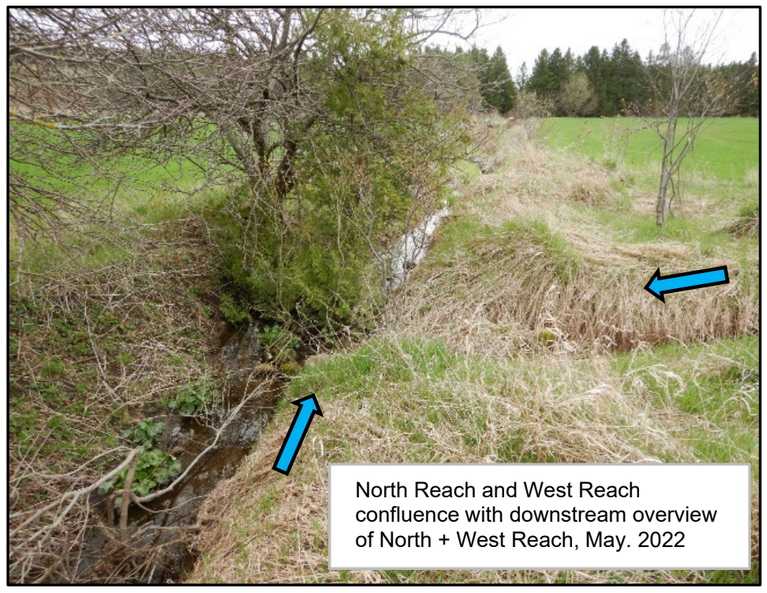
Belwood Lake Tributary, Photo Inventory



North Reach, overview looking upstream, May 2022

North Reach, overview looking upstream, Aug. 2022

North Reach, overview looking downstream, May 2022



North Reach and West Reach confluence with downstream overview of North + West Reach, May. 2022

North + West Reach, overview looking upstream, May 2022

North + West Reach, culvert crossing and local erosion scar, May 2022

Belwood Lake Tributary, Photo Inventory

East Reach and North + West Reach confluence, Main Branch downstream, May. 2022

Main Branch confined bank erosion scar, May. 2022

Main Branch entrenched bank erosion scars and undercuts, May. 2022

Main Branch, looking upstream from Wellington Rd. 19, May and Aug. 2022

Main Branch, dam upstream of Wellington Rd. 19, May and Aug. 2022. with and without flow over top

Main Branch, standing water above and below dam, Aug. 2022

SPRING Assessment Results

GEO-RAP v.2.0 Rapid Assessment Protocol Model

Project: **Headwater Drainage Feature Assessment**
Belwood Lake Tributary, West Reach
SPRING Inspection

1) Rapid Geomorphic Assessment (RGA)

Aggradation	Lobate bar	
	Coarse material in riffles embedded	
	Siltation in pools	
	Medial bars	
	Accretion on point bars	
	Poor longitudinal sorting of bed materials	1
	Deposition in the overbank zone	
	n/7 =	0.14
Degradation	Exposed bridge footing(s)	
	Exposed sanitary/storm sewer/pipeline etc.	
	Elevated stormsewer outfall(s)	
	Undermined gabion baskets/concrete aprons etc.	
	Scour pools d/s of culverts/stormsewer outlets	
	Cut face on bar forms	1
	Head cutting due to knick point migration	1
	Terrace cut through older bar material	
	Suspended armour layer visible in bank	
	Channel worn into undisturbed overburden/bedrock	
	n/10 =	0.20

Widening	Fallen/leaning trees/fence posts etc.	
	Occurrence of Large Organic Debris	
	Exposed tree roots	
	Basal scour on inside meander bends	
	Basal scour on both sides of channel through riffle	
	Gabion baskets/concrete walls etc. out flanked	
	Length of basal scour >50% through subject reach	
	Exposed length of previously buried pipe/cable etc.	
	Fracture lines along top of bank	
	Exposed building foundation	
	n/10 =	0.00
Planimetric Form	Formation of chute(s)	
	Single thread channel to multiple channel	
	Evolution of pool-riffle form to low bed relief form	
	Cut-off channel(s)	
	Formation of island(s)	
	Thalweg alignment out of phase meander form	1
	Bar forms poorly formed/reworked/removed	
	n/7 =	0.14
	STABILITY INDEX (SI) = (A + D + W + P) / 4 =	**0.12**
	SI < 0.2	In Regime
	0.2 < SI < 0.4	Transitional
	SI > 0.4	In Adjustment
	100 - (100*SI) =	**87.9**

2) Rapid Habitat Assessment (RHA)

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	15	20--16	15-11	10-6	5-0
Embeddedness	15	20--16	15-11	10-6	5-0
Velocity / Depth Regime	6	20--16	15-11	10-6	5-0
Sediment Deposition	15	20--16	15-11	10-6	5-0
Channel Flow Status	5	20--16	15-11	10-6	5-0
Channel Alteration	5	20--16	15-11	10-6	5-0
Frequency of Riffles	15	20--16	15-11	10-6	5-0
Bank Stability u/s L	9	10-8	7-6	5-3	2-0
u/s R	9	10-8	7-6	5-3	2-0
Vegetative Protection u/s L	6	10-8	7-6	5-3	2-0
u/s R	6	10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L	5	10-8	7-6	5-3	2-0
u/s R	5	10-8	7-6	5-3	2-0
/200	116				
/100	**58.0**	Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

Glide Pool Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover		20--16	15-11	10-6	5-0
Pool Substrate Characterization		20--16	15-11	10-6	5-0
Pool Variability		20--16	15-11	10-6	5-0
Sediment Deposition		20--16	15-11	10-6	5-0
Channel Flow Status		20--16	15-11	10-6	5-0
Channel Alteration		20--16	15-11	10-6	5-0
Channel Sinuosity		20--16	15-11	10-6	5-0
Bank Stability u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Vegetative Protection u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
/200					
/100		Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

3) Rapid Stream Assessment Technique (RSAT)

		Optimal	Good	Fair	Poor
Channel Stability	9	11-9	8-6	5-3	2-0
Channel Scouring/Deposition	6	8-7	6-5	4-3	2-0
Physical Instream Habitat	5	8-7	6-5	4-3	2-0
Water Quality	6	8-7	6-5	4-3	2-0
Riparian Habitat Conditions	4	7-6	5-4	3-2	1-0
Biological Indicators	0	8-7	6-5	4-3	2-0
/50	30				
/100	**60.0**	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

1) - 3) Combined Assessment

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
(RGA + RHA + RSAT) / 3 =	**68.6**	100-80	80-56	55-30	29-0

Glide Pool Channel Type

		Optimal	Good	Fair	Poor
(RGA + RHA + RSAT) / 3 =		100-80	80-56	55-30	29-0

4) TRCA & CVCA Headwater Drainage Features Guideline (HDFG)

DA (ha)	QC	FC	FT	RM
28.5	**C**	**3**	**1+5+7**	**F**

QC — Flow Classification: A - perennial, B - intermittent, C - ephemeral, D - dry or standing water w/recharge, E - dry or standing water w/no recharge

FC — Flow Condition: 1 - no surface water, 2 - standing water, 3 - interstitial flow, 4 - <0.5l/sec, 5 - >0.5l/sec

FT — Feature Type: 1 - defined bed & banks, 2 - channelized historically, 3 - multi-thread, 4 - no defined feature, 5 - tile drain, 6 - wetland, 7 - swale, 8 - roadside ditch, 9 - online pond outlet

RM — Recommended Management: A - protection, B - conservation, C - mitigation, D - recharge protection, E - maintain/replicate terrestrial linkage, F - no management

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4) Toronto and Region Conservation Authority and Credit Valley Conservation Authority. 2014. Evaluation, Classification and Management of Headwater Drainage Features Guideline. TRCA Approval July 2013 (Finalized January 2014).

GEO-RAP v.2.0 Rapid Assessment Protocol Model

Project: **Headwater Drainage Feature Assessment**
Belwood Lake Tributary, North Reach
SPRING Inspection

1) Rapid Geomorphic Assessment (RGA)

Aggradation	Lobate bar	
	Coarse material in riffles embedded	
	Siltation in pools	
	Medial bars	
	Accretion on point bars	1
	Poor longitudinal sorting of bed materials	
	Deposition in the overbank zone	
	n/7 =	0.14
Degradation	Exposed bridge footing(s)	
	Exposed sanitary/storm sewer/pipeline etc.	
	Elevated stormsewer outfall(s)	
	Undermined gabion baskets/concrete aprons etc.	
	Scour pools d/s of culverts/stormsewer outlets	
	Cut face on bar forms	1
	Head cutting due to knick point migration	
	Terrace cut through older bar material	
	Suspended armour layer visible in bank	
	Channel worn into undisturbed overburden/bedrock	
	n/10 =	0.10

Widening	Fallen/leaning trees/fence posts etc.	
	Occurrence of Large Organic Debris	
	Exposed tree roots	
	Basal scour on inside meander bends	
	Basal scour on both sides of channel through riffle	
	Gabion baskets/concrete walls etc. out flanked	
	Length of basal scour >50% through subject reach	
	Exposed length of previously buried pipe/cable etc.	
	Fracture lines along top of bank	
	Exposed building foundation	
	n/10 =	0.00
Planimetric Form	Formation of chute(s)	
	Single thread channel to multiple channel	
	Evolution of pool-riffle form to low bed relief form	
	Cut-off channel(s)	
	Formation of island(s)	
	Thalweg alignment out of phase meander form	1
	Bar forms poorly formed/reworked/removed	
	n/7 =	0.14
	STABILITY INDEX (SI) = (A + D + W + P) / 4 =	**0.10**
	SI < 0.2	In Regime
	0.2 < SI < 0.4	Transitional
	SI > 0.4	In Adjustment
	100 - (100*SI) =	**90.4**

2) Rapid Habitat Assessment (RHA)

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	17	20--16	15-11	10-6	5-0
Embeddedness	17	20--16	15-11	10-6	5-0
Velocity / Depth Regime	12	20--16	15-11	10-6	5-0
Sediment Deposition	15	20--16	15-11	10-6	5-0
Channel Flow Status	15	20--16	15-11	10-6	5-0
Channel Alteration	11	20--16	15-11	10-6	5-0
Frequency of Riffles	15	20--16	15-11	10-6	5-0
Bank Stability u/s L	9	10-8	7-6	5-3	2-0
u/s R	9	10-8	7-6	5-3	2-0
Vegetative Protection u/s L	8	10-8	7-6	5-3	2-0
u/s R	8	10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L	7	10-8	7-6	5-3	2-0
u/s R	7	10-8	7-6	5-3	2-0
/200	150				
/100	**75.0**	Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

Glide Pool Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover		20--16	15-11	10-6	5-0
Pool Substrate Characterization		20--16	15-11	10-6	5-0
Pool Variability		20--16	15-11	10-6	5-0
Sediment Deposition		20--16	15-11	10-6	5-0
Channel Flow Status		20--16	15-11	10-6	5-0
Channel Alteration		20--16	15-11	10-6	5-0
Channel Sinuosity		20--16	15-11	10-6	5-0
Bank Stability u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Vegetative Protection u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
/200					
/100		Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

3) Rapid Stream Assessment Technique (RSAT)

		Optimal	Good	Fair	Poor
Channel Stability	9	11-9	8-6	5-3	2-0
Channel Scouring/Deposition	7	8-7	6-5	4-3	2-0
Physical Instream Habitat	7	8-7	6-5	4-3	2-0
Water Quality	6	8-7	6-5	4-3	2-0
Riparian Habitat Conditions	6	7-6	5-4	3-2	1-0
Biological Indicators	3	8-7	6-5	4-3	2-0
/50	38				
/100	**76.0**	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

1) - 3) Combined Assessment

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
(RGA + RHA + RSAT) / 3 =	**80.5**	Optimal	Good	Fair	Poor
		100-80	80-56	55-30	29-0

Glide Pool Channel Type

		Optimal	Good	Fair	Poor
(RGA + RHA + RSAT) / 3 =		Optimal	Good	Fair	Poor
		100-80	80-56	55-30	29-0

4) TRCA & CVCA Headwater Drainage Features Guideline (HDFG)

DA (ha)	QC	FC	FT	RM
44	**A**	**5**	**1 + 5**	**A**

QC — Flow Classification: A - perennial, B - intermittent, C - ephemeral, D - dry or standing water w/recharge, E - dry or standing water w/no recharge

FC — Flow Condition: 1 - no surface water, 2 - standing water, 3 - interstitial flow, 4 - <0.5l/sec, 5 - >0.5l/sec

FT — Feature Type: 1 - defined bed & banks, 2 - channelized historically, 3 - multi-thread, 4 - no defined feature, 5 - tile drain, 6 - wetland, 7 - swale, 8 - roadside ditch, 9 - online pond outlet

RM — Recommended Management: A - protection, B - conservation, C - mitigation, D - recharge protection, E - maintain/replicate terrestrial linkage, F - no management

References

1) Ontario Ministry of Environment and Energy. 2003. Stormwater Management Planning and Design Manual. Appendix C.

2) United States Environmental Protection Association. 2004. Wadeable Stream Assessment: Field Operations Manual. EPA841-B-04-004. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, DC.

3) Galli, J., 1996. Rapid stream assessment technique, field methods. Metropolitan Washington Council of Governments.

4) Toronto and Region Conservation Authority and Credit Valley Conservation Authority. 2014. Evaluation, Classification and Management of Headwater Drainage Features Guideline. TRCA Approval July 2013 (Finalized January 2014).

GEO-RAP v.2.0 Rapid Assessment Protocol Model

Project: **Headwater Drainage Feature Assessment**
Belwood Lake Tributary. West Reach + North Reach
SPRING Inspection

1) Rapid Geomorphic Assessment (RGA)

Aggradation	Lobate bar	
	Coarse material in riffles embedded	
	Siltation in pools	
	Medial bars	
	Accretion on point bars	1
	Poor longitudinal sorting of bed materials	
	Deposition in the overbank zone	
	n/7 =	0.14
Degradation	Exposed bridge footing(s)	
	Exposed sanitary/storm sewer/pipeline etc.	
	Elevated stormsewer outfall(s)	
	Undermined gabion baskets/concrete aprons etc.	
	Scour pools d/s of culverts/stormsewer outlets	1
	Cut face on bar forms	1
	Head cutting due to knick point migration	
	Terrace cut through older bar material	
	Suspended armour layer visible in bank	
	Channel worn into undisturbed overburden/bedrock	
	n/10 =	0.20

Widening	Fallen/leaning trees/fence posts etc.	
	Occurrence of Large Organic Debris	
	Exposed tree roots	
	Basal scour on inside meander bends	
	Basal scour on both sides of channel through riffle	
	Gabion baskets/concrete walls etc. out flanked	
	Length of basal scour >50% through subject reach	
	Exposed length of previously buried pipe/cable etc.	
	Fracture lines along top of bank	1
	Exposed building foundation	
	n/10 =	0.10
Planimetric Form	Formation of chute(s)	
	Single thread channel to multiple channel	
	Evolution of pool-riffle form to low bed relief form	
	Cut-off channel(s)	
	Formation of island(s)	
	Thalweg alignment out of phase meander form	
	Bar forms poorly formed/reworked/removed	
	n/7 =	0.00

STABILITY INDEX (SI) = (A + D + W + P) / 4 = **0.11**

SI < 0.2	In Regime
0.2 < SI < 0.4	Transitional
SI > 0.4	In Adjustment
100 - (100*SI) =	**88.9**

2) Rapid Habitat Assessment (RHA)

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	17	20--16	15-11	10-6	5-0
Embeddedness	17	20--16	15-11	10-6	5-0
Velocity / Depth Regime	12	20--16	15-11	10-6	5-0
Sediment Deposition	15	20--16	15-11	10-6	5-0
Channel Flow Status	15	20--16	15-11	10-6	5-0
Channel Alteration	9	20--16	15-11	10-6	5-0
Frequency of Riffles	15	20--16	15-11	10-6	5-0
Bank Stability u/s L	9	10-8	7-6	5-3	2-0
u/s R	9	10-8	7-6	5-3	2-0
Vegetative Protection u/s L	7	10-8	7-6	5-3	2-0
u/s R	7	10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L	6	10-8	7-6	5-3	2-0
u/s R	6	10-8	7-6	5-3	2-0
/200	144				
/100	**72.0**	Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

Glide Pool Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover		20--16	15-11	10-6	5-0
Pool Substrate Characterization		20--16	15-11	10-6	5-0
Pool Variability		20--16	15-11	10-6	5-0
Sediment Deposition		20--16	15-11	10-6	5-0
Channel Flow Status		20--16	15-11	10-6	5-0
Channel Alteration		20--16	15-11	10-6	5-0
Channel Sinuosity		20--16	15-11	10-6	5-0
Bank Stability u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Vegetative Protection u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
/200					
/100		Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

3) Rapid Stream Assessment Technique (RSAT)

		Optimal	Good	Fair	Poor
Channel Stability	9	11-9	8-6	5-3	2-0
Channel Scouring/Deposition	7	8-7	6-5	4-3	2-0
Physical Instream Habitat	7	8-7	6-5	4-3	2-0
Water Quality	6	8-7	6-5	4-3	2-0
Riparian Habitat Conditions	4	7-6	5-4	3-2	1-0
Biological Indicators	3	8-7	6-5	4-3	2-0
/50	36				
/100	**72.0**	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

1) - 3) Combined Assessment

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
(RGA + RHA + RSAT) / 3 =	**77.6**				
		100-80	80-56	55-30	29-0

Glide Pool Channel Type

		Optimal	Good	Fair	Poor
(RGA + RHA + RSAT) / 3 =					
		100-80	80-56	55-30	29-0

4) TRCA & CVCA Headwater Drainage Features Guideline (HDFG)

DA (ha)	QC	FC	FT	RM
46.1	**A**	**5**	**1 + 5**	**A**

QC — Flow Classification: A - perennial, B - intermittent, C - ephemeral, D - dry or standing water w/recharge, E - dry or standing water w/no recharge

FC — Flow Condition: 1 - no surface water, 2 - standing water, 3 - interstitial flow, 4 - <0.5l/sec, 5 - >0.5l/sec

FT — Feature Type: 1 - defined bed & banks, 2 - channelized historically, 3 - multi-thread, 4 - no defined feature, 5 - tile drain, 6 - wetland, 7 - swale, 8 - roadside ditch, 9 - online pond outlet

RM — Recommended Management: A - protection, B - conservation, C - mitigation, D - recharge protection, E - maintain/replicate terrestrial linkage, F - no management

References

1) Ontario Ministry of Environment and Energy. 2003. Stormwater Management Planning and Design Manual. Appendix C.

2) United States Environmental Protection Association. 2004. Wadeable Stream Assessment: Field Operations Manual. EPA841-B-04-004. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, DC.

3) Galli, J., 1996. Rapid stream assessment technique, field methods. Metropolitan Washington Council of Governments.

4) Toronto and Region Conservation Authority and Credit Valley Conservation Authority. 2014. Evaluation, Classification and Management of Headwater Drainage Features Guideline. TRCA Approval July 2013 (Finalized January 2014).

GEO-RAP v.2.0 Rapid Assessment Protocol Model

Project: **Headwater Drainage Feature Assessment**
Belwood Lake Tributary, East Reach
SPRING Inspection

1) Rapid Geomorphic Assessment (RGA)

Aggradation	Lobate bar	
	Coarse material in riffles embedded	
	Siltation in pools	
	Medial bars	
	Accretion on point bars	1
	Poor longitudinal sorting of bed materials	
	Deposition in the overbank zone	
	n/7 =	0.14
Degradation	Exposed bridge footing(s)	
	Exposed sanitary/storm sewer/pipeline etc.	
	Elevated stormsewer outfall(s)	
	Undermined gabion baskets/concrete aprons etc.	
	Scour pools d/s of culverts/stormsewer outlets	
	Cut face on bar forms	
	Head cutting due to knick point migration	
	Terrace cut through older bar material	
	Suspended armour layer visible in bank	
	Channel worn into undisturbed overburden/bedrock	
	n/10 =	0.00

Widening	Fallen/leaning trees/fence posts etc.	
	Occurrence of Large Organic Debris	
	Exposed tree roots	
	Basal scour on inside meander bends	
	Basal scour on both sides of channel through riffle	
	Gabion baskets/concrete walls etc. out flanked	
	Length of basal scour >50% through subject reach	
	Exposed length of previously buried pipe/cable etc.	
	Fracture lines along top of bank	
	Exposed building foundation	
	n/10 =	0.00
Planimetric Form	Formation of chute(s)	1
	Single thread channel to multiple channel	
	Evolution of pool-riffle form to low bed relief form	
	Cut-off channel(s)	
	Formation of island(s)	
	Thalweg alignment out of phase meander form	
	Bar forms poorly formed/reworked/removed	
	n/7 =	0.14
	STABILITY INDEX (SI) = (A + D + W + P) / 4 =	**0.07**
	SI < 0.2	In Regime
	0.2 < SI < 0.4	Transitional
	SI > 0.4	In Adjustment
	100 - (100*SI) =	**92.9**

2) Rapid Habitat Assessment (RHA)

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	12	20--16	15-11	10-6	5-0
Embeddedness	15	20--16	15-11	10-6	5-0
Velocity / Depth Regime	6	20--16	15-11	10-6	5-0
Sediment Deposition	16	20--16	15-11	10-6	5-0
Channel Flow Status	6	20--16	15-11	10-6	5-0
Channel Alteration	5	20--16	15-11	10-6	5-0
Frequency of Riffles	15	20--16	15-11	10-6	5-0
Bank Stability u/s L	9	10-8	7-6	5-3	2-0
u/s R	9	10-8	7-6	5-3	2-0
Vegetative Protection u/s L	8	10-8	7-6	5-3	2-0
u/s R	8	10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L	8	10-8	7-6	5-3	2-0
u/s R	8	10-8	7-6	5-3	2-0
/200	125				
/100	**62.5**	Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

Glide Pool Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover		20--16	15-11	10-6	5-0
Pool Substrate Characterization		20--16	15-11	10-6	5-0
Pool Variability		20--16	15-11	10-6	5-0
Sediment Deposition		20--16	15-11	10-6	5-0
Channel Flow Status		20--16	15-11	10-6	5-0
Channel Alteration		20--16	15-11	10-6	5-0
Channel Sinuosity		20--16	15-11	10-6	5-0
Bank Stability u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Vegetative Protection u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
/200					
/100		Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

3) Rapid Stream Assessment Technique (RSAT)

		Optimal	Good	Fair	Poor
Channel Stability	9	11-9	8-6	5-3	2-0
Channel Scouring/Deposition	6	8-7	6-5	4-3	2-0
Physical Instream Habitat	4	8-7	6-5	4-3	2-0
Water Quality	6	8-7	6-5	4-3	2-0
Riparian Habitat Conditions	4	7-6	5-4	3-2	1-0
Biological Indicators	6	8-7	6-5	4-3	2-0
/50	35				
/100	**70.0**	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

1) - 3) Combined Assessment

Riffle Run Channel Type

(RGA + RHA + RSAT) / 3 =	**75.1**	Optimal	Good	Fair	Poor
		100-80	80-56	55-30	29-0

Glide Pool Channel Type

(RGA + RHA + RSAT) / 3 =		Optimal	Good	Fair	Poor
		100-80	80-56	55-30	29-0

4) TRCA & CVCA Headwater Drainage Features Guideline (HDFG)

DA (ha)	QC	FC	FT	RM
47.5	**A**	**5**	**1 + 5**	**A**

QC — Flow Classification: A - perennial, B - intermittent, C - ephemeral, D - dry or standing water w/recharge, E - dry or standing water w/no recharge

FC — Flow Condition: 1 - no surface water, 2 - standing water, 3 - interstitial flow, 4 - <0.5l/sec, 5 - >0.5l/sec

FT — Feature Type: 1 - defined bed & banks, 2 - channelized historically, 3 - multi-thread, 4 - no defined feature, 5 - tile drain, 6 - wetland, 7 - swale, 8 - roadside ditch, 9 - online pond outlet

RM — Recommended Management: A - protection, B - conservation, C - mitigation, D - recharge protection, E - maintain/replicate terrestrial linkage, F - no management

References

1) Ontario Ministry of Environment and Energy. 2003. Stormwater Management Planning and Design Manual. Appendix C.

2) United States Environmental Protection Association. 2004. Wadeable Stream Assessment: Field Operations Manual. EPA841-B-04-004. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, DC.

3) Galli, J., 1996. Rapid stream assessment technique, field methods. Metropolitan Washington Council of Governments.

4) Toronto and Region Conservation Authority and Credit Valley Conservation Authority. 2014. Evaluation, Classification and Management of Headwater Drainage Features Guideline. TRCA Approval July 2013 (Finalized January 2014).

GEO-RAP v.2.0 Rapid Assessment Protocol Model

Project: **Headwater Drainage Feature Assessment**
Belwood Lake Tributary, West + North + East = Main Branch
SPRING Inspection

1) Rapid Geomorphic Assessment (RGA)

Aggradation	Lobate bar	
	Coarse material in riffles embedded	
	Siltation in pools	1
	Medial bars	1
	Accretion on point bars	1
	Poor longitudinal sorting of bed materials	1
	Deposition in the overbank zone	
	n/7 =	0.57
Degradation	Exposed bridge footing(s)	
	Exposed sanitary/storm sewer/pipeline etc.	
	Elevated stormsewer outfall(s)	
	Undermined gabion baskets/concrete aprons etc.	
	Scour pools d/s of culverts/stormsewer outlets	
	Cut face on bar forms	1
	Head cutting due to knick point migration	
	Terrace cut through older bar material	
	Suspended armour layer visible in bank	
	Channel worn into undisturbed overburden/bedrock	1
	n/10 =	0.20

Widening	Fallen/leaning trees/fence posts etc.	1
	Occurrence of Large Organic Debris	1
	Exposed tree roots	1
	Basal scour on inside meander bends	
	Basal scour on both sides of channel through riffle	1
	Gabion baskets/concrete walls etc. out flanked	
	Length of basal scour >50% through subject reach	1
	Exposed length of previously buried pipe/cable etc.	
	Fracture lines along top of bank	1
	Exposed building foundation	
	n/10 =	0.60
Planimetric Form	Formation of chute(s)	
	Single thread channel to multiple channel	
	Evolution of pool-riffle form to low bed relief form	
	Cut-off channel(s)	
	Formation of island(s)	
	Thalweg alignment out of phase meander form	1
	Bar forms poorly formed/reworked/removed	1
	n/7 =	0.29
	STABILITY INDEX (SI) = (A + D + W + P) / 4 =	**0.41**
	SI < 0.2	In Regime
	0.2 < SI < 0.4	Transitional
	SI > 0.4	In Adjustment
	100 - (100*SI) =	**58.6**

2) Rapid Habitat Assessment (RHA)

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	15	20--16	15-11	10-6	5-0
Embeddedness	10	20--16	15-11	10-6	5-0
Velocity / Depth Regime	12	20--16	15-11	10-6	5-0
Sediment Deposition	10	20--16	15-11	10-6	5-0
Channel Flow Status	15	20--16	15-11	10-6	5-0
Channel Alteration	9	20--16	15-11	10-6	5-0
Frequency of Riffles	15	20--16	15-11	10-6	5-0
Bank Stability u/s L	6	10-8	7-6	5-3	2-0
u/s R	6	10-8	7-6	5-3	2-0
Vegetative Protection u/s L	6	10-8	7-6	5-3	2-0
u/s R	6	10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L	7	10-8	7-6	5-3	2-0
u/s R	7	10-8	7-6	5-3	2-0
/200	124				
/100	**62.0**	Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

Glide Pool Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover		20--16	15-11	10-6	5-0
Pool Substrate Characterization		20--16	15-11	10-6	5-0
Pool Variability		20--16	15-11	10-6	5-0
Sediment Deposition		20--16	15-11	10-6	5-0
Channel Flow Status		20--16	15-11	10-6	5-0
Channel Alteration		20--16	15-11	10-6	5-0
Channel Sinuosity		20--16	15-11	10-6	5-0
Bank Stability u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Vegetative Protection u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
/200					
/100		Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

3) Rapid Stream Assessment Technique (RSAT)

		Optimal	Good	Fair	Poor
Channel Stability	6	11-9	8-6	5-3	2-0
Channel Scouring/Deposition	4	8-7	6-5	4-3	2-0
Physical Instream Habitat	6	8-7	6-5	4-3	2-0
Water Quality	6	8-7	6-5	4-3	2-0
Riparian Habitat Conditions	6	7-6	5-4	3-2	1-0
Biological Indicators	3	8-7	6-5	4-3	2-0
/50	31				
/100	**62.0**	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

1) - 3) Combined Assessment

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
(RGA + RHA + RSAT) / 3 =	**60.9**	100-80	80-56	55-30	29-0

Glide Pool Channel Type

		Optimal	Good	Fair	Poor
(RGA + RHA + RSAT) / 3 =		100-80	80-56	55-30	29-0

4) TRCA & CVCA Headwater Drainage Features Guideline (HDFG)

DA (ha)	QC	FC	FT	RM
129.2	**A**	**5**	**1 + 5**	**A**

QC — Flow Classification: A - perennial, B - intermittent, C - ephemeral, D - dry or standing water w/recharge, E - dry or standing water w/no recharge

FC — Flow Condition: 1 - no surface water, 2 - standing water, 3 - interstitial flow, 4 - <0.5l/sec, 5 - >0.5l/sec

FT — Feature Type: 1 - defined bed & banks, 2 - channelized historically, 3 - multi-thread, 4 - no defined feature, 5 - tile drain, 6 - wetland, 7 - swale, 8 - roadside ditch, 9 - online pond outlet

RM — Recommended Management: A - protection, B - conservation, C - mitigation, D - recharge protection, E - maintain/replicate terrestrial linkage, F - no management

References

1) Ontario Ministry of Environment and Energy. 2003. Stormwater Management Planning and Design Manual. Appendix C.

2) United States Environmental Protection Association. 2004. Wadeable Stream Assessment: Field Operations Manual. EPA841-B-04-004. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, DC.

3) Galli, J., 1996. Rapid stream assessment technique, field methods. Metropolitan Washington Council of Governments.

4) Toronto and Region Conservation Authority and Credit Valley Conservation Authority. 2014. Evaluation, Classification and Management of Headwater Drainage Features Guideline. TRCA Approval July 2013 (Finalized January 2014).

SUMMER Assessment Results

GEO-RAP v.2.0 Rapid Assessment Protocol Model

Project: **Headwater Drainage Feature Assessment**
Belwood Lake Tributary, West Reach
SUMMER Inspection

1) Rapid Geomorphic Assessment (RGA)

Aggradation	Lobate bar	
	Coarse material in riffles embedded	
	Siltation in pools	
	Medial bars	
	Accretion on point bars	
	Poor longitudinal sorting of bed materials	1
	Deposition in the overbank zone	
	n/7 =	0.14
Degradation	Exposed bridge footing(s)	
	Exposed sanitary/storm sewer/pipeline etc.	
	Elevated stormsewer outfall(s)	
	Undermined gabion baskets/concrete aprons etc.	
	Scour pools d/s of culverts/stormsewer outlets	
	Cut face on bar forms	1
	Head cutting due to knick point migration	1
	Terrace cut through older bar material	
	Suspended armour layer visible in bank	
	Channel worn into undisturbed overburden/bedrock	
	n/10 =	0.20

Widening	Fallen/leaning trees/fence posts etc.	
	Occurrence of Large Organic Debris	
	Exposed tree roots	
	Basal scour on inside meander bends	
	Basal scour on both sides of channel through riffle	
	Gabion baskets/concrete walls etc. out flanked	
	Length of basal scour >50% through subject reach	
	Exposed length of previously buried pipe/cable etc.	
	Fracture lines along top of bank	
	Exposed building foundation	
	n/10 =	0.00
Planimetric Form	Formation of chute(s)	
	Single thread channel to multiple channel	
	Evolution of pool-riffle form to low bed relief form	
	Cut-off channel(s)	
	Formation of island(s)	
	Thalweg alignment out of phase meander form	1
	Bar forms poorly formed/reworked/removed	
	n/7 =	0.14
	STABILITY INDEX (SI) = (A + D + W + P) / 4 =	**0.12**
	SI < 0.2	In Regime
	0.2 < SI < 0.4	Transitional
	SI > 0.4	In Adjustment
	100 - (100*SI) =	**87.9**

2) Rapid Habitat Assessment (RHA)

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	15	20--16	15-11	10-6	5-0
Embeddedness	15	20--16	15-11	10-6	5-0
Velocity / Depth Regime	0	20--16	15-11	10-6	5-0
Sediment Deposition	15	20--16	15-11	10-6	5-0
Channel Flow Status	0	20--16	15-11	10-6	5-0
Channel Alteration	5	20--16	15-11	10-6	5-0
Frequency of Riffles	15	20--16	15-11	10-6	5-0
Bank Stability u/s L	9	10-8	7-6	5-3	2-0
u/s R	9	10-8	7-6	5-3	2-0
Vegetative Protection u/s L	6	10-8	7-6	5-3	2-0
u/s R	6	10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L	5	10-8	7-6	5-3	2-0
u/s R	5	10-8	7-6	5-3	2-0
/200	105				
/100	**52.5**	Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

Glide Pool Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover		20--16	15-11	10-6	5-0
Pool Substrate Characterization		20--16	15-11	10-6	5-0
Pool Variability		20--16	15-11	10-6	5-0
Sediment Deposition		20--16	15-11	10-6	5-0
Channel Flow Status		20--16	15-11	10-6	5-0
Channel Alteration		20--16	15-11	10-6	5-0
Channel Sinuosity		20--16	15-11	10-6	5-0
Bank Stability u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Vegetative Protection u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
/200					
/100		Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

3) Rapid Stream Assessment Technique (RSAT)

		Optimal	Good	Fair	Poor
Channel Stability	9	11-9	8-6	5-3	2-0
Channel Scouring/Deposition	6	8-7	6-5	4-3	2-0
Physical Instream Habitat	5	8-7	6-5	4-3	2-0
Water Quality	6	8-7	6-5	4-3	2-0
Riparian Habitat Conditions	4	7-6	5-4	3-2	1-0
Biological Indicators	0	8-7	6-5	4-3	2-0
/50	30				
/100	**60.0**	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

1) - 3) Combined Assessment

Riffle Run Channel Type

(RGA + RHA + RSAT) / 3 =	**66.8**	Optimal	Good	Fair	Poor
		100-80	80-56	55-30	29-0

Glide Pool Channel Type

(RGA + RHA + RSAT) / 3 =		Optimal	Good	Fair	Poor
		100-80	80-56	55-30	29-0

4) TRCA & CVCA Headwater Drainage Features Guideline (HDFG)

DA (ha)	QC	FC	FT	RM
28.5	**E**	**1**	**1+5+7**	**F**

QC — Flow Classification: A - perennial, B - intermittent, C - ephemeral, D - dry or standing water w/recharge, E - dry or standing water w/no recharge

FC — Flow Condition: 1 - no surface water, 2 - standing water, 3 - interstitial flow, 4 - <0.5l/sec, 5 - >0.5l/sec

FT — Feature Type: 1 - defined bed & banks, 2 - channelized historically, 3 - multi-thread, 4 - no defined feature, 5 - tile drain, 6 - wetland, 7 - swale, 8 - roadside ditch, 9 - online pond outlet

RM — Recommended Management: A - protection, B - conservation, C - mitigation, D - recharge protection, E - maintain/replicate terrestrial linkage, F - no management

References

1) Ontario Ministry of Environment and Energy. 2003. Stormwater Management Planning and Design Manual. Appendix C.

2) United States Environmental Protection Association. 2004. Wadeable Stream Assessment: Field Operations Manual. EPA841-B-04-004. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, DC.

3) Galli, J., 1996. Rapid stream assessment technique, field methods. Metropolitan Washington Council of Governments.

4) Toronto and Region Conservation Authority and Credit Valley Conservation Authority. 2014. Evaluation, Classification and Management of Headwater Drainage Features Guideline. TRCA Approval July 2013 (Finalized January 2014).

GEO-RAP v.2.0 Rapid Assessment Protocol Model

Project: Headwater Drainage Feature Assessment
Belwood Lake Tributary, North Reach
SUMMER Inspection

1) Rapid Geomorphic Assessment (RGA)

Aggradation	Lobate bar	
	Coarse material in riffles embedded	
	Siltation in pools	
	Medial bars	
	Accretion on point bars	1
	Poor longitudinal sorting of bed materials	
	Deposition in the overbank zone	
	n/7 =	0.14
Degradation	Exposed bridge footing(s)	
	Exposed sanitary/storm sewer/pipeline etc.	
	Elevated stormsewer outfall(s)	
	Undermined gabion baskets/concrete aprons etc.	
	Scour pools d/s of culverts/stormsewer outlets	
	Cut face on bar forms	1
	Head cutting due to knick point migration	
	Terrace cut through older bar material	
	Suspended armour layer visible in bank	
	Channel worn into undisturbed overburden/bedrock	
	n/10 =	0.10

Widening	Fallen/leaning trees/fence posts etc.	
	Occurrence of Large Organic Debris	
	Exposed tree roots	
	Basal scour on inside meander bends	
	Basal scour on both sides of channel through riffle	
	Gabion baskets/concrete walls etc. out flanked	
	Length of basal scour >50% through subject reach	
	Exposed length of previously buried pipe/cable etc.	
	Fracture lines along top of bank	
	Exposed building foundation	
	n/10 =	0.00
Planimetric Form	Formation of chute(s)	
	Single thread channel to multiple channel	
	Evolution of pool-riffle form to low bed relief form	
	Cut-off channel(s)	
	Formation of island(s)	
	Thalweg alignment out of phase meander form	1
	Bar forms poorly formed/reworked/removed	
	n/7 =	0.14
	STABILITY INDEX (SI) = (A + D + W + P) / 4 =	**0.10**
	SI < 0.2	In Regime
	0.2 < SI < 0.4	Transitional
	SI > 0.4	In Adjustment
	100 - (100*SI) =	**90.4**

2) Rapid Habitat Assessment (RHA)

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	17	20--16	15-11	10-6	5-0
Embeddedness	17	20--16	15-11	10-6	5-0
Velocity / Depth Regime	3	20--16	15-11	10-6	5-0
Sediment Deposition	15	20--16	15-11	10-6	5-0
Channel Flow Status	3	20--16	15-11	10-6	5-0
Channel Alteration	11	20--16	15-11	10-6	5-0
Frequency of Riffles	15	20--16	15-11	10-6	5-0
Bank Stability u/s L	9	10-8	7-6	5-3	2-0
u/s R	9	10-8	7-6	5-3	2-0
Vegetative Protection u/s L	8	10-8	7-6	5-3	2-0
u/s R	8	10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L	7	10-8	7-6	5-3	2-0
u/s R	7	10-8	7-6	5-3	2-0
/200	129				
/100	**64.5**	Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

Glide Pool Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover		20--16	15-11	10-6	5-0
Pool Substrate Characterization		20--16	15-11	10-6	5-0
Pool Variability		20--16	15-11	10-6	5-0
Sediment Deposition		20--16	15-11	10-6	5-0
Channel Flow Status		20--16	15-11	10-6	5-0
Channel Alteration		20--16	15-11	10-6	5-0
Channel Sinuosity		20--16	15-11	10-6	5-0
Bank Stability u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Vegetative Protection u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
/200					
/100		Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

3) Rapid Stream Assessment Technique (RSAT)

		Optimal	Good	Fair	Poor
Channel Stability	9	11-9	8-6	5-3	2-0
Channel Scouring/Deposition	7	8-7	6-5	4-3	2-0
Physical Instream Habitat	7	8-7	6-5	4-3	2-0
Water Quality	6	8-7	6-5	4-3	2-0
Riparian Habitat Conditions	6	7-6	5-4	3-2	1-0
Biological Indicators	1	8-7	6-5	4-3	2-0
/50	36				
/100	**72.0**	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

1) - 3) Combined Assessment

Riffle Run Channel Type

(RGA + RHA + RSAT) / 3 =	**75.6**	Optimal	Good	Fair	Poor
		100-80	80-56	55-30	29-0

Glide Pool Channel Type

(RGA + RHA + RSAT) / 3 =		Optimal	Good	Fair	Poor
		100-80	80-56	55-30	29-0

4) TRCA & CVCA Headwater Drainage Features Guideline (HDFG)

DA (ha)	QC	FC	FT	RM
44	**B + C**	**2**	**1 + 5**	**A**

QC — Flow Classification: A - perennial, B - intermittent, C - ephemeral, D - dry or standing water w/recharge, E - dry or standing water w/no recharge

FC — Flow Condition: 1 - no surface water, 2 - standing water, 3 - interstitial flow, 4 - <0.5l/sec, 5 - >0.5l/sec

FT — Feature Type: 1 - defined bed & banks, 2 - channelized historically, 3 - multi-thread, 4 - no defined feature, 5 - tile drain, 6 - wetland, 7 - swale, 8 - roadside ditch, 9 - online pond outlet

RM — Recommended Management:
A - protection, B - conservation, C - mitigation, D - recharge protection, E - maintain/replicate terrestrial linkage, F - no management

References

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GEO-RAP v.2.0 Rapid Assessment Protocol Model

Project: **Headwater Drainage Feature Assessment**
Belwood Lake Tributary, West Reach + North Reach
SUMMER Inspection

1) Rapid Geomorphic Assessment (RGA)

Aggradation	Lobate bar	
	Coarse material in riffles embedded	
	Siltation in pools	
	Medial bars	
	Accretion on point bars	1
	Poor longitudinal sorting of bed materials	
	Deposition in the overbank zone	
	n/7 =	0.14
Degradation	Exposed bridge footing(s)	
	Exposed sanitary/storm sewer/pipeline etc.	
	Elevated stormsewer outfall(s)	
	Undermined gabion baskets/concrete aprons etc.	
	Scour pools d/s of culverts/stormsewer outlets	1
	Cut face on bar forms	1
	Head cutting due to knick point migration	
	Terrace cut through older bar material	
	Suspended armour layer visible in bank	
	Channel worn into undisturbed overburden/bedrock	
	n/10 =	0.20

Widening	Fallen/leaning trees/fence posts etc.	
	Occurrence of Large Organic Debris	
	Exposed tree roots	
	Basal scour on inside meander bends	
	Basal scour on both sides of channel through riffle	
	Gabion baskets/concrete walls etc. out flanked	
	Length of basal scour >50% through subject reach	
	Exposed length of previously buried pipe/cable etc.	
	Fracture lines along top of bank	1
	Exposed building foundation	
	n/10 =	0.10
Planimetric Form	Formation of chute(s)	
	Single thread channel to multiple channel	
	Evolution of pool-riffle form to low bed relief form	
	Cut-off channel(s)	
	Formation of island(s)	
	Thalweg alignment out of phase meander form	
	Bar forms poorly formed/reworked/removed	
	n/7 =	0.00

STABILITY INDEX (SI) = (A + D + W + P) / 4 = **0.11**

SI < 0.2	In Regime
0.2 < SI < 0.4	Transitional
SI > 0.4	In Adjustment
100 - (100*SI) =	**88.9**

2) Rapid Habitat Assessment (RHA)

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	17	20--16	15-11	10-6	5-0
Embeddedness	17	20--16	15-11	10-6	5-0
Velocity / Depth Regime	3	20--16	15-11	10-6	5-0
Sediment Deposition	15	20--16	15-11	10-6	5-0
Channel Flow Status	3	20--16	15-11	10-6	5-0
Channel Alteration	9	20--16	15-11	10-6	5-0
Frequency of Riffles	15	20--16	15-11	10-6	5-0
Bank Stability u/s L	9	10-8	7-6	5-3	2-0
u/s R	9	10-8	7-6	5-3	2-0
Vegetative Protection u/s L	7	10-8	7-6	5-3	2-0
u/s R	7	10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L	6	10-8	7-6	5-3	2-0
u/s R	6	10-8	7-6	5-3	2-0
/200	123				
/100	**61.5**	Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

Glide Pool Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover		20--16	15-11	10-6	5-0
Pool Substrate Characterization		20--16	15-11	10-6	5-0
Pool Variability		20--16	15-11	10-6	5-0
Sediment Deposition		20--16	15-11	10-6	5-0
Channel Flow Status		20--16	15-11	10-6	5-0
Channel Alteration		20--16	15-11	10-6	5-0
Channel Sinuosity		20--16	15-11	10-6	5-0
Bank Stability u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Vegetative Protection u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
/200					
/100		Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

3) Rapid Stream Assessment Technique (RSAT)

		Optimal	Good	Fair	Poor
Channel Stability	9	11-9	8-6	5-3	2-0
Channel Scouring/Deposition	7	8-7	6-5	4-3	2-0
Physical Instream Habitat	7	8-7	6-5	4-3	2-0
Water Quality	6	8-7	6-5	4-3	2-0
Riparian Habitat Conditions	4	7-6	5-4	3-2	1-0
Biological Indicators	1	8-7	6-5	4-3	2-0
/50	34				
/100	**68.0**	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

1) - 3) Combined Assessment

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
(RGA + RHA + RSAT) / 3 =	**72.8**	100-80	80-56	55-30	29-0

Glide Pool Channel Type

		Optimal	Good	Fair	Poor
(RGA + RHA + RSAT) / 3 =		100-80	80-56	55-30	29-0

4) TRCA & CVCA Headwater Drainage Features Guideline (HDFG)

DA (ha)	QC	FC	FT	RM
46.1	**B + C**	**2**	**1 + 5**	**A**

QC — Flow Classification: A - perennial, B - intermittent, C - ephemeral, D - dry or standing water w/recharge, E - dry or standing water w/no recharge

FC — Flow Condition: 1 - no surface water, 2 - standing water, 3 - interstitial flow, 4 - <0.5l/sec, 5 - >0.5l/sec

FT — Feature Type: 1 - defined bed & banks, 2 - channelized historically, 3 - multi-thread, 4 - no defined feature, 5 - tile drain, 6 - wetland, 7 - swale, 8 - roadside ditch, 9 - online pond outlet

RM — Recommended Management: A - protection, B - conservation, C - mitigation, D - recharge protection, E - maintain/replicate terrestrial linkage, F - no management

References

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GEO-RAP v.2.0 Rapid Assessment Protocol Model

Project: **Headwater Drainage Feature Assessment**
Belwood Lake Tributary, East Reach
SUMMER Inspection

1) Rapid Geomorphic Assessment (RGA)

Aggradation	Lobate bar	
	Coarse material in riffles embedded	
	Siltation in pools	
	Medial bars	
	Accretion on point bars	1
	Poor longitudinal sorting of bed materials	
	Deposition in the overbank zone	
	n/7 =	0.14
Degradation	Exposed bridge footing(s)	
	Exposed sanitary/storm sewer/pipeline etc.	
	Elevated stormsewer outfall(s)	
	Undermined gabion baskets/concrete aprons etc.	
	Scour pools d/s of culverts/stormsewer outlets	
	Cut face on bar forms	
	Head cutting due to knick point migration	
	Terrace cut through older bar material	
	Suspended armour layer visible in bank	
	Channel worn into undisturbed overburden/bedrock	
	n/10 =	0.00

Widening	Fallen/leaning trees/fence posts etc.	
	Occurrence of Large Organic Debris	
	Exposed tree roots	
	Basal scour on inside meander bends	
	Basal scour on both sides of channel through riffle	
	Gabion baskets/concrete walls etc. out flanked	
	Length of basal scour >50% through subject reach	
	Exposed length of previously buried pipe/cable etc.	
	Fracture lines along top of bank	
	Exposed building foundation	
	n/10 =	0.00
Planimetric Form	Formation of chute(s)	1
	Single thread channel to multiple channel	
	Evolution of pool-riffle form to low bed relief form	
	Cut-off channel(s)	
	Formation of island(s)	
	Thalweg alignment out of phase meander form	
	Bar forms poorly formed/reworked/removed	
	n/7 =	0.14
	STABILITY INDEX (SI) = (A + D + W + P) / 4 =	**0.07**
	SI < 0.2	In Regime
	0.2 < SI < 0.4	Transitional
	SI > 0.4	In Adjustment
	100 - (100*SI) =	**92.9**

2) Rapid Habitat Assessment (RHA)

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	12	20--16	15-11	10-6	5-0
Embeddedness	15	20--16	15-11	10-6	5-0
Velocity / Depth Regime	2	20--16	15-11	10-6	5-0
Sediment Deposition	16	20--16	15-11	10-6	5-0
Channel Flow Status	2	20--16	15-11	10-6	5-0
Channel Alteration	5	20--16	15-11	10-6	5-0
Frequency of Riffles	15	20--16	15-11	10-6	5-0
Bank Stability u/s L	9	10-8	7-6	5-3	2-0
u/s R	9	10-8	7-6	5-3	2-0
Vegetative Protection u/s L	8	10-8	7-6	5-3	2-0
u/s R	8	10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L	8	10-8	7-6	5-3	2-0
u/s R	8	10-8	7-6	5-3	2-0
/200	117				
/100	**58.5**	Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

Glide Pool Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover		20--16	15-11	10-6	5-0
Pool Substrate Characterization		20--16	15-11	10-6	5-0
Pool Variability		20--16	15-11	10-6	5-0
Sediment Deposition		20--16	15-11	10-6	5-0
Channel Flow Status		20--16	15-11	10-6	5-0
Channel Alteration		20--16	15-11	10-6	5-0
Channel Sinuosity		20--16	15-11	10-6	5-0
Bank Stability u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Vegetative Protection u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
/200					
/100		Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

3) Rapid Stream Assessment Technique (RSAT)

		Optimal	Good	Fair	Poor
Channel Stability	9	11-9	8-6	5-3	2-0
Channel Scouring/Deposition	6	8-7	6-5	4-3	2-0
Physical Instream Habitat	4	8-7	6-5	4-3	2-0
Water Quality	6	8-7	6-5	4-3	2-0
Riparian Habitat Conditions	4	7-6	5-4	3-2	1-0
Biological Indicators	1	8-7	6-5	4-3	2-0
/50	30				
/100	**60.0**	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

1) - 3) Combined Assessment

Riffle Run Channel Type

(RGA + RHA + RSAT) / 3 =	**70.5**	Optimal	Good	Fair	Poor
		100-80	80-56	55-30	29-0

Glide Pool Channel Type

(RGA + RHA + RSAT) / 3 =		Optimal	Good	Fair	Poor
		100-80	80-56	55-30	29-0

4) TRCA & CVCA Headwater Drainage Features Guideline (HDFG)

DA (ha)	QC	FC	FT	RM
47.5	**D**	**2**	**1 + 5**	**B**

QC — Flow Classification: A - perennial, B - intermittent, C - ephemeral, D - dry or standing water w/recharge, E - dry or standing water w/no recharge

FC — Flow Condition: 1 - no surface water, 2 - standing water, 3 - interstitial flow, 4 - <0.5l/sec, 5 - >0.5l/sec

FT — Feature Type: 1 - defined bed & banks, 2 - channelized historically, 3 - multi-thread, 4 - no defined feature, 5 - tile drain, 6 - wetland, 7 - swale, 8 - roadside ditch, 9 - online pond outlet

RM — Recommended Management: A - protection, B - conservation, C - mitigation, D - recharge protection, E - maintain/replicate terrestrial linkage, F - no management

References

1) Ontario Ministry of Environment and Energy. 2003. Stormwater Management Planning and Design Manual. Appendix C.

2) United States Environmental Protection Association. 2004. Wadeable Stream Assessment: Field Operations Manual. EPA841-B-04-004. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, DC.

3) Galli, J., 1996. Rapid stream assessment technique, field methods. Metropolitan Washington Council of Governments.

4) Toronto and Region Conservation Authority and Credit Valley Conservation Authority. 2014. Evaluation, Classification and Management of Headwater Drainage Features Guideline. TRCA Approval July 2013 (Finalized January 2014).

GEO-RAP v.2.0 Rapid Assessment Protocol Model

Project: **Headwater Drainage Feature Assessment**
Belwood Lake Tributary, West + North + East = Main Branch
SUMMER Inspection

1) Rapid Geomorphic Assessment (RGA)

Aggradation	Lobate bar	
	Coarse material in riffles embedded	
	Siltation in pools	1
	Medial bars	1
	Accretion on point bars	1
	Poor longitudinal sorting of bed materials	1
	Deposition in the overbank zone	
	n/7 =	0.57
Degradation	Exposed bridge footing(s)	
	Exposed sanitary/storm sewer/pipeline etc.	
	Elevated stormsewer outfall(s)	
	Undermined gabion baskets/concrete aprons etc.	
	Scour pools d/s of culverts/stormsewer outlets	
	Cut face on bar forms	1
	Head cutting due to knick point migration	
	Terrace cut through older bar material	
	Suspended armour layer visible in bank	
	Channel worn into undisturbed overburden/bedrock	1
	n/10 =	0.20

Widening	Fallen/leaning trees/fence posts etc.	1
	Occurrence of Large Organic Debris	1
	Exposed tree roots	1
	Basal scour on inside meander bends	
	Basal scour on both sides of channel through riffle	1
	Gabion baskets/concrete walls etc. out flanked	
	Length of basal scour >50% through subject reach	1
	Exposed length of previously buried pipe/cable etc.	
	Fracture lines along top of bank	1
	Exposed building foundation	
	n/10 =	0.60
Planimetric Form	Formation of chute(s)	
	Single thread channel to multiple channel	
	Evolution of pool-riffle form to low bed relief form	
	Cut-off channel(s)	
	Formation of island(s)	
	Thalweg alignment out of phase meander form	1
	Bar forms poorly formed/reworked/removed	1
	n/7 =	0.29
	STABILITY INDEX (SI) = (A + D + W + P) / 4 =	**0.41**
	SI < 0.2	In Regime
	0.2 < SI < 0.4	Transitional
	SI > 0.4	In Adjustment
	100 - (100*SI) =	**58.6**

2) Rapid Habitat Assessment (RHA)

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover	15	20--16	15-11	10-6	5-0
Embeddedness	10	20--16	15-11	10-6	5-0
Velocity / Depth Regime	5	20--16	15-11	10-6	5-0
Sediment Deposition	10	20--16	15-11	10-6	5-0
Channel Flow Status	5	20--16	15-11	10-6	5-0
Channel Alteration	9	20--16	15-11	10-6	5-0
Frequency of Riffles	15	20--16	15-11	10-6	5-0
Bank Stability u/s L	6	10-8	7-6	5-3	2-0
u/s R	6	10-8	7-6	5-3	2-0
Vegetative Protection u/s L	6	10-8	7-6	5-3	2-0
u/s R	6	10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L	7	10-8	7-6	5-3	2-0
u/s R	7	10-8	7-6	5-3	2-0
/200	107				
/100	**53.5**	Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

Glide Pool Channel Type

		Optimal	Good	Fair	Poor
Epifaunal Substrate / Available Cover		20--16	15-11	10-6	5-0
Pool Substrate Characterization		20--16	15-11	10-6	5-0
Pool Variability		20--16	15-11	10-6	5-0
Sediment Deposition		20--16	15-11	10-6	5-0
Channel Flow Status		20--16	15-11	10-6	5-0
Channel Alteration		20--16	15-11	10-6	5-0
Channel Sinuosity		20--16	15-11	10-6	5-0
Bank Stability u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Vegetative Protection u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
Riparian Vegetation Zone Width u/s L		10-8	7-6	5-3	2-0
u/s R		10-8	7-6	5-3	2-0
/200					
/100		Optimal	Good	Fair	Poor
		100-78	77-53	52-28	27-0

3) Rapid Stream Assessment Technique (RSAT)

		Optimal	Good	Fair	Poor
Channel Stability	6	11-9	8-6	5-3	2-0
Channel Scouring/Deposition	4	8-7	6-5	4-3	2-0
Physical Instream Habitat	6	8-7	6-5	4-3	2-0
Water Quality	6	8-7	6-5	4-3	2-0
Riparian Habitat Conditions	6	7-6	5-4	3-2	1-0
Biological Indicators	2	8-7	6-5	4-3	2-0
/50	30				
/100	**60.0**	Optimal	Good	Fair	Poor
		100-83	82-59	58-31	30-0

1) - 3) Combined Assessment

Riffle Run Channel Type

		Optimal	Good	Fair	Poor
(RGA + RHA + RSAT) / 3 =	**57.4**	Optimal	Good	Fair	Poor
		100-80	80-56	55-30	29-0

Glide Pool Channel Type

		Optimal	Good	Fair	Poor
(RGA + RHA + RSAT) / 3 =		Optimal	Good	Fair	Poor
		100-80	80-56	55-30	29-0

4) TRCA & CVCA Headwater Drainage Features Guideline (HDFG)

DA (ha)	QC	FC	FT	RM
129.2	**B**	**3**	**1 + 5**	**A**

QC — Flow Classification: A - perennial, B - intermittent, C - ephemeral, D - dry or standing water w/recharge, E - dry or standing water w/no recharge

FC — Flow Condition: 1 - no surface water, 2 - standing water, 3 - interstitial flow, 4 - <0.5l/sec, 5 - >0.5l/sec

FT — Feature Type: 1 - defined bed & banks, 2 - channelized historically, 3 - multi-thread, 4 - no defined feature, 5 - tile drain, 6 - wetland, 7 - swale, 8 - roadside ditch, 9 - online pond outlet

RM — Recommended Management: A - protection, B - conservation, C - mitigation, D - recharge protection, E - maintain/replicate terrestrial linkage, F - no management

References

1) Ontario Ministry of Environment and Energy. 2003. Stormwater Management Planning and Design Manual. Appendix C.

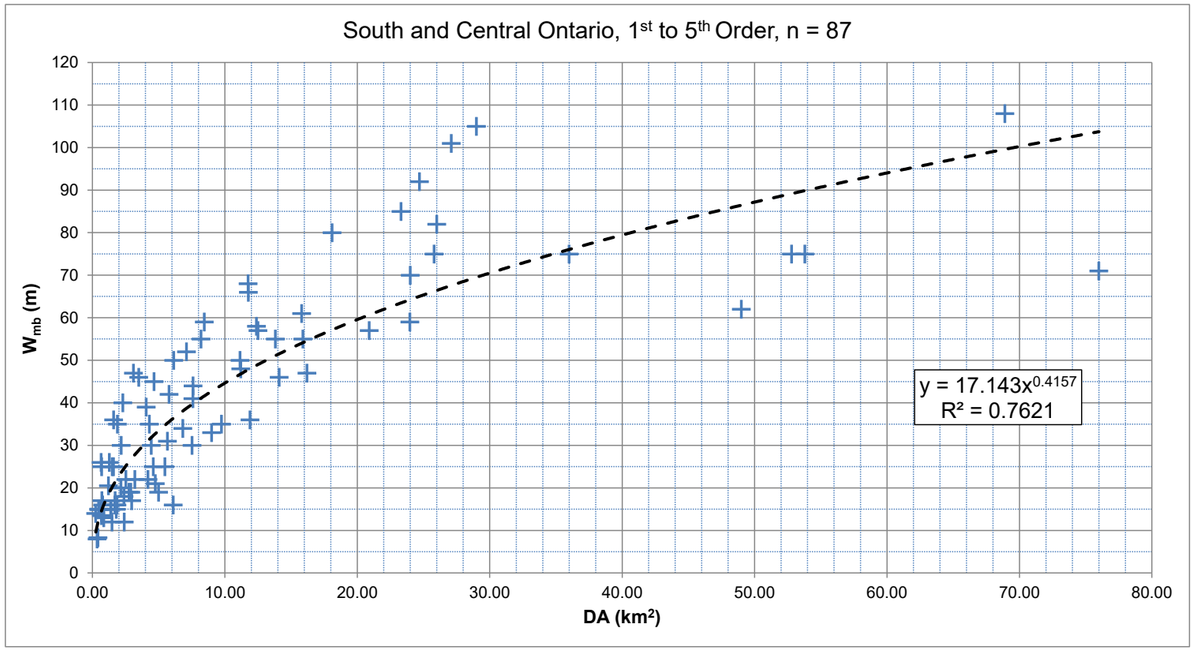
2) United States Environmental Protection Association. 2004. Wadeable Stream Assessment: Field Operations Manual. EPA841-B-04-004. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, DC.

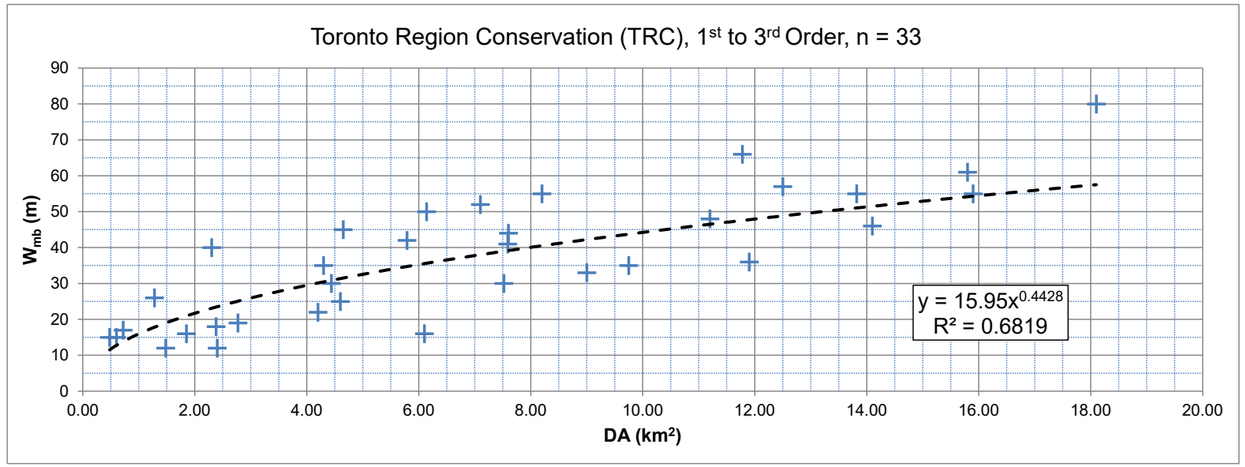
3) Galli, J., 1996. Rapid stream assessment technique, field methods. Metropolitan Washington Council of Governments.

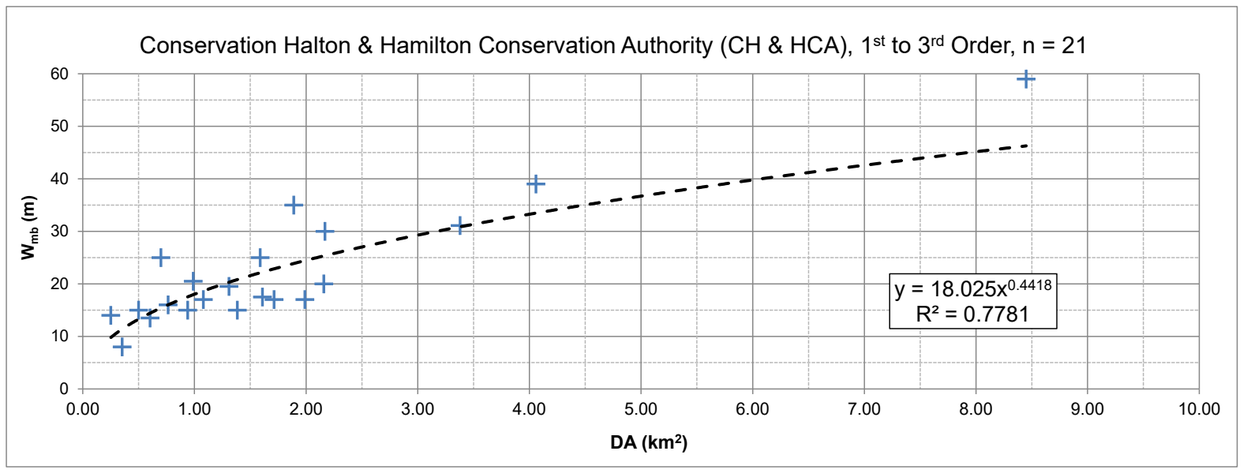
4) Toronto and Region Conservation Authority and Credit Valley Conservation Authority. 2014. Evaluation, Classification and Management of Headwater Drainage Features Guideline. TRCA Approval July 2013 (Finalized January 2014).

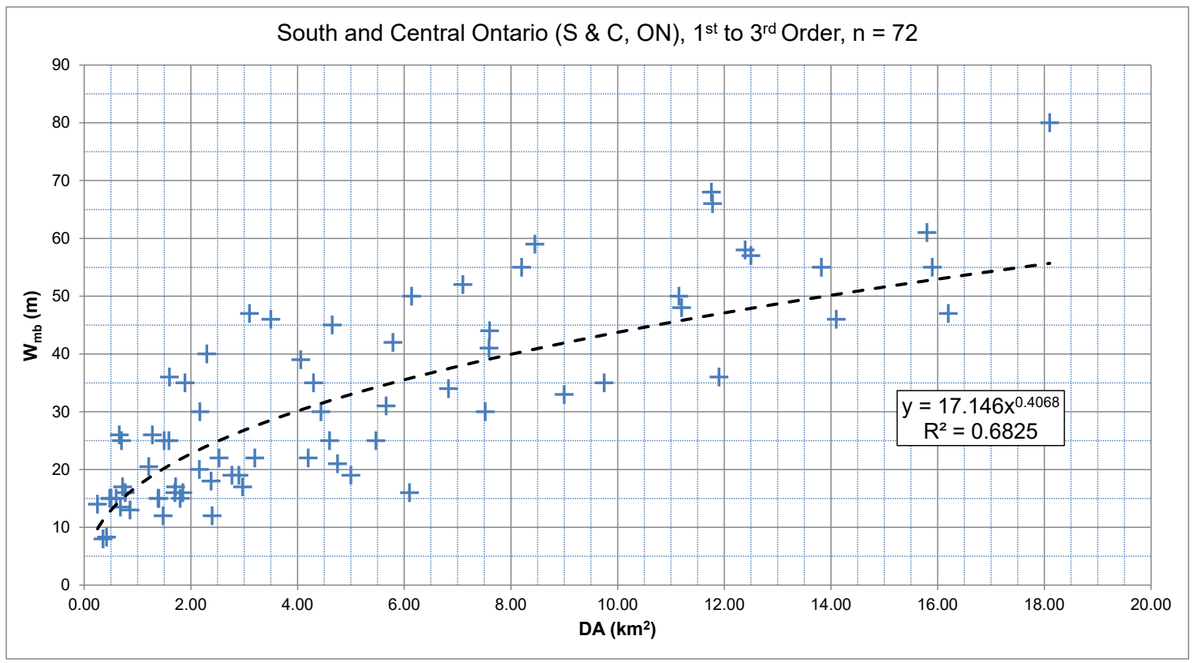
Belwood Lake Tributary Reaches, Meander Belt Analysis

Regional Regression Curves for Meander Belt Width









Solve for *(using 1st to 3rd Order Regime Equation):*	DA (km^2)	W_{mb} (m) S & C ON	W_{mb} (m) TRC	W_{mb} (m) CH & HCA	max *1.2 FS (m)	$\text{ceil}(x)$ (m)
West Reach	0.27	10.07	8.93	10.11	12.13	**13**
North Reach	0.44	12.28	11.09	12.54	15.05	**16**
West Reach + North Reach	0.74	15.17	13.96	15.78	18.94	**19**
East Reach	0.44	12.28	11.09	12.54	15.05	**16**
West Reach + North Reach + East Reach = Main Branch	1.27	18.90	17.73	20.03	24.04	**25**

APPENDIX

B HYDROLOGIC MODELLING

Appendix B - Hydrology

Table B1 Summary of Existing Conditions Parameters

SUBCATCHMENTS	TYPE	AREA (HA)	SCS CURVE		OUTLET	DT (MIN)	TP
			CN	IA (mm)			
PR-W01	NasHyd	12.46	73	7.9	2	10	0.4
PR-W02		9.98	79	8.6	1		0.3
PR-N01		7.99	78	7.1	4		0.4
PR-N02		43.12	79	8.4	3		0.5
PR-E01		1.8	72	8.0	6		0.3
PR-E02		42.15	79	8.2	5		0.6
PR-M01		11.16	84	6.8	9		0.4
PR-M02		0.87	79	4.4	13		0.1
PR-M03		4.35	85	7.0	12		0.4
PR-M04		1.12	84	7.3	15		0.2
PR-M05		1.57	83	6.1	14		0.3
PR-S01		1.94	85	7.0	-		0.3

Table B2 Summary of Proposed Conditions Parameters

SUBCATCHMENTS	TYPE	AREA (HA)	SCS CURVE		IMPERVIOUSNESS		PERVIOUS AREA		IMPERVIOUS AREA	
			CN	IA (MM)	TIMP (%)	XIMP (%)	FLOW LENGTH	SLOPE (%)	FLOW LENGTH	SLOPE (%)
PO-W01	StandHyd	3.69	60	10.00	N/A		220	5	N/A	
PO-W02		10.5	85	3.00	0.54	0.05	44	1.5	150	5
PO-W03		3.35	90	3.00	0.50	0.05	44	1.9	208	3.5
PO-N01		2.62	85	3.00	0.07	0.05	22	3	200	1.8
PO-N02		2.49	85	3.00	0.55	0.05	32	4	230	2.5
PO-N03		1.23	85	3.00	0.29	0.05	13.5	1	125	1.3
PO-M01		4.0	77.3	8.93	0.00	0.05	105	3.5	105	3.3
PO-M05		7.18	90	3.00	0.52	0.05	32	3.5	220	3
PO-E01		1.1	75.76	9.31	0.20	0.05	150	5.5	65	5
PO-M03		0.7	90	3.00	0.52	0.05	45	4	54	1.8
PO-M06		2.34	90	3.00	0.07	0.05	16.5	3	140	1.2
PO-M02	NasHyd	1.2	79	4.4	N/A					
PO-M04		0.32	84	7.3	N/A					
PST_SWM	SWM-POND	1.01	N/A							
PST_M03		0.7	N/A							

Table B3 Typical (Conservation Halton) Curve Numbers

LAND USE	NOTES	A	B	C	D
Agriculture		67	78	85	89
Buildings		98	98	98	98
Bedrock		98	98	98	98
Cemetery /Golf course		49	69	79	84
Commercial and business area	85% imp	89	92	94	95
Dirt		72	82	87	89
Extraction		98	98	98	98
Field / Meadow / Pasture		49	69	79	84
Forest / Plantation		36	60	73	79
Grass / Highway Median		49	69	79	84
Hedge Row / Orchard		45	66	77	83
Industrial	72% imp	81	88	91	93
Institutional	50% imp	71	80	88	90
Open Water		98	98	98	98
Residential High Density		89	92	94	95
Residential Medium / Low Density	65% imp	77	85	90	92
Residential Trailer Park		71	80	88	90
Residential Rural		51	69	79	98
SWM Pond		50	50	50	84
Transportation	roads, railway, parking	98	98	98	98
Wetland / Marsh		50	50	50	50

Table B4 **Existing Conditions Curve Numbers**

CATCHMENT	MODEL LAND USE	SOIL TYPE	CN VALUE	AREA (M2)	TOTAL AREA (M2)	AREA PERCENTAGE	WEIGHTED AMC2 CN VALUE
S01	Agricultural	C	85				
N02	Agricultural	C	85	209179.5	431191.417	49%	79
	Forest		73	211192.3		49%	
	Residential		79	10819.62		3%	
W02	Agricultural	C	85	47366.32	99789.387	47%	79
	Forest		73	52423.06		53%	
W01	Agricultural	B	78	86977.84	124553.189	70%	73
	Forest		60	37575.35		30%	
E01	Agricultural	B	78	12318.52	18031.522	68%	72
	Forest		60	5713.006		32%	
M05	Agricultural	C	85	10065.01	15741.963	64%	83
	Residential		79	5676.953		36%	
M04	Agricultural	C	85	10237.24	11224.021	91%	84
	Forest		73	986.779		9%	
M02	Residential	C	79				
M03	Agricultural	C	85				
M01	Agricultural	C	85	93235.22	111567.604	84%	84
	Forest		73	4174.833		4%	
	Residential		79	14157.55		13%	
E02	Agricultural	C	85	179730.9	421526.209	43%	79
	Forest		73	205240.2		49%	
	Residential		79	36555.17		9%	

CATCHMENT	MODEL LAND USE	SOIL TYPE	CN VALUE	AREA (M2)	TOTAL AREA (M2)	AREA PERCENTAGE	WEIGHTED AMC2 CN VALUE
N01	Agricultural	B	78	78964.3	80344.083	98%	78

Table B5 **Proposed Conditions Curve Numbers**

CATCHMENT	MODEL LAND USE	SOIL TYPE	CN VALUE	AREA (M2)	TOTAL AREA	AREA PERCENTAGE	WEIGHTED CN VALUE
PO-W01	Forest	B	60	3690	3690	100%	60
PO-W02	Residential Medium / Low Density	B	85	10500	10500	100%	85
PO-W03	Residential Medium / Low Density	C	90	3350	3350	100%	90
PO-N01	Residential Medium / Low Density	B	85	2620	2620	100%	85
PO-N02	Residential Medium / Low Density	B	85	2490	2490	100%	85
PO-N03	Residential Medium / Low Density	B	85	1230	1230	100%	85
PO-M01	Agricultural	C	85	4000	11180	36%	77.3
	Forest	C	73	7180		64%	
PO-M05	Residential Medium / Low Density	C	90	1100	1100	100%	90
PO-E01	Agricultural	C	85	700	3040	23%	75.76
	Forest	C	73	2340		77%	
PO-M03	Residential Medium / Low Density	C	90	1200	1200	100%	90
PO-M06	Residential Medium / Low Density	C	90	320	320	100%	90

Table B6 Typical (Conservation Halton) Initial Abstraction Values

LAND USE	IA (MM)
Impervious	2
Open Space / Green Space / Lawns	5
Crop / Cultivated	7
Pasture / Meadow	8
Woods / Woodlot / Forest	10
Wetlands	15

Residential: Assuming 20% impervious as per Residential Rural Estate then IA is 4.4 mm

Table B7 **Existing Conditions Initial Abstraction Values**

CATCHMENT	LAND USE	LAND USE AREA (M2)	TOTAL AREA (M2)	LAND USE PERCENT	IA (MM)	AVERAGED IA (MM)
S01	Agricultural	7				
N02	Agricultural	209179.532	431191.417	49%	7	8.4
	Forest	211192.264		49%	10	
	Residential	10819.621		3%	4.4	
W02	Agricultural	47366.324	99789.387	47%	7	8.6
	Forest	52423.063		53%	10	
W01	Agricultural	86977.842	124553.189	70%	7	7.9
	Forest	37575.347		30%	10	
E01	Agricultural	12318.516	18031.522	68%	7	8.0
	Forest	5713.006		32%	10	
M05	Agricultural	10065.01	15741.963	64%	7	6.1
	Residential	5676.953		36%	4.4	
M04	Agricultural	10237.242	11224.021	91%	7	7.3
	Forest	986.779		9%	10	
M02	Residential	4.4				
M03	Agricultural	7				
M01	Agricultural	93235.218	111567.604	84%	7	6.8
	Forest	4174.833		4%	10	
	Residential	14157.553		13%	4.4	
E02	Agricultural	179730.888	421526.209	43%	7	8.2
	Forest	205240.155		49%	10	
	Residential	36555.166		9%	4.4	
N01	Agricultural	78964.297	80344.083	98%	7	7.1

	Forest	1379.786		2%	10	

Table B8 Proposed Conditions Initial Abstraction Values

CATCHMENT	MODEL LAND USE	AREA (M2)	TOTAL AREA	AREA PERCENTAGE	IA	AVERAGED IA
PO-W01	Forest	3690	3690	100%	10	10
PO-W02	Residential Medium / Low Density	10500	10500	100%	3	3
PO-W03	Residential Medium / Low Density	3350	3350	100%	3	3
PO-N01	Residential Medium / Low Density	2620	2620	100%	3	3
PO-N02	Residential Medium / Low Density	2490	2490	100%	3	3
PO-N03	Residential Medium / Low Density	1230	1230	100%	3	3
PO-M01	Agricultural	4000	11180	36%	7	8.93
	Forest	7180		64%	10	
PO-M05	Residential Medium / Low Density	1100	1100	100%	3	3
PO-E01	Agricultural	700	3040	23%	7	9.31
	Forest	2340		77%	10	
PO-M03	Residential Medium / Low Density	1200	1200	100%	3	3
PO-M06	Residential Medium / Low Density	320	320	100%	3	3

Table B9 **Centre Wellington Development Manual Runoff Coefficients and Percentage Impervious**

LAND USE		RUNOFF COEFFICIENT	PERCENTAGE IMPERVIOUS
- Minimum storm drainage runoff coefficients with 10 minute Time of Concentration:			
Parks	>4 hectares	0.2	0%
	<4 hectares	0.25	7%
Single Family Residential	>18 m frontage (59 ft.)	0.55	50%
	12-18m frontage (39 – 59 ft.)	0.6	60%
	<12m frontage (39 ft.)	0.65	65%
- Minimum storm drainage runoff coefficients with 5 minute Time of Concentration			
Semi - Detached		0.7	70%
Maisonettes, Townhouses, etc.		0.75	80%
Apartments		0.75	80%
Schools		0.75	80%
Churches		0.75	80%
Industrial		0.9	100%
Commercial, Highway Commercial		0.9	100%
Heavily Developed Areas		0.9	100%

Table B10 Existing Conditions Runoff Coefficients

CATCHMENT	MODEL LAND USE	RUNOFF COEFFICIENT	AREA (M2)	TOTAL AREA (M2)	AREA PERCENTAGE	WEIGHTED RUNOFF COEFFICIENT
S01	Agricultural	0.2				
N02	Agricultural	0.2	209179.532	431191.417	49%	0.21
	Forest	0.2	211192.264		49%	
	Residential	0.55	10819.621		3%	
W02	Agricultural	0.2	47366.324	99789.387	47%	0.20
	Forest	0.2	52423.063		53%	
W01	Agricultural	0.2	86977.842	124553.189	70%	0.20
	Forest	0.2	37575.347		30%	
E01	Agricultural	0.2	12318.516	18031.522	68%	0.20
	Forest	0.2	5713.006		32%	
M05	Agricultural	0.2	10065.01	15741.963	64%	0.33
	Residential	0.55	5676.953		36%	
M04	Agricultural	0.2	10237.242	11224.021	91%	0.20
	Forest	0.2	986.779		9%	
M02	Residential	0.55				
M03	Agricultural	0.2				
M01	Agricultural	0.2	93235.218	111567.604	84%	0.24
	Forest	0.2	4174.833		4%	
	Residential	0.55	14157.553		13%	
E02	Agricultural	0.2	179730.888	421526.209	43%	0.23
	Forest	0.2	205240.155		49%	

	Residential	0.55	36555.166		9%	
N01	Agricultural	0.2	78964.297	80344.083	98%	0.20
	Forest	0.2	1379.786		2%	

Table B11 Proposed Conditions Imperviousness

CATCHMENT	AREA (HA)	LOT AREA	ROAD AREA	REAR YARD AREA	TIMP
PO-W01	3.69	N/A			
PO-W02	10.5	7.81	2.69	0.00	53.8%
PO-W03	3.35	3.28	0.07	0.00	50.3%
PO-N01	2.62	0.00	0.00	2.62	7.0%
PO-N02	2.49	1.64	0.85	0.00	55.1%
PO-N03	1.23	0.00	0.47	0.76	29.4%
PO-M01	4.0	0.00	0.00	0.00	0.0%
PO-M05	7.18	6.17	1.01	0.00	52.1%
PO-E01	1.1	0.00	0.33	0.00	19.5%
PO-M03	0.7	0.63	0.07	0.00	51.5%
PO-M06	2.34	0.00	0.00	2.34	7.0%

Meteorological Data

Table B12 Centre Wellington Development Manual IDF Data

RETURN PERIOD	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR
A	23.3	30.7	35.6	41.8	46.4	51
B	-0.699	-0.699	-0.699	-0.699	-0.699	-0.699

Table B13 Chicago 6 hr Distribution

TIME (MIN)	STORM EVENT RAINFALL INTENSITY (MM/HR)					
	2YR	5YR	10YR	25YR	50YR	100YR
0	2.033	2.679	3.106	3.647	4.048	4.45
5	2.092	2.757	3.197	3.754	4.167	4.58
10	2.157	2.841	3.295	3.869	4.295	4.72
15	2.226	2.932	3.4	3.993	4.432	4.871
20	2.3	3.031	3.514	4.126	4.581	5.035
25	2.381	3.137	3.638	4.272	4.742	5.212
30	2.47	3.254	3.773	4.43	4.918	5.405
35	2.566	3.381	3.921	4.604	5.111	5.617
40	2.673	3.522	4.084	4.795	5.323	5.85
45	2.791	3.677	4.264	5.007	5.558	6.109
50	2.922	3.85	4.465	5.243	5.819	6.396
55	3.07	4.045	4.69	5.507	6.113	6.719
60	3.237	4.265	4.946	5.807	6.446	7.085
65	3.428	4.517	5.238	6.15	6.827	7.504
70	3.649	4.808	5.576	6.547	7.267	7.988
75	3.909	5.15	5.972	7.012	7.784	8.556
80	4.218	5.558	6.445	7.568	8.4	9.233
85	4.595	6.054	7.021	8.243	9.15	10.058
90	5.066	6.674	7.74	9.088	10.088	11.088
95	5.674	7.476	8.669	10.179	11.299	12.419
100	6.498	8.561	9.928	11.657	12.939	14.222
105	7.691	10.134	11.751	13.798	15.316	16.834
110	9.617	12.671	14.694	17.253	19.151	21.05
115	13.434	17.7	20.525	24.1	26.752	29.404
120	26.346	34.713	40.254	47.264	52.466	57.667

TIME (MIN)	STORM EVENT RAINFALL INTENSITY (MM/HR)					
	2YR	5YR	10YR	25YR	50YR	100YR
125	132.344	174.376	202.208	237.424	263.552	289.68
130	25.316	33.356	38.68	45.416	50.414	55.412
135	16.626	21.906	25.403	29.827	33.109	36.392
140	12.854	16.937	19.64	23.06	25.598	28.136
145	10.663	14.049	16.292	19.129	21.234	23.339
150	9.204	12.128	14.063	16.513	18.33	20.147
155	8.153	10.742	12.456	14.626	16.235	17.845
160	7.353	9.688	11.234	13.19	14.642	16.094
165	6.72	8.854	10.268	12.056	13.382	14.709
170	6.205	8.176	9.481	11.133	12.358	13.583
175	5.777	7.612	8.827	10.364	11.505	12.646
180	5.415	7.134	8.273	9.714	10.783	11.852
185	5.103	6.723	7.796	9.154	10.161	11.169
190	4.831	6.365	7.381	8.667	9.621	10.575
195	4.592	6.051	7.016	8.238	9.145	10.052
200	4.38	5.771	6.692	7.858	8.723	9.587
205	4.19	5.521	6.403	7.518	8.345	9.172
210	4.02	5.296	6.141	7.211	8.005	8.798
215	3.865	5.092	5.905	6.933	7.696	8.459
220	3.723	4.906	5.689	6.68	7.415	8.15
225	3.594	4.736	5.492	6.448	7.158	7.867
230	3.475	4.579	5.31	6.235	6.921	7.607
235	3.366	4.435	5.142	6.038	6.702	7.367
240	3.264	4.301	4.987	5.856	6.5	7.144
245	3.17	4.176	4.843	5.686	6.312	6.938
250	3.081	4.06	4.708	5.528	6.136	6.745
255	2.999	3.951	4.582	5.38	5.972	6.564
260	2.922	3.85	4.464	5.242	5.818	6.395
265	2.849	3.754	4.353	5.111	5.674	6.236
270	2.781	3.664	4.249	4.989	5.538	6.087
275	2.716	3.579	4.15	4.873	5.409	5.946
280	2.655	3.499	4.057	4.764	5.288	5.812

TIME (MIN)	STORM EVENT RAINFALL INTENSITY (MM/HR)					
	2YR	5YR	10YR	25YR	50YR	100YR
285	2.598	3.423	3.969	4.66	5.173	5.686
290	2.543	3.351	3.885	4.562	5.064	5.566
295	2.491	3.282	3.806	4.469	4.96	5.452
300	2.441	3.217	3.73	4.38	4.862	5.344
305	2.394	3.154	3.658	4.295	4.768	5.24
310	2.349	3.095	3.589	4.214	4.678	5.142
315	2.306	3.038	3.523	4.137	4.592	5.047
320	2.265	2.984	3.46	4.063	4.51	4.957
325	2.225	2.932	3.4	3.992	4.432	4.871
330	2.188	2.882	3.342	3.924	4.356	4.788
335	2.151	2.835	3.287	3.859	4.284	4.709
340	2.116	2.789	3.234	3.797	4.215	4.633
345	2.083	2.744	3.182	3.737	4.148	4.559
350	2.051	2.702	3.133	3.679	4.084	4.489
355	2.02	2.661	3.086	3.623	4.022	4.421

Table B14 SCS 12 hr Distribution

TIME (MIN)	STORM EVENT RAINFALL INTENSITY (MM/HR)					
	2YR	5YR	10YR	25YR	50YR	100YR
0	1.05888	1.39463	1.62706	1.91115	2.11776	2.32438
6	1.07058	1.41004	1.64504	1.93227	2.14117	2.35006
12	1.08228	1.42545	1.66302	1.95339	2.16457	2.37574
18	1.09398	1.44086	1.681	1.97451	2.18797	2.40143
24	1.10568	1.45627	1.69898	1.99562	2.21137	2.42711
30	1.11738	1.47168	1.71696	2.01674	2.23477	2.45279
36	1.12908	1.48709	1.73493	2.03786	2.25817	2.47848
42	1.14078	1.5025	1.75291	2.05898	2.28157	2.50416
48	1.15249	1.51791	1.77089	2.0801	2.30497	2.52985
54	1.16419	1.53332	1.78887	2.10121	2.32837	2.55553
60	1.17589	1.54873	1.80685	2.12233	2.35177	2.58121
66	1.18759	1.56414	1.82483	2.14345	2.37517	2.6069
72	1.19929	1.57955	1.84281	2.16457	2.39857	2.63258
78	1.21099	1.59496	1.86078	2.18568	2.42197	2.65826
84	1.22269	1.61037	1.87876	2.2068	2.44537	2.68395
90	1.23439	1.62578	1.89674	2.22792	2.46878	2.70963
96	1.24609	1.64119	1.91472	2.24904	2.49218	2.73532
102	1.25779	1.6566	1.9327	2.27015	2.51558	2.761
108	1.26949	1.67201	1.95068	2.29127	2.53898	2.78668
114	1.28119	1.68742	1.96866	2.31239	2.56238	2.81237
120	1.33969	1.73365	2.02259	2.37574	2.63258	2.88942
126	1.32214	1.8107	2.11249	2.48133	2.74958	3.01784
132	1.31044	1.88775	2.20238	2.58692	2.86659	3.14625
138	1.29289	1.9648	2.29227	2.69251	2.98359	3.27467
144	1.28119	2.04185	2.38216	2.7981	3.10059	3.40309
150	1.26364	2.11891	2.47206	2.90369	3.2176	3.53151
156	1.25194	2.19596	2.56195	3.00927	3.3346	3.65993
162	1.23439	2.27301	2.65184	3.11486	3.45161	3.78835
168	1.22269	2.35006	2.74174	3.22045	3.56861	3.91677
174	1.20514	2.42711	2.83163	3.32604	3.68561	4.04518
180	1.19344	2.46564	2.87658	3.37883	3.74411	4.10939

TIME (MIN)	STORM EVENT RAINFALL INTENSITY (MM/HR)					
	2YR	5YR	10YR	25YR	50YR	100YR
186	1.17589	2.46564	2.87658	3.37883	3.74411	4.10939
192	1.16419	2.46564	2.87658	3.37883	3.74411	4.10939
198	1.14663	2.46564	2.87658	3.37883	3.74411	4.10939
204	1.13493	2.46564	2.87658	3.37883	3.74411	4.10939
210	1.11738	2.52728	2.94849	3.46331	3.83772	4.21213
216	1.10568	2.65056	3.09232	3.63225	4.02492	4.4176
222	1.08813	2.77384	3.23615	3.80119	4.21213	4.62307
228	1.07643	2.89712	3.37998	3.97013	4.39933	4.82854
234	1.05888	3.0204	3.5238	4.13907	4.58654	5.03401
240	1.31629	3.17451	3.70359	4.35025	4.82055	5.29084
246	1.37479	3.35943	3.91933	4.60366	5.10136	5.59905
252	1.43329	3.54435	4.13508	4.85707	5.38216	5.90725
258	1.4918	3.72927	4.35082	5.11049	5.66297	6.21546
264	1.5503	3.9142	4.56656	5.3639	5.94378	6.52366
270	1.6088	4.16076	4.85422	5.70178	6.31819	6.9346
276	1.6673	4.46897	5.21379	6.12414	6.78621	7.44828
282	1.7258	4.77717	5.57337	6.54649	7.25422	7.96195
288	1.7843	5.08537	5.93294	6.96885	7.72224	8.47562
294	1.84281	5.39358	6.29251	7.3912	8.19025	8.9893
300	1.87206	5.91753	6.90378	8.1092	8.98587	9.86254
306	1.87206	6.65722	7.76675	9.12285	10.10911	11.09536
312	1.87206	7.39691	8.62973	10.1365	11.23234	12.32818
318	1.87206	8.1366	9.4927	11.15015	12.35558	13.561
324	1.87206	8.87629	10.35567	12.1638	13.47881	14.79382
330	1.91886	18.36899	21.43049	25.17232	27.89365	30.61498
336	2.01246	36.6147	42.71715	50.1757	55.6001	61.02449
342	2.10606	58.89018	68.70521	80.70136	89.42583	98.1503
348	2.19967	105.614	123.2163	144.7303	160.3768	176.0233
354	2.29327	73.30644	85.52419	100.457	111.3172	122.1774
360	2.41027	14.60889	17.04371	20.0196	22.18388	24.34816
366	2.55068	12.85213	14.99415	17.61218	19.5162	21.42021
372	2.69108	11.09536	12.94459	15.20476	16.84851	18.49227

TIME (MIN)	STORM EVENT RAINFALL INTENSITY (MM/HR)					
	2YR	5YR	10YR	25YR	50YR	100YR
378	2.83149	9.3386	10.89503	12.79734	14.18083	15.56433
384	2.97189	7.58183	8.84547	10.38992	11.51315	12.63639
390	3.1591	6.50312	7.58697	8.91168	9.8751	10.83853
396	3.3931	6.10245	7.11952	8.36262	9.26668	10.17075
402	3.62711	5.70178	6.65208	7.81356	8.65826	9.50297
408	3.86112	5.30112	6.18464	7.26449	8.04985	8.8352
414	4.09512	4.90045	5.71719	6.71543	7.44143	8.16742
420	4.49294	4.59225	5.35762	6.29308	6.97341	7.65375
426	5.05455	4.3765	5.10592	5.99743	6.6458	7.29417
432	5.61617	4.16076	4.85422	5.70178	6.31819	6.9346
438	6.17779	3.94502	4.60252	5.40614	5.99058	6.57503
444	6.73941	3.72927	4.35082	5.11049	5.66297	6.21546
450	13.94683	3.54435	4.13508	4.85707	5.38216	5.90725
456	27.80005	3.39025	3.95529	4.6459	5.14816	5.65042
462	44.71291	3.23615	3.77551	4.43472	4.91415	5.39358
468	80.18839	3.08205	3.59572	4.22354	4.68014	5.13674
474	55.6586	2.92794	3.41593	4.01237	4.44614	4.8799
480	11.09194	2.82778	3.29907	3.8751	4.29403	4.71296
486	9.7581	2.76614	3.22716	3.79063	4.20043	4.61023
492	8.42426	2.7199	3.17322	3.72728	4.13023	4.53317
498	7.09042	2.65826	3.10131	3.64281	4.03662	4.43044
504	5.75658	2.61203	3.04737	3.57945	3.96642	4.35339
510	4.93755	2.55039	2.97546	3.49498	3.87282	4.25065
516	4.63334	2.50416	2.92152	3.43163	3.80262	4.1736
522	4.32913	2.44252	2.84961	3.34716	3.70901	4.07087
528	4.02492	2.39629	2.79567	3.2838	3.63881	3.99382
534	3.72071	2.33465	2.72376	3.19933	3.54521	3.89108
540	3.48671	2.28842	2.66982	3.13598	3.47501	3.81403
546	3.3229	2.22678	2.59791	3.05151	3.3814	3.7113
552	3.1591	2.18055	2.54397	2.98816	3.3112	3.63424
558	2.99529	2.11891	2.47206	2.90369	3.2176	3.53151
564	2.83149	2.07268	2.41812	2.84033	3.1474	3.45446

TIME (MIN)	STORM EVENT RAINFALL INTENSITY (MM/HR)					
	2YR	5YR	10YR	25YR	50YR	100YR
570	2.69108	2.01103	2.34621	2.75586	3.05379	3.35172
576	2.57408	1.9648	2.29227	2.69251	2.98359	3.27467
582	2.45707	1.90316	2.22036	2.60804	2.88999	3.17194
588	2.34007	1.85693	2.16642	2.54468	2.81979	3.09489
594	2.22307	1.79529	2.09451	2.46021	2.72618	2.99215
600	2.14702	1.76447	2.05855	2.41798	2.67938	2.94078
606	2.10021	1.74136	2.03158	2.3863	2.64428	2.90226
612	2.06511	1.72595	2.0136	2.36518	2.62088	2.87658
618	2.01831	1.70283	1.98663	2.33351	2.58578	2.83805
624	1.98321	1.68742	1.96866	2.31239	2.56238	2.81237
630	1.93641	1.6643	1.94169	2.28071	2.52728	2.77384
636	1.90131	1.64889	1.92371	2.2596	2.50388	2.74816
642	1.85451	1.62578	1.89674	2.22792	2.46878	2.70963
648	1.81941	1.61037	1.87876	2.2068	2.44537	2.68395
654	1.7726	1.58725	1.8518	2.17512	2.41027	2.64542
660	1.7375	1.57184	1.83382	2.15401	2.38687	2.61974
666	1.6907	1.54873	1.80685	2.12233	2.35177	2.58121
672	1.6556	1.53332	1.78887	2.10121	2.32837	2.55553
678	1.6088	1.5102	1.7619	2.06954	2.29327	2.517
684	1.5737	1.49479	1.74392	2.04842	2.26987	2.49132
690	1.5269	1.47168	1.71696	2.01674	2.23477	2.45279
696	1.4918	1.45627	1.69898	1.99562	2.21137	2.42711
702	1.44499	1.43315	1.67201	1.96395	2.17627	2.38859
708	1.40989	1.41774	1.65403	1.94283	2.15287	2.3629
714	1.36309	1.39463	1.62706	1.91115	2.11776	2.32438

Table B15 SCS 24 hr Distribution

TIME (MIN)	STORM EVENT RAINFALL INTENSITY (MM/HR)					
	2YR	5YR	10YR	25YR	50YR	100YR
0	0.606	0.79992	0.94536	1.0908	1.212	1.3332
6	0.606	0.79992	0.94536	1.0908	1.212	1.3332
12	0.618	0.81576	0.96408	1.1124	1.236	1.3596
18	0.618	0.81576	0.96408	1.1124	1.236	1.3596
24	0.63	0.8316	0.9828	1.134	1.26	1.386
30	0.63	0.8316	0.9828	1.134	1.26	1.386
36	0.642	0.84744	1.00152	1.1556	1.284	1.4124
42	0.642	0.84744	1.00152	1.1556	1.284	1.4124
48	0.654	0.86328	1.02024	1.1772	1.308	1.4388
54	0.654	0.86328	1.02024	1.1772	1.308	1.4388
60	0.666	0.87912	1.03896	1.1988	1.332	1.4652
66	0.666	0.87912	1.03896	1.1988	1.332	1.4652
72	0.678	0.89496	1.05768	1.2204	1.356	1.4916
78	0.678	0.89496	1.05768	1.2204	1.356	1.4916
84	0.69	0.9108	1.0764	1.242	1.38	1.518
90	0.69	0.9108	1.0764	1.242	1.38	1.518
96	0.702	0.92664	1.09512	1.2636	1.404	1.5444
102	0.702	0.92664	1.09512	1.2636	1.404	1.5444
108	0.714	0.94248	1.11384	1.2852	1.428	1.5708
114	0.714	0.94248	1.11384	1.2852	1.428	1.5708
120	0.726	0.95832	1.13256	1.3068	1.452	1.5972
126	0.726	0.95832	1.13256	1.3068	1.452	1.5972
132	0.738	0.97416	1.15128	1.3284	1.476	1.6236
138	0.738	0.97416	1.15128	1.3284	1.476	1.6236
144	0.75	0.99	1.17	1.35	1.5	1.65
150	0.75	0.99	1.17	1.35	1.5	1.65
156	0.762	1.00584	1.18872	1.3716	1.524	1.6764
162	0.762	1.00584	1.18872	1.3716	1.524	1.6764
168	0.774	1.02168	1.20744	1.3932	1.548	1.7028
174	0.774	1.02168	1.20744	1.3932	1.548	1.7028
180	0.786	1.03752	1.22616	1.4148	1.572	1.7292

TIME (MIN)	STORM EVENT RAINFALL INTENSITY (MM/HR)					
	2YR	5YR	10YR	25YR	50YR	100YR
186	0.786	1.03752	1.22616	1.4148	1.572	1.7292
192	0.798	1.05336	1.24488	1.4364	1.596	1.7556
198	0.798	1.05336	1.24488	1.4364	1.596	1.7556
204	0.81	1.0692	1.2636	1.458	1.62	1.782
210	0.81	1.0692	1.2636	1.458	1.62	1.782
216	0.822	1.08504	1.28232	1.4796	1.644	1.8084
222	0.822	1.08504	1.28232	1.4796	1.644	1.8084
228	0.834	1.10088	1.30104	1.5012	1.668	1.8348
234	0.834	1.10088	1.30104	1.5012	1.668	1.8348
240	0.846	1.11672	1.31976	1.5228	1.692	1.8612
246	0.858	1.13256	1.33848	1.5444	1.716	1.8876
252	0.87	1.1484	1.3572	1.566	1.74	1.914
258	0.882	1.16424	1.37592	1.5876	1.764	1.9404
264	0.894	1.18008	1.39464	1.6092	1.788	1.9668
270	0.906	1.19592	1.41336	1.6308	1.812	1.9932
276	0.918	1.21176	1.43208	1.6524	1.836	2.0196
282	0.93	1.2276	1.4508	1.674	1.86	2.046
288	0.942	1.24344	1.46952	1.6956	1.884	2.0724
294	0.954	1.25928	1.48824	1.7172	1.908	2.0988
300	0.966	1.27512	1.50696	1.7388	1.932	2.1252
306	0.978	1.29096	1.52568	1.7604	1.956	2.1516
312	0.99	1.3068	1.5444	1.782	1.98	2.178
318	1.002	1.32264	1.56312	1.8036	2.004	2.2044
324	1.014	1.33848	1.58184	1.8252	2.028	2.2308
330	1.026	1.35432	1.60056	1.8468	2.052	2.2572
336	1.038	1.37016	1.61928	1.8684	2.076	2.2836
342	1.05	1.386	1.638	1.89	2.1	2.31
348	1.062	1.40184	1.65672	1.9116	2.124	2.3364
354	1.074	1.41768	1.67544	1.9332	2.148	2.3628
360	1.086	1.43352	1.69416	1.9548	2.172	2.3892
366	1.098	1.44936	1.71288	1.9764	2.196	2.4156
372	1.11	1.4652	1.7316	1.998	2.22	2.442

TIME (MIN)	STORM EVENT RAINFALL INTENSITY (MM/HR)					
	2YR	5YR	10YR	25YR	50YR	100YR
378	1.122	1.48104	1.75032	2.0196	2.244	2.4684
384	1.134	1.49688	1.76904	2.0412	2.268	2.4948
390	1.146	1.51272	1.78776	2.0628	2.292	2.5212
396	1.158	1.52856	1.80648	2.0844	2.316	2.5476
402	1.17	1.5444	1.8252	2.106	2.34	2.574
408	1.182	1.56024	1.84392	2.1276	2.364	2.6004
414	1.194	1.57608	1.86264	2.1492	2.388	2.6268
420	1.206	1.59192	1.88136	2.1708	2.412	2.6532
426	1.218	1.60776	1.90008	2.1924	2.436	2.6796
432	1.23	1.6236	1.9188	2.214	2.46	2.706
438	1.242	1.63944	1.93752	2.2356	2.484	2.7324
444	1.254	1.65528	1.95624	2.2572	2.508	2.7588
450	1.266	1.67112	1.97496	2.2788	2.532	2.7852
456	1.278	1.68696	1.99368	2.3004	2.556	2.8116
462	1.29	1.7028	2.0124	2.322	2.58	2.838
468	1.302	1.71864	2.03112	2.3436	2.604	2.8644
474	1.314	1.73448	2.04984	2.3652	2.628	2.8908
480	1.35	1.782	2.106	2.43	2.7	2.97
486	1.41	1.8612	2.1996	2.538	2.82	3.102
492	1.47	1.9404	2.2932	2.646	2.94	3.234
498	1.53	2.0196	2.3868	2.754	3.06	3.366
504	1.59	2.0988	2.4804	2.862	3.18	3.498
510	1.65	2.178	2.574	2.97	3.3	3.63
516	1.71	2.2572	2.6676	3.078	3.42	3.762
522	1.77	2.3364	2.7612	3.186	3.54	3.894
528	1.83	2.4156	2.8548	3.294	3.66	4.026
534	1.89	2.4948	2.9484	3.402	3.78	4.158
540	1.92	2.5344	2.9952	3.456	3.84	4.224
546	1.92	2.5344	2.9952	3.456	3.84	4.224
552	1.92	2.5344	2.9952	3.456	3.84	4.224
558	1.92	2.5344	2.9952	3.456	3.84	4.224
564	1.92	2.5344	2.9952	3.456	3.84	4.224

TIME (MIN)	STORM EVENT RAINFALL INTENSITY (MM/HR)					
	2YR	5YR	10YR	25YR	50YR	100YR
570	1.968	2.59776	3.07008	3.5424	3.936	4.3296
576	2.064	2.72448	3.21984	3.7152	4.128	4.5408
582	2.16	2.8512	3.3696	3.888	4.32	4.752
588	2.256	2.97792	3.51936	4.0608	4.512	4.9632
594	2.352	3.10464	3.66912	4.2336	4.704	5.1744
600	2.472	3.26304	3.85632	4.4496	4.944	5.4384
606	2.616	3.45312	4.08096	4.7088	5.232	5.7552
612	2.76	3.6432	4.3056	4.968	5.52	6.072
618	2.904	3.83328	4.53024	5.2272	5.808	6.3888
624	3.048	4.02336	4.75488	5.4864	6.096	6.7056
630	3.24	4.2768	5.0544	5.832	6.48	7.128
636	3.48	4.5936	5.4288	6.264	6.96	7.656
642	3.72	4.9104	5.8032	6.696	7.44	8.184
648	3.96	5.2272	6.1776	7.128	7.92	8.712
654	4.2	5.544	6.552	7.56	8.4	9.24
660	4.608	6.08256	7.18848	8.2944	9.216	10.1376
666	5.184	6.84288	8.08704	9.3312	10.368	11.4048
672	5.76	7.6032	8.9856	10.368	11.52	12.672
678	6.336	8.36352	9.88416	11.4048	12.672	13.9392
684	6.912	9.12384	10.78272	12.4416	13.824	15.2064
690	14.304	18.88128	22.31424	25.7472	28.608	31.4688
696	28.512	37.63584	44.47872	51.3216	57.024	62.7264
702	45.858	60.53256	71.53848	82.5444	91.716	100.8876
708	82.242	108.5594	128.2975	148.0356	164.484	180.9324
714	57.084	75.35088	89.05104	102.7512	114.168	125.5848
720	11.376	15.01632	17.74656	20.4768	22.752	25.0272
726	10.008	13.21056	15.61248	18.0144	20.016	22.0176
732	8.64	11.4048	13.4784	15.552	17.28	19.008
738	7.272	9.59904	11.34432	13.0896	14.544	15.9984
744	5.904	7.79328	9.21024	10.6272	11.808	12.9888
750	5.064	6.68448	7.89984	9.1152	10.128	11.1408
756	4.752	6.27264	7.41312	8.5536	9.504	10.4544

TIME (MIN)	STORM EVENT RAINFALL INTENSITY (MM/HR)					
	2YR	5YR	10YR	25YR	50YR	100YR
762	4.44	5.8608	6.9264	7.992	8.88	9.768
768	4.128	5.44896	6.43968	7.4304	8.256	9.0816
774	3.816	5.03712	5.95296	6.8688	7.632	8.3952
780	3.576	4.72032	5.57856	6.4368	7.152	7.8672
786	3.408	4.49856	5.31648	6.1344	6.816	7.4976
792	3.24	4.2768	5.0544	5.832	6.48	7.128
798	3.072	4.05504	4.79232	5.5296	6.144	6.7584
804	2.904	3.83328	4.53024	5.2272	5.808	6.3888
810	2.76	3.6432	4.3056	4.968	5.52	6.072
816	2.64	3.4848	4.1184	4.752	5.28	5.808
822	2.52	3.3264	3.9312	4.536	5.04	5.544
828	2.4	3.168	3.744	4.32	4.8	5.28
834	2.28	3.0096	3.5568	4.104	4.56	5.016
840	2.202	2.90664	3.43512	3.9636	4.404	4.8444
846	2.154	2.84328	3.36024	3.8772	4.308	4.7388
852	2.118	2.79576	3.30408	3.8124	4.236	4.6596
858	2.07	2.7324	3.2292	3.726	4.14	4.554
864	2.034	2.68488	3.17304	3.6612	4.068	4.4748
870	1.986	2.62152	3.09816	3.5748	3.972	4.3692
876	1.95	2.574	3.042	3.51	3.9	4.29
882	1.902	2.51064	2.96712	3.4236	3.804	4.1844
888	1.866	2.46312	2.91096	3.3588	3.732	4.1052
894	1.818	2.39976	2.83608	3.2724	3.636	3.9996
900	1.782	2.35224	2.77992	3.2076	3.564	3.9204
906	1.734	2.28888	2.70504	3.1212	3.468	3.8148
912	1.698	2.24136	2.64888	3.0564	3.396	3.7356
918	1.65	2.178	2.574	2.97	3.3	3.63
924	1.614	2.13048	2.51784	2.9052	3.228	3.5508
930	1.566	2.06712	2.44296	2.8188	3.132	3.4452
936	1.53	2.0196	2.3868	2.754	3.06	3.366
942	1.482	1.95624	2.31192	2.6676	2.964	3.2604
948	1.446	1.90872	2.25576	2.6028	2.892	3.1812

TIME (MIN)	STORM EVENT RAINFALL INTENSITY (MM/HR)					
	2YR	5YR	10YR	25YR	50YR	100YR
954	1.398	1.84536	2.18088	2.5164	2.796	3.0756
960	1.374	1.81368	2.14344	2.4732	2.748	3.0228
966	1.356	1.78992	2.11536	2.4408	2.712	2.9832
972	1.344	1.77408	2.09664	2.4192	2.688	2.9568
978	1.326	1.75032	2.06856	2.3868	2.652	2.9172
984	1.314	1.73448	2.04984	2.3652	2.628	2.8908
990	1.296	1.71072	2.02176	2.3328	2.592	2.8512
996	1.284	1.69488	2.00304	2.3112	2.568	2.8248
1002	1.266	1.67112	1.97496	2.2788	2.532	2.7852
1008	1.254	1.65528	1.95624	2.2572	2.508	2.7588
1014	1.236	1.63152	1.92816	2.2248	2.472	2.7192
1020	1.224	1.61568	1.90944	2.2032	2.448	2.6928
1026	1.206	1.59192	1.88136	2.1708	2.412	2.6532
1032	1.194	1.57608	1.86264	2.1492	2.388	2.6268
1038	1.176	1.55232	1.83456	2.1168	2.352	2.5872
1044	1.164	1.53648	1.81584	2.0952	2.328	2.5608
1050	1.146	1.51272	1.78776	2.0628	2.292	2.5212
1056	1.134	1.49688	1.76904	2.0412	2.268	2.4948
1062	1.116	1.47312	1.74096	2.0088	2.232	2.4552
1068	1.104	1.45728	1.72224	1.9872	2.208	2.4288
1074	1.086	1.43352	1.69416	1.9548	2.172	2.3892
1080	1.074	1.41768	1.67544	1.9332	2.148	2.3628
1086	1.056	1.39392	1.64736	1.9008	2.112	2.3232
1092	1.044	1.37808	1.62864	1.8792	2.088	2.2968
1098	1.026	1.35432	1.60056	1.8468	2.052	2.2572
1104	1.014	1.33848	1.58184	1.8252	2.028	2.2308
1110	0.996	1.31472	1.55376	1.7928	1.992	2.1912
1116	0.984	1.29888	1.53504	1.7712	1.968	2.1648
1122	0.966	1.27512	1.50696	1.7388	1.932	2.1252
1128	0.954	1.25928	1.48824	1.7172	1.908	2.0988
1134	0.936	1.23552	1.46016	1.6848	1.872	2.0592
1140	0.924	1.21968	1.44144	1.6632	1.848	2.0328

TIME (MIN)	STORM EVENT RAINFALL INTENSITY (MM/HR)					
	2YR	5YR	10YR	25YR	50YR	100YR
1146	0.906	1.19592	1.41336	1.6308	1.812	1.9932
1152	0.894	1.18008	1.39464	1.6092	1.788	1.9668
1158	0.876	1.15632	1.36656	1.5768	1.752	1.9272
1164	0.864	1.14048	1.34784	1.5552	1.728	1.9008
1170	0.846	1.11672	1.31976	1.5228	1.692	1.8612
1176	0.834	1.10088	1.30104	1.5012	1.668	1.8348
1182	0.816	1.07712	1.27296	1.4688	1.632	1.7952
1188	0.804	1.06128	1.25424	1.4472	1.608	1.7688
1194	0.786	1.03752	1.22616	1.4148	1.572	1.7292
1200	0.78	1.0296	1.2168	1.404	1.56	1.716
1206	0.774	1.02168	1.20744	1.3932	1.548	1.7028
1212	0.774	1.02168	1.20744	1.3932	1.548	1.7028
1218	0.768	1.01376	1.19808	1.3824	1.536	1.6896
1224	0.768	1.01376	1.19808	1.3824	1.536	1.6896
1230	0.762	1.00584	1.18872	1.3716	1.524	1.6764
1236	0.762	1.00584	1.18872	1.3716	1.524	1.6764
1242	0.756	0.99792	1.17936	1.3608	1.512	1.6632
1248	0.756	0.99792	1.17936	1.3608	1.512	1.6632
1254	0.75	0.99	1.17	1.35	1.5	1.65
1260	0.75	0.99	1.17	1.35	1.5	1.65
1266	0.744	0.98208	1.16064	1.3392	1.488	1.6368
1272	0.744	0.98208	1.16064	1.3392	1.488	1.6368
1278	0.738	0.97416	1.15128	1.3284	1.476	1.6236
1284	0.738	0.97416	1.15128	1.3284	1.476	1.6236
1290	0.732	0.96624	1.14192	1.3176	1.464	1.6104
1296	0.732	0.96624	1.14192	1.3176	1.464	1.6104
1302	0.726	0.95832	1.13256	1.3068	1.452	1.5972
1308	0.726	0.95832	1.13256	1.3068	1.452	1.5972
1314	0.72	0.9504	1.1232	1.296	1.44	1.584
1320	0.72	0.9504	1.1232	1.296	1.44	1.584
1326	0.714	0.94248	1.11384	1.2852	1.428	1.5708
1332	0.714	0.94248	1.11384	1.2852	1.428	1.5708

TIME (MIN)	STORM EVENT RAINFALL INTENSITY (MM/HR)					
	2YR	5YR	10YR	25YR	50YR	100YR
1338	0.708	0.93456	1.10448	1.2744	1.416	1.5576
1344	0.708	0.93456	1.10448	1.2744	1.416	1.5576
1350	0.702	0.92664	1.09512	1.2636	1.404	1.5444
1356	0.702	0.92664	1.09512	1.2636	1.404	1.5444
1362	0.696	0.91872	1.08576	1.2528	1.392	1.5312
1368	0.696	0.91872	1.08576	1.2528	1.392	1.5312
1374	0.69	0.9108	1.0764	1.242	1.38	1.518
1380	0.69	0.9108	1.0764	1.242	1.38	1.518
1386	0.684	0.90288	1.06704	1.2312	1.368	1.5048
1392	0.684	0.90288	1.06704	1.2312	1.368	1.5048
1398	0.678	0.89496	1.05768	1.2204	1.356	1.4916
1404	0.678	0.89496	1.05768	1.2204	1.356	1.4916
1410	0.672	0.88704	1.04832	1.2096	1.344	1.4784
1416	0.672	0.88704	1.04832	1.2096	1.344	1.4784
1422	0.666	0.87912	1.03896	1.1988	1.332	1.4652
1428	0.666	0.87912	1.03896	1.1988	1.332	1.4652
1434	0.66	0.8712	1.0296	1.188	1.32	1.452

Table B16 Regional 12 hr Storm Event

TIME (MIN)	RAINFALL INTENSITY (MM/HR)
0	0
10	6.35
20	6.35
30	6.35
40	6.35
50	6.35
60	6.35
70	4.32
80	4.32
90	4.32
100	4.32
110	4.32
120	4.32
130	6.35
140	6.35
150	6.35
160	6.35
170	6.35
180	6.35
190	12.7
200	12.7
210	12.7
220	12.7
230	12.7
240	12.7
250	16.76
260	16.76
270	16.76
280	16.76
290	16.76
300	16.76
310	13.97

TIME (MIN)	RAINFALL INTENSITY (MM/HR)
320	13.97
330	13.97
340	13.97
350	13.97
360	13.97
370	23.11
380	23.11
390	23.11
400	23.11
410	23.11
420	23.11
430	12.7
440	12.7
450	12.7
460	12.7
470	12.7
480	12.7
490	12.7
500	12.7
510	12.7
520	12.7
530	12.7
540	12.7
550	52.83
560	52.83
570	52.83
580	52.83
590	52.83
600	52.83
610	37.85
620	37.85
630	37.85
640	37.85

TIME (MIN)	RAINFALL INTENSITY (MM/HR)
650	37.85
660	37.85
670	12.7
680	12.7
690	12.7
700	12.7
710	12.7
720	12.7

Table B17 Regional 48 hr Storm Event

TIME (MIN)	RAINFALL INTENSITY (MM/HR)
0	0
60	2
120	2
180	2
240	2
300	2
360	2
420	2
480	2
540	2
600	2
660	2
720	2
780	2
840	2
900	2
960	2
1020	2
1080	2
1140	2
1200	2
1260	2

TIME (MIN)	RAINFALL INTENSITY (MM/HR)
1320	2
1380	2
1440	2
1500	2
1560	2
1620	2
1680	2
1740	2
1800	2
1860	2
1920	2
1980	2
2040	2
2100	2
2160	3
2220	6
2280	4
2340	6
2400	13
2460	17
2520	13
2580	23
2640	13
2700	13
2760	53
2820	38
2880	13

SWM Sizing

Table B18 SWM Pond Sizing

EVENT	UNITARY DISCHARGE (M^3/S/HA)	UNITARY STORAGE (M^3/IMP.HA)
SWM_POND1		
2 yr	0.0297	220
5 yr	0.0490	300
10 yr	0.0646	350
25 yr	0.0810	410
50 yr	0.0950	440
100 yr	0.1092	480
SWM_POND2		
2 yr	0.0297	180
5 yr	0.0490	210
10 yr	0.0646	250
25 yr	0.0810	290
50 yr	0.0950	350
100 yr	0.1092	390

Table B19 Storage Tank Sizing

EVENT	UNITARY DISCHARGE (M3/S/HA)	UNITARY STORAGE (M3/IMP.HA)
TANK_STREETD		
2 yr	0.0297	355
5 yr	0.0490	490
10 yr	0.0646	590
25 yr	0.0810	700
50 yr	0.0950	790
100 yr	0.1092	1050
TANK_STREETE		
2 yr	0.0297	150
5 yr	0.0490	350
10 yr	0.0646	550
25 yr	0.0810	750
50 yr	0.0950	900
100 yr	0.1092	1200
TANK_PO_M06		
2 yr	0.0297	280
5 yr	0.0490	430
10 yr	0.0646	530
25 yr	0.0810	630
50 yr	0.0950	700
100 yr	0.1092	770

Table B20 Total Discharge at Outlet

	EXISTING (M3/S)	PROPOSED (M3/S)	DIFF (%)	SWM (M3/S)	SWM DIFF (%)
2 yr	4.059	5.743	41%	4.01	-1%
5 yr	6.692	9.372	40%	6.56	-2%
10 yr	8.829	12.012	36%	8.647	-2%
25 yr	11.06	14.741	33%	10.797	-2%
50 yr	12.972	17.067	32%	12.772	-2%
100 yr	14.92	19.427	30%	14.667	-2%

Hydrology Results

Table B24 Existing Conditions Peak Flows

POINT OF INTEREST		PEAK FLOW (M3/S)																	
		CHICAGO 6HR						SCS TYPE2 12 HOUR						SCS TYPE2 24 HOUR					
NYHD	NAME	2	5	10	25	50	100	2	5	10	25	50	100	2	5	10	25	50	100
Nodes																			
60	7	0.295	0.572	0.788	1.090	1.331	1.584	0.672	1.049	1.396	1.850	2.196	2.554	0.773	1.295	1.725	2.178	2.568	2.969
55	8	0.637	1.209	1.649	2.259	2.744	3.250	1.364	2.110	2.788	3.670	4.338	5.024	1.564	2.589	3.423	4.295	5.041	5.803
9	9	0.484	0.909	1.234	1.685	2.042	2.414	0.999	1.543	2.037	2.678	3.164	3.663	1.144	1.891	2.498	3.132	3.684	4.248
10	10	0.920	1.739	2.368	3.240	3.932	4.671	1.970	3.052	4.034	5.309	6.277	7.272	2.252	3.731	4.943	6.235	7.348	8.486
11	11	1.370	2.602	3.553	4.873	5.922	7.020	2.940	4.555	6.031	7.950	9.409	10.908	3.374	5.604	7.423	9.327	10.962	12.631
57	18	0.101	0.179	0.237	0.316	0.377	0.440	0.196	0.292	0.375	0.481	0.559	0.639	0.219	0.345	0.444	0.545	0.631	0.720
58	19	1.721	3.191	4.336	5.920	7.176	8.487	3.547	5.461	7.203	9.461	11.171	12.928	4.059	6.692	8.829	11.060	12.972	14.920
Subcatchments																			
5	PR-E01	0.023	0.044	0.060	0.083	0.102	0.123	0.052	0.082	0.110	0.147	0.175	0.205	0.060	0.102	0.137	0.174	0.206	0.240
61	PR-E02	0.470	0.879	1.193	1.630	1.975	2.336	0.968	1.494	1.972	2.593	3.063	3.545	1.108	1.832	2.420	3.033	3.559	4.095
12	PR-M01	0.224	0.402	0.536	0.716	0.857	1.003	0.442	0.661	0.853	1.098	1.280	1.466	0.498	0.788	1.018	1.253	1.452	1.653
53	PR-M02	0.032	0.055	0.073	0.098	0.118	0.138	0.055	0.082	0.105	0.134	0.155	0.178	0.060	0.094	0.121	0.149	0.172	0.196
14	PR-M03	0.091	0.163	0.216	0.289	0.345	0.403	0.179	0.267	0.343	0.440	0.513	0.586	0.201	0.317	0.408	0.501	0.579	0.658
54	PR-M04	0.033	0.059	0.079	0.106	0.127	0.148	0.071	0.107	0.138	0.177	0.206	0.236	0.080	0.126	0.163	0.200	0.231	0.263
63	PR-M05	0.038	0.066	0.088	0.118	0.141	0.166	0.075	0.112	0.143	0.183	0.213	0.244	0.083	0.131	0.168	0.207	0.239	0.272
4	PR-N01	0.118	0.217	0.295	0.403	0.489	0.579	0.243	0.374	0.493	0.648	0.766	0.888	0.278	0.458	0.606	0.760	0.893	1.029

POINT OF INTEREST		PEAK FLOW (M3/S)																	
		CHICAGO 6HR						SCS TYPE2 12 HOUR						SCS TYPE2 24 HOUR					
NYHD	NAME	2	5	10	25	50	100	2	5	10	25	50	100	2	5	10	25	50	100
62	PR-N02	0.527	0.994	1.360	1.869	2.273	2.696	1.123	1.740	2.305	3.038	3.594	4.165	1.291	2.145	2.840	3.565	4.188	4.822
20	PR-S01	0.048	0.085	0.114	0.153	0.184	0.215	0.098	0.146	0.187	0.238	0.276	0.314	0.109	0.170	0.218	0.267	0.308	0.349
2	PR-W01	0.139	0.264	0.365	0.509	0.626	0.749	0.302	0.474	0.637	0.853	1.020	1.193	0.350	0.596	0.802	1.022	1.214	1.412
56	PR-W02	0.161	0.309	0.423	0.581	0.714	0.853	0.370	0.575	0.759	0.997	1.177	1.361	0.423	0.699	0.922	1.155	1.355	1.557

Table B25 Proposed Uncontrolled Conditions Peak Flows

POINT OF INTEREST		PEAK FLOW (M3/S)																	
		CHICAGO 6HR						SCS TYPE2 12 HOUR						SCS TYPE2 24 HOUR					
NYHD	NAME	2	5	10	25	50	100	2	5	10	25	50	100	2	5	10	25	50	100
Nodes																			
7	7	0.882	1.482	2.089	2.74	3.249	3.776	1.344	1.976	2.938	3.72	4.304	4.899	1.464	2.63	3.354	4.1	4.734	5.378
8	8	0.568	1.064	1.445	1.971	2.388	2.824	1.191	1.829	2.409	3.161	3.73	4.313	1.362	2.24	2.952	3.694	4.329	4.976
48	9	1.738	2.922	4.266	5.604	6.654	7.742	3.125	4.637	6.434	8.202	9.527	10.879	3.467	5.845	7.499	9.209	10.666	12.145
49	10	1.955	3.366	4.511	5.966	7.113	8.308	3.646	5.428	7.422	9.545	11.144	12.781	4.094	6.828	8.833	10.915	12.694	14.504
19	19	2.774	4.603	6.762	8.848	10.473	12.156	5.188	7.668	10.282	13.095	15.204	17.357	5.743	9.372	12.012	14.741	17.067	19.427
56	56	2.622	4.345	6.374	8.334	9.861	11.442	4.883	7.218	9.713	12.375	14.373	16.412	5.41	8.861	11.362	13.948	16.153	18.393
64	64	0.374	0.581	0.727	0.918	1.064	1.211	0.481	0.681	0.833	1.021	1.16	1.299	0.509	0.734	0.906	1.081	1.228	1.376
65	65	1.126	1.836	2.816	3.658	4.313	4.987	1.766	2.592	3.771	4.741	5.464	6.198	1.926	3.363	4.26	5.18	5.962	6.754
55	AddHyd - 55	0.142	0.24	0.313	0.411	0.487	0.566	0.217	0.319	0.4	0.501	0.576	0.652	0.235	0.355	0.448	0.543	0.623	0.703
60	AddHyd - 60	0.085	0.177	0.25	0.377	0.466	0.56	0.208	0.345	0.46	0.612	0.727	0.846	0.239	0.422	0.564	0.713	0.842	0.973

POINT OF INTEREST		PEAK FLOW (M3/S)																	
		CHICAGO 6HR						SCS TYPE2 12 HOUR						SCS TYPE2 24 HOUR					
NYHD	NAME	2	5	10	25	50	100	2	5	10	25	50	100	2	5	10	25	50	100
Subcatchments																			
69	PO_M06	0.105	0.172	0.221	0.285	0.334	0.385	0.144	0.207	0.256	0.315	0.359	0.403	0.154	0.226	0.28	0.335	0.381	0.426
39	PO-E01	0.014	0.028	0.043	0.068	0.087	0.107	0.032	0.062	0.086	0.117	0.141	0.167	0.037	0.078	0.107	0.138	0.164	0.192
67	PO-M01	0.077	0.158	0.221	0.309	0.379	0.453	0.181	0.284	0.377	0.498	0.589	0.684	0.207	0.346	0.459	0.578	0.68	0.784
15	PO-M02	0.044	0.076	0.101	0.136	0.163	0.191	0.075	0.113	0.144	0.184	0.214	0.245	0.083	0.129	0.167	0.205	0.238	0.271
52	PO-M03	0.089	0.136	0.169	0.212	0.245	0.277	0.097	0.136	0.164	0.2	0.225	0.251	0.102	0.144	0.176	0.209	0.236	0.263
16	PO-M04	0.009	0.017	0.023	0.03	0.036	0.042	0.02	0.031	0.039	0.051	0.059	0.067	0.023	0.036	0.046	0.057	0.066	0.075
37	PO-M05	0.848	1.298	1.61	2.014	2.32	2.628	1.004	1.402	1.693	2.049	2.308	2.567	1.053	1.485	1.809	2.134	2.405	2.676
38	PO-M07	0.099	0.164	0.212	0.275	0.325	0.375	0.142	0.206	0.256	0.317	0.362	0.407	0.152	0.225	0.281	0.338	0.385	0.432
30	PO-N01	0.164	0.281	0.369	0.489	0.585	0.683	0.254	0.378	0.478	0.605	0.698	0.793	0.276	0.423	0.539	0.657	0.757	0.857
31	PO-N02	0.252	0.4	0.504	0.642	0.747	0.854	0.322	0.457	0.559	0.684	0.776	0.867	0.341	0.492	0.607	0.722	0.817	0.913
32	PO-N03	0.093	0.155	0.201	0.263	0.311	0.36	0.134	0.197	0.245	0.306	0.351	0.396	0.145	0.217	0.273	0.329	0.376	0.424
63	PO-SWM	0.015	0.03	0.042	0.06	0.074	0.089	0.035	0.055	0.074	0.1	0.119	0.14	0.04	0.068	0.092	0.118	0.141	0.164
50	PO-W01	0.01	0.028	0.045	0.072	0.096	0.122	0.042	0.078	0.116	0.169	0.213	0.26	0.053	0.11	0.162	0.221	0.275	0.333
29	PO-W02	0.726	1.157	1.81	2.33	2.731	3.141	0.938	1.335	2.148	2.654	3.026	3.399	0.997	1.886	2.346	2.812	3.202	3.593
36	PO-W03	0.367	0.567	0.707	0.888	1.026	1.165	0.449	0.63	0.764	0.928	1.047	1.167	0.472	0.669	0.818	0.968	1.093	1.218
6	PR-E02	0.47	0.879	1.193	1.63	1.975	2.336	0.968	1.494	1.972	2.593	3.063	3.545	1.108	1.832	2.42	3.033	3.559	4.095
17	PR-M05	0.038	0.066	0.088	0.118	0.141	0.166	0.075	0.112	0.143	0.183	0.213	0.244	0.083	0.131	0.168	0.207	0.239	0.272
3	PR-N02	0.527	0.994	1.36	1.869	2.273	2.696	1.123	1.74	2.305	3.038	3.594	4.165	1.291	2.145	2.84	3.565	4.188	4.822
1	PR-W02	0.161	0.309	0.423	0.581	0.714	0.853	0.37	0.575	0.759	0.997	1.177	1.361	0.423	0.699	0.922	1.155	1.355	1.557

TABLE B26 PROPOSED CONTROLLED CONDITIONS PEAK FLOWS

POINT OF INTEREST		PEAK FLOW (M3/S)																	
		CHICAGO 6HR						SCS TYPE2 12 HOUR						SCS TYPE2 24 HOUR					
NYHD	NAME	2	5	10	25	50	100	2	5	10	25	50	100	2	5	10	25	50	100
Nodes																			
88	7	0.882	1.157	0.045	0.581	2.731	0.853	0.938	0.575	2.148	2.654	3.026	1.361	0.053	0.110	2.346	1.155	3.202	3.593
89	8	0.568	1.064	0.369	0.489	2.388	2.824	1.191	0.378	2.409	3.161	3.730	0.793	0.341	2.240	2.952	0.657	4.329	4.976
100	9	1.058	1.820	2.816	1.630	1.975	1.789	1.947	1.494	4.016	2.593	6.313	3.545	0.746	0.217	4.932	3.033	7.361	8.484
101	10	1.525	2.687	0.101	5.795	0.163	0.191	2.876	5.276	5.923	0.184	9.302	12.467	3.895	1.832	7.309	10.514	10.881	12.530
90	19	1.892	3.329	0.088	0.030	7.187	0.166	3.577	0.112	0.143	9.367	11.003	0.244	0.023	0.036	8.654	0.207	12.777	0.272
105	56	1.820	0.028	0.043	0.309	0.087	0.107	0.032	0.284	0.164	0.117	0.141	0.684	0.102	0.346	0.107	0.578	0.236	0.263
109	64	0.374	0.567	0.042	0.060	1.026	3.776	0.449	0.055	0.764	0.928	1.047	0.140	0.472	0.068	0.818	0.118	1.093	1.218
112	AddHyd - 112	1.126	0.581	0.707	0.888	1.064	1.165	0.481	0.630	0.833	1.021	1.160	1.167	0.509	3.672	0.906	0.968	1.228	1.376
104	AddHyd - 55	0.146	0.168	0.215	0.136	0.326	0.375	0.141	0.113	0.249	0.307	0.350	0.245	0.083	0.129	0.273	0.205	0.609	0.416
107	AddHyd - 60	0.085	1.298	0.241	0.346	2.320	0.502	1.004	0.321	0.422	2.049	2.308	0.759	0.229	0.389	1.809	0.644	0.757	0.873
Subcatchments																			
115	PO_M06	0.105	0.172	4.409	0.118	0.334	8.487	0.144	5.439	7.133	0.315	0.359	12.819	0.083	0.131	0.280	10.802	0.381	14.671
98	PO-E01	0.014	0.025	0.169	0.068	0.057	0.277	0.028	0.062	0.086	0.075	0.089	0.167	0.037	0.078	0.070	0.138	0.164	0.192
67	PO-M01	0.077	0.244	0.157	0.414	0.036	0.282	0.216	0.315	0.377	0.051	0.059	0.637	0.154	6.382	0.046	0.531	0.371	0.784
85	PO-M02	0.044	3.215	4.266	0.212	6.976	8.246	3.463	0.136	6.931	9.115	10.715	0.251	0.123	6.564	8.426	0.209	0.311	0.348
103	PO-M03	0.089	0.117	3.557	0.285	5.970	7.105	0.114	0.167	0.207	7.872	0.292	0.327	3.263	1.266	0.229	0.273	12.396	14.232
86	PO-M04	0.009	0.017	0.317	0.278	0.489	0.566	0.020	0.202	0.393	0.492	0.564	0.392	0.150	0.220	0.440	0.327	0.066	0.686
96	PO-M05	0.848	0.508	1.610	2.014	0.893	2.628	0.503	1.402	1.693	1.038	1.180	2.567	1.053	1.485	0.919	2.134	2.405	2.676
97	PO-M07	0.102	0.076	0.221	4.903	0.379	0.453	0.075	4.433	0.144	0.498	0.214	10.883	0.207	0.144	0.167	9.179	0.238	0.271
92	PO-N01	0.164	0.281	1.360	1.869	0.585	0.683	0.254	1.740	0.478	0.605	0.698	4.165	1.362	0.423	0.539	3.565	0.757	0.857
93	PO-N02	0.252	0.400	1.445	1.971	0.747	0.854	0.322	1.829	0.559	0.684	0.776	4.313	0.073	0.492	0.607	3.694	0.817	0.913
94	PO-N03	0.093	0.155	0.088	0.118	0.311	0.360	0.134	0.105	0.245	0.306	0.351	0.239	1.926	0.734	0.273	0.201	0.376	0.424

TABLE B26 PROPOSED CONTROLLED CONDITIONS PEAK FLOWS

POINT OF INTEREST		PEAK FLOW (M3/S)																	
		CHICAGO 6HR						SCS TYPE2 12 HOUR						SCS TYPE2 24 HOUR					
NYHD	NAME	2	5	10	25	50	100	2	5	10	25	50	100	2	5	10	25	50	100
102	PO-W01	0.010	0.309	2.414	0.263	4.065	4.841	0.370	0.197	0.759	5.350	1.177	0.396	2.190	0.226	0.922	0.329	1.355	1.557
91	PO-W02	0.726	0.028	0.423	3.340	0.096	2.336	0.042	2.993	0.116	0.169	0.213	7.412	0.423	0.699	0.162	6.187	0.275	0.333
95	PO-W03	0.367	0.030	2.089	2.330	0.074	3.141	0.035	1.335	0.074	0.100	0.119	3.399	1.464	2.630	0.092	2.812	3.559	0.164
84	PR-E02	0.470	0.675	1.193	2.740	0.714	0.089	0.681	1.976	1.420	0.997	2.315	4.899	1.291	3.363	1.767	4.100	2.789	3.261
87	PR-M05	0.038	0.066	0.023	0.206	0.141	0.042	0.075	0.031	0.039	0.183	0.213	0.067	0.233	0.349	0.168	0.057	0.239	0.075
83	PR-N02	0.527	0.994	0.848	1.201	2.273	2.696	1.123	1.052	2.305	3.038	3.594	2.842	0.276	2.145	2.840	2.240	4.188	4.822
82	PR-W02	0.161	0.879	0.727	0.918	4.313	1.211	0.968	0.681	1.972	4.741	3.063	1.299	0.040	0.669	2.420	1.081	0.141	4.095
108	PST-SWM	0.015	1.482	1.810	0.072	3.249	0.122	1.344	0.078	2.938	3.720	4.304	0.260	0.997	1.886	3.354	0.221	4.734	5.378
SWM Ponds and Storage Tanks																			
120	SW_Storage	0.068	0.158	0.221	5.977	0.244	0.385	0.181	0.207	0.256	0.256	0.589	0.403	4.018	5.463	0.459	0.335	0.680	0.426
116	SWM_POND1	0.429	1.836	0.201	3.658	1.479	4.987	1.766	2.592	3.771	1.954	5.464	6.198	1.108	0.184	4.260	5.180	5.962	6.754
117	SWM_POND2	0.305	0.136	0.625	0.768	0.245	1.018	0.097	0.677	0.840	0.200	0.225	1.325	0.542	0.740	0.176	1.100	1.251	1.405
118	TANK_STREETD	0.045	0.068	0.504	0.642	0.143	0.168	0.068	0.457	0.139	0.181	0.211	0.867	0.145	0.122	0.163	0.722	0.236	0.249
119	TANK_STREETE	0.011	0.173	0.035	0.048	0.422	0.068	0.200	0.045	0.058	0.554	0.655	0.105	0.032	0.054	0.513	0.088	0.105	0.113

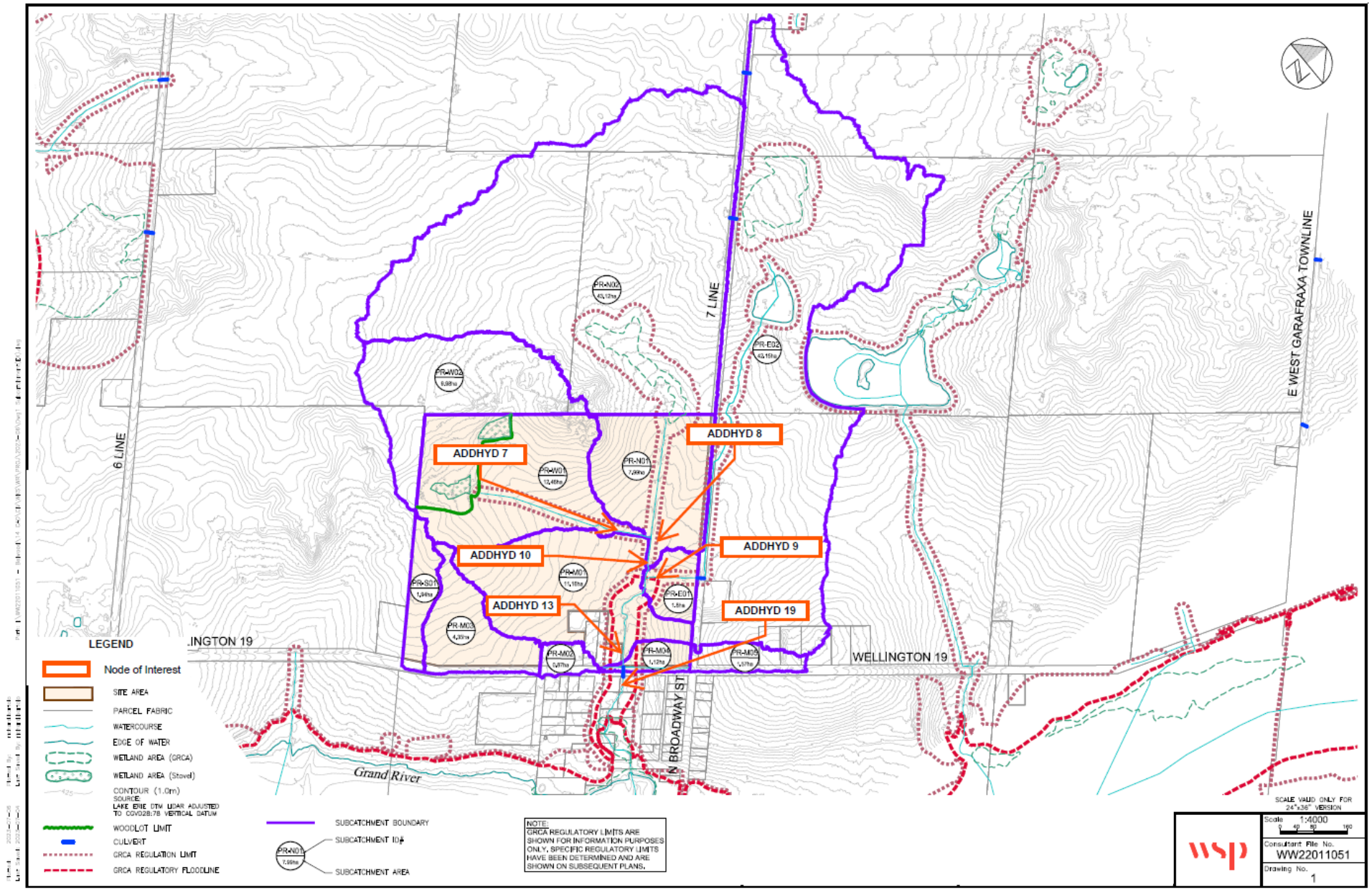


Figure B1 Nodes of Interest Existing Conditions

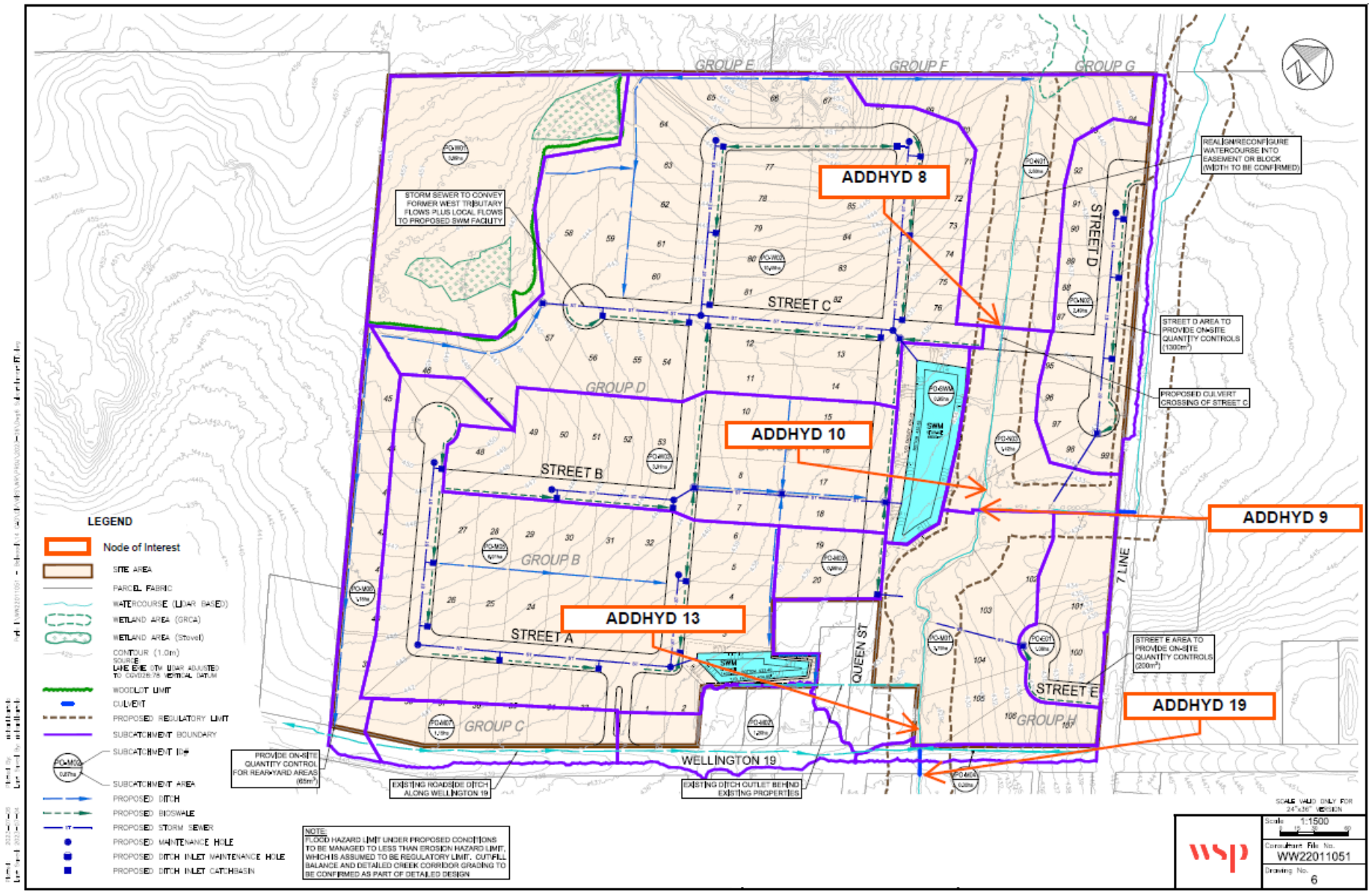


Figure B2 Nodes of Interest Proposed Conditions

APPENDIX

C HYDRAULIC MODELLING

Hydraulic Results

Table C.1 Existing Conditions 100 Year Storm Event Flood Elevations Associated with Cross Sections

RIVER	REACH	RIVER STATION	Q TOTAL (M3/S)	MIN CH EL (M)	W.S. ELEV (M)	CRIT W.S. (M)
River 6	Main Trib	353	14.20	431.50	432.63	
River 6	Main Trib	334	14.20	431.26	432.35	432.35
River 6	Main Trib	313	14.20	431.08	432.03	432.03
River 6	Main Trib	288	14.20	430.55	431.54	431.54
River 6	Main Trib	250	14.20	429.24	430.35	430.35
River 6	Main Trib	229	14.20	429.03	429.86	429.86
River 6	Main Trib	207	14.20	428.65	429.68	
River 6	Main Trib	181	14.20	428.30	429.68	
River 6	Main Trib	158	15.17	427.93	429.68	
River 6	Main Trib	150	15.17	427.91	429.67	
River 6	Main Trib	139	15.17	427.80	429.63	428.71
River 6	Main Trib					
River 6	Main Trib	110	15.17	427.84	428.82	428.82
River 6	Main Trib	99	15.17	427.75	428.71	428.71
River 6	Main Trib	84	15.17	427.65	428.59	
River 6	Main Trib	59	15.17	427.21	428.41	428.32
River 6	Main Trib	35	15.17	426.93	428.39	
River 6	Main Trib	16	15.17	426.57	428.14	428.14
River 6	Main Trib	1	15.17	426.45	427.83	427.83
River 4	East Trib	120	4.25	433.18	433.53	433.53
River 4	East Trib	105	4.25	432.86	433.14	433.14
River 4	East Trib	86	4.25	432.62	432.94	
River 4	East Trib	69	4.25	432.28	432.76	432.76
River 4	East Trib	55	4.25	432.24	432.74	
River 4	East Trib	44	4.25	432.10	432.74	
River 4	East Trib	33	4.25	431.97	432.73	
River 3	North West Trib	85	8.49	432.99	433.71	
River 3	NorthWest Trib	70	8.49	432.80	433.51	433.50
River 3	North West Trib	55	8.49	432.50	433.37	433.35
River 3	North West Trib	42	8.49	432.43	433.28	
River 3	North West Trib	29	8.49	432.26	433.24	433.14
River 3	North West Trib					
River 3	North West Trib	17	8.49	432.06	433.08	433.08
River 3	North West Trib	11	8.49	431.89	432.98	432.98
River 2	North Trib	279	5.80	438.29	439.06	439.06
River 2	North Trib	258	5.80	437.87	438.61	438.61
River 2	North Trib	234	5.80	437.33	438.10	438.10
River 2	North Trib	210	5.80	436.97	437.56	437.56

RIVER	REACH	RIVER STATION	Q TOTAL (M3/S)	MIN CH EL (M)	W.S. ELEV (M)	CRIT W.S. (M)
River 2	North Trib	182	5.80	436.17	436.94	436.94
River 2	North Trib	156	5.80	435.86	436.47	436.47
River 2	North Trib	129	5.80	435.49	435.88	435.88
River 2	North Trib	103	5.80	435.10	435.36	435.33
River 2	North Trib	78	5.80	434.70	434.91	434.89
River 2	North Trib	54	5.80	434.05	434.57	434.51
River 2	North Trib	32	5.80	433.74	434.18	434.18
River 1	West Trib	410	2.97	443.95	444.35	444.35
River 1	West Trib	379	2.97	443.00	443.32	443.32
River 1	West Trib	347	2.97	442.09	442.49	442.49
River 1	West Trib	315	2.97	441.28	441.67	441.67
River 1	West Trib	281	2.97	440.13	440.54	440.54
River 1	West Trib	254	2.97	439.58	439.94	439.94
River 1	West Trib	226	2.97	438.89	439.45	439.45
River 1	West Trib	198	2.97	438.05	438.58	438.58
River 1	West Trib	171	2.97	437.50	437.88	437.88
River 1	West Trib	143	2.97	436.89	437.38	437.38
River 1	West Trib	117	2.97	436.00	436.61	436.61
River 1	West Trib	90	2.97	435.05	435.61	435.61
River 1	West Trib	54	2.97	434.50	434.97	434.97
River 1	West Trib	34	2.97	434.23	434.58	434.58
River 1	West Trib	18	2.97	433.97	434.15	

Table C.2 Existing Conditions 12 Hr Regional Storm Event Flood Elevations Associated with Cross Sections

RIVER	REACH	RIVER STATION	Q TOTAL (M3/S)	MIN CH EL (M)	W.S. ELEV (M)	CRIT W.S. (M)
River 6	Main Trib	353	15.93	431.50	432.68	
River 6	Main Trib	334	15.93	431.26	432.39	432.390
River 6	Main Trib	313	15.93	431.08	432.08	432.080
River 6	Main Trib	288	15.93	430.55	431.57	431.570
River 6	Main Trib	250	15.93	429.24	430.37	430.370
River 6	Main Trib	229	15.93	429.03	429.88	429.880
River 6	Main Trib	207	15.93	428.65	429.73	
River 6	Main Trib	181	15.93	428.30	429.73	
River 6	Main Trib	158	16.92	427.93	429.72	
River 6	Main Trib	150	16.92	427.91	429.72	
River 6	Main Trib	139	16.92	427.80	429.68	428.760
River 6	Main Trib	138 Culvert				
River 6	Main Trib	110	16.92	427.84	428.87	428.870
River 6	Main Trib	99	16.92	427.75	428.74	428.740

RIVER	REACH	RIVER STATION	Q TOTAL (M3/S)	MIN CH EL (M)	W.S. ELEV (M)	CRIT W.S. (M)
River 6	Main Trib	84	16.92	427.65	428.63	
River 6	Main Trib	59	16.92	427.21	428.44	428.370
River 6	Main Trib	35	16.92	426.93	428.43	
River 6	Main Trib	16	16.92	426.57	428.22	428.220
River 6	Main Trib	1	16.92	426.45	427.86	427.860
River 4	East Trib	120	5.21	433.18	433.55	433.550
River 4	East Trib	105	5.21	432.86	433.17	433.170
River 4	East Trib	86	5.21	432.62	432.96	
River 4	East Trib	69	5.21	432.28	432.79	432.780
River 4	East Trib	55	5.21	432.24	432.79	
River 4	East Trib	44	5.21	432.10	432.79	
River 4	East Trib	33	5.21	431.97	432.78	
River 3	North West Trib	85	9.32	432.99	433.73	
River 3	North West Trib	70	9.32	432.80	433.52	433.520
River 3	North West Trib	55	9.32	432.50	433.38	433.350
River 3	North West Trib	42	9.32	432.43	433.29	
River 3	North West Trib	29	9.32	432.26	433.26	433.150
River 3	North West Trib	22 North + West Cul				
River 3	North West Trib	17	9.32	432.06	433.09	433.090
River 3	North West Trib	11	9.32	431.89	432.99	432.990
River 2	North Trib	279	6.42	438.29	439.10	439.100
River 2	North Trib	258	6.42	437.87	438.63	438.630
River 2	North Trib	234	6.42	437.33	438.11	438.110
River 2	North Trib	210	6.42	436.97	437.58	437.580
River 2	North Trib	182	6.42	436.17	436.95	436.950
River 2	North Trib	156	6.42	435.86	436.48	436.480
River 2	North Trib	129	6.42	435.49	435.90	435.900
River 2	North Trib	103	6.42	435.10	435.38	435.350
River 2	North Trib	78	6.42	434.70	434.93	434.900
River 2	North Trib	54	6.42	434.05	434.59	434.530
River 2	North Trib	32	6.42	433.74	434.20	434.200
River 1	West Trib	410	2.97	443.95	444.35	444.350
River 1	West Trib	379	2.97	443.00	443.32	443.320
River 1	West Trib	347	2.97	442.09	442.49	442.490
River 1	West Trib	315	2.97	441.28	441.67	441.670
River 1	West Trib	281	2.97	440.13	440.54	440.540
River 1	West Trib	254	2.97	439.58	439.94	439.940
River 1	West Trib	226	2.97	438.89	439.45	439.450
River 1	West Trib	198	2.97	438.05	438.58	438.580
River 1	West Trib	171	2.97	437.50	437.88	437.880

RIVER	REACH	RIVER STATION	Q TOTAL	MIN CH EL	W.S. ELEV	CRIT W.S.
			(M3/S)	(M)	(M)	(M)
River 1	West Trib	143	2.97	436.89	437.38	437.380
River 1	West Trib	117	2.97	436.00	436.61	436.610
River 1	West Trib	90	2.97	435.05	435.61	435.610
River 1	West Trib	54	2.97	434.50	434.97	434.970
River 1	West Trib	34	2.97	434.23	434.58	434.580
River 1	West Trib	18	2.97	433.97	434.16	

Table C.3 Proposed Conditions 100 Year Storm Event

RIVER	REACH	RIVER STATION	Q TOTAL	MIN CH EL	W.S. ELEV	CRIT W.S.	E.G. SLOPE	VEL CHNL	TOP WIDTH
			(M3/S)	(M)	(M)	(M)	(M/M)	(M/S)	(M)
River 6	Main Trib	353	14.2	431.5	432.63		0.00227	1.18	35.08
River 6	Main Trib	334	14.2	431.26	432.35	432.35	0.009464	2.3	20.44
River 6	Main Trib	313	14.2	431.08	432.03	432.03	0.009208	2.12	27.35
River 6	Main Trib	288	14.2	430.55	431.54	431.54	0.008367	2.19	41.33
River 6	Main Trib	250	14.2	429.24	430.35	430.35	0.008733	2.11	40.81
River 6	Main Trib	229	14.2	429.03	429.86	429.86	0.021011	2.31	36.16
River 6	Main Trib	207	14.2	428.65	429.68		0.004913	1.73	40.96
River 6	Main Trib	181	14.2	428.3	429.68		0.000954	0.9	54.85
River 6	Main Trib	158	15.17	427.93	429.68		0.000492	0.69	50.58
River 6	Main Trib	150	15.17	427.91	429.67		0.000398	0.68	53.79
River 6	Main Trib	139	15.17	427.8	429.63	428.71	0.000687	1.05	88.16
River 6	Main Trib	138 Culvert	Culvert						
River 6	Main Trib	110	15.17	427.84	428.82	428.82	0.012203	2.64	16.35
River 6	Main Trib	99	15.17	427.75	428.71	428.71	0.007406	1.93	40.38
River 6	Main Trib	84	15.17	427.65	428.59		0.005388	1.62	39.88
River 6	Main Trib	59	15.17	427.21	428.41	428.32	0.005349	1.8	40.37
River 6	Main Trib	35	15.17	426.93	428.39		0.001882	1.39	64.48
River 6	Main Trib	16	15.17	426.57	428.14	428.14	0.005857	2.26	32.5
River 6	Main Trib	1	15.17	426.45	427.83	427.83	0.005892	1.99	58.61
River 4	East Trib	120	4.25	433.18	433.53	433.53	0.016244	1.5	48.69
River 4	East Trib	105	4.25	432.86	433.14	433.14	0.026707	1.47	20.91

RIVER	REACH	RIVER STATION	Q TOTAL	MIN CH EL	W.S. ELEV	CRIT W.S.	E.G. SLOPE	VEL CHNL	TOP WIDTH
			(M3/S)	(M)	(M)	(M)	(M/M)	(M/S)	(M)
River 4	East Trib	86	4.25	432.62	432.94		0.004477	0.68	40.2
River 4	East Trib	69	4.25	432.28	432.76	432.76	0.013115	1.65	29.83
River 4	East Trib	55	4.25	432.24	432.74		0.001721	0.61	51.33
River 4	East Trib	44	4.25	432.1	432.74		0.000383	0.31	50.73
River 4	East Trib	33	4.25	431.97	432.73		0.000514	0.39	65.43
River 2	North Trib	279	5.8	438.29	439.06	439.06	0.012258	1.89	12.56
River 2	North Trib	258	5.8	437.87	438.61	438.61	0.009898	1.77	21.28
River 2	North Trib	234	5.8	437.33	438.1	438.1	0.011179	1.87	16.28
River 2	North Trib	210	5.8	436.97	437.56	437.56	0.017255	1.75	18.59
River 2	North Trib	182	5.8	436.17	436.94	436.94	0.01033	1.76	18.59
River 2	North Trib	156	5.8	435.86	436.47	436.47	0.013938	1.73	23.27
River 2	North Trib	129	5.8	435.49	435.88	435.88	0.023035	1.76	19.91
River 2	North Trib	103	5.8	435.1	435.38		0.012958	1.03	27.14
River 2	North Trib	88	5.8	434.7	434.89	434.89	0.02672	1.24	21.71
River 2	North Trib	87	5.8	433.79	434.26		0.015382	1.52	18.86
River 2	North Trib	86	5.8	433.39	433.96		0.010839	1.36	25.13
River 2	North Trib	85	8.49	432.99	433.71		0.009424	1.4	31.51
River 2	North Trib	70	8.49	432.8	433.5	433.5	0.013185	1.86	37.21
River 2	North Trib	55	8.49	432.5	433.39	433.34	0.006982	1.49	46.8
River 2	North Trib	42	8.49	432.43	433.25	433.25	0.010259	1.83	49.18
River 2	North Trib	29	8.49	432.26	433.14	433.14	0.00647	1.55	58.28
River 2	North Trib	17	8.49	432.06	433.06	433.06	0.00438	1.54	67.22
River 2	North Trib	11	8.49	431.89	432.98	432.98	0.003973	1.45	74.24

Table C.4 Proposed Conditions 12 Hr Regional Storm Event

RIVER	REACH	RIVER STA	Q TOTAL	MIN CH EL	W.S. ELEV	CRIT W.S.	E.G. SLOPE	VEL CHNL	TOP WIDTH
			(M3/S)	(M)	(M)	(M)	(M/M)	(M/S)	(M)
River 6	Main Trib	353	15.93	431.5	432.68		0.002235	1.22	41.05
River 6	Main Trib	334	15.93	431.26	432.39	432.39	0.009415	2.37	21.05
River 6	Main Trib	313	15.93	431.08	432.08	432.08	0.008256	2.12	29.52
River 6	Main Trib	288	15.93	430.55	431.57	431.57	0.008706	2.28	42.22
River 6	Main Trib	250	15.93	429.24	430.37	430.37	0.009328	2.22	42.19
River 6	Main Trib	229	15.93	429.03	429.88	429.88	0.021523	2.4	37.21
River 6	Main Trib	207	15.93	428.65	429.73		0.004585	1.74	44.34
River 6	Main Trib	181	15.93	428.3	429.73		0.000977	0.94	58.81
River 6	Main Trib	158	16.92	427.93	429.72		0.000514	0.73	51.54
River 6	Main Trib	150	16.92	427.91	429.72		0.000422	0.72	56.92
River 6	Main Trib	139	16.92	427.8	429.68	428.76	0.000708	1.08	89.18
River 6	Main Trib	13 Culvert	Culvert						
River 6	Main Trib	110	16.92	427.84	428.87	428.87	0.012023	2.74	21.98
River 6	Main Trib	99	16.92	427.75	428.74	428.74	0.007258	1.97	42.06
River 6	Main Trib	84	16.92	427.65	428.63		0.005078	1.63	43.31
River 6	Main Trib	59	16.92	427.21	428.44	428.37	0.005416	1.87	48.4
River 6	Main Trib	35	16.92	426.93	428.43		0.001831	1.4	73.86
River 6	Main Trib	16	16.92	426.57	428.22	428.22	0.004917	2.17	47.9
River 6	Main Trib	1	16.92	426.45	427.86	427.86	0.005775	2.02	60.61
River 4	East Trib	120	5.21	433.18	433.55	433.55	0.016219	1.57	54.47
River 4	East Trib	105	5.21	432.86	433.17	433.17	0.024587	1.57	23.86
River 4	East Trib	86	5.21	432.62	432.96		0.004664	0.75	41.79
River 4	East Trib	69	5.21	432.28	432.79	432.78	0.012419	1.69	31.07
River 4	East Trib	55	5.21	432.24	432.79		0.001441	0.61	57.64
River 4	East Trib	44	5.21	432.1	432.79		0.000379	0.34	62.09
River 4	East Trib	33	5.21	431.97	432.78		0.000492	0.41	68.11
River 2	North Trib	279	6.42	438.29	439.1	439.1	0.011773	1.91	15.11
River 2	North Trib	258	6.42	437.87	438.63	438.63	0.00998	1.83	22.17
River 2	North Trib	234	6.42	437.33	438.11	438.11	0.01156	1.94	16.52
River 2	North Trib	210	6.42	436.97	437.58	437.58	0.017688	1.82	18.87
River 2	North Trib	182	6.42	436.17	436.95	436.95	0.01082	1.84	19.07

RIVER	REACH	RIVER STA	Q TOTAL	MIN CH EL	W.S. ELEV	CRIT W.S.	E.G. SLOPE	VEL CHNL	TOP WIDTH
			(M3/S)	(M)	(M)	(M)	(M/M)	(M/S)	(M)
River 2	North Trib	156	6.42	435.86	436.48	436.48	0.014645	1.81	23.47
River 2	North Trib	129	6.42	435.49	435.9	435.9	0.021231	1.79	22.22
River 2	North Trib	103	6.42	435.1	435.4		0.012916	1.09	30.01
River 2	North Trib	88	6.42	434.7	434.9	434.9	0.026255	1.29	22.13
River 2	North Trib	87	6.42	433.79	434.28		0.015646	1.55	19.12
River 2	North Trib	86	6.42	433.39	433.98		0.010715	1.37	27.5
River 2	North Trib	85	9.32	432.99	433.73		0.009455	1.43	34.72
River 2	North Trib	70	9.32	432.8	433.52	433.52	0.013021	1.9	41.25
River 2	North Trib	55	9.32	432.5	433.39		0.007745	1.59	47.6
River 2	North Trib	42	9.32	432.43	433.26	433.26	0.00953	1.81	51.79
River 2	North Trib	29	9.32	432.26	433.14	433.14	0.007256	1.65	58.94
River 2	North Trib	17	9.32	432.06	433.08	433.08	0.004427	1.57	70.53
River 2	North Trib	11	9.32	431.89	432.99	432.99	0.004361	1.53	74.91