



A.

Terms of Reference

PREPARED BY STANTEC CONSULTING LTD, GEOPROCESS RESEARCH ASSOCIATES INC. AND PALMER ENVIRONMENTAL CONSULTING GROUP (PART OF SLR CONSULTING LTD) ON BEHALF OF THE ELFRIDA COMMUNITY BUILDERS GROUP INC.

Elfrida - SWS Terms of Reference

Elfrida Subwatersheds Study

6/25/2025

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1.0 INTRODUCTION

1.1. Study Area

The Elfrida Community Builders Group Inc. has retained GeoProcess Research Associates Inc. (GeoProcess), Palmer Environmental Consulting Group part of SLR Consulting Ltd. (Palmer/SLR), and Stantec Consulting Ltd. (Stantec), “the consultants”, to prepare an Elfrida Subwatersheds Study and provide environmental direction for land use decisions in the Elfrida study area. The proposed Elfrida Study Area is approximately 1,233 gross hectares and is generally bounded by Trinity Church Road to the west, Golf Club Road to the southwest/south, Hendershot Road to the southeast/east, Mud Street to the northeast and the existing Urban Boundary to the north (i.e., study area), should the lands be included in the settlement area. A detailed map of the study area is in Figure 1 of this Term of Reference (TOR). The Elfrida study area falls within five (5) subwatersheds: Twenty Mile Creek, Sinkhole Creek, Stoney Creek, Upper Davis Creek, and Hannon Creek. The Hannon Creek Subwatershed Study is currently being undertaken through the Upper Hannon Creek Master Drainage and Servicing Study (HCMDSS) assignment. The recommendations coming out of the HCMDSS will be included in the overall Elfrida Subwatersheds Study.

Figure 1: Elfrida Study Area and Subwatersheds

1.2. Background

On May 18, 2006, the City of Hamilton’s (the City) Council endorsed GRIDS (Growth Related Integrated Development Strategy), which identified the Elfrida area as part of the preferred “Nodes and Corridors” scenario to accommodate residential growth to the year 2031. The Elfrida area was included in this scenario as a key location to meet residential land needs. This designation positioned Elfrida as one of the City’s next major mixed-use growth areas.

Building on this direction, the City included the Elfrida lands as an Urban Expansion Area (Neighbourhoods) in the Urban Hamilton Official Plan (UHOP), recognizing the area’s long-term potential to accommodate future urban development. The UHOP was adopted by City Council in 2009 and came into effect in 2013. The UHOP provides city-wide direction on land use, infrastructure, and environmental management, with specific policies in Chapter B and Chapter C.2 focused on protecting natural heritage systems, managing hazard lands, and guiding development in a way that supports ecological integrity. Complementing this, the Rural Hamilton Official Plan (RHOP) governs land use in the City’s rural areas and includes policies that protect agricultural lands, rural character, and natural features, while also guiding the transition of rural lands into urban uses where appropriate.

In 2022, the Province imposed an expansion of Hamilton’s urban boundary to include additional rural lands. However, following significant public opposition, the Province reversed this decision on October 23, 2023, through the introduction of Bill 150, and restored the City’s original urban boundary. Despite this reversal, a Subwatershed Study for the Elfrida area had already been initiated in 2023 to assess existing environmental conditions and constraints. This included a desktop review of natural heritage

features, watercourses, floodplains, and headwater drainage features, as well as preliminary field surveys conducted in summer and fall 2023.

Following the Province's reversal and the preliminary work completed under the Subwatershed Study, an Urban Boundary Expansion (UBE) application was submitted to the City in April 2025 by the Elfrida Community Builders Group Inc. for the Elfrida lands. The findings submitted as part of the UBE application will partially inform the Phase 1 Report of the Subwatershed Study, anticipated for completion in fall 2025. In accordance with the City's *Appendix F: Subwatershed Study (Phase 1) (Urban Boundary Expansion)*, should the UBE application be approved, the Phase 1 findings will be integrated into subsequent Phase 2 and Phase 3 work for the Subwatershed Study, to be completed through the Secondary Planning process.

1.3. Purpose & Objectives

The purpose of the Elfrida Subwatersheds Study is to develop a plan that allows sustainable development, while ensuring maximum benefits to the natural and human environments on a watershed basis. The Subwatersheds Study is intended to present an approach to manage resource use that will protect, rehabilitate, and enhance the environment within the Elfrida study area limits, as well as downstream. Some subwatersheds within the study area have existing downstream conditions and constraints beyond the identified study area, which shall be considered in the study objectives and ultimate targets.

The Subwatersheds Study will provide the following:

- Identification of the locations, extents, present statuses, significance, and sensitivities of the existing natural heritage feature;
- Identification of sensitive areas and hazardous lands, as well as recommended buffers and appropriate management practices;
- Identification of lands where development may be permitted, and determination of how existing and future land uses can be integrated compatibly with natural features;
- Direction on best management practices (BMPs) (from a drainage perspective);
- Direction on future infrastructure needs (from a drainage perspective);
- Implementation strategies and requirements for environmental monitoring; and,
- Technical information to assist in the development of a Secondary Plan, and the completion of Class Environmental Assessment process.

2.0 SUBWATERSHEDS STUDY STAGING

The Subwatersheds Study will be conducted in three stages:

Stage 1 – Subwatersheds Characterization

Stage 2 – Subwatersheds Management Strategies

Stage 3 – Implementation and Monitoring Plans

For each study component, the level of investigation may vary across subwatersheds, but shall be sufficient to provide a level of details to support the decision-making process of the Subwatersheds Study,

and to meet the study's goals and objectives to the satisfaction of the City of Hamilton and the Technical Steering Committee. The Technical Steering Committee is anticipated to consist of multidisciplinary professionals from the City and respective Conservation Authorities, including the Niagara Peninsula Conservation Authority (NPCA) and Hamilton Conservation Authority (HCA). It is also noted that each subwatershed is distinct and may require different assessments, management strategies, and approaches based on their unique characterizations. The geographic scope and level of investigation undertaken for each study component shall be explained and justified in the report.

2.1. STAGE 1 – SUBWATERSHED CHARACTERIZATION

During Stage 1, the subwatersheds shall be characterized and a preliminary statement of constraints and opportunities shall be developed. Information shall be obtained through three levels of investigation, including:

- (i) A review of secondary sources (compiling information from existing documents);
- (ii) Reconnaissance-level fieldwork; and,
- (iii) Detailed fieldwork.

The consultants shall review existing information relevant to the Elfrida Subwatersheds Study. Documents to be reviewed include:

- Provincial Policy Statement (2024)
- City of Hamilton Rural Official Plan (as Amended, 2023)
- City of Hamilton Urban Official Plan (as Amended, 2023)
- City of Hamilton Climate Change Action Strategy (2024)
- City of Hamilton Biodiversity Action Plan (2024)
- City of Hamilton Urban Forest Strategy (2021)
- City of Hamilton Stormwater Master Plan – Class Environmental Assessment Report, May 2007
- City of Hamilton Environmental Impact Statement Guidelines
- City of Hamilton Green Standards and Guidelines for Site Servicing (Stormwater)
- City of Hamilton Comprehensive Development Guidelines
- City of Hamilton Linkage Assessment Guidelines (March 2015)
- Ministry of Environment, Conservation and Parks DRAFT Subwatershed Planning Guide (January 2022)
- Upper Hannon Creek Master Drainage and Servicing Study
- Stoney Creek and Battlefield Creek Flood and Erosion Class EA, AMEC, September 2011
- Niagara Peninsula Conservation Authority Twenty Mile Creek Watershed Study, 2006
- Niagara Peninsula Conservation Authority Twenty Mile Creek Flood Plain Mapping Study Report, 2007
- Niagara Peninsula Conservation Authority Sinkhole Creek Flood Plain Mapping Study Report, 2006
- Niagara Peninsula Source Protection Assessment Report, including Niagara Peninsula Conservation Authority Groundwater Study, Waterloo Hydrogeologic, Inc., 2005

- Water Availability Study for the Twenty Mile Creek Watershed Plan Area, Niagara Peninsula Source Protection Area, AquaResource Inc. and Niagara Peninsula Conservation Authority, 2009
- Significant Groundwater Recharge Area Delineation, Niagara Peninsula Source Protection Area, AquaResource Inc. and Niagara Peninsula Conservation Authority, 2009
- Groundwater Vulnerability Analysis, Niagara Peninsula Source Protection Area, Niagara Peninsula Conservation Authority, 2009.
- Updated Assessment Report, Niagara Peninsula Source Protection Area, Niagara Peninsula Source Protection Committee, 2013
- Hamilton Groundwater Resources Characterization and Wellhead Protection Partnership Study, Charlesworth and Associates, and SNC-Lavalin Engineers and Constructors Inc., 2006
- Geologic Hazard Mapping Study, Karst Topography, Phase 1, Niagara Peninsula Conservation Authority Watershed Area, Terra-Dynamics, 2006

Additional documents may be recommended by the Technical Steering Committee for review. The Technical Steering Committee will provide the consultants with a list of GIS and environmental databases relevant to the study and will make available to them information from these sources upon request.

The consultants shall document background data used to prepare the subwatersheds study, listing its source and format (e.g. municipal report/agency website/personal communication). For map data, the map scale shall be specified. The list of source materials shall follow a generally accepted bibliographic format.

A paragraph summary of each document from which information was used to prepare the Elfrida Subwatersheds Study. For each source, a brief (single paragraph) review shall be produced, summarizing the source's contents, describing its relevance to the subwatersheds study, and indicating the level of details, i.e. for species occurrence records site, Ecological Land Classification (ELC) polygon, or Universal Transverse Mercator (UTM) co-ordinates.

Once all the background data has been collected, the requirements for additional information shall be determined, and a proposed program for collecting new data shall be outlined to the collection program. Required studies are discussed below and data requirements are outlined in Appendix A: Suggested Data Collection Requirement.

2.1.1. Hydrology and Hydraulics

Background information on the study area is to be collected from all available sources, refer to Appendix A: Suggested Data Collection Requirement. Maps of the associated data collection locations shall be provided. In addition, the mapping of each watershed's (Twenty Mile Creek, Sinkhole Creek and Stoney Creek's) physical features (e.g. watershed boundary, major watercourses, drainage swales and wetland features) shall be verified, and subwatersheds shall be delineated, and nodes at points of interest shall be established with development interests, environmental features, and / or watercourse system importance.

A detailed hydrologic model shall be developed for the subwatersheds' existing condition for all events storms, ranging from 25 mm, 2, 5, 25, 100 years up to and including the Regional Storm.

The consultants shall develop a water balance model based on the output of the hydrologic model and hydrogeology of the area. The water budget shall include a monthly estimate of precipitation, evapotranspiration, runoff and infiltration, including groundwater recharge / discharge estimations.

The consultants shall be responsible for the numeric modelling to establish the baseline hydrology and hydraulics of the subwatershed systems. The exercise should meet the accuracy and completeness to provide a comprehensive understanding of the existing condition of the study area, including an inventory of creeks, road crossings (culverts and bridges), stormwater facilities, etc. The current drainage systems and outlets shall be identified with drainage constraints and opportunities. The intent of modelling is to provide the details required for secondary planning, and identify additional criteria for water quality control, baseflow targets, infiltration targets, erosion and flood control targets.

The model shall be evaluated for comparable flows at the subwatershed outlets to those determined in the previous watershed studies for the given watercourses, if such studies exist, and/or against regional regression charts for headwater watercourses in Ontario. The model input parameters shall be compared to previous studies and modified to represent more detailed subwatershed model. Hydrographs are to be established at the key nodes in the study area for all event storms, from 2-year to up to and including the Regional Storm. For established watercourses located in the study area, hydraulic analysis shall be conducted. Flood lines shall be established for the greater of the 100-year storm or Regulatory Storm for existing conditions. For the creeks that have flood plain delineation, as identified in previous studies, the flood lines shall be updated to reflect the current surveyed conditions. The flood plain delineation includes the hydraulic modelling, using the Hydrologic Engineering Centers River Analysis System HEC-RAS model from the U.S. Army Corps of Engineers, to generate the associated flood lines based on the hydrographs established with the hydrologic analysis conducted for this subwatersheds study. The Conservation Authorities' Flood Plain Mapping Standards will be referred to, as to the approaches for survey, hydrology, hydraulics and flood plain maps.

The proposed detailed hydrology plan for this study is included in **Appendix B: Proposed Hydrology Plan**. The plan includes use of the following potential models:

1. Visual OTTHYMO and/or U.S. Army Corps of Engineers Hydraulic Modelling Center Hydrologic Modeling System (HEC-HMS) are the anticipated models to be selected for hydrology to ensure consistency with the background models applied by the respective Conservation Authority
2. Modelling is to be established for discrete design event simulations, to produce runoff hydrographs at the nodes of interest in the study area and to size the required Stormwater Management (SWM) facilities;
3. HEC-RAS hydraulic models will be developed for determining and/or updating the existing watercourse hydraulics and flood elevations.

The consultants will justify the applicability and sufficiency in utilizing any of the given numerical models. The modelling exercises should ensure the hydrology and hydraulics features are quantified for each watershed within the study area.

2.1.2. Hydrogeology

The goal of this subwatersheds study with respect to hydrogeology is to establish a geological conceptual model for the study area, determining the key characteristics of the bedrock and overburden systems, in addition to their functions in terms of controlling groundwater movement, availability, and quality in these subwatersheds. An integral component is to assess the interactions between the groundwater system and the surface water system, and to determine the overall role or function of these interactions in an ecosystem context. It is also important to have an understanding of the effects of future development on the local groundwater resource to assist in the need and implementation of low-impact development.

In order to accomplish the above goals, the consultants shall integrate all of the data collected in Stage 1 to develop a detailed understanding of the hydrogeological processes operating within the subwatersheds. The consultants shall:

- Conduct a detailed site reconnaissance to identify surface watercourses, areas of visible groundwater discharge and recharge, and areas of groundwater piezometer installations. Particular focus shall be placed on identification of sinkholes and their outlets typical of karst topography;
- Carry out a karst geology study of the site to the satisfaction of a karst expert agreed upon by the Technical Steering Committee. The study shall identify any significant karst features, delineate any hazardous lands as a result of karst, and identify and characterize key subsurface flow paths within the karst. Groundwater tracing using fluorescent dyes may need to be carried out at selected locations to understand subsurface hydrology and geology;
- Review and compile the following hydrogeological information from the relevant Source Protection Plan; Identify and address any data gaps:
 - General delineation of aquifers and karst topography
 - Well locations as obtained from the MOE well record database
 - Areas of ground or surface water takings as permitted by the MOE
 - Areas of significant groundwater recharge or discharge
 - Areas susceptible to contamination
 - Areas suitable for stormwater infiltration
- Drilling of boreholes at twenty-two (22) locations with each borehole advanced to a depth of approximately 6 m and equipped with a single monitoring well.
- Drilling of boreholes at four (4) locations, with each location consisting of a multi-level monitoring well installation (i.e. A shallow overburden and deeper bedrock monitoring well, each installed into a separate borehole). Assume that the overburden monitoring well will be drilled to a depth of six (6) meters below ground surface (BGS), with the deeper monitoring well being drilled to a depth of 10 m BGS and screened in the bedrock. The purpose of the multi-level monitoring wells

will be to evaluate vertical hydraulic gradients and groundwater interaction / flow between the overburden and bedrock groundwater systems and provide further insight into potential groundwater source contributions to local watercourses throughout the Secondary Plan Area.

- Each monitoring well is to be constructed of 50 mm inside diameter, Schedule 40 polyvinyl chloride (PVC) pipe, having a No. 10 slot screen (0.01-inch slot) measuring from 1.5 to 3.0 m in length. Backfilling of the screened interval consisted of No.3 grade silica sand to a height of 0.3 m above the top-of-screen, followed by granular bentonite (which is to be gradually hydrated through the pouring of water down the annular space throughout the installation process) to ground surface to prevent a hydraulic connection from occurring between the screened formation and overlying soils. The monitoring well stick-up is to be encased in a lockable steel casing, with the base of this casing being cemented into place.
- Install a series of drive-point piezometers (assume 14 piezometers) across the study area, when considered necessary by the Technical Steering Committee, to determine water table levels, assess shallow groundwater flow directions, and determine the functional relationships between the shallow aquifers and Sinkhole, Twenty Mile and Stoney Creeks;
- All monitoring well and drive-point piezometers are to be surveyed for elevation (i.e., ground surface and top-of-pipe) to a geodetic benchmark. This information is required to effectively construct groundwater elevation contours and, subsequently, interpret groundwater flow direction throughout the Secondary Plan Area.
- Establish pre-development infiltration targets to preserve and/or enhance existing groundwater recharge function under the post-development condition at the sub-catchment level.
- Perform two (2) rounds of in-situ stream flow measurements (coinciding with drive-point piezometer locations) under baseflow conditions (i.e., during summer to early fall on days where the preceding three or more consecutive days experienced no rainfall) to be used in combination with piezometer vertical hydraulic gradient measurements to confirm the groundwater recharge and/or discharge function of the watercourse(s). The stream flow monitoring program should first utilize existing monitoring data from sources of Conservation Authorities, municipalities and other available studies. The monitoring could also be combined with the flow monitoring that is necessary to calibrate the hydrologic model;
- Combined manual (discrete) and automated (continuous) measurements of groundwater levels from the monitoring wells and drive-point piezometers for a one-year period to capture seasonal fluctuations in levels within aquifer system and surface water features. Assume that each monitoring well and drive-point piezometer will be equipped with a data logger.
- Excavate a total of 12 test pits in identified SGRA and non-SGRA throughout the Secondary Plan Area. Assume that each test pit will be excavated to a depth of 1.5 m BGS. Where conditions are suitable (i.e., above water table) perform in-situ permeability testing of the native soil (i.e., not topsoil) at the base of the test pit using a Guelph Permeameter, with these data being used to complete a preliminary assessment of the soil suitability for future low impact development (LID) stormwater management practices.
- Collect groundwater quality samples from fifteen (15) of the monitoring wells for general inorganic chemistry, dissolved metals (i.e., collected samples to be field filtered), petroleum

hydrocarbons, and volatile organic compounds, with these data serving as a benchmark for the assessment of potential future development impacts to groundwater quality.

- Identify potential impacts of construction and development on the features and functions of surface water and groundwater systems;
- Identify hazard lands in GIS mapping (particularly those relating to karst), in accordance with MNR Guidelines, regarding the Natural Hazards Policies of Section 3.1 of the Provincial Policy Statement;
- Identify hydrogeological sensitive areas and hazardous lands (i.e., karst features) and recommend potential management strategies for such features.
- Hydrogeological characterization of the Secondary Plan Area shall include the following features/considerations:
 - Hydrogeological Investigation Plan / Groundwater Monitoring Locations
 - Monitoring Well and Drive-Point Piezometer Hydrographs
 - Physiography
 - Topography
 - Surficial Geology
 - Karst Geology / Hazardous Lands
 - Significant Groundwater Recharge Areas
 - Highly Vulnerable Aquifers
 - Potential Groundwater Discharge Areas
 - Depth to High Groundwater Table
 - Groundwater Flow
 - Pre-Development Water Balance Target Plan

The proposed detailed hydrogeology plan for this study is included in Appendix C: Proposed Hydrogeological Plan.

2.1.3. Stream Morphology

Some of the objectives concerning aquatic habitats within the Elfrida study area are to protect the morphological and fluvial character of the streams, restore sinuosity (where appropriate and feasible), maintain physical habitat attributes (e.g. pools, riffles, etc.), habitat diversity, and fluvial processes (e.g. bed load transport, energy reduction through sinuosity, etc.), and to prevent increased erosion and deposition (processes that can be negated by the maintenance of the hydrological regime).

The consultants shall review available data collected during the Conservation Authorities' Watershed Studies, as well as other existing data sources. This data was used as a reference when the retained consultants completed updated field investigations. Where previous data was unavailable, the consultants characterized each reach of the streams (where site access was granted) using industry-standard methods. Drones were used to collect information about stream morphology in inaccessible areas. The baseline morphological assessment will include a detailed inventory of the stream morphology observations, including stream characterization and flood / erosion considerations. Baseline data

requirements and standards for downstream monitoring will be based on the assessment of a qualified fluvial geomorphologist.

2.1.4. Channel Erosion

The consultants will undertake an erosion hazard analysis, based on fluvial geomorphological data collected during field investigations. This analysis shall be completed to understand erosional processes within the Elfrida study area, to identify areas that are highly prone to erosion, to document where erosion is occurring, and to determine where current and future structures may be at risk of erosional processes. The erosion hazard analysis also determined the threshold flows for erosion at strategic points within the subwatersheds to assist with informing an appropriate erosion control SWM strategy. Thus, the comprehensive assessment will identify sites most sensitive to erosion covering the entire Elfrida study area. It should be noted that the Stoney Creek and Battlefield Creek Flood and Erosion Class EA (September 2011), which evaluates subwatersheds downstream of the study area, identified several issues and concerns, which will be considered as part of the Subwatershed Study.

One approach for the assessment of erosion potential is included in Appendix D: Tractive Force Analysis. Erosion thresholds and associated critical discharges shall be established at locations of erosion concern within the study area. The consultants will identify and develop the method, with the Technical Steering Committee's approval, to examine high erosion potential areas, bank erosion concerns and erosion thresholds.

The downstream work, to next flow node at the specific subwatersheds outlets, shall be linked to the erosion hazard assessment from the future secondary plan area development. The intent of the Subwatersheds Study is that any new development will maintain flows in accordance with existing conditions. At the time of the future proposed development, if developments cannot meet pre-development conditions, then downstream conditions will need to be studied in greater detail to ensure there are no impacts to downstream areas.

2.1.5. Aquatic Environment

There are a variety of aquatic core features that have been identified as part of the Natural Heritage System within the Rural Hamilton Official Plan. These features include:

- A Local Natural Area - Earth Science Area of Natural and Scientific Interest (ANSI)
- Significant Woodlands
- Wetlands
- Lakes and littoral zones
- Watercourses

The consultants have assessed fisheries and benthic invertebrate communities within the subwatersheds. When assessing these communities, the federal, provincial, and local rankings of these aquatic species were considered. In addition to this, stream and headwater drainage feature (HDF) classifications were determined based on applicable guidelines. Thermal regimes (i.e., cold, cool and warm water designations) were identified using available data. An assessment of stream barriers and on-line ponds

shall also be conducted, and temperature survey data collected to verify the thermal regimes attained from background resources. Where applicable, the criteria / guideline and considerations contained in Table 1 (see below) forms the basis for evaluating aquatic habitats within the Elfrida study area.

Through review it is noted that certain subwatersheds have more background information than the others. Stoney Creek Subwatershed, for instance, was deemed to be lacking existing aquatic information, thus additional field reconnaissance of the subwatershed shall be conducted. To ensure consistency between the subwatersheds, detailed field assessments of the aquatic environments will be undertaken. Maps identifying the results of the aquatic investigations shall be provided upon completion of the comprehensive assessment.

Surveys shall be completed within the appropriate seasonal window in accordance with applicable protocols and guidelines. The detailed survey protocol for benthic invertebrate sampling can be found in Appendix E: Proposed Protocol to Sample Benthic Invertebrates.

Table 1: Aquatic Environment Inventory Requirements

Biophysical Inventory	Inventory Requirements
Fisheries Assessment	Electrofishing shall be completed by certified ecologists during the appropriate survey window following acceptable protocols (i.e., Ontario Stream Assessment Protocol (OSAP)).
Habitat Assessment	Watercourse / stream habitat features classified as per modified OSAP protocol.
Benthic Invertebrate Assessment	Benthic invertebrate communities assessed in the spring and fall in flowing watercourses using acceptable protocols (i.e., Ontario Benthos Biomonitoring Network (OBBN) protocols). Benthic invertebrates will be identified to family level, at a minimum.
HDF Assessments	HDFs will be classified using Evaluation, Classification and Management of Headwater Drainage Features Guidelines (CVC & TRCA, January 2014). Surveys will be completed during spring freshet, early spring, and the summer, as outlined in the guidelines.

Biophysical Inventory	Inventory Requirements
Species at Risk (SAR) Screening	Screenings will include the review of records from available sources (i.e., the Natural Heritage Information Centre (NHIC), the Ministry of Natural Resources (MNR), municipal lists, conservation authority databases, and the Department of Fisheries and Oceans Canada (DFO)) and will be compared to the most up to date Species at Risk in Ontario (SARO) list (2025). Species observed during aquatic surveys will also be compared to the 2025 SARO list.

The data collected will be used to ensure that future development will have no negative impacts on fish habitat or the ecological functions for which the area has been identified.

2.1.6. Terrestrial Environment

An assessment of terrestrial resources in the Elfrida study area will be undertaken. The Natural Area Inventory works from NPCA and HCA will be consulted as a reference. Data collected shall be used to ensure that future development has regard to Section 4.1 of the Provincial Planning Statement. The criteria for evaluating the terrestrial features will adhere to the requirements outlined in Table 2 below. Depending on the vegetation community Ecological Land Classification (ELC) results and habitats determined to be present in the Elfrida study area, it may be appropriate to undertake targeted surveys for certain taxa or species on a property-by-property basis at the time of proposed development (i.e., snag tree surveys and acoustic monitoring). Significant Wildlife Habitat Eco-Region 7E Criteria Schedule (MNR, January 2015) will be used in conjunction with the Significant Wildlife Habitat Technical Guide when assessing the Elfrida study area for Significant Wildlife Habitat.

Table 2: Terrestrial Environment Inventory Requirements

Biophysical Inventory	Inventory Requirements
Vegetation Community Identification	Use Ecological Land Classification (Lee <i>et al.</i> , 1998) to classify vegetation communities.
Botanical Inventory	A three (3) season survey (spring, summer, and fall) to identify plant species.
Desktop Evaluation of Unclassified Wetlands and ELC Characterization	Use MNRF wetland evaluation system (MNRF, 2023) for desktop classification of unevaluated wetlands supported by ELC for vegetation community characterization.

Biophysical Inventory	Inventory Requirements
Breeding Bird Surveys	Two (2) surveys at least 10 days apart; the first between May 24th and June 15th and the second between June 15th and July 10th using Ontario Breeding Bird Atlas protocol.
Amphibian Breeding Surveys	Three (3) surveys between April and July 5th corresponding to specific nighttime temperatures of >5°C, >10°C and >17°C using the Marsh Monitoring Protocol.
Reptile Surveys	<p>Use active searching or other commonly accepted protocols/methods (April-July and September-October) to be completed during other field investigations.</p> <p>A desktop-based assessment will be conducted to complete a screening of the potential presence of snake species.</p>
Incidental Wildlife Observations	Sightings of mammals, insects, birds, and herptiles.
Species at Risk Screening	Screening should include results from all available sources (i.e., Natural Heritage Information Centre (NHIC), MNRF Municipal Lists, Conservation Authority databases, professional experience, etc.).
Assessment of Significant Wildlife Habitat	This assessment will utilize the MNRF's Significant Wildlife Habitat Technical Guide (2000) and SWH Eco-Region 7E Criteria Schedule and may include seasonal wildlife concentration areas, rare vegetation communities, specialized wildlife habitat, habitat for species at risk, and animal movement corridors.
Winter Wildlife Tracking Surveys	

The landscape level analyses are required to identify terrestrial features connectivity, species movement, percent natural cover, etc.; while detailed field assessment of the terrestrial resources shall be provided to characterize the terrestrial environment and establish a baseline terrestrial environment for the study area, including the proximity to, and the degree of linkage with other habitats. When assessing species, status should include federal, provincial and local rankings. In addition, maps that identify natural heritage features and the results of terrestrial investigations shall be provided.

2.1.7. Surface Water Quality

Background information shall be used to define the baseline water quality in the subject study area, with a focus on sediment loadings in the surface water environment. Both NPCA and HCA have surface water quality monitoring stations within or downstream of the study area. Where available, the existing dataset shall be reviewed to understand the existing water quality status of the study area. Where background information is unavailable, a water quality sampling program shall be conducted for each subwatershed as described in Appendix A: Suggested Data Collection Requirement to assess baseline water quality conditions. The existing water quality status shall be assessed to provide the baseline reference and identify any water quality concerns and constraints in the study area. Whenever possible, the water quality sampling should be conducted at the same location and time as when benthic surveys are conducted. The study will also identify any existing SWM pond and the respective catchment areas, as the baseline reference for stormwater management in terms of water quantity/ quality control.

2.1.8. Stage 1 Report – Subwatershed Characterization

At the completion of Stage 1, the general characteristics of the subwatersheds area will be identified and a clear understanding of the major issues and opportunities. The Stage 1 report will provide the general characteristics of the Elfrida study area, which will act as the starting point from which the Secondary Land Use planning can occur. The Stage 1 report shall consider climate change in accordance with the Provincial Policy Statement.

The Phase 1 report shall include a:

- Summary of background literature and data reviewed;
- Subwatersheds characterization based on the findings of the initial subwatersheds study;
- Summary of the subwatersheds major issues, concerns and constraints; and,
- Summary of the potential opportunities for improvement or enhancement.

The following are considerations to determine the constraint analysis. The constraints shall be assessed with consideration of the core features and linkages, in accordance with the policy and definitions as indicated in the Official Plans.

- High Constraint: Native communities with highly significant habitat attributes present and / or with severe slope constraints and / or located directly adjacent to the permanent watercourse. High constraints should be protected.

- Medium Constraint: Native communities with moderately significant habitat attributes present and / or with moderate slope constraints and / or associated with imperfect drainage and may include successional communities. Features protected and integrated into development where feasible; if not protected, opportunities to replace these features should be examined.
- Low Constraint: Cultural communities with limited significant habitat attributes present, no slope constraints and not associated with hydrological linkages. These features don't represent direct constraints to development and represent opportunities for habitat restoration.

2.2. STAGE 2 – SUBWATERSHED MANAGEMENT STRATEGIES

Based on data obtained in Stage 1 through the review of background information sources and supplementary fieldwork, Stage 2 involves assessing the impacts of future land use changes on the natural environment within the study area. The findings from the Stage 1 characterization work, completed for various disciplines, will be considered in an integrated manner in developing the subwatershed management strategies. The Stage 2 work will be completed concurrently to the land use plan, transportation plan and water / wastewater servicing plan. The intent of Stage 2 is to develop the management strategies that

- protect the critical elements of the subwatershed;
- prevent environmental degradation;
- provide adequate flexibility for integration with adjacent development and redevelopment areas;
- assist in the establishment of open space linkages;
- identify opportunities and constraints to development;
- provide a strategy to manage existing land uses;
- detail location and area requirements for stormwater management facilities;
- provide conceptual sizing recommendations for existing and proposed watercourse crossings; and
- identify restoration and enhancement opportunities.

In Stage 2, a detailed analysis shall be completed to assess the impacts of future land use changes on the subject study area. Different options for mitigating these impacts shall be reviewed and management strategies shall be recommended. The proposed assessment of future land use changes shall include multiple future scenarios. This should include considerations of a scenario that allows for enhancement of environmental conditions by incorporating the use of a connected network of environmental features and functions, as well as low impact development practices for industrial, commercial and institutional (ICI) lands to help sustain the local groundwater resource. In addition, constraint and opportunity mapping shall be provided.

2.2.1. Hydrologic Analysis

A hydrologic analysis shall be conducted for the future development conditions to determine post-development flows, hydrographs and water balance.

The existing conditions model shall be modified to reflect post-development conditions for all event storms, ranging from 25 mm, 2, 5, 25, 100 years up to and including the Regional Storm. It shall be used to determine the potential impacts on surface water, groundwater and water balance, with details of infiltration and runoff character changes. Surface water and groundwater interaction changes shall be addressed due to land use changes on the prevalent karst topography in the study area. The hydrologic analysis will:

- Delineate a discretized drainage area plan based on potential development;
- Develop a Model schematic diagram;
- Calculate post-development flows for all event storms at the predetermined locations, as per discretized drainage area plan and model schematic diagram within the study area. The post-development flows shall be compared to existing flows for all storm events at the hydrologic nodes of interest to help inform a proper water quantity control strategy;
- Conduct the water balance assessment at the nodes of interests. Estimate the fraction of flows, which will be maintained within the watercourses, versus the fraction, which will be lost to the sinkholes. The water balance for the study area shall be completed in consultation with a hydrogeologist, and shall include an estimate of precipitation, evapotranspiration, runoff and infiltration, in addition to the groundwater recharge and discharge;
- Identify constraints related to imperviousness and intensity of development. Assess the requirement and/or performance of proposed stormwater management facilities; Consideration shall also be given to the timing, phasing and types of stormwater management measures;
- Develop stormwater management strategies on the principles of source control, conveyance control, and end of pipe treatment;
- Investigate/screen potential Low Impact Development (LID) designs for industrial, commercial and institutional (ICI) lands, when groundwater recharge and discharge is critical;
- Assess the future infrastructure discharge impacts on the local creek and lake systems.

Refer to Appendix B: Proposed Hydrology Plan in assessing future development conditions. The future development impact assessment should evaluate the impacts on both runoff volumes and peak flow rates.

2.2.2. Hydrogeology

The hydrogeology analysis shall examine the impact of future development and land use changes on groundwater systems. It may need to investigate the rural septic systems for potential interactions with sub-surface aquifer systems. It will make recommendations to adequately protect groundwater from both water quality and quantity perspectives. The hydrogeology plan also prevents disturbing the significant recharge/discharge areas identified in Stage 1. The hydrogeological component of the subwatersheds investigation shall:

- In accordance with the recharge / discharge areas delineated in Stage 1, ensure the groundwater sensitive areas are recognized and protected from future urbanizing and disturbances;

- Within the water balance assessment, conduct an overall groundwater budget, at the pre-determined nodes of interest in the study area and the subwatersheds outlet, along with the surface water components for both existing and future scenarios.

2.2.3. Hydraulics

The existing hydraulic condition shall be reviewed in the context of the proposed development, with the land use changes, runoff increases and/or channel modifications. The study shall assess the impacts of the proposed development on watercourse water levels, flow velocities and water surface profiles for all storm events. Any potential erosion and flood concerns due to the proposed development shall be identified. Current flood line information shall be updated for post-development scenarios, using HEC-RAS models in accordance with standards set out in the Flood Damage Reduction Program. The model shall be modified with the updated topography, such as the changes in channel morphology, cross sections, bank lines, culverts and bridges, etc. Backwater analysis is expected where flows are constrained due to flatness or downstream conveyance limitations. Additional hydraulic tools may be required to address the headwater area, where channels are not well defined.

The updated flood lines are to be presented on the maps, with Regulatory Storm flood line locations and cross sections identified with flood elevations. The overtopping depths, caused by the Regional Storm, shall be assessed and documented on existing roads at all crossing structures. The flood plain maps should confirm the post-development flood levels are in consistent with the current condition. Any changes in the flood inundation magnitude must be listed in inventory, with explanations of such changes. Any stormwater management (SWM) strategies, required to match the post-development flows to existing conditions, shall be identified and to be addressed as prescribed quantity control criteria.

2.2.4. Stream Morphology and Erosion Analysis

The continuous erosion analysis for existing condition shall be updated with the future development scenarios. Erosion potentials for the study area shall be estimated by applying the existing channel / bank conditions and the post-development flows to the same cross sections, as outlined in the proposed methodology in Appendix D: Tractive Force Analysis. Appropriate mitigation measures shall be recommended for sections showing a significant increase (minimum of 5%) in erosion potential. Stormwater management criteria shall be established for the proposed development to ensure there is no increase in downstream erosion.

Natural channel design principles as outlined by the Province in Natural Channel Systems, “An Approach to Management and Design”, MNR, 1994 (or most recent update) and/or “Adaptive Management of Stream Corridors in Ontario”, MNR 2002 (or most recent update) as referenced by the City of Hamilton. These natural channel design principles shall be applied in reaches where it has been previously altered, or will be reconstructed through the development process, or where it has been determined that enhancements are required due to the morphological condition of the watercourse. Based on the results presented in Stage 1, the consultants shall identify which watercourses and drainage features in the proposed development area are stable and have sufficient conveyance capacity; and which need restoration or alteration through natural channel design approaches. Stream morphology shall be

assessed in the downstream areas of future development areas, with a focus on the existing and potential erosion concerns. Existing and future development impacts shall be evaluated with development strategy indicated to limit the negative impacts, while accommodating opportunities to restore and improve the existing channel condition.

For areas of new development, the size of the channel corridor, necessary to allow natural channel design to occur, shall be determined. The natural channel design information, on which the preliminary assessments are made, shall be documented for use at the final design stage. The natural channel design strategy must clearly define that all channel blocks have the ability to convey flows associated with the Regulatory Storm event (Regional or 100-year, whichever is greater). Conceptual channel restoration / improvement, where required, shall indicate the overall stream morphology changes with these proposed section changes. The determination should be made based on stream morphology, in addition to the considerations of aquatic and terrestrial features and setbacks. The determination, of which watercourses and drainage features are to be maintained and which are to be considered for relocation or removal, needs approval of the Technical Steering Committee and will be based on the results of the recommended management strategies resulting from the headwater drainage feature assessments following TRCA/CVC 2014 protocol. The respective Conservation Authorities and Department of Fisheries Ontario must be consulted for approval of any channel works proposed.

2.2.5. Aquatic Environment

The consultants shall assess the potential impacts of future land use on the aquatic resources. Recommendations shall be identified for improvement of aquatic habitat, including in-stream, stream bank and flood plain habitat enhancement, removal of barriers and on-line ponds, and retrofitting existing altered habitats. The assessment shall relate physical characteristics and processes of the aquatic environment to biological communities. The assessment shall also identify and protect appropriate buffers/setbacks, and linkage of these habitats, which reflect the specific stream sensitivity and required buffer functions.

Detailed assessment shall be generally focused on the sensitive areas identified in Stage 1 and areas immediately downstream of new developments. Considerations should be given to cooling trenches for SWM facility, i.e. trenches, open channel drainage with shading areas through landscaping commitments, etc.

2.2.6. Terrestrial Environment

The consultants shall investigate potential land use impacts for areas adjacent to terrestrial resource features and identify buffer and management strategies. In addition, appropriate buffers/setbacks to disturbance, specific to the resource sensitivity and required buffer functions, shall be identified and protected. In addition, potential linkages (natural areas that ecologically connect core areas) shall be identified and protected. Linkages are important in reducing the adverse impacts of habitat fragmentation on natural areas. The management strategies shall be documented, regarding the protection of these sensitive resources and functions. A graphic visualization of corridor and buffer

alternatives, including successional habitats under a longer-term scenario (20-50 years), shall be presented in maps to:

- Identify habitat features that may be retained and incorporated into the Natural Heritage System due to their quality;
- Consider the potential impacts of development on wetlands, wildlife habitats, woodlands, valley lands, endangered and threatened species (if present) and their habitat; and
- Propose management strategies to protect these resources.

The assessment shall generally focus on the sensitive areas identified in Stage 1 and areas in the immediate vicinity of new developments. Where a continuous ELC-defined vegetation community extends beyond the subject areas, the assessment shall generally address the entire community, including portions beyond the study area boundaries.

2.2.7. Surface Water Quality

The consultants shall investigate potential land use impacts and develop strategies to maintain or enhance in-stream water quality. Actions to address existing point and non-point sources of pollution resulting in degraded water quality shall be developed. Best Management Practices (BMPs) for urban stormwater management shall be recommended for all new development to address stormwater quality. The proposed BMPs shall be in accordance with the requirements of the Ministry of Environment and the City of Hamilton.

A detailed stormwater management strategy shall be determined for future development lands. BMPs shall be recommended for source controls and conveyance controls. Conceptual designs of the SWM facilities are required to ensure the discharging water will meet the MOE standards for total suspended solid removal. Water temperature indicators are to be evaluated, especially when receiving water are sensitive, i.e. cold-water system for aquatic habitat. The stormwater strategy should also identify Low Impact Development (LID) measures, which can be incorporated within industrial, commercial and institutional developments to maintain the water balance and groundwater recharge in particular.

2.2.8. Development of Stormwater Management Strategy

Results of the hydrologic analysis for existing and developed conditions shall be used to develop a stormwater management strategy to control post-development peak flows as a result of urbanization. The fluvial geomorphological and erosion assessments, in conjunction with the hydrologic and hydrogeologic analyses shall be used to determine the quantity control, extended detention and water balance targets. In addition, storm runoff must be treated before it is discharged to receiving waters by the use of source controls, conveyance controls, or end of pipe controls. All proposed SWM strategies shall confirm to acceptable standards as determined in the MOE Stormwater Management Practice Manual (2003), the City's drainage policy and stormwater management guidelines, in addition to the requirement of the respective Conservation Authorities.

The stormwater management strategy for the proposed development shall incorporate relevant SWM measures, alternate development proposal, including low impact development screening of alternatives. Constraints and opportunities shall be evaluated for the specific strategy. Conceptual design shall be completed for end-of-pipe facilities required to achieve the specific targets. For example, the drainage areas for proposed SWM features are to be delineated; The length of routes, size of conveyance conduits, and open channel drainage vs. SWM ponds are to be evaluated; End of pipe treatments should include the required storage volumes, flow targets, land area requirements and locations; Details should include the stage – storage – discharge charts, SWM facility types and outlet control methods.

In general, with effective SWM source control measures at development stage, the post-development flow rates are to be controlled to pre-development levels as close as feasible. Consequently, the future flood plains are expected to be consistent with the existing conditions. As part of the stormwater management strategy for future development, the consultants shall:

- Identify any drainage and stormwater management (SWM) works required for the Elfrida Urban Expansion study area, including stormwater management ponds, channel modifications and infiltration commitments;
- Assess the performance of existing drainage facilities (i.e. ditches, culverts);
- Based on MOE guidelines, establish stormwater management criteria related to water quality (Total Suspended Solid);
- Identify the SWM facility locations and the appropriate outlets to the receiving water bodies;
- Incorporate the proposed stormwater management facilities into the post-development model and select the sizes of the facilities to conform to the established criteria;
- Prepare a conceptual design of the proposed stormwater management facilities for water quantity and quality control;
- Consider general criteria for stormwater management as described in Appendix F: General Criteria for Stormwater Management.

2.2.9. Reporting – Stage 2 Subwatersheds Management Strategies

The consultants shall develop a detailed subwatersheds management strategy for the proposed development, which will evaluate a range of subwatersheds management options based on the subwatershed goals, objectives and targets. The consultants shall identify additional studies to be completed in support of future Draft Plans of Subdivisions, as required to meet the objectives and targets of this subwatersheds study. Each of the subwatershed management options shall be evaluated to determine preferred subwatershed strategies. The consultants shall recommend a comprehensive plan for the evaluation of the management options, which will form part of the subwatersheds study proposal. Options such as alternative development forms/patterns, stormwater management and best management practices, rehabilitation and retrofitting of existing features shall also be considered in the subwatershed management options.

At the completion of Stage 2, a draft document shall be submitted to evaluate the stormwater management options and recommended subwatershed management strategies as they relate to the

proposed development. The computer modelling input and output files shall be appended to this report. In addition, constraints and opportunities present in the study area, in terms of urban expansion, environment impacts and protection, shall be clearly documented with GIS maps for the associated locations.

2.3. STAGE 3 – IMPLEMENTATION AND MONITORING PLAN

Stage 3 shall set the framework for implementation and monitoring of the preferred subwatersheds management strategy. An implementation and monitoring plan shall be developed, which sets out the requirements for phasing, financing, operation of facilities, and monitoring to ensure the future developments are in compliance with the approved subwatersheds study. The Stage 3 work will be completed at the end of the land use planning work, when a preferred land use plan has been determined. The findings of this study will provide a technical framework for future infrastructure works and support the future development proposals in accordance with the approved secondary plan.

Where applicable, Stage 3 shall outline the agencies/organizations that are responsible for carrying out the various recommendations and specify when in the development process the various recommendations need to be initiated. Stage 3 shall include:

- Timing for the construction of any required facilities with respect to the future development;
- Funding formula for the construction of these facilities;
- Recommendations for future studies, if required;
- The operation and maintenance responsibilities for the recommended facilities;
- A monitoring program to ensure compliance with the subwatersheds study, and a strategy for corrective actions which may be necessary based on results of the monitoring program;
- Time frame for the review/update of the subwatersheds plans; and
- The estimated cost of the monitoring program.

The implementation plan shall recommend the phasing of development. This will permit changes to recommend mitigation measures and management strategies for future phases of the development, in the case results of monitoring from the initial phases suggest that changes are warranted.

APPENDIX A
Suggested Data Collection Requirements

This appendix outlines the suggested data collection to meet the goals and objectives of the study. Where available the study will make use of existing data.

Rainfall

Data for existing rainfall gauges located in proximity to the subject subwatersheds, at the Hamilton Airport and Binbrook Reservoir, are to be reviewed and analyzed. The consultant is to determine if additional temporary rain gauge(s) is necessary for model calibration and water balance evaluation. The Next-Generation Radar (NEXRAD) information, available from the various agents in and around the study area, shall be exposed for its suitability to fill in any data gaps.

Stream Flow

Recorded flows for the subject watercourses, with rating curves developed for the relationship between flow depth and flow rate. There is no stream flow gauges within the study area. The consultants are to examine the downstream flow gauges data available from the respective Conservation Authorities and determine the additional temporary flow monitoring program as needed. In addition, regional regression plots for headwater drainage features in Ontario may also be referenced to confirm models are within general observed ranges elsewhere under similar regimes.

Surface Water Quality

The respective Conservation Authorities manage water quality monitoring stations in and/or around the study area. These datasets shall be reviewed and analyzed. Where existing background information is unavailable, a water quality sampling program shall be conducted to provide a detailed assessment of the existing water quality in the subwatersheds. Where appropriate, this information will be used to design Best Management Practices (BMPs) and to provide background information for a post-development monitoring program.

The sampling program will incorporate two (2) discrete dry weather sampling for dissolved oxygen, temperature, bacteria, nutrients, general chemistry, pesticides and metals. The dissolved oxygen and temperature monitoring should be conducted over the course of a dry day, from before daybreak to after dark. Ideally, monitoring should be conducted during a warm, dry period. Deployment of logging equipment to capture the entire 24-hour cycle for these parameters should also be reviewed.

If necessary, a composite wet weather sample from at least one significant event will be taken to identify the pollutant constituents in the runoff. Samples will be analyzed for bacteria, nutrients, suspended solids, pesticides and metals. Chloride / sodium sampling would capture the road salt loading.

Sampling will be done on a frequent, discrete basis throughout the course of the event. Sampling frequency required depends on runoff response time of the subwatersheds, but may be as frequent as 15-minute intervals. Samples will be analyzed for bacteria (*E. coli*) and suspended solids only. Where water quality and stream flow are being collected, area-based contaminant load could be calculated.

If necessary, an analysis of benthic invertebrates will be conducted as an indicator of long-term water quality.

Stream Geomorphology and Channel Erosion

Collect site-specific environmental data at an appropriate time of year to characterize the form and function of each reach. This data would include channel slope, flow velocity, soils, sinuosity, width to depth ratio, particle size of sediment in bedding and banks, stream entrenchment ratio, landform feature/stability class, cross-sectional measurements and bank vegetative cover. Where sensitive reaches are identified, a detailed geomorphic survey will be completed.

The erosion database will identify areas that are highly prone to erosion or where structures may be at risk. Data collected will also be used in flow duration exceedance analysis and as background information in the monitoring plan.

For sections selected for erosion control assessment and monitoring, determination of critical shear strengths, surveyed cross sections, and inventories shall be done reach by reach in order to be sufficiently thorough. Consequently, it provides documentation of areas to be targeted for rehabilitation. The channel erosion monitoring will be extended from the study area to the next hydrologic nodes of interest, typically at the subwatershed outlets where the subject watercourses join other branches. Existing downstream areas of concern from previous studies should also be considered in the erosion assessment.

Groundwater

In an effort to understand the surface and subsurface hydrology of the site, geological and hydrogeological maps shall be reviewed, in addition to the studies in and surrounding the study area published by the MOE, MNR, Ministry of Northern Development and Mines (MNDM) and Conservation Authorities.

Stream flow surveys shall be carried out in the permanent streams where data gaps are identified. The purpose of collecting stream flow measurements is to assess the interaction between the surface water and groundwater regimes and will specifically answer questions related to the groundwater recharge and discharge. After review of the published information listed above, the requirement for data collection and the proposed locations within the study area shall be determined for data collection. Depending on the duration of the required monitoring and seasonality, some intermittent watercourses may need to be included as well. This work should be coordinated with fisheries habitat consideration and surface water quality modelling.

If data gaps are identified, site specific geological and hydrogeological information should be collected through the installation of groundwater piezometers at selected locations across the study area to ensure a thorough understanding of groundwater recharge, as well as surface water-groundwater interactions. If required, the consultants are to carry out a site study of the karst geology using field mapping, and possibly dye tracing techniques, in an effort to understand the significant subsurface flow paths.

Natural Heritage System

Where necessary, collect site-specific environmental data over four seasons at the appropriate time of year, including the following:

- Field data on vegetation communities and linkages using the Ecological Land Classification System for Southern Ontario;
- Fish (via electrofishing) and benthic invertebrate data from local streams;
- Temperature data related to fisheries;
- Riparian habitat and stream erosion data to evaluate the need and potential for stream restoration and to establish buffer/setback criteria;
- Evaluate unevaluated wetlands using the 3rd Edition Provincial Wetland Evaluation System;
- Update previously evaluated wetlands to the 3rd Edition Provincial Wetland Evaluation;
- Identify significant wetlands, woodlands, valley lands, wildlife habitat, areas of natural and scientific interest and fish habitat, as defined by the Provincial Policy Statement;
- Species occurrences for plants, birds, mammals, reptiles, amphibians, fish, Lepidoptera, Odonata and other invertebrates known to occur in the study area;
- Identify and map (UTM coordinates) for regionally, provincially, nationally or globally rare species.

Where specific locality data is available, species occurrences will be reported to the Natural Heritage Information Centre. Focus shall be placed on core features and the possible linkage of these species.

APPENDIX B
Proposed Hydrology Plan

The Hydrological component of the subwatersheds study will be based on the following hydrologic and hydraulic modelling exercises:

1. HEC-HMS or Visual OTTHYMO
2. Modelling established to produce runoff hydrographs for the study area for existing and future conditions, and to size the required SWM facilities if applicable;
3. HEC-RAS to determine and / or update the existing flood elevations, with consideration given to the prevalent flat study area that requires other applicable tools for hydraulic analysis.

Proposed Hydrology Approach:

Water Balance

1. Evaluate the available meteorological and hydrometric data, including but not limited to, precipitation, flow, solar radial, wind, etc. Examine the statistical characteristics of the study area, in terms of wet, dry and average conditions. Assessment shall be carried out using Thornthwaite & Mather method.
2. Delineate discretized drainage areas in the study area, the drainage area should be indicated with consideration of the subsurface hydrological activities. If required, perform dye tracing (by a hydrogeologist) prior to conducting water balance simulations. Investigate limits of the active karst area in the study area (i.e. less than 3 m overburden). The karst investigation is to be performed by the hydrogeologist in cooperation with a karst expert.
3. Sufficient details should be obtained regarding the storage and flow capacity characteristics of the karst formation, in order to count for the surface water and groundwater interactions through the conduit flow and storage reservoir unit within the groundwater systems.

Hydrology and Hydraulics

1. Develop discrete design event simulation to generate runoff hydrographs for the development area for existing and future development conditions for all storms events, ranging from 25 mm, 2, 5, 25, 100 years up to and including the Regional Storm.
2. The consultants shall ensure the Intensity-Duration-Frequency (IDF) values are obtained from reliable sources, i.e. Environment Canada, or generated with the approved methodologies, i.e. Consolidated Frequency Analysis (CFA). The IDF values used in the hydrology analysis and suggested temporal storm distribution shall be reviewed and approved by the Technical Steering Committee. Peak flow rates derived by different methods should be compared and assessed.
3. Extent of the active karst areas should be considered in developing the model input parameters (i.e. surface runoff infiltration). Drainage patterns in and around the karst formation areas shall be verified in the field. This may require sufficient details be obtained, regarding the storage and flow capacity characteristics of karst formations, in support of the karst impacts on surface water and groundwater interactions.

4. The calibration and verification of hydrologic model shall include up to three (3) low and two (2) high flow events. Model calibration should focus on providing comparable peak flows, runoff volumes and hydrograph shape (flow timing) to observed flow gauge data. Alternatively, reference to regional regression plots for headwater drainage features elsewhere in Ontario may be acceptable.
5. Conduct hydraulic analysis on the established watercourses, based on the updated hydrographs for all storm events from the hydrologic model, to assess the water levels, flow velocities, inundation depths, water profiles, etc. under the current land uses and proposed development conditions.

Flood Risk Analysis

1. Review the existing flood plain mapping for the Sinkholes and Twenty Mile Creeks from the Niagara Peninsula Conservation Authority, and Stoney Creek from Hamilton Conservation Authority, where available.
2. Update the flood lines using HEC-RAS model to determine existing flood elevations for all storm events up to the Regional Storm.
3. Establish the post-development flood lines with the input of future land uses projections within the Phase 2 Report.
4. Determine flood plain extents with existing conditions, and the post-development flood lines with the proposed development. The model results shall be presented in a geo-referenced format such as GIS maps.

SWM Facility Sizing

1. Identify the existing and proposed stormwater facility locations in the study area, in consideration with the appropriate outlets to the receiving water bodies. Use the pre- and post-development hydrographs to size the required SWM facilities.
2. If SWM ponds are required, it should be extended detention wet basins. Conceptual design of these facilities shall be included to determine stage-storage-discharge curves, outflow hydrographs, etc.
3. Use the proposed SWM pond outflow curves as input to the hydrologic model and select design storms to test the SWM strategy from a peak flow perspective, for the entire study area extending to the downstream hydrologic nodes of interest, or flow gauge stations.
4. The proposed SWM facilities shall be included in the post-development hydraulic models, to assess the potential impacts on future flood elevations, and to eliminate increased flood inundation and/or erosion concern.
5. Stormwater management facilities are to be evaluated from a water quality perspective. The receiving water systems shall be investigated for the applicable standards of stormwater

discharges. The potential stormwater impacts on receiving water body quality must be closely assessed and controlled to eliminate environmental degrading. The SWM water quality control criteria are based the MOE Stormwater Management Practice Manual (2003), and the City's stormwater management guidelines. In addition, the respective Conservation Authority's requirement are to be confirmed and addressed.

Erosion Assessment

1. Select typical cross sections of the established watercourses in the study area, with existing erosion concerns, downstream of the future development, and/or branches with known downstream erosion concerns, for erosion assessment. Consider the sections selected in previous studies and the ones identified in the field observations of erosion, deposition and incision.
2. Export outflow hydrographs from the hydrologic model for existing and future conditions to the selected cross sections.
3. Assess the erosion potential of the selected cross sections and the overall subwatersheds. Based on discrete hydrologic and hydraulic simulations of the watercourse flows, cumulative shear stress exceedances shall be evaluated. The assessment should consider separate shear stress on the channel and creek banks.
4. The erosion concerns are to be identified for existing situation as a baseline. Consequently, the erosion potential during post development conditions shall be assessed, with the potential impacts on downstream regimes. Opportunities should be evaluated for segments of channels, as to the suitability /feasibility to be naturalized / restored to eliminate erosion concerns.

It is critical that conceptual SWM designs for the study area shall include considerations to ensure stormwater is controlled, in an appropriate manner to prevent any increase in erosion potential (ie. establish a proper erosion control strategy).

Summary and Verification

A summary of any software selection and migration shall be documented, with the modelling approach, calibration (if feasible) and any assumptions used in the modelling exercises.

Updating of the flood inundation scenarios (i.e. flood lines) requires a detailed node-by-node comparison of the modelling parameters and results, to ensure that the information is not lost or misinterpreted.

Discussions shall be included regarding verification of the simulated peak flows, hydrographs, erosion assessment, flood lines delineations, and proposed stormwater management strategy.

APPENDIX C
Proposed Hydrogeological Plan

1.1 Objectives

The primary objectives of the hydrogeological investigation are to:

- Define the local and regional geology and hydrogeology of the Elfrida Urban Expansion study area;
- Identify any significant karst features, delineate any hazardous lands as a result of the karst, and characterize key subsurface flow paths within the karst formation;
- Identify and evaluate the functional relationship and interactions groundwater has with the existing surface watercourses (Twenty Mile, Sinkholes, and Stoney Creeks); and
- Evaluate the potential impacts that the proposed future development may have on the groundwater resources in the study area.

The investigation shall identify the depth, extent and directions of groundwater flow in the aquifer system(s) of the study area. Emphasis should be placed on identifying and evaluating the existing groundwater recharge and discharge areas within the study area, and the potential impact future development may have on them.

1.2 Scope of Work

1.2.1 Literature and Existing Data Review

The data review will assemble, review, and collate all available relevant hydrogeological information for the study area. Data will include the published information and relevant documentation provided by Agencies (e.g. City of Hamilton, Niagara Escarpment Commission, Niagara Peninsula Conservation Authority, Hamilton Conservation Authority, Ministries of the Environment, Natural Resources, Northern Development and Mines, etc.). Examples of existing data include, but not limited to, the following:

- 1:10,000 Ontario Base Maps (OBM)
- Ministry of Natural Resources (MNR) Aggregate Resource Maps
- Ministry of Northern Development and Mines (MNDM) Quaternary and Bedrock Geological Maps
- Ministry of the Environment (MOE) Aquifer Maps and Drainage Basin Studies (if any)
- MOE recently published The Hydrogeology of Southern Ontario
- MOE Water Well Records
- Background geological/hydrogeological and other relevant reports

Cross-sections will be drawn to assist in the interpretation of local hydrogeological conditions. The sections will show geological formations, aquifers, aquitards, water tables, potentiometric surfaces, and groundwater flow directions.

Following a review and assessment of available information, data gaps and required updates will be identified and documented; If required, karst studies may further define and evaluate the geological and hydrogeological regime at specific locations with karst formation.

1.2.2 Stream Flow Measurements

Stream flow measurements shall be taken at appropriate locations along the subject creeks, to identify areas of groundwater recharge/discharge and establish baseflow conditions.

1.2.3 Drilling Program (If Applicable)

The purpose of the drilling program is to assess the overburden stratigraphy of the study area, determine depths to bedrock, and to install groundwater piezometers.

The specific purpose of the groundwater piezometers is to measure water table levels and elevations to determine shallow groundwater flow direction and to determine the functional relationships between the shallow aquifer and the surface watercourse in these creeks. The proposed drilling program will generally include the following:

- Drilling of boreholes at twenty-two (22) locations with each borehole advanced to a depth of approximately 6 m and equipped with a single monitoring well.
- Drilling of boreholes at four (4) locations, with each location consisting of a multi-level monitoring well installation (ie. A shallow overburden and deeper bedrock monitoring well, each installed into a separate borehole). Assume that the overburden monitoring well will be drilled to a depth of six (6) meters below ground surface (BGS), with the deeper monitoring well being drilled to a depth of 10 m BGS and screened in the bedrock. The purpose of the multi-level monitoring wells will be to evaluate vertical hydraulic gradients and groundwater interaction / flow between the overburden and bedrock groundwater systems and provide further insight into potential groundwater source contributions to local watercourses throughout the Secondary Plan Area.
- Each monitoring well is to be constructed of 50 mm inside diameter, Schedule 40 polyvinyl chloride (PVC) pipe, having a No. 10 slot screen (0.01-inch slot) measuring from 1.5 to 3.0 m in length. Backfilling of the screened interval consisted of No.3 grade silica sand to a height of 0.3 m above the top-of-screen, followed by granular bentonite (which is to be gradually hydrated through the pouring of water down the annular space throughout the installation process) to ground surface to prevent a hydraulic connection from occurring between the screened formation and overlying soils. The monitoring well stick-up is to be encased in a lockable steel casing, with the base of this casing being cemented into place.
- Install a series of drive-point piezometers (assume 14 piezometers) across the study area, when considered necessary by the Technical Steering Committee, to determine water table levels, assess shallow groundwater flow directions, and determine the functional relationships between the shallow aquifers and Sinkhole, Twenty Mile and Stoney Creeks;

1.2.4 Karst Study

The purpose of the karst study is to identify any significant karst features, delineate any hazardous lands as a result of the karst, and to identify and characterize key subsurface flow paths within the karst.

The extent of the study area for the karst study should be assessed during the initial fieldwork. However, the study area may extend to include any potential resurgences (springs) that may be recharged from

groundwater and runoff from the development site. It may include the adjacent areas immediately to the east, west, south and north of the development site.

The study includes three components: 1) Karst geology and field mapping; 2) Groundwater tracing; and 3) Reporting. Each is described below.

Karst Geology and Field Mapping

The scope of work for this component includes:

- Defining the study area based on a field reconnaissance;
- Field mapping the major karst features that may significantly influence the hydrogeology of the site, or that may be affected by surface runoff and groundwater recharge from the site;
- Identifying the specific natural hazards of the study area that result from the karst;
- Delineating any hazardous lands and sites (as described by the Provincial Policy Statement and the Planning Act) that relate to development;
- Preparing a brief interim report that includes results from the field mapping and recommendations regarding the groundwater tracing;
- Meeting with the members of the Technical Steering Committee to discuss the initial findings and review the scope of work for the groundwater tracing.

Groundwater Tracing (if applicable)

The scope of work for this component includes:

- Informing the Ministries of the Environment and Natural Resources about the groundwater tracing and obtain approval, if necessary;
- Providing fluorescent dye tracers and preparing them for use in the field;
- Conducting groundwater tracing with injections at specified sites, and water sampling at appropriate springs as required;
- Augmenting groundwater tracing observations with spot measurements of discharge, conductivity and temperature, as required;
- Conducting water analysis in an established laboratory using a scanning fluorometer, and performing data analysis and interpretation;
- Identifying and characterizing the key groundwater flow routes from sink points in the study area; and

- Identifying the subwatersheds within the study area that groundwater contributes flow to the creeks, based in part on the subsurface flow routes determined by tracing.

Reporting

- Preparing and submitting a draft report for review. The report should be concise and document the results of the study. It should focus on karst geology, hydrogeology, and any hazardous lands that result from the karst;
- A map shall be included showing significant karst features, springs, traced groundwater flow routes and any lands deemed as hazardous because of the karst (including its relevance to the development);
- The report shall also include any data relevant to the interpretation of hydrogeology; and
- Finalizing and submitting the final report.

1.2.5 Overall Data Assessment and Interpretation

All collected background information and field data shall be compiled, assessed, and interpreted, so as to provide a comprehensive assessment of the groundwater conditions.

1.2.6 Future Development and its Potential Groundwater Impacts

All gathered hydrogeological data shall be assessed, with areas identified as most susceptible to groundwater and surface water impacts resulting from construction and developmental activities. Groundwater protection, mitigation and management measures should be discussed to ensure that the existing groundwater and surface water hydrological regime across the study area is maintained.

1.2.7 Reporting

A comprehensive hydrogeological report summarizing all findings, interpretations and recommendations shall be prepared to include:

- background geological and hydrogeological information;
- descriptions of field activities, procedures, and protocols;
- evaluation and interpretation of all results;
-
- Hydrogeological characterization of the Secondary Plan Area shall include the following features/considerations for presentation within the report deliverable:
 - Hydrogeological Investigation Plan / Groundwater Monitoring Locations
 - Monitoring Well and Drive-Point Piezometer Hydrographs
 - Physiography
 - Topography

- Surficial Geology
 - Karst Geology / Hazardous Lands
 - Significant Groundwater Recharge Areas
 - Highly Vulnerable Aquifers
 - Potential Groundwater Discharge Areas
 - Depth to High Groundwater Table
 - Groundwater Flow
 - Pre-Development Water Balance Target Plan
- recommendations for groundwater protection, mitigation, and management measures, as well as recommendations regarding future development practices that will promote groundwater sustainability.

APPENDIX D
Tractive Force Analysis

Tractive force analysis is an essential component of any development/environmental study, in that it allows investigators to determine erosion-sensitive reaches and provides guidance for the delivery of flow volumes from stormwater management facilities.

The concept of tractive force analysis is relatively simple: a stream system or watercourse develops over many years with respect to the timing and volume of flow contributions by groundwater (baseflow contributions) and overland flow (volumes greater than baseflow in streams), by the process of erosion and sediment transport. Therefore, a watercourse develops a cross-sectional area and profile in the downstream direction for the transfer of water and sediment from headwaters to river mouths. When alterations to the hydrologic regime of a watershed occur, the response of the watercourse is to change either its cross-sectional area (via lateral or vertical erosion) or to modify its gradient (becoming steeper or more gentle depending on the conditions). These changes are not immediate in most cases, nor are they limited to a particular temporal boundary as cumulative impacts usually prevent re-establishment of a natural flow regime.

Development of rural or agricultural lands to a more impervious surface is one such alteration, which has in the past resulted in considerable change to stream systems. Paved surfaces and reduced infiltration result in two major impacts in streams: First, rapid delivery of flow to the watercourse causes increased flow competence and thereby sediment transport and erosion; Second, a decrease in infiltration causes a potential decrease in baseflow contributions as subsurface hydro-potential gradients are altered.

The preferred management strategy to the groundwater recharge issue is the development and maintenance of infiltration galleries within stormwater management ponds. However, the problem of accelerated erosion by overflows during storm events is a more serious and complicated matter.

Stormwater management ponds will discharge excess water during periods of high input to surrounding stream systems. The delivery of that excess flow has the potential to cause erosion by either increased flow velocity or lower velocity over extended periods of time. Both conditions will result in channel alterations downstream of the structure, particularly in erosion-sensitive reaches. The challenge for managers is to effectively create stormwater management strategies which do not impact receiving watercourses and contribute to accelerated (faster than natural rate) erosion.

Methodology

Tractive force analysis (also known as excess shear, excess velocity, and / or excess stream power) allows geomorphologists to work with engineers, as to the rate and timing of stormwater discharge from SWM ponds. The methodology to undertake such analyses includes the following:

1. A stream walk is undertaken at the start of the assessment to document overall watercourse conditions and to identify areas of potential erosion risk. During this walk notations of changes in soil type and bed characteristics are made and digital photographs are taken. A further purpose of the walk is to choose potential cross-sections for further study. The number of cross-sections chosen reflects the concerns of the study area.
2. A rapid reach assessment is undertaken, which identifies particular concerns with respect to channel form, bank properties, riparian conditions, substrate and flow characteristics. A numerical score (0-100) is assigned which can be used comparatively to select reaches for further study.
3. Once all potential cross-sections have been identified, choices are made as to which ones would require further analysis. This decision is based on relative stability to other reaches and the proximity to areas of concerns or specific interests, in particular areas of differing soil type, proximity to structures, or proximity to catchment nodes in the hydrological modelling.
4. Each cross-section is monumented for future use. Cross-sectional measurements of channel and bank full area are made at tight intervals to get a detailed indication of form. Local slope is determined using a leveling exercise. This cross-sectional data is input into a flow model along with information on channel roughness (Manning's 'n') to determine stage/discharge relationships and specific velocities.
5. Bed samples of pavement and sub-pavement are collected and returned to the lab for grain-size analysis; bank samples are also collected. The grain size distribution is used in the tractive force analysis.
6. Critical shear stress for the bed material (pavement and sub-pavement) is determined using standardized methods for the D_{10} , D_{50} and D_{90} fraction of each sample.
7. Boundary shear stress is determined from the cross-sectional profile, slope and roughness components measured in the field. Comparisons are made between the critical and boundary shear at bank full stage to establish erosion potential for each fraction.
8. Critical discharge to match the critical/boundary shear relationship is then mathematically determined and reported to the engineer for placement in the hydrological model as a threshold value. The hydrological model is then run against the threshold value to determine exceedance for the pre-development and post-development scenarios; this is input into the decision matrix for the sizing of the stormwater management pond to help inform an erosion control and quantity control strategy.
9. Reporting includes critical shear, critical discharge, critical velocity, stream power and erosion potential for the selected cross-sections. These other critical thresholds are reported in case there are issues surrounding the use of shear stress as a decision-making tool.
10. Recommendations are made from the perspectives of fluvial functioning of the watercourse, as a component of the final report.

Specific Considerations for the Elfrida Subwatersheds Study

The watercourses may be flatter at some locations within the study area. Under normal circumstances these flat lands would reflect the downstream limit of concern for the tractive force analysis, as they represent a settling out of stream energy caused by flows upstream of their location. However, a visual assessment of erosion potential shall be completed in the downstream reaches in order to provide fuller input into the erosion potential process.

In conclusion, erosion study will be established on each watercourse, in order to comply with the requirements from City of Hamilton, the Conservation Authorities and the Provincial jurisdictions, as to the proposed development of the headwater areas of Twenty Mile Creek, Sinkhole Creek, Stoney Creek, Upper Davis Creek and Hannon Creek. Fieldwork to establish these study sites and collect data is to commence upon approval of this document. Critical discharges for excess shear computations shall be provided with the final reporting meeting the study deadline.

APPENDIX E
Proposed Protocol to Sample Benthic Invertebrates

Purpose

This appendix defines a sampling protocol to identify the benthic macroinvertebrate community of the study area. As the composition of a stream's benthic macroinvertebrate community reflects its substrate, water quality and temperature, repeated sampling of benthic macroinvertebrates may be used to monitor changes in its condition.

Timing

The sampling of benthic macroinvertebrates can yield different results depending on the sampling period, because seasonal disturbances (e.g. spring flood) and stream conditions strongly affect the diversity, abundance, and life stage progression of aquatic insects (Hynes, 1970).

Samples of benthic macroinvertebrates will be collected in early spring after the in-stream environment has stabilized following the spring flood. This timing is intended to include the pre-emergence period (typically mid-spring to late summer) to ensure that species representation is at a maximum.

Sampling Locations

Appropriate sample locations, and the number of stations to be sampled, shall be determined based on the length of the stream and the availability of suitable sampling habitat.

Each sample site should be located in areas with run or riffle habitat, moderate to high current velocity and a substratum of diverse particle sizes, but preferably dominated by gravel and larger particles. Only sites that are shallow enough to provide a safe foothold will be selected for sampling.

Sampling Procedure

The effort required to achieve a sufficient sample of benthic macroinvertebrates varies from stream to stream. A standard sampling time (usually between 15 seconds and 1 minute) and length of stream to be sampled (usually between 3 and 5 meters) should be established when initial samples are taken. These standards are to be applied to all sampling stations in the study area.

Benthic invertebrates will be sampled by kick net and preserved in 70-80% ethanol or 10% buffered formalin.

Field Measurements and Observations

Benthic invertebrate sampling will include appropriate descriptions/measurements of stream conditions at sampling sites, including habitat type, stream width and depth, current velocity, substrate composition, the amount of algae and plant material. A photograph of each sample site shall be taken.

Analysis

Sampled invertebrates will be identified to the lowest taxonomic level possible – at a minimum, to family

level. Each taxon shall be enumerated, and the results are to be used to calculate the proportions of functional feeding groups and EPT taxa (Ephemeroptera, Plecoptera and Trichoptera). Additional indices may be calculated as required.

APPENDIX F
General Criteria for Stormwater Management

The consultants shall consider the following general criteria for stormwater management.

1. Control of post-development peak flows to pre-development levels is recommended in all areas. Priority should be given to control of runoff increase at source by reducing imperviousness, and maximizing dispersal of runoff and infiltration potential, especially in headwater and cold water subwatersheds, or those subwatershed areas which ultimately feed cold water creeks.
2. Storm runoff must be treated before discharge to receiving waters. General sizing guidelines for water quality control are provided in MOE (2003), which can be used for preliminary ponds sizing. Special design considerations are required to control temperature in cold water subwatersheds, such as bottom draws or other modified outfall structures, and shading. Source controls, reduced imperviousness, swales and small-scale shallow wetland type facilities should be emphasized to reduce the loss or diversion of local stream flow and head water habitat.
3. Duration exceedance characteristics of the SWM discharges shall be addressed to minimize erosion potential. In general, it should be maintained in accordance with the existing functions and values of the stream and drainage system. The SWM design analysis for erosion control shall include a critical flow threshold analysis for the receiving creeks. The flow duration characteristics, specified from the hydrological analysis given in Appendix B: Proposed Hydrology Plan, should be considered in design SWM control measures from an erosion control perspective.
4. The proposed SWM facilities shall identify the unitary control rates (discharge and storage) per hectare of development area from flood control and erosion perspectives. The proponent shall verify the effectiveness of source controls, and the magnitude of the runoff volume reductions, with a detailed analysis of the specific SWM measures proposed.
5. Maintenance of existing groundwater recharge rates on an annual basis and the protection of groundwater quality should be verified through hydrogeological studies. Further fieldwork and hydrologic modelling could be required for implementing and monitoring in this regard as part of future Draft Plan of Subdivision applications.