Hydrogeological Assessment Submissions

Conservation Authority Guidelines for Development Applications

June, 2013

Note to Reader: This document has been provided in an attempt to standardize the hydrogeological study requirements to support development applications reviewed by Conservation Authorities and should be referred to for guidance purposes only. It is not a legal document and should not be used as such. In addition, this document has not been endorsed by all Conservation Authorities. This document has been drafted to satisfy specific requirements applicable to hydrogeologic studies that meet the needs of most Conservation Authorities and for that reason, not all content of the document may be appropriate for your hydrogeologic study or Conservation Authority. Therefore, while this document may serve as an excellent starting point for undertaking hydrogeologic studies, independent judgment and pre-consultation with your Conservation Authority and municipality is strongly recommended to determine the scope of your study.

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1 INTRODUCTION

This guidance document has been developed by the Conservation Authorities Geoscience Group which is made up of Conservation Authority hydrogeologists. The main purpose of this document is to provide information and guidance material to Conservation Authorities, their municipalities and consultant hydrogeologists related to hydrogeological assessment requirements that can be used to ensure comprehensive evaluations of potential impacts associated with development on natural ecological features and functions that are supported by groundwater resources. The intent is that it be used as a resource to promote consistency amongst Conservation Authorities in the development of terms of reference and the Conservation Authority review of the resulting technical studies. The document may also be used as a resource to assist the consulting community in the understanding of the Conservation Authority perspective regarding potential watershed impacts and serve to increase efficiencies and reduce approval timelines.

This guidance document provides a list of recommended requirements for hydrogeological investigations. The checklist outlines specific study requirements depending on the type of development application. Short descriptions of report expectations, report components, as well as some of the resources available have also been provided. Where a Conservation Authority has adopted these guidelines, the scope of the investigation and report requirements should follow this guidance document unless otherwise agreed upon during pre-consultation with Conservation Authority staff. It should be noted, however, that this is a guideline document aimed at consistency and not a legally binding instrument. A municipality and their Conservation Authority may choose to change the scope of the analyses required within their jurisdiction.

In carrying out plan review and regulation responsibilities, Conservation Authorities can be involved in the review of hydrological assessments addressing matters such as:

1. groundwater infiltration and recharge;
2. groundwater discharge and baseflow (supporting streams and wetlands);
3. coldwater fisheries supported by groundwater discharge;
4. water quality and temperature (wetland species/fisheries);

5. groundwater elevations and flow paths (potential to divert flow, cause flooding, divert shallow flow causing impacts on shallow rooted vegetation and wetland features); and
6. cumulative watershed impacts.

In summary, this guidance document may assist Conservation Authority involvement in requirements for hydrogeological submission by:

1. establishing a consistent approach in the review of studies;
2. clarifying upfront the information that should be included in hydrogeological studies;
3. providing a clearer understanding of potential hydrogeological issues and concerns;
4. providing minimum information requirements and best management practices in the preparation of hydrogeological reports;

As indicated earlier, this document attempts to satisfy specific requirements applicable to hydrogeological studies that meet the needs of most Conservation Authorities. The guidance information is not intended to be prescriptive or to replace professional judgment and is based upon a review of current practices for hydrogeologic reviews at Conservation Authorities. Therefore, while this document may serve as an excellent starting point for undertaking hydrogeologic studies, independent judgment and pre-consultation is strongly recommended to determine the scope of a hydrogeological submission.

Where applicable, this document takes into consideration existing provincial (e.g. Oak Ridges Moraine Conservation Plan, Niagara Escarpment Plan, Lake Simcoe Protection Plan, etc.), municipal and Conservation Authority policies and guidelines for information requirements for land development applications. Information contained within this document was drawn from Ministry of Environment and Energy (MOEE) Hydrogeological Technical Information Requirements for Land Development Applications (MOEE, 1995) but simplified and focused on watershed and ecological impacts associated with development.

2 HYDROGEOLOGICAL ASSESSMENT CONTENT AND REQUIREMENTS

It is strongly recommended, that prior to the commencement of any study, the proponent and their consultant(s) undertake pre-consultation with Conservation Authority staff to confirm the scope of the required technical study.

Hydrogeological studies will vary in scope, level of detail, and methodologies depending upon project scale and the study objectives. Sufficient detail should be provided to facilitate a review of the hydrogeological analysis and conclusions.

This guidance document provides a list of recommended requirements for hydrogeological investigations. The checklist (Table 1 in Section 2.2) outlines specific study requirements depending on the type of development application. Section 3 provides a short description of report expectations, report components, as well as some of the resources available. Where a Conservation Authority has adopted these guidelines, the scope of the investigation and report requirements should follow this guidance document unless otherwise agreed upon during pre-consultation with Conservation Authority staff. It should be noted, however, that this is a guideline document aimed at consistency and not a legally binding instrument. A municipality and their Conservation Authority may choose to change the scope of the analyses required within their jurisdiction. Further, where this guideline is adopted, a staged study approach may be taken whereby a preliminary phase of a study may be initially required followed in sequence by secondary, more detailed phases over a period of time. A broader scale of investigation is generally undertaken for larger scale developments such as supporting documentation for secondary plans.

The studies are expected to provide new or updated sources of data, particularly on a local, site-specific scale and identify potential changes in environmental conditions. Data provided should be of a qualitative and a quantitative nature and be suitable to identify a linkage between impact on recharge/discharge capability, long- and short-term watershed planning and environmental quality. The information provided should be sufficient to identify areas of concern. Additionally, it will give the opportunity for developers to indicate where potential concerns can be mitigated or avoided. In this respect, developments can be accurately assessed from a site specific and broader watershed development impact perspective.

It is strongly recommended that, prior to the commencement of any study, the proponent and their consultant(s) undertake pre-consultation with Conservation Authority staff to confirm the scope of the required technical study (ies).

2.1 QUALIFICATIONS

Proponents of development applications will be required to submit reports which summarize the work completed. These reports shall be prepared by Qualified Persons (QPs). A QP is a licensed Professional Geoscientist or an exempted Professional Engineer as set out in the *Professional Geoscientists Act of Ontario.*

2.2 STUDY CHECK LIST

The general purpose of a planning application hydrogeological study is to evaluate whether the proposed application is likely to result in adverse/negative impacts to the aquifer, existing groundwater users or natural functions of the ecosystem relying on groundwater. As such, the level of detail required in the hydrogeological study is normally expected to correspond with the level of risk posed to the ground and surface water resources, and the level of uncertainty associated with the available information. Where there is a low risk of negative impacts, a QP may be able to complete their report by qualitatively applying hydrogeological principles to existing information, such as in the form of a desk-top study. Where there is a high risk of negative impacts, a detailed site investigation and monitoring program may be required.

Table 1 has been developed to serve as an easy reference resource to identify hydrogeological study requirements in support of planning applications at the Conservation Authority. Table 1 outlines the type of planning application and general requirements most commonly required by Conservation Authorities in the review of different types and scales of Hydrogeological Assessments. However, it should be noted that Table 1 is not a complete list of all types of applications dealt with by each Conservation Authority, nor are all components of the checklist appropriate for every development type/situation. The following checklist represents recommended minimum requirements. Additional information may be required in some cases.

The table is not intended to replace professional judgment. Individual Conservation Authorities should be consulted for additional specific study requirements or conversely where study components may not be required. A description of the guidance checklist components is provided in more detail within Section 3 of this document.

The expected content of a hydrogeological assessment is broken out into three sections:

1) Existing Conditions;
2) Impact Assessment; and
3) Mitigation.

Table 1: Hydrogeological Assessment Check List intended to Support Development Applications

Groundwater Assessment	Master Environmental Servicing Plan or Equivalent	Environmental Assessment (EA)	Site Plan Commercial, Institutional, or Industrial	Subdivision or Condominium Development		Single lot Residential	Dewatering
				Municipal Servicing	Private Servicing		
1. EXISTING CONDITIONS:							
Introduction and background	☐	☐	☐	☐	☐	☐	☐
Site location and description	☐	☐	☐	☐	☐	☐	☐
Description of: • Topography & Drainage • Physiography • Geology & Soils	☐	☐	☐	☐	☐	☐	☐
Test pits/Boreholes	☐	☐	☐	☐	☐	GNR	☐
Monitoring Wells	☐	☐	☐	☐	☐	GNR	☐
Private Well Survey	☐	☐	☐	☐	☐	GNR	☐
Hydrostratigraphy/Hydrogeology: • Aquifer properties • Groundwater Levels • Groundwater flow direction	☐	☐	☐	☐	☐	☐	☐
Description of surface water features and functions	☐	☐	☐	☐	☐	☐	☐
Water Taking Permit details	GNR	GNR	GNR	GNR	GNR	GNR	☐
Water Quality	☐	☐	☐	☐	☐	GNR	☐
D-5-5 (Water Supply)	GNR	GNR	GNR	GNR	☐	GNR	GNR

Groundwater Assessment	Master Environmental Servicing Plan or Equivalent	Environmental Assessment (EA)	Site Plan Commercial, Institutional, or Industrial	Subdivision or Condominium Development		Single lot Residential	Dewatering
				Municipal Servicing	Private Servicing		
2. IMPACT ASSESSMENT:							
Groundwater Levels	☐	☐	☐	☐	☐	GNR	☐
Pumping Tests*	☐	☐	GNR	GNR	☐	GNR	☐
Groundwater Discharge (Baseflow)	☐	☐	☐	☐	☐	GNR	☐
Water Balance	☐	☐	☐	☐	☐	GNR	GNR
Groundwater Quality	☐	☐	☐	☐	☐	GNR	☐
D-5-4 (Onsite Sewage Systems)	GNR	GNR	GNR	GNR	☐	GNR	GNR
3. MITIGATION MEASURES:							
Maintenance of Infiltration/Recharge	☐	☐	☐	☐	☐	GNR	GNR
Maintenance Groundwater Quality	☐	☐	☐	☐	☐	GNR	☐
Monitoring Program	☐	☐	☐	☐	☐	GNR	☐
Contingency Plans**	GNR	GNR	GNR	☐	☐	GNR	☐

NOTES: This table outlines the type of planning application and associated requirements most commonly required by Conservation Authorities in the review of Hydrogeological Assessments. This table is not a complete list of all types of applications dealt with by each Conservation Authority nor is the checklist appropriate for every development situation. Individual Conservation Authorities should be consulted with for specific requirements.

☐ - *Recommended*
GNR – Generally Not Required
** Where development is municipally serviced, these tests will be necessary on a case by case basis (sensitive aquifer/ aquatic considerations).*
***May be scoped, Contingency Plans will not be needed in most cases.*

3 HYDROGEOLOGICAL ASSESSMENT REPORT REQUIREMENTS

This section outlines the minimum requirements that should be provided in a report format for review by Conservation Authority staff. The technical requirements are based on the type of planning application as outlined in Table 1. This section should be used along with Table 1 to ensure all application study recommended requirements are being met.

3.1 EXISTING CONDITIONS

3.1.1 Introduction & Background

The following introductory information should be provided within the report:

- Description of the planning context and relevant policies
- Outline of the scope of the assessment and the specific issues
- Contact information for the landowner and/or person engaged in the activity or land use, if they are different people (e.g. tenant versus landlord)

3.1.2 Site Location & Description

Identification of the site location should include the following information:

- Site location including street address, UTM (or northing and easting, NAD83),
- Township/municipality, lot, concession, size of property, area to be developed/disturbed
- Description of the proposed undertaking or development (size and purpose)
- Identification of the type of site servicing
- Description of construction/site disturbance activities
- Provision of the development plan or draft plan
- Land use designations of the Official Plan(s) and permitted uses in the zoning of the site
- Present land use of the site and adjacent lands
- Regional map
- Local map showing the site, major/minor roads, environmentally sensitive areas, wetland and watercourse features within 500 metres of the site or the area of influence; whichever is greater

3.1.3 Topography & Drainage

The report should include the following information with respect to topography and drainage conditions on the site:

- Description and figure of existing surface topography and drainage patterns of the site
- Description and figure of the proposed site alteration that clearly outlines ground elevations and change in drainage patterns

3.1.4 Physiography

A description of the physiography of the study area should be presented within the report. Its purpose is to provide background information regarding the landscape and the type of landforms present.

- Description of study area physiography
- Regional (watershed or larger) physiography map of the study area showing the site

3.1.5 Geology and Soils

The description of the geology should include both regional and site-specific descriptions. This discussion should contain a description of the overburden and bedrock materials including thickness. Features such as bedrock valleys, karst, and tunnel channels should be noted where known/relevant. The consultant should reference existing relevant regional studies e.g. the Ontario Geologic Survey maps and reports, Ontario Ministry of Agriculture and Foods soils maps, Ecological Land Classification data, Watershed Management reports and Assessment Reports prepared under the Clean Water Act, 2006. An overview of the regional stratigraphy including thicknesses of the formations, and unit name is expected. This description should also include an assessment of soils and infiltration properties inferred from grain size analyses from on-site test pits/boreholes where completed.

The report should also contain a minimum of two cross-sections (along perpendicular lines) to support discussions on geology, stratigraphy and flow patterns. Ideally, the cross-sections will be oriented along the groundwater flow path and across the groundwater flow path. In some cases, the cross-sections will be constructed based on the available data (regional sections along roads, etc.). Borehole logs should be shown on the cross sections with an interpretation of geologic units encountered. For shallow construction, test pit data may be correlated where possible.

- Description of surficial and bedrock material

Summary of on-site borehole information

Characterization of soil stratigraphy

Provision of detailed cross sections showing boreholes and interpolation (a min. of 2 sections are highly recommended).

Figures:

- Surficial and bedrock geology
- Soils
- Cross sections with plan

3.1.6 Test Pits and Boreholes

On-site investigations comprised of excavation of test pits with a backhoe, or shallow boreholes, are advised to determine surficial geologic and hydro-geologic conditions. While no minimum number of test pits is stipulated, the consultant is expected to construct as many test pits as required by the geo-technical regulations and to use professional judgment to determine the number and location of test pits required to adequately assess the soils and overburden materials present on the site.

Boreholes may be constructed in place of test pits and may be finished as monitoring wells. Like test pits, boreholes should be installed at strategic locations across the site so that potential impacts to sensitive groundwater dependent features can be adequately assessed.

Test pits/boreholes should be advanced to a depth to correspond with the engineering plans associated with planned development. Test pit/borehole locations should be provided on a figure and all data should be provided in an Appendix. Each test pit or borehole record should show the date of excavation and data collection. Ground elevation (masl) must be provided for each pit.

Representative soil samples shall be analysed in the laboratory to determine grain size distribution and an estimate of material percolation rates provided.

Description of test pits/boreholes on site including date of construction/abandonment

Grain size analysis and logs are required within the appendix of the report

Figures:

- Site test pit/borehole location map including historic boreholes

3.1.7 Monitoring Wells

Monitoring wells provide access to groundwater and may be required to assess short and long term changes in water levels, aquifer properties, hydraulic gradients, groundwater flow direction, connection to surface water features and impacts from dewatering.

It is recommended that a representative number of monitoring wells are constructed onsite and water levels be recorded upon well installation and at least two other occasions to determine stabilized water levels, seasonal influences and the seasonally highest (spring) and seasonally low (fall) water table elevation. A field survey should be conducted to establish reference elevations for each monitoring point and used to provide consistent elevations of soil contacts and groundwater elevations.

It may be necessary to install piezometers instead of monitoring wells where shallow groundwater levels need to be obtained and an area that is not accessible to drill rigs due to the proximity to a sensitive feature(s).

Description of monitoring wells/piezometers on site including date of construction/abandonment

Grain size analysis and logs are required within the appendix of the report

Figures:

- Site test monitoring wells/piezometers location map including historic boreholes
- Water levels (with sample dates) and hydrographs if available

3.1.8 Private Well Surveys

In addition to boreholes installed on the site, well data from wells within 500m of site should be used to characterize the groundwater conditions. If used, all relevant/supporting information should be provided within the report.

A house-to-house water well survey within 500 m of the site should be completed to obtain well location, construction details and water levels where possible. In addition, Ministry of the Environment (MOE) water well data within 500 m of the site should be obtained to supplement and confirm the data collected through the house-to-house survey.

Well data for private wells within 500 m of the site is to be used for the impact assessment

Figure of the well locations

3.1.9 Hydrogeology/Hydrostratigraphy

Hydraulic conductivity (K) of each geologic unit should be characterized or estimated. The proponent may refer to published reports regarding typical hydraulic conductivity properties for the geologic units or utilize data from field tests (single well response tests) conducted on monitoring or test wells on the site. Both K_h and K_v estimates should be provided where available.

To characterize the groundwater conditions at the site, both groundwater levels and flow patterns should be discussed along with the appropriate documentation. This should include: 1) a description of groundwater levels and seasonal fluctuations; 2) direction of groundwater flow; and 3) areas of groundwater discharge along with estimated volumes. A description of both shallow and deep (where appropriate) groundwater flow systems should be provided along with a contour plan showing flow direction. Flow system attributes such as the average horizontal hydraulic gradient, and vertical gradients between hydrogeological units should be included. An indication of seasonal fluctuations and highest seasonal water table is expected over a period of time. Where site grade alterations are anticipated, the water table should be discussed in relation to both pre-development and the finished grade.

Field work should be carried out to assess the potential impacts of the proposed development on sensitive groundwater dependent features such as surface water and wetlands. In addition, the consultant should also provide a description of regional groundwater conditions that can be summarized from regional monitoring well data (where available) and water well records within the vicinity of the site (range and average well depth, range and average pumping rate, shallowest/deepest well, any flowing well conditions, etc.) to supplement site specific data.

Identification and characterization of hydrostratigraphic units, including local and regional aquifers

A summary of infiltration and recharge rates associated with the site materials

Description and characterization of hydraulic conductivity and hydraulic gradients

General description of surface water/groundwater relationships

Water well characteristics that may be useful in characterization of the system (well depth, pumping rate, water level, types of wells, flowing conditions etc.)

Summary of groundwater levels, including seasonal fluctuations and highest water table evaluation

Groundwater flow characteristics

Characterization of hydraulic gradients

General description of surface water/groundwater relationships

Figures:

- Water table figure showing shallow groundwater flow direction
- Piezometeric surface for deeper aquifers showing groundwater flow direction (if applicable to the study)

3.1.10 Description of Surface Water Features

A description of the study area should include all stream orders (Strahler, 1952) and other surface water features (e.g. wetlands) on/or bounding the site.

Surface and groundwater interactions and associated features should be noted. Areas of groundwater discharge should be noted where anticipated; either through water table elevations generated from water well records mapped above or near ground surface elevation or observed in the field. Where groundwater models exist, figures showing simulated groundwater discharge within the gauged reach may be provided. Where tile drainage is known to exist, it should be noted.

General description of surface water features on or near the site and their relationship to groundwater discharge and location to the water table

Figure of watercourses and wetlands (provincially and locally significant) on or near the site

3.1.11 Water Taking Permit Details

Where a Permit to Take Water (PTTW) is required from the MOE, the proponent should provide the Conservation Authority with the supporting PTTW information as provided to the MOE (if available). This should include permitted and actual planned taking details as well as special conditions of the permit, where applicable.

Permit to Take Water application material should to be provided

3.1.12 Water Quality

A description of water quality (ground and surface) should be provided. This is to establish a baseline to assess potential future impacts. The consultant should request monitoring data where such data are available, and comment on anticipated impacts from the development to both ground and surface water bodies in the area. Where impacts are anticipated, the consultant should suggest ways to mitigate these impacts. Even where these impacts may be unavoidable or necessary to ensure human safety (such as impacts from road salting), such considerations would allow a holistic approach to the maintenance of watershed health.

A description of surface and groundwater quality

3.1.13 D-5-5 (Water Supply)

Where a planned development is to establish a private water supply, the Ministry of Environment D-5-5 (*Technical Guideline for Private Wells: Water Supply Assessment, 1996*) is the provincial technical guideline that a proponent is generally required to adhere to. It is noted that the health and public works departments of some Ontario municipalities set their own requirements for applications for private servicing. Per the D-5-5 guideline, the capability of the aquifer to supply a sufficient quantity of water in accordance with the requirements of Regional `Guidelines for Small Groundwater Supply Systems August 1987' (MOE, 1995) must be demonstrated. Pumping tests are required as part of the guideline and details for the number of test wells required as well as the duration of the pumping test are outlined.

D-5-5 stipulates the minimum number of test wells as well as other considerations for a given size of property and a survey of private wells within a minimum of 500m of the site. Where there are private water wells in the vicinity of the development, information should be obtained where possible to establish pre-development conditions and to assess impacts during pumping tests. Where possible, new subdivision water supply wells should be developed in deeper confined aquifers to provide protection from surface activities. In locations where a protective aquitard does not exist, or it is limited in vertical thickness and extent, recommendations and decisions associated with the location of wells should take into consideration potential sources of off-site and on-site contamination such as septic leaching beds, farming operations, industrial operations, etc., recognizing, where appropriate, the potential formation of contaminant plumes from these sources.

Regardless of the aquifer chosen for the water supply, the water quality of the upper shallow aquifer, if applicable, should be determined. The shallow aquifer assessment will also include the potential impact of the development to the overall groundwater flow system which could lead to potential impacts on nearby groundwater dependent features such as wetlands and watercourses.

3.2 IMPACT ASSESSMENT

Developments typically result in impacts including: increased runoff, reduction in infiltration potentially leading to reduced interflow and baseflow discharge, raised or lowered water levels in shallow aquifers, changes in shallow groundwater flow direction, and creation of preferential pathways that may increase susceptibility of contamination in the subsurface. Impacts may be cumulative in areas where intensive development is planned.

The proponent must provide an assessment of potential impacts. The impact assessment will vary depending on the trigger of the hydrogeological assessment (e.g. a significant recharge area may require a water balance). Therefore, each Conservation Authority should be consulted to determine specific policies and associated requirements. In addition, acceptable impacts and appropriate mitigation will require the input of a qualified ecologist and/or biologist.

The assessment of potential development impacts may include, but is not limited to, a description of the following potential impacts:

- Changes to water table elevation (including seasonal fluctuations)
- Changes in groundwater flow direction
- Reduction to infiltration/recharge/discharge rates and volumes on varying time scales (i.e., daily to annual depending upon proximal environmental features)
- Reduction in baseflow
- Impacts on water quality
- Impacts to nearby receiving surface waters (wetlands, watercourses or other significant features)
- Impacts to environmental features

The impact assessment should demonstrate a degree of understanding of site conditions such that the potential impact of the proposed development is recognized and discussed. In addition, the assessment should evaluate the potential changes to existing conditions of the recharge/discharge features and functions resulting from the proposed development. This should include a description of the estimated post-development change from existing conditions as assessed and the direct and indirect effects over short-term and long-term periods should be described. A pre-development and post-development water balance is expected for most, though not all, development applications (see Table 1). The impact assessment should discuss how pre-development infiltration, evapotranspiration, runoff and flow paths can be maintained. Groundwater quantity, quality, water level patterns (duration, frequency and spatial distribution) and the link to nearby wetlands/watercourses should all be considered.

3.2.1 Groundwater Levels

Where the pre-development shallow groundwater levels are shown to support natural features (wetland and/or discharge to another surface water feature), and where the proposed development will require dewatering or is anticipated to result in a change in the volume and/or alteration to infiltration or recharge rates, an impact assessment of the groundwater levels must be included in the report. The following information should be included:

- Where the proposed development will result in a change in the infiltration/recharge rate, information on how and where water levels will be changed (i.e. increased or decreased)
- Anticipated impacts to sensitive groundwater-dependent features (wetland and watercourse) - mitigation plans to address the impacts (see Section 3.3 Mitigation)

3.2.2 Pumping Tests

Where the proposed development requires a dewatering pumping test, the design and interpretation of the test should be done by a qualified professional. The following information should be provided:

- Rate and duration of pumping test water level data in the form of hydrographs from observation wells used to measure impacts (i.e. shallow and deep aquifer units, mini-piezometers in surface water features, nearby private wells)
- Documentation of the test and interpretations should be provided (i.e. data and output from a manual analysis or from a commercially available software e.g. AquiferTest)

3.2.3 Groundwater Discharge (Baseflow)

As part of their mandate, Conservation Authorities are concerned with the potential impact of development on groundwater contribution to baseflow. In many areas in the province, baseflow represents between 50 and 90% of summer flow in many creeks with established aquatic life and watershed species dependencies. Dewatering and tile drain or large pipe installations can significantly reduce the volume of baseflow contributions from the subsurface. Changes to shallow groundwater flow patterns induced through development have also been linked to flooding and resulting damage to private property. It is recommended that the proponent ensure that the impact assessment considers and either avoids, or sufficiently mitigates, impacts to baseflow.

Estimate/quantify reduction to baseflow

3.2.4 Water Balance Analysis

A water balance analysis is required to estimate the pre-development and post-development infiltration and runoff for most development applications as outlined in Table 1. Many Conservation Authorities have policies related to maintaining infiltration. The maintenance of pre-development 'recharge' is a general requirement in the Oak Ridges Moraine Conservation Plan, Lake Simcoe Protection Plan and the Provincial Policy Statement that is often captured in municipal Official Plans. Groundwater frequently supports significant watershed features that are necessary components to the maintenance of a healthy watershed. The purpose of the water budget analysis is to reasonably estimate the current infiltration rates to the subsurface and to then determine how much this rate will change as a result of the proposed development. It is recognized that site specific water budgets are difficult to accurately estimate, the goal should be to assess the difference between pre-development and post development conditions and to mitigate for impacts on infiltration. Please see Section 3.3 for more information on mitigation measures and the example in APPENDIX A: Water Balance Example.

The terms 'infiltration' and 'recharge' are commonly used interchangeably in development application supporting documents. Infiltration relates to the capacity for the soil to allow water to enter the subsurface. Some of this infiltration results in lateral movement in the shallow unsaturated zone where interflow may predominate and some of the infiltration is directed downward to the deeper aquifer system. Recharge is considered to be primarily water that reaches the saturated zone of the aquifer and becomes part of the regional groundwater flow system. The maintenance of infiltration rates is essential to the sustainability of the groundwater flow system which may support local significant ecological features. In addition, infiltration may move to a regional deeper flow system that may be important at a regional scale from either an ecological or water supply perspective.

It is common practice and an accepted method (by most Conservation Authorities) to provide estimates of surplus using a Thornthwaite and Mather approach where surplus is estimated based on precipitation minus evapotranspiration (Steenhuis and Van Der Molen, 1986). Infiltration portion of the surplus can be estimated by applying the infiltration factors provided in the Ministry of the Environment and Energy Hydrogeological Technical Information Requirements for Land Development Applications (1995). These factors consider slope, vegetation and soils. The remainder of surplus is considered to be runoff.

The water balance should be prepared by subdividing the development site into zones that reflect drainage outlets. In a simple case, there would be one catchment and one drainage outlet, whereas a more detailed case may have multiple stream catchments and several outlets. These catchments would be further subdivided by similar infiltration properties (i.e. grades, soils and vegetations). Pre-development and post-development water balances may have different catchments depending on the change in drainage patterns, grading, soil and vegetation as a result of the development. These changes should be clearly documented in the report and within a figure.

In most cases, one surplus value may be calculated for the entire site however, it may be requested that the surplus is calculated for each catchment for both pre- and post-development.

The Ontario Ministry of the Environment Stormwater Planning and Design Manual (2003) provides representative values for evapotranspiration in Ontario and provides guidance for factors to be used (based on MOEE, 1995 guidance) in determining recharge and runoff. It should be noted that the MOE Stormwater Manual (2003) provides examples only and where possible, local estimates of evapotranspiration and water surplus are to be provided using the Thornthwaite and Mather approach and data obtained from a local climatic station.

Post-development infiltration calculations/estimations should account for changes in imperviousness, vegetation, soil conditions, grading and site design by using adjusted infiltration factors based on these changes. These calculations should take into account the change in surplus (i.e. decrease in evapotranspiration) in areas where there will be impervious surfaces (e.g. roadways, driveways and rooftops). Where an amount of evaporation is assumed to occur on impervious surfaces these assumptions should be documented and supported accordingly. Generally, a 10-20% loss of precipitation is acceptable for these areas and is highly dependant on the drainage of the site.

With the recent completion of technical studies required under The Clean Water Act, 2006, many of the Conservation Authorities now utilize numerical models to estimate, interception, evaporation, potential and actual evapotranspiration, snowmelt, runoff, infiltration, interflow, and groundwater recharge. Many of these model estimates are based on soils, surficial geology and land use mapping products but may also consider detailed vegetation attributes as well as hydrological cycle functions. These modelling output data may be available from the Conservation Authority and consultants are encouraged to liaise with staff for access to the information.

Regardless of the water balance method applied, site-specific data and estimates should be incorporated as appropriate. The water balance should provide monthly calculations based on Thronthwaite and Mather to show Potential ET, Actual ET, and then use these to determine the annual surplus. However, a monthly water balance may be requested to take into account short-term or seasonal scale in addition to long-term or annual scale effects.

As much as possible, calculations should estimate the amount of infiltration necessary to maintain pre-development conditions. Detailed information on the proposed mitigation measures should be provided to account the loss of infiltration. These details should include location of enhanced infiltration (e.g. infiltration trench), the volume/rate and condition of the soils to support water being infiltrated. Mitigation is discussed further in Section 3.3.1.

At a minimum, the following are required when conducting a water balance analysis:

- Obtain precipitation values from a reliable source such as Environment Canada Meteorological Services for the area (utilize closest station with adequate data)
- Estimate of local values for major water balance components (evapotranspiration, surplus, runoff, and infiltration) for pre-development, post-development and post-development with mitigation conditions
- Calculations of impervious areas that reflect actual conditions based on the proposed site plan or a reasonable range of impervious areas used in those cases where only a conceptual development plan is provided
- Runoff coefficients consistent with generally accepted numbers (e.g. MOE guidelines)
- The water balance is required to take into account the changes to grading/topography and land cover.
- Grain size analysis for both the fill material and on-site soils to confirm fill material is similar to existing soil conditions (maybe recommended).
- Appropriate catchments should be used within the analysis (i.e. delineate catchments based on drainage, grades, vegetation, soils and show how infiltration and runoff will change within these zones for both pre- and post-development).
- Figure of catchments used within the pre- and post-development water balance.
- All calculations should be provided in a table format which clearly demonstrates that inputs (precipitation, additional runoff, water from municipal wells, etc.) are equal to outputs (i.e. infiltration, runoff, water use).

3.2.5 Groundwater Quality

The impact of the proposed development on groundwater quality should be assessed. This may include impacts to a surface water feature from road maintenance, landscaping practices and/or chemical processing or storage. In addition, water quality should be assessed as it relates to:

- Private water supply servicing
- Discharge water as a result of dewatering activities

Activities that can be undertaken in areas that are delineated as Highly Vulnerable Aquifers (HVAs) and Significant Groundwater Recharge Areas (SGRAs), completed as part of the Assessment Report required in support of The Clean Water Act, 2006.

The existing water quality will need to be determined by sampling and testing of the water source to understand baseline conditions. The parameters analyzed should include general chemistry, bacteriological parameters, and site specific parameters of concern relating to past, existing and proposed land use. Based on the type of proposed development, an appropriate guideline (e.g. Ontario Drinking Water Quality Standards or Provincial Water Quality Objectives) should be selected from which to compare the test results. Other water quality guidelines may be considered for comparison on a case by case basis. Regardless of the aquifer chosen for the water supply, the water quality, and the potential impacts that might arise from the proposed development, within the upper shallow aquifer, if applicable, must be assessed. This assessment will include the potential water quality impacts to the shallow groundwater flow system as well as to any sensitive groundwater dependent features such as wetlands or watercourses.

3.2.6 D-5-4 Technical Guideline for Individual On-Site Sewage Systems: Water Quality Impact Risk Assessment 1996 - Septic System Suitability Evaluation

Where a planned development is to establish individual on-site sewage systems, the Ministry of Environment D-5-4 (Technical Guideline for Individual On-Site Sewage Systems: Water Quality Impact Risk Assessment, *1996*) is the provincial technical guideline that a proponent is generally required to adhere to. The septic system study should be consistent with the minimum requirements of the MOE Manual of Policy, Procedures and Guidelines for Private Sewage Disposal Systems and any Regional Health Unit and Public Works Departments Guidelines.

The evaluation should take into consideration the hydrogeological conditions of the site and groundwater resource evaluation and integrate these with septic effluent disposal issues.

The septic system suitability evaluation will require soils investigations to determine soil profiles and to estimate percolation for each lot across the site. Soil profiles to a minimum depth of 2 meters are required for each surficial geologic material on the property. The percolation times can be determined by the following methods:

- Grain size analysis of representative soil samples, and/or

- In-situ Percolation tests, and/or
- Guelph permeameter tests

Any one method can be used to determine percolation times but it is recommended that more than one method be used to provide comparative results. Representative percolation times are required for all soil types on the property. Lot specific testing will be required prior to draft approval for the design of private sewage systems.

Percolation times will be used to determine the design of the septic system according to the details given by MOE's Manual of Policy, Procedures and Guidelines for Private Sewage Disposal Systems, and Regional Health Services and Public Works Departments guidelines. All of the limiting factors such as depth to the water table, thickness of acceptable soils, range of percolation times, and distances to wells and surface water, as set out in the MOE and Regional Guidelines, must be considered in the design. Based on the septic system design and the design sewage flow, the hydraulic loading to the groundwater must be assessed. In determining the hydraulic loading, consideration must be given to the hydraulic properties of the soil materials in which the septic systems will be placed as well as the underlying materials. The loading must be calculated on a lot-by- lot basis as well as in consideration of the development as a whole.

Using all of the information described above, provision of a diagram(s) showing the typical lot plan, building and leaching bed envelopes is recommended for each leaching bed design. Each leaching bed must be designed specific to the conditions on each lot.

3.3 MITIGATION REQUIREMENTS

The majority of development application studies should include recommendation(s) for actions to mitigate potential impacts identified through the hydrogeological studies. Specific measures should be described to mitigate the potential impacts identified in Section 3.2. Mitigation recommendations shall address both the anticipated long-term and short-term impacts. To this end, a monitoring program to address potential impacts prior to, during and post-development may be requested by the Conservation Authority at its discretion. In this case a contingency plan may also be required (see contingency plans).

Mitigation measures might include, but are not limited to:

- Recharge or infiltration basins for urban runoff
- Preservation of setbacks (buffer areas) from recharge/discharge areas
- Sedimentation control plans to prevent siltation of recharge/discharge areas
- Spill Control Plans
- Re-vegetation plans for disturbed areas
- Re-orientation of local surface water drainage
- Provisions for land use and site control plans (e.g., tree cutting restrictions, prohibition of use or storage of specified contaminants, access restrictions, etc.)

3.3.1 Maintenance of Infiltration

The maintenance of infiltration and interflow hydraulic functions is a key target to ensure that discharge to ecological features in close proximity will not be impacted and that the overall watershed health is sustained. It is recommended that especially in areas delineated as High Volume Recharge Areas, Significant Groundwater Recharge Areas, and Ecologically Significant Recharge Areas, pre-development infiltration should be matched in the post-development scenarios utilizing low impact development solutions. In other areas, professional judgement should prevail.

There are various approaches to mitigating the impacts through Low Impact Development (LID) measures. The proponent is encouraged to plan for such measures, even in areas with low infiltration (i.e. low permeability materials) given that the cumulative impact of development even on these areas can be significant over time. Any recommended approaches should be feasible/practical given the site's surficial native soils. Please refer to the Low Impact Development Stormwater Management Planning and Design Guide, Version 1.0 for some more information (Toronto and Region Conservation Authority and Credit Valley Conservation Authority, 2011).

It should be noted that promoting infiltration from paved surfaces, such as parking lots, roadways, etc. will generally not be approved unless the water has been pre-treated to prevent groundwater contamination.

Another consideration in recommending enhanced infiltration techniques is thermal considerations. Thermal impacts are important to aquatic life in areas where shallow discharge to streams is significant. Where proposed mitigation measures to increase infiltration are identified, these can also be beneficial to creeks with cold water thermal regimes by buffering them from prolonged spikes in air temperatures or inputs of hot urban stormwater. Cold water fish community assemblages have limits to the water temperatures they can tolerate. If these limits are surpassed frequently or for prolonged periods of time, then degradation in the health and the makeup of the fish community can be expected. As such, mitigation measures that promote stormwater infiltration can be of great benefit to enhancing groundwater contributions to cold water creeks thereby protecting and enhancing the thermal stability of these fish communities.

Green infrastructure may include downspouts connected to rain water cisterns, rain gardens, green roofs, vegetated filter strips, dry and bio swales, perforated pipe, infiltration trenches, and permeable pavement. Different approaches may be combined depending on the available space, configuration, topography and soil types associated with the development. These mitigation approaches are intended to move from the more conventional approach of "pipe and convey" to one that maintains the hydrologic cycle and mitigates water quality impacts. The above is not a complete list of current approaches being applied to development. Technical documents should be reviewed for the details on appropriate approaches that may be recommended for any particular site.

Clean water (roof, walkways, parking lot and road runoff with adequate treatment) may be infiltrated through infiltration trenches that may be modular in design. Enhanced infiltration measures should not receive runoff from high traffic areas where large amounts of de-icing salts are used nor areas where there are several or large sources of pollutants. Site topography and the location of the seasonally high water table are additional considerations.

Where a proposed mitigation measure to increase infiltration has been identified, the following points should be presented/discussed:

- the mitigation method(s) selected;
- location of mitigation measures on site plan
- impacts to groundwater and surface water quality;
- the amount (or range) of the annual enhanced infiltration estimated (based on available literature for each mitigation method recommended);
- limitations - practical matters need to be considered (such as the nature of the native soil and its capacity to allow enhanced infiltration);

- the long term expected success of the measures, for example clogging or siltation of infiltration facilities is a common issue that needs to be addressed;
- long term maintenance of the measure should be discussed (i.e. will maintenance be required and who will undertake such maintenance)
- post-development monitoring - often recommended but it is uncertain whether the monitoring actually occurs and to whom the data is being provided.

The current practice of simply increasing the infiltration factor where a form of mitigation is recommended with no documentation or breakdown calculation on the expected enhancement values for each individual method or how these methods will be evaluated is unacceptable.

It is understood that some developers and or their consultants do work with municipal or Conservation Authority staff in designing and monitoring LIDs but this is not common across the province.

3.3.2 Maintenance of Groundwater Quality

The mitigation measures should address not only water quantity, but also the potential for water quality impacts on groundwater and surface water resources as a result of the development. Depending on the zoned use of the site, water quality concerns will vary. For example, in the case where shallow groundwater flow discharging to nearby streams is significant, potential temperature changes are also relevant, as aquatic life may be impacted. A discussion of potential impacts to sensitive features (i.e. wetlands, watercourses, etc.), along with recommendations for mitigation of the impacts, should be provided.

3.3.3 Monitoring Program

Pre-Development monitoring program:

A monitoring program will need to be implemented prior to development in order to assess existing conditions and to undertake an impact assessment as outlined in Section 3.2. Pre-development monitoring may also assist in addressing public concerns that could arise in the future. The proposed monitoring program should outline the following:

- Location of the proposed monitoring stations;
- Description of the monitoring locations (well type, depth and conditions, wetland, reservoir, stream, etc);

Frequency of specific data collection;

Chemical and other parameters to be monitored as well as frequency of monitoring.

Development monitoring program:

In certain cases where an impact assessment indicates that potential impacts may arise during construction, the developer may be required by the Conservation Authority to monitor the impact of development during construction activities. In certain situations a contingency plan may also be required to mitigate observed impacts (see below). The monitoring program would be designed to assess water levels and/or water quality impacts during development activities. Where the MOE has required a monitoring program as a condition of a Permit to Take Water (PTTW) application, these results may also be requested by the Conservation Authority.

In certain cases where an impact assessment indicates that potential impacts may arise during construction, the developer may be required by the Conservation Authority to monitor the impact of development during construction activities. In certain situations a contingency plan may also be required to mitigate observed impacts (see below). The monitoring program would be designed to assess water levels and/or water quality impacts during development activities. Where the MOE has required a monitoring program as a condition of a Permit to Take Water (PTTW) application, these results may also be requested by the Conservation Authority.

Both up gradient and down gradient monitoring wells may be required for baseline data and information. Any required monitoring program would be designed in co-operation with the Conservation Authority to meet their concerns. The program would address:

rationale for location of the proposed monitoring well(s);

source of water supply (i.e. communal vs. individual wells);

zone(s) to be monitored (i.e. depth of well, aquifer receiving effluent, aquifer supplying water, receptors);

frequency of monitoring;

necessary parameters to be monitored (e.g. nitrate, bacteria)

Monitoring results will be provided to the Conservation Authority (and municipality) at a pre-determined interval

Post-development monitoring program:

Post-development monitoring will not be required in most cases. In some circumstances the Conservation Authority may request that the development monitoring program (above) continue for a pre-determined amount of time following development activities to assess delayed impacts to groundwater resources.

3.3.4 Contingency Plans

Where determined during pre-consultation or review of the proposed development, a contingency plan may be required. This requirement would come into effect if significant impacts are anticipated from the proposed development. This could include for example, situations where large quantities or long duration of de-watering are expected, where a significant reduction in recharge is possible, or where degradation to water quality might be anticipated. The report must include contingency plans to address such potential impacts. Contingency plans can be requested to address short and long term impacts depending on the duration and complexity of the development and the potentiality of impacts.

3.4 SUMMARY AND RECOMMENDATIONS

Each report will summarize the study findings and provide recommendations to minimize negative impacts to the groundwater-dependent features and their functions.

3.5 FIGURES

The report should include appropriately scaled figure(s) sufficient to describe the subject property in the context of the environmental resources under discussion. Sections 3.1 through 3.3 outline the suggested minimum recommended figures to be included within the report.

Figures as outlined in Sections 3.1 through 3.3

3.6 REFERENCES

List references

3.7 APPENDICES

Well records and borehole logs

Pumping test and associated water level information

In-situ hydraulic conductivity testing results

Soil analysis results

Water balance calculations – Table format

Laboratory water quality results

Copies of relevant planning policies, agency guidelines

4 REFERENCES

Low Impact Development Stormwater Management Planning and Design Guide, Version 1, Toronto and Region and Credit Valley Conservation, 2010.

Ministry of Environment and Energy. 1995, MOEE Hydrogeological Technical Information Requirements for Land Development Applications.

Ministry of Environment and Energy. 1995, MOEE Hydrogeological Technical Information Requirements for Land Development Applications. Appendix C2: D-5-5 Technical Guideline for Private Wells: Water Supply Assessment, 1996.

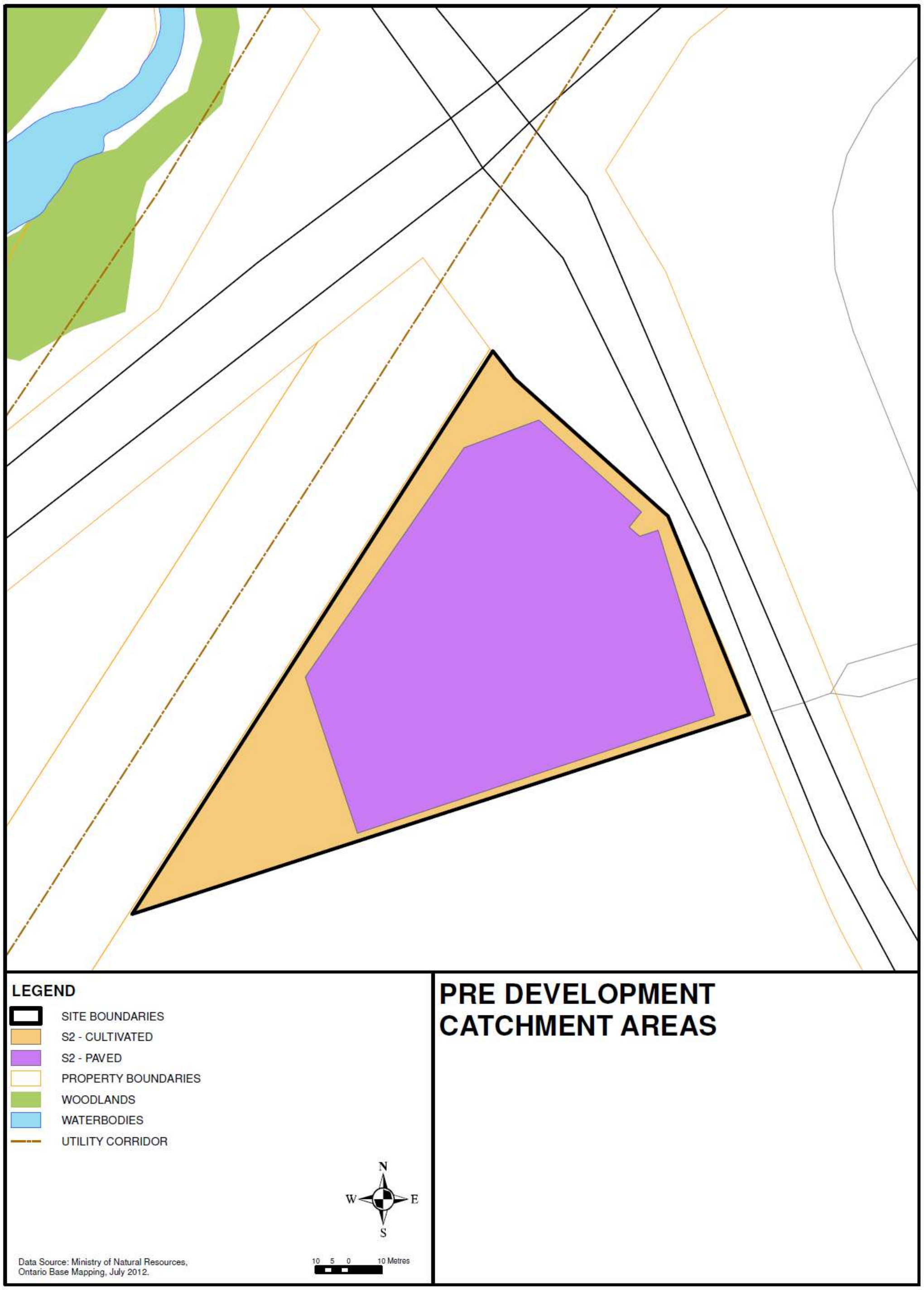
Ministry of Environment and Energy. 1995, MOEE Hydrogeological Technical Information Requirements for Land Development Applications. Appendix C3: D-5-4 Technical Guideline for Individual On-Site Sewage Systems: Water Quality Impact Risk Assessment, 1996.

Strahler, A. N. (1952). "Dynamic basis of geomorphology". Geological Society of America Bulletin 63: 923–938.

Strahler, A. N. (1952). "Hypsometric (Area-Altitude) analysis of erosional topography". Geological Society of America Bulletin 63: 1117–1142

T.S. Steenhuis, W.H. Van Der Molen, The Thornthwaite-Mather procedure as a simple engineering method to predict recharge, Journal of Hydrology, Volume 84, Issues 3–4, 30 May 1986, Pages 221-229, ISSN 0022-1694, 10.1016/0022-1694(86)90124-1

APPENDIX A: Water Balance Example



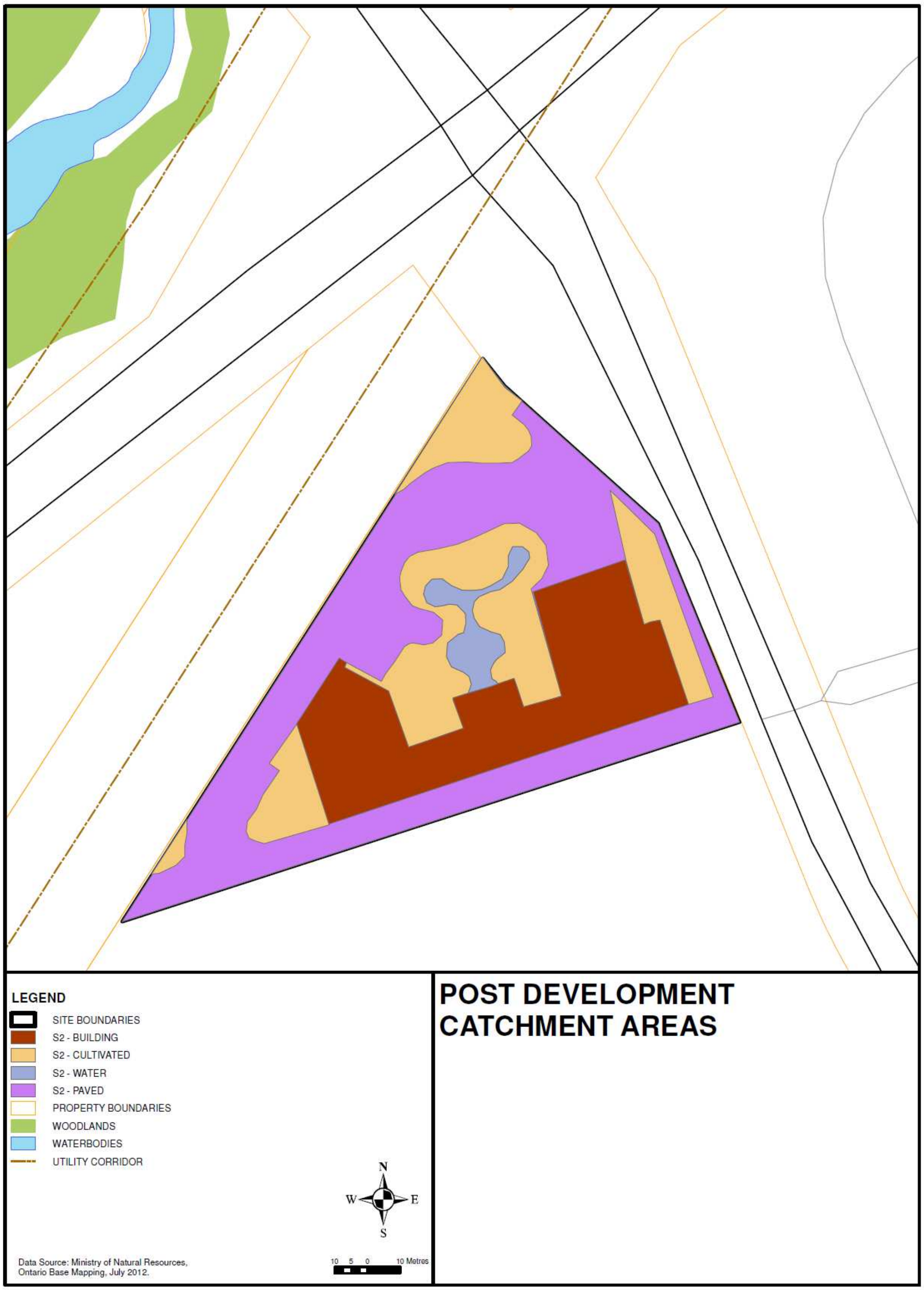

LEGEND
SITE BOUNDARIES
S2 - BUILDING
S2 - CULTIVATED
S2 - WATER
S2 - PAVED
PROPERTY BOUNDARIES
WOODLANDS
WATERBODIES
UTILITY CORRIDOR
N
W
E
S
10 5 0 10 Metres
Data Source: Ministry of Natural Resources,
Ontario Base Mapping, July 2012.
POST DEVELOPMENT
CATCHMENT AREAS

TABLE 1
CLIMATIC WATER BUDGET: CLIMATE NORMAL 1971-2000 (TORONTO LESTER B. PEARSON INT'L AIRPORT)
Potential Evapotranspiration
TRILLIUM HEALTH CENTRE

	Thornthwaite (1948)							
Month	**Mean Temperature (°C)**	**Heat Index**	**Potential Evapo-transpiration (mm)**	**Daylight Correction Value**	**Adjusted Potential Evapo-transpiration (mm)**	**Total Precipitation (mm)**	**Surplus (mm)**	**Deficit (mm)**
January	-6.3	0.0	0.0	0.81	0.0	52.2	52.2	0.0
February	-5.4	0.0	0.0	0.81	0.0	42.6	42.6	0.0
March	-0.4	0.0	0.0	1.02	0.0	57.1	57.1	0.0
April	6.3	1.4	28.4	1.12	31.8	68.4	36.6	0.0
May	12.9	4.2	61.8	1.27	78.5	72.5	0.0	6.0
June	17.8	6.8	87.7	1.29	113.1	74.2	0.0	38.9
July	20.8	8.7	103.8	1.30	134.9	74.4	0.0	60.5
August	19.9	8.1	98.9	1.20	118.7	79.6	0.0	39.1
September	15.3	5.4	74.4	1.04	77.4	77.5	0.1	0.0
October	8.9	2.4	41.3	0.95	39.3	64.1	24.8	0.0
November	3.2	0.5	13.6	0.80	10.9	69.3	58.4	0.0
December	-2.9	0.0	0.0	0.74	0.0	60.9	60.9	0.0
TOTALS		**37.5**			**604.6**	**792.8**	**332.8**	**144.6**

TOTAL WATER SURPLUS **188.2** **mm**

NOTES:
1) Water budget adjusted for latitude and daylight.
2) (°C) - Represents calculated mean of daily temperatures for the month.
3) Precipitation and Temperature data from the Toronto Lester B. Pearson Int'l Airport located at latitude 43°40'38.0" N, longitude 79°37'50.0" W, elevation 173.40 m.
4) Total Water Surplus (Thornthwaite, 1948) is calculated as total precipitation minus adjusted potential evapotranspiration.
5) Total Moisture Surplus (Thornthwaite and Mather, 1957) is calculated as total precipitation minus actual evapotranspiration for 2007 and 2008.

TABLE 2
WATER BUDGET - PRE-DEVELOPMENT
WATER BALANCE/ WATER BUDGET ASSESSMENT

Catchment Designation	Site		
	S2 - Cultivated	S2 - Paved	S2 - Totals
Area (m^2)	4,229	9,427	13,656
Pervious Area (m^2)	4,229	9,427	13,656
Impervious Area (m^2)	4,229	9,427	13,656
Infiltration Factors			
Topography Infiltration Factor	0.15	0.15	
Soil Infiltration Factor	0.1	0.1	
Land Cover Infiltration Factor	0.1	0	
MOE Infiltration Factor	0.35	0	
Actual Infiltration Factor	0.35	0	
Run-Off Coefficient	0.65	1	
Runoff from Impervious Surfaces*	0	0.8	
Inputs (per Unit Area)			
Precipition (mm/yr)	793	793	793
Run-On (mm/yr)	0	0	0
Other Inputs (mm/yr)	0	0	0
Total Inputs (mm/yr)	**793**	**793**	**793**
Outputs (per Unit Area)			
Precipitation Surplus (mm/yr)	188	634	496
Net Surplus (mm/yr)	188	634	496
Evapotranspiration (mm/yr)	605	159	297
Infiltration (mm/yr)	66	0	20
Rooftop Infiltration (mm/yr)	0	0	0
Total Infiltration (mm/yr)	66	0	20
Runoff Pervious Areas	122	0	122
Runoff Impervious Areas	0	634	1,413
Total Runoff (mm/yr)	122	634	476
Total Outputs (mm/yr)	**793**	**793**	**793**
Difference (Inputs - Outputs)	**0**	**0**	**0**
Inputs (Volumes)			
Precipition (m^3/yr)	3,354	7,476	10,829
Run-On (m^3/yr)	0	0	0
Other Inputs (m^3/yr)	0	0	0
Total Inputs (m^3/yr)	**3,354**	**7,476**	**10,829**
Outputs (Volumes)			
Precipitation Surplus (m^3/yr)	795	5,977	6,772
Net Surplus (m^3/yr)	795	5,977	6,772
Evapotranspiration (m^3/yr)	2,559	1,499	4,057
Infiltration (m^3/yr)	278	0	278
Rooftop Infiltration (m^3/yr)	0	0	0
Total Infiltration (m^3/yr)	278	0	278
Runoff Pervious Areas (m^3/yr)	517	0	517
Runoff Impervious Areas (m^3/yr)	0	5,977	5,977
Total Runoff (m^3/yr)	517	5,977	6,494
Total Outputs (m^3/yr)	**3,354**	**7,476**	**10,829**
Difference (Inputs - Outputs)	**0**	**0**	**0**

* Evaporation from impervious areas was assumed to be 20% of precipitation

TABLE 3
WATER BUDGET, POST-DEVELOPMENT
WATER BALANCE/ WATER BUDGET ASSESSMENT

Catchment Designation	Site				
	S2 - Cultivated	S2 - Paved	S2 - Building	S2 - Water	S2 - Totals
Area (m^2)	3,609	5,977	3,655	415	13,656
Pervious Area (m^2)	3,609	0	0	0	3,609
Impervious Area (m^2)	0	5,977	3,655	415	10,047
Infiltration Factors					
Topography Infiltration Factor	0.15	0.15	0.15	0.15	
Soil Infiltration Factor	0.1	0.1	0.1	0.1	
Land Cover Infiltration Factor	0.1	0	0	1	
MOE Infiltration Factor	0.35	0	0	0	
Actual Infiltration Factor	0.35	0	0	0	
Run-Off Coefficient	0.65	1	1	1	
Runoff from Impervious Surfaces*	0	0.8	0.8	0.8	
Inputs (per Unit Area)					
Precipition (mm/yr)	793	793	793	793	793
Run-On (mm/yr)	0	0	0	0	0
Other Inputs (mm/yr)	0	0	0	0	0
Total Inputs (mm/yr)	**793**	**793**	**793**	**793**	**793**
Outputs (per Unit Area)					
Precipitation Surplus (mm/yr)	188	634	634	634	516
Net Surplus (mm/yr)	188	634	634	634	516
Evapotranspiration (mm/yr)	605	159	159	159	277
Infiltration (mm/yr)	66	0	0	0	17
Rooftop Infiltration (mm/yr)	0	0	0	0	0
Total Infiltration (mm/yr)	66	0	0	0	17
Runoff Pervious Areas	122	0	0	0	122
Runoff Impervious Areas	0	634	634	634	1,765
Total Runoff (mm/yr)	122	634	634	634	499
Total Outputs (mm/yr)	**793**	**793**	**793**	**793**	**793**
Difference (Inputs - Outputs)	**0**	**0**	**0**	**0**	**0**
Inputs (Volumes)					
Precipition (m^3/yr)	2,862	4,740	2,898	329	10,829
Run-On (m^3/yr)	0	0	0	0	0
Other Inputs (m^3/yr)	0	0	0	0	0
Total Inputs (m^3/yr)	**2,862**	**4,740**	**2,898**	**329**	**10,829**
Outputs (Volumes)					
Precipitation Surplus (m^3/yr)	678	3,789	2,317	263	7,048
Net Surplus (m^3/yr)	678	3,789	2,317	263	7,048
Evapotranspiration (m^3/yr)	2,183	950	581	66	3,781
Infiltration (m^3/yr)	237	0	0	0	237
Rooftop Infiltration (m^3/yr)	0	0	0	0	0
Total Infiltration (m^3/yr)	237	0	0	0	237
Runoff Pervious Areas (m^3/yr)	441	0	0	0	441
Runoff Impervious Areas (m^3/yr)	0	3,789	2,317	263	6,370
Total Runoff (m^3/yr)	441	3,789	2,317	263	6,811
Total Outputs (m^3/yr)	**2,862**	**4,740**	**2,898**	**329**	**10,829**
Difference (Inputs - Outputs)	**0**	**0**	**0**	**0**	**0**

* Evaporation from impervious areas was assumed to be 20% of precipitation

TABLE 4
WATER BUDGET, POST-DEVELOPMENT WITH MITIGATION
WATER BALANCE/ WATER BUDGET ASSESSMENT

Catchment Designation	Site				
	S2 - Cultivated	S2 - Paved	S2 - Building	S2 - Water	S2 - Totals
Area (m^2)	3,609	5,977	3,655	415	13,656
Pervious Area (m^2)	3,609	0	0	0	3,609
Impervious Area (m^2)	0	5,977	3,655	415	10,047
Infiltration Factors					
Topography Infiltration Factor	0.15	0.15	0.15	0.15	
Soil Infiltration Factor	0.1	0.1	0.1	0.1	
Land Cover Infiltration Factor	0.1	0	0	1	
MOE Infiltration Factor	0.35	0	0	0	
Actual Infiltration Factor	0.35	0	0	0	
Run-Off Coefficient	0.65	1	1	1	
Runoff from Impervious Surfaces*	0	0.8	0.8	0.8	
Inputs (per Unit Area)					
Precipition (mm/yr)	793	793	793	793	793
Run-On (mm/yr)	0	0	0	0	0
Other Inputs (mm/yr)	0	0	0	0	0
Total Inputs (mm/yr)	**793**	**793**	**793**	**793**	**793**
Outputs (per Unit Area)					
Precipitation Surplus (mm/yr)	188	634	634	634	516
Net Surplus (mm/yr)	188	634	634	634	516
Evapotranspiration (mm/yr)	605	159	159	159	277
Infiltration (mm/yr)	66	0	0	0	17
Rooftop Infiltration (mm/yr)	0	0	10	0	3
Total Infiltration (mm/yr)	66	0	10	0	20
Runoff Pervious Areas	122	0	0	0	122
Runoff Impervious Areas	0	634	624	634	1,755
Total Runoff (mm/yr)	122	634	624	634	496
Total Outputs (mm/yr)	**793**	**793**	**793**	**793**	**793**
Difference (Inputs - Outputs)	**0**	**0**	**0**	**0**	**0**
Inputs (Volumes)					
Precipition (m^3/yr)	2,862	4,740	2,898	329	10,829
Run-On (m^3/yr)	0	0	0	0	0
Other Inputs (m^3/yr)	0	0	0	0	0
Total Inputs (m^3/yr)	**2,862**	**4,740**	**2,898**	**329**	**10,829**
Outputs (Volumes)					
Precipitation Surplus (m^3/yr)	678	3,789	2,317	263	7,048
Net Surplus (m^3/yr)	678	3,789	2,317	263	7,048
Evapotranspiration (m^3/yr)	2,183	950	581	66	3,781
Infiltration (m^3/yr)	237	0	0	0	237
Rooftop Infiltration (m^3/yr)	0	0	37	0	37
Total Infiltration (m^3/yr)	237	0	37	0	274
Runoff Pervious Areas (m^3/yr)	441	0	0	0	441
Runoff Impervious Areas (m^3/yr)	0	3,789	2,281	263	6,333
Total Runoff (m^3/yr)	441	3,789	2,281	263	6,774
Total Outputs (m^3/yr)	**2,862**	**4,740**	**2,898**	**329**	**10,829**
Difference (Inputs - Outputs)	**0**	**0**	**0**	**0**	**0**

* Evaporation from impervious areas was assumed to be 20% of precipitation
Approximately 6% of total roof runoff is to be infiltrated to match pre-development infiltration

TABLE 5
WATER BUDGET SUMMARY
WATER BALANCE/ WATER BUDGET ASSESSMENT

Characteristic	Site				
	Pre-Development	Post-Development	Change (Pre- to Post-)	Post-Development with Mitigation	Change (Pre- to Post- with Mitigation
Inputs (Volumes)					
Precipition (m^3/yr)	10,829	10,829	0.0%	10,829	0.0%
Run-On (m^3/yr)	0	0	0.0%	0	0.0%
Other Inputs (m^3/yr)	0	0	0.0%	0	0.0%
Total Inputs (m^3/yr)	**10,829**	**10,829**	**0.0%**	**10,829**	**0.0%**
Outputs (Volumes)					
Precipitation Surplus (m^3/yr)	6,772	7,048	4.1%	7,048	4.1%
Net Surplus (m^3/yr)	6,772	7,048	4.1%	7,048	4.1%
Evapotranspiration (m^3/yr)	4,057	3,781	-6.8%	3,781	-6.8%
Infiltration (m^3/yr)	278	237	-14.7%	237	-14.7%
Rooftop Infiltration (m^3/yr)	0	0	0.0%	37	0.0%
Total Infiltration (m^3/yr)	278	237	-14.7%	274	-1.5%
Runoff Pervious Areas (m^3/yr)	517	441	-14.7%	441	-14.7%
Runoff Impervious Areas (m^3/yr)	5,977	6,370	6.6%	6,333	6.0%
Total Runoff (m^3/yr)	6,494	6,811	4.9%	6,774	4.3%
Total Outputs (m^3/yr)	**10,829**	**10,829**	**0.0%**	**10,829**	**0.0%**