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Managing New Urban Development in Phosphorus-Sensitive Watersheds

Prepared for: Nottawasaga Valley Conservation Authority
Job #: J130014

October 31, 2014

Final Report

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October 31, 2014 HESL Job #: J130014

Mr. Glenn Switzer
Nottawasaga Valley Conservation Authority
8195 8th Line
Utopia, ON LOM 1T0

Dear Mr. Switzer:

Re: Managing New Urban Development in Phosphorus-Sensitive Watersheds – Final Report and Database Tool

We are pleased to present our final technical report that provides guidance for a generic approach for assessing pre- and post-development phosphorus loadings from new development in Ontario watersheds. This approach has been coded into a Microsoft ACCESS Database Tool, which is accompanied by a Database User's Manual (submitted under separate cover) to facilitate its use and the review process for development applications. Minor revisions to draft versions of these deliverables were made to address your comments at our meeting of August 11th, 2014 and feedback received at the workshop for practitioners held October 27th, 2014.

The approach that we developed is based on export coefficient modeling that uses recent, representative phosphorus export for different land uses in Ontario, with refinements to address site-specific variation in phosphorus loading for agricultural and urban lands. Phosphorus export from cropland is based on a relationship between soil loss estimated using the Universal Soil Loss Equation and phosphorus export. For urban lands, export coefficients are derived using an approach to account for site-specific variation in runoff conditions in urban settings. Recommendations are provided for consideration of Best Management Practices and Low Impact Development techniques to reduce phosphorus loading from development including the construction phase. In addition, the approach gives greater consideration for the use of runoff reduction (infiltration) BMP/LIDs to reduce phosphorus loads by assigning a phosphorus removal efficiency of 100% for all rainfall that is infiltrated if the effectiveness of this technique is verified in the submitted Stormwater Management Plan for a development.

It has been a pleasure working with you and your team on this assignment and we thank you for this opportunity.

Sincerely,
Hutchinson Environmental Sciences Ltd.

Tammy Karst-Riddoch, Ph.D.
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Signatures

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Executive Summary

The Nottawasaga River watershed is one of several watersheds in Ontario, and many more across Canada, that are exhibiting symptoms of nutrient enrichment. The enrichment stems, in part, from land use practices that allow for erosion of nutrient rich soils, or runoff of nutrient rich waters, to surface waters. Although poorly managed population growth has been identified as a major potential source of nutrient enrichment, it also provides for the opportunity to manage new development such that nutrient loading is stabilized, or even reduced, as land use changes.

The Government of Ontario has allocated substantial population growth to the Nottawasaga River watershed and with that comes the potential for either increased nutrient loading to the Nottawasaga River and southern Georgian Bay, a highly valued low nutrient water body, or the opportunity to manage new development to stabilize or reduce current loadings.

The Nottawasaga Valley Conservation Authority (NVCA) recognizes the value in a) setting targets for phosphorus management and b) the use of BMPs and LID techniques to manage the impacts of land use change as population grows and lands are converted from agricultural or natural uses to urban development. The NVCA also sees the value of a standard and reproducible approach to estimate phosphorus loadings as a function of land use and to model the benefits of BMP and LID implementation and wishes to develop an approach and a tool that can be applied first to the Nottawasaga watershed, and ultimately to other watersheds, to allow the estimation of local and site-specific phosphorus loads. Accordingly, the "NVCA Tool" for Managing New Urban Development in Phosphorus-Sensitive Watersheds" was developed as a modification of a tool developed by the Province of Ontario for the Lake Simcoe Watershed in 2012.

The NVCA Tool is based on an export coefficient approach in recognition that export coefficients address export of both dissolved and particulate phase phosphorus and that recent estimates were available for the Lake Simcoe watershed. Export coefficients were modified to reflect site specific soil and runoff characteristics for those land use classes that are most often changed with urbanization (cropland, high intensity residential, industrial, commercial and transportation).

Phosphorus export coefficients for the following land use classes were derived as the mean phosphorus export for all 'monitored' Lake Simcoe subwatersheds (n = 7) using phosphorus loads and land use areas from CANWET (Berger 2010) modeling (Section 3.1):

- Forest, Transition, Wetland, Open Water, Turf/Sod, Hay/Pasture, Low Intensity Residential, Unpaved Roads, Open Water

Phosphorus export coefficients for cropland (Section 3.2) were derived from the relationship between CANWET-derived phosphorus export for Lake Simcoe subwatersheds and soil loss (A) as estimated using the Universal Soil Loss Equation (USLE):

- Phosphorus Export (kg/ha/yr) = (0.16 x A) +0.16

Phosphorus export coefficients for urban land use classes (high intensity residential, commercial, industrial and transportation) were derived (Section 3.3) from an equation using a standard value for phosphorus concentrations in urban runoff (TP_i), annual depth of precipitation (Precip), that fraction of precipitation producing runoff (Pi) and a runoff coefficient derived for impervious surfaces (Rv):

- Phosphorus Export (kg/ha/yr) = TP_i x Precip x P_j x R_V x 10^{-2}

These estimates are recommended for use in Modules 1 and 2 of the NVCA Tool to estimate phosphorus export for Pre-Development and Post-Development land uses (Section 4.2). Module 3 (Section 5) addresses means to mitigate and reduce phosphorus loads by implementing approved BMPs and LID techniques and Section 5.1.2 describes the requirements for this estimation using the Tool. Taken together, Modules 1,2 and 3 allow the user to calculate and compare pre-development phosphorus export to post-development export, with and without BMP/LID implementation.

The construction phase of development provides the greatest risk of phosphorus export as land cover is disturbed and soils exposed to wind and water erosion prior to the construction of SWM facilities. The dynamic nature of construction and its variable time lines mean that phosphorus export for these activities cannot be reliably estimated. Nevertheless, development must proceed with a full commitment to mitigation and management of exposed soils to reduce the potential for soil and phosphorus loss. Module 4 (Section 6) provides a summary of recommended techniques and a checklist by which reviewers can assess the magnitude and effectiveness of construction phase mitigation when reviewing development applications.

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1. Introduction

The Nottawasaga River watershed is one of several watersheds in Ontario, and many more across Canada, that are exhibiting symptoms of nutrient enrichment. The enrichment stems, in part, from land use practices that allow for erosion of nutrient rich soils, or runoff of nutrient rich waters, to surface waters. Although poorly managed population growth has been identified as a major potential source of nutrient enrichment, it also provides for the opportunity to manage new development such that nutrient loading is stabilized, or even reduced, as land use changes. For example, implementation of Best Management Practices (BMPs) or Low Impact Development (LID) techniques as intensive forms of agriculture are converted to urban land uses offers real potential for management or reduction of nutrient loads.

The Government of Ontario has allocated substantial population growth to the Nottawasaga River watershed and with that comes the potential for either increased nutrient loading to the Nottawasaga River and southern Georgian Bay, a highly valued low nutrient water body, or the opportunity to manage new development to stabilize or reduce current loadings.

In 2010, the Ontario Ministry of the Environment implemented the *Lake Simcoe Protection Act* and accompanying Phosphorus Reduction Strategy to help reduce nutrient enrichment in Lake Simcoe as population grew. Policy 4.8e of the Lake Simcoe Protection Plan states that:

"An application for major development shall be accompanied by a stormwater management plan that demonstrates...

> *e. through an evaluation of anticipated changes in phosphorus loadings between pre-development and post-development, how the loadings shall be minimized."*

The MOE completed the "Phosphorus Budget Tool in Support of Sustainable Development for the Lake Simcoe Watershed" (HESL et al., 2012) to be used to calculate phosphorus loadings and reductions through BMPs and LID techniques, in support of the plan. The "Tool" was developed to be specific to Lake Simcoe and is based on the application of BMPs with demonstrated effectiveness in phosphorus reduction to estimates of phosphorus export made for specific land uses in each of the Lake Simcoe subwatersheds that was derived based on CANWET modeling results (Berger, 2010).

The Nottawasaga Valley Conservation Authority (NVCA) recognizes the value in a) setting targets for phosphorus management and b) the use of BMPs and LID techniques to manage the impacts of land use change as population grows and lands are converted from agricultural or natural uses to urban development. The NVCA also sees the value of a standard and reproducible approach to estimate phosphorus loadings as a function of land use and to model the benefits of BMP and LID implementation as was developed by the MOE for the Lake Simcoe watershed. The NVCA wishes however to develop an approach and a tool that is more generic - one that can be applied first to the Nottawasaga watershed, and ultimately to other watersheds, to allow the estimation of local and site-specific phosphorus loads.

In November of 2013, the NVCA retained Hutchinson Environmental Sciences Ltd. (HESL) to adapt the MOE Phosphorus Budget Tool for use in the Nottawasaga River subwatersheds and as a generic tool for estimating how phosphorus loads will change as lands are developed in other Ontario watersheds. Development of the generic tool was to be informed by:

- A comprehensive literature review of phosphorus export from different land uses and factors controlling export from disturbed lands,
- A comprehensive literature review of Best Management Practices (BMPs) and Low Impact Development (LID) techniques to document their effectiveness in reducing phosphorus export from developed lands, and
- An evaluation of existing monitoring and modeling data from the Nottawasaga River watershed for use in calculating phosphorus export.

2. Components of the Generic Phosphorus Budget Tool

The generic Phosphorus Budget Tool ("Tool" or "NVCA Tool") consists of three elements:

1. A **Technical Guidance Manual** (this document) that provides the reference materials used in developing the Tool and documents the derivation of export coefficients and estimation routines.
2. A Microsoft ACCESS© **Database Tool** that facilitates the calculation of a phosphorus budget for new development in accordance with the technical guidance, and
3. A **Database User's Manual** explaining the operation of the database.

The Technical Guidance Manual and Database Tool are divided into four modules that consider sediment and nutrient loss as follows:

- **Module 1** – Estimates pre-development phosphorus loads for representative, sub-catchment level land uses contained within the study site,
- **Module 2** – Estimates post-development phosphorus loads that are representative of the proposed land uses for the study site without BMPs and LID techniques to reduce phosphorus loads,
- **Module 3** – Estimates the reduction in phosphorus loads from the post-development scenario with implementation of BMPs and LID techniques, and
- **Module 4** – Provides a checklist for users to guide selection and implementation of BMPs for the construction phase of development to minimize sediment loss and resultant phosphorus export.

The NVCA Tool uses information that is normally required of the proponent as part of the standard process of planning approvals. Pre- and post-development land uses are derived from the Environmental Impact Statement (EIS) prepared by the proponent and BMPs for stormwater management would be developed and described in the Stormwater Management Plan for the new development that is prepared in support of the application. The proponent uses these materials as input to the Database Tool to calculate loadings in a standard format by the approved process.

Once the four modules are completed by entering information into the Database Tool, the pre- and post-development phosphorus loads are compared to determine if phosphorus loads are reduced relative to existing conditions, and that all reasonable and feasible construction phase BMPs have been identified and considered for implementation. The Database Tool provides summaries of all inputs and calculations in a standard format that facilitates review by planning authorities.

3. Modules 1 and 2: Pre- and Post-Development Phosphorus Load Estimation

Phosphorus loadings for pre-development and post-development scenarios are based on an export coefficient modeling approach. This approach was developed in North America to predict nutrient inputs to lakes and streams (Dillon and Kirchner, 1975; Beaulac and Reckhow, 1982; Rast and Lee, 1983) and is a well-established method of estimating phosphorus export when measured tributary flows and total phosphorus concentration data are lacking (e.g., Dillon et al. 1986, Johnes 1996, Winter and Duthie 2000, Paterson et al., 2006). The export coefficient approach is also used where it is desirable to forecast nutrient export from a land area prior to a change in land use or prior to implementing Best Management Practices (BMPs), in which case it is used as a predictive tool.

The use of phosphorus export coefficients for estimating phosphorus loading is based on the knowledge that specific land forms and land uses yield or export known quantities of phosphorus over an annual cycle. Knowing the area of land in a watershed devoted to specific uses and the quantities of nutrients exported per unit area of these uses (as nutrient export coefficients), annual phosphorus loading can be calculated as:

$$L = \Sigma\, EiAi \qquad \text{Equation (1)}$$

where L is the total phosphorus load from a given area of land (e.g., development site), Ei is the export coefficient selected for a specific land use and Ai is the area of that land use.

Export coefficients for a specific land use (Ei) are most often derived from measured phosphorus concentrations ($[TP]$) and water discharge (Q) in a watercourse draining a known area (A) that is dominated by that land use, where:

$$Ei = [TP] * Q / Ai \qquad \text{Equation (2)}$$

Since the development of export coefficient modeling, several more complex computer-based predictive models have become available (e.g., Soil and Water Assessment Tool (SWAT) developed by the US Department of Agriculture Agricultural Research Service (Chaubey et al., 2006); the CANadian ArcView Nutrient and Watershed Evaluation Tool (CANWET™); EPA's Storm Water Management Model (SWMM); Hydrological Simulation Program (HSPF) (US EPA, 2014); the Generalized Watershed Loading Function (GWLF) (Haith et al., 1992); and the SPAtially Referenced Regressions on Watershed attributes (SPARROW, USGS 2009)). These models are useful tools for predicting phosphorus loadings at a watershed scale where delivery mechanisms can be complex, but they require an abundance of data and modeling expertise of the user. At a smaller scale of a development site, however, the simpler export coefficient modeling remains an effective approach that requires only minimal information to establish annual phosphorus loads and potential changes in loading with development.

3.1 Derivation of Export Coefficients

Phosphorus export can be highly variable for any given land use due to differences in physiographic and climatological characteristics. The accuracy of phosphorus loading estimates from export coefficient modeling therefore is dependent on the selection of export coefficients that are representative of characteristics controlling phosphorus export for different land use. The most appropriate export coefficients are those that have been derived from the watershed where they are to be applied. Existing monitoring and modeling data specific to the Nottawasaga River subwatershed, however, were not suitable for deriving export coefficients (Appendix A).

Phosphorus export coefficients were compiled and reviewed from 36 published scientific papers for their potential use in estimating phosphorus loads for the Tool. The review focused on studies from Ontario and the north-eastern US that derived export coefficients from monitoring data. Summaries of the literature reviewed are provided in Appendix B.

The bulk of the phosphorus export coefficients available in the scientific literature for specific land uses were derived from studies conducted more than 30 years ago, and these have been previously summarized by Reckhow et al. (1980), Beaulac and Reckhow (1982), Rast and Lee (1983), Lin (2004), and Alberta Environment (2006). While these export coefficients have been used extensively in studies of phosphorus loading, their applicability to the Nottawasaga subwatersheds and to other areas in Ontario are questionable as they are unlikely to represent existing conditions of phosphorus export as land use practices (agriculture and urban development), phosphorus analysis techniques and climate conditions have changed since they were developed .

The most recent, representative export coefficients suitable for use in the NVCA Tool were developed by HESL (2012) for the Lake Simcoe Phosphorus Budget Tool. These were derived from results of modeled phosphorus loads from CANWET modeling (Berger, 2010) with the exception of those for High Intensity Development (Commercial/Industrial and High Intensity Residential), which was derived by MOE (unpublished data) and Open Water, which was derived from estimates of atmospheric loads to the surface of Lake Simcoe (Scott et al., 2006; LSRCA, 2009). For Cropland and urban land uses (Commercial/Industrial and High Intensity Residential Development), however, methods were refined to derive more site specific export coefficients for the NVCA Tool, as described in the following sections.

The resultant export coefficients recommended for the NVCA Tool are summarized in Table 1 with descriptions of land uses provided in Table 2. Details of the derivation of export coefficients are provided in Sections 3.1 - 3.3. The export coefficients are coded into the database tool to derive subwatershed-specific estimates of phosphorus export from specific land uses for the pre- and post-development (with no BMPs) calculations.

Table 1. Recommended Phosphorus Export Coefficients for Use in the Generic Phosphorus Budget Tool

Land Use	Export Coefficient (kg/ha/yr)	Notes
Forest	0.06	Mean phosphorus export for all 'monitored' Lake Simcoe subwatersheds (n = 7) derived using phosphorus loads from CANWET modeling. Monitored subwatersheds are those with sufficient measured data to validate and calibrate the model.
Transition	0.07	
Wetland	0.05	
Turf/Sod	0.11	
Hay/Pasture	0.08	
Low Intensity Residential	0.13	
Unpaved Roads	0.83	
Open Water	0.26	Calculated from the mean measured atmospheric load of 19 tonnes/yr averaged over 5 years from 2002 to 2007 to the surface of Lake Simcoe (surface area = 722 km^2) (Scott et al., 2006; LSRCA, 2009).
Cropland	0.16 x A +0.16	Developed from the relationship between CANWET derived phosphorus export for Lake Simcoe subwatersheds and soil loss. Where: A = soil loss determined using the Universal Soil Loss Equation (USLE) **Detailed derivation is provided in Section 3.1.**
Residential	TP_i x Precip x P_j x R_V x 10^{-2}	Where: TP_i is total phosphorus concentration (mg/L) in runoff measured from land use (i) from the SWAMP studies (TRCA, 2005), Precip is the annual precipitation (mm/yr), Pj is the fraction of Precip that produces runoff, and R_V is the runoff coefficient = 0.05 + 0.91 x impervious fraction following US EPA's Simple Method. **Detailed derivation is provided in Section 3.2.**
Commercial		
Industrial		
Transportation		

Table 2. Description of Land Uses for the NVCA Tool

Land Use	Description
Forest	Tree cover >60% of the land area. Includes ELC Forest (FO) and Cultural Plantation (CUP) classes. Also includes ELC Cultural Woodland (CUW) classes with tree cover between 35% and 60%).
Transition	Tree cover generally <60% and often with a large proportion of non-native plant species. Includes ELC Cultural Meadow (CUM), Cutltural Thicket (CUT), Open Alvar (ALO) and Open Tallgrass Prairie (TPO) classes.
Wetland	Water generally <2 m deep, with variable flooding regimes, standing water or saturated soils. Includes ELC Swamp (SW), Fen (FE), Bog (BO), Marsh (MA) and Shallow Water (SA) classes.
Turf/Sod	Turf/sod farms. Includes Golf courses, including lane ways, but not the isolated woodlots within, unless the area of the woodlots is < 0.5 ha.
Hay/Pasture	Hay and pasture fields, including the related agricultural buildings such as barns, silos and the farm residence. Fields are dominated with herbaceous vegetation and grasses with an understory of similar material in a state of decay. Weedy hay and/or pasture covers more than 50% of the area.
Low Intensity Residential	Cleared areas with a low density of trees, including lawns and landscaping. Land use is dominated by gardens, parkland and lawns, e.g., cemeteries, urban parks, ski hills and residential estate properties with a minimum size of 2 ha or with <5% impervious area. Includes rail lines and associated cleared adjacent areas and rural development properties not directly associated with an agricultural operation. On developed portions, these properties are under intensive use. Based on canopy cover, these areas will often appear as Cultural Savannah or Cultural Woodland in aerial photographs or satellite imagery. However, the presence of buildings and manicured lands identify the properties as Rural Development.
Unpaved Roads	Unpaved roads and associated shoulders. Excludes driveways and unpaved parking lots.
Open Water	Water generally >2 m deep, with no tree or shrub cover, as per ELC Open Water (OW) class. Also includes streams and rivers.
Cropland	Cultivated row crops, including the related agricultural buildings (e.g., barns, silos and the farm residence), producing crops in varying degrees (e.g., corn and wheat) and includes specialty agriculture (i.e., orchards, market gardens, Christmas tree plantations and nurseries).
Residential	Urban related land uses with >10% impervious area. Includes residential properties (single, semi-detached and strip dwellings, apartment buildings and associated out-buildings, driveways, parking lots and paved roadways). Excludes green land areas such as parks or river valleys.
Commercial	Impervious properties that contain a building and an adjacent parking lot (e.g., shopping and strip malls, power centres, scrap yards). Excludes green land areas such as parks or river valleys. Exludes roadways.
Industrial	Impervious properties that are not commercial and include industrial operations e.g., factories, manufacturing facilities, processing facilities, bulk fuel storage. Excludes green land areas such as parks or river valleys. Excludes roadways.
Transportation	Includes major transportation corridors (highways) and paved roadways that are not considered in other land use designations. Excludes driveways.

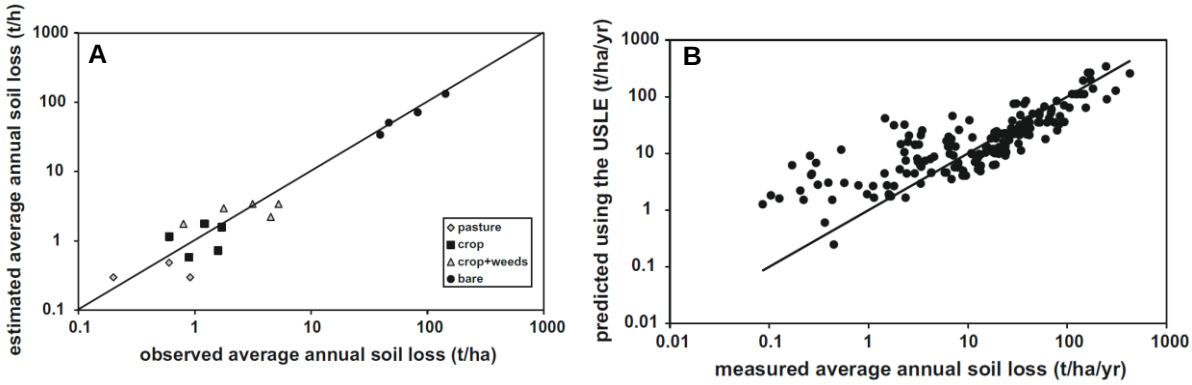
Notes: ELC is the provincial Ecological Land Classification for Southern Ontario

3.2 Calculating Phosphorus Export for Cropland

Recent applicable phosphorus export coefficients for cropland in Ontario were derived from loading estimates for the Lake Simcoe subwatersheds using CANWET modeling results and varied from 0.11 to 0.36 kg/ha/yr (mean = 0.21 kg/ha/yr) (HESL, 2011). These export coefficients are relatively low in comparison to values in the published literature, but are specific to Ontario and were developed and validated using detailed watershed characteristics making them applicable for use in the generic Tool. These export coefficients, however, are modified for more generic use to account for variation in soil loss potential at a site-level. This modification recognizes that phosphorus export from agricultural lands is strongly related to loss of phosphorus-bearing soils (e.g., Line et al., 2000; Miller et al., 2010).

The Universal Soil Loss Equation (USLE) is long established as a tool to predict long-term average annual rates of soil loss by sheet or till erosion from an agricultural slope based on rainfall, soil type, topography, crop system and management practices. The USLE is strongly predictive of observed annual soil loss over smaller geographic regions like those of a typical development site where inputs into the model are more site specific, but predictability is reduced for a larger geographic regions as the input variables become increasingly generic (Rosewell, 1993; Risse et al., 1993; Figure 1. 1).

Figure 1. A) USLE applied over small geographic area in New South Wales, Australia (from Rosewell, 1993) and B) USLE applied over large geographic area across the USA (from Risse et al., 1993).



The USLE has been revised (RUSLE2) by the United States Department of Agriculture's Agricultural Research Service (USDA-ARS), the Natural Resources Conservation Service (USDA-NRCS), and the Biosystems Engineering and Environmental Science Department of the University of Tennessee for application across the United States. The revised version utilizes a statistical approach that relies on a wealth of field observations and simulations calibrated to measurements. It can be used to estimate soil loss from cropland, pastureland, forestland, construction sites, mined land and reclaimed land. RUSLE2 has since been further revised by the Ontario Ministry of Agriculture and Food (OMAF) using data sets specific to Ontario. RUSLE2 has several benefits over the original USLE including:

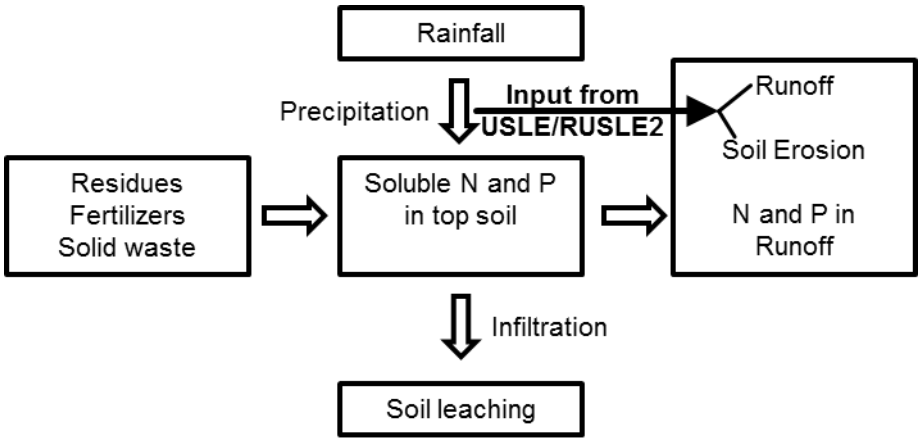
- Capability to estimate long-term average seasonal erosion rates with daily resolution,
- Increased flexibility to describe different practices used by land managers in much more detail than is possible with the USLE's old "C factor,
- Greater ability to describe the impact of detailed slope characteristics, and

- Embedded capacity to help assess soil quality such as the Soil Conditioning Index.

While RUSLE2 provides excellent resolution, it requires a more complex and comprehensive set of input parameters than USLE that may not be readily available. USLE therefore provides a simpler and more applicable option for broad application on a full field or site scale (Kevin McKague, OMAFRA, personal communication, December 5, 2013) and so is recommended for use in the Tool to modify export coefficients for cropland.

USLE/RUSLE2 and elements of the equation have commonly been used as input to models to assess phosphorus transport from agricultural landscapes. For example, it is used as input to the Agricultural Non-Point Source model (AGNPS) developed to predict phosphorus sensitivity of the Duffins Creek watershed located northeast of Toronto, Ontario (Booty et al., 2005). A variation of the AGNPS model was used by Das et al. (2008), as input into the Annualized Agricultural Nonpoint Source model (AnnAGNPS) to calculate soil transport and consequent transport of phosphorus in the Canagagigue watershed within the Grand River basin between 1991 and 2000. USLE/RUSLE2 was also utilized by Bolinder et al. 2000 to provide an indication of the risk of water contamination as part of the Agriculture and Agri-Food Canada Agri-Environmental Indicators project and elements of USLE/RUSLE2 are used in CANWET.

Figure 2. Schematic diagram of USLE input into models to predict P export (from Booty et al. 2005).



The proven use of USLE/RUSLE2 as input to larger models to predict soil loss demonstrates that it can be effectively used as part of a tool to predict phosphorus export if the concentration of phosphorus in soils is known. Estimating phosphorus loads only from soil loss and soil phosphorus concentration may, however, underestimate actual loads from agriculture because this approach would not account for soluble phosphorus that can contribute significantly to the total load. Moreover, soil phosphorus concentration can vary widely on a given site and across sites even for a given soil texture (Hooda et al., 2002; Table 3) such that it may be difficult to adequately characterize soil phosphorus concentrations from measured values without comprehensive sampling. The export coefficient approach, on the other hand, is derived from measurements of total phosphorus that include both particulate and soluble phosphorus. While this is advantageous, the approach does not allow modification to accommodate site-specific factors. A tool that

combines a) estimates of total phosphorus made using export coefficients and b) site-specific estimates of soil loss using USLE/RUSLE2 would therefore provide a solid foundation for a generic predictive tool.

Table 3. Total Phosphorus in Agricultural Soils Across the USA (adapted from Hooda et al., 2000)

Texture	Land Use and Management Details	Range of Phosphorus inputs	Total Phosphorus Range
		kg P ha^{-1} yr^{-1}	mg P kg^{-1} soil
Clay loam	Cereals; fertilized or no fertilizer	0-300	464-642
Clay loam	Grassland; no fertilizer or sewage sludge applied	0-130	852-1088
Loamy sand	Cereals; no fertilizer, fertilized, or poultry litter applied	0-82	526-873
Sandy clay loam	Grass-barley rotation; no fertilizer or fertilized	0-50	778-1042
Sandy clay loam	Grassland; sewage sludge applied	115-355	2042-3041
Sandy loam	Grass-barley rotation; no fertilizer or fertilized	0-40	944-1713
Sandy loam	Grass-barley rotation; no fertilizer or fertilized	0-40	1685-2320
Sandy loam	Grass-barley rotation; no fertilizer or fertilized	0-40	938-1145
Sandy loam	Grassland; no fertilizer or sewage sludge applied	0-44	919-1094
Silty clay loam	Grassland; fertilized and/or cattle slurry applied	45-75	813-891
Silty clay loam	Cereals; no fertilizer, fertilized, or cattle slurry applied	0-40	447-513

The USLE calculates soil loss (A) as:

$$A = R \times K \times LS \times C \times P \quad \textbf{(Equation 1)}$$

Where:

R is the rainfall and runoff factor for the geographic location as defined by the Upper Tier Municipality Designation.

K is a soil erodibility factor (tonnes/ha) which is a measure of the susceptibility of soil particles to detachment and transport by rain and runoff relative to a “standard” slope of 22.13 m at a steepness of 9%. It is specific to each soil type (texture and organic matter content) in cultivated, continuous fallow.

LS is the slope length-gradient factor that describes the potential soil loss from a given length of slope at a given grade relative to a “standard” slope of 22.13 m at a steepness of 9%.

C is the crop/vegetation and management factor. This takes into account the crop type and tillage method on soil export relative to continuously fallow and tilled land. For example, crops like hay and pasture are associated with better soil retention than beans and canola. Similarly, no-till produces less soil erosion than plowing.

P is the support practice factor. This factor reflects the impact of agricultural best management practices (BMPs) on reducing the runoff and thereby soil loss.

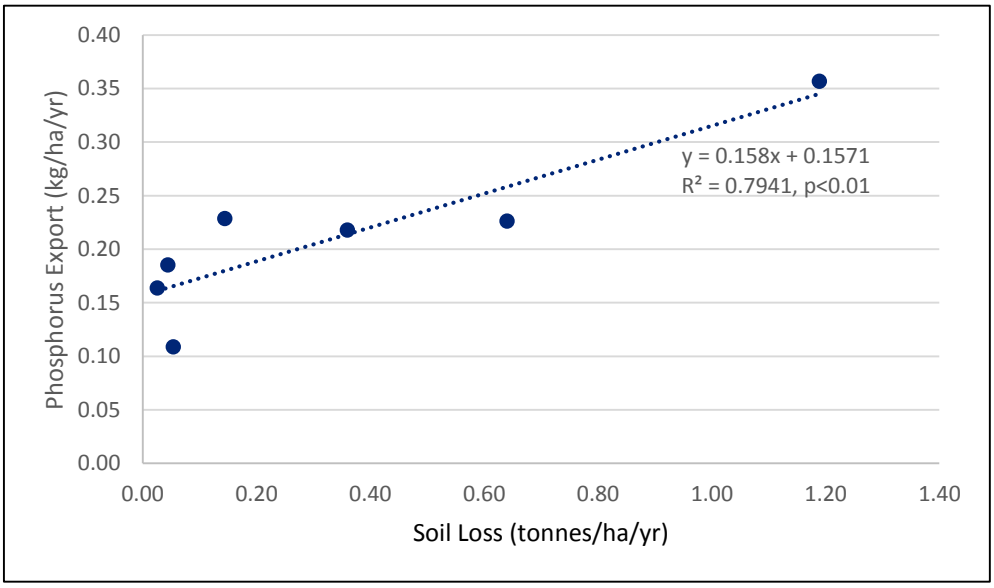
The factors used in the USLE have been developed for use in Ontario by the Ministry of Agriculture, Food and Rural Affairs (Stone and Hilborn, 2012).

Soil loss from each of the Lake Simcoe monitored subwatersheds was calculated using input parameters reported in Berger (2010) and compared to phosphorus export derived from CANWET modeling results for Cropland (also Berger 2010). The derived phosphorus export was significantly related to soil loss (linear regression, $r^2 = 0.79$, $p<0.01$, Figure 3). The CANWET derived export coefficient for Cropland can therefore be adjusted for site-specific soil loss (A) conditions whereby:

$$\textbf{Phosphorus Export (kg/ha/yr)} = 0.16 \times A + 0.16 \qquad \textbf{(Equation 2)}$$

Where A is calculated using the USLE (Equation 1).

Figure 3. Relationship between phosphorus export and soil loss for cropland in Lake Simcoe subwatersheds.



An advantage of the approach described above (Equation 2) is that it is based on a demonstrated relationship between soil loss and phosphorus export so that site-specific soil phosphorus export can be calculated using soil loss, as estimated from the USLE. We therefore used Equation 2 to calculate phosphorus loss from agricultural lands based on USLE estimates of soil loss and the proven relationship for Lake Simcoe subwatersheds.

The USLE has been designed for agricultural lands and is inherently less applicable to urban environments. For example, K and LS are both compared with a "standard" slope with a grade of 9%, and not representative of urban lands that are generally graded to be as flat as reasonable. Furthermore, fewer variables can be applied in the calculation of soil loss using the USLE in urban settings which reduces confidence in the output; the C and P factors are not applicable to urban environments as they specifically focus on crops and crop management. For these reasons, a different approach is developed to estimate phosphorus export from urban lands as described in Section 3.3.

3.3 Calculating Phosphorus Export for Urban Lands

A comprehensive search of the scientific literature identified few published export coefficients for urban land uses in Ontario and the northeastern United States, all of which are more than 30 years old (Table 4). While only two to four export coefficients are reported in these studies for different urban land use classes (i.e., commercial, commercial/industrial, high intensity residential and low intensity residential), these illustrate the wide range of phosphorus export that can exist within a single class of urban land use and the large degree of overlap in export between land uses.

Table 4. Published Export Coefficients for Urban Land Uses in Ontario and Northeastern US States

Land Use	Location	Total Phosphorus Export (kg/ha/yr)	Source[1]
Commercial	Appleton, Wisconsin	0.88	Much and Kemp, 1978
	Appleton, Wisconsin	4.08	Much and Kemp, 1978
	Meridian Township, Michigan	1.7	Landon, 1977
	Burlington, Ontario	1.6	Marsalek, 1984
	Mean	**2.22**	
Commercial/ Industrial	Menominee, Wisconsin	2.67	Konrad et al., 1978
	Lansing, Michigan	0.66	Landon, 1977
	Mean	**1.67**	
High Intensity Residential	East Lansing, Michigan	1.1	Landon, 1977
	Lansing, Michigan	0.56	Landon, 1977
	Saugeen and Grand River basins, Ontario	1.63	Avadhanula, 1979
	Burlington, Ontario	1.30	Marsalek, 1984[1]
	Mean	**1.15**	
Low Intensity Residential	Madison, Wisconsin	1.1	Kluesener and Lee, 1974
	Appleton, Wisconsin	0.35	Much and Kemp, 1978
	Okemos, Michigan	0.19	Landon, 1977
	Holt, Michigan	2.7	Landon, 1977
	Mean	**0.96**	

[1]All studies are cited in Reckhow et al. (1980) except for Marsalek (1984) which is cited in Chambers et al. (2002).

The Ontario Ministry of the Environment recommends phosphorus export coefficients of 1.32 kg/ha/yr for high intensity residential development and 1.82 kg/ha/yr for commercial and industrial land use in Ontario, which were derived from the results of the Stormwater Assessment and Monitoring Performance (SWAMP) program (TRCA, 2005). These export coefficients have been used to estimate phosphorus loads from

urban land uses in the Lake Simcoe watershed (Winter et al., 2002; 2007) and were adopted for use in the Lake Simcoe Phosphorus Budget Tool (HESL, 2012).

While the MOE export coefficients are well within the range of older values reported for Ontario and the northeastern US (Table 4), variability in the published export values suggest that a single value for an urban land use class may not be representative of phosphorus export at a site level, which is likely to have little variation in factors that control phosphorus export. A larger watershed scale, would include a wider range of characteristics that influence phosphorus export such that an 'average' value may be more suitably used to describe urban runoff in the watershed but this would still not reflect site-specific characteristics. Site-specific methods to estimate phosphorus export from urban land uses must therefore be developed for the NVCA Tool.

The SWAMP program synthesized comprehensive monitoring data for urban stormwater treatment facilities in Ontario collected between 1995 and 2002, but did not provide calculations of phosphorus export values, and MOE has not published their derivation of coefficients from this work. Information from the SWAMP reports was therefore compiled and used to calculate total phosphorus export values to assess a) variability in phosphorus export for urban lands and b) factors influencing differences between monitored sites that could potentially be used to refine estimates of urban phosphorus loads at a site level (Table 5).

Total phosphorus (TP) export coefficients were derived from SWAMP data as:

$$\textbf{TP export coefficient (kg/ha/yr)} = \textbf{TP} \times \textbf{Precip} \times P_j \times R_V \times 10^{-2} \qquad \textbf{(Equation 3)}$$

Where:

TP is the flow-weighted or event mean concentration (EMC) of total phosphorus concentration (mg/L) in runoff measured at the inflow of the treatment facility,

Precip is the annual precipitation mm/yr, which corresponds to $L/m^2/yr$,

Pj is the fraction of annual precipitation that produces runoff, and

R_V is the runoff coefficient.

Total phosphorus concentration was not measured for two of the SWAMP monitoring sites (Oil Grit Separator (OGS) facilities at Markham and Toronto). In a previous study, HESL (2012) derived total phosphorus concentrations for these sites as:

$$\textbf{TP (mg/L)} = \textbf{TSS} \times P_{sed} \times F_{DP} \times 10^{-3} \qquad \textbf{(Equation 4)}$$

Where:

TSS is the median TSS concentration (mg/L) measured in inflow to the Oil Grit Separators (OGS) at Markham (136.1 mg/L) and Etobicoke (162.8 mg/L) (SWAMP, 2005),

P_{sed} is the mean total phosphorus content of sediment collected in the OGSs of 0.53 mg/kg (calculated from data reported in SWAMP (2004)),

Table 5. Catchment, Hydrologic and Water Quality Characteristics for Stormwater Facilities Treating Residential Lands from the SWAMP project (TRCA, 2005) and Calculated Total Phosphorus Export

Parameter	Heritage Estates Pond	Harding Park Pond	Beaches Underground Detention	Markham Pond/ Wetland	Dunkers Flow Balancing System	Aurora Wetland	Rouge R. Highway Pond	Oil Grit Separator (Markham)	Oil Grit Separator (Toronto)
Drainage Area (ha)	52.4	16.8	114	45	174	82.4	129	4	2.9
Land Use	90-100% residential	90-100% residential	85% residential, 15% commercial/ industrial	60% residential, 7% commercial, 33% open space	60% residential, 40% industrial, institutional, commercial, open space	61% residential, 30% rural agricultural 4% commercial/ institutional, 5% parks/open space	75% transport, 25% residential	100% commercial (parking lot)	100% commercial (parking lot)
Soils	Clay Loam	Clay Till some Sand Till	Sandy Silt to Sand	Silty Sand	Sandy Silt to Sand	Sandy Silt and Clayey Silt	Silty sand to Sandy Silt	n/a	n/a
Runoff Coefficient (measured)	0.30	0.38	0.33	0.16	0.35	0.23	0.24	0.85	0.98
Runoff Coefficient (design)	0.39	0.39	0.39	0.29	0.39	0.27	0.45	1.0	1.0
Total inflow volume (m^3)[1]	163,488	52,416	355,680	104,400	542,880	177,984	464,400	32,000	23,200
Influent Event Mean Concentration (EMC) TP (mg/L)									
Winter/Spring	0.40	0.40	0.42	0.37	-	0.27	0.37	-	-
Summer/Fall	0.28	0.39	0.59	0.55	0.28	0.35	0.39	-	-
Mean	0.34	0.40	0.51	0.46	0.28	0.31	0.38	0.17[2]	0.20[2]
Total Phosphorus Export (kg/ha/yr)[3]									
Based on design runoff coefficient	1.06	1.23	1.58	1.07	0.87	0.67	1.37	1.36	1.60
Based on measured runoff coefficient	0.82	1.20	1.33	0.59	0.78	0.57	0.73	1.16	1.57

[1]assumes a total annual precipitation of 800 mm, which was cited as the approximate value for the study area (TRCA, 2005) and that all precipitation is converted to runoff ($P_j = 1$) as a conservative approach; [2]calculated using Equation 3; [3]calculated using Equation 4

F_{DP} is a correction factor to account for the proportion of dissolved phosphorus (here called PDP) in stormwater, which is not captured in the TSS measurements. This factor is calculated as 1/(1-PDP), with PDP = DP/TP from the U.S. National Stormwater Quality Database (NYDEC, 2010). Literature values for the proportion of dissolved phosphorus in stormwater TP vary, but most data summaries indicate that approximately 20-50% of the total phosphorus in stormwater occur in dissolved form (Table 6; Weiss, 2011).

Table 6. Mean Percentage of Dissolved and Particulate Phosphorus in Stormwater (from the U.S. National Stormwater Quality Database; NYDEC 2010).

	Residential	Commercial	Industrial	Open Space
Percent Dissolved Phosphorus (%)	49 (n = 963)	53 (n = 446)	36 (n = 434)	27 (n = 46)
Percent Particulate Phosphorus (%)	51 (n = 738)	47 (n = 323)	64 (n = 325)	73 (n = 44)

Export coefficients for a particular land use are best derived from monitoring data where that land use is dominant (>75%). Of the nine stormwater facilities included in the SWAMP program; three sites represented Residential development (Heritage Estates Pond, Harding Park Retrofit Pond, and Beaches Underground Detention; 85-100% residential), one site treated primarily highway runoff from Hwy. 401 (Rouge River Highway Stormwater Pond; 75% transport), and two sites treated runoff from large parking lots and represent Commercial development (Markham and Toronto Oil Grit Separator sites; 100% commercial). The remaining three facilities (Markham Pond/Wetland, Dunkers Flow Balancing and Aurora Wetland) treated runoff from mixed land uses. Export coefficients for Residential, Mixed, Transport and Commercial urban land uses derived from the SWAMP data are summarized in Table 7.

Table 7. Summary of Total Phosphorus Export Coefficients (kg/ha/yr) for Urban Lands Derived from the SWAMP Studies (TRCA, 2005)

	Residential	Mixed	Transport	Commercial	All Sites
N_{SITES}	3	3	1	2	9
Minimum	1.06	0.67	0.87	1.36	0.67
Maximum	1.58	1.07	1.58	1.60	1.60
Mean	1.29	0.87	1.17	1.48	1.20
Median	1.23	0.87	1.07	-	1.23
75th Percentile	1.40	0.97	1.32	-	1.37

Notes: Export coefficients derived using the design runoff coefficient (see Table 6)

The mean phosphorus export for Residential lands of 1.29 kg/ha/yr is within 3% of that recommended by the MOE of 1.32 kg/ha/yr. The mean export coefficient of 1.48 for Commercial lands, however, is considerably lower than MOE's value of 1.82 kg/ha/yr, which may be due to differences in determining phosphorus concentrations in the stormwater runoff. Mixed and Transport land uses have the lowest mean

phosphorus export coefficients of 0.87 and 1.17 kg/ha/yr, respectively. Overall, the export coefficients in Table 7 are considered to be conservative as they are based on a) design runoff coefficients, which were greater than the observed runoff coefficients therefore resulting in higher calculated export and b) assume that all of the rainfall generates runoff which is generally not the case due to storage and evaporation.

While the SWAMP export coefficients provide reasonable estimates of phosphorus export for the sites monitored in the program that are within the range of published values, there are only 1 to 3 sites for each land use class, and all of the sites were located within the Toronto area with similar hydrological characteristics (i.e., regional annual precipitation and runoff coefficients). Their general application for calculating phosphorus loads from urban sites may not be suitable for generic applications where runoff conditions vary from the SWAMP study sites.

The "Simple Method" developed by the US EPA is recommended as a suitable approach to account for variation in runoff conditions in urban settings. This method calculates phosphorus export as in Equation 3, but uses site-specific estimates of the runoff coefficient (Rv) and a representative total phosphorus concentration for urban land use.

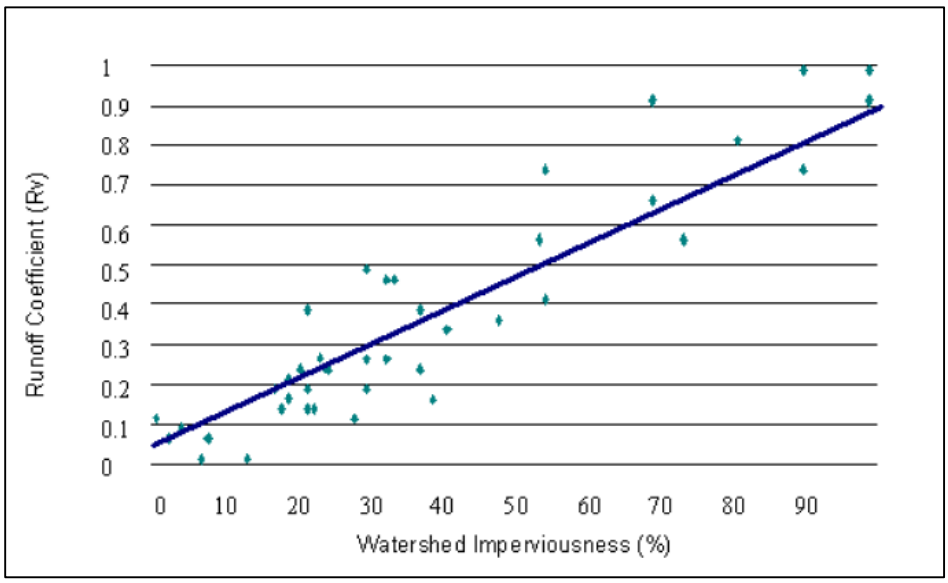
Rv is calculated based on the amount of impervious cover using the relationship developed by Schueler (1987) (Figure 5):

$$Rv = 0.05 + 0.91\ Ia \qquad \text{Equation 5}$$

Where:

Ia = the fraction of impervious area (0 – 1)

Figure 4. Relationship between watershed imperviousness and the stormwater runoff coefficient (Rv) (N=47, R^2=0.71; from Schueler, 1987).



Total phosphorus concentrations from the SWAMP studies (Table 7) can be used as representative values for residential and commercial urban land uses. These values are similar to those of other studies from Ontario (e.g., Marsalek and Ng, 1987) and the US (Tables 8 and 9), illustrating the consistency of phosphorus concentration in runoff from major classes of urban land use and providing confidence in their use. The SWAMP studies did not include industrial sites and so the concentration of 0.41 mg/L for Residential lands is recommended following the US EPA where the same concentration is used for industrial and residential lands.

Table 8. Comparison of Event Mean Total Phosphorus (TP) Concentrations in Stormwater for Urban Land Uses

Land Use	Mean TP (mg/L)		
	SWAMP (TRCA, 2005)	**Marsalek and Ng (1987)[1]**	**US EPA (Simple Method)[2]**
Residential	0.41	0.32	0.4
Commercial	0.19	0.19	0.2
Transport	0.38		0.5
Industrial	-	0.27	0.4

[1]Measured in stormwater runoff from sites in Windsor, Sault Ste. Marie and Sarnia; [2]Recommended for use nationwide in the US for the Simple Method (see Table 8)

The Simple Method should provide reasonable estimates of phosphorus loads in runoff from urban lands in Ontario at a site level. Assuming a total annual precipitation of 800 mm, phosphorus export for Residential and Industrial lands would range from 0.46 to 3.15 kg/ha/yr, and from 0.21 to 1.46 kg/ha/yr for Commercial lands with impervious cover ranging from 10% to 100% (Table 10).

The method, however, should not be applied at a larger scale (e.g., at a watershed scale) or where development density is low because it does not account for loads generated through baseflow (US EPA, National Stormwater Center). At a site level, pollutant loads from baseflow typically constitute only a small fraction of the total pollutant load. At a larger scale, or where urban development density is low (Impervious cover <5%), as much as 75% of the annual runoff volume can occur as baseflow and the resultant pollutant load may be equivalent to the baseflow load (US EPA, National Stormwater Center). For urban lands where impervious cover is <5%, the export coefficient derived for Low Intensity Residential development from CANWET modeling for Lake Simcoe (0.13 kg/ha/yr) is therefore recommended.

Table 9. Pollutant Concentrations by Land Use: Total Phosphorus (mg/L) (reproduced from US EPA Simple Method, National Stormwater Center)

Source	Land Use				Notes
	Residential	**Commercial**	**Roadway**	**Industrial**	
Schueler, 1987 mean	0.26	-	0.59	-	These values are taken from a Washington DC NURP study in 1980-81. At least 27 storm events were sampled at multiple sites within the specified land use.
Gibb et al., 1991 mean	0.33	-	0.59	-	These values represent recommended estimates for planning purposes and are based on analysis of mean concentrations from over 13 studies from the US and British Columbia.
Smullen and Cave, 1998 median	0.26				This study probably represents the most comprehensive data set, with 3,047 event samples being included from across the nation. The data includes pooled NURP, USGS, and NPDES sources. The value is a median of EMCs and applies to general urban runoff (i.e., mixed land uses).
US EPA, 1983, median	0.38	0.201	-	-	These values represent NURP data for residential and commercial land use. NURP data were collected in the early 1980s in over 28 different metropolitan areas across the US.
Barrett and Malina, 1998	-	-	0.4	-	This data reflects a study of vegetative swales treating highway runoff in Austin, TX. Value represents average of the mean inflow concentrations measured at 2 sites. Data were collected over 34 storm events.
Whalen and Cullum, 1988	0.62	0.29		0.42	These data are from an assessment of urban runoff quality that looked at NURP and State of Florida data. The NURP data summaries are what is shown. Residential and commercial values are mean values for specified land uses and reflect between 200 and 1,100 sampling events depending on the parameter and land use. Industrial values are from 4 NURP sites and generally represent light industrial land use.
Model Default Value	**0.4**	**0.2**	**0.5**	**0.4**	The model default values represent best professional judgement, and give additional weight to studies conducted at a national level. Data do not incorporate studies on arid climates.

Table 10. Range of Total Phosphorus Export Using the Simple Method for Urban Lands

Impervious Fraction	Rv	TP Export (kg/ha/yr)	
		Residential/Industrial (TP = 0.41)	Commercial (TP = 0.2 mg/L)
0.1	0.14	0.46	0.21
0.2	0.23	0.76	0.35
0.3	0.32	1.06	0.49
0.4	0.41	1.36	0.63
0.5	0.51	1.66	0.77
0.6	0.60	1.95	0.91
0.7	0.69	2.25	1.04
0.8	0.78	2.55	1.18
0.9	0.87	2.85	1.32
1	0.96	3.15	1.46

Assumes a total annual precipitation = 800 mm

3.4 Summary of Phosphorus Export Estimation Methods

The NVCA Tool is based on an export coefficient approach in recognition that export coefficients address export of both dissolved and particulate phase phosphorus and that recent estimates were available for the Lake Simcoe watershed. Export coefficients were modified to reflect site-specific soil and runoff characteristics for those land use classes that are most often changed with urbanization (cropland, high intensity residential, industrial, commercial and transportation).

Phosphorus export coefficients for the following land use classes were derived as the mean phosphorus export for all 'monitored' Lake Simcoe subwatersheds (n = 7) using phosphorus loads and landuse areas from CANWET (Berger 2010) modeling (Section 3.1):

- Forest, Transition, Wetland, Open Water, Turf/Sod, Hay/Pasture, Low Intensity Residential, Unpaved Roads, Open Water

Phosphorus export coefficients for cropland (Section 3.2) were derived from the relationship between CANWET-derived phosphorus export for Lake Simcoe subwatersheds and soil loss (A) as estimated using the Universal Soil Loss Equation (USLE):

- Phosphorus Export (kg/ha/yr) = (0.16 x A) +0.16

Phosphorus export coefficients for urban landuse classes (high intensity residential, commercial, industrial and transportation) were derived (Section 3.3) using a standard value for phosphorus concentrations in precipitation (TP_i), annual depth of precipitation (Precip), that fraction of precipitation producing runoff (Pi) and a runoff coefficient derived for impervious surfaces (Rv):

- Phosphorus Export (kg/ha/yr) = TP_i x Precip x P_j x R_V x 10^{-2}

These estimates are recommended for use in Modules 1 and 2 of the NVCA Tool to estimate phosphorus export from land uses in the pre-development and post-development scenarios (Sections 4.1 and 4.2).

4. Methods - Using the NVCA Tool

The technical derivation of export coefficients described in Section 3 is coded into the NVCA database tool to allow the user to estimate pre- and post-development phosphorus loads. The following sections describe how the user would run the Tool and is supplemented by detailed instructions on use of the database in the Users' Manual, which accompanies the database.

4.1 Calculating Pre-Development Phosphorus Export (Module 1)

The pre-development or "existing conditions" phosphorus load is calculated through the following steps, by the user:

1. The user will rely on the information documented and detailed in the Environmental Impact Study (EIS) for the development that will be used to support the planning application.
2. Areas of existing land uses will be delineated and their boundaries overlain on an orthographic aerial photograph that shall be included in the submission.
    a. The user will select the land uses for the development area that most closely match those delineated in their mapping and will document the rationale for the choice in a comment field for the database report. (e.g.," ELC classifications a, b and c are present, which correspond to "forest", or "actively tilled corn fields are classified as "cropland").
    b. Land use classifications will be chosen by the user from a "drop down" list in the database, which will contain the land use classifications that are to be used in the model.
    c. For Cropland, areas of the development site are to be further subdivided into areas of uniform slope gradient and length.
    d. The user will provide areas (in ha) of each identified land use and Cropland subareas on the development site.
3. The user will populate the fields required for calculation of phosphorus export from:
    a. Urban lands (% impervious cover, total annual precipitation, effective precipitation)
    b. Agricultural Lands (Upper Tier Municipality Designation, soil texture class, organic matter content of soils, slope length, % slope, crop type, tillage method and support practices)
4. The database calculates phosphorus export coefficients for urban and agricultural lands and links each of the other land uses to the respective phosphorus export coefficient for that land use as shown in Table 1. The user may adjust a particular export coefficient for site-specific characteristics, but must provide a detailed rationale and supporting analysis for any user-defined export coefficients.

5. The database calculates the total annual phosphorus load (kg/yr) from each land use (as area (ha) x phosphorous export (kg/ha/yr)) and sums the loads from each land use to produce the total annual pre-development load from the site.
6. The database produces a summary table that includes the land uses on the development site, the areas, phosphorus coefficient and phosphorus load for each land use and the total phosphorus load from the site representing pre-development conditions. Any user-defined changes to the export coefficients are flagged in the table and a summary of the user's rationale for the changes is provided (with the understanding that the details are provided as part of the planning application).

4.2 Methods - Calculating Post-Development Phosphorus Export (Module 2)

The post-development phosphorus load (without BMP implementation) will be calculated by the user, using the following steps:

1. The user will rely on the information on the proposed development that is documented and detailed in the planning application (EIS and SWM plans).
2. The user will delineate the post-development land uses and overlay their boundaries on an orthographic aerial photograph that shall be included in their submission.
    a. Land uses will be defined using the same methods described for the pre-development conditions in Section 4.1, Step 2.
    b. The site will be divided into post-development blocks; each block with a unique combination of a land use and Best Management Practice or Treatment Train that will be applied to that land use in Module 3
    c. Land use for each block will be chosen by the user from a "drop down" list in the database, which contains the land use classifications.
    d. The user will input areas (in ha) of each post-development block.
    e. The database will provide a check to make sure that the sum of post-development blocks is the same as the sum of the pre-development land use areas.
3. For each block, the user will populate the fields required for calculation of phosphorus export from:
    a. Urban lands (% impervious cover, total annual precipitation, effective precipitation
    b. Agricultural Lands (Upper Tier Municipality Designation, soil texture class, organic matter content of soils, slope length, % slope, crop type, tillage method and support practices)
4. The database calculates phosphorus export coefficients for urban and agricultural lands and links each of the other land uses to the respective phosphorus export coefficient for that land use as shown in Table 1. The user may adjust a particular export coefficient for site-specific characteristics, but must provide a detailed rationale and supporting analysis for any user-defined export coefficients.
5. The database calculates the total annual phosphorus load (kg/yr) from each land use (as area (ha) x phosphorous export (kg/ha/yr)) for each block, and sums the loads from each block to produce the total annual post-development load from the site.

6. The database produces a summary table that includes the land uses in each block, the areas, phosphorus export coefficient and phosphorus load for each land use, and the total phosphorus load from the site representing post-development conditions. Any user-defined changes to the export coefficients are flagged in the table and a summary of the user's rationale for the changes is provided (with the understanding that the details are provided as part of the planning application).
7. The database produces a summary showing:
    a. Pre-development phosphorus load (in kg/yr) for the entire development site,
    b. Post-development phosphorus load (in kg/yr) for each block and for the entire development site, and the
    c. Difference between pre- and post-development phosphorus loads (in kg/yr and as a %).

5. Module 3: Post-Development Load Reduction with BMPs

The following approach for applying phosphorus removal efficiencies for a variety of Best Management Practices (BMPs) is reproduced from HESL et al. (2012) with refinements based on the addition of new data obtained from a literature review (Appendix C). Phosphorus removal efficiencies were evaluated for their applicability to the Ontario watersheds and a representative % removal efficiency for each applicable BMP was derived where possible (Section 5.1). In addition, the NVCA Tool gives greater consideration for the use of runoff reduction methods (Infiltration) to reduce phosphorus loads (Section 5.1.1) based on recent developments in stormwater management requirements.

The user is not limited to using the BMP/LIDs and % removal efficiencies recommended in the Tool, but if custom BMP/LIDs or % removal efficiencies are used, or a treatment train approach is utilized, then supporting scientific rationale for their use must be provided in the Stormwater Management (SWM) plan for the development. The US EPA provides comprehensive supporting data on BMP effectiveness[1] and guidance for the design and management of BMPs/LIDs that can be consulted for additional information or to design custom approaches[2].

5.1 Selection of Appropriate BMP Phosphorus Removal Efficiencies

For any given stormwater management BMP there are a range of reported values that describe the expected phosphorus reduction. This is also true for stormwater mitigation strategies relating to the construction phase of development projects (see Module 4, Section 6). In both cases, there may be a wide range in reported percent reductions of phosphorus and these numbers may be highly qualified by various elements of BMP design, setting and stormwater quality. For this reason, it is difficult to derive a single removal efficiency value for even narrow categories of BMPs and almost all stormwater practice documents that were reviewed reported a range of removal efficiency values for a given BMP category.

There are, however, reasonable decisions that can be made to derive appropriate and applicable single numbers that represent average expected phosphorus removal efficiency of various BMPs. This involves an examination of the regional variation that is inherent in the range of observed values together with any

[1] *National Stormwater Quality Database (NSQD) available online at http://www.bmpdatabase.org*
[2] *Available online at http://www.epa.gov/oaintrnt/stormwater/*

specific design aspects that may be contributing to the reported range. If, for example, the focus is confined to only those reported values that are regionally significant and the range in those values that apply to well-designed or appropriately installed measures, then the result should be a narrower range in reported values.

Much of the confidence in selecting a phosphorus removal efficiency for any given stormwater management technique will result from the collection of a large number of regionally significant values that fall within a narrow range. In most cases, however, our review of available information showed that the availability of these types of data was the exception rather than the rule.

The decision tree shown in Figure 5 allows the consistent, objective selection of phosphorus removal efficiencies for individual stormwater or construction runoff management techniques by considering the range of reported efficiencies, the applicability of the reported efficiencies for use in Ontario watersheds and design characteristics that may influence the reported efficiencies.

In the example below, a phosphorus removal efficiency range of +/-20% (40% total) is used to describe an acceptable range in values (this corresponds generally to the median range of values observed for the techniques described in the documents that have been reviewed). The median of these values is chosen as a conservative estimate of phosphorus reduction. In the most difficult cases where the ranges in reported values are >40%, the removal efficiency value may require a design qualification to be acceptable (see Table 11).

The BMPs reviewed for the Tool (Table 11) are classes of BMPs and there may be unique features for any given BMP that make it more or less effective at phosphorus removal. Any BMP that is chosen should be assessed against the references given for the BMPs in Column 2 of Table 11 to determine whether or not the % phosphorus removal efficiency is applicable to the BMP of choice and for the specific characteristics of the development site. If not, the user should select the appropriate removal efficiency and provide details in support of that efficiency in the Stormwater Management (SWM) plan.

The Table 11 values are recommended as general, representative phosphorus reduction efficiencies for major classes of BMPs and have sufficient documentation to demonstrate their effectiveness in Ontario's climate according to the decision rules provided above. ***They are only representative, however, under the assumption that they are built to design specification and maintained to design standards, to assure their effectiveness.***

Different BMPs or efficiency values than those presented in the Tool may better reflect site-specific knowledge or emerging technologies. Where the user wishes to use innovative BMPs, or if they can provide documented information or engineering design characteristics that alter the values provided in Table 10, then they would document their rationale according to the guidance provided and demonstrate the effectiveness of the BMP in the SWM plan submitted for the development.

Figure 5. Decision tree for selecting appropriate phosphorus removal efficiencies for stormwater and construction BMPs.

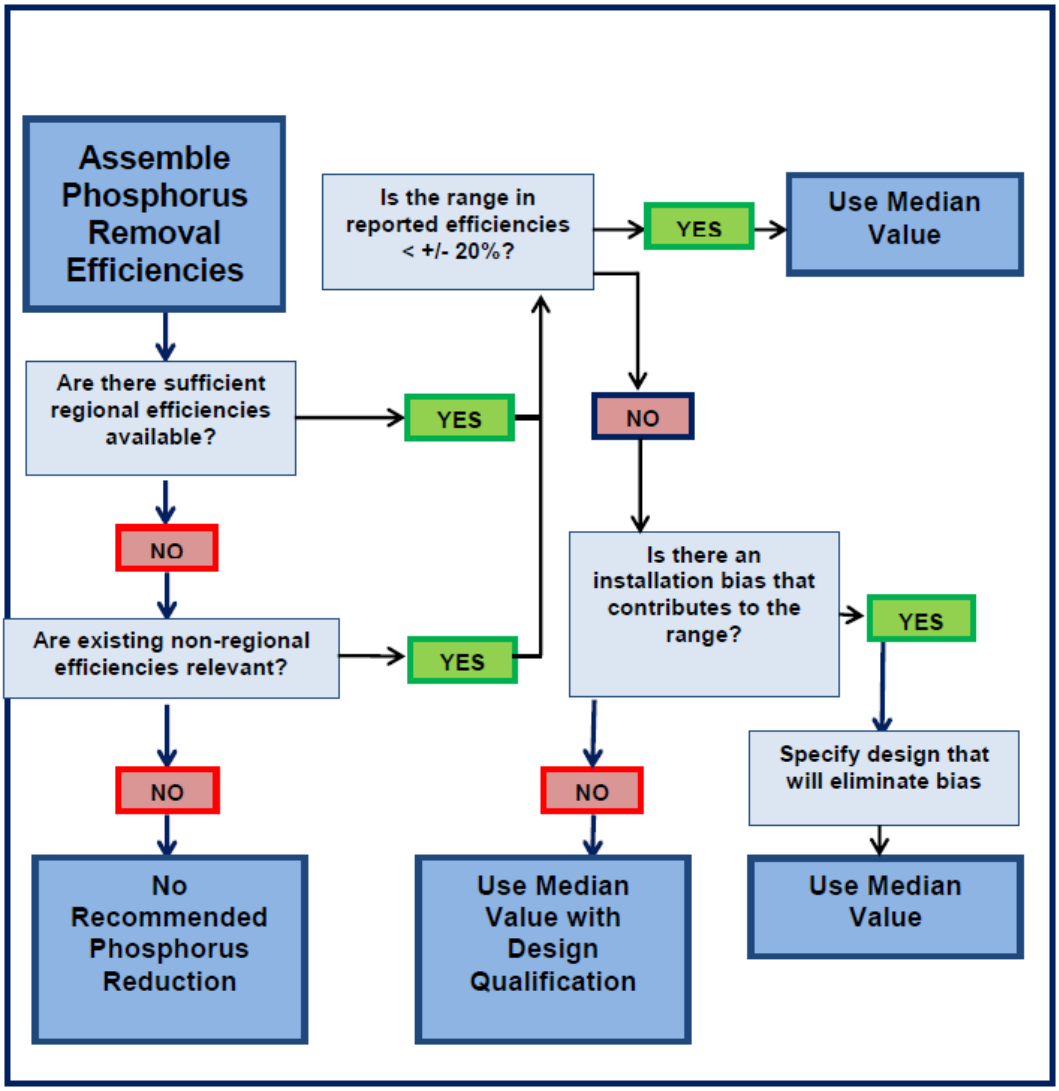


Table 11. Phosphorus Removal Efficiencies for Major Classes of BMPs Using the Decision Tree

BMP Class	Reference IDs[1]	Reported Phosphorus Removal Efficiency (%)		Relevant to Ontario?	Range <40%?	Are Non-Ontario values acceptable?	Possible design criteria?	Median % Removal Efficiency
		Min	Max					
Bioretention Systems	8-10, 12,13, 34-38, 40	-1552	80	no	no	no	No	**100***
Constructed Wetlands	104, 106, 109	72	87	yes	yes			77
Dry Detention Ponds	104, 109	0	20	no	yes	yes		10
Dry Swales	24, 26-32	-216	94	no	No	no	possible	none
Enhanced Grass/Water Quality Swales	21, 104	34	55	no	yes	no	No	**100***
Flow Balancing Systems	106	77		no	?	yes	Min data	77
Green Roofs	2	-248		no	No	no	No	**100***
Hydrodynamic Devices	109	-8		no	?	yes		none
Perforated Pipe Infiltration/Exfiltration Systems	7, 4	81	93	yes	yes			87
Permeable Pavement								**100***
Sand or Media Filters	104, 109	30	59	no	yes	yes		45
Soakaways - Infiltration Trenches	6, 104	50	70	no	yes	yes		60 (**100***)
Sorbtive Media Interceptors	111	78	80	no	yes	yes		79
Underground Storage	106	25		no	?	yes	Min data	25
Vegetated Filter Strips/Stream Buffers	6, 42, 104	60	70	no	yes	yes	Yes	65
Wet Detention Ponds	104-106, 109	42	85	yes	yes			63

Notes: [1]References associated with IDs are provided in Appendix C.; * infiltration techniques are credited with 100% removal efficiency if their effectiveness is verified in the SWM plan (Refer to Section 5.1.1), where no % efficiency is recommended, the user can assign an efficiency with scientific rationale for review and consideration by approval agencies in the SWM plan.

A treatment train approach, where more than one BMP is used in a series to treat stormwater runoff from the same land use area, can be used in the Tool. In a treatment train approach, the total phosphorus removal efficiency of the train is not necessarily the sum of the efficiencies for the individual BMPs in the train. This occurs because the efficiencies of several BMPs are influenced by phosphorus input concentrations. Treatment of runoff by one BMP may reduce the phosphorus concentration in the runoff to a level that reduces the effectiveness of the next BMP in the train. In addition, the Tool cannot anticipate or accommodate the many combinations of techniques that can make up a treatment train. The Tool,

therefore, does not provide suggested phosphorus removal efficiencies for a treatment train. The user must provide the total phosphorus removal efficiency of the proposed treatment train and document the scientific rationale for that efficiency in the SWM plan for the development.

5.1.1 Infiltration BMPs to Control Phosphorus Runoff

BMPs and LID techniques that promote infiltration of rainfall and runoff have a number of benefits including: reduced runoff volumes, reduced phosphorus runoff, replenishment of groundwater and cooling of runoff. Accordingly, infiltration techniques are increasingly promoted for new development and can be effective where soils are suitable and they achieve the desired level of infiltration. Therefore infiltration, like all storm water management techniques, must be supported by storm water management plans that have been prepared and approved by qualified professionals and which are implemented and maintained to achieve their design characteristics.

The NVCA has requested that the NVCA Tool include infiltration of rainfall and runoff as a BMP to reduce phosphorus export from developed sites. In practice, developments can be designed to infiltrate varying amounts of rainfall and a treatment train designed in which runoff that is not infiltrated is treated by conventional SWM techniques. For example lot level controls can be designed to infiltrate the first 20mm of all rain events (with 100% removal efficiency) and wet detention SWM ponds to capture and treat all runoff in excess of 20mm with efficiencies that are dependent on the technique used. Infiltration techniques are designed to be effective in cold climates, as drains and infiltration trenches are located below the frost line.

Infiltration effectiveness will depend, in part, on the intensity, duration and total volume of rain falling in an event. Precipitation data from Environment Canada's Shanty Bay Climate station in Barrie (station ID: 6117684) for the period between January 1, 2009 and May 3, 2014 was used to determine the amount of precipitation that fell during events of varying magnitudes (>0-5 mm, >5-10 mm, >10-15 mm, and >25-50 mm) in the NVCA area and these values were used to estimate the percentage of the total annual rainfall that could be infiltrated.

An average of 717.3 mm of rain fell each year over the five year period of record. Daily rainfall was recorded most frequently on days in which <5mm fell (71% of events, Figure 7), and the frequency of storm events correspondingly decreased with their magnitude (Figure 7). Approximately 68% of annual rainfall volume fell in events of up to 20 mm of precipitation (Figure 8), with the balance (32%) coming from the events greater than 20 mm.

Infiltration of the first 20 mm of all rain events (all precipitation for events up to 20 mm and the first 20 mm of greater magnitude events), results in cumulative infiltration of 83% of the total annual precipitation, leaving only 17% for run off and treatment by other methods (Figure 9). No phosphorus export would be associated with the 83% of precipitation that was infiltrated. Treatment of the remaining 17% by enhanced level SWM ponds would remove 63% of the phosphorus (from 17% of the annual precipitation total). If the SWM plan was designed for infiltration of only the first 10mm of rain, then this would remove 100 % of the potential phosphorus export from 64% of runoff (Figure 8) and conventional techniques would be applied to the remaining 36%.

We have therefore assigned a phosphorus removal efficiency of 100% for all rainfall that is infiltrated where the effectiveness of this SWM technique is verified in the submitted SWM plan for a development. Rainfall beyond 20 mm would need to be treated using the SWM techniques and efficiencies documented in Table 11.

Figure 6. Distribution of rainfall events at Shanty Bay (2009-2014).

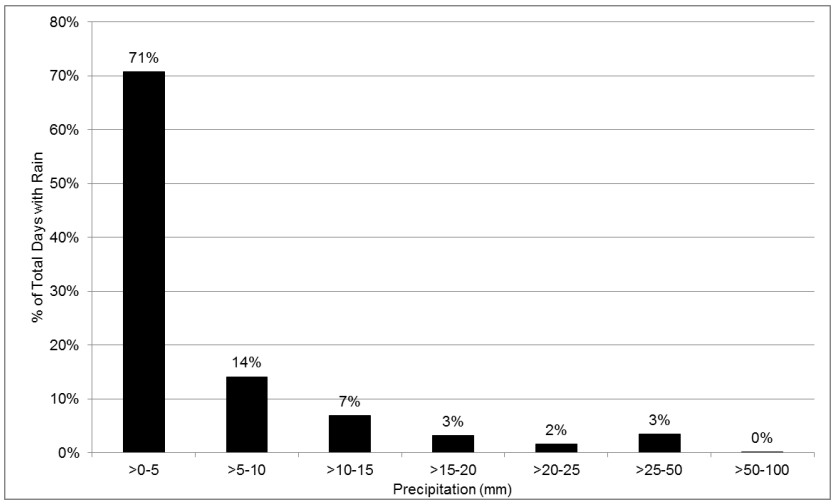


Figure 7. Percent of total precipitation based on magnitude of storm event at Shanty Bay (2009-2014).

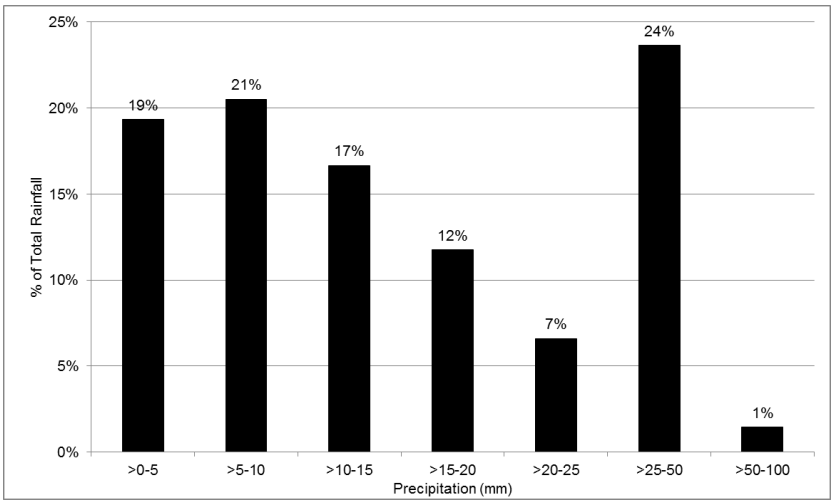
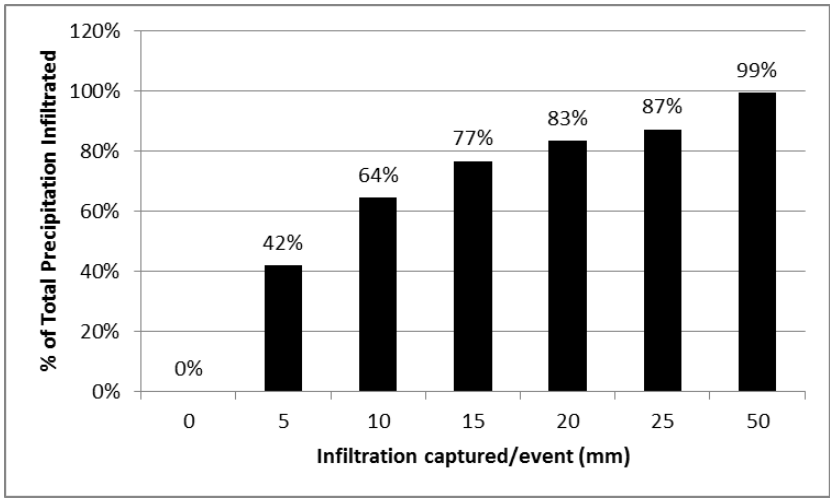


Figure 8. Cumulative percent of total annual precipitation infiltrated at Shanty Bay (2009-2014).



5.1.2 Module 3 - Modelling BMP Implementation

BMP selection and calculation of phosphorus load reductions for the post-development scenario will be completed by the user as follows:

1. The user will rely on the information documented and detailed in the SWM plan for the site that will be used to support the planning application to the Municipality.
2. The user will divide the development into a series of blocks, each of which represents a specific post-development land use that is treated by a specific BMP. If a runoff reduction (infiltration) BMP/LID is used, the user will provide the volume of water that will be treated as a percentage of the annual total (e.g., 64% for 10 mm infiltration and 83% for 20 mm infiltration).
3. The user will select the type of BMP (or a Treatment Train approach) that will be used to capture or treat runoff from each post-development block using the drop-down menu in the database. The user can select “Other” from the drop-down list if they plan to use an innovative BMP that is not coded in the database.
4. If runoff reduction (infiltration) BMP/LID is selected for 100% removal efficiency, the user will enter a brief rationale in the ‘rationale field’ that refers the reviewer to the SWM Plan for the full technical justification of the technique.
5. The user can choose to use the phosphorus removal efficiencies for the BMPs that are coded in the database, or can enter a custom efficiency. The User must enter a custom efficiency if a Treatment Train is selected.
6. If “Other” or “Treatment Train” are selected as a BMP, or if a custom efficiency is used for any BMP/LID, the user will enter a brief rationale in the ‘rationale field’ that refers the reviewer to the SWM Plan for the full technical justification.

7. The database links each combination of post-development phosphorus load and chosen BMP for each block to the phosphorus removal efficiency of the chosen BMP/LID to provide the load reduction that will be applied to runoff from that area.
8. The database calculates the total annual phosphorus load from each block (i.e., each land use/BMP combination) with BMP/LID implementation and sums the loads to produce the total post-development load with BMP/LIDs for the site.
9. The database produces a summary showing:
    a. Pre-development phosphorus load (in kg/yr) for the entire site,
    b. Post-development phosphorus load (in kg/yr) for the entire site, with and without BMPs, and
    c. Change in phosphorus load from pre-development conditions, with and without implementation of BMPs (in kg/yr and as a %).

6. Module 4: Controlling Construction Phase Phosphorus Loads

The construction phase of development provides the greatest risk of phosphorus export as land cover is removed and soils exposed to wind and water erosion prior to the construction of SWM facilities. Construction of a new development site can result in substantial phosphorus loads due to soil loss. For example, between 5 and 50 tonnes/ha/yr of sediment loss was reported by Dreher and Mertz-Erwin (1991), which is considerably greater that of other land uses (e.g., the mean soil loss from cropland in Lake Simcoe subwatersheds 0.3 tonnes/ha/yr). The dynamic nature of construction and its variable time lines mean that phosphorus export for these activities cannot be reliably estimated. Nevertheless, development must proceed with a full commitment to mitigation and management of exposed soils to reduce the potential for soil and phosphorus loss. Module 4 provides a summary of recommended techniques and a checklist (Table 12) by which reviewers can assess the magnitude and effectiveness of proposed construction phase mitigation when reviewing development applications.

The Greater Golden Horseshoe Area Conservation Authorities (GGHA CAs) prepared sediment and erosion control guidelines for urban construction (GGHA CA 2006) to provide a consistent approach to erosion and sediment control in the GGHA watersheds. The main function of the guidelines is to “protect and preserve the water quality, aquatic and terrestrial habitats, and form and function of their natural water resources” (GGHA CAs 2006) through the use of various erosion and sediment control measures available for urban construction sites. Erosion controls involve minimizing the extent of disturbed areas by vegetative control processes. Sediment controls are implemented in areas that are continually disturbed, or vegetative control practices do not have time to become fully effective. There are three types of sediment control practices: perimeter controls; settling controls; and filtration controls. Erosion prevention is the first approach for protecting aquatic habitat and water quality, and seen as the most effective method during the construction process, followed by sediment control practices that minimize movement of eroded materials to water bodies. Table 11 lists the commonly used erosion and sediment control methods and where they can be applied on a construction site (as described in the GGHA CA report).

Table 12. Erosion Control Measures (adapted from GGHA CAs 2006)

	Applicability						Temporary	Permanent
	Slopes	Streams/ Rivers	Surface Drainage Ways	Table Lands	Borrow/ Stockpile	Adjacent Property		
Erosion Control Measures								
Vegetative Filter Strips	✓	✓	✓	✓	✓	✓	✓	
Mechanical Seeding Practices*	✓		✓	✓	✓	✓	✓	✓
Terraseeding*	✓		✓	✓	✓	✓	✓	✓
Hydroseeding*	✓		✓	✓	✓	✓	✓	✓
Top soiling	✓		✓	✓	✓	✓		✓
Sodding	✓		✓	✓	✓	✓		✓
Mulching	✓		✓	✓	✓	✓	✓	✓
Re-vegetative Systems	✓		✓	✓	✓	✓	✓	✓
Tree and Shrub Planting	✓	✓	✓	✓	✓	✓		✓
Erosion Control Matting/Net (with Seed)	✓		✓	✓	✓	✓		✓
Growth Media Erosion Control Blanket	✓	✓	✓	✓	✓	✓	✓	✓
Lockdown Netting	✓		✓	✓			✓	✓
Buffer/Riparian Zone Preservation		✓						✓
Surface Roughening (Scarification)	✓				✓		✓	
Edge Saver	✓	✓		✓				✓
Sediment Control Measures - Perimeter Controls								
Sediment/Silt Fence	✓			✓	✓	✓	✓	
Interceptor Swale/Dike				✓	✓	✓	✓	
Silt Soxx	✓			✓	✓	✓		
Vehicle Tracking Control/Mud Mat				✓			✓	
Vehicle Wheel Washers				✓			✓	
Channel Soxx			✓	✓			✓	✓
Sediment Control Measures - Settling Controls								
Ditch/Swale Sediment Trap			✓	✓			✓	
Sediment Traps	✓		✓	✓	✓		✓	
Rock Check Dam	✓			✓			✓	
Ditch Chexx	✓			✓			✓	
Filter Berms			✓	✓			✓	✓
Straw/Wood Fibre Logs			✓	✓			✓	
Straw Bales			✓	✓			✓	✓
Sediment Control Ponds	✓	✓	✓				✓	
Storm Drain Outfall Protection				✓			✓	
Bulkheads within Storm Sewers			✓	✓			✓	

	Applicability						Temporary	Permanent
	Slopes	Streams/ Rivers	Surface Drainage Ways	Table Lands	Borrow/ Stockpile	Adjacent Property		
Sediment Control Measures - Filtration Controls								
Storm Drain Inlet Protection			✓	✓			✓	
InletSoxx Inlet Protection			✓	✓			✓	
Sediment Bags			✓	✓			✓	
Filter Rings			✓	✓			✓	

Note: *Various seeding practices

Table 11 is presented as a checklist which development engineers can use to select the BMPs best suited to mitigate soil losses during construction on a particular site and which reviewers can use to determine if all practical measures have been taken to mitigate soil and phosphorus loss during the construction phase. The Tool anticipates that this could best be accomplished through requirements for submission of a "Construction Soil Loss Management Plan" with the development application.

7. Analysis to Estimate Changes in Phosphorus Load

The NVCA Tool uses information that is normally required of the proponent as part of the standard process of planning approvals. Pre- and post-development land uses are derived from the Environmental Impact Statement (EIS) prepared by the proponent and BMPs for stormwater management would be developed and described in the Stormwater Management Plan for the new development that is prepared in support of the application. The proponent uses these materials as input to the Database Tool to calculate loadings in a standard format by the approved process.

Once the four modules are completed by entering information into the Database Tool, the pre- and post-development phosphorus loads are compared to determine if phosphorus loads are reduced relative to existing conditions, and that all reasonable and feasible construction phase BMPs have been identified and considered for implementation. The Database Tool provides summaries of all inputs and calculations in a standard format that facilitates review by planning authorities.

The intent of the analysis is to minimize phosphorus loadings from development such that:

Post-Development Load ≤ Pre-Development Load

AND

Construction Phase Loads are Minimized to the Most Practicable and Feasible Extent Possible.

In consideration of the above, the database tool calculates resulting loads from Modules 1 to 3 and determines the net impact of the proposed development on phosphorus export. The database then

generates a Summary Phosphorus Loading Data Sheet and a Construction Phase Load Reduction Check List (Table 11 from Module 4) that can be used in the development application.

The final component of phosphorus management is verification that the development and its construction are carried out to achieve the development plan and BMPs that informed the phosphorus budget development. The Tool is developed with the purpose of demonstrating, through scientifically valid methods, the conditions under which "no net increase in phosphorus load" can be achieved at the planning stages of development. The need for verification that the development was implemented as proposed needs to be considered, but is beyond the scope of this document and must be addressed as part of the planning approval and implementation process.

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Appendix A. Derivation of Phosphorus Export Coefficients Using Available Monitoring Data for the Nottawasaga River Watershed

Derivation of Phosphorus Export Coefficients Using Available Data for the Nottawasaga River Watershed

Task 2 - Compile existing flow and nutrient measurement data for specific creeks and subwatersheds in the Nottawasaga River watershed and assess the feasibility of developing export coefficients for site specific land uses.

1. *Assessment of Measured Data to Derive Phosphorus Export Coefficients for the Nottawasaga River Subwatersheds*

Phosphorus export coefficients can be derived where there are reliable long term records of water quality and discharge from individual subwatersheds. They are most usefully applied, however, where a single land use is dominant (>75%) within a subwatershed so that the annual export per unit area can be related with confidence to that land use. The feasibility of developing phosphorus export coefficients specific to the Nottawasaga River subwatershed was therefore assessed based on existing water quality, river discharge and land use data.

The NVCA monitors water quality at 19 Provincial Water Quality Monitoring Network (PWQMN) sites within the Nottawasaga River Watershed (Table 1). There is an adequate period of record for each site, but a low number of measurements made, on average, each year as sampling is typically monthly from April to November. Total phosphorus loads over the winter months therefore cannot be determined for accurate calculation of annual loads using the PWQMN data.

There are 9 of the PWQMN sites where a continuous record of flow data has been collected that could be used to develop annual estimates of phosphorus load for that portion of the subwatershed (Table 2). Land use breakdowns were provided for each subwatershed upstream of the PWQMN stations by GIS staff at NVCA (Table 3). They were then collapsed into fewer categories of similar characteristics to maximize specific land use types within each subwatershed (Table 4). None of the catchment areas upstream of the PWQMN stations have a single dominant land use that could be used to derive a reliable export coefficient that is representative of that land use in the Nottawasaga River subwatersheds. The maximum percentage land uses ranged from 1% for Open Water, 4.3% for Quarry + Road to 68% for Row Crop + Golf Course.

In conclusion, existing monitoring data from the Nottawasaga River subwatershed cannot be used to derive phosphorus export coefficients for specific land uses due to a combination of insufficient phosphorus data and lack of dominant land uses upstream of water quality monitoring stations.

Table 1. Nottawasaga River Watershed Provincial Water Quality Monitoring Network (PWQMN) Sites

PWQMN ID	Subwatershed	Location Description	Monitoring Period		# Obs.	Average Obs./yr
			Start	End		
3005400102	Batteaux River	At Highway 26 - Collingwood	1964	2012	248	9.2
3005703502	Bear Creek	5th Line, E of Angus	2006	2012	39	5.6
3005703202	Beeton Creek	11th Line, N of Beeton	2002	2012	67	6.1
3004900102	Black Ash Creek	At Highway 26 - Collingwood	1966	2012	90	5.3
3005703602	Black Creek	County Rd 28, N of Grenfell	2006	2012	39	5.6
3005700702	Boyne River	County Rd 10 - D/S from Alliston	1976	2012	343	9.5
3005703402	Coates Creek	County Rd 10, N of Brentwood	2006	2012	39	5.6
3005703102	Innisfil Creek	10 Sideroad, N of Beeton	2002	2012	86	7.8
3005700902	Lamont Creek	Highway 26 - Stayner	1976	2004	284	9.8
3005702102	Mad River	At Conc. Rd 2 - Tosorontio Township	1976	2012	339	9.4
3005703702	Marl Creek	Highway 26 - Minesing	2006	2012	39	5.6
3005703302	McIntyre Creek	Sunnidale Rd, Wasaga Beach	2006	2012	39	5.6
3005702502	Nottawasaga River	At Power Line Road (Klondike Park Rd)	1982	2012	902	29.1
3005702802	Nottawasaga River	Mono-Adjala Townline, Hockely	2002	2012	87	7.9
3005702902	Nottawasaga River	County Rd 21, E of Baxter	2002	2012	87	7.9
3005701002	Pine River	Upstream from Nottawasaga River - Angus	1976	2012	333	9.0
3005300102	Pretty River	At Parkway Bridge Collingwood	1964	2012	398	10.0
3004700102	Silver Creek	At Highway 26 - Collingwood	1966	2012	349	8.9
3005703002	Willow Creek	County Rd 28, S of Minesing	2002	2012	84	7.6

Table 2. Water Survey of Canada (WSC) Flow and Provincial Water Quality Monitoring Network (PWQMN) Sites in Nottawasaga River Subwatersheds

NVCA Subwatershed	PWQMN Site Location	WSC Flow Monitoring Site	WSC Site Number	Watershed Area (ha)	Period of Record
Beeton Creek	11th Line, N of Beeton	Beeton Cr. Near Tottenham	O2ED100	8,600	1977-2003
Boyne River	County Rd 10 - D/S from Alliston	Boyne R. at Earl Rowe Park	O2ED102	21,643	1977-2003
Innisfil Creek	10 Sideroad, N of Beeton	Innisfil Cr. Near Alliston	O2ED015	47,946	1999-2013
Mad River	At Conc. Rd 2 - Tosorontio Township	Mad R. below Avening	O2ED015	24,414	1988-2013
Nottawasaga River	At Power Line Road (Klondike Park Rd)	Nottawasaga R. near Alliston	O2ED101	32,760	1996-2013
Nottawasaga River	Mono-Adjala Townline, Hockely	Nottawasaga R. at Hockley	O2ED026	17,568	1989-2013
Nottawasaga River	County Rd 21, E of Baxter	Nottawasaga R. near Baxter	O2ED003	123,058	1949-2013
Pine River	Upstream from Nottawasaga River - Angus	Pine R. near Everett	O2ED014	18,999	1978-2013
Pretty River	At Parkway Bridge Collingwood	Pretty R. at Collingwood	O2ED032	6,824	2005-2013

Table 3. Land Uses in Upstream Catchments of PWQMN Monitoring Stations in the Nottawasaga River Watershed

PWQMN Catchment	Land Use (ha)															
	Beach	Coniferous forest	Deciduous forest	Mixed forest	Open wetland	Woody wetland	Open water	Golf course	Row crop	Sod Farm	Hay/pasture	Transitional	Urban impervious	Urban pervious	Quarry	Road
Batteaux		90	89	649	57	378	21	94	1,752		1,072	675	34	167	19	108
Bear		196	52	1,384	145	1,220	37	157	1,066		540	495	519	356	63	216
Beeton		610	277	2,401	300	1,621	131	161	7,964		3,796	2,277	274	1,028	142	551
Black		211	288	313	130	464	4	85	456		562	183	92	104	40	67
Black Ash		38	97	636	17	91	23	100	456		360	659	40	202	6	69
Boyne	2	594	492	2,473	654	1,619	230	64	7,565		5,546	2,386	684	656	136	720
Coates		224	139	590	101	555	34		1,449		967	437	21	41	66	104
Innisfil		929	684	4,176	721	3,457	209	385	23,340		7,907	3,460	458	1,478	191	1,308
Lamont		1	12	59	16	24	6		1,050		181	130	12	27		30
Mad		1,110	2,122	3,066	846	3,715	158		7,018		9,592	1,947	45	291	35	630
Marl		323	1,175	507	146	675	36	2	2,072		1,574	559	64	107	94	150
McIntyre		71	165	580	167	602	19	104	6,966	5	1,805	531	324	239	0	317
Nott/Baxter	2	3,185	1,983	14,731	2,204	8,638	672	695	47,780		22,415	11,766	1,490	3,343	459	3,246
Nott/Hockley		662	298	3,506	443	2,026	81	99	3,528		3,795	1,947	92	574	50	424
Nott/Klondike	2	9,744	10,468	38,153	7,646	27,829	1,788	1,441	82,656		50,408	24,887	3,631	6,771	1,106	6,877
Pine		1,783	669	9,064	454	2,265	169	23	6,940		5,279	4,800	282	945	47	783
Pretty		148	136	2,493	25	79	29	11	1,051		1,072	1,192	35	207		125
Silver		27	223	746	18	56	33	5	101		156	351	28	80		47
Willow		1,452	3,239	1,942	652	2,692	297	268	2,940		5,402	2,140	558	834	117	816

Table 4 Summarized Land Uses in Upstream Catchments of Nottawasaga River PWQMN Stations

PWQMN Catchment	% Land Use							
	Forest	Wetland	Open Water	Row Crop/ Golf Course	Hay/ Pasture	Transitional	Urban	Quarry/ Road
Batteaux	15.9	8.4	0.4	35.5	20.6	13.0	3.9	2.4
Bear	25.3	21.2	0.6	19.0	8.4	7.7	13.6	4.3
Beeton	15.3	8.9	0.6	37.7	17.6	10.6	6.0	3.2
Black	27.1	19.8	0.1	18.0	18.7	6.1	6.6	3.6
Black Ash	27.6	3.9	0.8	19.9	12.9	23.6	8.7	2.7
Boyne	14.9	9.5	1.0	32.0	23.3	10.0	5.6	3.6
Coates	20.2	13.9	0.7	30.6	20.4	9.2	1.3	3.6
Innisfil	11.9	8.6	0.4	48.7	16.2	7.1	4.0	3.1
Lamont	4.6	2.5	0.4	67.9	11.7	8.4	2.5	1.9
Mad	20.6	14.9	0.5	23.0	31.4	6.4	1.1	2.2
Marl	26.8	11.0	0.5	27.7	21.0	7.5	2.3	3.3
McIntyre	6.9	6.5	0.2	59.4	15.2	4.5	4.7	2.7
Nott/Baxter	16.2	8.8	0.5	39.5	18.3	9.6	3.9	3.0
Nott/Hockley	25.5	14.1	0.5	20.7	21.7	11.1	3.8	2.7
Nott/Klondike	21.3	13.0	0.7	30.8	18.4	9.1	3.8	2.9
Pine	34.4	8.1	0.5	20.8	15.8	14.3	3.7	2.5
Pretty	42.1	1.6	0.4	16.1	16.2	18.0	3.7	1.9
Silver	53.3	4.0	1.8	5.7	8.3	18.8	5.8	2.5
Willow	28.4	14.3	1.3	13.7	23.1	9.2	6.0	4.0
Maximum	53.3	21.2	1.8	67.9	31.4	23.6	13.6	4.3
Minimum	4.6	1.6	0.1	5.7	8.3	4.5	1.1	1.9

2. Assessment of CANWET-Derived Phosphorus Export for the Nottawasaga River Watershed

The CANWET™ model was used to estimate phosphorus loads (in kg/yr) from each of the 12 subwatersheds in the Nottawasaga River basin (Figure 1), but explicit phosphorus export coefficients were not determined for different land uses (Greenland, 2006; Berger and Greenland, 2006). Areas devoted to different land uses (Table 5) and phosphorus loads from several of those land uses were provided, however, for each subwatershed (Table 6; Berger and Greenland, 2006) which can be used to calculate export coefficients by dividing the load by the area of each land use.

Of the land uses identified in the Nottawasaga River subwatersheds by Berger and Greenland (2006), phosphorus loads were only reported for Hay/Pasture, High Intensity Development and Row Crop for which phosphorus export coefficients can be derived (Table 6). Phosphorus loads from the other land uses are

likely captured by the “Other” and “Groundwater” sources, but no explanation of these categories was provided and therefore phosphorus export coefficients cannot be derived for the other land uses.

Although some variation in phosphorus export between subwatersheds is expected for a given land use due to differences in environmental factors such as soil characteristics, physiography and runoff conditions, the range provided in Table 2 for similar land uses (i.e., 0.053 – 0.440 kg/ha/yr for Hay/Pasture, 0.017-0.100 kg/ha/yr for High Intensity Development, and 0.146-0.765 kg/ha/yr) is far greater than expected.

Similarly high variance was observed in export coefficients derived from the CANWET™ modeled phosphorus loads in the Lake Simcoe subwatersheds (HESL et al., 2012). Much of this variance was attributed to error in the modeled phosphorus loads for ‘unmonitored’ subwatersheds, that is, subwatersheds that did not have sufficient monitoring data to calibrate and validate the model. This conclusion was based on detailed analysis that failed to identify patterns in environmental characteristics that would explain the variance in export coefficients derived for the unmonitored subwatersheds (i.e., subwatersheds with similar environmental characteristics did not have similar phosphorus export coefficients). By contrast, there was far less variance in export coefficients for the monitored Lake Simcoe subwatersheds, with the exception of the East Holland River subwatershed. Higher phosphorus export from land use areas for this subwatershed were related to higher soil phosphorus concentrations, soil erosion and runoff in comparison to the other monitored subwatersheds.

The CANWET™ model was only calibrated and validated for four of the Nottawasage River subwatersheds, including the Boyne, Lower Nottawasaga, Mad and Pine river subwatersheds. As was the case for Lake Simcoe, there is much less variance in export coefficients for individual land uses for the monitored subwatersheds (Table 6).

Figure 1. Subwatersheds of the Nottawasaga River Watershed.

(From Berger and Greenland, 2006, Fig. 3.0-1)

Table 5. Land Use Categories Used in the CANWET™ Model for the Nottawasaga Valley Subwatersheds (from Greenland, 2006)

CANWET™ Land Use	ELC Equivalent Categories
Water	Open Water
Low Intensity Developed	Estate Residential; Rail; Rural Development; Manicured Open Space. Defined by percentage of surface area deemed impervious.
High Intensity Developed	Commercial; Industrial; Institutional; Urban; Landfill. Defined by percentage of surface area deemed impervious.
Hay/Pasture	Non-Intensive Agriculture
Row Crop	Intensive Agriculture (except for sod farms)
Coniferous Woodland	Coniferous Forest/Plantation/Woodland
Mixed Woodland	Deciduous Forest/Plantation/Woodland
Woody Wetland	Coniferous/Mixed/Deciduous Swamp
Quarries	Active and Inactive Aggregate
Sod Farm/Golf Course	Sod Farms; Golf Courses
Road	Roads

Table 6. Phosphorus (P) Export for Nottawasaga River Subwatersheds Derived from CANWET™ Modeled Phosphorus Loads and Land Use Areas

Subwatershed	Hay/Pasture			High Intensity Development			Row Crop		
	Area (ha)	Total P Load (kg)	P Export (kg/ha/yr)	Area (ha)	Total P Load (kg)	P Export (kg/ha/yr)	Area (ha)	Total P Load (kg)	P Export (kg/ha/yr)
Un-calibrated Subwatersheds									
Bear Creek	1,025	74	0.072	1,032	47	0.046	3,050	525	0.172
Black (Willow) Creek	740	72	0.097	133	1	0.008	2,088	452	0.216
Coates Creek	1,055	56	0.053	176	1	0.006	4,585	690	0.150
Innisfil Creek	7,547	487	0.065	1,500	112	0.075	28,365	4,687	0.165
Marl Creek	1,279	279	0.218	145	1	0.007	4,080	1,004	0.246
Matheson	3,121	201	0.064	1,816	119	0.066	13,574	1,978	0.146
McIntyre Creek	1,837	809	0.440	637	28	0.044	8,032	6,144	0.765
Upper Nottawasaga	4,841	298	0.062	563	37	0.066	18,281	3,593	0.197
Mean	2,372	283	0.144	1,246	77	0.057	9,111	2,211	0.266
Median	1,279	201	0.072	1,266	79.5	0.056	4,585	1,004	0.172
Minimum	740	56	0.053	637	28	0.044	2,088	452	0.146
Maximum	7,547	809	0.440	1,816	119	0.075	28,365	6,144	0.765
Standard Deviation	2,416	278	0.142	518	46	0.015	9,342	2,286	0.223
Calibrated Subwatersheds									
Boyne River	2,953	271	0.092	1,508	151	0.100	14,584	3,728	0.256
Lower Nottawasaga	6,062	356	0.059	2,484	109	0.044	20,621	3,179	0.154
Mad River	3,139	213	0.068	600	10	0.017	19,044	3,504	0.184
Pine River	4,267	405	0.095	1,613	105	0.065	15,341	2,937	0.191
Mean	4,252	309	0.075	1,354	82	0.058	17,574	3,388	0.196
Median	4,267	298	0.068	1,508	105	0.065	18,281	3,504	0.191
Minimum	2,953	213	0.059	563	10	0.017	14,584	2,937	0.154
Maximum	6,062	405	0.095	2,484	151	0.100	20,621	3,728	0.256
Standard Deviation	1,280	75	0.017	800	58	0.031	2,543	323	0.037
All Subwatersheds									
Mean	3,156	277	0.115	1,306	80	0.058	12,637	2,702	0.237
Median	3,037	275	0.070	1,500	105	0.065	14,079	3,058	0.188
Minimum	740	10	0.053	563	10	0.017	2,088	452	0.146
Maximum	7,547	809	0.440	2,484	151	0.100	28,365	6,144	0.765
Standard Deviation	2,172	226	0.112	651	49	0.024	8,304	1,804	0.170

Note: Shaded cells were excluded from calculation of the summary statistics as small land use areas and reported phosphorus loads from High Intensity Development resulted in very low export coefficients that are suspect for this land use and likely due to rounding errors.

Appendix B. Phosphorus Export Literature Review Summaries

Source	Reference	Summary
AlberaEnvironment-2006	Alberta Environment, 2006: Southern Alberta Landscapes: Meeting the Challenges Ahead, Export Coefficients for Total Phosphorus, Total Nitrogen and Total Suspended Solids in the Southern Alberta Region, A Review of Literature. Report prepared by Y. Jeje. Province of Alberta, 22pp.	
Winter&Duthie-2000	Winter, J.G. And H.C. Duthie, 2000: Export coefficient modeling to assess phosphorus loading in an urban watershed. Journal of the American Water Resources Association 36:1053-1061	An export coefficient modeling approach was used to assess the influence of land use on phosphorus loading to a Southern Ontario stream (Laurel Creek in Waterloo, Ontario). The model was calibrated to a 1977-1978 data set which subsequently validated it within 7%.
Dillon and Kirchner 1974	Dillon, P.J. and Kirchner, W.B. 1975. The effects of geology and land use on the export of phosphorus from watersheds. Water Research. 9(2):135-148.	Export of total phosphorus from 34 watersheds in Southern Ontario was measured over a 20-month period.
Winter et al. 2002	Winter, J.G., Dillon, P.J., Futter, M.N., Nicholls, K.H., Scheider, W.A. and Scott, L.D. 2002. Total phosphorus budgets and nitrogen loads: Lake Simcoe, Ontario (1990-1998). J. Great Lakes Res. 28(3):301-314.	Analyzed all TP loads into Lake Simcoe from subwatersheds. Did not offer TP from individual land uses but cited export coefficient for urban NPS from the MOE and US EPA.
Beaulac and Reckhow. 1982	Beaulac, M.N. and Reckhow, K.H. 1982. An examination of land use-nutrient export relationships. Water Resources Bulletin. 18(6):1013-1024	Summarizes the export coefficients from various nutrient export studies. The studies are evaluated and export coefficients screened accordingly
Reckhow and Simpson, 1980	Reckhow, K.H. and Simpson, J.T. A procedure using modeling and error analysis for the prediction of lake phosphorus concentration from land use information.	This is the peer reviewed publication of the phosphorus modeling gleaned from the department of resource development report. It presents the summary of high, medium and low frequencies of TP export under various land uses as well as a description of the modelling approach for calculating export from new locations using the export coefficients.
Reckhow et al. 1980	Reckhow, K.H., Beaulac, M.N. and Simpson, J.T. 1980. Modeling phosphorus loading and lake response under uncertainty: a manual and compilation of export coefficients. Department of Resource Development, Michigan State University. 136 pp.	Presents a modeling approach used to generate high, medium and low frequency occurances of TP export under various land uses. It also presents a compilation of export coefficients from various sources. A wide range of rural and urban land uses are covered.
Coote et al. , 1978	Coote D.R., Macdonald, E.M. and Dickinson, W.T., eds. 1978. Agricultural Watershed Studies in the Canadian Great Lakes Drainage Basin; Final summary Report. PLUARG Technical Report Series, 79 pp.	study discussed in this document was carried out as part of the efforts of the Pollution from Land Use Activities Reference Group, an organization of the International Joint Commission. Agricultural Watershed Studies consisted of a variety of investigations into the relationships between agricultural land and water quality in the Great Lakes Basin. Monitoring of water quality and quantity at eleven small (19 to 73 km2) watersheds, selected to be representative of major agricultural regions of the Canadian Great Lakes Basin
Coote and Hore. 1978	Coote, D.R. and Hore, F.R. 1978. Pollution potential of cattle feedlots and manure storages in the Canadian Great Lakes Basin. PLUARG Technical Report Series, 89 pp.	Presents the results of a two-year study of runoff quality and quantity from two beef feedlots and two manure storage areas in Southern Ontario
Nicholls 2001.	Nicholls, K.H. 2001. Phosphorus loading to Lake Simcoe, 1990-1998: Highlights and Preliminary Interpretation in Historical Ecosystem Contexts	
Hargan, K.E.	Hargan, K.E., Paterson, A.M. and Dillon, P.J. 2011. A total phosphorus budget for the Lake of the Woods and the Rainy River catchment. Journal of Great Lakes Research. 37:753-763.	Study attempting to quantify the major and minor sources and losses of TP to the Lake of the Woods. The study primarily deals with loads but offers one assessment of land use based TP export.
Winter et al. 2007	Winter, J.G., Eimers, M.C., Dillon, P.J., Scott, L.D., Scheider, W.A. and Willox, C.C. 2007. Phosphorus inputs to Lake Simcoe from 1990 to 2003: Declines in tributary loads and observations on lake water quality. J. Great Lakes Res. 33:381-396.	Assessed concentrations and loads for Lake Simcoe Subwatersheds. Not all data is numerically reported so only 4 of the 6 subwatersheds has specific export coeffecients reported. Samples were collected frequently over a period of 5-14 years providing strong evidance for the coefficients reported.
Lin. 2004.	Lin, J.P. 2004. Review of published export coefficient and event mean concentration (EMC) data. *WRAP Technical Notes Collection* (ERDC TN-WRAP-04-3), U.S. Army Engineer Research and Development Centre, Vicksburg, MS. *www.wes.army.mil/el/wrap*	A technical report which summarizes and reviews published export coefficient data for use in estimating pollutant loading into watersheds.
Ahl. 1988.	Ahl, T. 1988. Background yield of phosphorus from drainage area and atmosphere: An empirical approach. Hydrobiologia. 170:35-44.	Study investigates the background export of TP and associated TSS as well as deposition from atmospheric sources. While the study area is from Finland, that author notes that the data is similar to that found from Ongley. 1976. Investigation of the Ongley paper found that export coefficients are not expressly described. Thus the Ongley paper was not included in this review.
Hejzlar et al. 2009	Hejzlar, J., Anthony, S., Arheimer, B., Behrendt, H., Bouraoui, F., Grizzetti, B., Groenendijk, P., Leuken, M.H.J.L., Lo Porto, A., Kronvang, B., Panagopoulos, Y., Siderius, C., Silgram, M., Venohr, M. and Zaloudik, J. 2009. Nitrogen and phospohrus retention in surface waters: an inter-comparison of predictions by catchment models of different complexity. J. Environ. Monit. 11:584-593.	Nitrogen and phosphorus retention estimates in streams and standing water bodies were compared for four European catchments by a series of catchment-scale modelling tools. The work hinged on accurate baseline information for the watersheds. A temperate continental watershed was selected from the Czech Republic comparable to the climate and land uses found in the NVCA.
Rast and Lee, 1983.	Rast, W. and Lee, G.F. 1983. Nutrient loading estimates for lakes. J. Environ. Eng. 109:502-517.	Study looked to develop nationally applicable phosphorus export coeffecients for the US and compare them to measured values from 38 OECD water bodies.
LSRCA 2009	Lake Simcoe Region Conservation Authority. 2009. Report on the Phosphorus Loads to Lake Simcoe 2004-2009. 18 pp.	This report presents the state of phosphorus inputs to Lake Simcoe over the 2004-2007 period. It does not provide the catchment areas so must be used in conjunction with LSRCA 2010. The export coefficients I calculated using the two reports correspond with the ranges presented in the LSRCA report indicating the same catchment sizes were used in both the LSRCA reports.
LSRCA 2010.	Lake Simcoe Region Conservation Authority. 2010. Estimation of the Phosphorus Loadings to Lake Simcoe. Report prepared by Lous Berger Group, Inc. 33 pp.	Models P export in Lake Simcoe watershed. Useful in reference to LSRCA 2009 to provide catchment areas to calculate export of P.
Wang et al. 2005	Want, Y., Choi, W. and Deal, B.M. 2005. Long-term impacts of land-use change on non-point source pollutant loads for the St. Louis Metropolitan Area, USA.	A land-use-change simulation model (LEAM) and a non-point-source (NPS) water quality model (L-THIA) were closely coupled as LEAMwq in order to determine the long-term implications of various degree of urbanization on NPS total nitrogen (TN), total suspended particles (TSP), and total phosphorus (TP) loads. The study included an examination of monitoring data from the watershed.

Appendix C. Annotated Bibliography of Development BMP Literature (modified from HESL et al., 2012)

Ref. #	Citation	Reference	Comments
1	Berger Group 2010	Estimation of Phosphorus Loadings to Lake Simcoe.	Reviewed to establish phosphorus loading coefficients for the land uses in each of the Lake Simcoe subwatersheds
2	Toronto Region Conservation Authority 2006	Erosion and Sediment Control Guidelines for Urban Construction	Focuses on sediment runoff mitigation for construction sites. The document does not quantify either percents or concentrations
3	Credit Valley Conservation 2010	Low Impact Development Stormwater Management Planning and Design Guide CVC Version 1, 2010	Uses the treatment train approach to Low Impact Development. Ten techniques are described and runoff reduction estimates or TP reduction estimates are given for each LID technique
4	Schueler, T.R., 2000a	Comparative Pollutant Removal Capability of Stormwater Treatment Practices Technical Note #95 from Watershed Protection Techniques. 2(4): 515-520.	Compares median % pollutant removal efficiencies for several stormwater treatment practices from the Centre for Watershed Protection database including: wet and dry ponds, wetlands, filters, infiltration, water quality swales and ditches - insufficient monitoring data to confidently assess performance of several commonly used practices, i.e. infiltration, bioretention, filter strips and swales
5	Schueler, T.R., 2000b	Pollutant Removal Dynamics of Three Wet ponds in Canada Technical Note #114 from Watershed Protection Techniques. 3(3): 721-728.	Removal efficiencies and design details reported in this document are also presented in Reference #6 along with those of other Ontario stormwater treatment practices monitored under the SWAMP program
6	MOE et al 2005, SWAMP	Synthesis of Monitoring Studies Conducted Under the Stormwater Assessment Monitoring and Performance Program	Provides evaluation of four wet ponds (including the 3 ponds in Reference #5), one wetland, one flow-balancing system, one underground tank and two oil grit separators in Ontario. Provides an overview of stormwater management practices and guidelines in Ontario, maintenance considerations, monitoring designs, and operational costs. Performance evaluations in the report are more relevant to the Lake Simcoe watershed than those reported for

Ref. #	Citation	Reference	Comments
			similar systems in the US (References #4, 7 and 9). The report is therefore the recommended prime source of information for these stormwater treatment practices.
7	Winer, R., 2000	National Pollutant Removal Performance Database for Stormwater Treatment Practices 2nd Edition March 2000. Report prepared for the EPA Office of Science and Technology	Performance results of stormwater treatment practices in the US from 135 studies contained in the database - as % removal efficiencies and effluent concentrations (no influent concentrations are reported). Specific site or design characteristics are not considered. Contains a bibliography for more detailed site and design information. This is the detailed report summarized in Reference #4. All primary findings from the report are noted in the review of Reference #4 above.
8	Ontario Ministry of the Environment, 2003	Stormwater Management Planning and Design Manual, 2003 and Ministry Guideline: Erosion and Sediment Control Best Management Practices (December 2006)	Guidance for the selection and sizing of stormwater management infrastructure with information on cost and maintenance for each technology. Reference for describing those types of stormwater mitigation technologies that are known for use in Ontario climates. No performance details given. Some references to the fact that certain techniques under certain conditions will export no water from the watershed to the receiving water.
9	*http://www.bmpdatabase.org*	The International Stormwater Best Management Practices (BMP) Database Project website	Provides access to the downloadable MS Access database as well as summary reports. Allows downloading information summaries for each practice study using specified criteria (facility type, state/province, water quality parameters) that include design details, site characteristics and monitoring results. Useful to refine performance evaluations for specific practices.
10	Mary T. Nett1, Mark J. Carroll, Brian P. Horgan, A. Martin Petrovic, 2008 American Chemical Society	Fate of Pesticides and Nutrients in the Urban Environment.	Empirical dataset based on measurements taken in an urban watershed in Ithaca, NY. The study was limited to 3 types of urban land use, Forested urban, general urban and

Ref. #	Citation	Reference	Comments
	Volume 997, September 12, 2008		fertilized lawns. Outcomes were useful only in a descriptive manner because load differences were not significant between land use types unless precipitation and runoff characteristics met certain conditions. General export coefficients that are divided between dissolved and particulate fraction may have some use for comparison. these types of data are rare therefore tabulated
11	Dr. John Sansalone of the Dept. of Environmental Engineering Sciences at the Univ. of Florida. February 2009	TARP Field Test Performance Evaluation of Sorbtive Filter using Sorbtive Media for Imbrium Systems Corporation	Very detailed and contains conclusive evidence with respect to both solids and P removal efficiencies for a single active sorbtive media stormwater treatment system The system monitored removed 78% of TP with 12% confidence limits
12	LSRCA	Black River, East Holland River, West Holland River, Uxbridge Brook, Maskinonge River subwatershed Plans	Provides projected phosphorous loadings under subwatershed development scenarios. Berger 2010 provide projections of development phosphorous loading based on the 2010 modelling data - also provides details that characterize the land uses in each subwatershed pertinent to phosphorus loading - details provided in these reports are useful for assessing the conditions of development sites that could contribute to phosphorus loading in the subwatershed

Appendix D. Table of Construction BMPs, Descriptions and Efficiencies (modified from HESL et al., 2012)

Description	Beneficial Management Practice (BMP) Category	Addresses what Loading Source?	Applicable to what site features?	Known Limitations of BMP	Reported Efficiency	Efficiency References (Appendix E)	Efficiency to Use
Anionic Polymer Runoff Treatment - flocculation and or coagulation of fine particles using polymers for the clarification of construction runoff to enhance downstream detention practices.	Runoff capture	Surface Runoff	Interior site	Requires proper design and monitoring to ensure that floc or polymer-dosed water does not get released to the environment	TSS = 88 to 94% (mean = 91%) with TSS influent concentration of 171 to 706 mg/L	41	91%
Bioretention Systems - biologic activity to filter/clean stormwater (infiltration basins, rainwater gardens, surface sand filters)	Filtration Systems	Surface runoff	Interior site	Can't treat large drainage areas, susceptible to clogging, consume a large area, high cost	TSS = 95% (45cm) TP = -1552-80%	8-10, 12, 13, 34-38, 40, CAST 2013	Site and design specific
Check Dams- permanent or temporary barrier that present erosion and promote sedimentation by slowing flows and filtering	Soil erosion control	Surface runoff		Requires periodic repair and sediment removal, removal can be expensive and difficult			Not available
Construction Phasing - creating a specified work schedule that coordinate the time of land-disturbing activities and the installation of erosion and sedimentation control measures to minimize the area and duration of exposed soil	Construction practices		Interior site, Stream, Drainage Channels	Requires more complex planning; potentially more costly as grading in done in multiple steps	TSS= 40%	112, article 54	Site specific
Dry Detention Ponds - collects stormwater runoff and store temporarily until infiltration and evaporation can occur	Detention Systems	Surface runoff	Interior site	For drainage areas greater than 10 acres, clogging, marginal removal of pollutants, unattractive, collect trash and debris	TSS = 61% TP = 0-20% Soluble P = -11%	104, 109	10%
Flow Splitters - restricts stormwater flows and creates bypass around the exposed areas	Flow Control Structures	Surface runoff	Interior site	Can create flow reversal, only for small systems			Site specific
Inlet Protection- prevention methods around storm drains limiting the amount of sediment entering the unit (sediment filter, sand bag	Filtration Systems	Impervious areas	Interior site	Needs to be properly maintained, not as	TSS = 69% (for 5 rolls each 45cm diameter	114	69%

Description	Beneficial Management Practice (BMP) Category	Addresses what Loading Source?	Applicable to what site features?	Known Limitations of BMP	Reported Efficiency	Efficiency References (Appendix E)	Efficiency to Use
barrier, geotextile barrier, compost biofilters, etc)				effective for find-grained sediments or large loads; compost biofilters increase in efficiency with increased number of rolls used	compost biofilters		
Maintenance - maintaining the BMPs that you currently have in place	House-keeping techniques	House-keeping	Entire site	Expensive, needs to be done somewhat frequently			Site specific
Mulches and Fibre or Geotextile Blankets and Mats - the application of organic materials, blankets or mats to form a temporary protective soil cover	Soil erosion control	Exposed soil, surface runoff	Interior site, Stream, Drainage Channels	Must be installed properly to be effective, mulching may not be effective on slopes greater than 3:1	29% - 99% TSS reduction (median = 90%) for various natural mulches and fiber blankets on slopes between 9% and 34% with various soils	112	90%
Pavement Management - cleaning streets and construction areas (sweeping, minimizing sand and salt applications, etc)	Housekeeping techniques	Impervious areas	Interior site		TSS = 9% TP = 3%	MDE 2013	
Silt Fences - temporary barrier to retain sediment along the perimeter and watercourses on a construction site	Filtration Systems	Stockpiling, watercourse and perimeter protection	Stream, Site perimeter, Stockpiles	Not always effective, proper installation is crucial, maintenance and inspection is required frequently, poor efficiency with fine particles	TSS = 70% (median)	112, article 56	70%
Soakaways-Infiltration Trenches - area to capture stormwater runoff, retain it, and then infiltrate it into the ground over a period of days	Infiltration Systems	Surface runoff	Interior site	Potential high failure if not designed properly, possible groundwater contamination, not for high	TSS = 95% TP = 50-70% Soluble P = 51%	6, 104	60%

Description	Beneficial Management Practice (BMP) Category	Addresses what Loading Source?	Applicable to what site features?	Known Limitations of BMP	Reported Efficiency	Efficiency References (Appendix E)	Efficiency to Use
				sediment/polluted areas, cannot use in industrial areas, requires large flat area, maintenance, inspection			
Structural Methods - installation of inlet/outlet riprap, permanent diversion, temporary diversions	Soil erosion control	Stream and watercourse runoff	Stream, Drainage Channels	Removal of temporary diversion structures can be expensive and time consuming			Site and design specific
Vegetative Filter Strips/Stream Buffers - maintain densely vegetated, uniformly graded areas that treat sheet flow from adjacent impervious surfaces	Filtration Systems	Surface runoff	Interior site	Can't use in hilly areas, difficult to monitor effectiveness, can use in contaminate areas, large area required, ineffective if improperly graded	TSS=70%TP = 60-70%	6, 42, 104	65%
Vegetative Methods - vegetative stabilization on site to prevent erosion, e.g., temporary seeding, sod	Soil erosion control	Exposed soil, surface runoff	Interior site, Stream, Drainage Channels	Cannot be implemented during off-seasons. In the fall heavy mulches will be used instead of vegetation.	99% TSS reduction (biomass at 2464 lb/acre compared to zero.)	113	99%
Vehicle Tracking Pad - entrance pad at construction access locations reduces the amount of mud transported onto paved roads by vehicles or surface runoff	Construction practices	Surface runoff	Interior site	Some sites will require extensive maintenance, some pads can become quickly saturated and plugged reducing effectiveness	Not available		Site specific
Wet Detention Ponds - stormwater pond with permanent pool. Provides peak flow control and water quality treatment	Retention Systems	Surface runoff	Interior site	For drainage areas greater than 10 acres, high cost, large area required, engineered design	TSS = 80% TP = 42-85% Soluble P = 66%	104-106, 109	63%

Description	Beneficial Management Practice (BMP) Category	Addresses what Loading Source?	Applicable to what site features?	Known Limitations of BMP	Reported Efficiency	Efficiency References (Appendix E)	Efficiency to Use
				required, warm water discharges. Less effective on fine soils.			
Permeable Pavement - Pavement or pavers that reduce runoff volume and treat water quality through both infiltration and filtration mechanisms. Water filters through open voids in the pavement surface to a washed gravel subsurface storage reservoir, where it is then slowly infiltrated into the underlying soils or exits via an underdrain.	Infiltration Systems	Surface runoff	Interior site	High cost.	TSS = 55-85%; TP = 20-80%	MDE 2013	Site specific

Appendix E. References for BMP Phosphorus % Reduction Cited in Table 10 and Appendix D (modified from HESL et al., 2012)

Ref ID	Author	Year	Title	Publication
2	Van Seters et al.	2009	Referenced in: Low Impact Development Stormwater Management Planning and Design Guide - CVC Version1, 2010	Credit Valley Conservation
4	J.F. Sabourin & Ass.	2008		
6	ASCE	2000		
7	SWAMP	2002		
8	Dietz and Caausen	2005		
9	Hunt et al.	2006		
10	Davis	2007		
12	Hunt et al.	2008		
13	Roseen et al.	2009		
21	Deletic and Fletcher	2006		
23	U of Florida	2009	FDEP contract # WM 910	Dept. Env. Eng. Sciences, Gainesville FL
24	Wanielista et al.	1978	Shallow water roadside ditches for stormwater purification	www.stormwater.ucf.edu/FILES/wan1978paper.pdf
26	Harper, H.H.	1988	Effects of Stormwater Management Systems on Groundwater Quality	Florida Dept of Env Reg - project WM190
27	Dorman et al.	1989	Retention/Detention and overland flow for Pollutant removal from Highway stormwater runoff	Vol I research report. Federal Hwy Admin FJWA/RD-89/202pp
28	Yu, S.L. Et al.	1993	Testing of BMPs for controlling highway runoff	Virginia Transportation Research Council. FHWA/VA-93-R16.60pp
29	Goldberg, J.	1993	Dayton Ave Swale Biofiltration Study	Seattle Eng Dept - Seattle WA 67pp
30	Barrett et al.	1998	Performance of Vegetative Controls for Treating Highway Runoff	J. Environ Eng., 124(11) 1121-1128
31	Rushton et al.	2001	Florida Aquarium Parking Lot: A treatment train approach to SWM	SWFWMD, Brooksville, FL. Www.swfwmd.state.fl.us/ppr/reports/files/
32	Lloyd, S.D. Et al.	2001	Assessment of Pollutant Removal in a Newly constructed Bio-retention system	2nd South Pacific Stormwater Conference, Auckland, New Zealand

34	Lombardo &Line	2004	Evaluating the effectiveness of LID NCSU Water Quality Group	NC State U - conf proc: http://lowimpactdevelopment.org
35	Sharkey & Hunt	2005	Case Studies on the performance of Bioretention Areas in NC	8th biennial Stormwater research & wshed man conf www.swfwmd.state.fl.us/documents/
36	Birch et al.	2005	Efficiency of an Infiltration Basin in Removing Contaminants from Urban Stormwater	Env. Mon. and Ass. 101: 23-38
37	Davis et al.	2006	WQ improvement through Bioretention Media:N amd P removal	Water Environment Research 78(3):284-293
38	Brown & Hunt	2008	Bioretention performance in the upper coastal plain of NC	ASCE/EWRI World Environmental and Water Resources Congress
40	Osborn & Packman	2008	A comparison of conventional and low impact dev stormwater BMPs	ASCE/EWRI World Environmental and Water Resources Congress
41	Toronto and Region Conservation Authority	2010	Performance Evaluation of an Anionic Polymer for treatment of Construction Runoff	TRCA
42	Woodard and Rock	1995	Control of Residential Stormwater by Natural Buffer Strips	Lake &Reservoir Management 11(1), 37-45
104	Schueler, T.R.	2000	Comparative Pollutant Removal Capability of Stormwater Treatment Practices	Technical Note #95 from Watershed Protection Techniques. 2(4): 515-520.
105	Schueler, T.R.	2000	Pollutant Removal Dynamics of Three Wet ponds in Canada	Technical Note #114 from Watershed Protection Techniques. 3(3): 721-728.
106	Ministry of the Environment	2005	Synthesis of Monitoring Studies Conducted Under the Stormwater Assessment Monitoring	Prepared by the SWAMP program for GLSF, TRCA, MEAO and MOE, published by Toronto and Region Conservation Authority

			and Performance Program	
109	http://www.bmpdatabase.org		The International Stormwater Best Management Practices (BMP) Database Project website	
111	Sansalone, J	2009	TARP Field Test Performance Evaluation of Sorbtive Filter using Sorbtive Media for Imbrium Systems Corporation	Dept. of Environmental Engineering Sciences at the Univ. of Florida. February 2009
112	Schueler and Holland	2000	The Practice of Watershed Protection	Centre for Watershed Protection, Ellicott City, MD
113	Lee, C.R. and Skogergboe, J.G.	1985	Quantification of Erosion Control by Vegetation on Problem Soils	Soil Conservation Society of America, Arkeny, IA. pp.437-444
114	Taleban, V., Finney, K., Gharabaghi, B., McBean, E., Rudra, R. and Van Seters, T.	2009	Effectiveness of Compost Biofilters in Removal of Sediments from Construction Site Runoff	Water Quality Research Journal of Canada Vol. 44, No.1, 71-80

Appendix F. Database Manual - "Using the NVCA Phosphorus Loading Development Tool

October 2014

Using the NVCA Phosphorus Loading Development Tool

The "NVCA Tool for Managing New Urban Development in Phosphorus-Sensitive Watersheds" is a generic tool for estimating how phosphorus loads will change as lands are developed in Ontario watersheds located off the Precambrian Shield. It is intended for use by the development community, municipalities, the MOE and Conservation Authorities as a scientifically-sound method to assess if phosphorus loading from new development is maintained or reduced over pre-development conditions by modelling Best management Practices (BMPs) and Low Impact Development (LID) techniques.

The Tool consists of three elements:

1. A **Technical Guidance Manual** (HESL 2014[1]) that provides the reference materials used in developing the Tool and documents the derivation of export coefficients and estimation routines.
2. A Microsoft ACCESS© **Database Tool** that facilitates the calculation of a phosphorus budget for new development in accordance with the technical guidance, and
3. A **Database User's Manual** (this document) that provides step-by-step instructions explaining the operation of the database. The user's manual was prepared by Stoneleigh Data for use with the Microsoft ACCESS© Database Tool. The NVCA has developed a web based application of the Tool that follows the same procedures and calculations as the ACCESS© version but which differs in some features and operations. This manual may not be completely compatible with the NVCA web-based Tool and is intended only for use with the ACCESS© version.

The Technical Guidance Manual and Database Tool are divided into four modules as follows:

- **Module 1** – Estimates pre-development phosphorus loads for representative land uses (categorized in separate Natural Heritage, Urban and Cropland sub-types) contained within the study site,
- **Module 2** – Estimates post-development phosphorus loads that are representative of the proposed land uses for the study site without BMPs and LID techniques to reduce phosphorus loads,
- **Module 3** – Estimates the reduction in phosphorus loads from the post-development scenario with implementation of BMPs and LID techniques, and

[1] Hutchinson Environmental Sciences Ltd. 2014. Managing New Urban Development in Phosphorus-Sensitive Watersheds. Prepared for Nottawasaga Valley Conservation Authority. October 2014. 65pp.

- **Module 4** – Provides a checklist for users to guide selection and implementation of BMPs for the construction phase of development to minimize sediment loss and resultant phosphorus export.

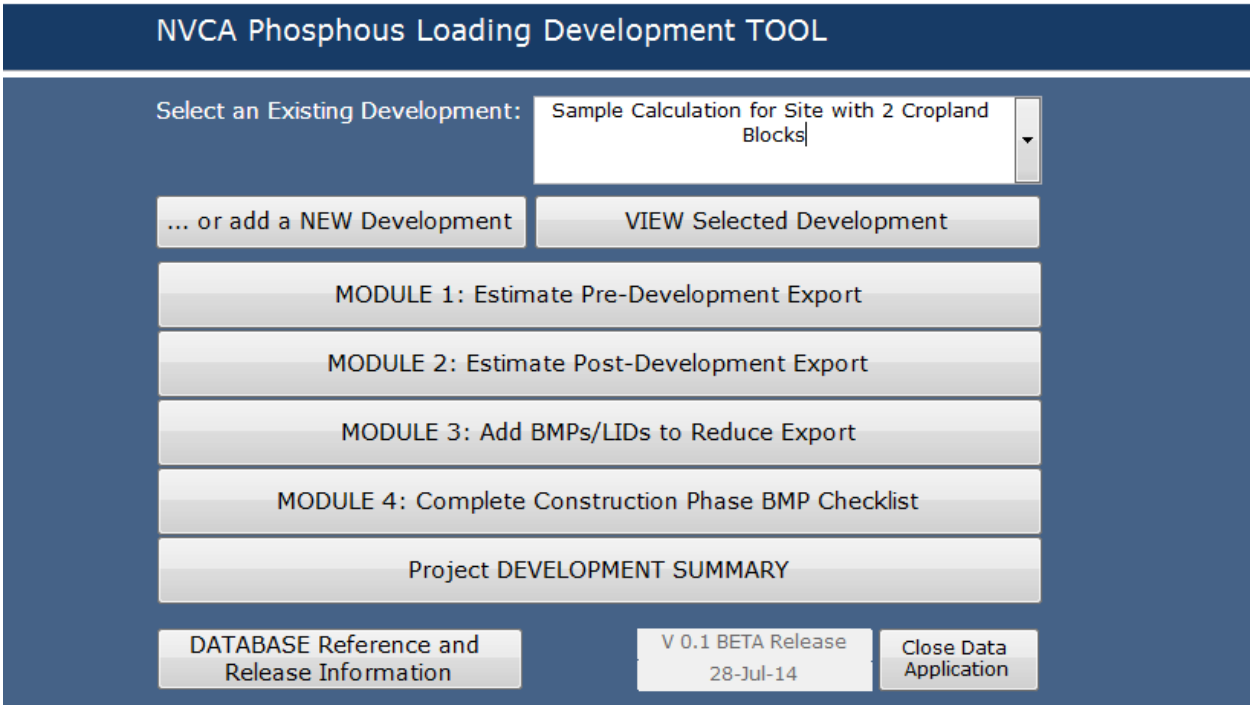
The following User's Manual is not intended as a "stand alone" description of the Tool or the estimation process, but as a set of instructions on operating the **Microsoft ACCESS© Database Tool.** The user must always rely on the **Technical Guidance Manual** as the primary technical source.

To start:

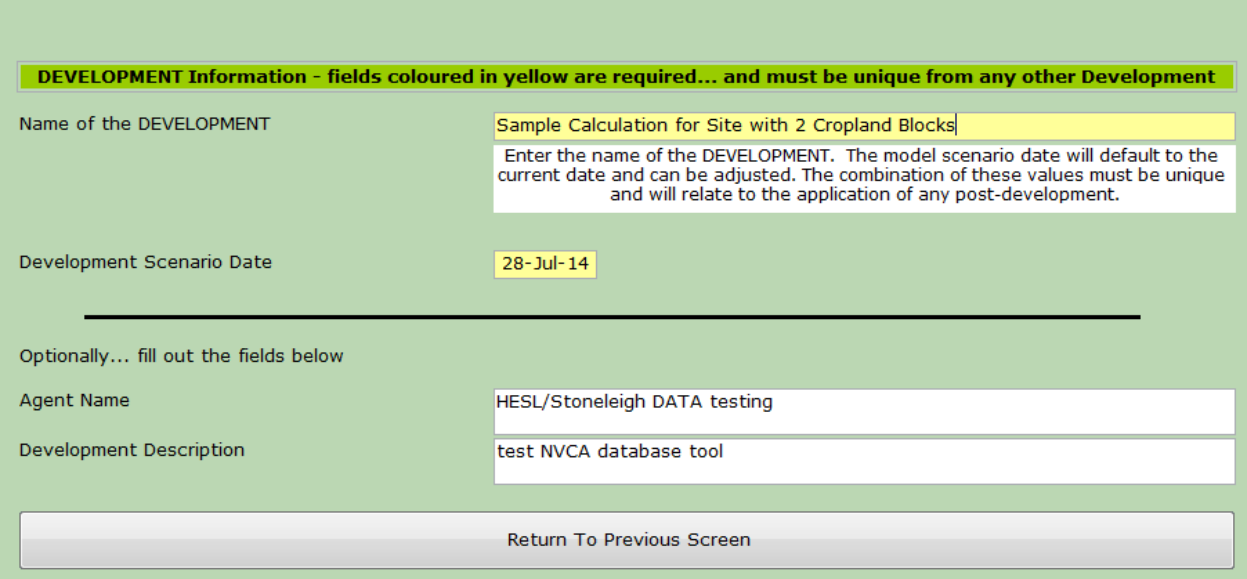
- Save the database file to any folder – all support reference data tables are warehoused within this single file.

- The database opens to a main screen – all features of the database are accessed from this opening view. The version code and date show in the lower portion of this screen and cannot be adjusted by users.

Healthy Watershed, Healthy Communities



STEP 1: For a new development you will need to enter information about the development first– a unique development name and date combination are required. Other optional information includes the developer or agent name and a description of the development (e.g., location, size, development type).



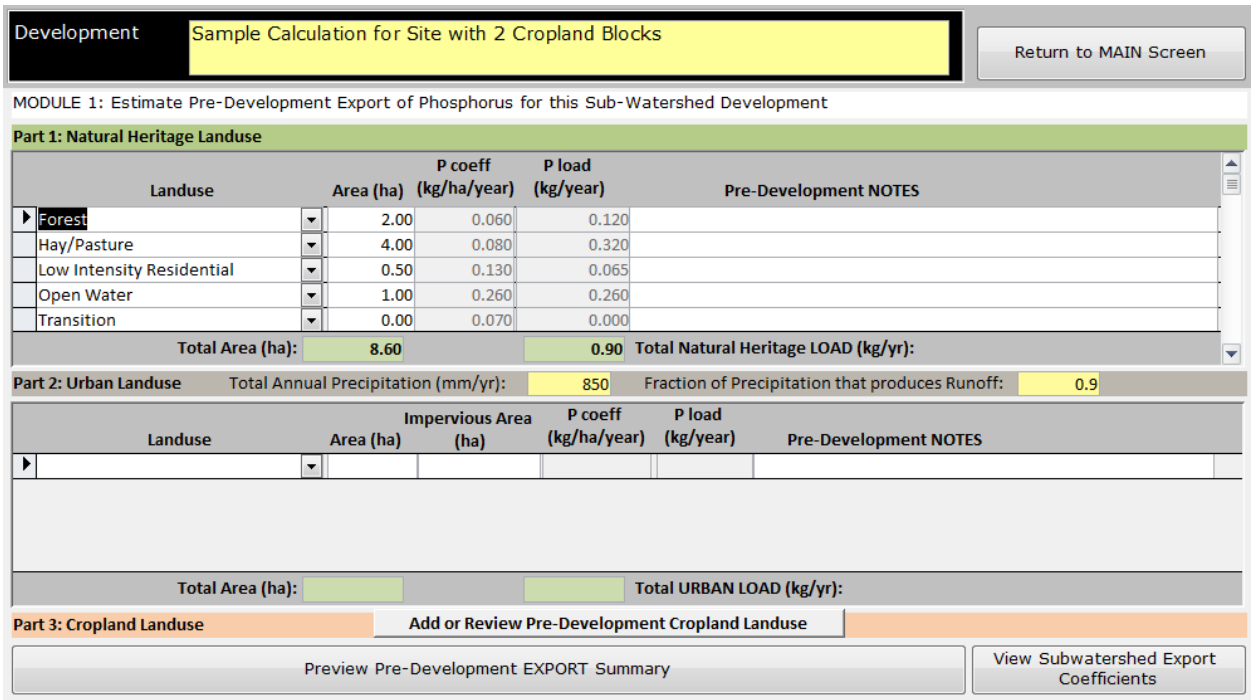
The following 3 MODULES are entered in sequence as you enter the information about pre-development conditions, expected post-development conditions (including the development/transformation of existing land uses and the application of BMPs/LIDs). The last MODULE contains a checklist of construction phase BMP's and is not part of the derivative phosphorus modeling.

The landuse options are contained in a drop-down list reference table along with phosphorus export coefficients for all land uses except Cropland and Urban Lands, which are calculated based on site characteristics. With this release version, these values may NOT be adjusted by the user. These values are not watershed dependent and are considered valid for all areas off the Canadian Shield.

MODULE 1: Pre-development conditions are entered by the user as displayed with the screen below. Users must first have selected a development using the drop-down box on the main screen before they will be able to gain access to this screen. A listing of all phosphorus export coefficients and an overall summary of the Pre-development conditions can also be viewed from this screen using the buttons provided. Data is entered in three (3) parts as follows:

- Part 1 – Enter the Natural Heritage Landuses – as selected from the drop-down list. Enter the area of each land use and the corresponding phosphorus export coefficient (P coeff) will automatically populate and be used to derive the phosphorus load.

- Part 2 – Enter the total annual precipitation and the fraction that produces runoff in the boxes provided above the Part 2 data form ("Part 2 Urban Land Use" as shown below). Enter the Urban Landuses – as selected from the drop-down list along with both the total area and the portion that is impervious. The phosphorus export coefficient and load will be derived automatically.



Development: Sample Calculation for Site with 2 Cropland Blocks

Return to MAIN Screen

MODULE 1: Estimate Pre-Development Export of Phosphorus for this Sub-Watershed Development

Part 1: Natural Heritage Landuse

Landuse	Area (ha)	P coeff (kg/ha/year)	P load (kg/year)	Pre-Development NOTES
Forest	2.00	0.060	0.120	
Hay/Pasture	4.00	0.080	0.320	
Low Intensity Residential	0.50	0.130	0.065	
Open Water	1.00	0.260	0.260	
Transition	0.00	0.070	0.000	
Total Area (ha):	8.60		0.90	Total Natural Heritage LOAD (kg/yr):

Part 2: Urban Landuse — Total Annual Precipitation (mm/yr): 850 — Fraction of Precipitation that produces Runoff: 0.9

Landuse	Area (ha)	Impervious Area (ha)	P coeff (kg/ha/year)	P load (kg/year)	Pre-Development NOTES
Total Area (ha):					Total URBAN LOAD (kg/yr):

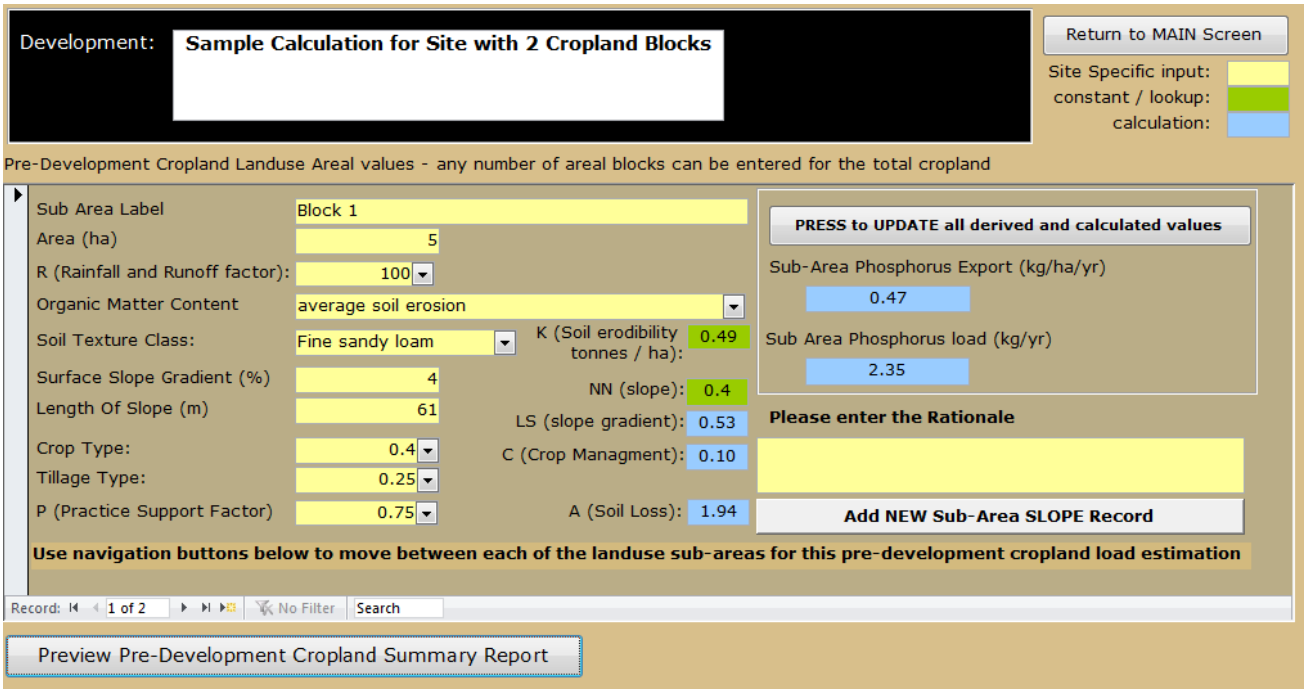
Part 3: Cropland Landuse — Add or Review Pre-Development Cropland Landuse

Preview Pre-Development EXPORT Summary

View Subwatershed Export Coefficients

- Part 3 - Click on the button beside the Part 3 label ("Part 3: Cropland Landuse") to open the Cropland Landuse screen. Enter the values shaded in yellow. Values in green will be entered as either constants or filled in automatically from reference lookup tables in the database using the values you enter. Fields shaded in blue are derived by the database using the formulae described in the *Guidance Manual*. After users enter the necessary input values and press the tab to advance to the notes field, the phosphorus load in kg/year is derived automatically. For Cropland, areas must be divided into blocks with similar slope and slope length and phosphorus export calculated separately for each block. There is no limit to the number of blocks for Cropland. The total area of the

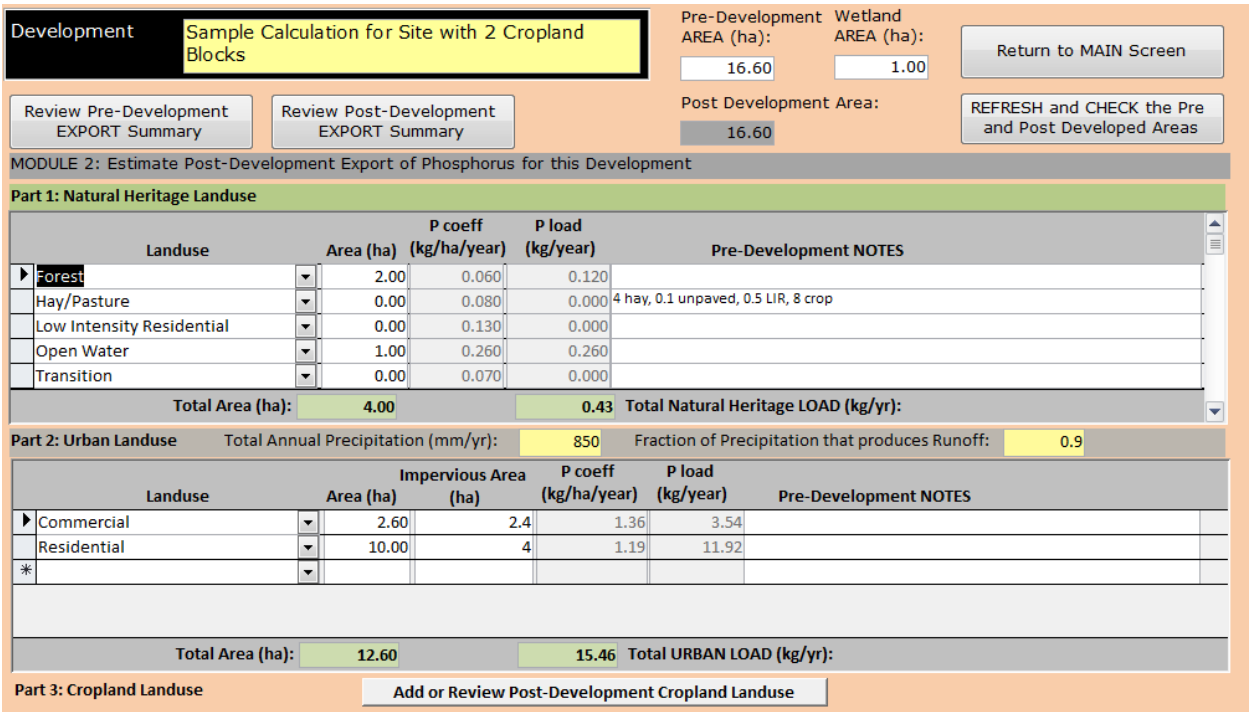
development site is also derived automatically along with a total P load. A summary of the pre-development conditions can be viewed using the button provided.



MODULE 2: Post-development conditions can be added only after pre-development conditions have been entered (a blank screen will display if this is not the case). You must also have selected a development using the drop-down box on the main screen to display the information screen for post-development conditions. The screen illustration following shows the development and pre- and post-development areas (along with any wetland area) at the top of the screen. This upper information may not be adjusted and displays and updates automatically.

Select the land use and enter the required input data as done for Module 1 using the lower part of the screen. Area values can be entered to hundredths. If the area of wetland is altered from the Pre-Development scenario, a warning flag will be posted on the screen and in the report, as a reminder that wetland areas should be protected in the course of development and a recognition that changes may occur if approved. The default phosphorus export coefficient is automatically entered from the lookup table or based on calculations for Cropland and Urban Land Uses, and may not be adjusted.

The Cropland Landuse screen is identical to that of Module 1. Enter the cropland landuse in blocks as provided earlier.



There are several checks against both wetland land use and comparisons against pre and post development site areas on this screen. As users enter the areas in each of the three land use categories, they can, at any time, use the “REFRESH” button at the top of the screen to appraise them of the results of these comparisons. The code is listed on the following page, with comments about the impact of these results. The procedural code is also executed when users push the “Return to Main Screen” button. In some cases, users will be unable to leave the screen and proceed to the next step until the pre- and post-areal totals match. The procedural logic and code is as follows:

Total Development Area

Open two record-sets within the code as follows

- open a record-set for the development the user has open with the total PRE and POST development areas over all of the three land use categories
- derive the difference between the PRE and POST development areas

If PreArea > PostArea Then

- *Message "The Pre-Development Total Area is GREATER than the current Post-Development Total Area by " & AreaDiff & ". Please review development areas to*

ensure that the area of the entire site is included in the pre- and post-development scenarios (pre-development area should equal post-development area)."

If PreArea < PostArea Then

- *Message "The Pre-Development Total Area is LESS than the current PostDevelopment Total Area by " & AreaDiff * -1 & ". Please review development areas to ensure that the area of the entire site is included in the pre- and post-development scenarios (pre-development area should equal post-development area)."*

Otherwise they are equal

- *Message "The PreDevelopment Total Area EQUALS the current PostDevelopment Total Area."*

Wetland Area

Open two other record-sets for the development that show the total PRE and POST development area that is WETLAND

- If there is none, display it as 0 hectares, otherwise return the value

If WETLAND = 0

Then no need to warn the user about encroaching on wetland areas

If WETLAND > 0

There is WETLAND so check if development is encroaching on wetland areas

Evaluate the PRE and POST Wetland differences (WETdiff = PRE – POST)

If WETdiff > 0 Then

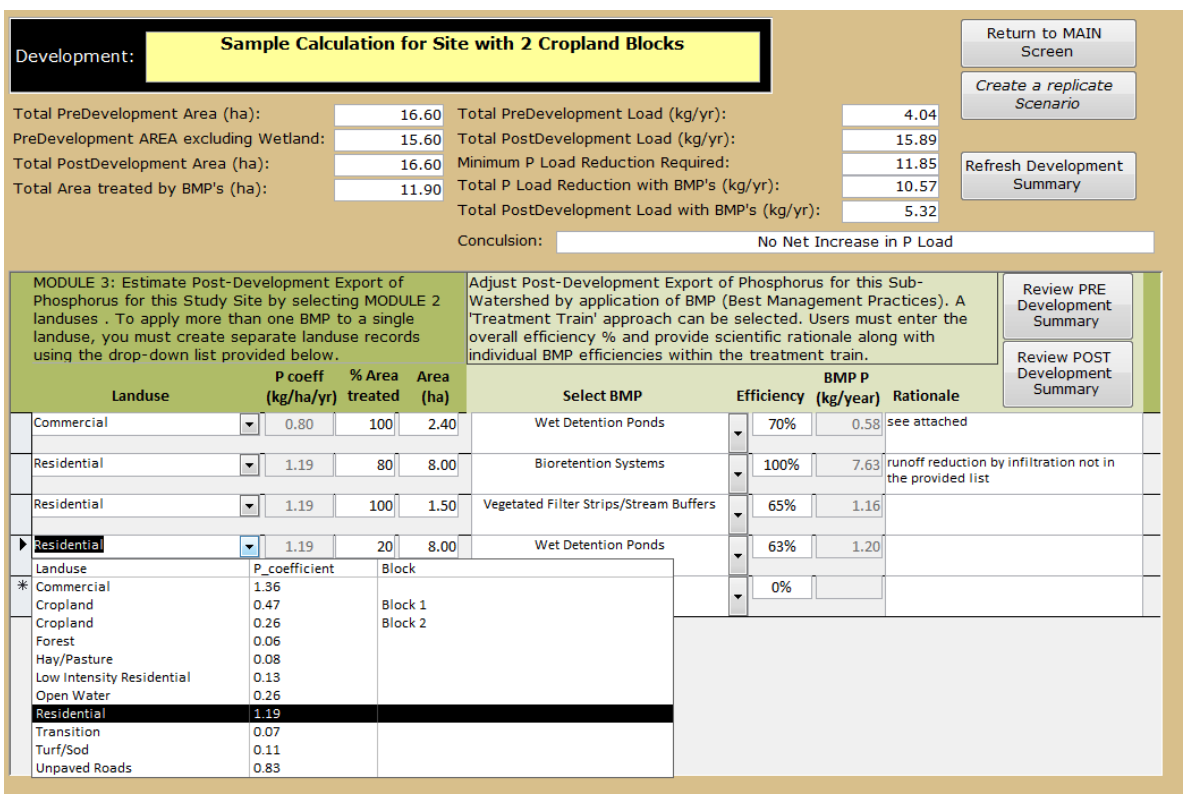
- *Message* "*Please ensure that you include the Wetland Land Use specified in the Pre-Developed Area (" & WET & " hectares) in the Post-Development"*

If WETdiff < 0 Then

- *Message* "*Wetland area has been modified from the pre-development scenario. Please provide a rationale*"

.

MODULE 3: The next step is to select the BMPs/LIDs from the drop-down list to be applied on the development site. Some of them have defined efficiencies while others do not. Efficiency values will be applied to reduce the load for that landuse by the value that you select/enter. Note that phosphorus reduction efficiencies that are greater than the default values can be applied to Runoff Reduction techniques (e.g. 100% for infiltration) if these are documented and supported in the Stormwater Management Plan for the site. You will not be allowed to enter a BMP for wetlands. If the removal efficiency for a block is achieved through one BMP then the user would simply choose that technique from the drop down menu. If a SWM treatment train approach has been used then the user must document the rationale for the chosen removal efficiency in the SWM report / plan for review and approval. Enter information to the rationale field (up to 255 characters may be typed) along with the total efficiency in the field provided. If users select "Other" as a BMP, or adjust the efficiency value, they will be prompted to enter a rationale. Users may also adjust the efficiency from the base reference value that is automatically inserted as you select a BMP from the drop-down list. You will be prompted to enter a rationale for this change. The change will also be reflected in the Post Development summary report and both the base reference efficiency and the user adjusted value will display along with an information note. A summary of the total development can also be produced from this page using a button located at the middle of the bottom of the screen.

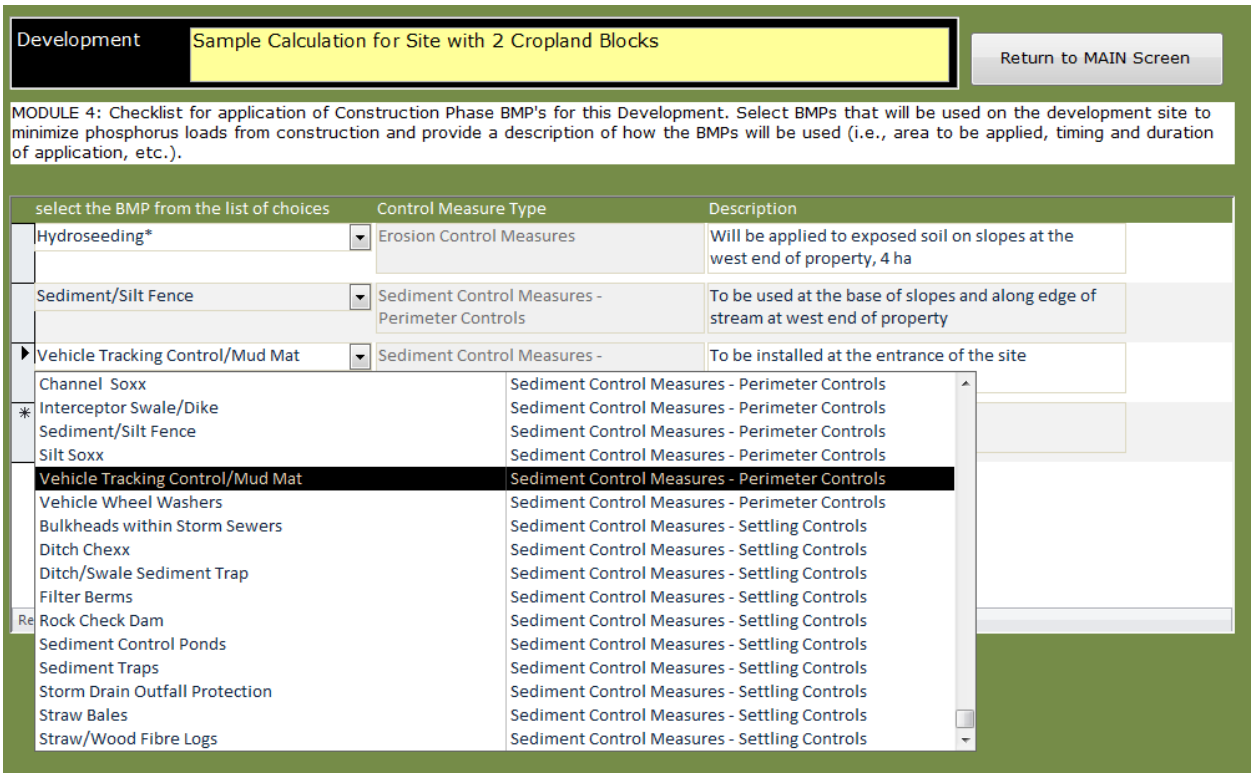


The tool can be used to model multiple BMP/LID scenarios to derive the optimum development plan by creating multiple scenarios of the same development with differing versions of post-development land use and BMP implementation. A procedure to create a replicate scenario can be executed using the button marked ‘Create a replicate scenario’ at the top right of the screen (and shown below). A new Development will be created (and the message below will display) when this button is pressed. The name of the replicated development will be the same as the one that the user has selected with a suffix added containing the name ‘-replicate scenario’ followed by a data and time stamp (enabling users to create multiple replicates on the same day). Users should adjust this name by returning to the main screen and selecting it from the drop-down list. Adjustments to the post-development information will also be required to distinguish it from the original.

The replication includes all pre- and post-development landuse designations and relevant data. It does not include the application of any BMPs (Module 3).

When users leave this view, there is a check to see if the treatment area total exceeds the Pre-development area total. If so, a warning message displays and users will not be able to leave this screen.

MODULE 4: For this Module, a checklist of Construction Phase BMPs is provided. The User will select BMPs that will be used on the development site to minimize phosphorus loads from construction and provide a description of how the BMPs will be used (i.e., area to be applied, timing and duration of application, etc.).



DATA SUMMARIES:

Each stage of the model allows users to review a data summary as an Access Report. These reports can be printed or distributed as pdf documents. Summaries include:

- Phosphorus export coefficients by Landuse
- Pre-Development landuse and Phosphorus Export – with separate Cropland sub-area review of all derived model parameters
- Post-Development landuse and Phosphorus Export – with separate Cropland sub-area review of all derived model parameters
- Overall Development summary including:
    - Pre-Development including Cropland model parameters
    - Post-Development including Cropland model parameters
    - BMP application by landuse summary with efficiencies and rationale
    - BMP application summary of load reductions with conclusion statement
    - Construction BMP application checklist with rationale statements

Sample Summary Reports

PHOSPHORUS EXPORT COEFFICIENTS: Development

Updated: July 2014

Land-Use Specific Phorphorus Export Coefficients for any off Canadian Shield Watersheds for development

	Annual Phosphorus Load (kg/ha/year)												
	Agricultural	Urban				Natural Heritage							
	Cropland	Residential	Commercial	Industrial	Trans-portation	Forest	Transition	Wetland	Turf / Sod	Hay / Pasture	Low Intensity Residential	Unpaved Roads	Open Water
		TPi * Precip * Pj * Rv * 100											
	0.16 + 0.16 * A	TPi = 0.41	TPi = 0.20	TPi = 0.41	TPi = 0.50	0.06	0.07	0.05	0.11	0.08	0.13	0.83	0.26

Notes:

Natural Heritage land uses mean phosphorus export for all 'monitored' Lake Simcoe subwatersheds (n = 7) derived using phosphorus loads from CANWET modeling. Monitored subwatersheds are those with sufficient measured data to validate and calibrate the model.

Open Water land use is calculated from the mean measured atmospheric load of 19 tonnes/yr averaged over 5 years from 2002 to 2007 to the surface of Lake Simcoe (surface area = 722 km2) (Scott et al., 2006; LSRCA, 2009).

Cropland land uses are developed from the relationship between CANWET derived phosphorus export for Lake Simcoe subwatersheds and soil loss. Where A = soil loss determined using the Universal Soil Loss Equation (USLE)

Urban land uses are derived where TPi is total phosphorus concentration (mg/L) in runoff measured from land use (i) from the SWAMP studies (TRCA, 2005), Precip is the annual precipitation (mm/yr), Pj is the fraction of Precip that produces runoff, and Rv is the runoff coefficient = 0.05 + 0.91 x impervious fraction following US EPA's Simple Method.

August-12-14

Page 1 of 1

Database Version: V 0.2 BETA Release
Update Date: 29-Jul-14

PRE-DEVELOPMENT Phosphorus EXPORT

DEVELOPMENT: **Sample Calculation for Site with 2 Cropland Blocks**

Landuse		Area (ha)	P coeff (kg/ha)	Pload (kg/yr)
Agricultural				
Cropland	Block 1	5	0.47	2.35
Cropland	Block 2	3	0.26	0.79
	Agricultural Land use Class Total	***8.0***		***3.14***
Natural Heritage				
Forest		2	0.06	0.12
Hay/Pasture		4	0.08	0.32
Low Intensity Residential		0.5	0.13	0.06
Open Water		1	0.26	0.26
Transition		0	0.07	0.00
Turf/Sod		0	0.11	0.00
Unpaved Roads		0.1	0.83	0.08
Wetland		1	0.05	0.05
	Natural Heritage Land use Class Total	***8.6***		***0.90***
	Development TOTAL:	**16.6**		**4.04**

July-29-14 Page 1 of 1

Database Version:	V 0.3 BETA Release
Update Date:	12-Aug-14

Cropland Site Sediment and Phosphorus Pre-Development EXPORT

DEVELOPMENT: **Sample Calculation for Site with 2 Cropland Blocks**

Site Specific input:		constant / lookup:	
		calculation:	

Sub Area: Block 1

Slope Area (ha):	5.0	R (Rainfall / Runoff for Lake Simcoe)	100
Surface Slope Gradient (%):	4	K (Soil erodability factor):	0.49
Length Of Slope (m):	61.0	NN (determined by slope):	0.4
Crop Type Factor:	0.4	LS (slope length gradient factor):	*0.53*
Tillage Type Factor:	0.25	C (crop management factor):	*0.100*
		P (prevention + capture):	*0.75*
		Soil Loss (kg/year):	*1.94*
		Phosphorus export (kg/ha/yr):	*0.47*
		Phosphorus load (kg/yr):	*2.35*

Sub Area: Block 2

Slope Area (ha):	3.0	R (Rainfall / Runoff for Lake Simcoe)	100
Surface Slope Gradient (%):	2	K (Soil erodability factor):	0.83
Length Of Slope (m):	20.0	NN (determined by slope):	0.3
Crop Type Factor:	0.35	LS (slope length gradient factor):	*0.18*
Tillage Type Factor:	0.25	C (crop management factor):	*0.087*
		P (prevention + capture):	*0.50*
		Soil Loss (kg/year):	*0.64*
		Phosphorus export (kg/ha/yr):	*0.26*
		Phosphorus load (kg/yr):	*0.79*

PRE Developed AREA (ha):	8.0
Phosphorus Export (kg/ha/yr):	0.73
Phosphorus Load (kg/ha):	3.14

August-12-14 Page 1 of 1

Database Version: V 0.2 BETA Release
Update Date: 29-Jul-14

POST-DEVELOPMENT Phosphorus EXPORT - Module 2

DEVELOPMENT: Sample Calculation for Site with 2 Cropland Blocks

Landuse		Area (ha)	P coeff (kg/ha)	P Load (kg/yr)
Agricultural				
Cropland	Block 1	0	0.47	0.00
Cropland	Block 2	0	0.26	0.00
	Agricultural Land use Class Total	***0.0***		***0.00***
Natural Heritage				
Forest		2	0.06	0.12
Hay/Pasture		0	0.08	0.00
Low Intensity Residential		0	0.13	0.00
Open Water		1	0.26	0.26
Transition		0	0.07	0.00
Turf/Sod		0	0.11	0.00
Unpaved Roads		0	0.83	0.00
Wetland		1	0.05	0.05
	Natural Heritage Land use Class Total	***4.0***		***0.43***
Urban				
Commercial		2.6	1.25	3.25
Residential		10	1.19	11.92
	Urban Land use Class Total	***12.6***		***15.16***
	POST Development Total	***16.6***		***15.59***

July-29-14 Page 1 of 1

BMP Application Summary

Area	Treated Area	P coefficient	Efficiency	Pload	Rationale
BMP					
Residential					
8.00	20.00	1.19	0.63	1.20	
Wet Detention Ponds					
Residential					
1.50	100.00	1.19	0.65	1.16	
Vegetated Filter Strips/Stream Buffers					
Residential					
8.00	80.00	1.19	1.00	7.63	runoff reduction by infiltration not in the provided list
Bioretention Systems					
Commercial					
2.40	100.00	1.25	0.63	1.89	
Wet Detention Ponds					

Total PreDevelopment Area (ha):	16.60
PreDevelopment Area excluding Wetlands (ha):	7.60
Total PostDevelopment Area (ha):	16.60
Total Area treated by BMP's (ha):	19.90
Treated Area total:	11.90
Total PreDevelopment Load (kg/yr):	4.04
PostDevelopment Load (kg/yr):	15.59
Total P Load Reduction with BMP's (kg/yr):	11.88
Minimum P Load Reduction Required:	11.55
Total PostDevelopment Load with BMP's (kg/yr)	3.72

Conclusion: No Net Increase in P Load

July-29-14 Page 5 of 5

DEVELOPMENT:
Sample Calculation for Site with 2 Cropland Blocks

Database Version: **V 0.3 BETA Release**
Update Date: **12-Aug-14**

Construction Phase BMP Applied	Rationale Description
Erosion Control Measures	
Hydroseeding*	Will be applied to exposed soil on slopes at the west end of property, 4 ha
Sediment Control Measures - Perimeter Controls	
Sediment/Silt Fence	To be used at the base of slopes and along edge of stream at west end of property
Vehicle Tracking Control/Mud Mat	To be installed at the entrance of the site

August-12-14 Page 5 of 5