Prioritizing Catchments for Stewardship:

A Summary of Modelling Approaches for Lake Huron's Southeastern Shore

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EXECUTIVE SUMMARY

Due to the complexity of synthesizing watershed variables related to complex slope, soil, and land management data, the building of scenarios through watershed modelling is necessary to evaluate the effectiveness of stewardship practices being employed in study watersheds of the Healthy Lake Huron Initiative. Three modelling approaches were examined and compared in this report: GIS techniques, Soil and Water Assessment Tool (comprehensive and simplified), and a new geospatial modelling software referred to as Prioritize, Target, Measure Application (PTMApp). From the model comparisons, it was determined that GIS techniques and PTMApp software have sufficient capacity to synthesize land management information, and determine priority catchments for stewardship initiatives. As an initial diagnostic step to identify where watershed management agencies should promote best management practices (BMPs), GIS software and PTMApp contain valuable and user-friendly tools.

Based on the complexity of the Soil and Water Assessment Tool (SWAT), it was not advised to use readily-available provincial land management data in conjunction with the default parameters of SWAT to determine priority locations. The complexity of SWAT and its ability to model the interconnectedness of soil conditions, topography, and the hydrological cycle is necessary for evaluating the effectiveness of the BMPs. Explaining the differences in nutrient concentrations between streams, as well as the yearly differences in concentration loads cannot, at this time, be accomplished without a complex hydrologic process-based model such as SWAT.

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1.0 INTRODUCTION

One of the key objectives for the Healthy Lake Huron – Clean Waters, Clean Beaches Initiative is to reduce the amount of phosphorus entering Lake Huron. Phosphorus concentrations have been linked to increased algae growth in some near-shore areas of the Great Lakes. Changes in land management activities have been promoted in five priority watersheds. Monitoring the enhanced employment of agricultural Best Management Practices (BMPs) in these study watersheds can be difficult due to spatial and temporal variation in soil conditions, topography, vegetative cover that exist in the landscape and the extensive resources required by a water quality monitoring program designed to capture runoff events.

Due to the complexity of synthesizing watershed variables related to complex slope, soil, and land management data, the building of scenarios may be necessary. Hydrologic models can help to synthesize observations, analyze interactions amongst different processes and fill gaps in information. Hydrologic process-based models, such as the Rural Stormwater Management Model (RSWMM) and the Soil and Water Assessment Tool (SWAT), can be utilized by watershed management agencies to conceptualize the relationship between land management practices and the hydrological cycle, and ultimately the effects of runoff on nutrient concentrations. Ecosystem models can also help to locate future study areas for water quality improvements and BMP implementation.

Process-based hydrologic models such SWAT and RSWMM need extensive data sets to be informative. Collecting water quality, quantity and land management in every lakeshore catchment to run hydrologic models would be too expensive and impracticable for a watershed management agency. The four Lake Huron shoreline study watersheds, which account for 0.6% of the total drainage area of Lake Huron's southeastern shore from Sarnia to Southampton, may be representative of other lakeshore catchments (excluding large river systems e.g., Maitland Bayfield etc.). These lakeshore catchments account for approximately 15 percent of the total drainage area for Lake Huron's southeastern shore. These study watersheds have detailed data that can be used to extrapolate land management and water quantity and quality relationships in other similar lakeshore catchments.

From the perspective of a watershed management agency there is an array of potential models. The benefits and the limitations of the different tools may not be clear at the outset of a project. Building and enhancing the human resource capacity of the watershed management agency improves understanding of a model's limitations and the ability to choose the most applicable model. Understanding and utilizing process-based models at the watershed management level helps to transfer knowledge about the interconnectedness of land management decisions and nutrient loading across the watershed and along the Great Lakes. Therefore, the objective of this report was to further explore hydrological process models, and assess the benefits and limitations of three selected approaches: GIS techniques, SWAT, and Prioritize, Target, Measure Application (PTMApp). Models were assessed on ease of use and their ability to prioritize lakeshore catchments for sediment loadings.

This report is divided into multiple sections:

1. Overview of modelling techniques
2. Summarization of three modelling techniques
    a. GIS Techniques in Gully Creek
    b. SWAT executed with limited base data in Gully Creek
    c. PTMApp in Gully Creek
3. Assessing the accuracy of PTMApp
4. Applying PTMApp to the shoreline
5. Next steps

2.0 STUDY AREA

The study area for the catchment prioritization project was Lake Huron's southeastern shoreline from Sarnia to Southampton. This area encompassed four conservation authorities: St. Clair Region CA, Ausable Bayfield CA, Maitland Valley CA, and Saugeen Valley CA (Figure 1). The catchments spanned over 200 kilometers of shoreline, and the focus was placed primarily on gully catchments. Watersheds for major rivers such as the Maitland River and Ausable River were excluded. Drainage area for shoreline catchments ranged in size from 1 square kilometer to over 200 square kilometers for large creeks. The landscape and topography of the lakeshore catchments also differed between conservation authorities. The region within the jurisdiction of the St. Clair Region CA was largely flat with a relative slope of 1% whereas slopes along watercourses were over 30% in Maitland Valley CA's jurisdiction. In addition to slope, the land cover along the shoreline was not homogenous. Ausable Bayfield CA, within its lakeshore catchments, was predominately agricultural with approximately 71% of its landmass covered by cultivated fields and only 17% by natural vegetation. Conversely, the Saugeen Valley CA had approximately 15% of its lakeshore catchments covered by natural vegetation and 56% was considered agricultural land. Proceeding forward, it is important to note that ecological variances exist across this large study area, and that these differences will contribute largely to a model's calculated output.

Figure 1: Study area for shoreline catchment prioritization

3.0 MODEL TYPES

Hydrologic process models such as the SWAT are popular due to the model's ability to calculate nutrient loadings and simulate watershed conditions. The SWAT predicts water quantity and quality by simulating hydrological, climate, and land management conditions. Watershed agencies may find hydrologic process models difficult to run because of the necessary detailed datasets and knowledge required to run the software. In the absence of hydrologic models, McPherson and Veliz (2016) found that a series of tools run in sequence in Geographic Information System (GIS) software can be used to conduct a suitability analysis for future best management practices with satisfactory results. In an attempt to merge hydrologic process models with GIS, Houston Engineering Inc., in partnership with the International Water Institute, Red River Watershed Management Board, and the Minnesota Board of Soil and Water Resources, designed the PTMApp. The software allows water quality practitioners to PRIORITIZE locations where BMPs should be implemented, TARGET the locations for their BMP effectiveness, and MEASURE water quality goals and load reductions (Houston Engineering Inc. n.d.). Only the sediment loading tools contained in the Catchments and Loadings module of PTMApp were used in this project.

4.0 PREVIOUS STUDIES AND LIMITATIONS

4.1 Study Area: Gully Creek Watershed

To test the models, the project's study area was scaled down in scope to one smaller area of interest. The Gully Creek watershed in Ausable Bayfield CA was chosen because of its long term water quality monitoring data, and its availability of simulated sediment loadings from a complete and exhaustive SWAT model. Researchers at the University of Guelph previously ran the SWAT model with funding from the Ontario Ministry of Agriculture, Food and Rural Affairs through the Watershed Based Best Management Practices Evaluation program (Yang et al. 2013).

Gully Creek is located north of Bayfield, outlets directly into Lake Huron, and has a drainage area of approximately 14 km^2 (Figure 2). Elevation in Gully Creek ranges from 176 meters to 281 meters with slopes of 0% to 95%. Land cover in Gully Creek is predominately agriculture at 70% and natural vegetation, found mostly along watercourses, is 25% of the total surface area (Yang et al. 2013).

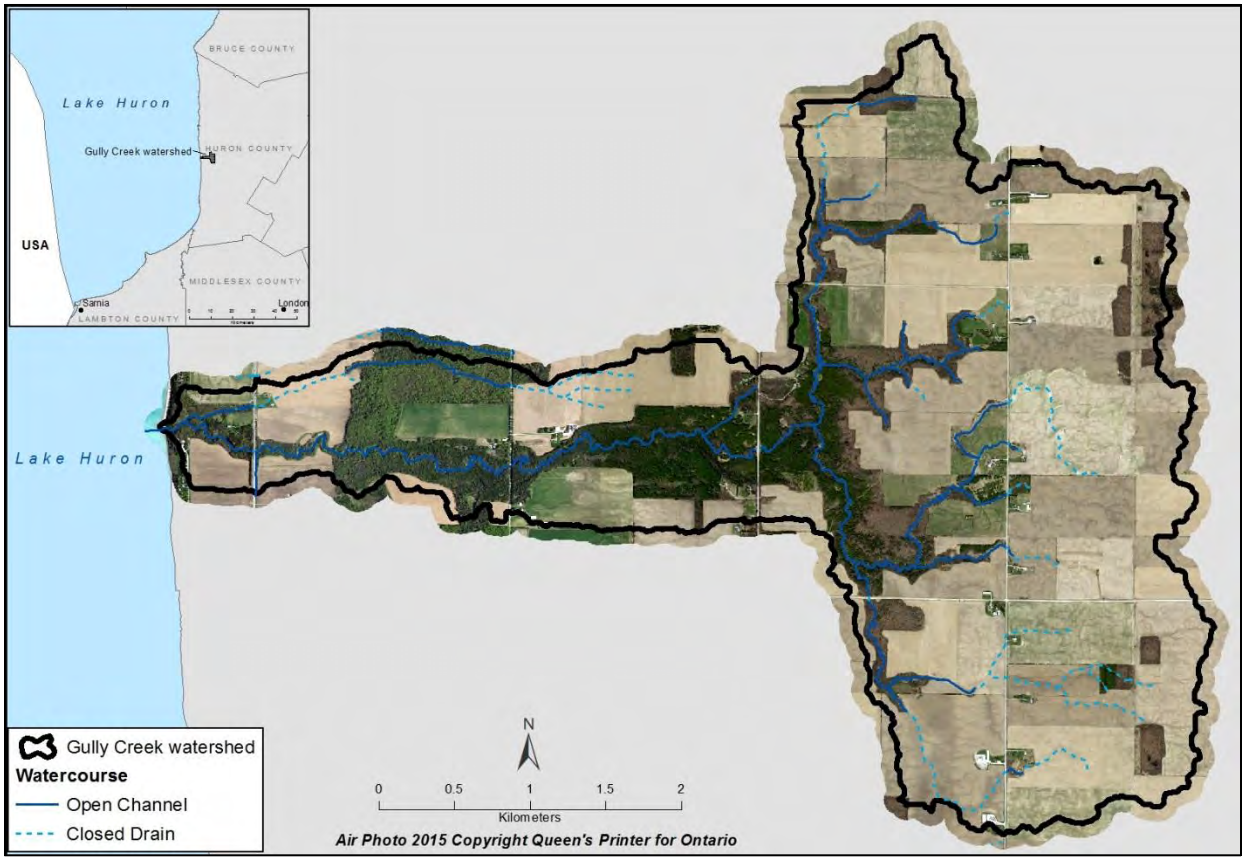

Figure 2: Gully Creek study area

4.2 GIS Approaches: Gully Creek

4.2.1 Purpose

McPherson and Veliz (2016) proposed with the use of GIS technologies to calculate sediment and surface run-off as a solution to overcome the challenges presented by hydrologic models. Objectives of the study included: identifying and ranking areas with different run-off risk assessment methods, comparing run-off risk outputs from SWAT results run by researchers at the University of Guelph, and identifying locations for BMPs with the framework proposed by Tomer et al. (2013).

4.2.2 Methodology

GIS modelling was completed with tools in Environmental System Research Institute's (ESRI) ArcGIS software package. Calculations were performed on a filled and hydrologically corrected LiDAR Digital Elevation Model (DEM) with a 1 meter by 1 meter spatial resolution (McPherson and Veliz 2016). The GIS techniques applied by Ausable Bayfield CA in Gully Creek were:

1. Potential for Sheet Erosion (PSE) – modified Revised Universal Soil Loss Equation (RUSLE)
2. Stream Power Index (SPI) to calculate potential for gully erosion
3. Run-off risk assessment based on slope steepness and proximity to open watercourses
4. Surface run-off assessment with convergent foot slopes and Topographic Wetness Index (TI)

The core GIS layers used for this study are listed below in Table 1.

Table 1: Data layers and sources used for “The use of GIS in the Gully Creek Watershed to Identify Suitable Locations for Agricultural Best Management Practices” study

Data Layer	Source
1 meter Digital Elevation Model	LiDAR data acquired in spring 2011
Soils	Ontario Ministry of Agriculture, Food and Rural Affairs
Land Use	Agricultural Resources Inventory (AgRI) - Ontario Ministry of Agriculture, Food and Rural Affairs

A ranking system with standard deviation was developed to assign a high, moderate, or low potential for sediment loss for fields in Gully Creek. The ranking system is outlined below in Table 2.

Table 2: Ranking system used in “The use of GIS in the Gully Creek Watershed to Identify Suitable Locations for Agricultural Best Management Practices” study

Rank	Standard Deviation
High Potential	Standard deviation greater than (>) 0.5 from the mean
Moderate Potential	Standard deviation between -0.5 and 0.5 from the mean
Low Potential	Standard deviation less than (<) -0.5 from the mean

4.2.3 Results

Using the four GIS approaches, it was concluded that GIS was capable of achieving results comparable to SWAT. From the results, 48 fields in Gully Creek were identified by one or more of the GIS methods for their high run-off potential (McPherson and Veliz 2016). In the SWAT model, 36 fields were ranked high for sediment output. Of the 36 fields identified by SWAT, 25 of those fields were identified by the GIS analysis undertaken by McPherson and Veliz (2016). While the four GIS methods required less data inputs and staff effort, the four GIS methods could not calculate the quantity of sediment reaching an open watercourse. The SWAT model remained capable of offering a more robust analysis of sediment loading and the effects of BMPs. McPherson and Veliz (2016) recommended that future GIS methods for sediment and surface run-off be combined with a sediment transport index to compensate for the current inability of the tested GIS methods to calculate sediment deposition.

4.3 SWAT Model: Gully Creek

4.3.1 Purpose

In 2016, the Ausable Bayfield Conservation Authority (ABCA) worked with Kevin McKague, Ontario Ministry of Agriculture, Food and Rural Affairs, to explore the feasibility of running SWAT in Gully Creek with readily available data and minimal model customizations. As a watershed management agency, the ABCA found that certain detailed geospatial and tabular data sets required for the SWAT model only existed once staff spent an extensive amount of time collecting and processing these data. To determine if the SWAT model could be used in efficiently locating high priority catchments for future stewardship projects, without monopolizing staff time, the ABCA tested the feasibility of executing a SWAT model simulation with best available data and default model parameters.

4.3.2 Methodology

The geospatial data sets utilized in this SWAT simulation where those data that were readily available to the conservation authority through the Ontario provincial government or the federal government of Canada. Tabular data such as climate data were obtained from a nearby weather station maintained by Environment and Climate Change Canada. The assembled data and corresponding acquisition sources are listed below in Table 3.

Table 3: Data sets required for SWAT model

Data Layer	Source
2 meter Digital Elevation Model	Ausable Bayfield Conservation Authority through the South Western Ontario Orthoimagery Project (SWOOP)
Soils	Ontario Ministry of Agriculture, Food and Rural Affairs
Land Use	Agriculture and Agri-Food Canada (AAFC) Crop Inventory
Gully Creek Watershed Boundary	Ausable Bayfield Conservation Authority
Goderich Ontario Climate Data (Temperature and Precipitation)	Environment and Climate Change Canada

When initializing the SWAT project, the catchment delineation process produced 59 sub-basins and 255 Hydraulic Response Units (HRUs). Catchment numbers were similar to those generated by Yang et al. (2013). The SWAT simulation was run from April 2011 to October 2016 with no warm up period. The results were calculated on a daily basis. Two runs were executed with the same data sets and simulation time period. The first run used default SWAT parameters while the second was calibrated with parameter values recommended by Yang et al. (2013).

4.3.3 Results

The Nash-Sutcliffe coefficient of efficiency (NSE) was used to determine the accuracy of the SWAT model results. The NSE coefficient is commonly used to evaluate the accuracy between observed and predicted model outputs. NSE coefficients range from negative infinity to one. A value of one indicates a perfect fit between observed and modelled data (Nash and Sutcliffe 1970). In this case, NSE was used to evaluate the SWAT model's performance at two locations: GULGUL2, the outlet of Gully Creek, and GULGUL5, a monitoring station 3.5 kilometers upstream. The parameter chosen for evaluation was flow data as it plays an important role in determining nutrient loading concentrations. In addition, monitored flow data was readily available within the conservation authority; and therefore, a complete data set was available for comparison between observed and modelled. Observed versus modelled flow for the period of December 25th, 2014 to April 25th, 2015 has been graphed for GULGUL2 and GULGUL5 in Figure 3.

The observed flow at monitoring stations GULGUL2 and GULGUL5 was not consistent with modelled flow produced by SWAT. The NSE coefficients for the SWAT model, with default parameters, were 0.13

and -0.45 for GULGUL2 and GULGUL5, respectively. The low NSE scores indicated that observed flow values were a better predictor than the model.

To improve the model's performance, a second simulation was run with revised parameter calibrations as per the recommendations of Yang et al. (2013). The second simulation returned different modelled results, yet the observed and modelled data continued to generate negative NSE coefficients. The NSE values for GULGUL2 and GULGUL5 were -0.45 and -0.13, respectively. Figure 3 compares observed and modelled flow for GULGUL2 and GULGUL5, as well as modelled flow with default and calibrated parameters.

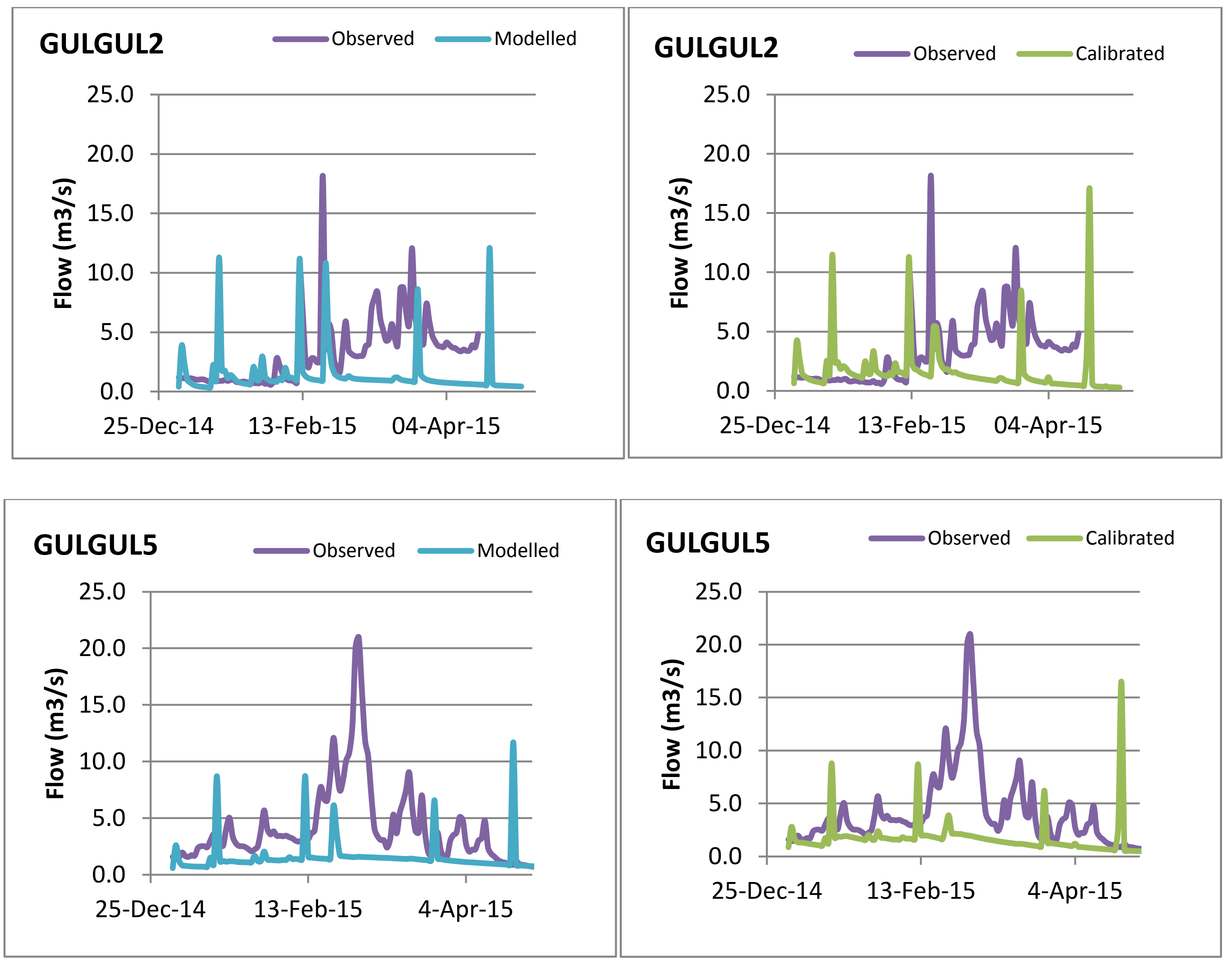

Figure 3: SWAT simulated flow versus observed flow at GULGUL2 and GULGUL5 (blue – modelled with default parameters, green – modelled with calibrated parameters and purple – observed flow)

An accuracy assessment of total sediment and total phosphorous was not undertaken as these nutrient concentrations are calculated with simulated flow data. It was also noted that simulated flow was not consistent with monitored baseflow data. Parameter adjustments and incorporation of locally monitored climate data could improve flow conditions. For this project, these recommendations were not pursued. The SWAT, based on minimal model customizations and readily available data, was not recommended for effectively and efficiently determining priority catchments along Lake Huron. SWAT models should be used in watersheds for full scale comprehensive studies that allow for time to be invested in acquiring and preparing accurate detailed data sets.

5.0 NEW SOFTWARE OPTIONS: PTMAPP

The limitations and challenges discovered through testing the SWAT model and GIS approaches in Gully Creek prompted an exploration into GIS software that could prioritize catchments and include a sediment transport analysis. The PTMApp software included a sediment routing tool and met the next steps identified by McPherson and Veliz (2016). Through a sequence of tools, PTMApp software calculates loads and geospatially tags those results to a catchment. With the estimated loads per catchment, water quality practitioners are able to locate the highest contributing catchments and recommend those areas for conservation practices.

5.1 PTMApp's Underlying Mathematical Calculations

The PTMApp software uses three main tools for its analysis of sediment loads. The Revised Universal Soil Loss Equation (RUSLE) forms the base layer and determines the sediment yield leaving the landscape through erosion. A ratio with distance and catchment area further determines the quantity of sediment delivered to a stream channel. A first-order transport function that incorporates time of travel and an exponential decay algorithm calculates sediment delivery through a channel to an outlet for final loading estimates. For detailed descriptions of equations used in the software, refer to PTMApp Theory and Development Documentation (Houston Engineering Inc. 2016). In all three modelling studies, the RUSLE was used to determine the initial amount of sediment generated through erosion. The RUSLE equation has five components:

$$A = R \times K \times C \times LS \times P$$

where,

A is the average annual sediment loss in tons per hectare per year
R is the rainfall erosivity factor or energy potential of a precipitation event. Areas are at risk for erosion during an intense precipitation event.
K is the soil erodibility factor or susceptibility of soils to erosion. Soil structure and texture will influence erosion potential.
C is the cover management factor. A cover coefficient reflects the ability of certain cover types to reduce erosion.
LS is the slope factor. Slope length and angle affects erosion with steeper slopes being more susceptible to sediment loss.
P is the support practice factor and reflects land management practices that may be employed to combat erosion. The P factor usually has a default value of 1 to reflect no management practices and the worse case scenario.

6.0 ASSESSING THE ACCURACY OF PTMAPP

6.1 Study Area: Gully Creek

For implementation of the PTMApp software, the Gully Creek watershed was chosen because of the availability of simulated sediment loadings from a comprehensive SWAT model. Once PTMApp outputs were validated and verified, the study area was re-expanded to the initial project area of Sarnia to Southampton.

6.2 Methodology

To begin a PTMApp simulation, a series of geospatial data layers were required. These data were compiled from a variety of different sources and represented the best available data for Gully Creek at the time of this study. All data were cleaned and formatted to meet the criteria outlined in the PTMApp software documentation. Table 4 summarizes the data sets and their acquisition sources.

Table 4: Data sets required for PTMApp

Data Layer	Source
5 meter by 5 meter resampled Lidar Digital Elevation Model (DEM)	Ausable Bayfield Conservation Authority
watercourses and catchments	Retrieved from SWAT modelling files
RUSLE – Soil erodibility factor (K) in tons/acre	GIS soil layer and published K values both from Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA)
RUSLE - Rainfall-runoff erosivity factor (R)	Created with Ontario Ministry of Agriculture, Food and Rural Affairs' RUSLE2 application
RUSLE – Support practice factor (P)	Created by assigning default value of 1 to entire study area. Reference: OMAFRA
RUSLE – M weight factor	Created by assigning default value of 1 to entire study area. Reference: PTMApp Documentation
RUSLE - Cover management factor	Created by with AgRI data and assigning coefficients published by USDA National Agricultural Statistics Service. Reference: PTMApp Documentation
Flow Travel Time grid in seconds	Created with Minnesota Department of Natural Resources - Calculate Time of Travel GIS tool
Agriculture Resource Inventory (AgRi) Landuse*	Ausable Bayfield Conservation Authority via OMAFRA

*the landuse layer was altered to mimic classifications used by the United States National Land Cover Dataset (NLCD) for modelling purposes.

In the PTMApp software, under Catchment and Loadings, the following tools were used: RUSLE Calculator, Travel Time to Catchment Outlet, Sediment Delivery Ratio (SDR) to Catchment Outlet, Sediment Routing to Catchment Outlet, and Summarize Catchment Loadings. PTMApp calculated final sediment outputs in US tons and acres. For comparison with SWAT, all sediment outputs were converted to metric tons and hectares where necessary.

6.3 Results

To assess the accuracy of the PTMApp tools, the sediment loading results were compared to the SWAT results generated by Yang et al. (2013). Comparing sediment results was relatively easy since the catchment boundaries delineated in SWAT were imported into PTMApp. For each model simulation, Gully Creek watershed was subdivided into 64 catchments, and had an overall drainage area of 1427 hectares. To increase consistency between the SWAT model and PTMApp, the 1 meter LiDAR DEM was resampled to 5 meters. In the initial SWAT model (Yang et al. 2013), computing inefficiencies restricted the use of the 1 meter LiDAR DEM in SWAT, and required the resolution of the DEM to be decreased to 5 meters. Results are compared in Table 5.

Table 5: Estimated sediment load comparisons between SWAT and PTMApp with a 5m LiDAR DEM

	SWAT (5m scale)	**PTMApp (5m scale)**
Total Sediment (T) at outlet	2554.6	3830.1
Lowest Sediment Load (T/ha) per catchment	0.02	0.6
Highest Sediment Load (T/ha) per catchment	6.0	5.7
Average Sediment Load (T/ha) per catchment	1.8	2.7

* All results are calculated in metric tons

The initial run of PTMApp revealed that the total annual sediment load at the outlet of Gully Creek was 1.5 times higher than the estimated total load from SWAT. On average, the PTMApp software over-estimated sediment loads on a per catchment basis by approximately 1 ton per hectare. Sediment loads for catchments in both models ranged between zero (0) and six (6) tons per hectare. Results from the models are mapped in Figure 4. Similarities existed between the models in terms of which catchments generated between 0-2 T/ha, 2-4 T/ha, and 4-6 T/ha of sediment. As Figure 4 demonstrates, both models highlighted catchments in the southeast quadrant of the watershed as being among the highest contributors while catchments along the main branch of Gully Creek were deemed low contributors.

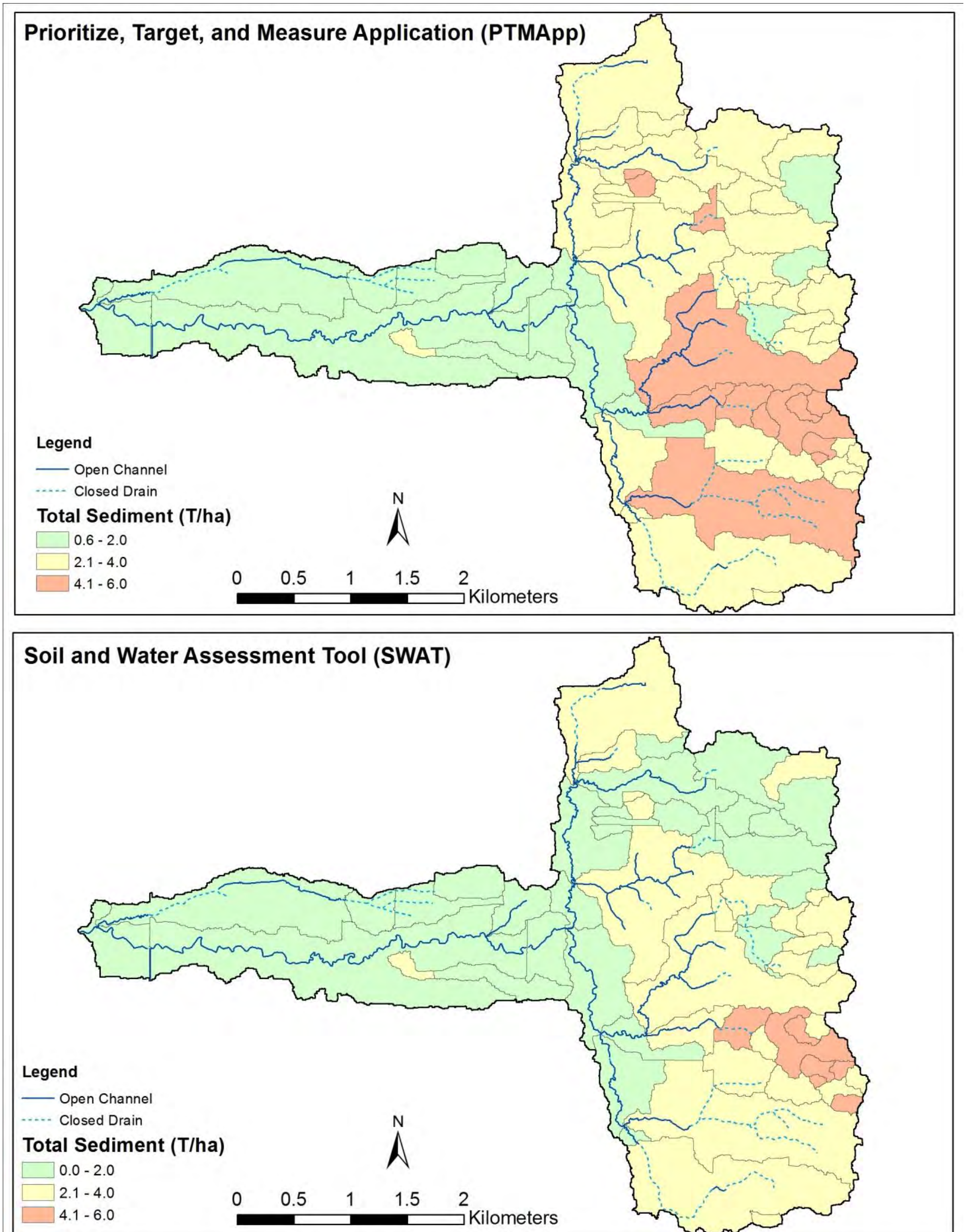

Figure 4: Sediment loadings per catchment in Gully Creek watershed as calculated by PTMApp and SWAT

6.4 Sensitivity Analysis

A small scale sensitivity analysis was conducted to determine the impact of the initial DEM on the final sediment loads. A hypothesis was developed that the coarser the spatial resolution of the DEM, the smaller the sediment output as predicted by PTMApp. With a coarse resolution DEM, the slope calculated from the elevation values would be generalized over a larger cell size. A gradual slope will produce less erosion. To continue testing this hypothesis, the 10 meter provincially available DEM was acquired for the Gully Creek watershed. It was expected that this coarse 10 meter DEM would produce a smaller total sediment load at the watershed outlet, and a smaller sediment load per catchment. All other PTMApp input layers remained unaltered, and the software was re-run. In addition, another simulation was run in PTMApp where the original 1 meter LiDAR DEM was used. This simulation was used to evaluate the effect of a high resolution DEM on final sediment loads.

The 10 meter provincial DEM annual total sediment load was the closest to that calculated by SWAT. Ranges for potential sediment loss per catchment were also similar to that of SWAT. With the high resolution DEM, the annual total sediment load at the outlet and the potential sediment loss per catchment was over 2 times greater than the SWAT model. All simulated sediment loads are compared in Table 6.

Table 6: Estimated sediment load comparisons between SWAT and PTMApp model with 1m, 5m, and 10m DEMs

	SWAT (5m scale)	**PTMApp (5m scale)**	**PTMApp (10m scale)**	**PTMApp (1m scale)**
Total Sediment (T) at outlet	2554.6	3830.1	2903.3	6944.3
Lowest Sediment Load (T/ha) per catchment	0.02	0.6	0.1	1.1
Highest Sediment Load (T/ha) per catchment	6.0	5.7	5.3	12.5
Average Sediment Load (T/ha) per catchment	1.8	2.7	2.0	4.7

Two conclusions were drawn from the sensitivity analysis. First, the spatial resolution of the DEM affected the final sediment load with a greater spatial resolution generating larger sediment loads. Second, PTMApp is capable of highlighting erosion prone catchments that are similar to the SWAT output and can be used as an initial diagnostic tool for prioritization.

Although this hypothesis was not tested, it was theorized that the coefficient used for the cover management factor would also influence the final annual total sediment load at the outlet. Increasing the cover coefficient for fields, and likelihood for erosion, would generate larger sediment loss. When comparing PTMApp results to the underlying land use (Figure 5), it was noted that the highest contributing catchments were those that coincided with cultivated fields while the lowest contributing catchments were predominately covered by natural areas.

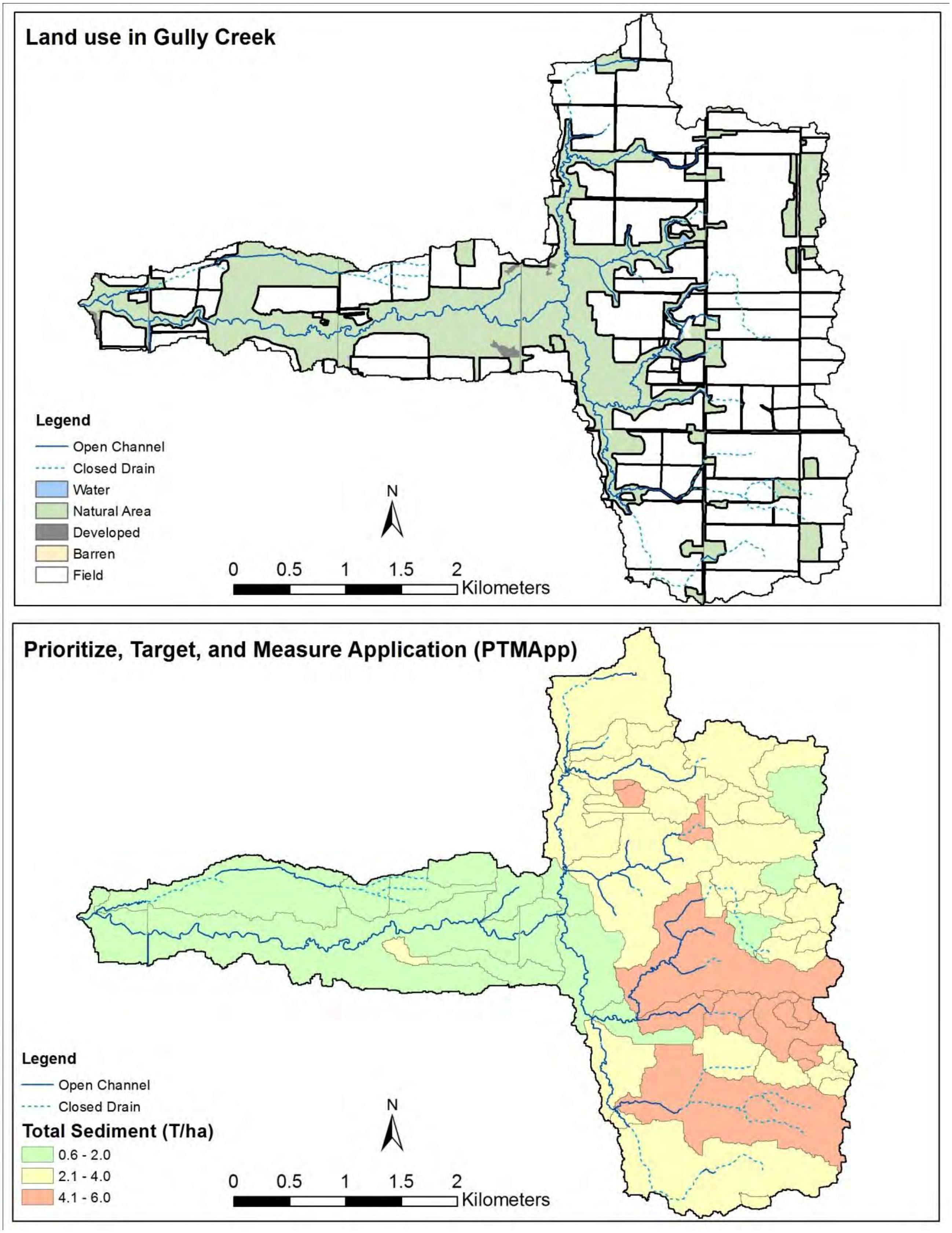

Figure 5: Relationship between PTMApp high contributing catchments and land use

7.0 MOVING FORWARD WITH PTMAPP ALONG LAKE HURON'S SOUTHEASTERN SHORELINE

7.1 Study Area and Methodology

Preliminary tests of the PTMApp software in the Gully Creek watershed demonstrated the software's ability to predict sediment loadings similar to that of SWAT. To proceed with the project, the study area was expanded to the original area of Sarnia to Southampton. Only provincial data sets available through open data portals were used in the final PTMApp simulation. This restriction helped to mimic a watershed agency's need to efficiently and effectively acquire data for modelling. In addition to the provincial DEM, readily available SOLRIS land cover data was acquired. Table 7 summarizes the required data layers and the sources of the data.

Table 7: Data sets required for PTMApp model at the 10m scale

Data Layer	Source
10 meter by 10 meter Digital Elevation Model (DEM)	Acquired from Ministry of Natural Resources and Forestry
Watercourse	Created with ESRI ArcGIS and DEM
catchments	Created with ESRI ArcGIS's ArcHydro package and DEM
RUSLE – Soil erodibility factor (K) in tons/acre	Created with soils GIS layers and published K values from Ontario Ministry of Agriculture, Food and Rural Affairs
RUSLE - Rainfall-runoff erosivity factor (R)	Created with Ontario Ministry of Agriculture, Food and Rural Affairs' RUSLE2 application
RUSLE – Support practice factor (P)	Created by assigning default value of 1 to entire study area. Reference: OMAFRA
RUSLE – M weight factor	Created by assigning default value of 1 to entire study area. Reference: PTMApp Documentation
RUSLE - Cover management factor	Created with SOLRIS data and assigning coefficients published by USDA National Agricultural Statistics Service. Reference: PTMApp Documentation
Flow Travel Time grid in seconds	Created with Minnesota Department of Natural Resources - Calculate Time of Travel GIS tool. Reference: PTMApp Documentation
Southern Ontario Land Resource Information System (SOLRIS) land cover*	Acquired from Ministry of Natural Resources and Forestry

*the land cover layer was altered to mimic classifications used by the United States National Land Cover Dataset (NLCD) for modelling purposes.

The process for executing the PTMApp software remained the same as in the Gully Creek simulation with the following core tools being run in sequence: RUSLE Calculator, Sediment Delivery Ratio (SDR) to Catchment Outlet, and Sediment Routing to Catchment Outlet.

7.2 Results

Along the Lake Huron's southeastern shoreline, PTMApp predicted annual total sediment loads as low as 0.04 tons for low contributing catchments and up to 28 000 tons for high contributing catchments. In terms of sediment loss per catchment, loadings ranged from 0 tons per hectare to 2.5 tons per hectare (Figure 6). According to the Revised Universal Soil Loss Equation for Application in Canada (Wall et al 2002), the suggested tolerance for sediment loss is 6 tons per hectare per year. Results from the shoreline PTMApp simulation were all less than 6 tons per hectare; however, sediment values were averaged over the entire lakeshore catchment.

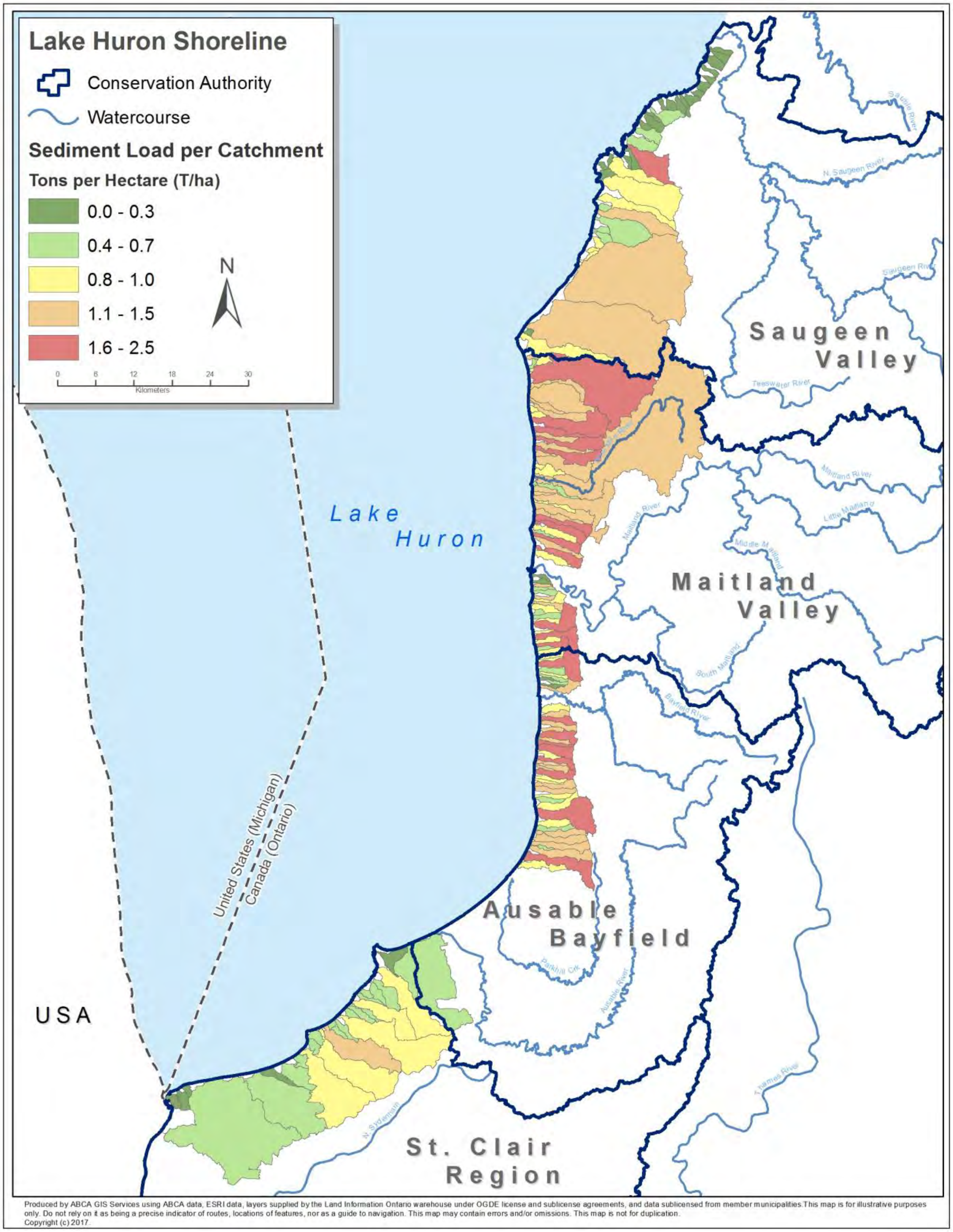

Figure 6: PTMApp results along the shoreline for sediment loading (represented as T/ha per catchment)

7.3 Challenges and Limitations

One of the main challenges that existed with provincially available data sets was the integrity of the data layers. While the layers were easy to access, time was spent on cleaning and preparing these data. Secondary layers developed from Digital Elevation Model also required pre-processing. Time was invested to develop a stream network layer for the entire study area from the DEM, as well as delineate all lakeshore catchments. Upon completion of the project and review of PTMApp capabilities, it was noted that PTMApp cannot calculate sediment loss generated through channel erosion because it does not require flow data as an input. Therefore, PTMApp is limited to only calculating sediment loads from overland erosion. In addition, PTMApp cannot calculate different sediment loads for individual years as it does not require temporal data.

8.0 MOVING FORWARD

PTMApp is a tool that can be used to start the prioritization process and choose future study areas. When choosing priority catchments, stakeholders should use their local knowledge to set an appropriate benchmark for sediment loads. The results of PTMApp can assess if high contributing catchments should be considered for stewardship efforts to reduce loadings or if low contributing catchments should be managed for preservation. It is suggested that PTMApp results be combined with a comprehensive SWAT model once a prioritized catchment has been chosen. Running a comprehensive SWAT model will allow CA staff to better understand the relationship between land management practices and hydrological processes especially since SWAT incorporates flow data. To run a comprehensive SWAT simulation, complete land management and water quantity and quality data sets will be required. If monitoring data is non-existent for the priority catchment, a monitoring program should be established if the goal is to proceed with hydrologic modelling beyond the scope of PTMApp. Inventorying existing monitoring data, similar to the inventory conducted below, can help to further narrow possible candidates.

8.1 Shoreline water monitoring inventory

Small tributaries (<5000 ha) along the shore of Lake Huron were identified by staff at the Ausable Bayfield Conservation Authority, Maitland Valley CA, St. Clair Region CA, and Saugeen Valley CA. These tributaries were inventoried on the basis of having continuous water quantity (stage/flow) data and some water quality data to calculate nutrient and sediment loads in future. Coordinates and the status of each site were described for use in subsequent analyses.

Six tributaries along Lake Huron were identified where both water quantity (stage/flow) and water quality data exist (Table 8). Some issues will have to be resolved to calculate loads for future reports. For instance, Pine River is the main branch that the South Pine River (a current monitoring station) flows into; however, its drainage area, at 15,400 ha, is larger than the suggested 5,000 ha threshold. Since we are currently monitoring the south branch of Pine River, it would be interesting to calculate the total nutrient and sediment loads transported into Lake Huron from this site (similar to including the Bayfield River in the current report). Additionally, Griffins Creek was part of a nutrient project run by the Ministry of Environment and Climate Change (MOECC), so further inquiry with the MOECC may be required to access the water quantity and quality data. The status of stage/flow measurements in

Griffins Creek is currently unknown. Lastly, Duffus Creek does not have a rating curve to convert stage into flow, which would be required to calculate loads.

Table 8: Potential sites to calculate future nutrient and sediment loads

Conservation Authority	Site ID	Latitude	Longitude	Period of stage measurements	Period of water quality collection
ABCA	Spring Creek	43.594	-81.705	2011 - 2016	2010 - 2013
ABCA	Ridgeway Drain	43.356	-81.720	2010 - 2016	2010 - 2015
ABCA	Zurich Drain	43.407	-81.707	2010 - 2016	2006 - 2015
MVCA	Griffins Creek	43.920	-81.714	unknown	2005 - 2014
SCRCA	Duffus Creek	43.182	-81.968	2012 - Present	2013 - Present
SVCA	Pine River	44.094	-81.727	2003 - Present	2002 - Present

Ausable Bayfield Conservation Authority (ABCA), Maitland Valley Conservation Authority (MVCA)
Saugeen Valley Conservation Authority (SVCA), St. Clair Region Conservation Authority (SCRCA)

9.0 CONCLUSIONS

Three techniques were assessed for their ability to prioritize catchments in terms of erosion and sediment loading. GIS techniques can be used to locate erosion prone areas, and should incorporate a sediment routing analysis. The Soil and Water Assessment Tool can be used for choosing a priority catchment if time is invested to assemble all the extensive data sets required. The use of SWAT as an initial diagnostic tool with its default parameters and broad scale data is not ideal. A third model designed for water quality practitioners by Houston Engineering Inc. works to merge the capability of hydrologic process models and GIS. With some time invested in acquiring and preparing the provincially available data sets, it was possible to run PTMApp's sediment loading tools along the lakeshore. As an initial step in the prioritization process, PTMApp can be used to determine low, moderate, and high contributing catchments.

GIS techniques and geospatial hydrologic models such as PTMApp are effective approaches for evaluating where to prioritize stewardship initiatives and land management practices. A large limitation of these two approaches is the inability to capture and assess the changes that have incurred as a result of implemented BMPs. To evaluate how BMPs improve water quality and understand the interconnectedness between processes on the landscape, hydrologic models such as SWAT are required. A model such as SWAT will be required to evaluate changes or fluctuations in water quality as a result of changes to land management. Long-term monitoring programs that capture continuous flow data, nutrient concentrations across the range of flow values, and detailed land management data will be required to run SWAT and to answer questions related to the effectiveness of BMPs. The process-based models will help us answer questions related to "is the quality of water improving as BMPs are employed" and "why do we see lower concentrations and loads in one creek compared to another".

10.0 REFERENCES

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