Development of a Canadian Version of SWAT to Examine Water Quantity and Quality Effects of Agricultural BMPs

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Watershed Evaluation of BMPs (WEBs): 2004 - 2013

(Harker 2011)

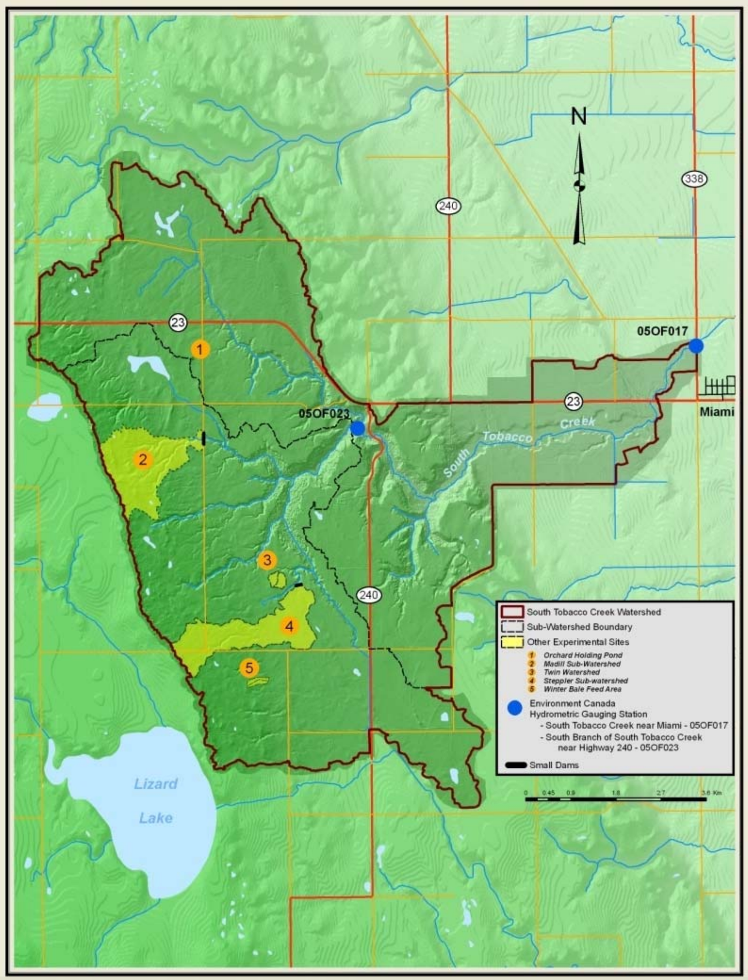
The purpose of the **W**atershed **E**valuation of **B**eneficial Management Practices (BMPs) project is to assess the environmental and economic performance of selected BMPs at the watershed scale.

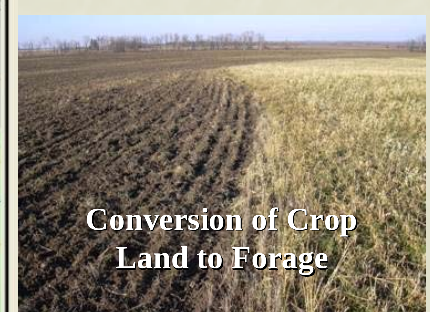
WEBs BMPs by Watershed

WEBs BMPs	BC	AB	SK	MB	ON	QC	NB	NS	PEI
Cattle exclusion fencing (off-stream water)	☯	☯			☯			☯	
Off-stream watering without fencing		☯							
Riparian vegetation management				☯					☯
Nutrient input / mgt (synthetic; manure)		☯	☯			☯		☯	
Tillage / residue mgt				☯		☯			☯
Crop rotations						☯			
Perennial cover			☯	☯					
Use of less-toxic herbicides						☯			
Winter bale-grazing			☯	☯					
Irrigation efficiency	☯								
Diversion terraces, grassed waterways							☯		
Surface runoff / tile drainage control					☯	☯			
Buffer strips		☯					☯		
Farmyard runoff management								☯	
Runoff retention pond				☯				☯	
Wetland restoration			☯						

(Harker 2011)

The South Tobacco Creek Watershed





7,500 ha

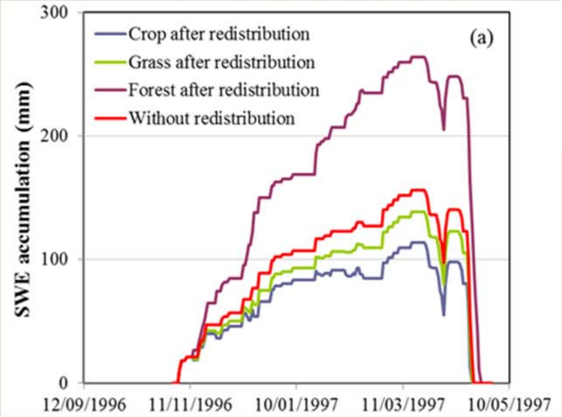
SWAT Adaptation and Development

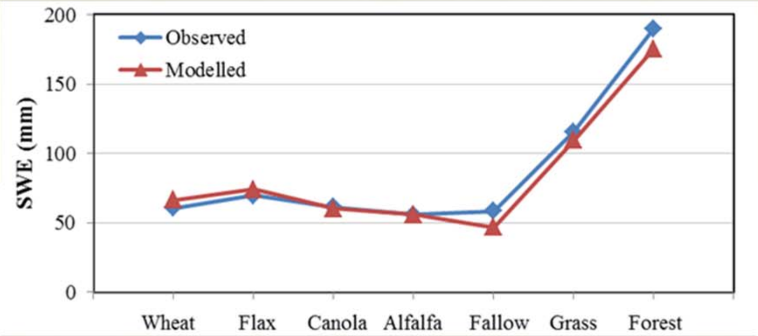
- Develop a Canadian version of SWAT (CanSWAT)
  - Snow redistribution and frozen soil algorithms
  - BMP modules (small reservoir, holding pond, wetland, WASCoB, conservation tillage, forage conversion, riparian grazing management)
- Develop a CanSWAT based integrated economic-hydrologic modelling system
  - On-farm economic model and CanSWAT
  - Integrated modelling interface

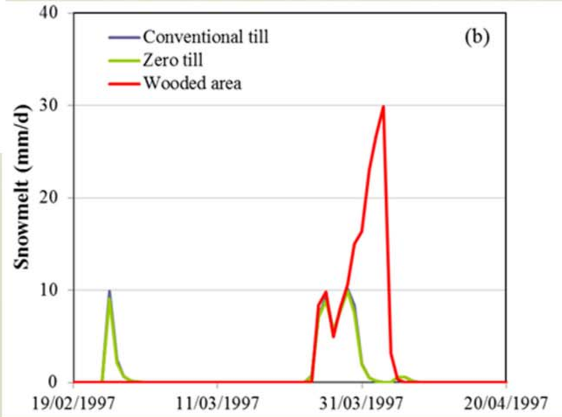
Snow Redistribution

- Three major controls:

- Climate (precipitation, wind speed and direction, temperature)
- Topography (elevation, slope, aspect, curvature)
- Land cover (forest, grassland, wetland, crop under no-till or conventional till, urban and open water)







Frozen Soil

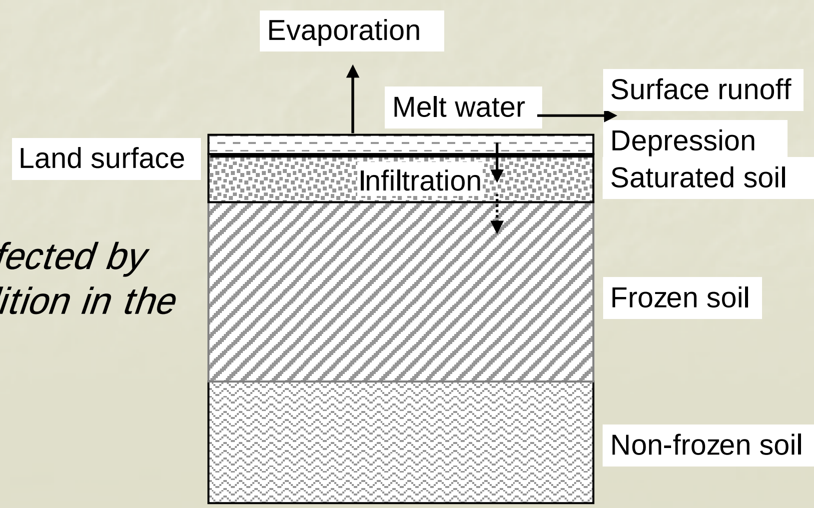
SWAT

- SWAT determines frozen soil based on the first layer temperature < 0°C and CNfrz is calculated based on SW of the entire profile.
- SWAT calculates sediment yield under thawing condition in a same way as for rainfall storms, and the USLE soil erodibility factor remains constant for the HRU over the simulation period.
- SWAT calculates N and P loading under thawing condition in a same way as for rainfall storms.

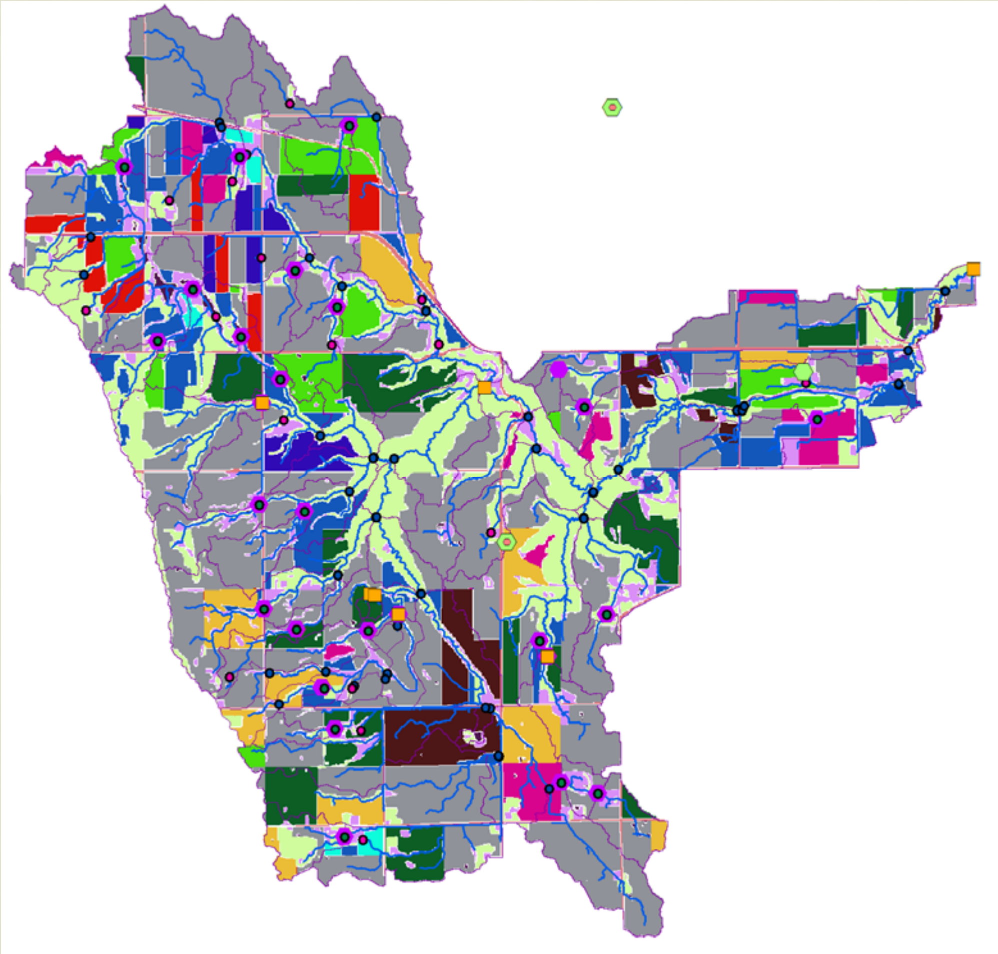
CanSWAT

- Calculate CNfrz based on SW from up to down layers consequently.
- Add a correction parameter to USLE erodibility factor.
- Set a user defined N&P enrichment ratios, nitrate percolation coefficient, and P soil partitioning coefficient

Snowmelt runoff is strongly affected by SWE, temperature and soil condition in the top soil layers



CanSWAT Setup

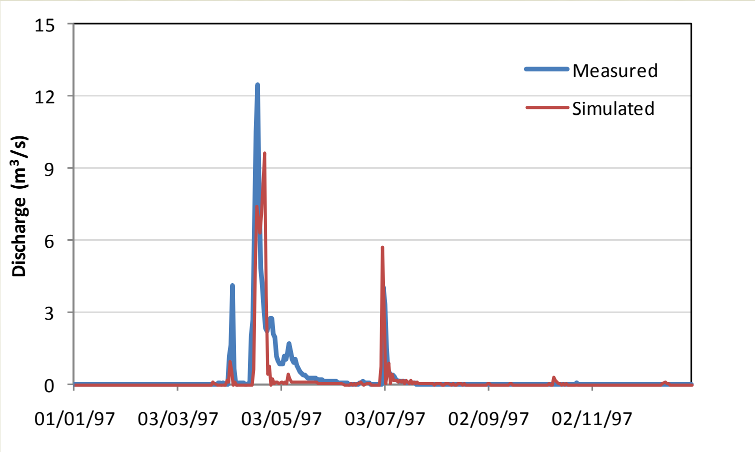


- 5 BMPs: small dam, holding pond, conservation tillage, forage conversion, riparian grazing management
- 3 climate stations
- 17 flow and water quality stations
- Elevation 306-506 m
- 14 CanSWAT landuse classes
- 34 CanSWAT soil classes
- 26 small dams
- 2 existing holding ponds
- 44 grazing sites
- 82 subbasins
- 348 HRUs

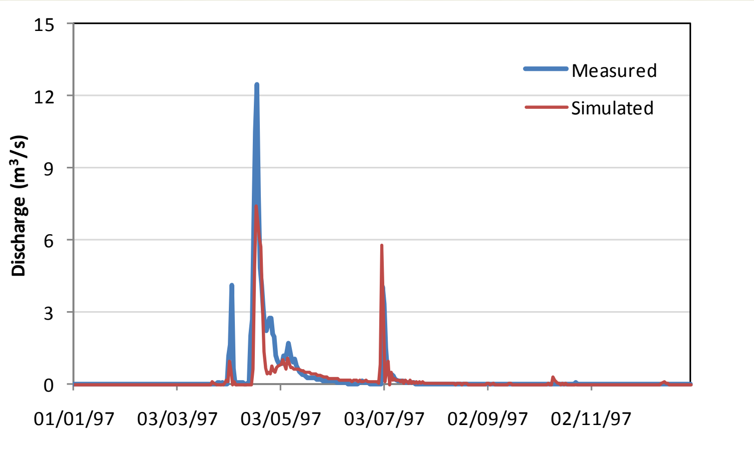
SWAT Daily Flow Calibration and Validation

Station	Calibration	Bias	NSE	Validation	Bias	NSE
Miami	2001-2010	-0.04	0.74	1991-2000	0.09	0.63
HYW240	2001-2010	-0.06	0.79	1995-2000	0.10	0.59
Pankiw Jim				1991-2002	-0.01	0.35
Madill Jak				2002-2004	-0.06	0.30
Steppler MS1	2005-2010	-0.08	0.46			
Steppler MS2	2005-2010	0.05	0.44			
Steppler MS3	2005-2010	-0.05	0.55			
Steppler MS4	2005-2010	-0.13	0.60			
Steppler MS5				2005-2010	-0.23	0.21
Steppler MS6				2005-2010	0.01	0.31
Steppler MS7				2005-2010	0.04	0.68
Steppler MS8				2005-2010	0.11	0.27
Steppler MS9				2005-2010	-0.16	0.60
Twin_West MS10	2001-2010	0.14	0.26	1991-2000	0.17	0.42
Twin_East MS11	2001-2010	0.18	0.23	1991-2000	0.11	0.33
Steppler Roy inflow	2001-2010	-0.07	0.45	1991-2000	-0.07	0.47
Steppler Roy outflow	2001-2010	-0.05	0.43	1991-2000	-0.05	0.34

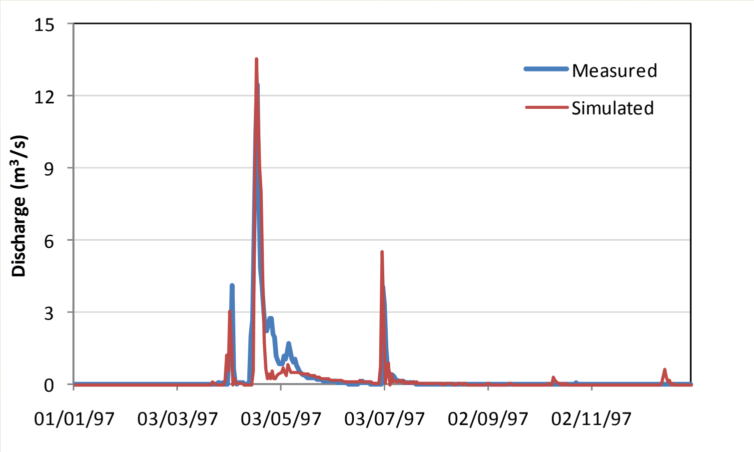
Improved Flow Result at Outlet



Without snow redistribution and frozen soil

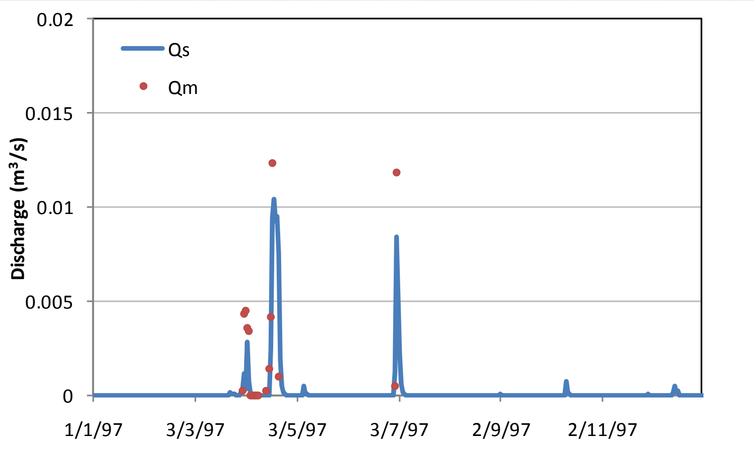


After snow redistribution

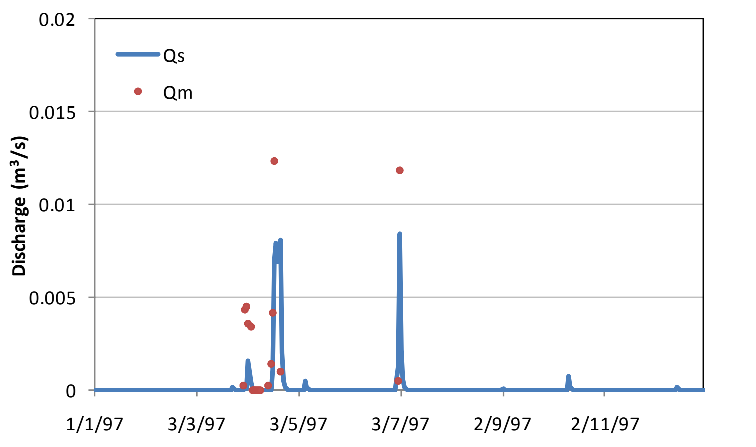


After snow redistribution and frozen soil

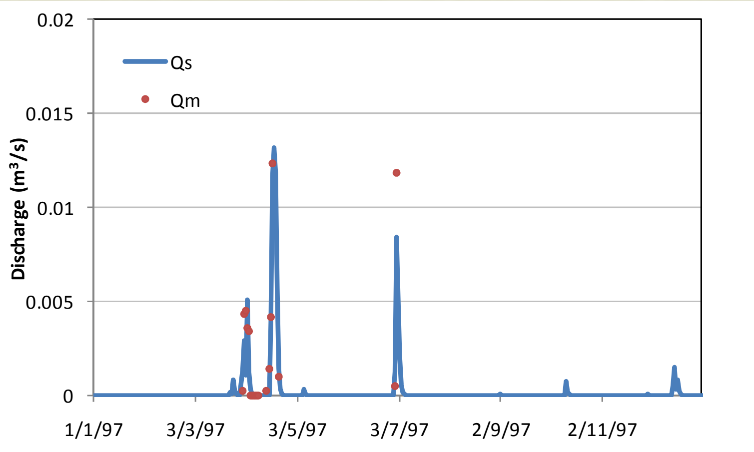
Improved Flow Result at TWIN WEST



Without snow redistribution and frozen soil

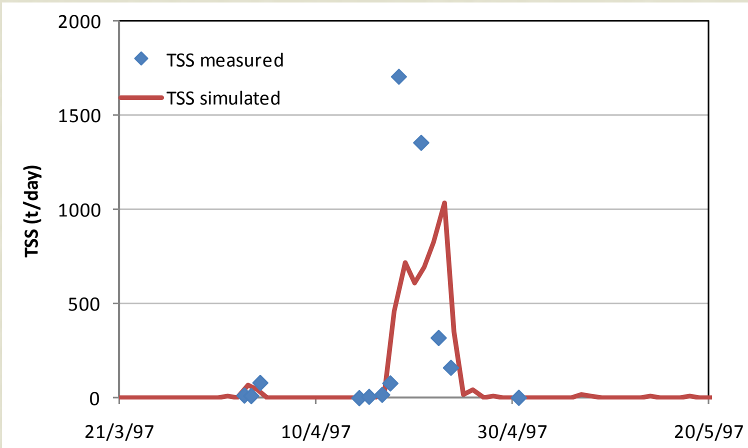


After snow redistribution

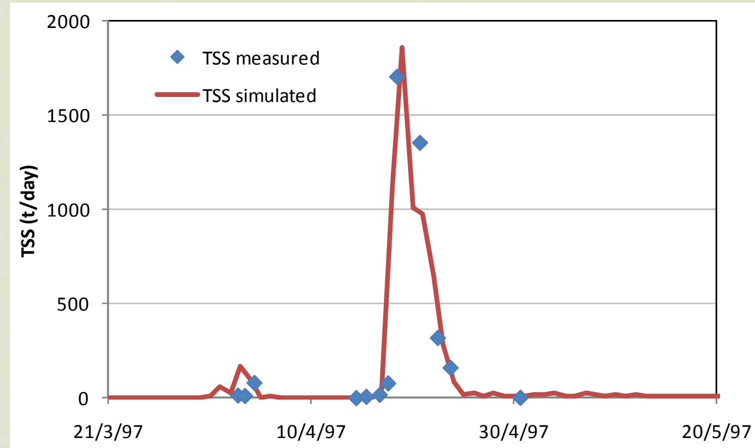


After snow redistribution and frozen soil

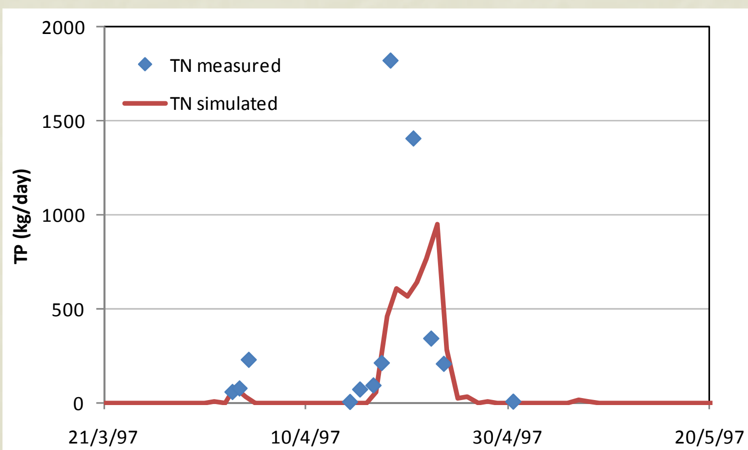
Improved TSS and TP Result at Outlet



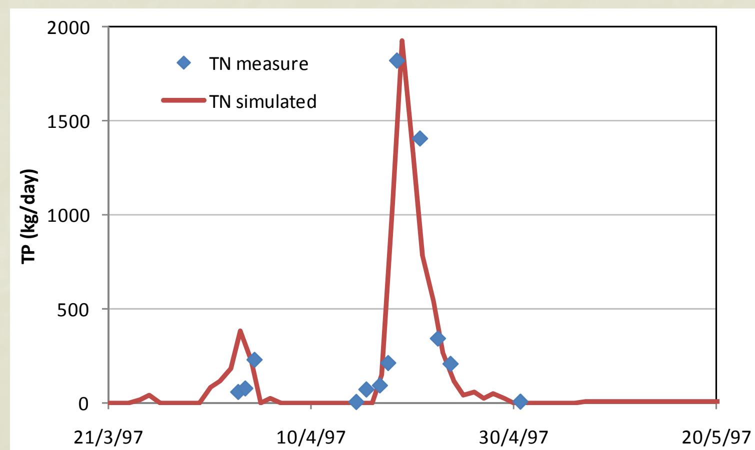
Without snow redistribution and frozen soil



After snow redistribution and frozen soil

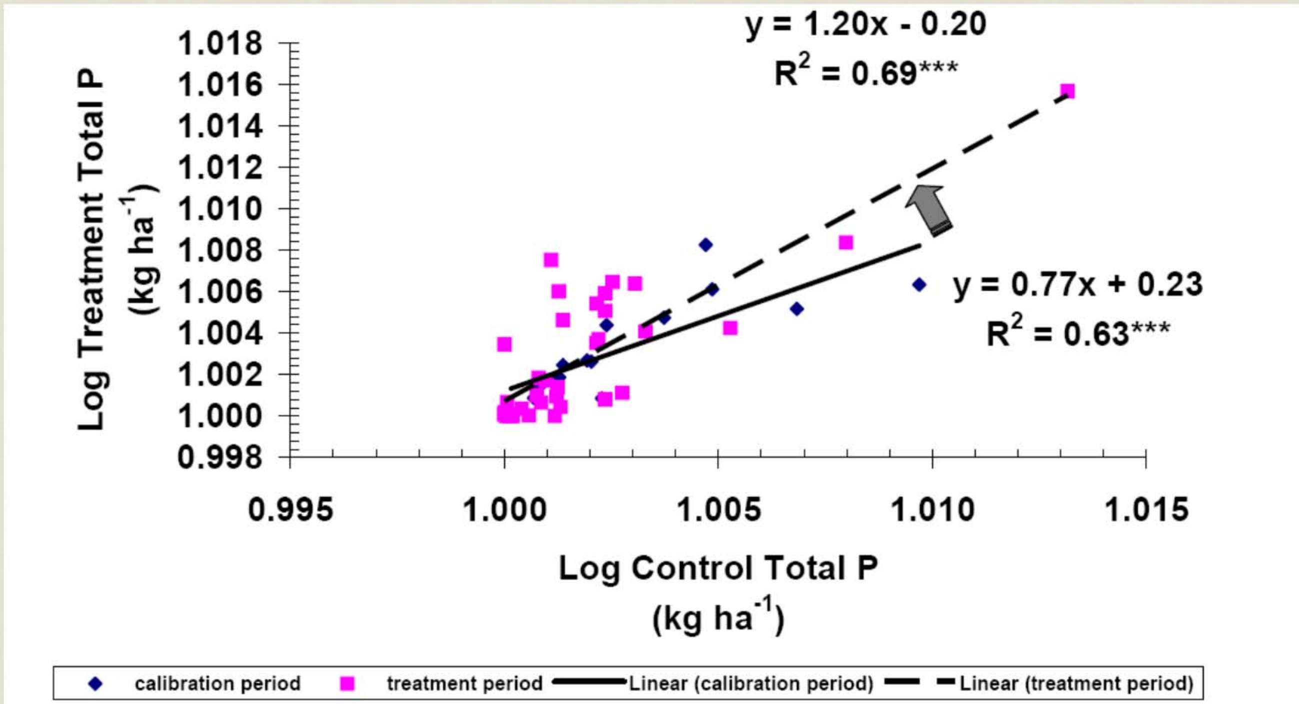


Without snow redistribution and frozen soil



After snow redistribution and frozen soil

Observed Conservation Tillage Effects



Conservation tillage ↑ Phosphorus export by 12%

- Particulate P ↓ by 37 %
- Dissolved P ↑ by 36%

Observed TP at Twin watershed after conservation tillage

Source: Yarotski et al., 2010

Calibration for Conservation Tillage

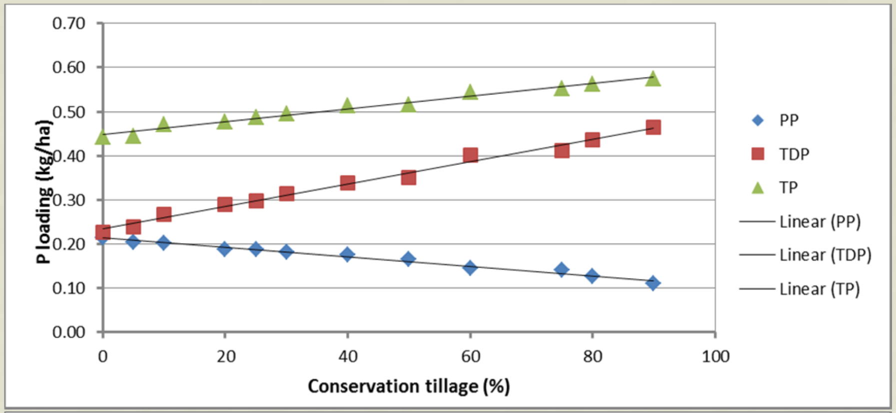
- Model parameters for conventional till and no-till practices under frozen soil condition

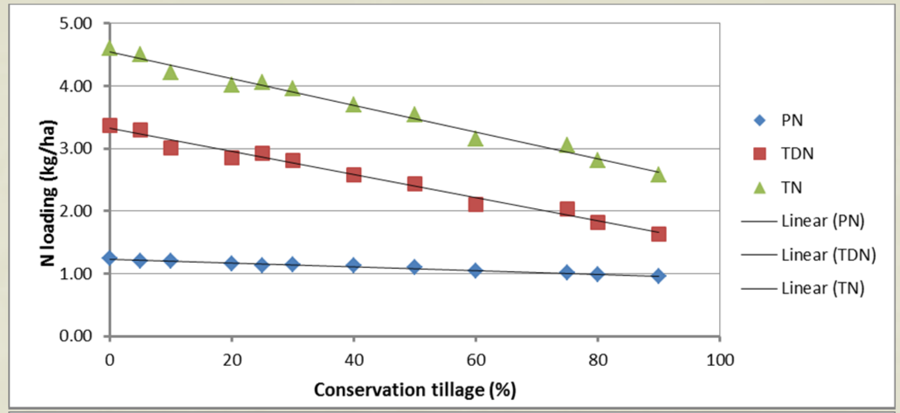
Parameter	Description	Conventional till	No-till
DEPTIL	Depth of mixing (mm)	150	0
EFFMIX	Mixing efficiency	0.7	0
RSD_COVCO	Residue cover factor	0.1	0.7
CN2	SCS curve number		95%
USLE_K	USLE K factor		120%
USLE_P	USLE P factor	0.6	0%
SOL_SOLP	Initial soil soluable P (ppm)	5.0	15.0
ERORGP	ORGP enrichment ratio	0.2	0.15
PHOSKD	P soil partitioning coefficient	65	85
PPERCO	P percolation coefficient	15	12
PSP	P availablity index	0.4	0.3
RSDCO	Residue decomposition coeffcient	0.1	0.15
P_UPDIS	P uptake distribution coefficient	15	10
EROGGN	ORGN enrichment ratio	2.5	2.5
NPERCO	N percolation coefficient	0.6	0.3
N_UPDIS	N uptake distribution coefficient	10	15

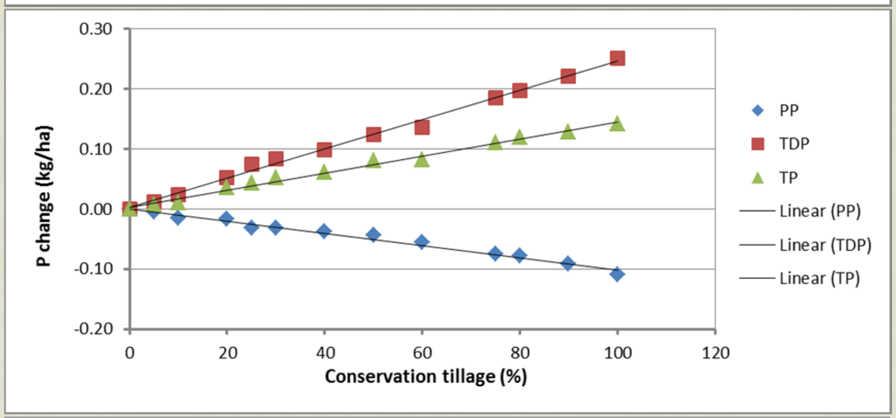
- Changes of flow, sediment, P and N between Twin West and Twin East (%)

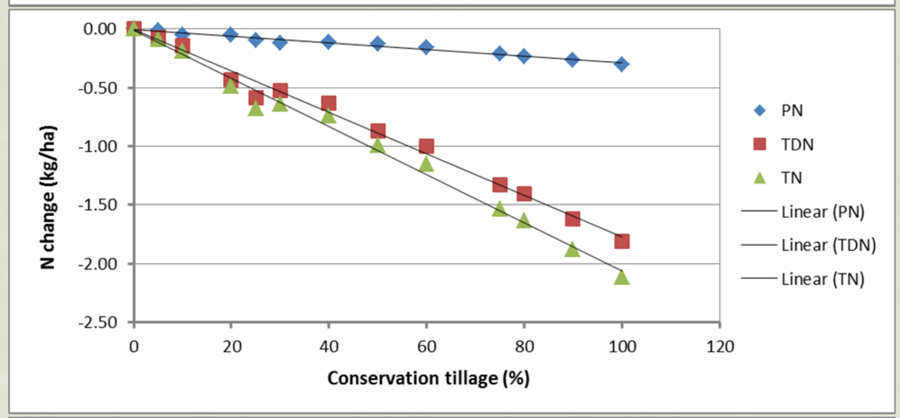
Year	WYLD	SYLD	TN	PN	TDN	TP	PP	DP
2004-2007	-6.91	-53.01	-36.78	-52.02	-31.22	43.16	-17.28	58.46
2004-2010	-6.62	-49.50	-31.61	-47.65	-27.30	30.71	-13.24	41.01
1997-2010	-6.13	-54.22	-41.86	-52.93	-38.62	55.36	-24.47	71.44
1991-2010	-6.23	-48.87	-29.62	-47.54	-25.48	37.87	-25.46	47.86

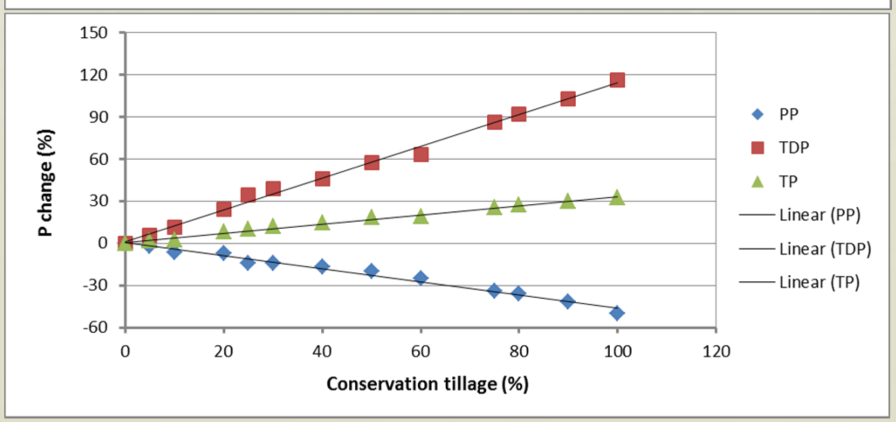
Evaluation of Conservation Tillage at Outlet

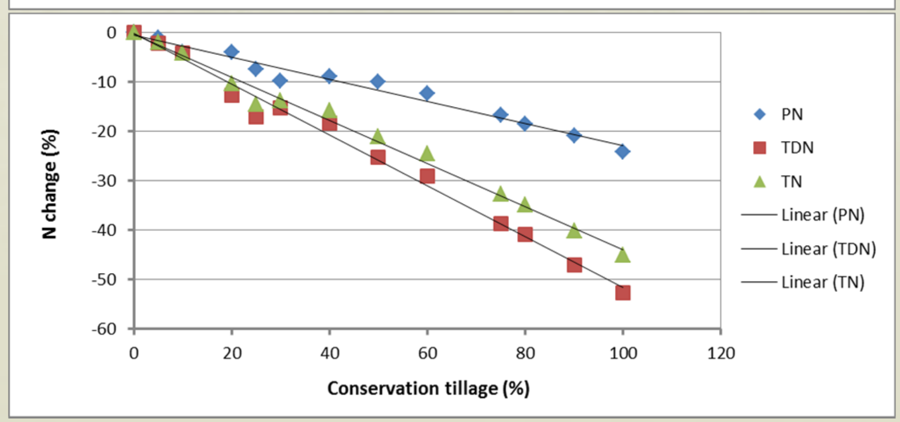




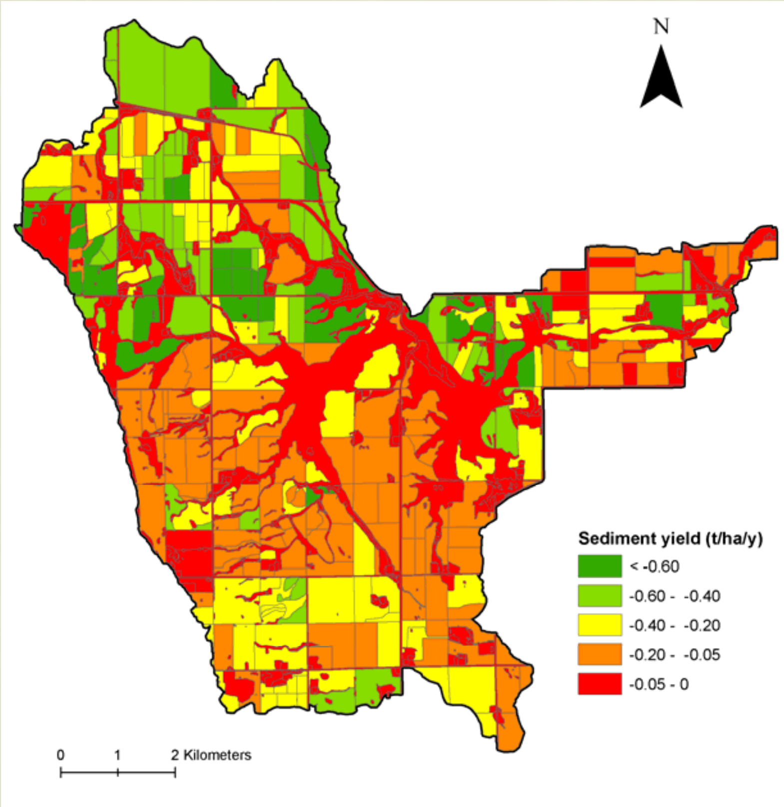


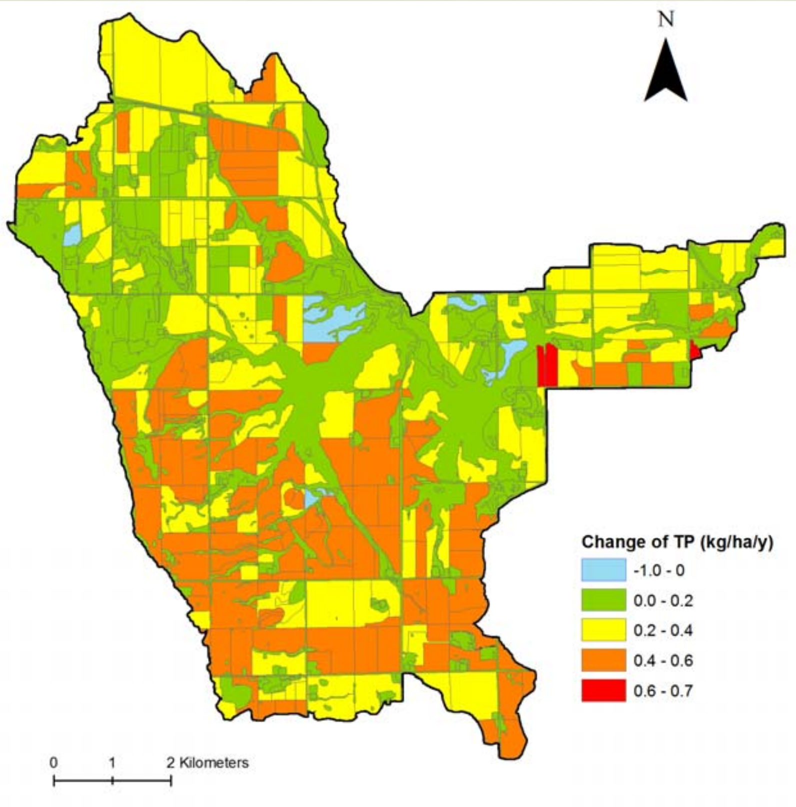




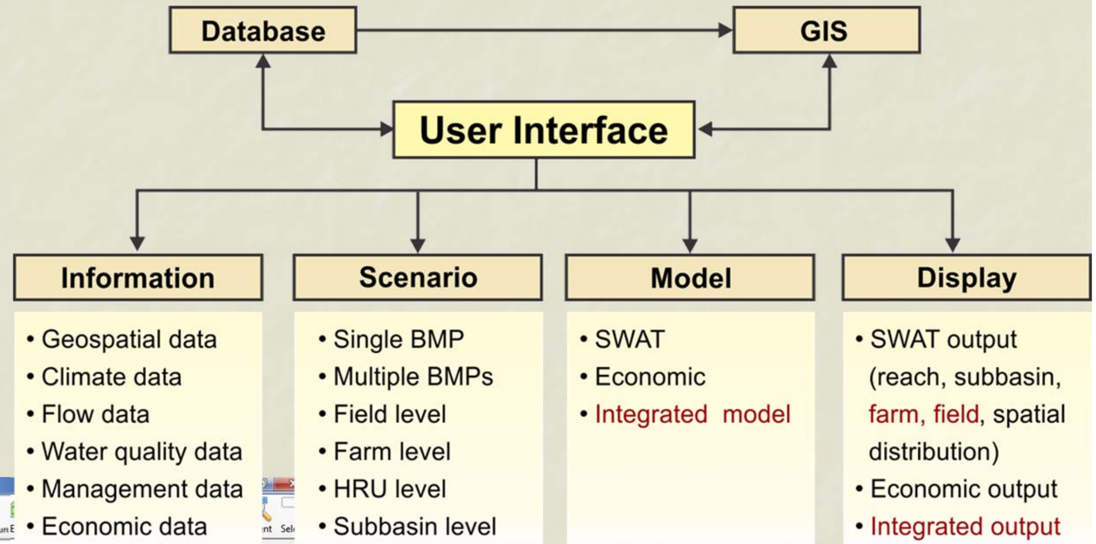


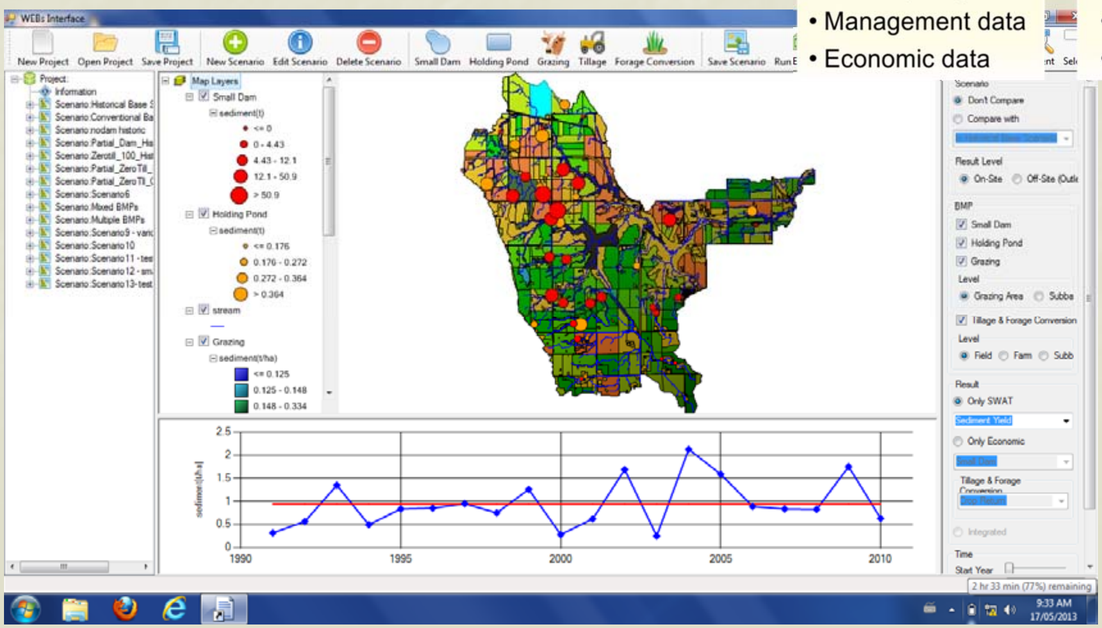
Spatial Distribution for the 100% Conservation Tillage Scenario





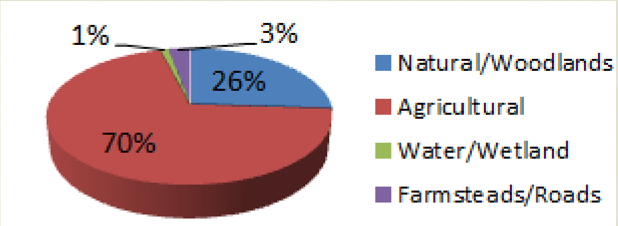
An Integrated Economic-Hydrologic Modelling Interface



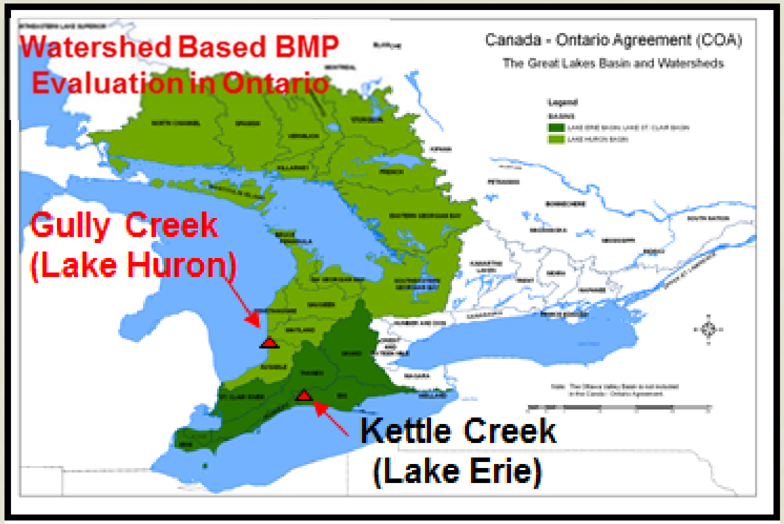


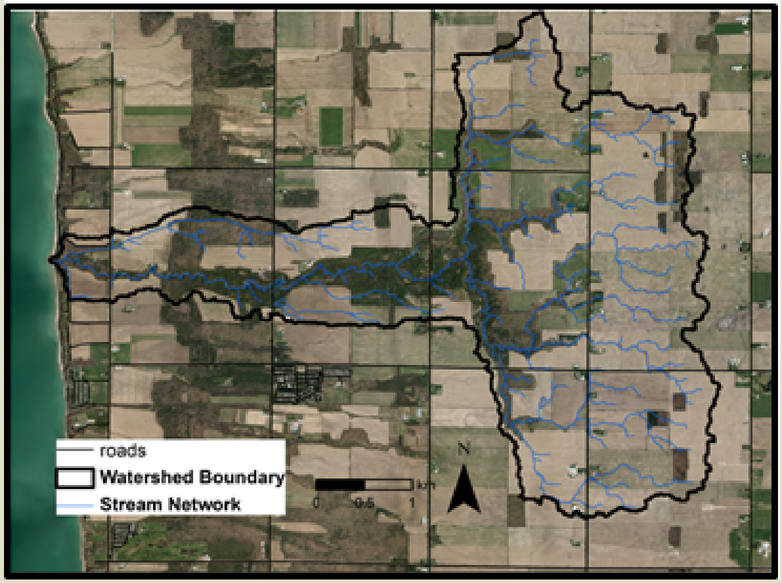
The Gully Creek Watershed in Ontario

- Size: 14.3 km2
- Soils: 75% clay loam (remainder loam, sandy loam)
- Topography: 50% of ag. area has 2-5% slopes (steeper along gully) (5m LiDAR)
- Landuse:



- Dominant crops: corn, soybeans, winter wheat
- Dominant livestock: broiler chickens (some dairy and hogs)
- Dominant BMPs present: (and evaluated)
  - Conservation tillage
  - Nutrients applied at BMP rates (NMP)
  - Fall cover crop (WW under seeded to red clover)
  - Water and Sediment Control basins **(WASCoBs)**



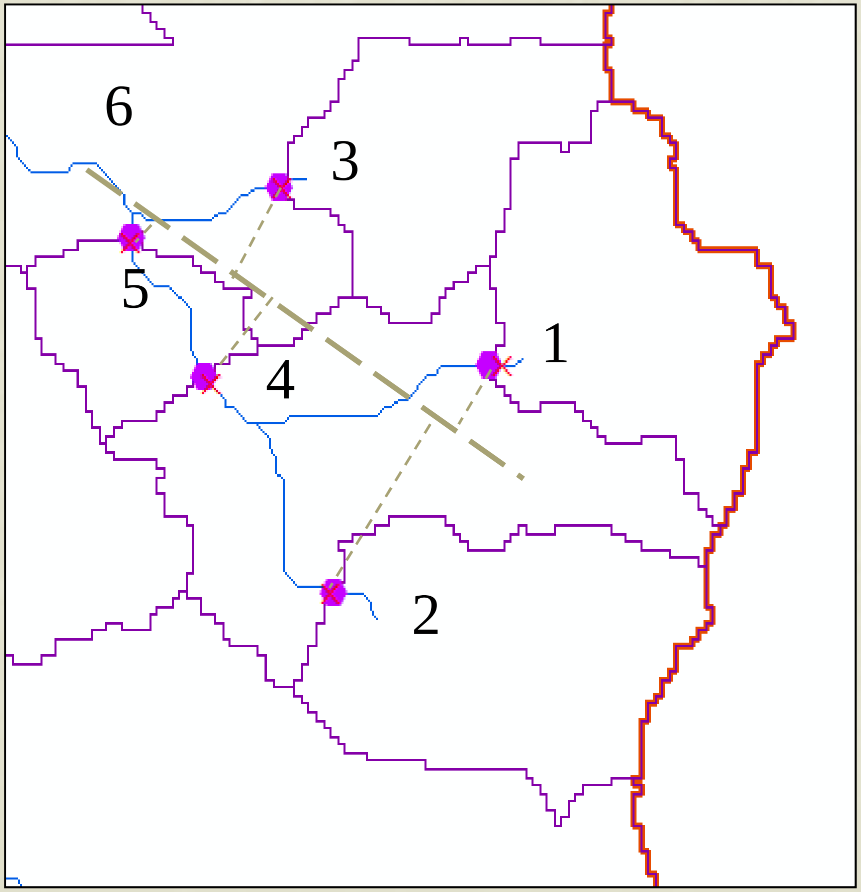


Water and Sediment Control Basins

Elevation (m)	Pond Vol. (m^3)
256.88	0
256.95	7
257.1	40
257.25	84
257.4	185
257.55	321
257.7	399
257.85	468
257.92	613

WASCoB Module Development

1. Set the berm site as a subbasin outlet so that the subbasin area equals the berm drainage area.
2. Set a reservoir right at the WASCoB
3. Pipe flow goes to tile drain using a transfer function
4. Over dam flow follows the DEM derived channel downstream
5. The reservoir is routed using a small dam module based on the V-A-Q curve
6. Discharge over the pipe capacity becomes over dam flow

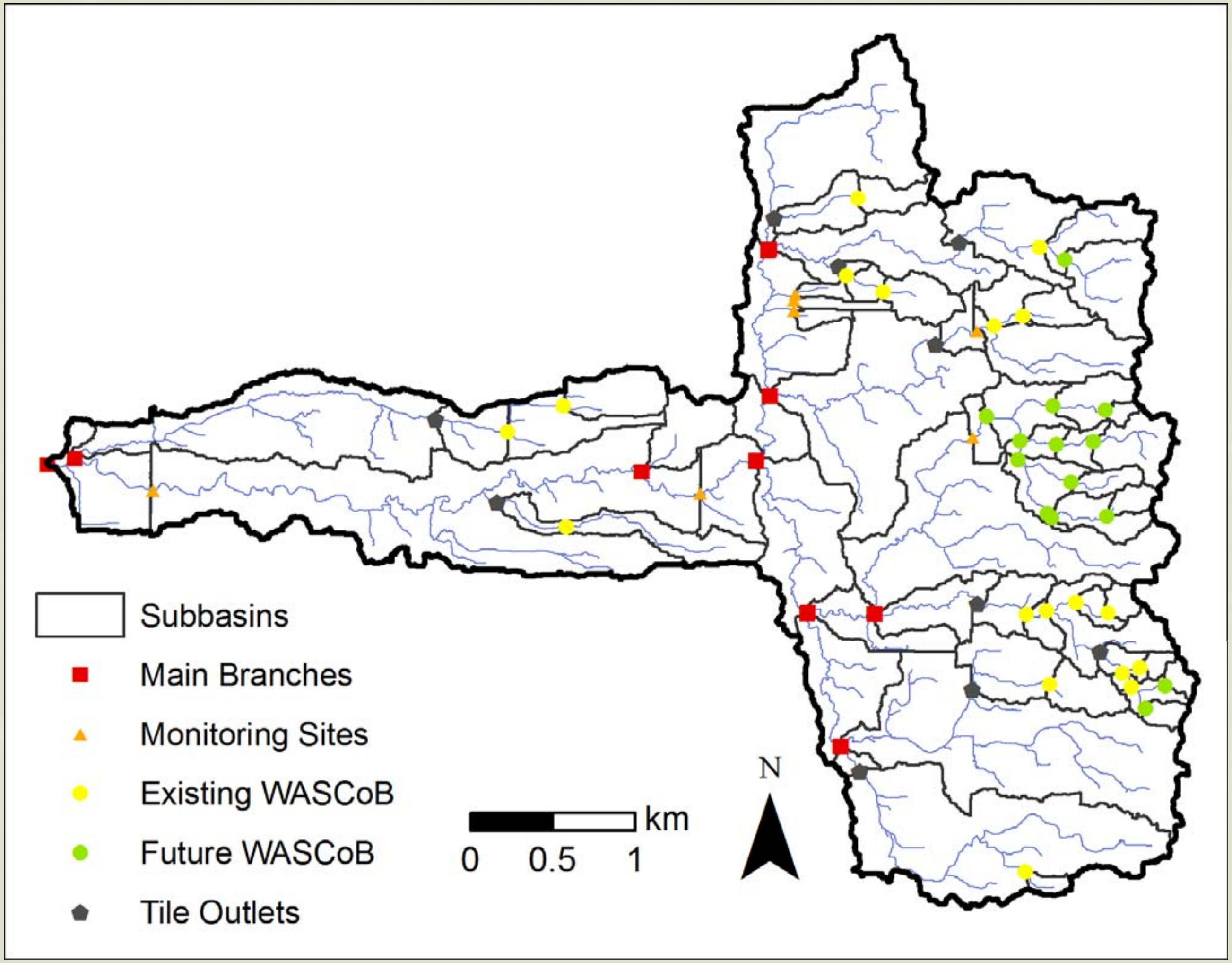


CanSWAT Model Setup

64 sub-basins based on:

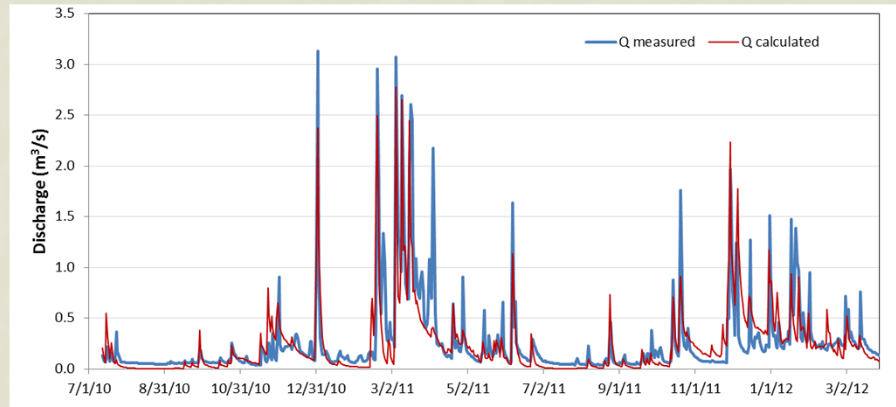
- 15 main tributary outlets
- 7 monitoring stations
- 18 existing WASCoBs
- 14 future WASCoBs
- 10 tile drain outlets

Subbasin areas from 0.6 to 175 ha, with an average of 22 ha

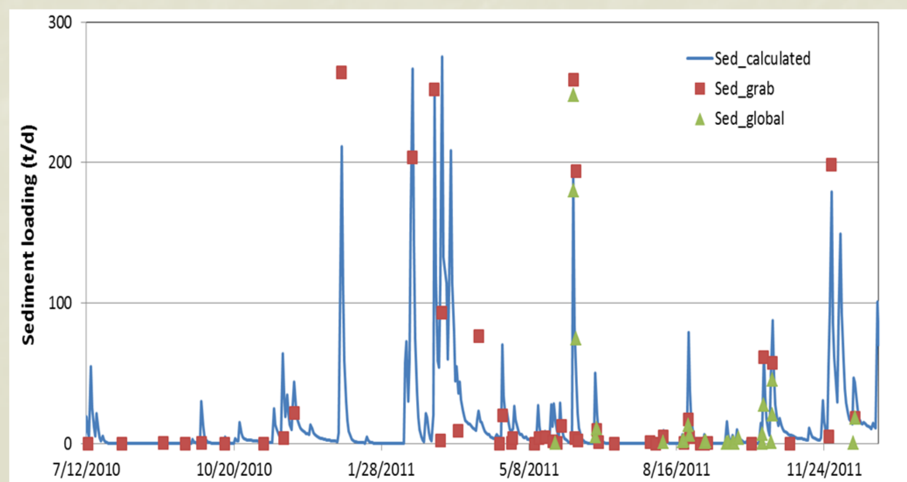


CanSWAT Model Calibration

- Sensitivity analysis of SWAT flow parameters
- Calibration of flow, sediment, nitrogen and phosphorus
- Statistical evaluation – e.g. Good Nash-Sutcliffe coefficients for flow at **daily** level
- Sediment and nutrient calibration is reasonable but can benefit from more samples (see chart)
- Time period for calibration dataset was short (07/10 to 03/12)



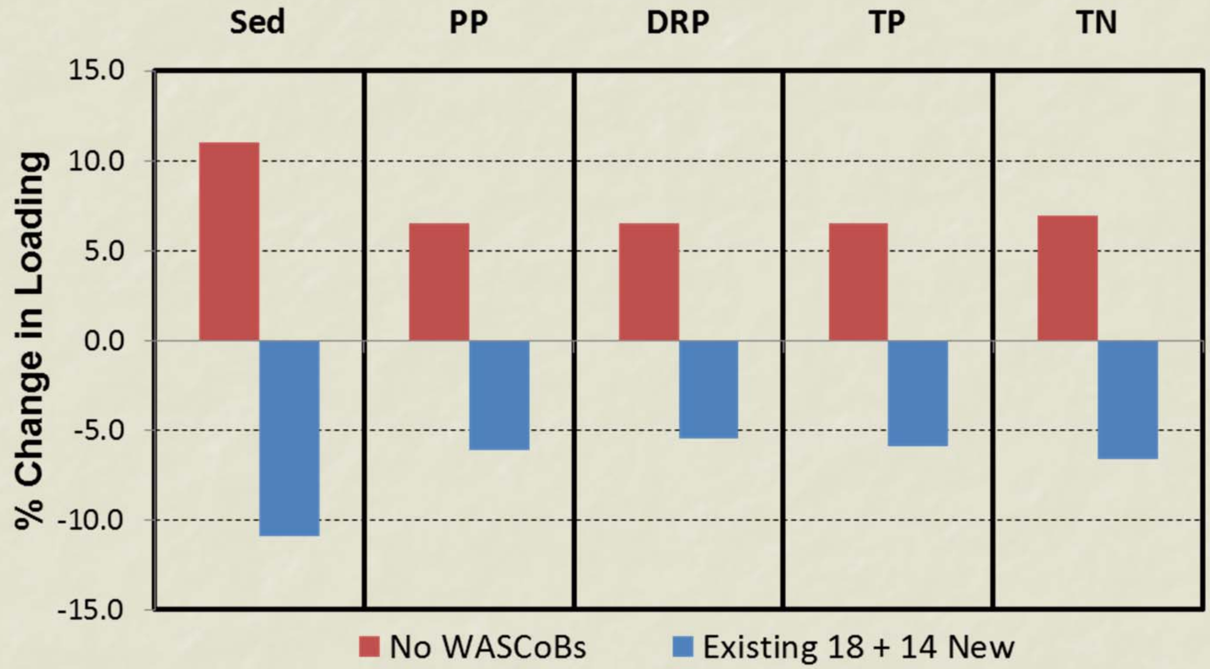
7/12/2010-3/28/2012	Bias	NS Coef	NS low flow	NS high flow
	-0.08	0.76	0.98	0.84



Water Quality and Quantity Effects of WASCoBs

QUALITY:

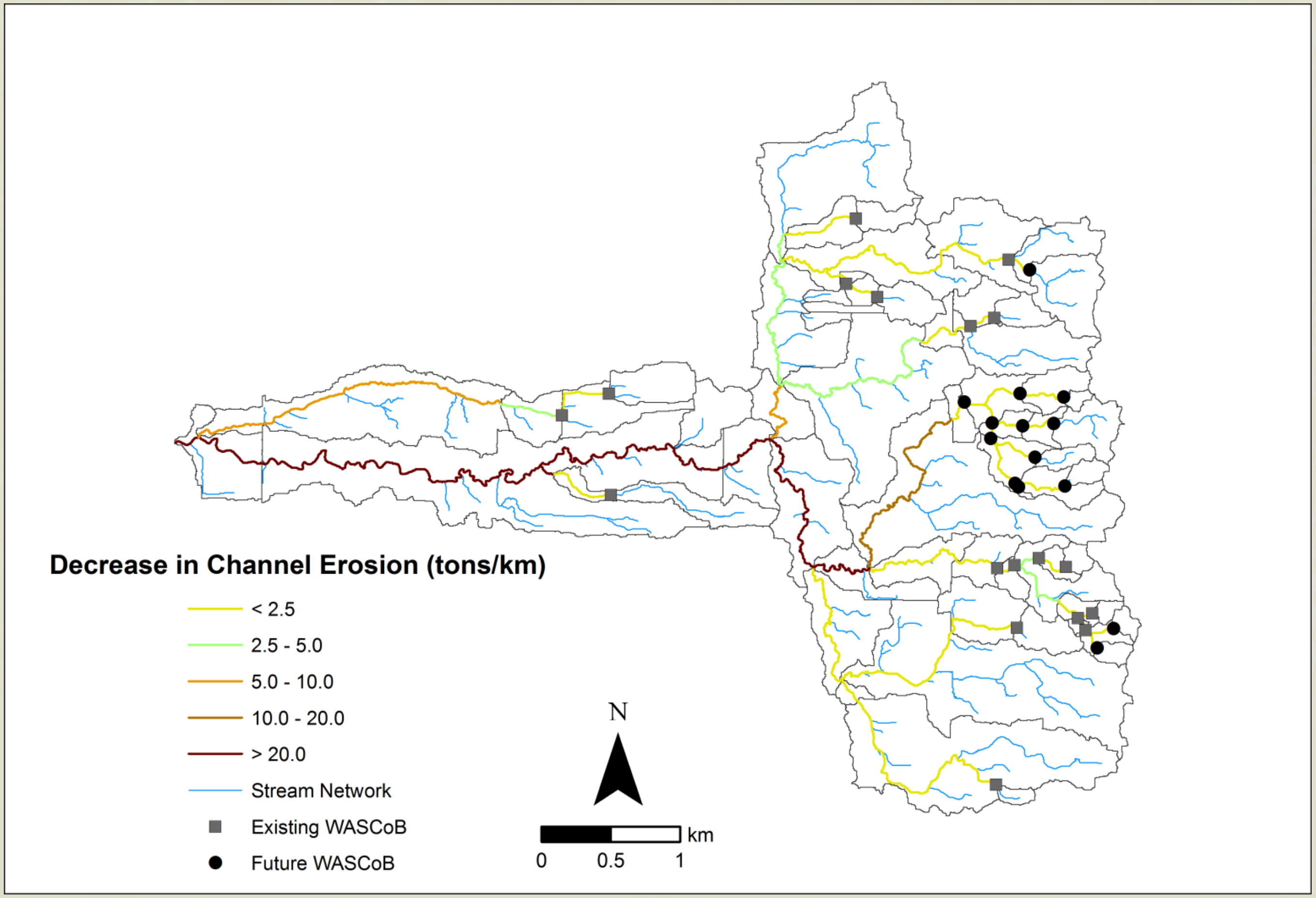
Note: Relative to existing (2011) conditions (i.e. 18 WASCoBs)



QUANTITY: Avg. Annual Streamflow:

No WASCoBS:	0.260 cms
Existing 18 (2011):	0.242 cms
Existing 18 + Future 14:	0.224 cms

CANSWAT's Estimate of Channel Erosion Reduction (ton/km) if 14 Future WASCoBs Installed



Contact Information

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