Nutrient Load Estimation and Reporting

Loading Calculations Technical Symposium

NOAA GLIER, Ann Arbor

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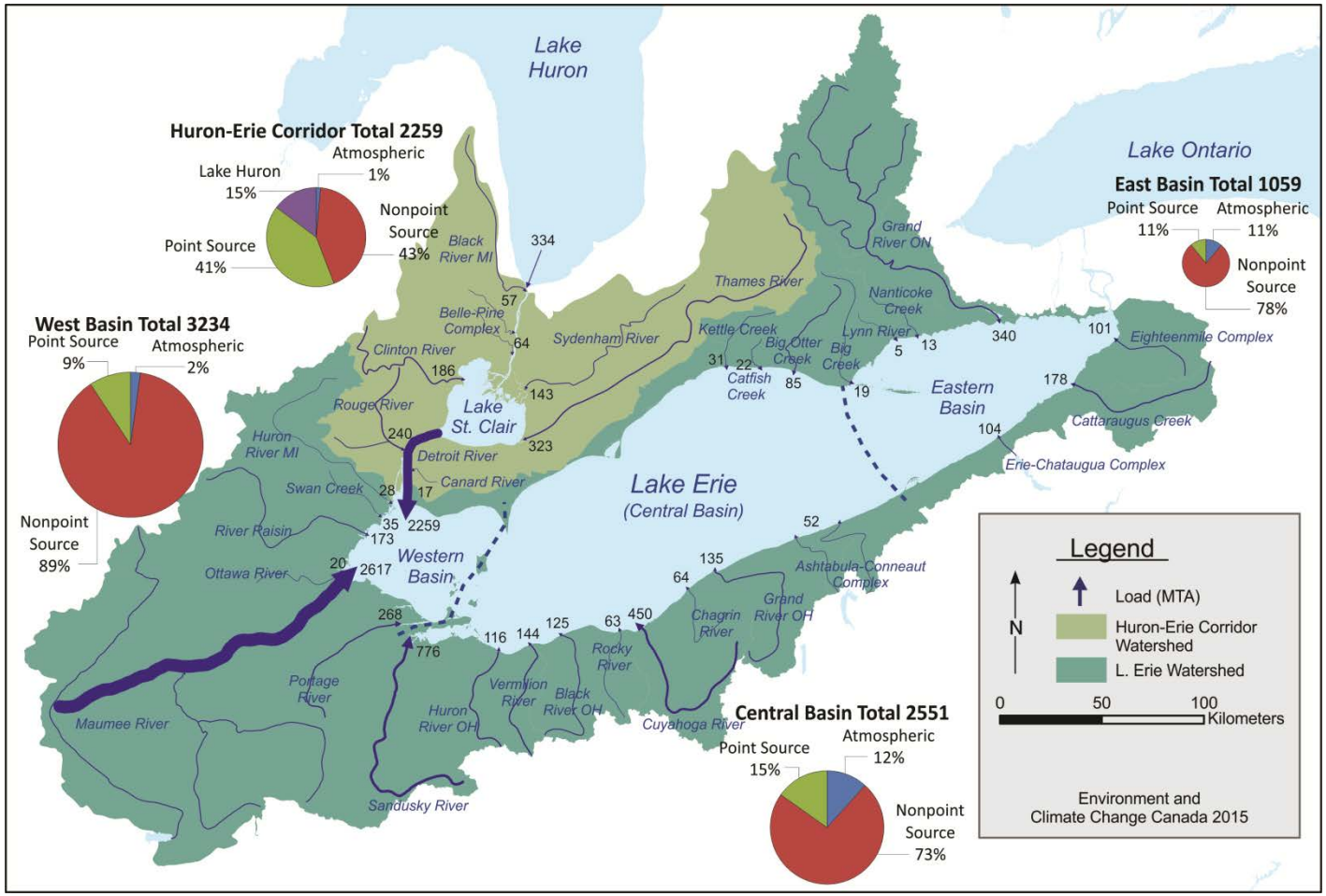
April 6, 2017

Contents

- Whole Lake Loads
- Tributary Monitoring
  - Sampling Methods and Load Estimation Methods
- Connecting Channel Monitoring
  - Unique opportunity to validate corridor estimates
  - Overview of St. Clair, Detroit and Niagara Loads
- Loading Estimate Decision Support System

Mean TP Loads to Lake Erie, 2003-2013 (MTA)



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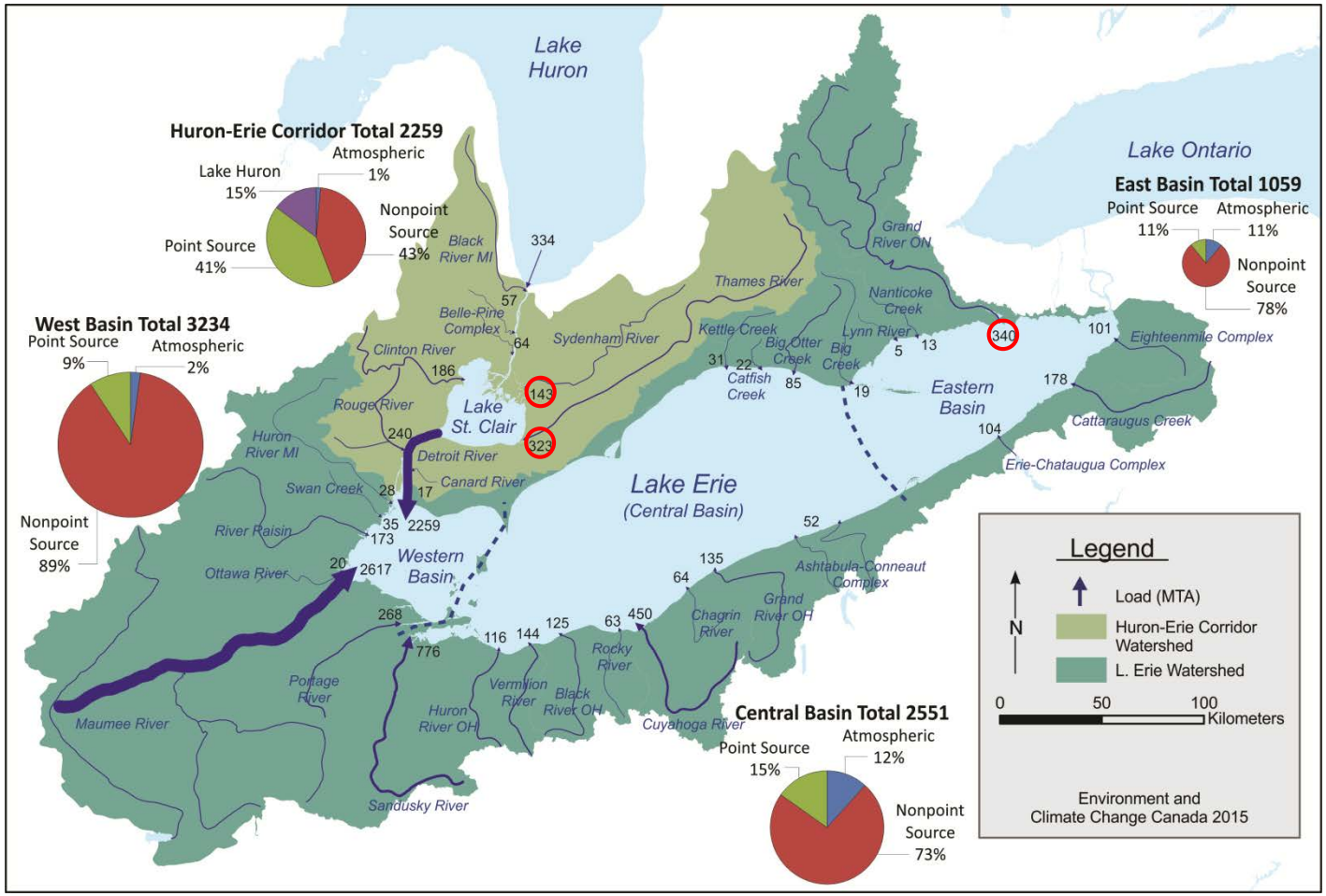


Tributary Sampling Approach

Field Program:

- Year-round, including the critical winter and early spring times
- Emphasis on rain and snow events plus low flow

- At automated sites:
  - Samples taken every 8 hours
  - On-site refrigeration
  - Samples are collected weekly
  - Retrospective analysis of the hydrograph for sample selection to target runoff events

- Total phosphorus
- Total dissolved phosphorus
- Soluble reactive phosphorus**
- Total suspended solids
- Major ions: Cl, F, SO_4
- Total Kjeldahl nitrogen
- Ammonia**
- Nitrate plus nitrite**

All Season Stations

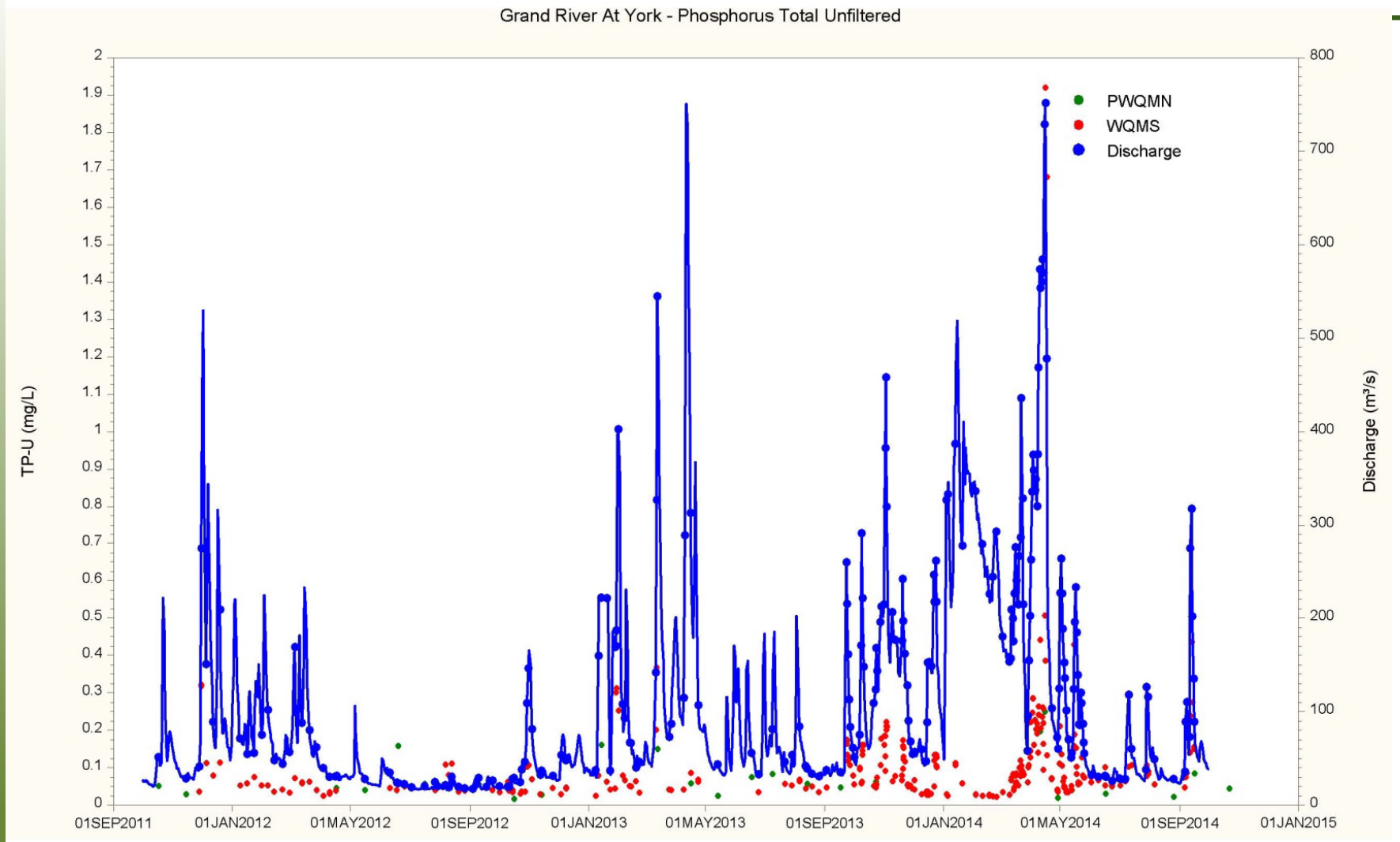
Grand River

Thames River

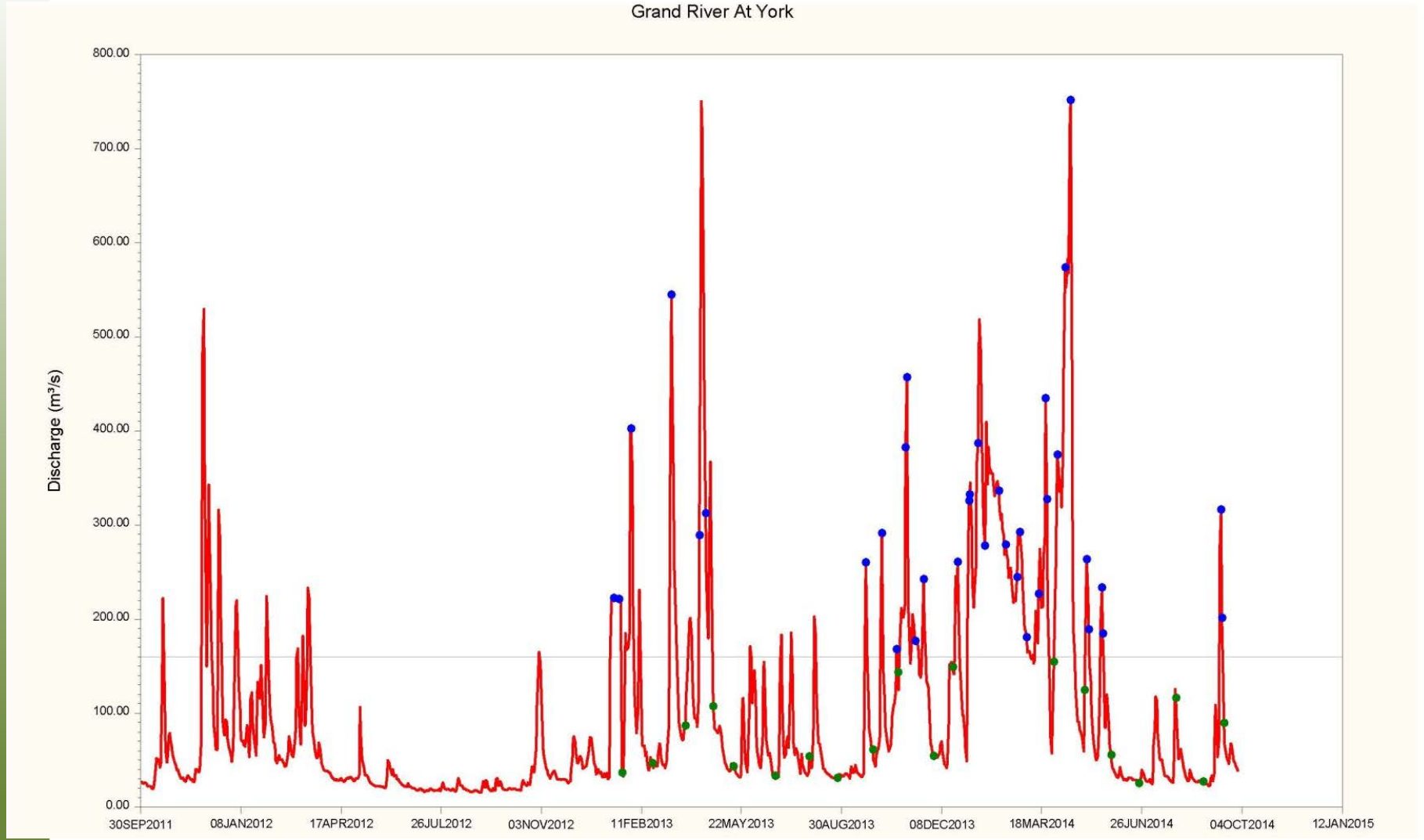
In-River Pumps

Flow-Through for ISCO and Sonde

Samples Achieved



Sufficient Samples?



Sample Selection Protocol

Example - Thames River at Thamesville:

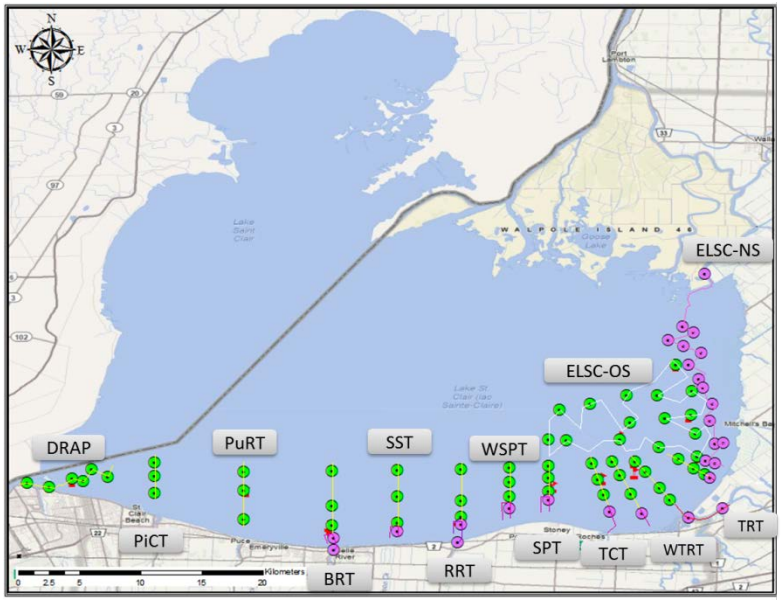
- For runoff events >200 m^3/s – three samples will be analyzed (rising limb, peak, falling limb)
- For runoff events >100 m^3/s up to 200 m^3/s – two samples will be analyzed (rising limb, peak)
- For runoff events >80 m^3/s up to 100 m^3/s – one sample will be analyzed (peak)
- If no runoff events (flow <80 m^3/s)– one sample will be analyzed every two weeks (most recent sample)
- One sample on each day of Lake St. Clair survey

Current Activities – St. Clair Detroit Corridor

- Ongoing St. Clair River monitoring with enhancements
  - Increased frequency, SRP monitoring
- Ongoing Detroit River monitoring on the Canadian side ***ONLY***
- Publication: *Nutrient Concentrations and Loadings from the St. Clair River (2001-2015) and the Detroit River (2014-2015)*

  Debbie Burniston, Alice Dove, Sean Backus

- Thames River and Sydenham River monitoring for loadings
- Nested monitoring in the Thames River watershed - 12 locations
- Collaborative monitoring in Lake St. Clair with MOECC



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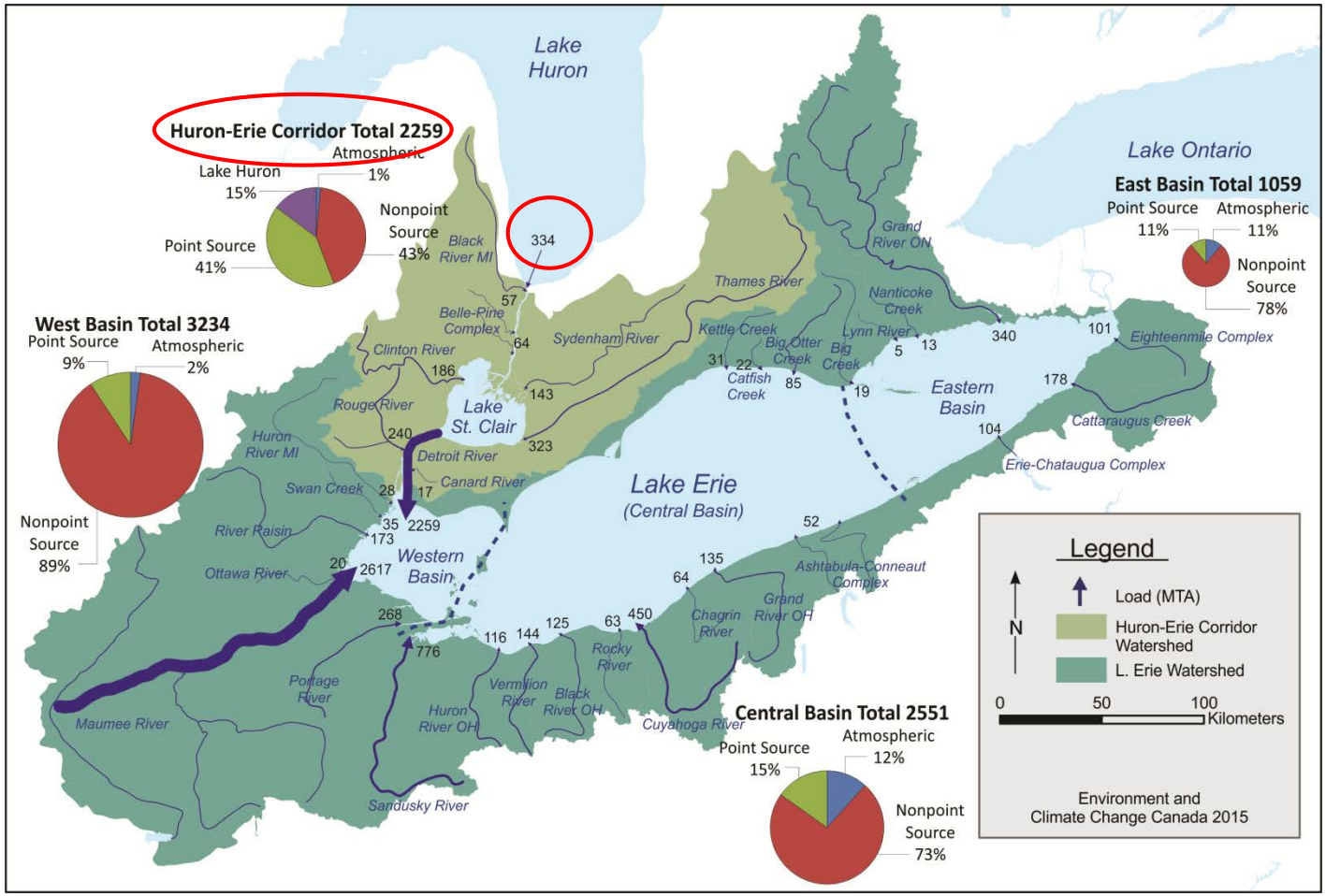
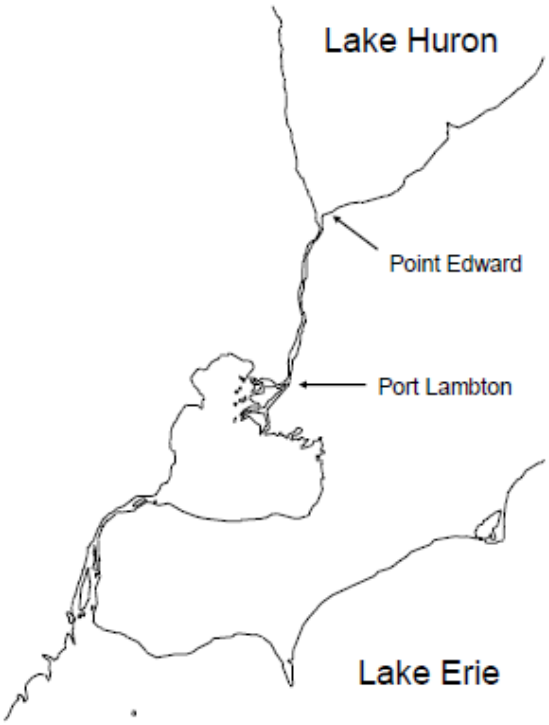


St. Clair River Upstream-Downstream Program



Year-round (all season) monitoring

- Every 2 weeks from 2001 – 2012
- Every 4 weeks 2012 to present

Nutrients (TP, TDP, NO_3+NO_2, TN, TDN, NH_3)

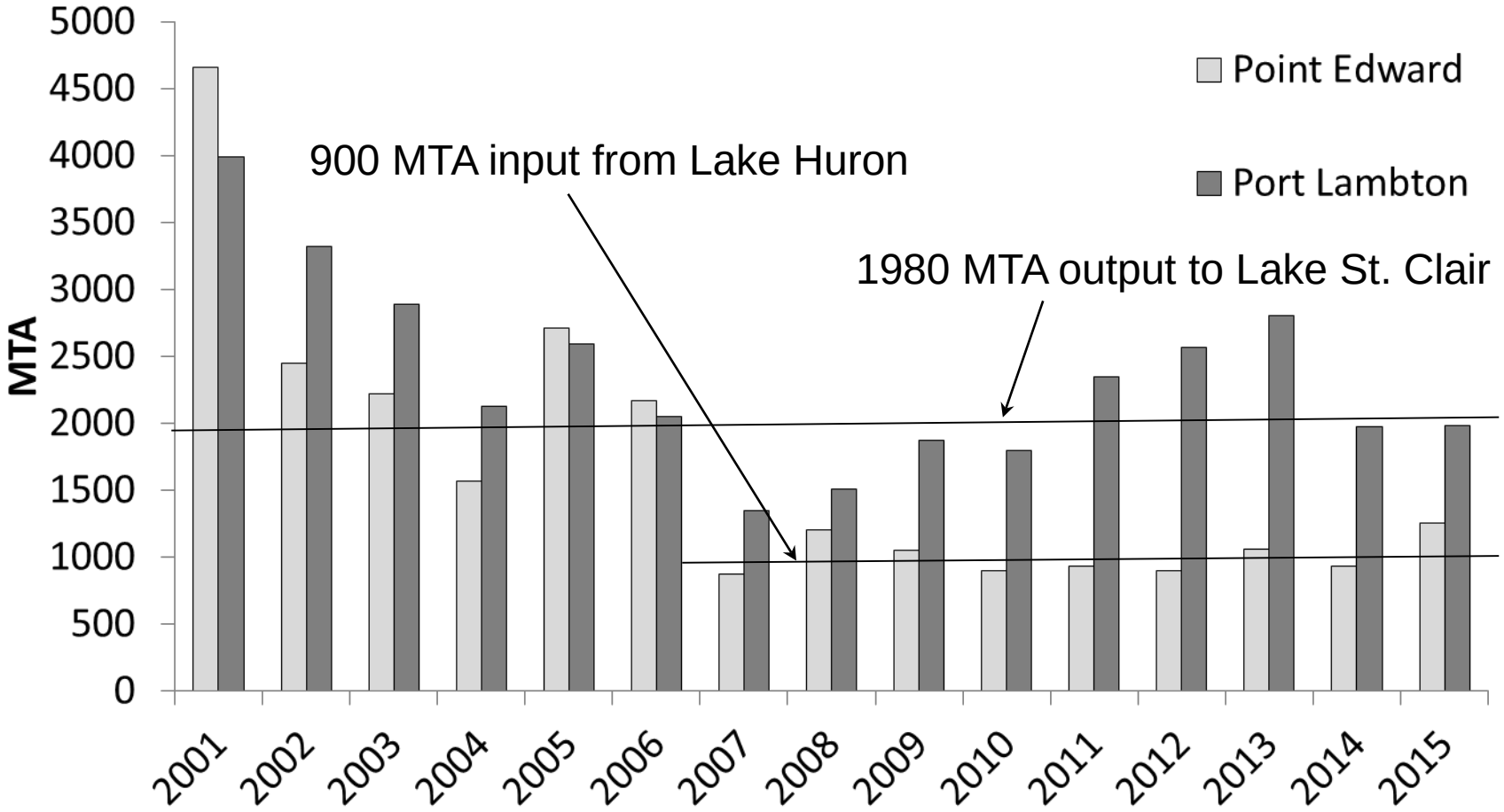
Major Ions (Ca, Cl, Mg, K, Na, SO_4, SiO_2)

Organic Contaminants

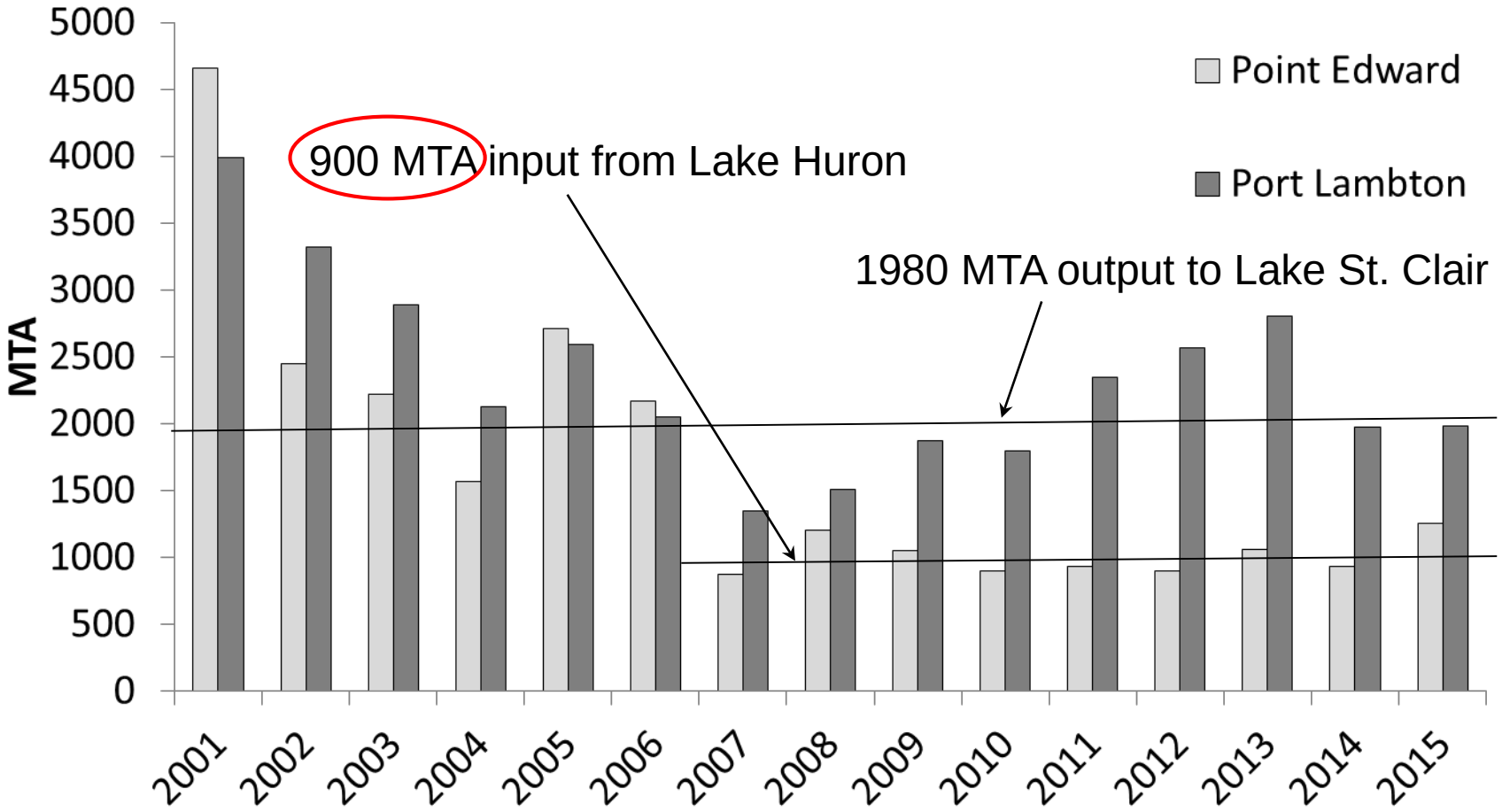
Trace Metals

} In water and suspended sediment

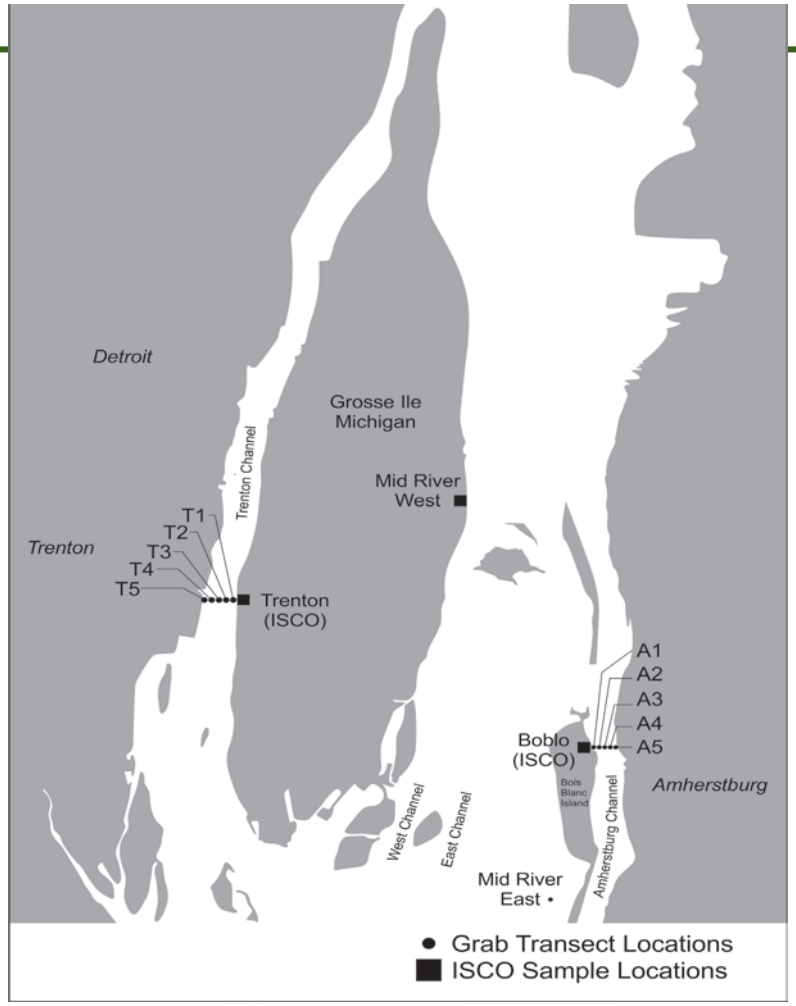
Total Phosphorus Loads - LOADEST



Total Phosphorus Loads - LOADEST



Detroit River 2014 and 2015 (2004 and 2007)



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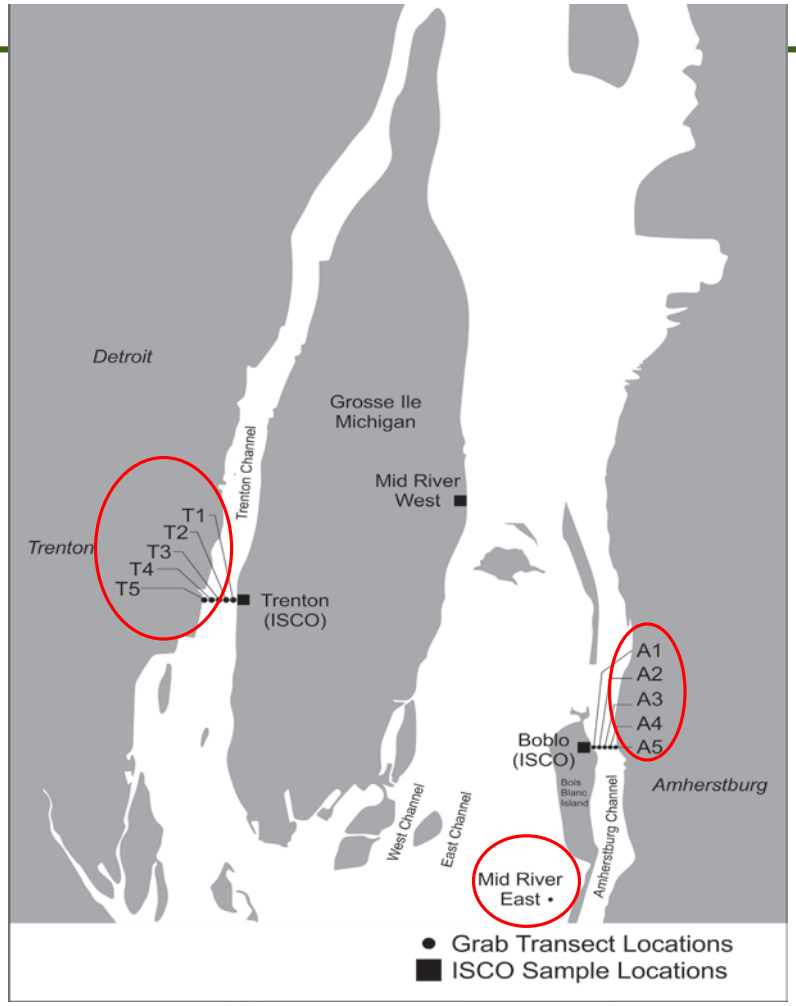
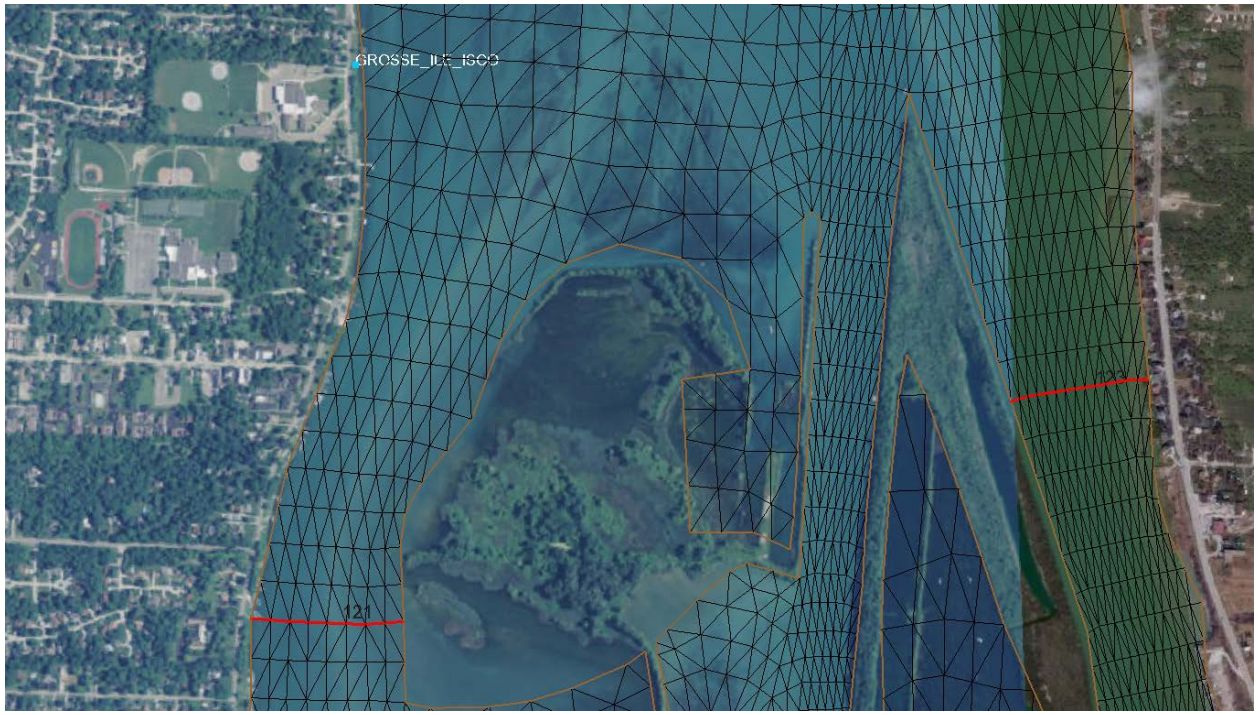


Hydrosim 2d and Dispersim 2d Model

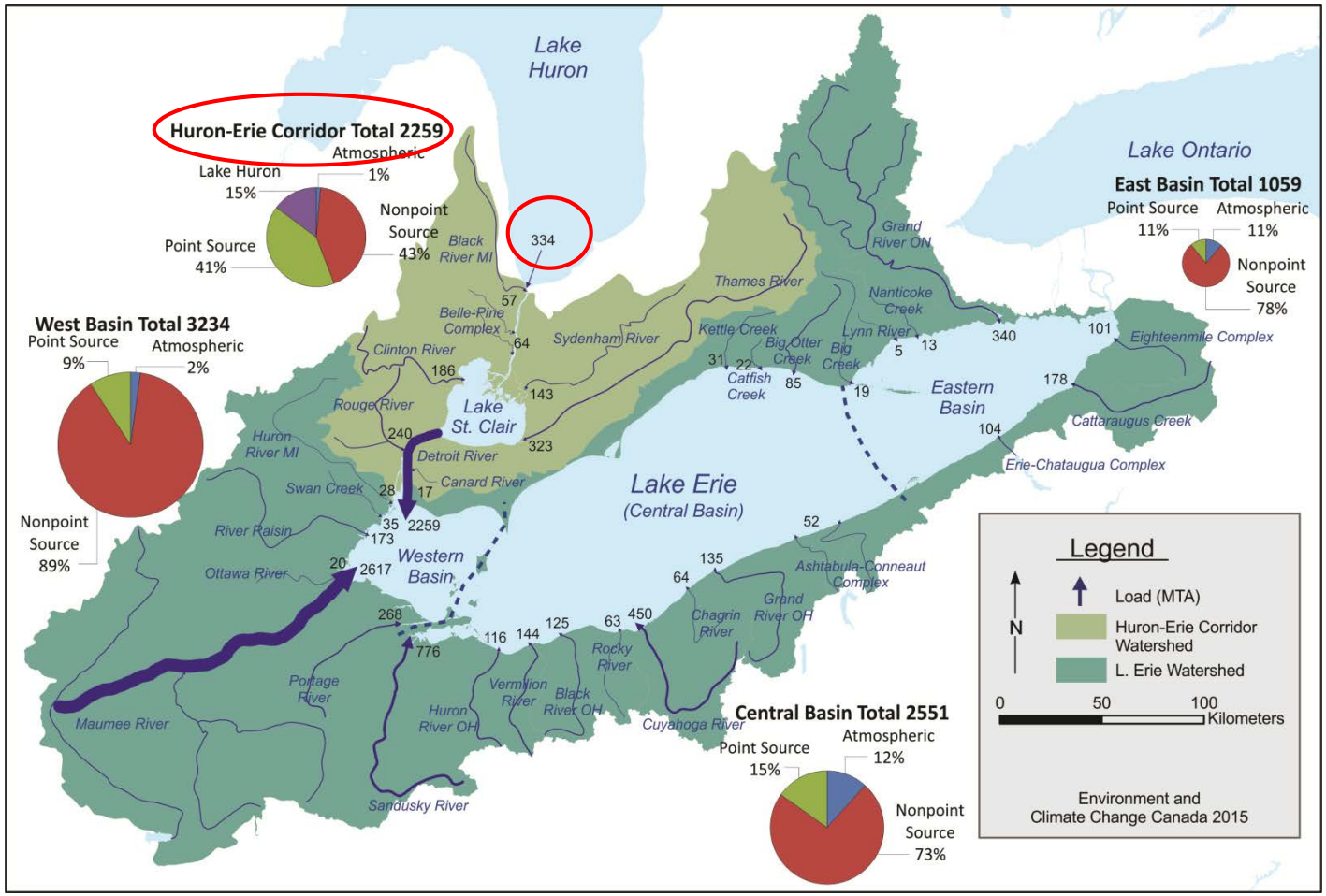


Boundary Waters Issues, Meteorological Survey of Canada

Corridor Total Phosphorus Loads

Water year, MTA	2007	2014	2015
Lake Huron	877	933	1250
St. Clair River	1350	1970	1980
Trenton Channel	2000-2500	718	584
Mid River	810	1580	837
Amherstburg Channel	870-1010	1250	1190
Total Load, Detroit River	3680-4320	3550	2610

Mean TP Loads to Lake Erie, 2003-2013 (MTA)



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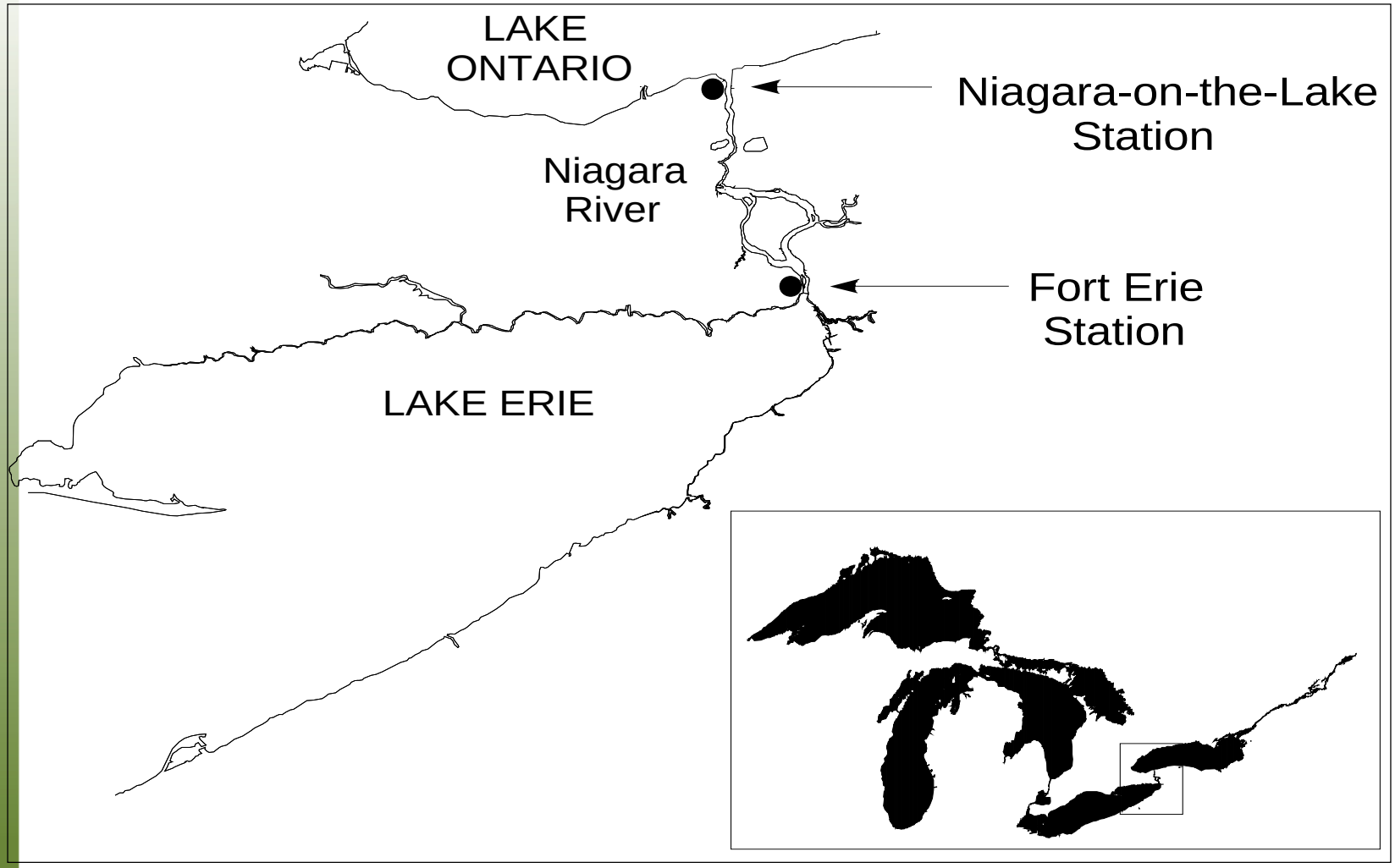
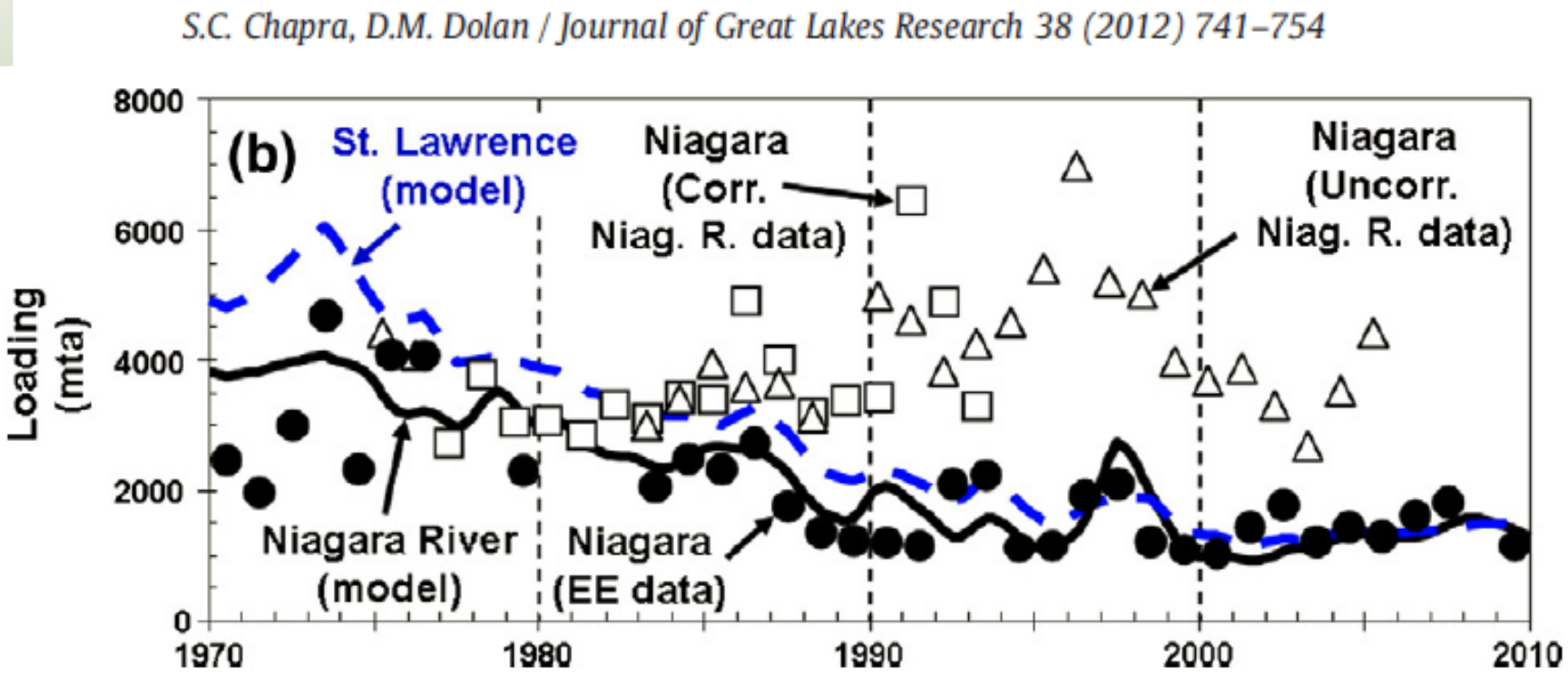
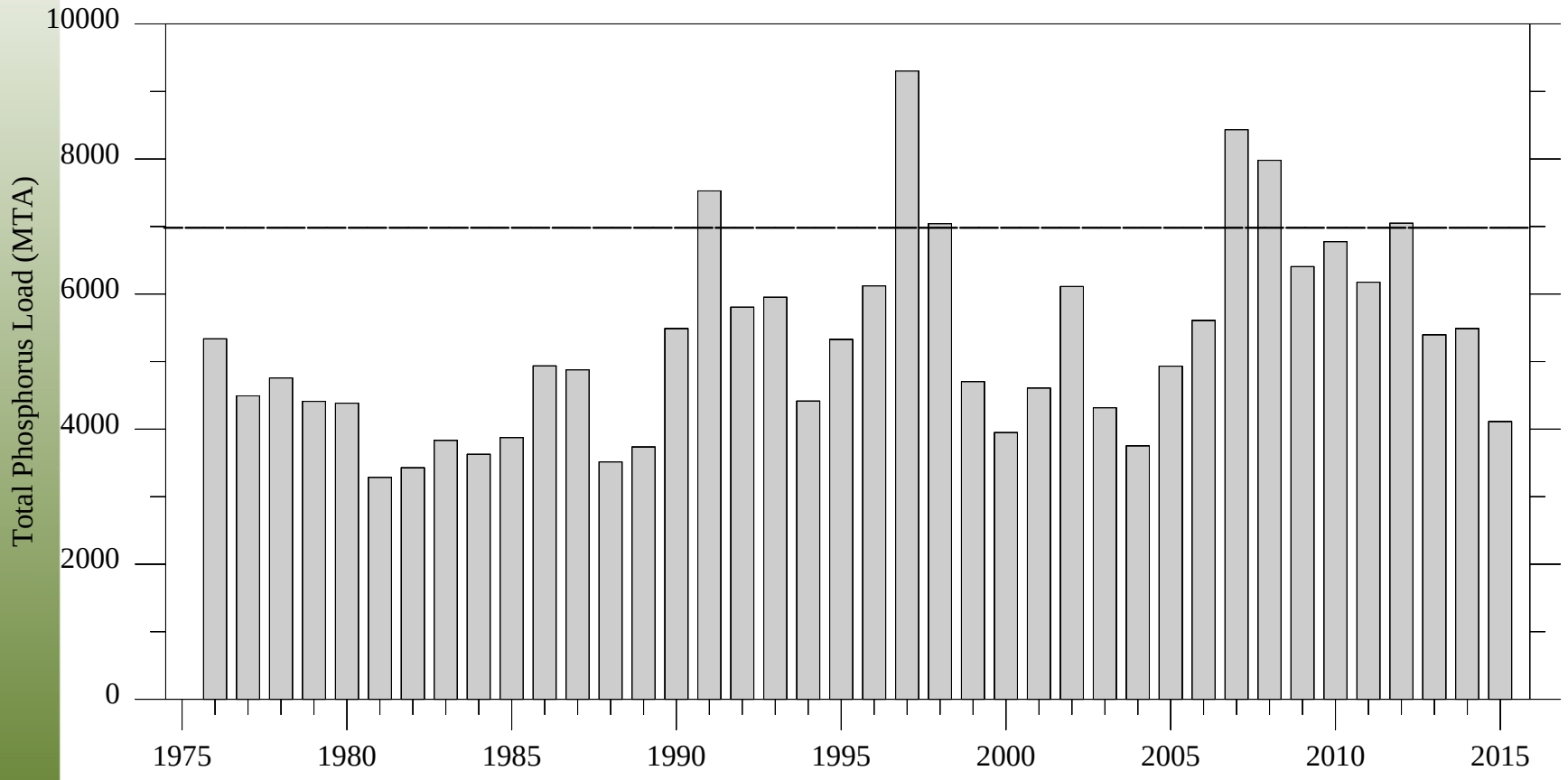
Niagara River Upstream-Downstream



What we thought we knew

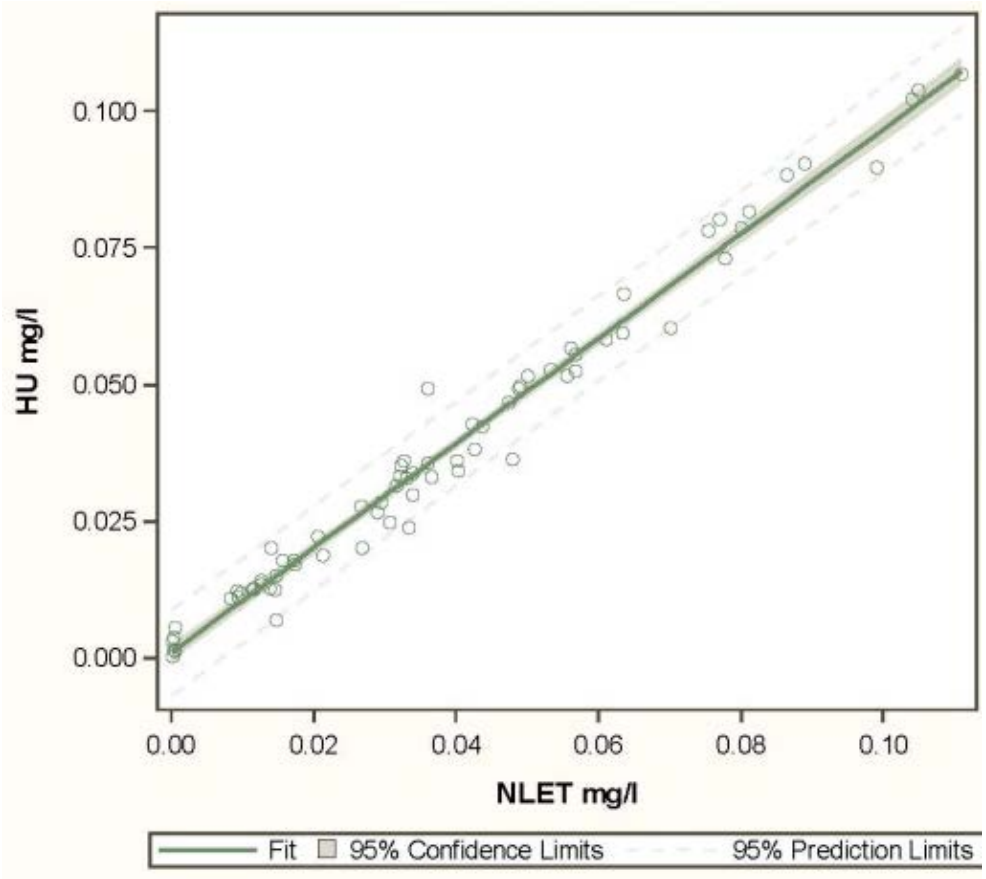


Total Phosphorus Loads at Niagara-on-the-Lake



Interlaboratory Comparison
Heidelberg University and ECCC NLET

SRP



Loading Estimate Decision Support System

- Collaborative Project between Water Quality Monitoring and Research Divisions
- Purpose: an updated, more highly automated tool to estimate annual TP and SRP loadings using Dolan Method
  - Monitored tributaries, unmonitored watershed areas, point sources (municipal and industrial), atmospheric deposition, upstream Great Lakes (i.e. Lake Huron)
  - Loadings calculated on a water year basis
  - Standard errors are provided for each estimate
- Project timeline:
  - April 2016: Start project
  - June 2016: Receive data files for Lake Erie loads
  - July 2016: Develop system design of loading estimate decision support system
  - September 2016: Began implementation of Dolan Method in decision support system (DSS)
  - March 2017 - present: In process of beta testing, bug fixing and verifying results

Maccoux, M.J., Dove, A., Backus, S.M., Dolan, D.M., 2016. Total and soluble reactive phosphorus loadings to Lake Erie, J. Great Lakes Res., http://dx.doi.org/10.1016/j.jglr.2016.08.005

Loading Estimate Decision Support System (DSS) Overview

- Initial beta implementation of Dolan Method
- DSS is a Windows application with a graphical user interface
- Input data (tributary flows and concentrations, point source effluent, atmospheric deposition, etc.) are stored in multiple csv-formatted text files
  - Data import function for point source data
- A “project” file is used to organize data and information
- Output results are saved in multiple csv-formatted text files
- Some input data and outputs are viewable within the DSS, others require external application (e.g., Excel)
  - Graphs generated by R software with EGRET library (Exploration and Graphics for RivEr Trends) from USGS

Data Sources (for Lake Erie Loadings)

Data	Agency
Tributary Flow	Canada Water Survey of Canada (Environment and Climate Change Canada) U.S. Water Resources Division (U.S. Geological Service)
Tributary Water Quality	Canada Water Quality and Monitoring and Surveillance Division (Environment and Climate Change Canada) Provincial Water Quality Monitoring Network (Ontario Ministry of Environment and Climate Change) U.S. National Center for Water Quality Research (Heidelberg University) Water Resources Division (Michigan Department of Environmental Quality) Division of Surface Water (Ohio Environmental Protection Agency) STORET (U.S. Environmental Protection Agency) Water Resources Division (U.S. Geological Survey)
Point Source	Canada MISA (Ontario Ministry of Environment and Climate Change) U.S. Water Division-PCS/ICIS (U.S. Environment Protection Agency)
Atmospheric Deposition	Canada Water Quality and Monitoring and Surveillance Division (Environment and Climate Change Canada)

Loading Estimate Decision Support System Project File

Project File: general information for tributary

Tributaries	Basin	Country	Watershed Area (km2)
Black-MI	Huron-Erie Corridor	US	1800
Belle-Pine Complex	Huron-Erie Corridor	US	1550
Clinton	Huron-Erie Corridor	US	1901
Rouge	Huron-Erie Corridor	US	1890
Thames	Huron-Erie Corridor	CAN	5706
Sydenham	Huron-Erie Corridor	CAN	3038
Canard	Huron-Erie Corridor	CAN	347
Turkey	Huron-Erie Corridor	CAN	28

Example of tributary sections in project file

Project File: monitored tributary data

Mon Tributary Loads	Parameter	Flow Data File	Concentration Data File	Loading Estimate Method
Black-MI	TP	Inputs\Black-MI flow.csv	Inputs\Black-MI TP.csv	Beale
Black-MI	SRP	Inputs\Black-MI flow.csv	Inputs\Black-MI SRP.csv	Beale
Clinton	TP	Inputs\Clinton flow.csv	Inputs\Clinton TP.csv	Beale
Clinton	SRP	Inputs\Clinton flow.csv	Inputs\Clinton SRP.csv	Beale
Rouge	TP	Inputs\Rouge flow.csv	Inputs\Rouge TP.csv	Beale
Rouge	SRP	Inputs\Rouge flow.csv	Inputs\Rouge SRP.csv	Beale
Huron-MI	TP	Inputs\Huron-MI flow.csv	Inputs\Huron-MI TP.csv	Beale
Huron-MI	SRP	Inputs\Huron-MI flow.csv	Inputs\Huron-MI SRP.csv	Beale

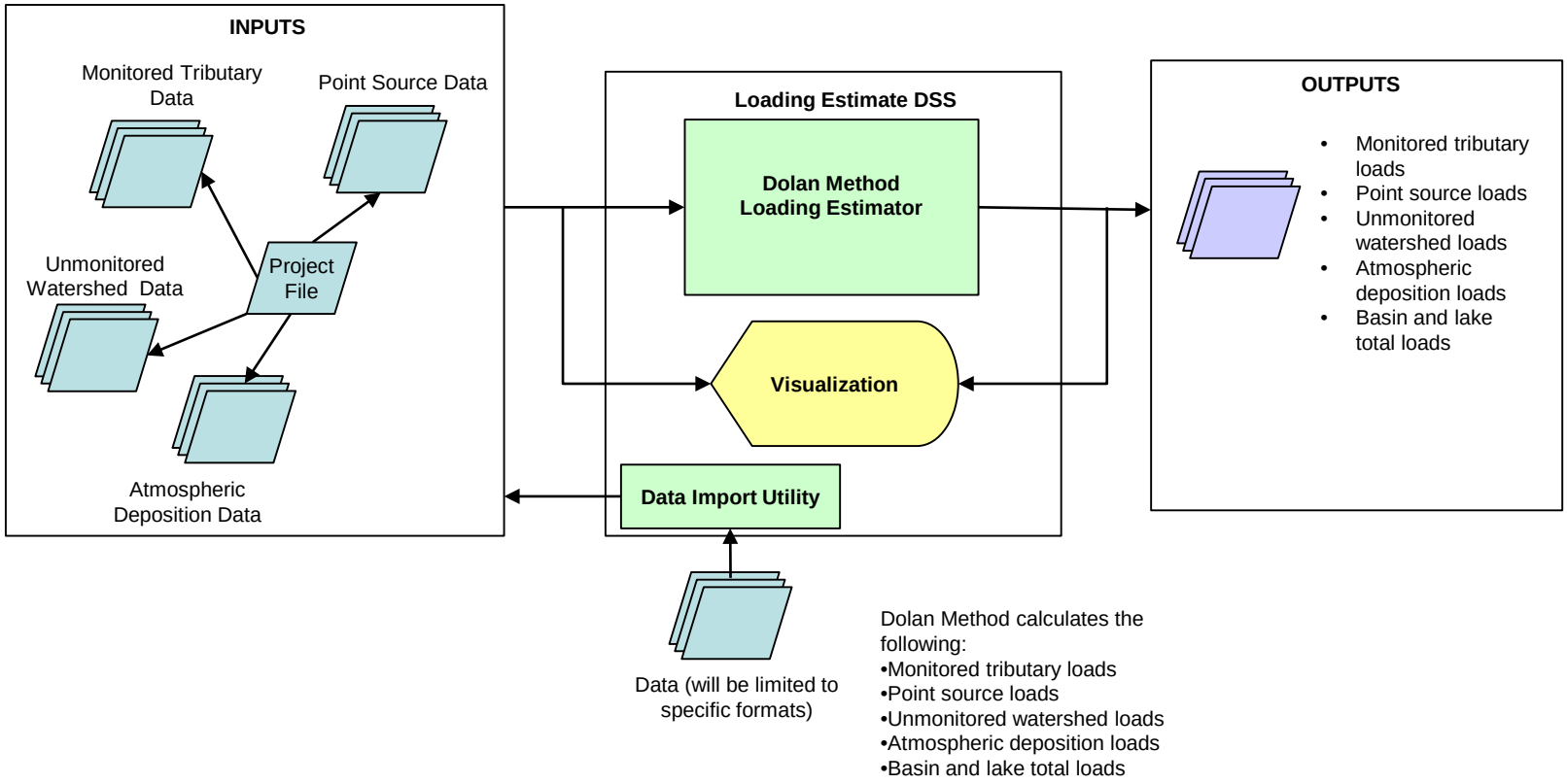
Concentration Data for Black-MI

Date	TP (mg/L)
21/10/2008	0.046
14/04/2009	0.035
15/06/2009	0.071
05/08/2009	0.059
06/10/2009	0.035
21/05/2010	0.076
19/07/2010	0.08
11/08/2010	0.055
12/10/2010	0.042
29/03/2011	0.06
20/06/2011	0.047
01/08/2011	0.059

Flow Data for Black-MI

DATE	Flow (cfs)
01/10/2008	449.4
02/10/2008	407.456
03/10/2008	331.058
04/10/2008	281.624
05/10/2008	229.194
06/10/2008	191.744
07/10/2008	164.78
08/10/2008	164.78
09/10/2008	187.25
10/10/2008	203.728
11/10/2008	185.752
12/10/2008	167.776
13/10/2008	142.31
14/10/2008	137.816
15/10/2008	130.326
16/10/2008	134.82
17/10/2008	146.804
18/10/2008	133.322
19/10/2008	127.33
20/10/2008	122.836
21/10/2008	115.346

Loading Estimate Decision Support System Schematic Diagram

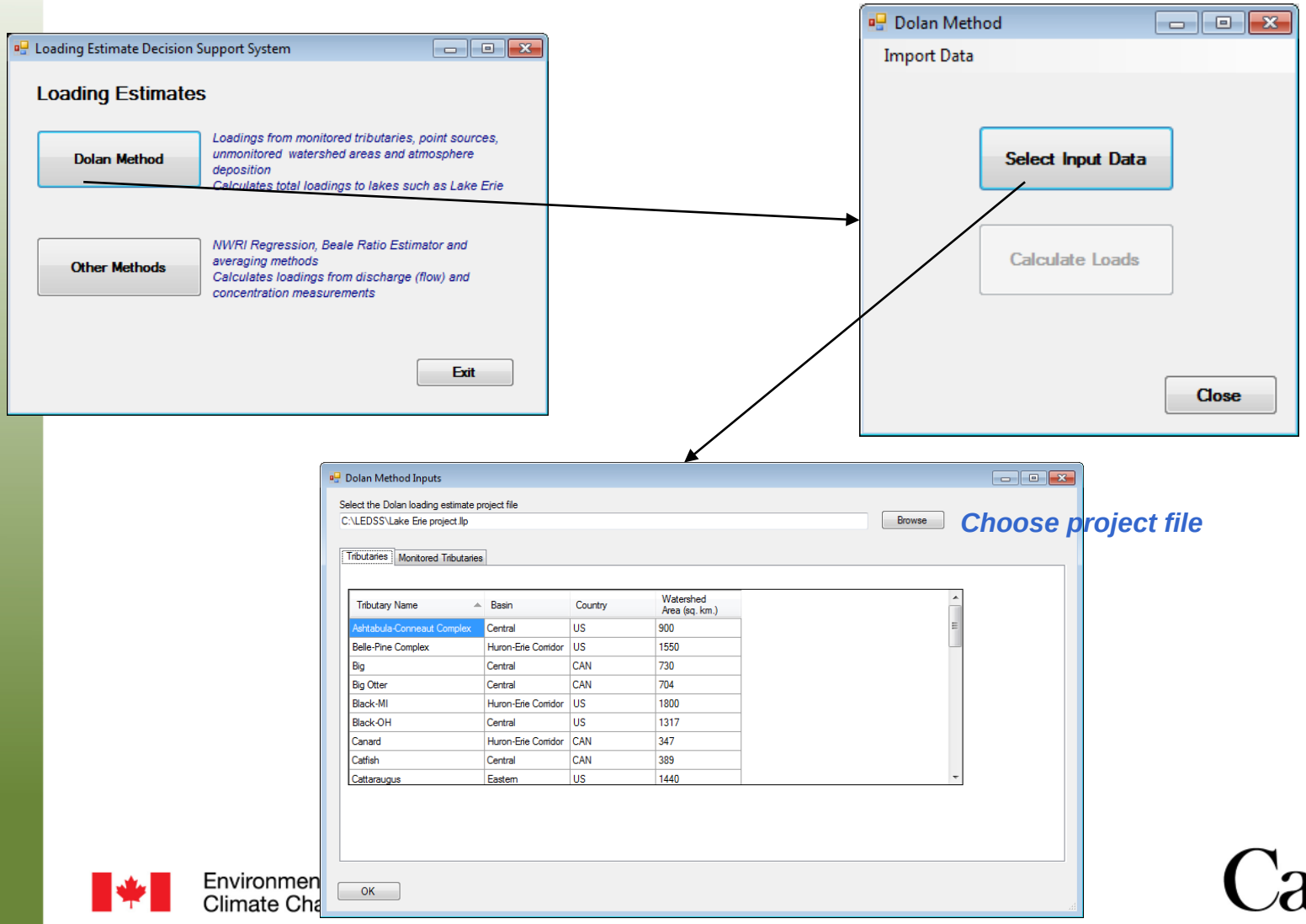


Loading Estimate Decision Support System Current Status

- Implemented loading calculations for:
  - monitored tributaries (Stratified Beale Ratio Estimator, Heidelberg data)
  - unmonitored watershed areas
  - point sources
  - atmospheric deposition
  - basin, country and lake totals

- In the process of beta testing, bug fixing and verifying results

Loading Estimate Decision Support System Demo



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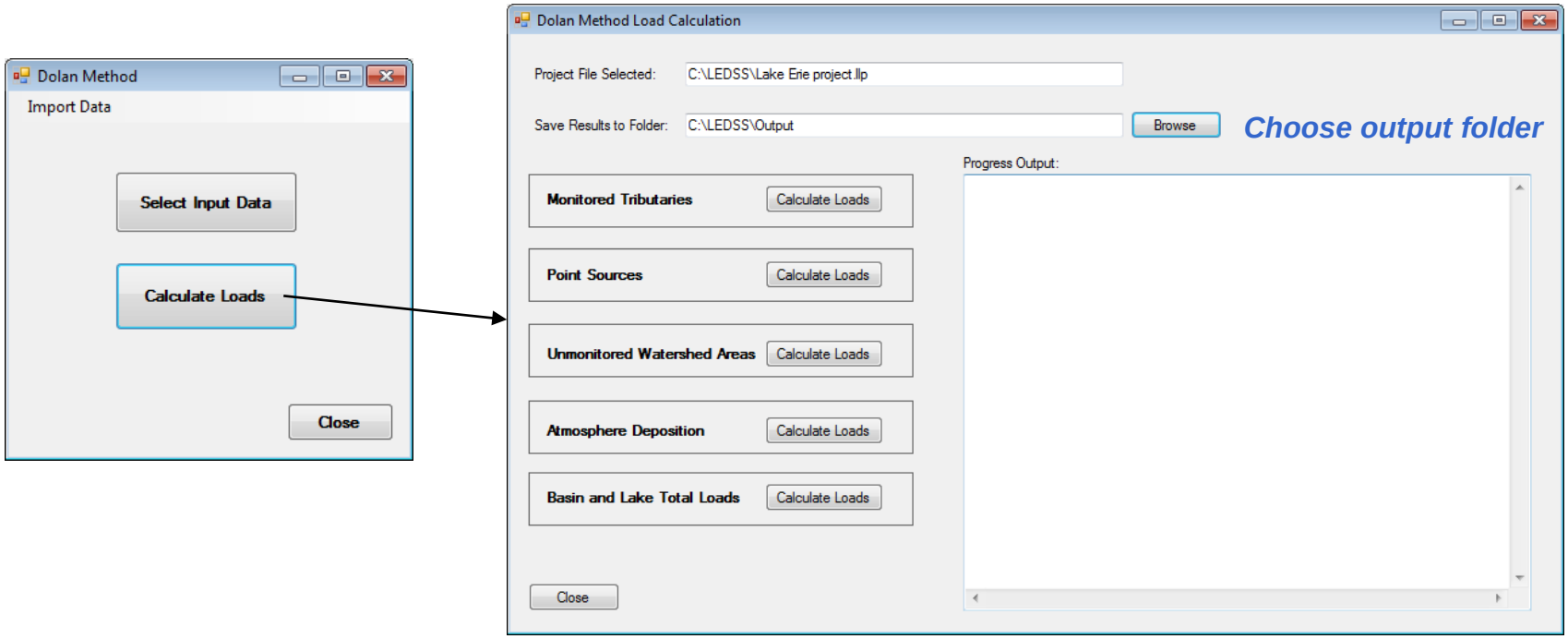
Loading Estimate Decision Support System Demo

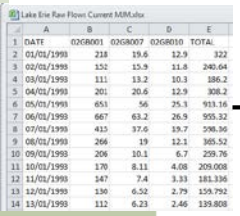


Loading Estimate Decision Support System
Monitored Tributaries (Stratified Beale Ratio)

Inputs — Program Execution — Outputs

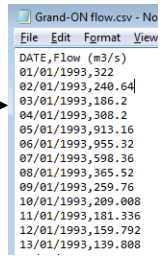
Grand-ON flow data

Original data file



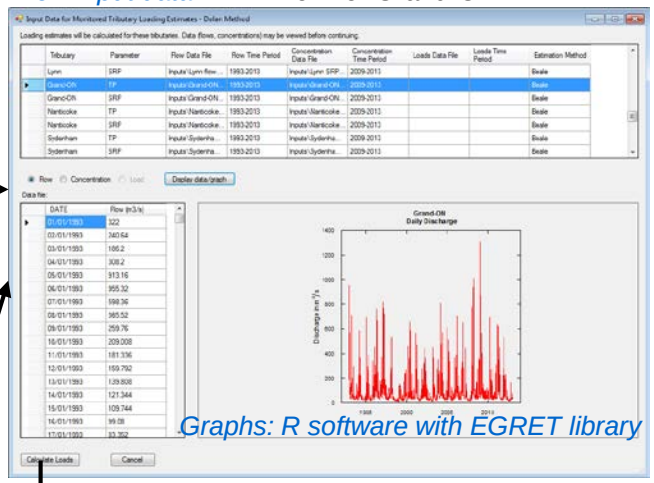
convert

csv file for DSS



View input data

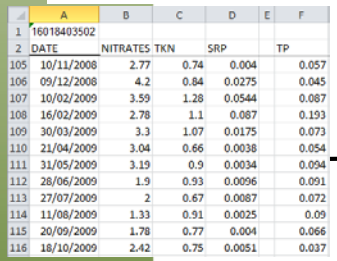
Flow for Grand-ON



Graphs: R software with EGRET library

Grand-ON concentration data

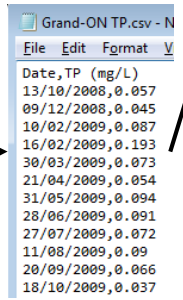
Original data file



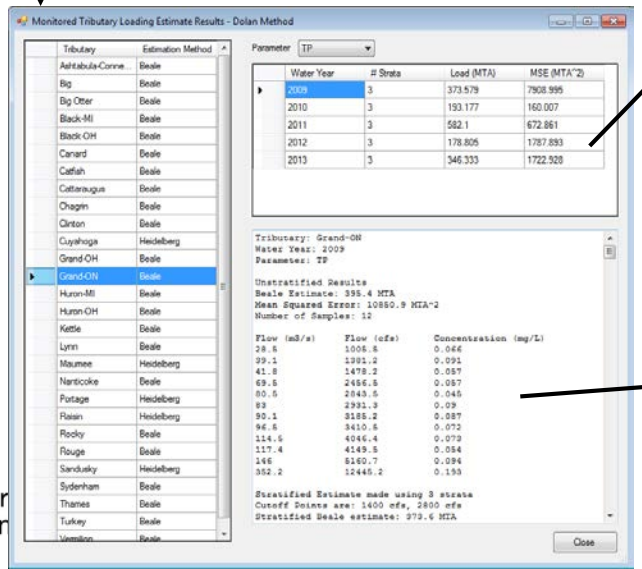
convert

csv file for DSS

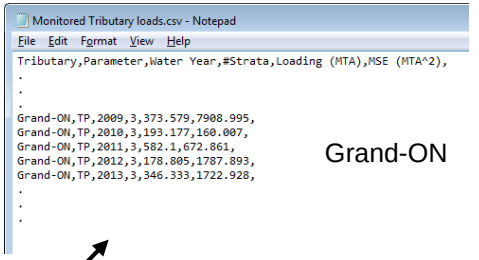
TP



Calculate monitored tributary loads and view results

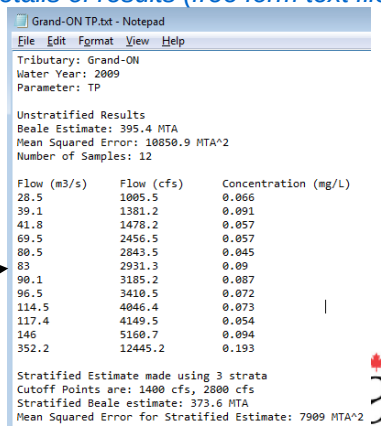


Annual loads for tributaries (csv file)



Grand-ON

Details of results (free form text file)



Data files converted into csv format using external program such as Excel

Environment and Climate Change Canada

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Loading Estimate Decision Support System
Monitored Tributaries (Heidelberg)

Inputs — Program Execution — Outputs

Original data file

Maumee daily loads

Maumee loads_updated to WY2013.xlsx

	A	B	C	D	E	F	G	H	I
1	Date	Month	Date 2	Maumee discharge (million cubic meters)	Maumee SS Load (tonnes)	SS Remark	Maumee TP Load (tonnes)	TP Remark	Maumee SRP Load (tonnes)
12421	10/01/2008	418	Oct-2008	0.861	21.3		0.109		0.004
12422	10/02/2008	418	Oct-2008	0.651	16.0		0.071		0.004
12423	10/03/2008	418	Oct-2008	0.487	8.6		0.043		0.002
12424	10/04/2008	418	Oct-2008	0.619	10.8		0.051		0.002
12425	10/05/2008	418	Oct-2008	0.663	12.4		0.055		0.002
12426	10/06/2008	418	Oct-2008	0.587	17.9		0.061		0.004
12427	10/07/2008	418	Oct-2008	0.565	15.2		0.055		0.005
12428	10/08/2008	418	Oct-2008	0.817	16.0		0.076		0.007
12429	10/09/2008	418	Oct-2008	0.810	16.7		0.082		0.005
12430	10/10/2008	418	Oct-2008	0.568	9.8		0.046		0.002
12431	10/11/2008	418	Oct-2008	0.553	15.2		0.060		0.002
12432	10/12/2008	418	Oct-2008	0.710	19.9		0.087		0.003
12433	10/13/2008	418	Oct-2008	0.673	15.0		0.073		0.005
12434	10/14/2008	418	Oct-2008	0.673	16.9		0.078		0.005
12435	10/15/2008	418	Oct-2008	0.548	14.2		0.075		0.003
12436	10/16/2008	418	Oct-2008	1.030	26.6		0.138		0.004
12437	10/17/2008	418	Oct-2008	1.084	27.9		0.142		0.004
12438	10/18/2008	418	Oct-2008	0.986	21.9		0.121		0.003
12439	10/19/2008	418	Oct-2008	1.311	53.2		0.173		0.003
12440	10/20/2008	418	Oct-2008	1.006	27.2		0.126		0.005
12441	10/21/2008	418	Oct-2008	1.050	24.0		0.104		0.005

convert

Maumee TP loads

csv file for DSS

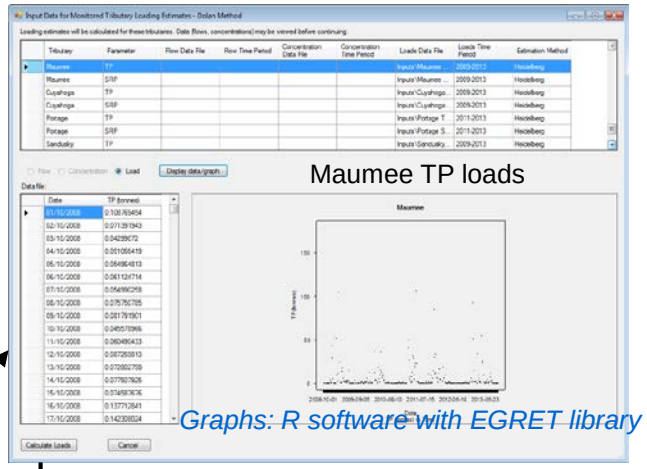
Maumee TP loads.csv - Notepad

File Edit Format View Help

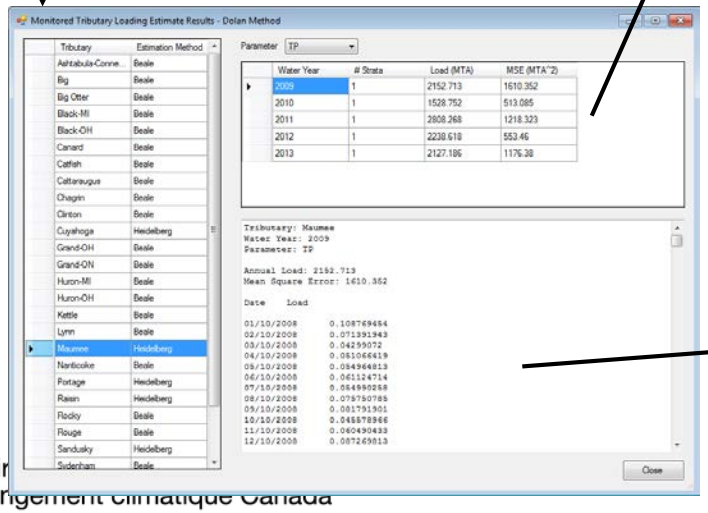
```
Date,TP (tonnes)
01/10/2008,0.108769454
02/10/2008,0.071391943
03/10/2008,0.04299072
04/10/2008,0.051066419
05/10/2008,0.054964813
06/10/2008,0.061124714
07/10/2008,0.054990258
08/10/2008,0.075750785
09/10/2008,0.081791901
10/10/2008,0.045578966
11/10/2008,0.060490433
12/10/2008,0.087269813
13/10/2008,0.072802799
14/10/2008,0.077507925
15/10/2008,0.074587676
16/10/2008,0.137712841
17/10/2008,0.142308024
18/10/2008,0.120880557
```

Data files converted into csv format using external program such as Excel

View input data



Sum up daily loads of monitored tributaries in water year and view results



Annual loads from tributaries (csv file)

Monitored Tributary loads.csv - Notepad

File Edit Format View Help

```
Tributary,Parameter,Water Year,#Strata,Loading (MTA),MSE (MTA^2),
.
.
.
Maumee,TP,2009,1,2152.713,1610.352,
Maumee,TP,2010,1,1528.752,513.085,
Maumee,TP,2011,1,2808.268,1218.323,
Maumee,TP,2012,1,2238.618,553.46,
Maumee,TP,2013,1,2127.186,1176.38,
.
.
.
```

Maumee

Details of results (free form text file)

Maumee TP.txt - Notepad

File Edit Format View Help

```
Tributary: Maumee
Water Year: 2009
Parameter: TP

Annual Load: 2152.713
Mean Square Error: 1610.352

Date    Load

01/10/2008      0.108769454
02/10/2008      0.071391943
03/10/2008      0.04299072
04/10/2008      0.051066419
05/10/2008      0.054964813
06/10/2008      0.061124714
07/10/2008      0.054990258
08/10/2008      0.075750785
09/10/2008      0.081791901
10/10/2008      0.045578966
11/10/2008      0.060490433
12/10/2008      0.087269813
13/10/2008      0.072802799
14/10/2008      0.077507925
15/10/2008      0.074587676
```

Environment Canada / Changement climatique Canada

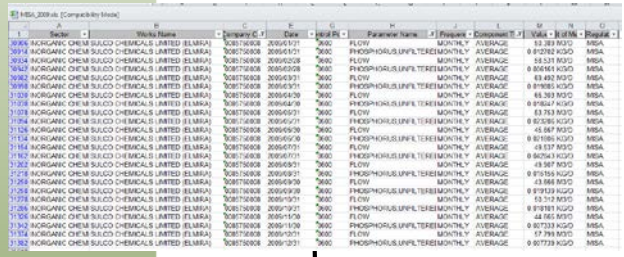
Loading Estimate Decision Support System
Point Sources

Inputs — Program Execution — Outputs

Point source effluents
(monthly average flows and concentrations or loads)

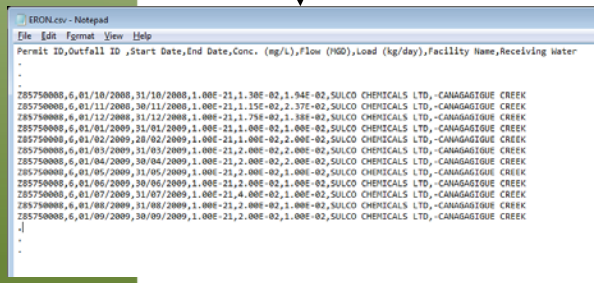
Original data file
(multiple facilities)

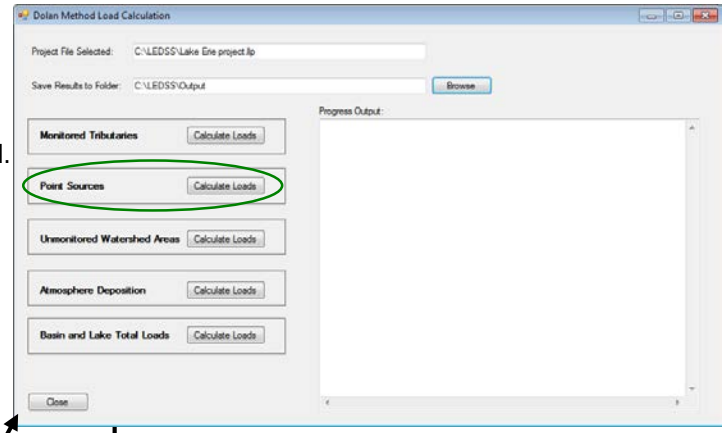
Industry: Sulco Chemicals Ltd.



convert

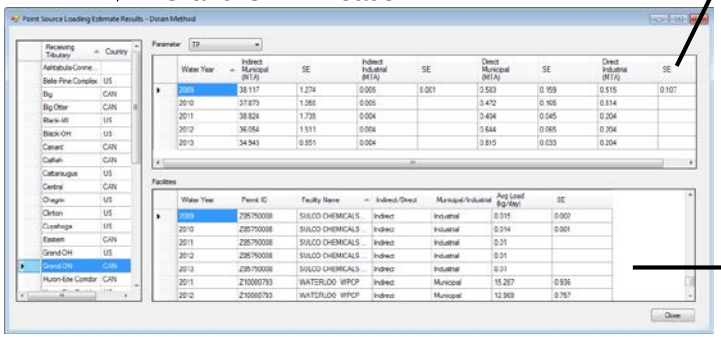
csv file for DSS
(multiple facilities)



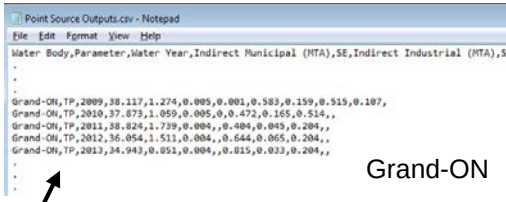


Calculate point source loads and view results

Grand-ON TP loads

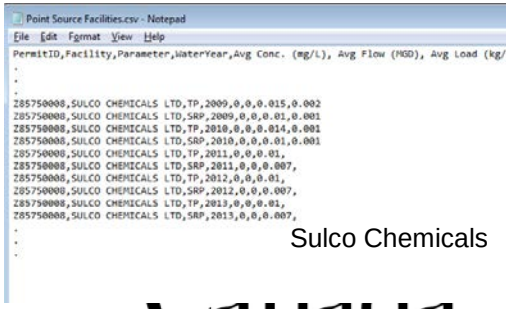


Annual loads from all point sources for each tributary (csv file)



Grand-ON

Average daily loads at individual point sources (csv file)



Sulco Chemicals

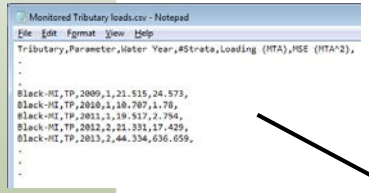
Function available in DSS to import point source data into required csv format.

Loading Estimate Decision Support System
Unmonitored Watershed Areas (Unit Area Load)

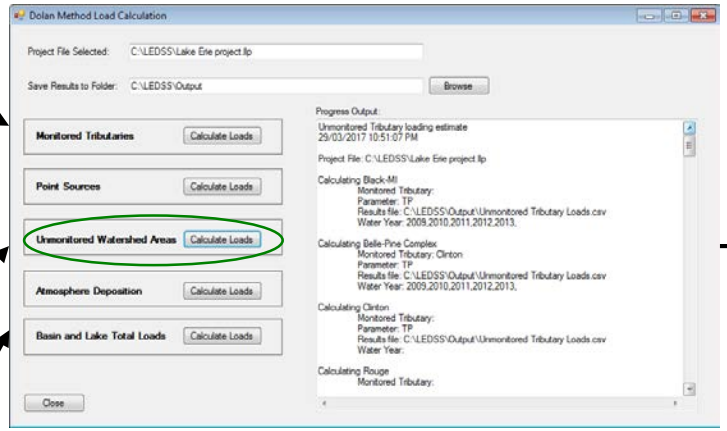
Inputs — Program Execution — Outputs

Annual loads for monitored tributaries calculated by DSS

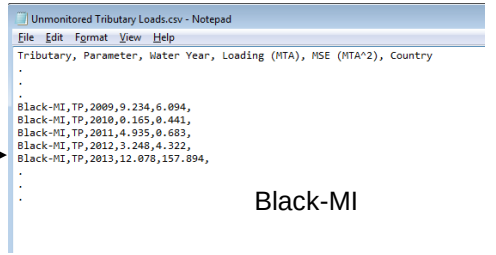
Black-MI TP loads



Calculate unmonitored watershed area loads



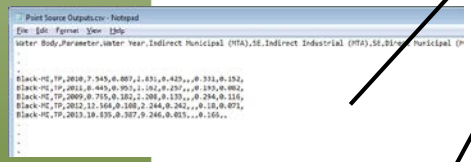
Annual loads for unmonitored watershed areas (csv file)



Black-MI

Annual loads from indirect point sources calculated by DSS

TP point source loads for Black-MI



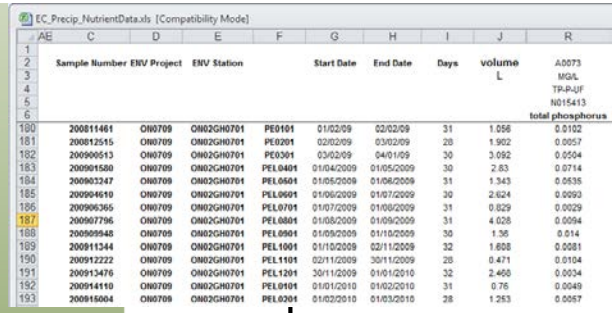
Areas of monitored and unmonitored watersheds

Loading Estimate Decision Support System
Atmospheric Deposition

Inputs — Program Execution — Outputs

Monthly precipitation volumes and TP concentrations

Original data file — Point Pelee



convert

csv file for DSS

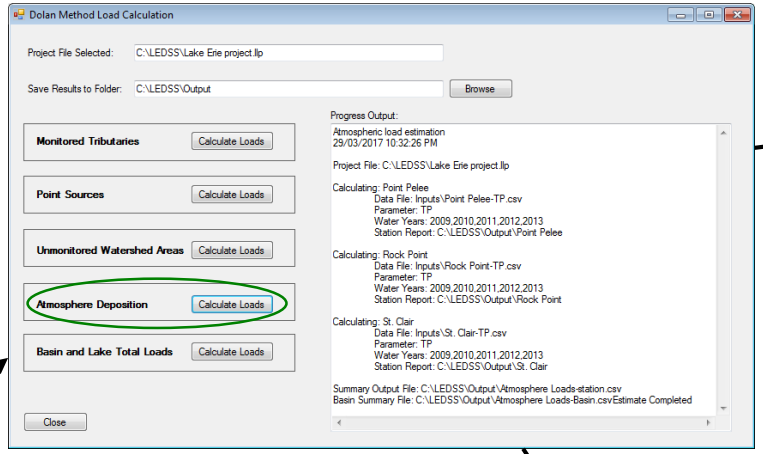
Point Pelee

Point Pelee-TP.csv - Notepad

File Edit Format View Help

```
Year,Month,Volume (L),TP (mg/L)
2009,1,1.056,0.0102
2009,2,1.902,0.0057
2009,3,3.092,0.0504
2009,5,1.343,0.0535
2009,6,2.624,0.0093
2009,7,0.829,0.0029
2009,8,4.028,0.0094
2009,9,1.36,0.014
2009,10,1.608,0.0081
2009,11,0.471,0.0104
2009,12,2.468,0.0034
2010,1,0.76,0.0049
2010,2,1.253,0.0057
2010,3,1.38,0.002
2010,4,3.349,0.0129
2010.5.3.159.0.0091
```

Calculate atmospheric deposition loads



Annual loads for basins (csv file)

Atmosphere Loads-Basin.csv - Notepad

File Edit Format View Help

```
Basin,Year,Parameter,Load (MTA), Std Error (MTA)
.
.
.
Huron-Erie Corridor,2009,TP,41.229,36.11
Huron-Erie Corridor,2010,TP,26.1,21.04
Huron-Erie Corridor,2011,TP,34.787,21.532
Huron-Erie Corridor,2012,TP,19.463,12.092
Huron-Erie Corridor,2013,TP,35.641,35.391
Western,2009,TP,89.037,53.066
Western,2010,TP,56.365,30.918
Western,2011,TP,75.125,31.643
Western,2012,TP,42.031,17.769
Western,2013,TP,76.97,52.009
Central,2009,TP,372.303,108.511
Central,2010,TP,235.684,63.224
Central,2011,TP,314.127,64.705
Central,2012,TP,175.75,36.335
Central,2013,TP,321.843,106.351
Eastern,2009,TP,148.765,68.592
.
.
.
```

Lake Erie basins

Annual loads at monitoring stations (csv file)

Atmosphere Loads-station.csv - Notepad

File Edit Format View Help

```
Station,Year,Parameter,Load (MTA), Std Error (MTA^2), # Samples
.
.
.
Point Pelee,2009,TP,222.529,92.36,11
Point Pelee,2010,TP,80.653,24.461,12
Point Pelee,2011,TP,263.858,76.729,12
Point Pelee,2012,TP,109.514,29.471,12
Point Pelee,2013,TP,167.367,84.775,11
.
.
.
```

Point Pelee

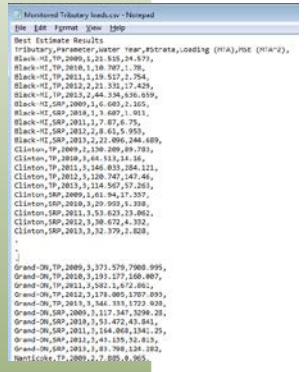
Data files converted into csv format using external program such as Excel

Loading Estimate Decision Support System
Basin and Lake Total Loads

Inputs

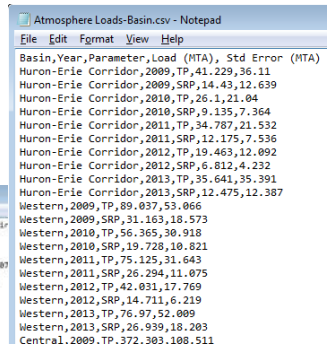
All annual loads calculated by DSS

Monitored tributaries

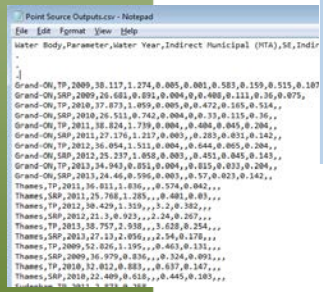


Unmonitored watershed areas

Atmospheric Deposition



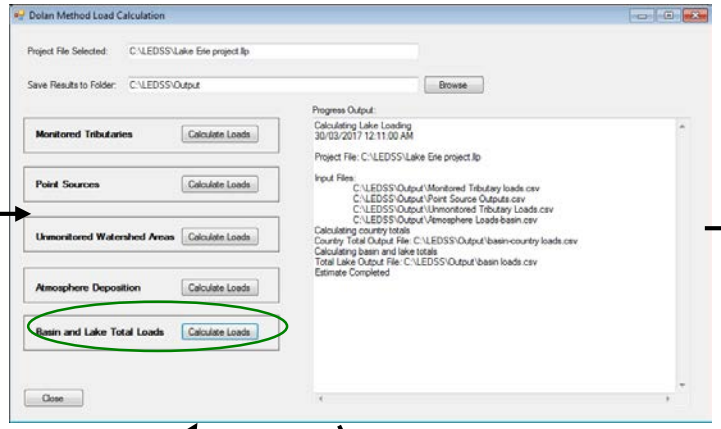
Point sources



Loads from Upstream Great Lakes

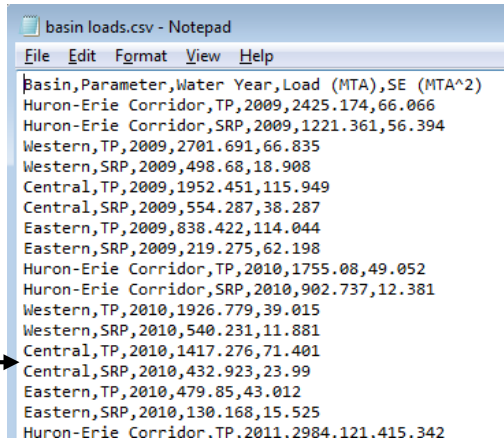
Program Execution

Sum up loads from all sources by basin, country, lake

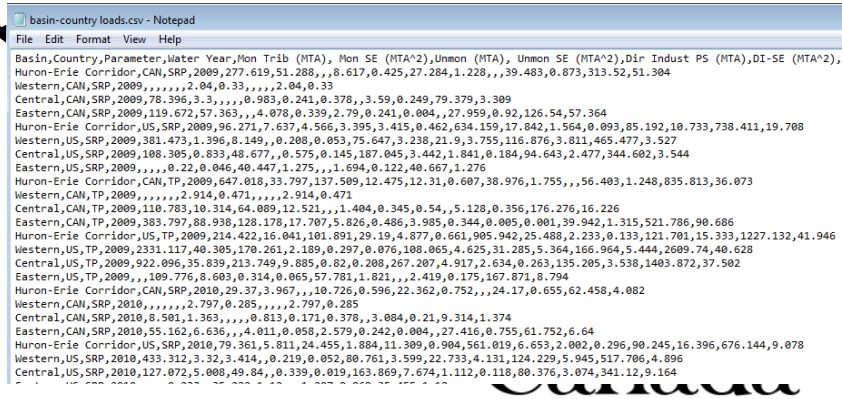


Outputs

Basin and lake total annual loads from all sources (csv file)



Basin and lake annual loads from each individual source (csv file)



Loading Estimate Decision Support System Implementation Issues

- After initial round of beta testing of DSS, discrepancies in some results were discovered
- Implementation is our interpretation of Dolan Method based on Maccoux *et al.,* (2016)

1. <u>Monitored tributaries:</u> When calculating loads using Stratified Beale Ratio Estimator, there were cases where the DSS used different flow cutoff values and/or number of strata compared to Maccoux *et al.*, (2016).

Examples: Black-MI in 2013

	# of strata	TP Load (MTA)	MSE (MTA^2)
Maccoux	1	49	709
DSS	2	44 (-10%)	637 (-10%)

Sydenham in 2013

	# of strata	Flow cutoff (cfs)	TP Load (MTA)	MSE (MTA^2)
Maccoux	2	400	90	1100
DSS	2	300	88 (-2%)	1085 (-1%)

If we have detail information on the algorithms from Dolan program used by Maccoux *et al.*, (2016) to compute flow cutoff values and to choose number of strata, then issue can be resolved.

Loading Estimate Decision Support System Implementation Issues (continued)

2. Point sources: Differences in assigning point sources to tributaries and/or categorizing them as indirect or direct. This process was performed manually using a GIS by visual inspecting point source locations in relation to tributaries and water quality monitoring stations.

   Example: Huron-MI in 2011

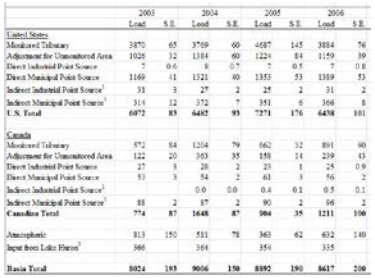
	Indirect Municipal (MTA)	Indirect Industrial (MTA)
Maccoux	27.95	0.17
DSS	33.06 (18%)	0.13 (-23%)

   Note that differences in aggregated loads from multiple point sources can be large. If the same tributary and indirect/direct assignments from Maccoux *et al.*, (2016) were used, then differences can be resolved.

2. Heidelberg data: Annual mean square errors (MSEs) were not computed by DSS, but were obtained from Maccoux *et al.*, (2016) data files. For future years, MSEs need to be provided or calculation method needs to be known. Also for future years, daily loads need to be provided since these were not calculated by the DSS.

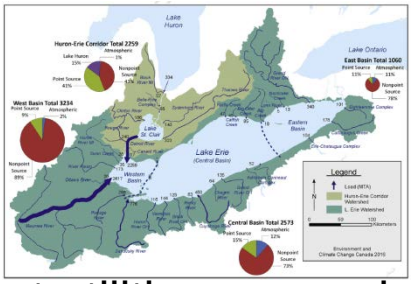
Loading Estimate Decision Support System Next Steps

- Refine implementation of Dolan Method in DSS to reduce differences in results
- Implement visualization of results
  - Tables: annual loads from individual sources (or all aggregated) by tributary, basin, lake, country



	2003		2004		2005		2006	
	Load	S.E.	Load	S.E.	Load	S.E.	Load	S.E.
United States								
Monitored Tributary	3870	65	3769	60	4687	145	3884	76
Adjustment for Unmonitored Area	1026	32	1384	60	1224	84	1159	39
Direct Industrial Point Source	7	0.6	8	0.7	7	0.5	7	0.8
Direct Municipal Point Source	1169	41	1321	40	1353	53	1389	53
Indirect Industrial Point Source[1]	33	3	27	2	25	2	31	2
Indirect Municipal Point Source[1]	314	12	272	7	351	6	366	8
U.S. Total	6072	83	6482	93	7371	176	6438	101
Canada								
Monitored Tributary	872	84	1264	79	662	32	891	90
Adjustment for Unmonitored Area	122	20	363	35	158	14	239	43
Direct Industrial Point Source	27	3	28	2	25	1	25	0.9
Direct Municipal Point Source	53	3	54	2	61	3	56	2
Indirect Industrial Point Source[1]			0.0	0.0	0.4	0.1	0.5	0.1
Indirect Municipal Point Source[1]	88	2	87	2	90	2	96	2
Canadian Total	774	87	1648	87	994	35	1211	100
Atmospheric	813	150	531	78	363	62	632	140
Input from Lake Huron[2]	366		364		354		335	
Basin Total	8024	193	9006	150	8992	190	8617	200

  - Maps and graphs



- Implement data import utilities as required

Summary

- ECCC is monitoring in the Huron-Erie corridor, priority Canadian tributaries to Lake Erie, nested monitoring in the Thames River watershed, Lake St. Clair with MOECC, and in the Great Lakes
- Loadings estimates based on Dolan approach, with 50-100 samples collected per location per water year
- LEDSS will be a publically available tool, modernizing the Dolan approach using AI and a user-friendly interface
- ECCC is working with partners to ensure data comparability and is supporting watershed and lake modeling initiatives with enhanced data