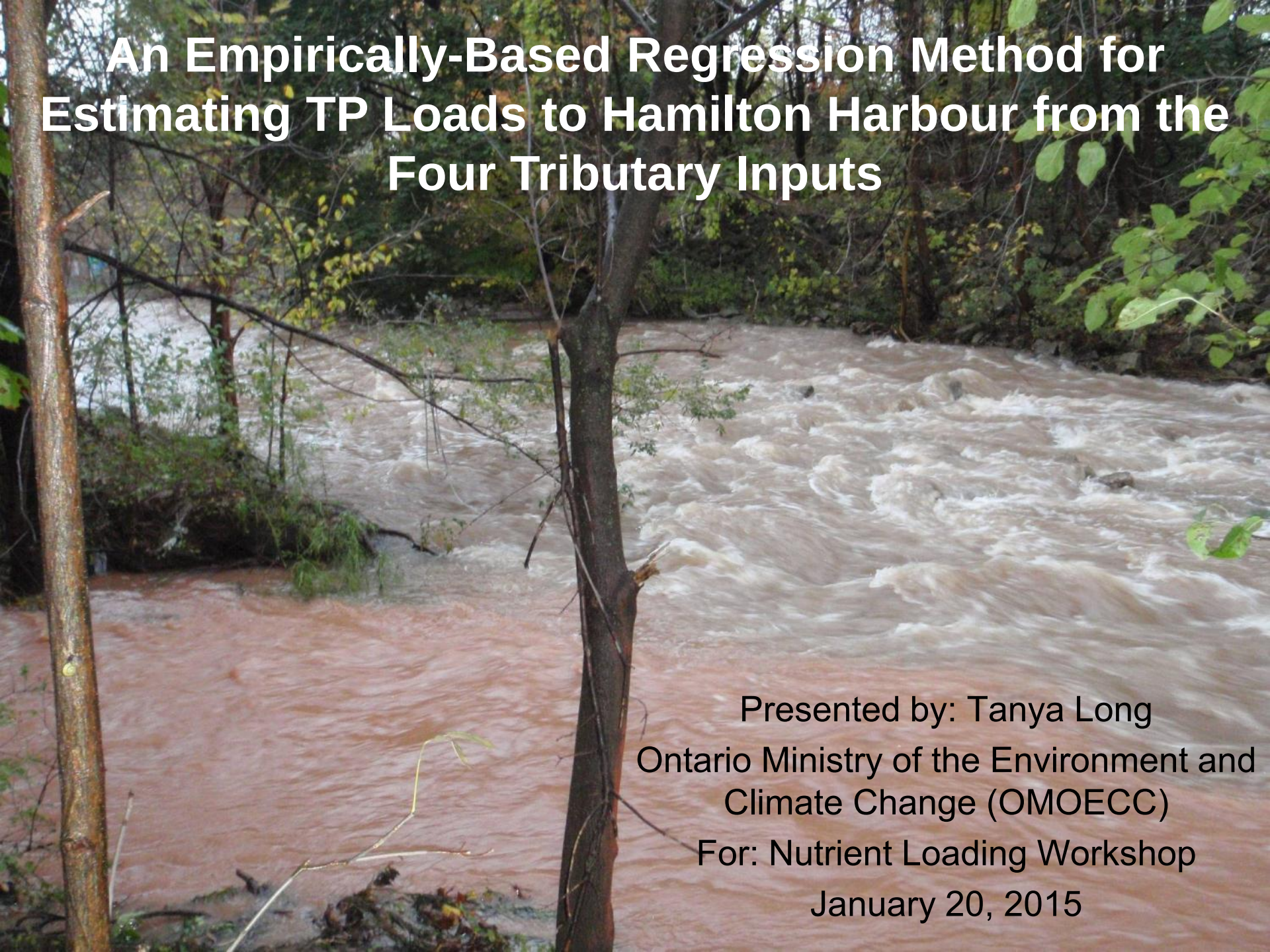
An Empirically-Based Regression Method for Estimating TP Loads to Hamilton Harbour from the Four Tributary Inputs



Presented by: Tanya Long

Ontario Ministry of the Environment and Climate Change (OMOECC)

For: Nutrient Loading Workshop

January 20, 2015

Overview

- Project Objectives
- Description of Data
- Description of Approach
- Rationale for Choosing Methodology
- Results
- Context of Results with other Studies
- What expertise and how much effort were required to collect the data and obtain the results?
- Project Outcomes
- Challenges and Limitations
- Knowing what you know now, what would you have done differently?
- Acknowledgments

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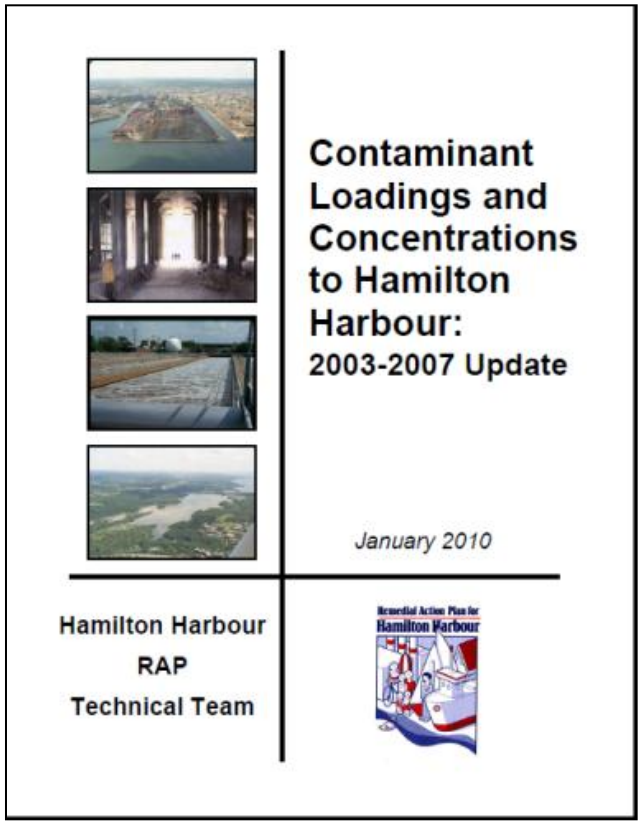
Project Objectives

- Project goal: to reduce uncertainty in total phosphorus (TP) loading estimates for the 4 tributaries to Hamilton Harbour
- HH RAP Loading Report: TP loads based on data 20+ years old & questionable method (Draper method)
- Hamilton Harbour Remedial Action Plan (HH RAP) has a TP goal of 20 ug/L for Hamilton Harbour – what is the role of the watersheds in the ability to obtain this goal?
- Desire to delist the Beneficial Use Impairment (BUI) *Eutrophication or Undesirable Algae*



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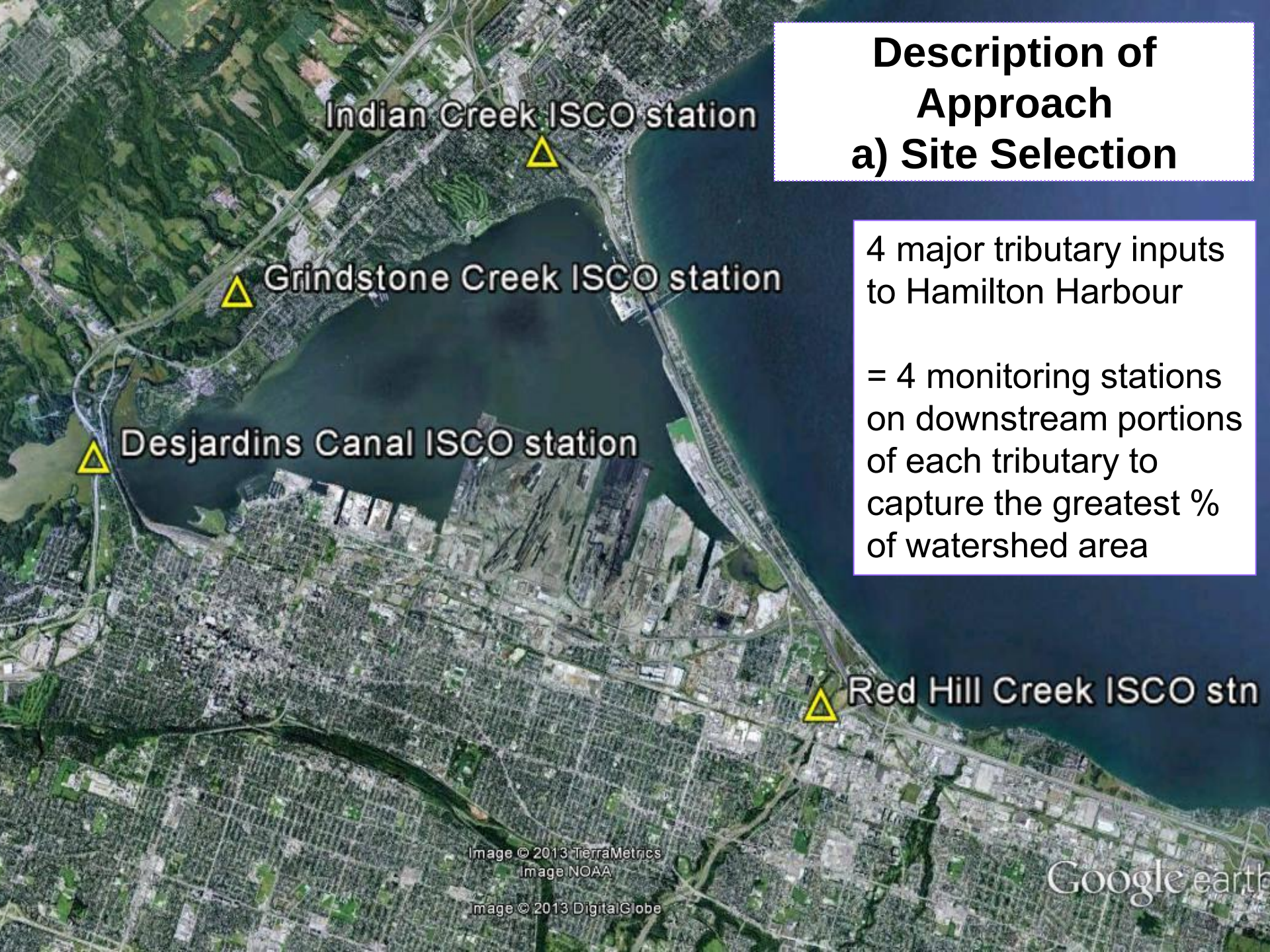
Description of Data

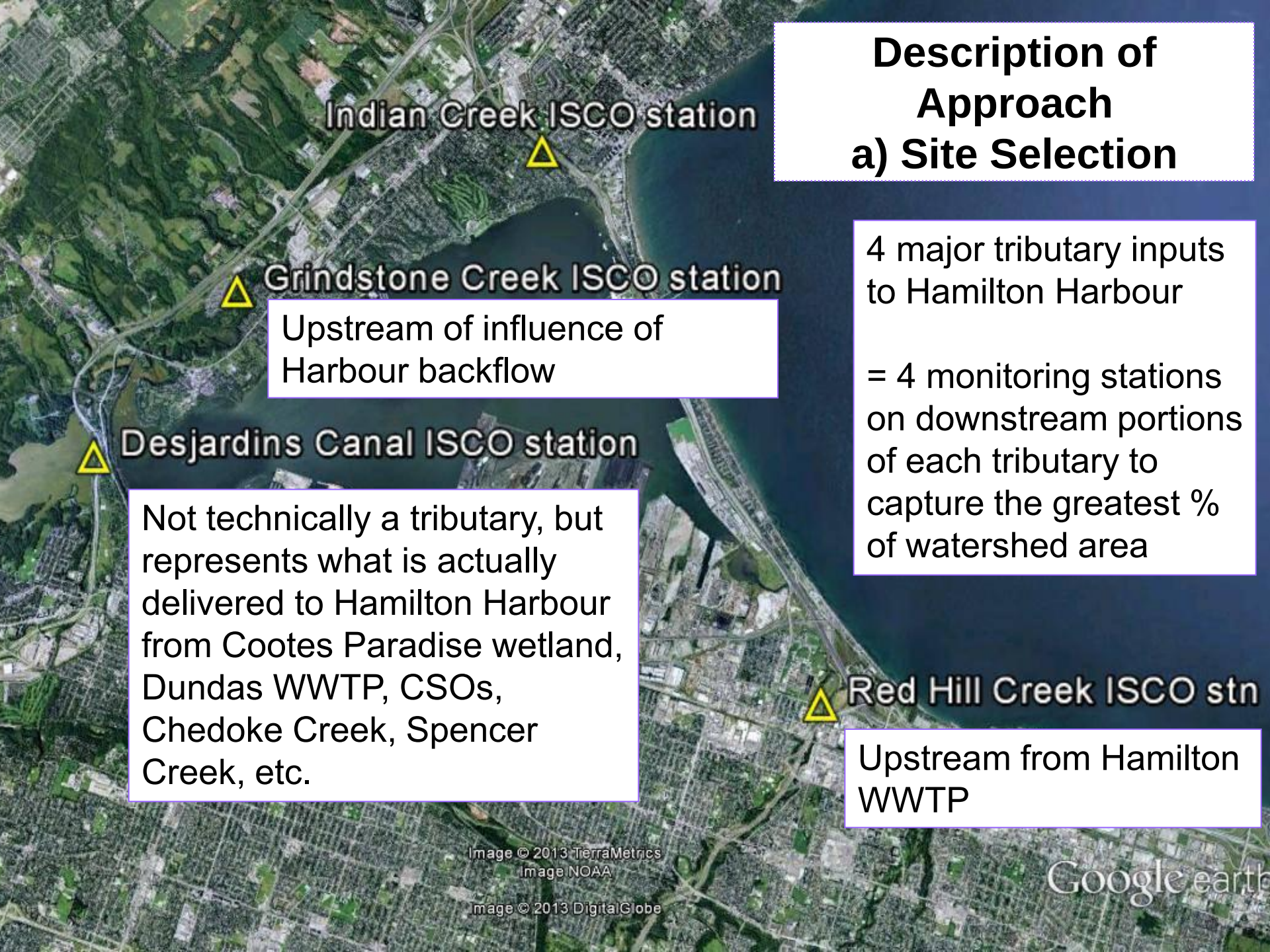
- Discharge data for 2 stations from Water Survey of Canada (WSC) Hydat Flow Stations; other 2 stations, discharge data based on regressions with other WSC Hydat stations
- Nutrient concentration data were specifically collected for this project; Why?
  - 2 /4 tribs: little to no existing data
  - 2 /4 tribs: only existing data from Provincial Water Quality Monitoring Network (PWQMN)(only 8 /12 months of year, mostly baseflow data)
  - Loading study required recent, event-based data for all seasons (& baseflow data for missing winter season)



Description of Approach
a) Site Selection

4 major tributary inputs to Hamilton Harbour

= 4 monitoring stations on downstream portions of each tributary to capture the greatest % of watershed area



Description of Approach
a) Site Selection

4 major tributary inputs to Hamilton Harbour

= 4 monitoring stations on downstream portions of each tributary to capture the greatest % of watershed area

Upstream of influence of Harbour backflow

Not technically a tributary, but represents what is actually delivered to Hamilton Harbour from Cootes Paradise wetland, Dundas WWTP, CSOs, Chedoke Creek, Spencer Creek, etc.

Upstream from Hamilton WWTP

Description of Approach
a) Site Selection

Downstream of Hagar-Rambo & Indian Creek confluence

Description of Approach
b) Sample Collection

- ISCO automated samplers used to capture peak flows during rain & snow melt events (& baseflow)
- 87 “events” sampled from July 2010 - May 2012
- ISCOs sampled 1x/hr for 24 hrs for each “event”
- For each “event”, 24-hour level-weighted composite sample submitted→ Excel spreadsheet template
- For select events, key hourly grab samples submitted (rising limb, peak, falling limb)
- Samples submitted for total suspended solids (TSS), nutrients (P & N species), heavy metals, DOC/DIC, silicates, chloride

Anatomy of the ISCO Monitoring Station

Telephone connection (cell/land line)

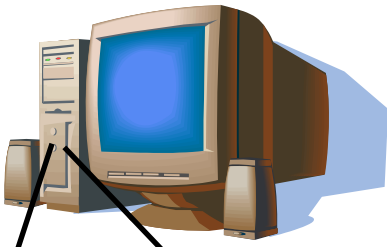
Metal hut

Electrical connection (ISCOs, heaters & heat trace lines)

ISCO (model #6712) with level bubbler module (model #730)

Intake & heat trace lines

56K Modem & Analog phone line



Flowlink

-level data

Hyperterminal

-program ISCO

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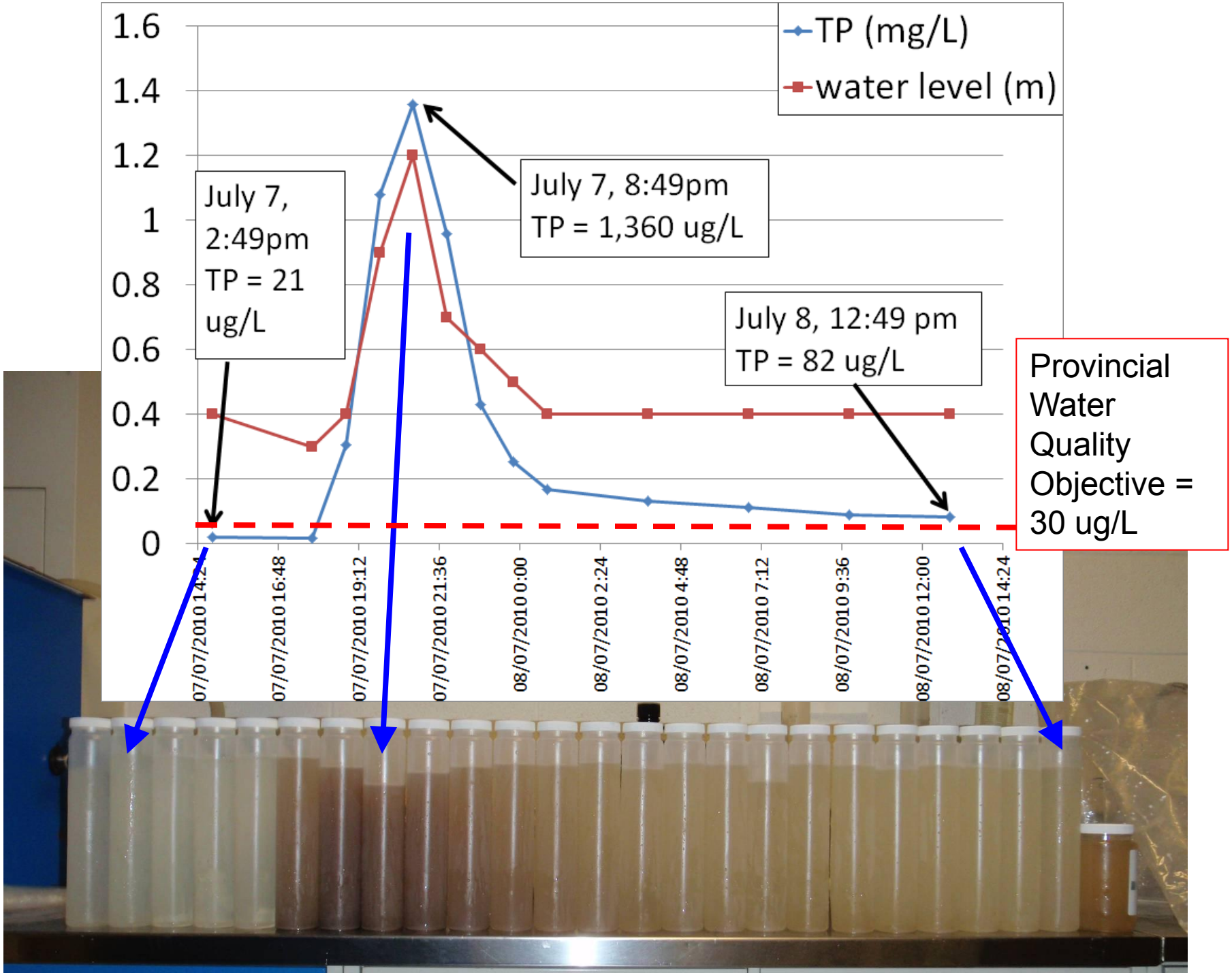
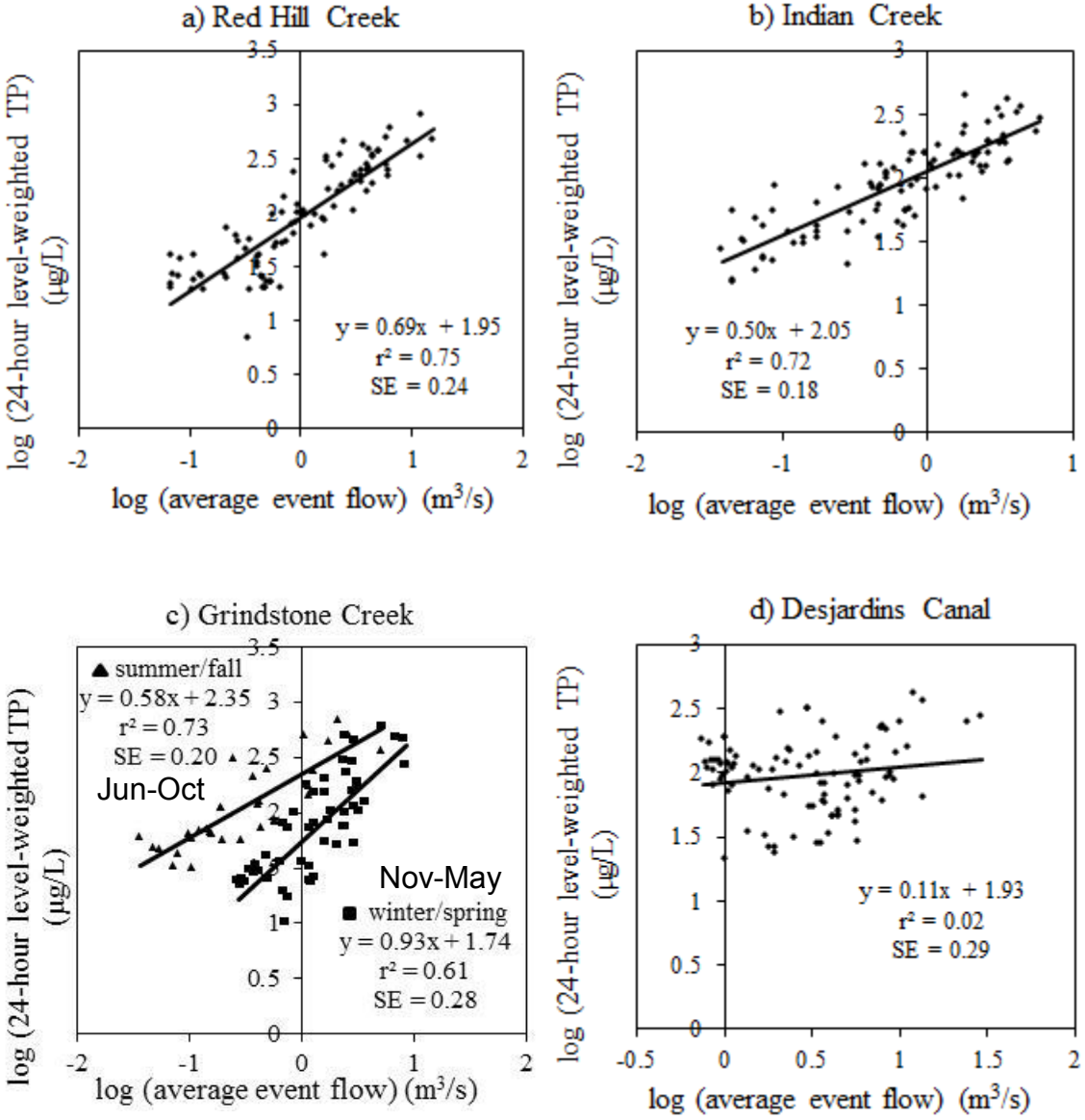

TP (mg/L)
water level (m)
July 7, 2:49pm TP = 21 ug/L
July 7, 8:49pm TP = 1,360 ug/L
July 8, 12:49 pm TP = 82 ug/L
Provincial Water Quality Objective = 30 ug/L
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
07/07/2010 16:48
07/07/2010 19:12
07/07/2010 21:36
08/07/2010 0:00
08/07/2010 2:24
08/07/2010 4:48
08/07/2010 7:12
08/07/2010 9:36
08/07/2010 12:00
08/07/2010 14:24

Description of Approach
c) Loading Estimation



- 24-hour level-weighted composite samples used in a regression-based approach
- To address re-transformation bias, Ferguson (1987) correction applied to all log-log regressions:

$$Load_{corrected} = L_{regression} \exp(2.651\ SE^2)$$

- Threshold of $r^2 > 0.5$ (Quilbé et al., 2006; Macrae et al., 2007; Moatar and Meybeck, 2005; Booty et al., 2013)
- Desjardins Canal needed a different loading estimation approach

Long et al., submitted JGLR

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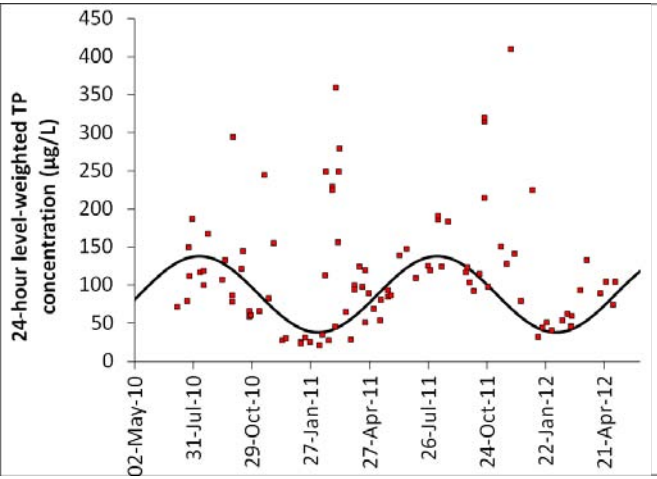
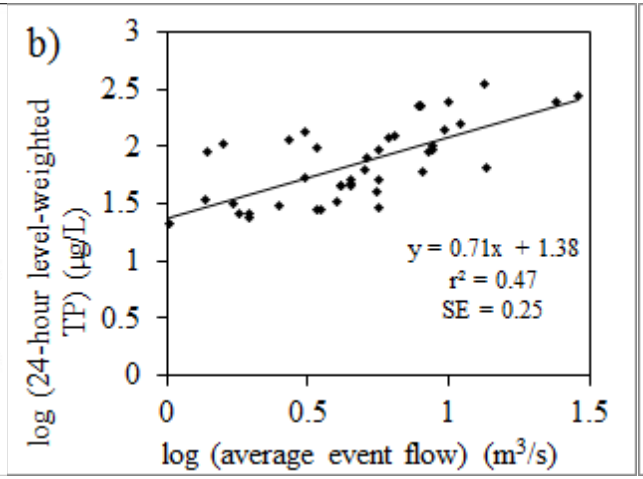
For the Desjardins Canal, daily average TP concentrations for 2008 to 2012 were estimated through a series of 3 empirically-derived equations based on data collected July 2010 – May 2012 in this study:

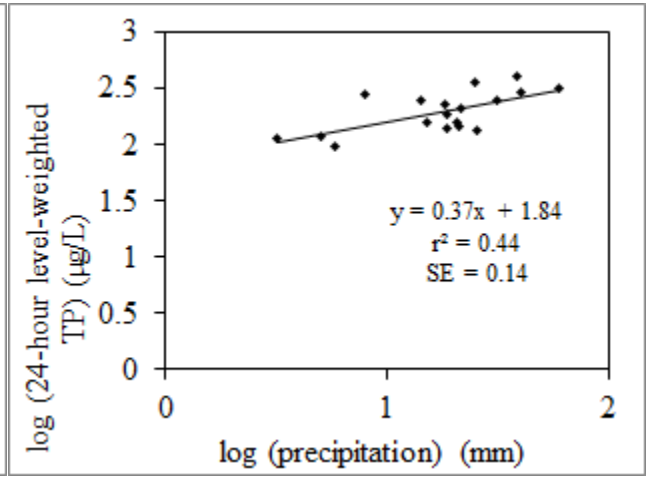
(1) a sine wave equation for May to Nov (for days w/ precip < 15mm);

(2) a TP conc-flow regression for Dec to Apr (for days w/ precip < 15mm);

(3) a TP concentration-precip regression for all days with precip > 15mm







- Background wetland processes
- Spring freshet
- CSO events

Long et al., submitted JGLR

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Rationale for choosing methodology

a) sample collection

- level-weighted samples ideal for loading estimation
- 24 hours was (usually) enough to capture full hydrograph
- autosamplers needed for capturing off-hours

b) loading estimation

- Goal was a simple loading method for future use by the Hamilton Harbour Remedial Action Plan
- Regression approach: only need Excel, WSC flow data, precip data
- Strong regressions were formed!
- Also considered stratified Beale ratio, LOADEST, Load Runner

Ontario

Results

- TP concentrations during high flow events did not vary spatially or seasonally
- Nutrient concentrations generally increased with flow except nitrate at two stations
- Nitrate and ammonia concentrations were elevated during an unseasonably cold winter
- In urban watersheds, nitrate and phosphate was highest during fall/winter
- In the agricultural watershed, nitrate and phosphate was highest during summer

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Evaluation of stormwater and snowmelt inputs, land use and seasonality on nutrient dynamics in the watersheds of Hamilton Harbour, Ontario, Canada

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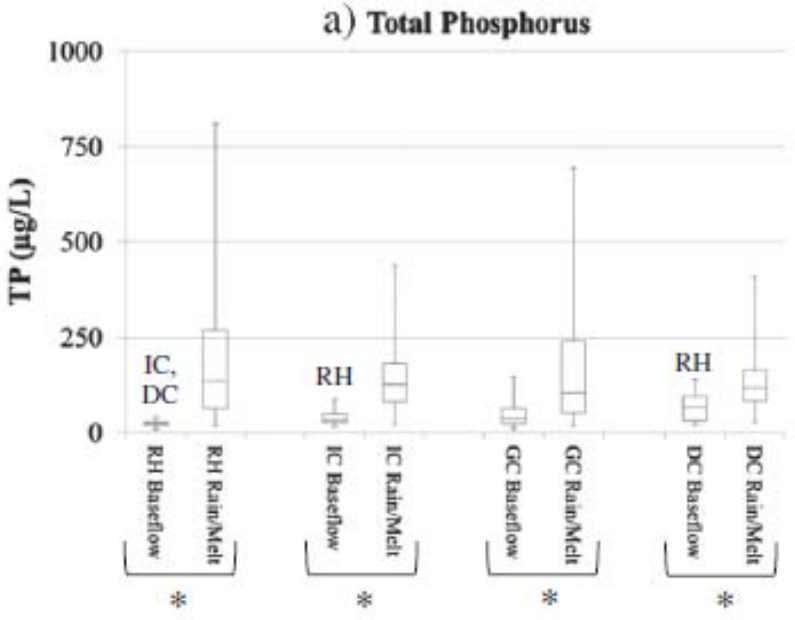
[c] Ecological Modelling Laboratory, Department of Physical & Environmental Sciences, University of Toronto, Toronto, ON M1C 1A4, Canada



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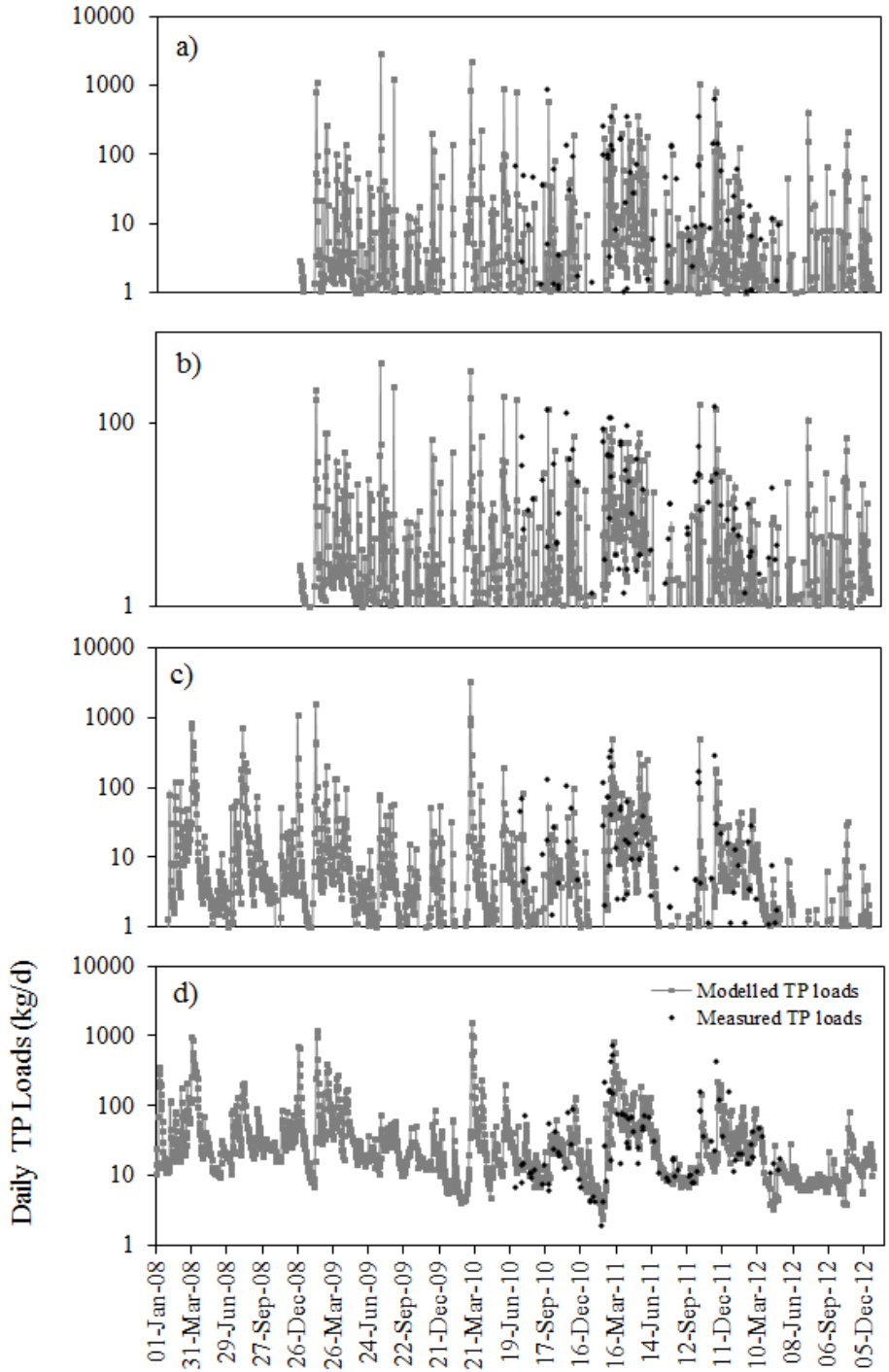

Red Hill Creek

Model performance: NSE=0.82; r^2=0.85
Measured daily TP loads: 0.1 - 841 kg/d
89% of TP load in 10% of time

Indian Creek

Model performance: NSE=0.86, r^2=0.86
Measured daily TP loads: 0.1 – 152 kg/d
73% of TP load in 10% of time

Grindstone Creek

Model performance: NSE=0.76, r^2=0.80
Measured daily TP loads: 0.2 – 334 kg/d
78% of TP load in 10% of time

Desjardins Canal

Model performance: NSE=0.91, r^2=0.91
Measured daily TP loads: 1.8 – 704 kg/d
52% of TP load in 10% of time

Long et al., submitted JGLR

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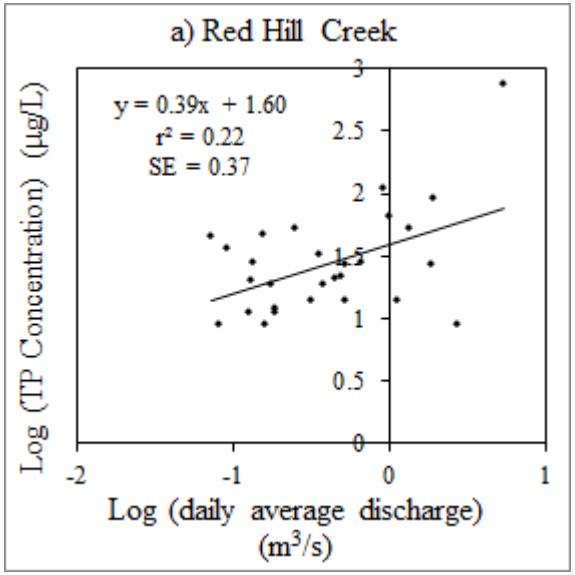
Comparison of TP Loads Estimated Through 3 Methods

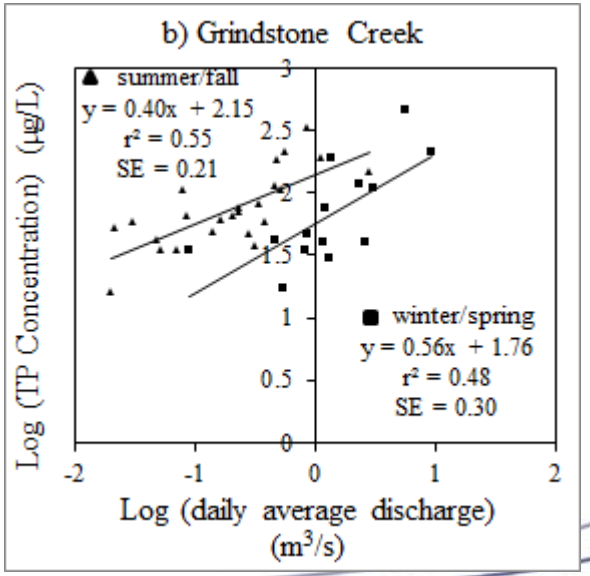
1. [TP]-flow regressions based on event-based monitoring data collected July 2010-May 2012

2. [TP]-flow regressions based on PWQMN data collected 2008-2012 (Red Hill Creek and Grindstone Creek only)

3. HH RAP methods
- Tributaries: [TP] applied to 2-3 pre-defined flow strata (RH & GC only)
- Cootes: [summer TP] * flow into Cootes

PWQMN regressions





Long et al., submitted JGLR

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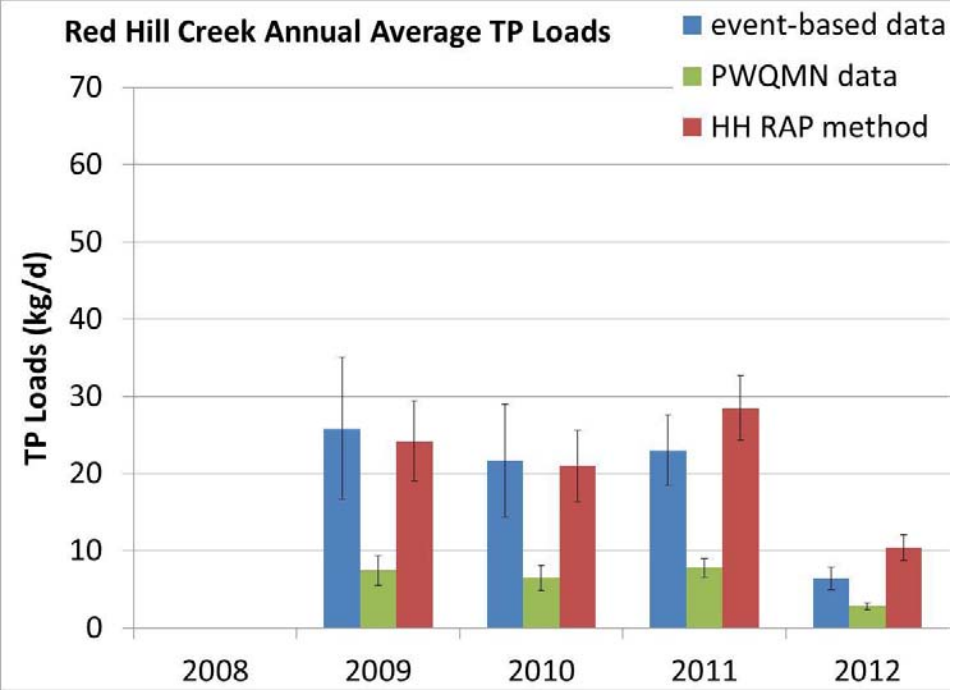
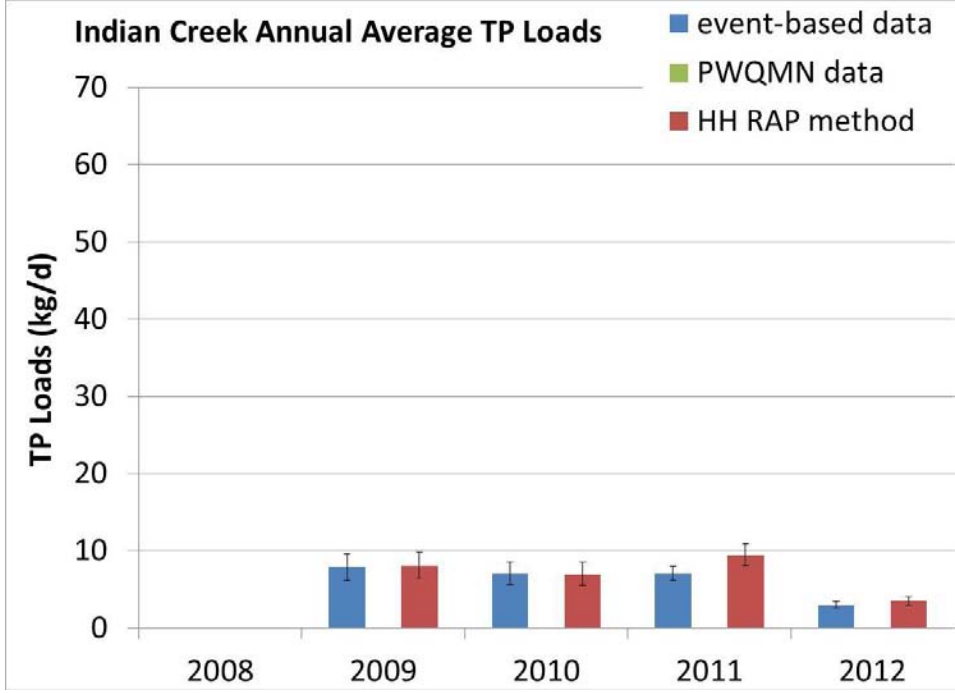
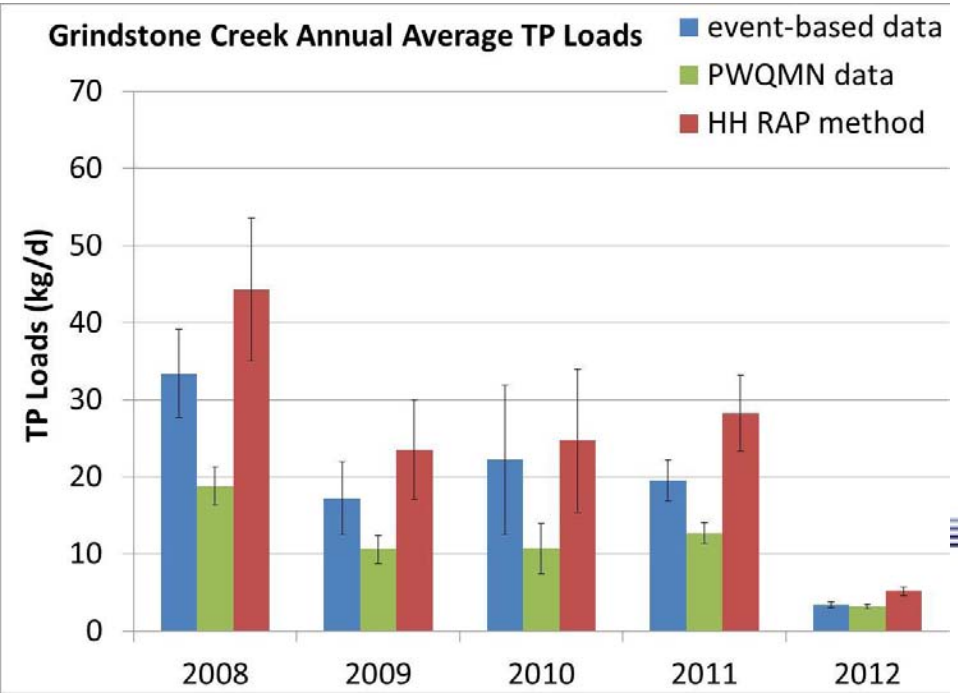
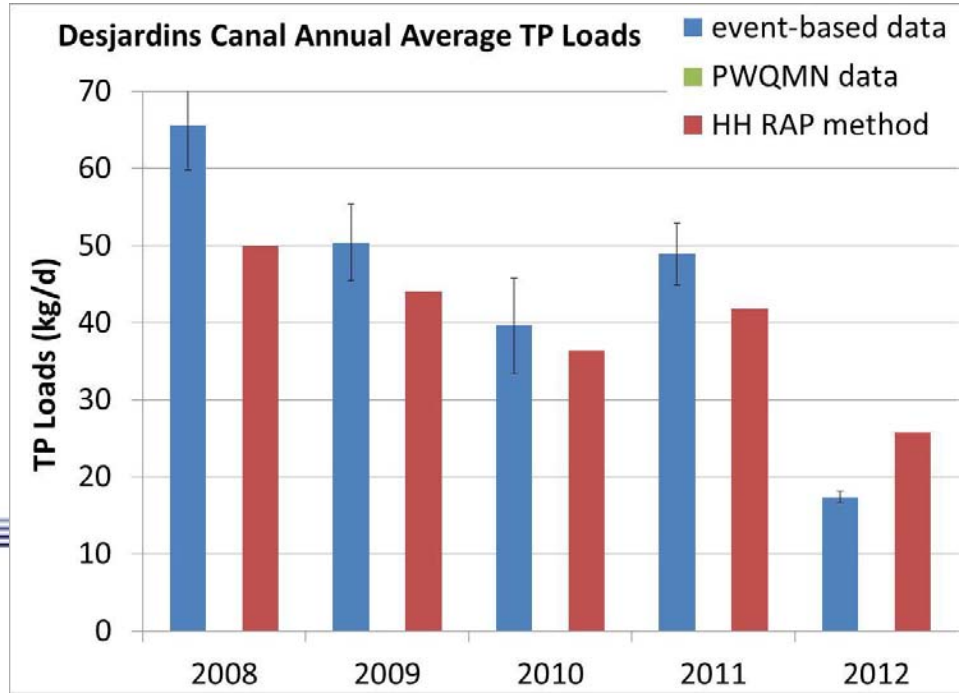
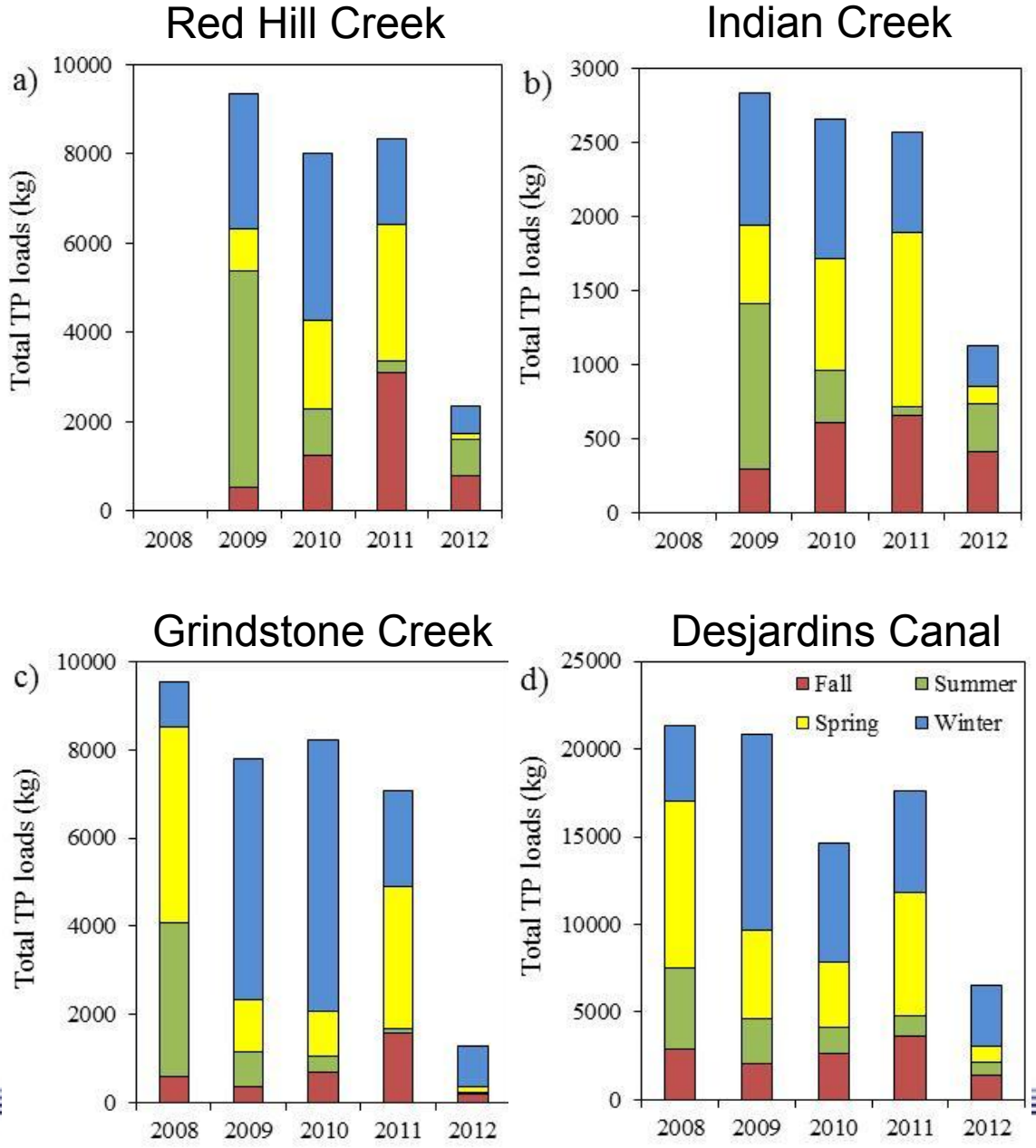

Red Hill Creek Annual Average TP Loads
event-based data
PWQMN data
HH RAP method
TP Loads (kg/d)
70
60
50
40
30
20
10
0
2008
2009
2010
2011
2012


Indian Creek Annual Average TP Loads
event-based data
PWQMN data
HH RAP method
TP Loads (kg/d)
70
60
50
40
30
20
10
0
2008
2009
2010
2011
2012


Grindstone Creek Annual Average TP Loads
event-based data
PWQMN data
HH RAP method
TP Loads (kg/d)
70
60
50
40
30
20
10
0
2008
2009
2010
2011
2012


Desjardins Canal Annual Average TP Loads
event-based data
PWQMN data
HH RAP method
TP Loads (kg/d)
70
60
50
40
30
20
10
0
2008
2009
2010
2011
2012

Seasonal TP Load Estimates



- Urban watersheds: TP loads driven by large storm events (e.g. 2 storms in summer 2009)
- Agricultural/rural watersheds: TP loads driven by spring freshet (either winter or spring bin)
- Winter season cannot be ignored!
- What is the impact of large spring freshet vs intermittent winter rain events?

Long et al., submitted JGLR

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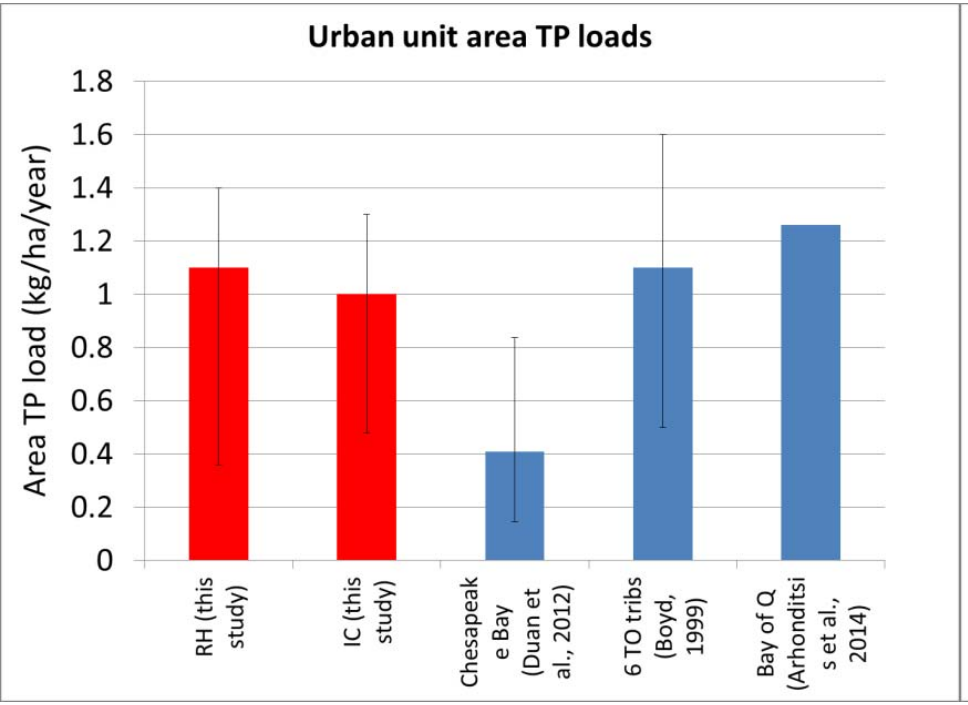
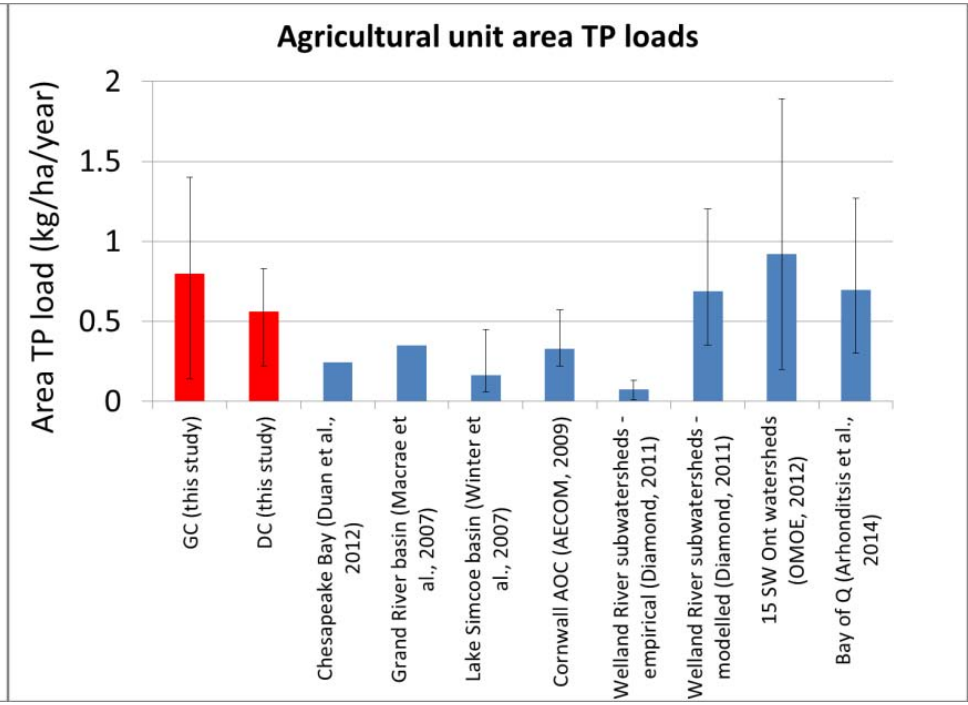
Context of Results with Other Studies





- Urban areal TP loads > agricultural areal TP loads
- Areal TP loads in Hamilton Harbour watersheds similar to other regional watersheds of similar land use

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What expertise and how much effort were required to collect the data and obtain the results?

- Sample collection (1 day/event) & ongoing site maintenance: 1 full time field tech + 1 co-op/summer student
- Sample processing (1 day/event): 1 full time field tech/co-op/summer student + 1 scientist
- QA/QC of data: 1 full time scientist (~2 months)
- Data analysis & manuscript preparation: 1 full time scientist (summer 2012 – present)
- Ongoing assistance & collaboration from partners

Project outcomes

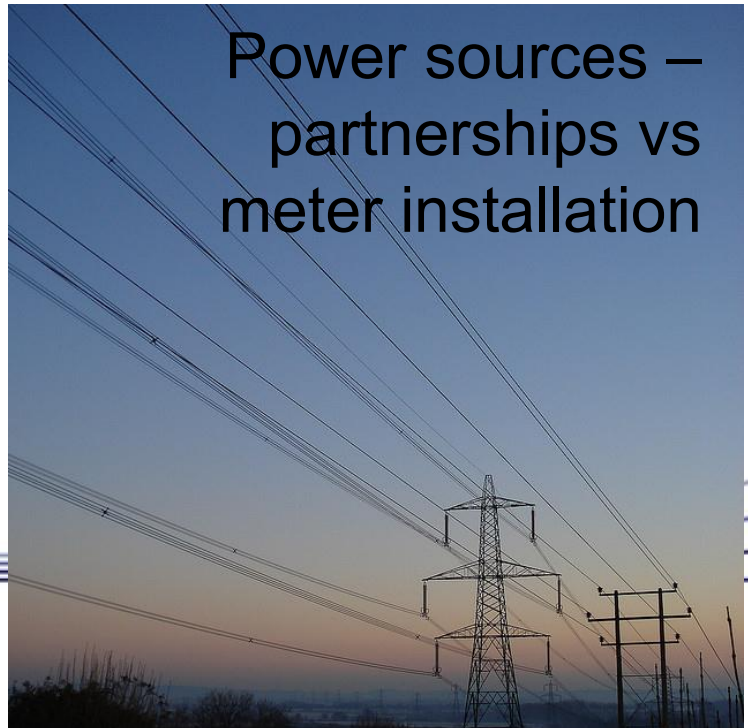
1. User-friendly TP loading estimation method with minimal data needs has been developed for ongoing use by the HH RAP
2. Newly estimated 2008-2012 tributary TP loads to Hamilton Harbour are a part of re-focusing nutrient/sediment mitigation efforts in the watersheds (i.e. HH RAP task groups)
3. Determination that the watersheds met the HH RAP TP loading target of 65 kg/d in 2012, but did not in 2009-2011
4. Contribution to the science: 1 publication in JGLR; 1 manuscript under review
5. No additional people were hired specifically for this project & the project was manageable size for staff resources available

Challenges, Limitations, and Opportunities

Landline vs Cellphone – an issue even in urban areas

There is only 1 Dave Supper!

Predicting ISCO trigger times at the Desjardins Canal



Power sources – partnerships vs meter installation

Challenges, Limitations, and Opportunities

Landowner permissions – I was lucky!

Washout of equipment during large storms, e.g. Sep 29, 2010

24L of water is heavy!

=

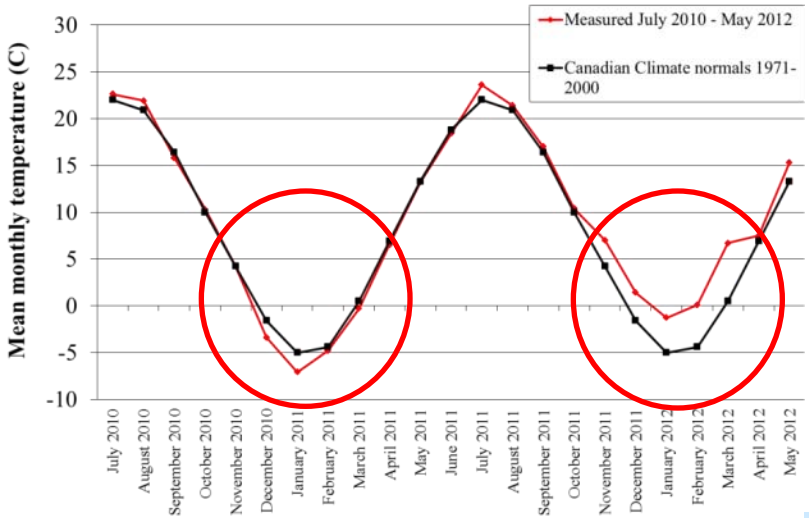
Winter 2010-11 vs 2011-12 – an “opportunity”….

Ontario

Winter Conditions During Study

Winter 2011

- Colder than average
- Accumulation of deep snowpack
- Low flows until spring freshet mid-February 2011



Winter 2012

- Warmer than average
- Very little snow; most precipitation in form of rain throughout winter
- No spring freshet

January 13, 2011:

Desjardins Canal monitoring station

January 11, 2012:

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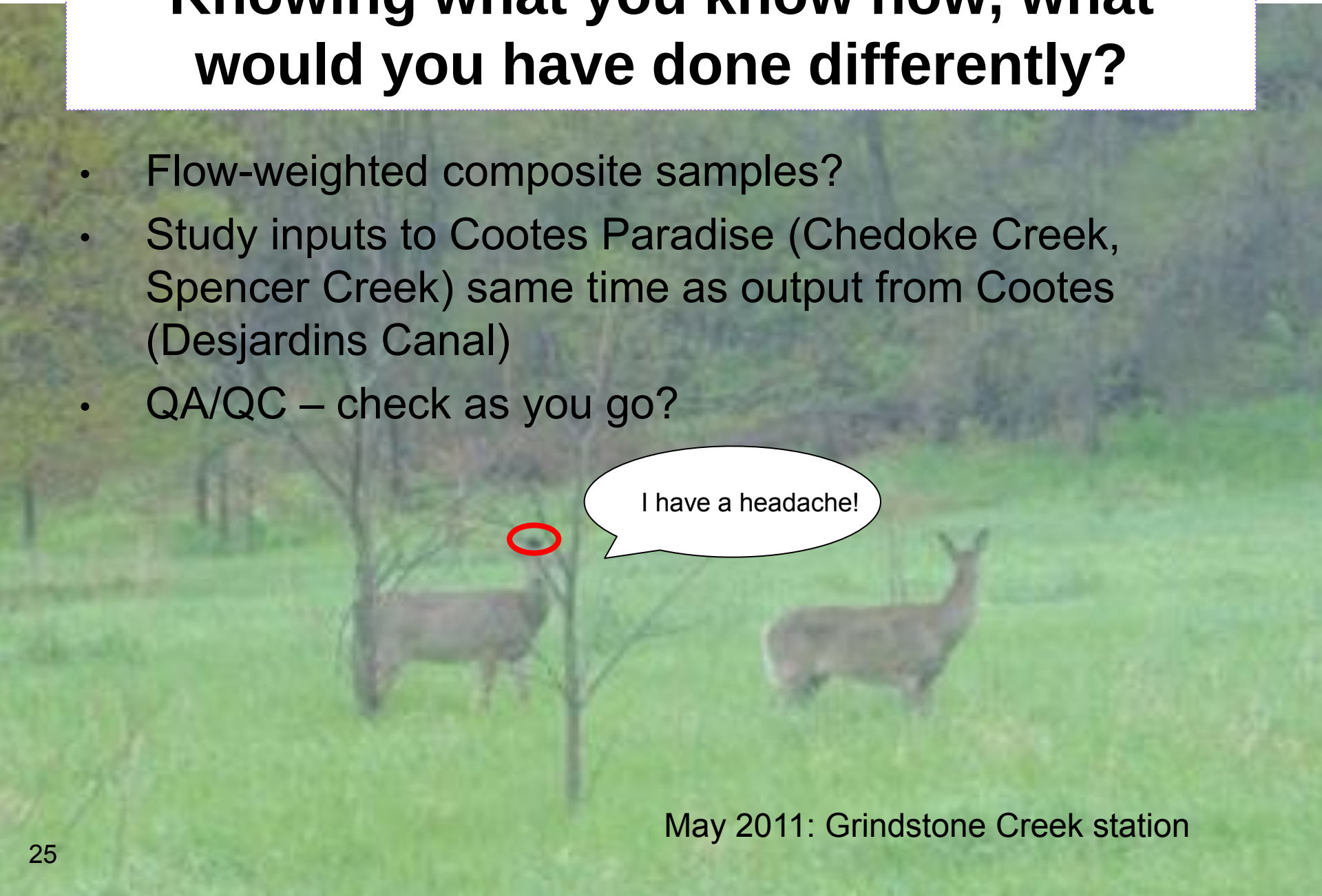
Knowing what you know now, what would you have done differently?

- Flow-weighted composite samples?
- Study inputs to Cootes Paradise (Chedoke Creek, Spencer Creek) same time as output from Cootes (Desjardins Canal)
- QA/QC – check as you go?



May 2011: Grindstone Creek station

Questions?

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- City of Hamilton
- Royal Botanical Gardens (Tys Theysmeyer)
- Water Survey of Canada (Tom Arsenault)
- Halton Conservation Authority
- Hamilton Conservation Authority