Lake Simcoe Region
conservation authority

A Watershed for Life

Optimization of water quality sampling and load estimation modeling in the Lake Simcoe watershed:

Evaluations using a continuous phosphorus dataset

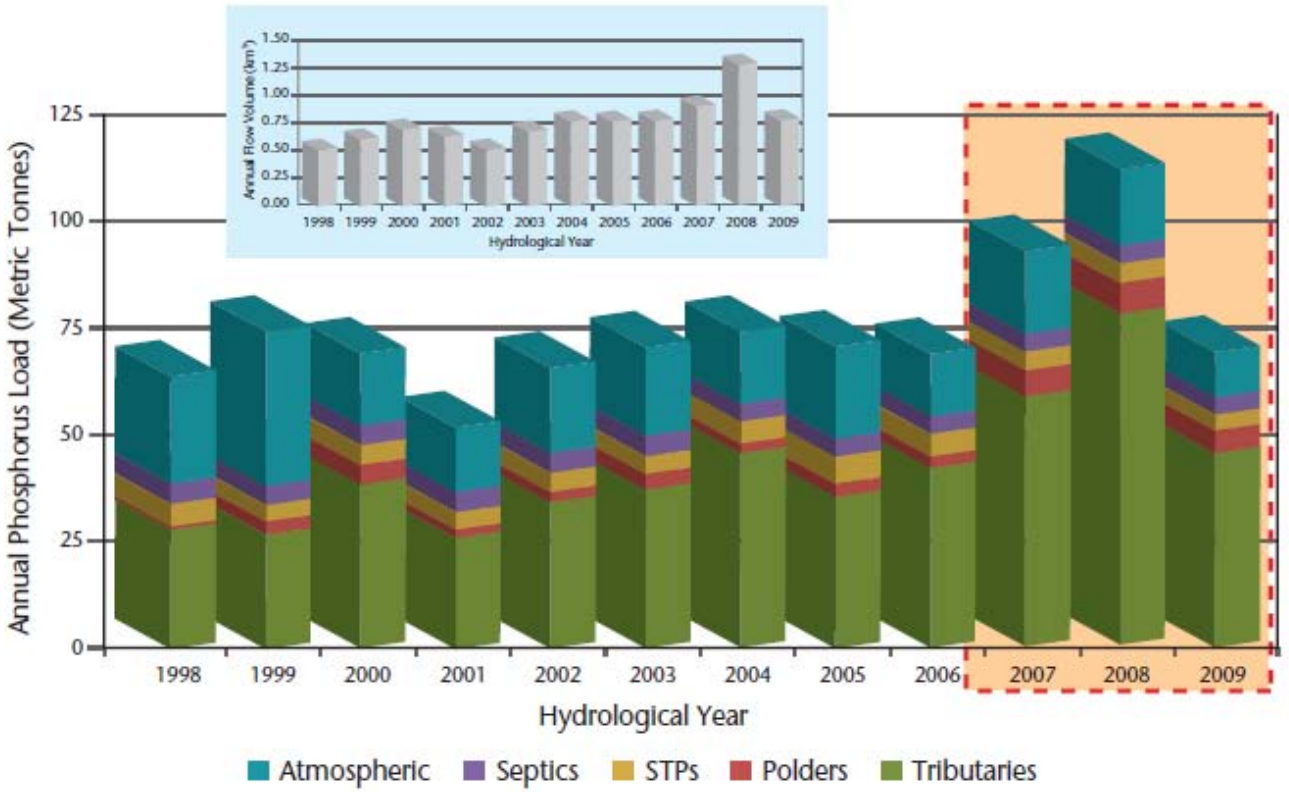
Eavan M. O'Connor, Lance Aspden, Jennifer G. Winter and David Lembcke

January 20, 2015

Sharing Loading Estimation Experiences Workshop Guelph

Phosphorus Loads

- **Report on Phosphorus Loads to Lake Simcoe**
- Tributaries provide about 60% of load on average



Tributary Phosphorus Loads

- A need to evaluate a range of **sampling scenarios**
- A need to evaluate a range of **load estimation models**

- Critical to optimize **both** of these elements to make accurate assessments of loads
- Compare and evaluate against a measured annual tributary load ("Actual" load)

Study Areas

Two large river systems in the Lake Simcoe Watershed

1) Beaver River - mainly agricultural (63% agriculture)
2) East Holland River - highly urbanized (22% urban)

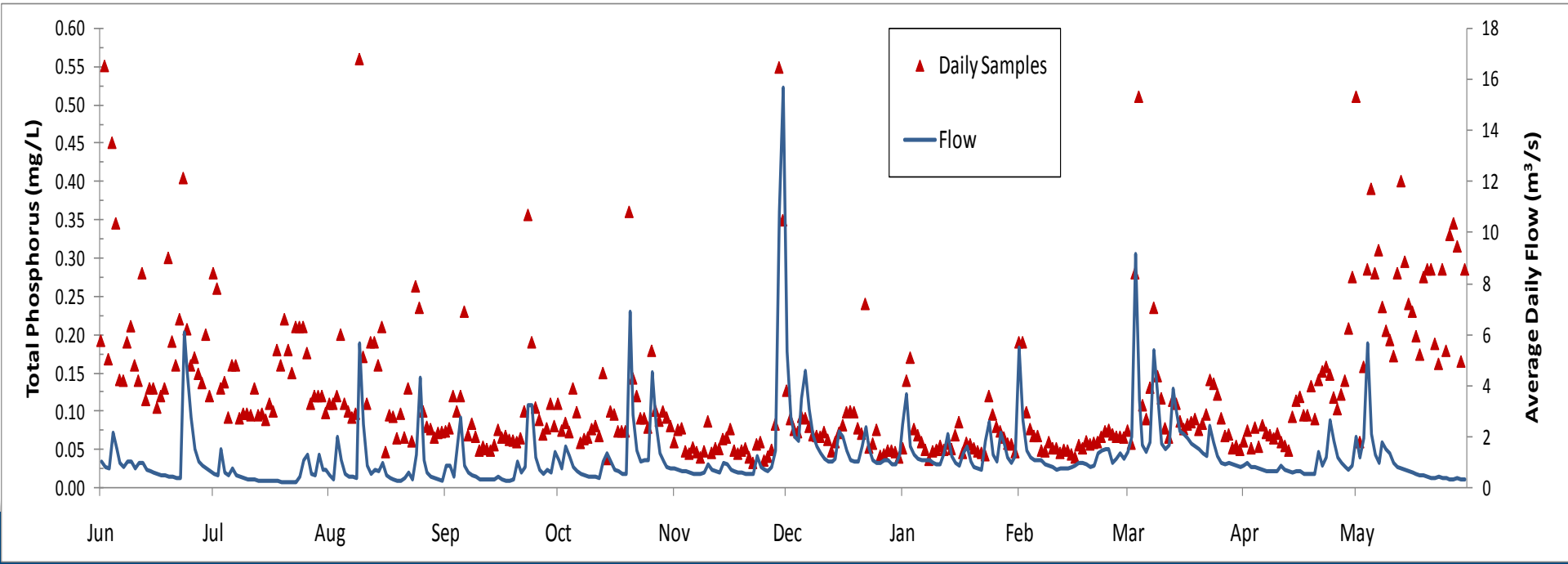
Methods

- Daily and episodic water quality samples were collected for a full year at each station
- Paired with continuous flow data
- Calculated an “actual” annual tributary load!

Methods

- The continuous TP record was artificially reduced to represent a variety of sampling scenarios.

- Various load estimation methods were then applied to these sampling simulations.



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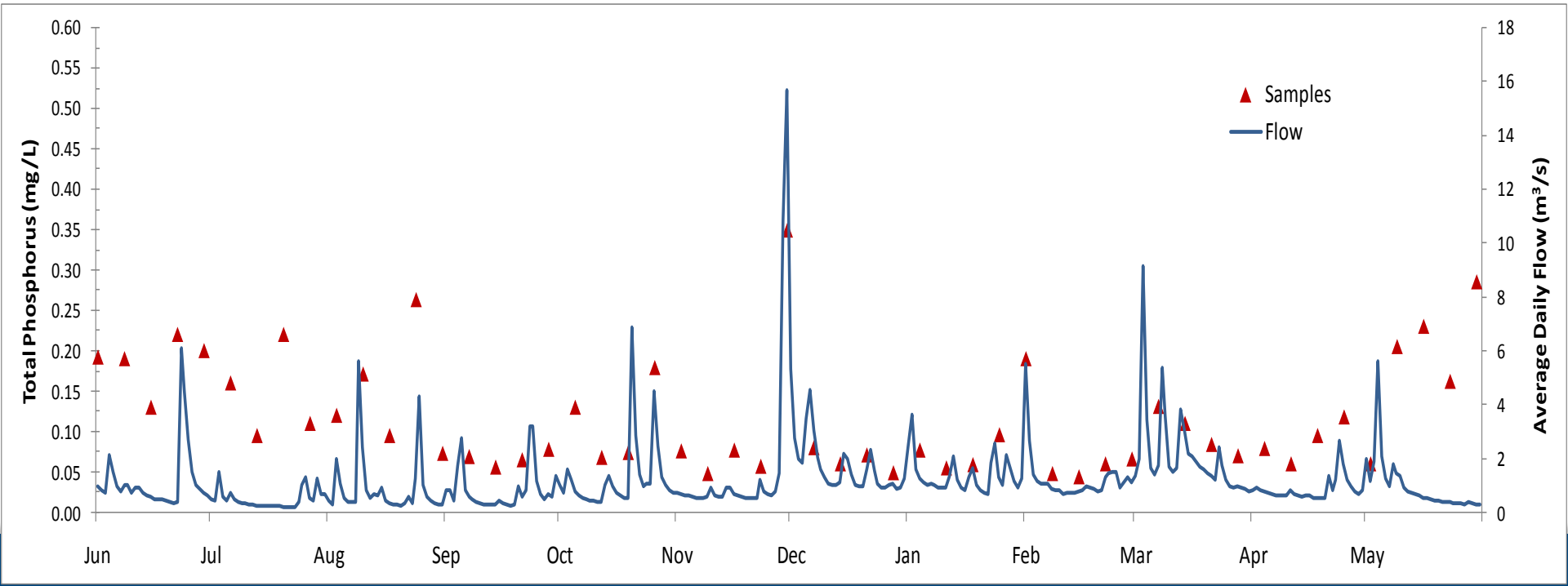

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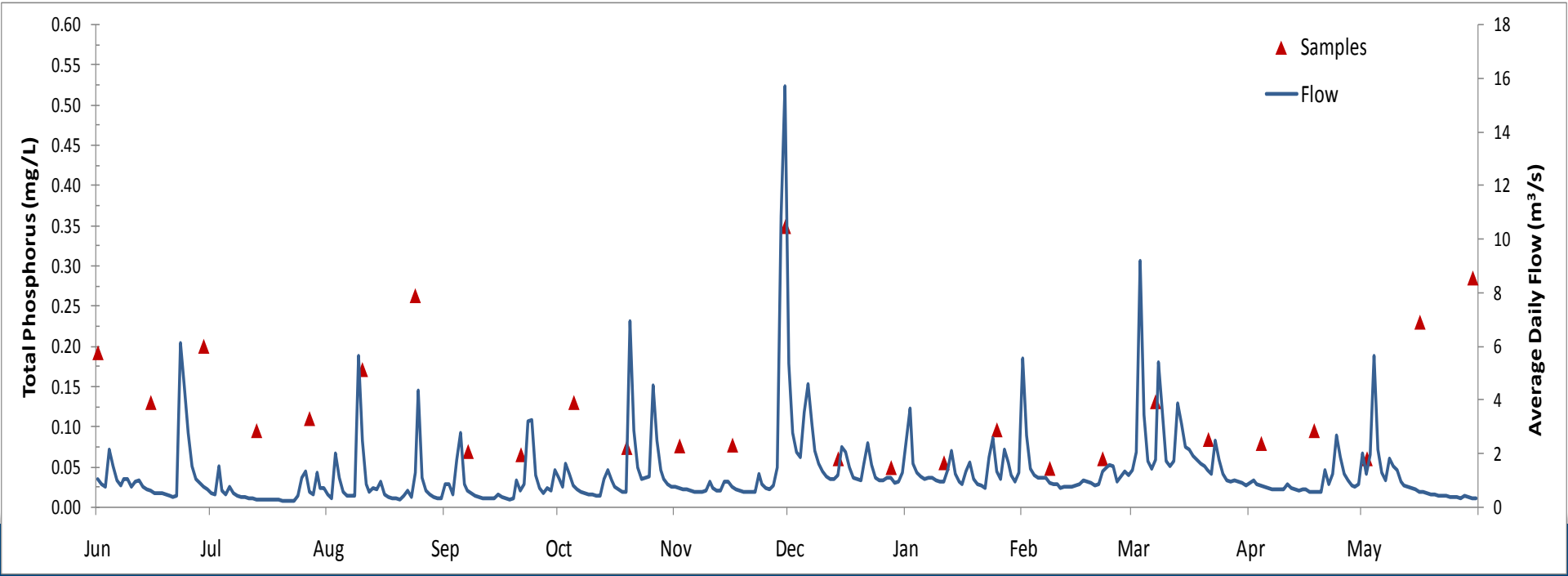


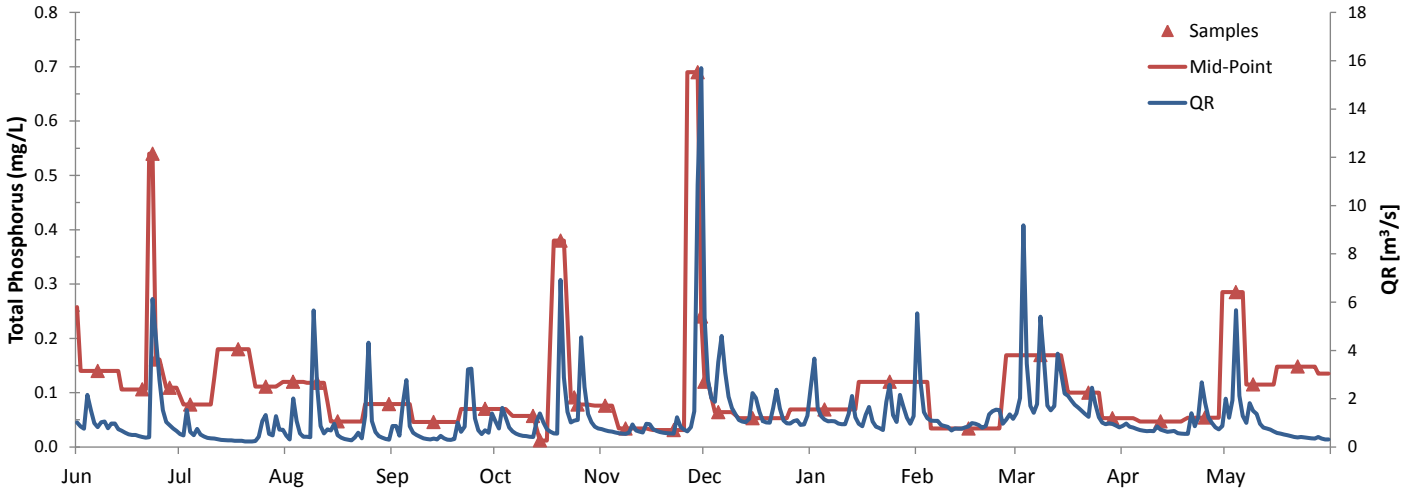
Methods - Sampling Scenarios

1	**Routine Sampling:** • Biweekly in the ice-free seasons, triweekly in the winter. • Plus event sampling.
2	**Weekly (same day every week):** • Mondays • Wednesdays
3	**Biweekly with intense event sampling:** • Wednesdays (observed more events)
4	**Biweekly with partial event sampling (peak only):** • Wednesday
5	**Monthly with intense event sampling:**
6	**Biweekly (same day every 2 weeks):** • Mondays • Wednesdays
7	~~Stratification by season~~

Load Estimation Methods

1. Midpoint method

Currently used



2. Beale Ratio Estimator

AVG Daily Load (kg) * [AVG Annual Q (m^3/s)/AVG Sampled Q (m^3/s)]

3. Regression

Calculates daily load using linear relationship

Load Estimation Methods

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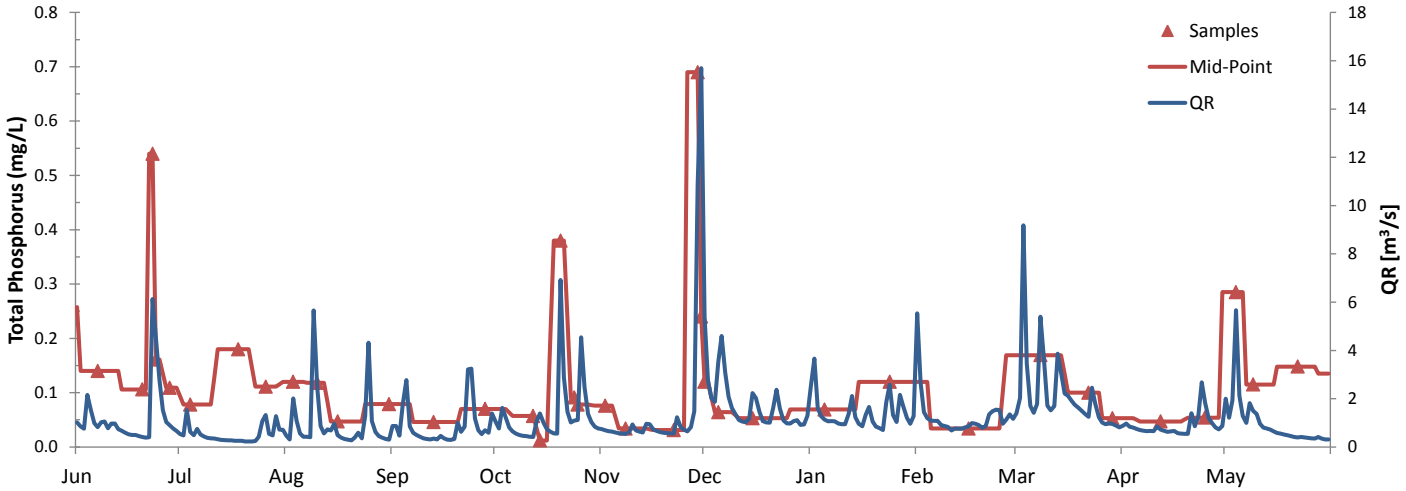

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Beale Ratio and Regression

Assumptions:

1. Significant slope and good r^2 of concentration versus flow
2. Sample across range of flows and conditions

FLUX software used for calculating these loads.
Other methods available too (averaging, etc).

Beale Ratio and Regression

Assumptions:

1. Significant slope and adjusted r^2 of concentration versus flow
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Violations

FLUX software used for calculating these loads.

Other methods available too (averaging, etc).

Beale Ratio and Regression

Assumptions:

1. Significant slope and adjusted r^2 of concentration versus flow
2. Sample across range of flows and conditions

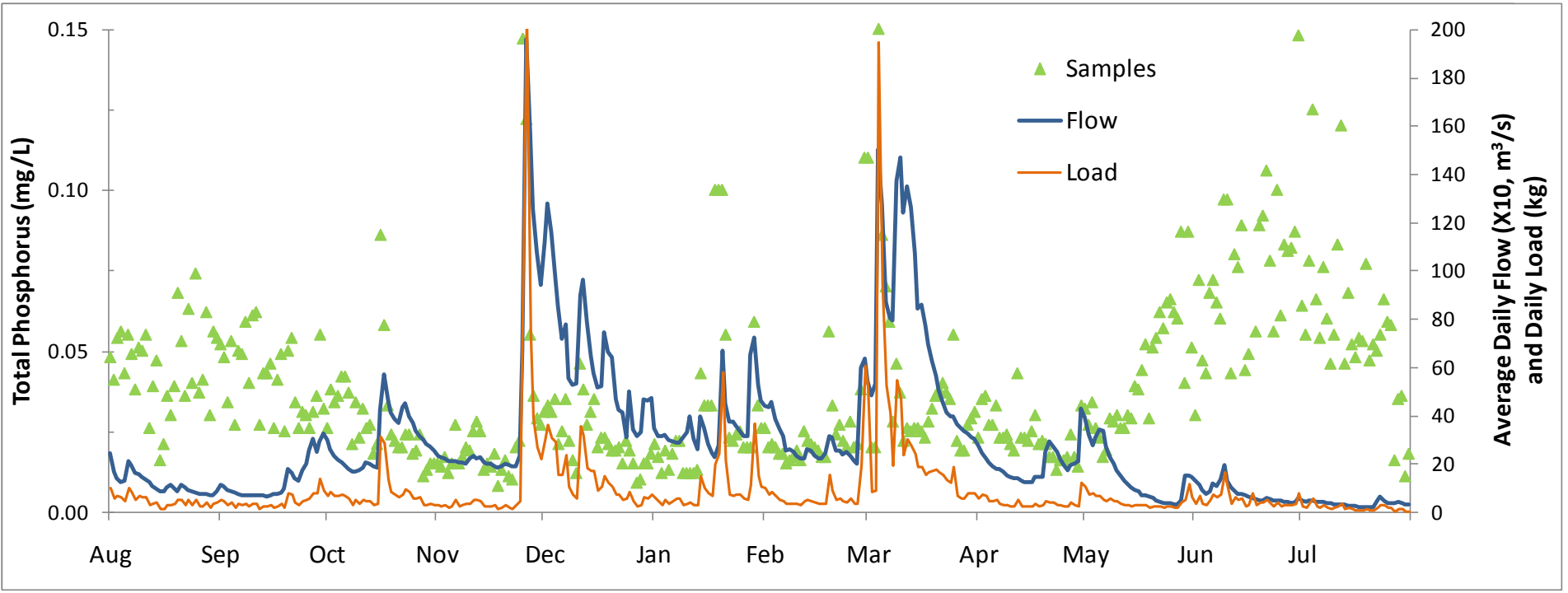
Violations

Potential:

- Seasonal or hydrograph stratification
  - May be suitable using long-term data
  - Potentially less intensive sampling required compared to midpoint

FLUX software used for calculating these loads.
Other methods available too (averaging, etc).

Beaver River – Autosampler dataset



- Agricultural subwatershed
- Long periods of elevated flow
- High concentrations at the beginning of flow events
- Concentrations drop out after the peak
- High loads at beginning of storm events
- High summer concentrations, low flow, low loads

Results of Midpoint Method – Beaver River

1	Routine Sampling: • Biweekly in ice-free seasons, triweekly in the winter. • Plus event sampling.	5106
2	Weekly (same day every week): • Mondays • Wednesdays	3187 3194
3	Biweekly with intense event sampling: • Wednesdays (observed more events)	3545
4	Biweekly with partial event sampling: • Wednesday	3570
5	Monthly with intense event sampling:	4005
6	Biweekly (same day every 2 weeks): • Mondays • Wednesdays	3493 3416
Actual Load (kg)		3430

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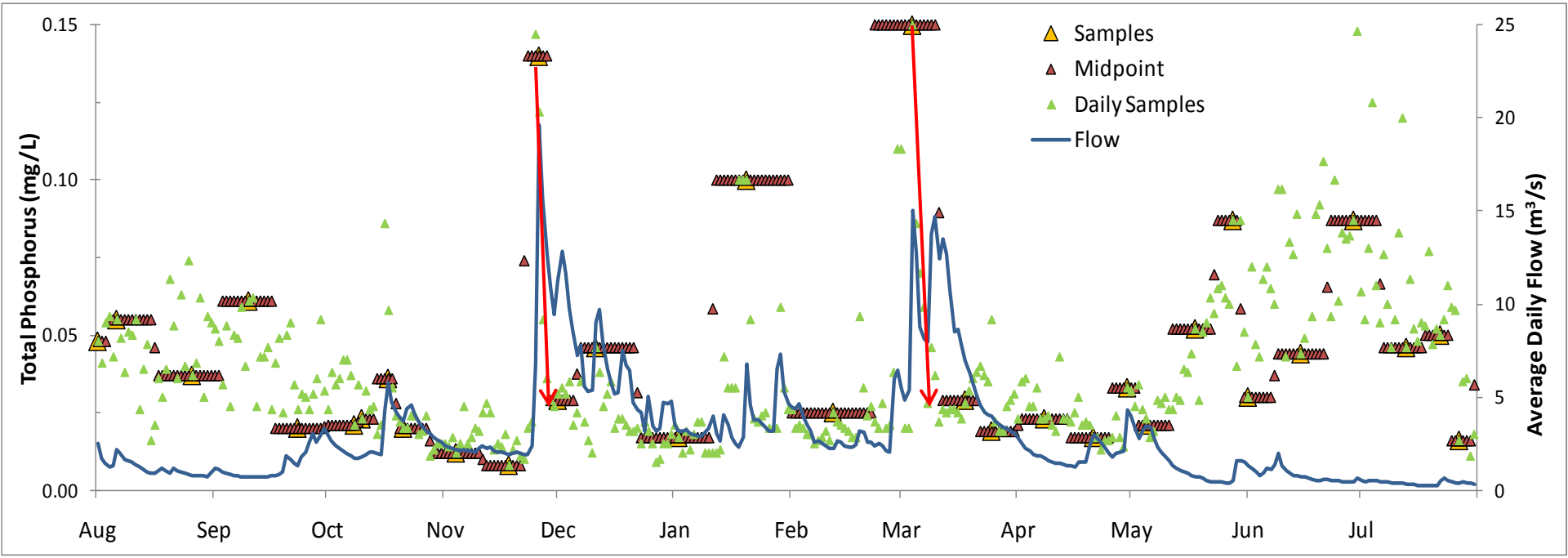
Routine Sampling Scenario – Midpoint Method Load Calculation

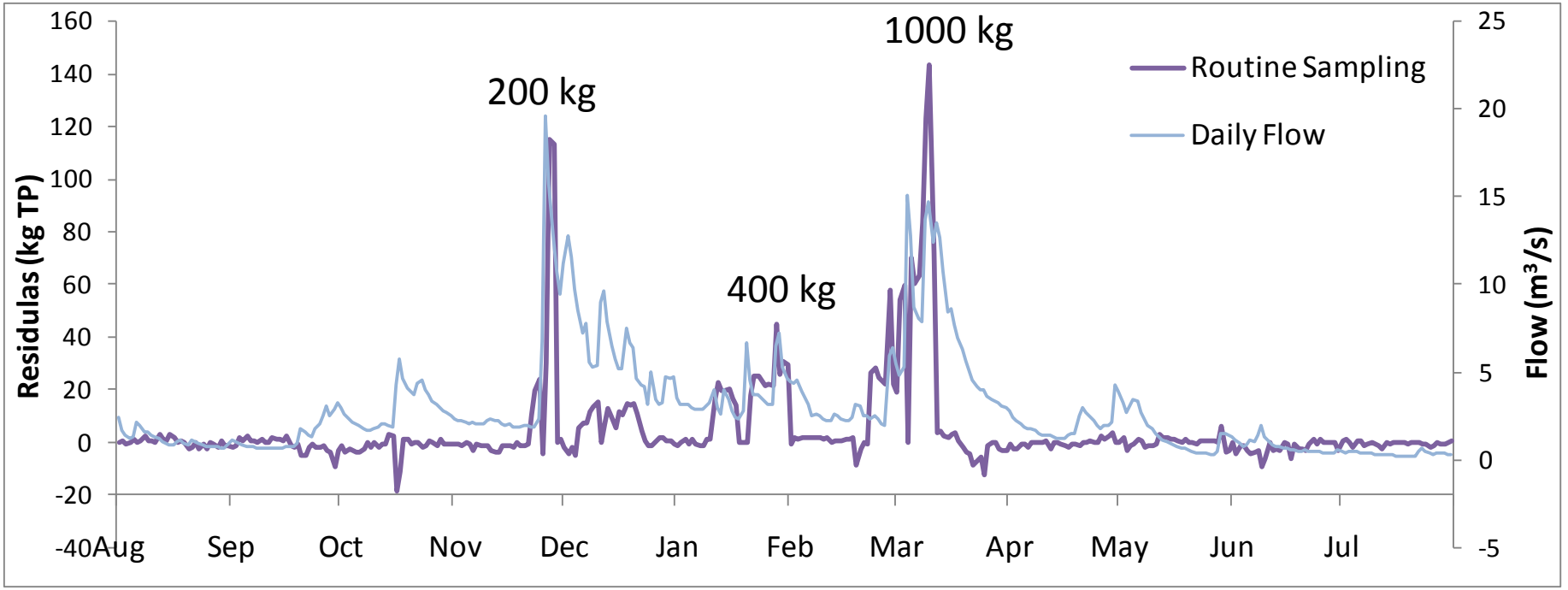
Beaver River



- Sampled at beginning/peak of flow events when concentrations were high
- Overestimates of concentrations

Routine Sampling Scenario – Midpoint Method Load Calculation

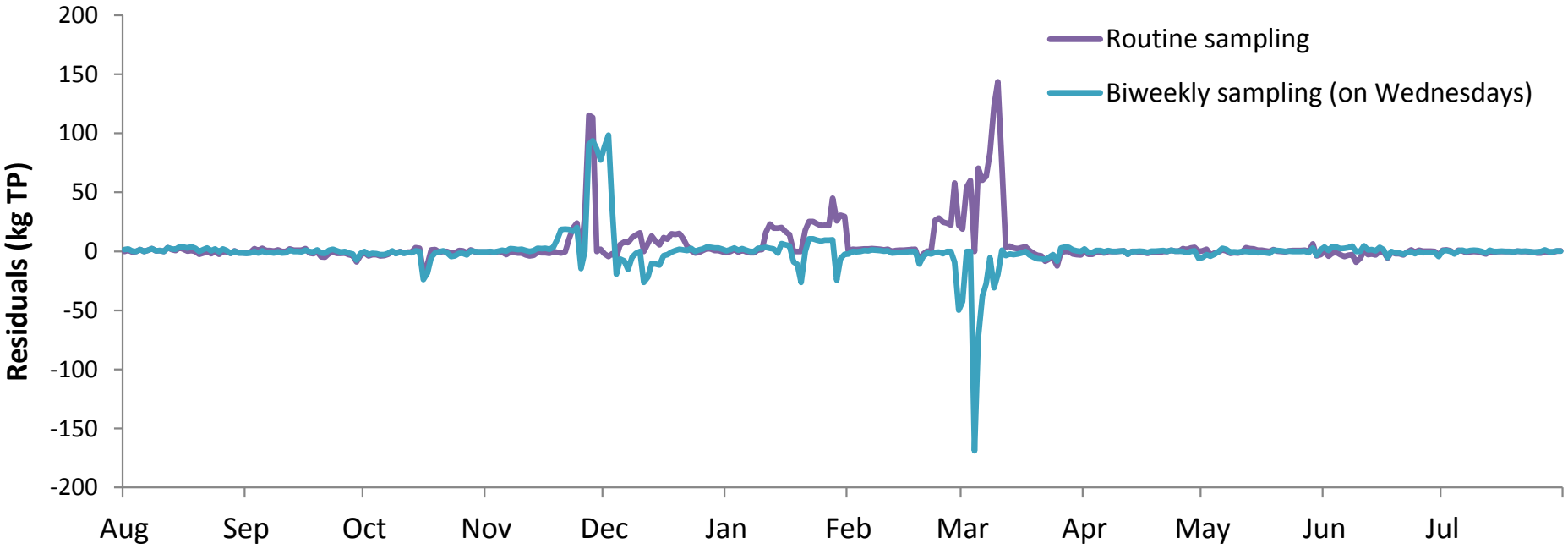
Beaver River



- Residuals (difference between observed and estimated daily loads)
- Overestimation of loads

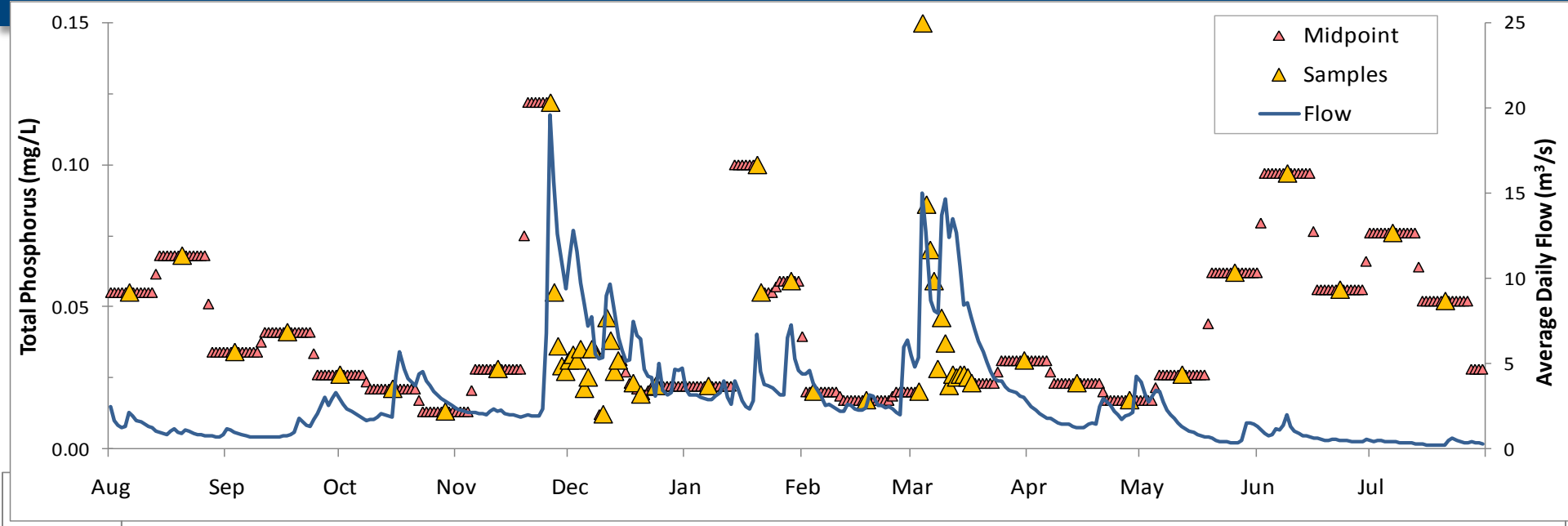
Biweekly Sampling Scenario – Midpoint Method Load Calculation

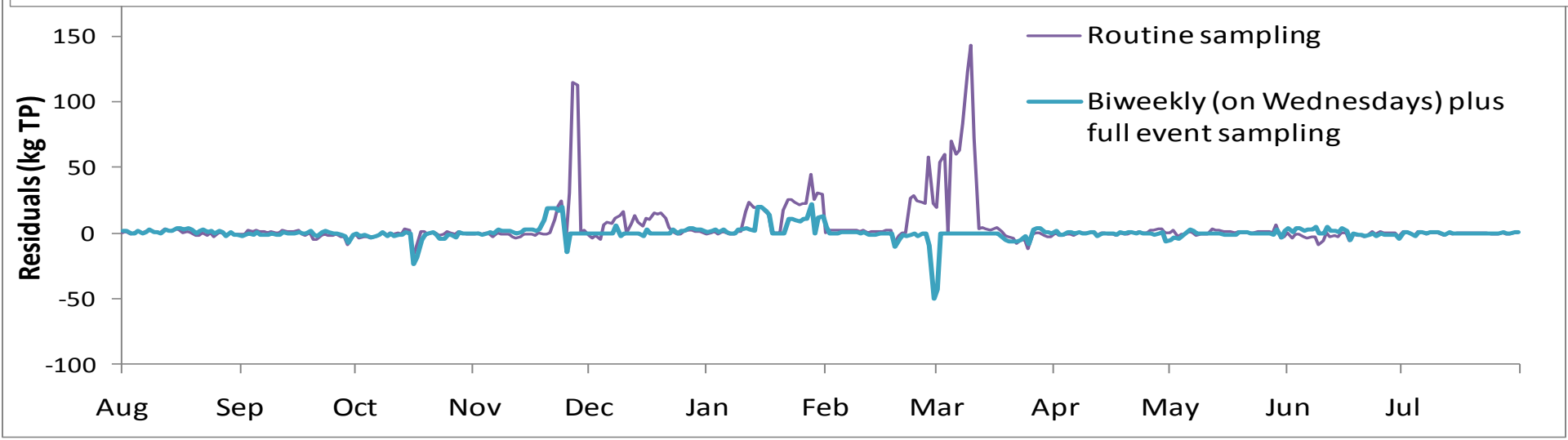
Beaver River



- **Biweekly sampling on Wednesdays had most accurate annual load (14kg from actual load)**
- **False-positive result!**

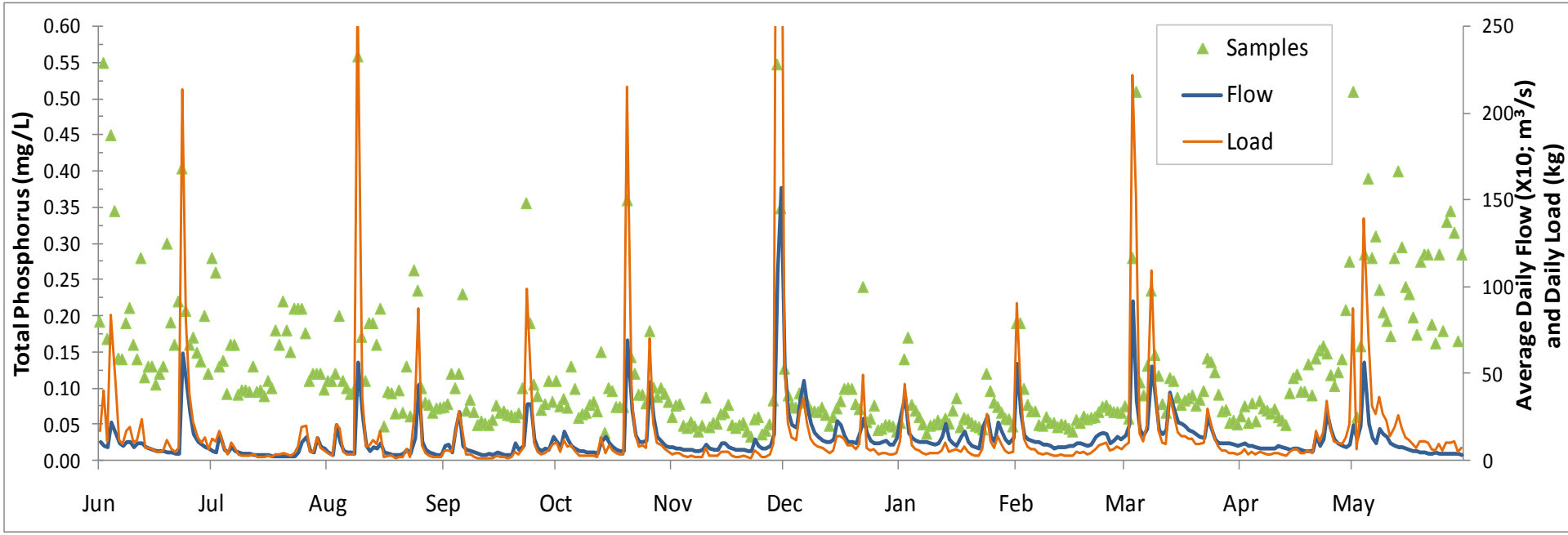
  overestimation = underestimation (not reliable).





Better characterization of the storms produced good annual load (100kg off) and better results on a daily basis.

East Holland River - Autosampler Dataset



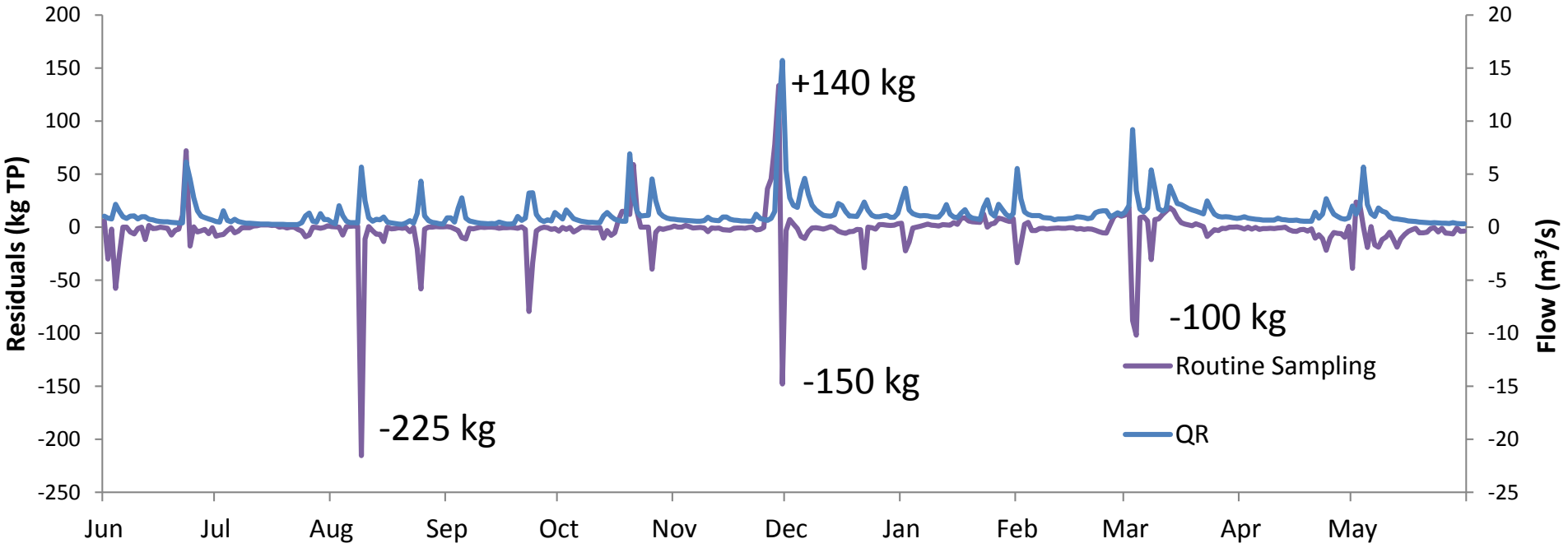
- Urban subwatershed
- Short intense peaks, numerous events in the year
- Concentrations rise and fall similarly to the hydrograph
- Most loads occur during high flow events
- High summer concentrations, low flow, low loads

Results of Midpoint Method – East Holland River

1	Routine Sampling: • Biweekly in the ice-free season triweekly in the winter. • Plus event sampling.	5380
2	Weekly (same day every week): • Mondays • Wednesdays	4318 5144
3	Biweekly with intense event sampling: • Wednesdays (observed more events)	6736
4	Biweekly with partial event sampling: • Wednesday	7135
5	Monthly with intense event sampling:	7952
6	Biweekly (same day every 2 weeks): • Mondays • Wednesdays	4386 5244
Actual Load (kg)		6325

Routine Sampling Scenario – Midpoint Method Load Calculation

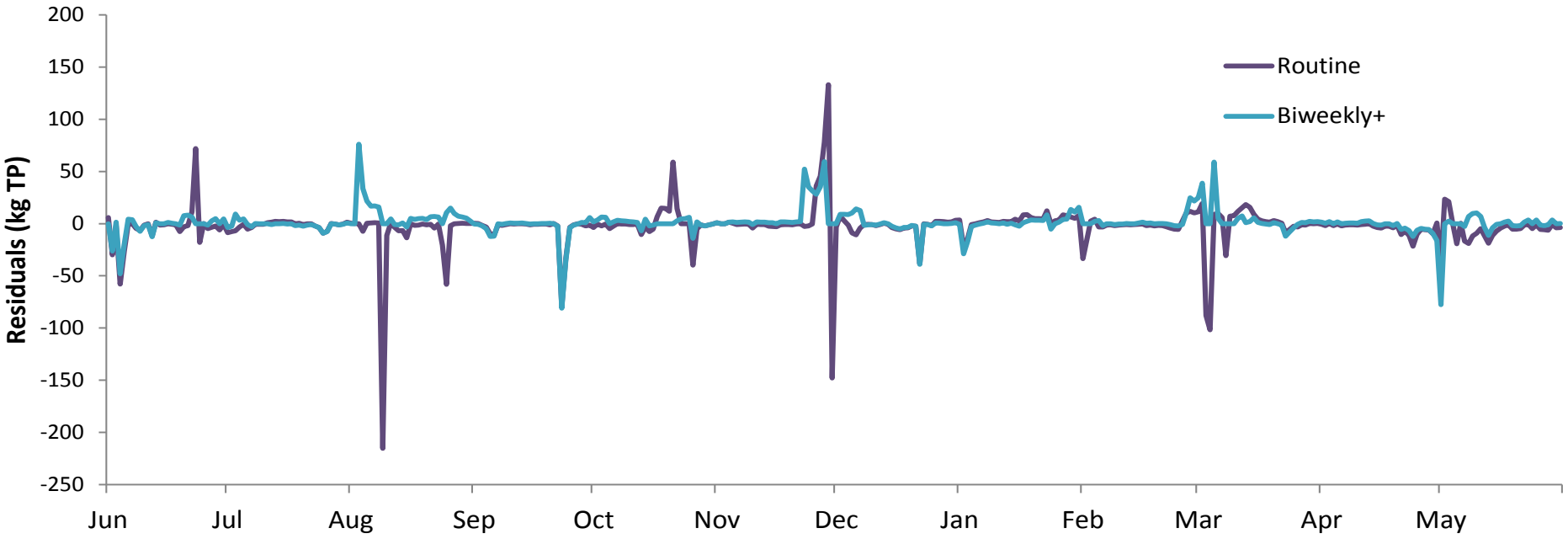
East Holland River



- Flashy urban system, hard to sample every storm!
- Routine sampling consistently underestimated phosphorous load (1000 kg/yr)!

Biweekly with Intense Event Sampling Scenario – Midpoint Method Load Calculation

East Holland River



- Some over and under estimations but not extreme (±50 kg).
- Biweekly w/ intense event sampling was the best sampling scenario for East Holland (+400 kg/yr)

Summary

Beaver River (agricultural)

- Routine sampling scenario lead to considerable over-estimation of P load!

East Holland River (urban)

- Routine sampling scenario lead to moderate underestimation of P load!

Best results for both systems:

- **Sampling regimen:**
  - **Biweekly plus intense event sampling**

- **Load estimation method:**
  - **Midpoint**

What it means for our sampling program:

- **Agricultural systems**
  - Flow events last longer (2-3 weeks)
  - Concentrations are high mainly at beginning of event
  - Be sure to sample after peak where concentrations are receding but flows are still elevated.

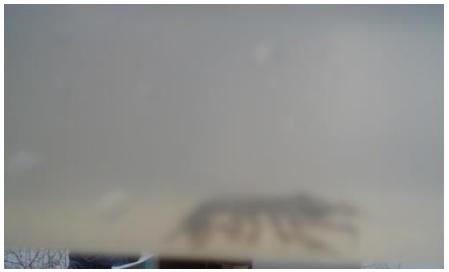
- **Urban systems**
  - Flashy (a few days)
  - Concentrations recede with flow
  - Need to sample numerous storm events per year

Sampling effort

- Refrigerated autosamplers (2)
  - Avalanche ISCO
  - ~$9000 for Avalanche
  - $2500 for shelter
  - $50 per sample
    - (TP, orthophosphate, TSS, chloride)
  - Almost 1500 samples collected
    - 26 storm events characterized
- Staff time
  - 6-10 hours per week X 2 persons
  - = 100-150 staff days per year
  - For 2 autosamplers

Challenges - Autosampler

- **Installation**
  - Housing, power, intake
- **Seasons**
  - Cooling, heating
- **Timing**
  - Capture event
- **Sampling failure**
  - Gaps!
  - 8 days at HL
  - 20 days at BV



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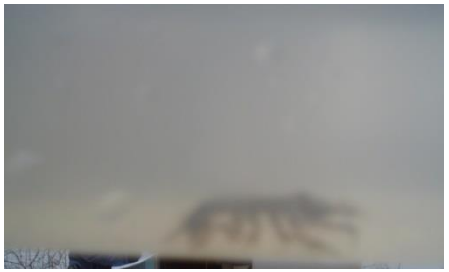
- Swirl sample to pour
- Set program
- Align bottle tray
- Position distributor arm
- Hit Run!
- Documentation (field notes)



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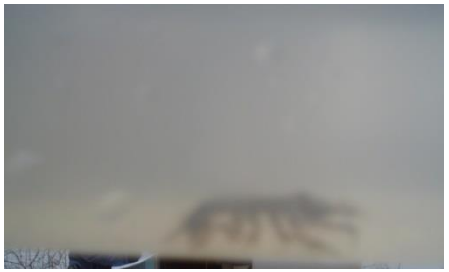
- Maintenance (clean, tubing)
- Volume calibration
- Ice at intake line
- Frozen samples
- Biofouling (amphipods)
- Capture events, on weekends too!
- Work with the quantity of bottles available
- **Don’t forget to pick up the samples!**



Challenges - Data Analysis

- **Funding was delayed**
  - Used allocation from our regular monitoring program
- **Organizing, QCing chemistry data – time consuming!**
  - Remove samples (tests, comparisons)
  - Add in monitoring program samples
  - Documentation important
  - Consistent times (EST)
- **Flow data**
  - Environment Canada
  - Daily and high resolution QC'd data
- **Three iterations of the data analysis!**

Acknowledgments

- Funding – Lake Simcoe Clean-Up Fund (LSCUF)
- Flow data – Environment Canada
- Sample Analysis – Maxxam Analytics, MOE
- LSRCA staff
  - Autosampler maintenance and sample collection
    - Sara Rawski, Chandler Eves, Ray Bolton, Kaitlin Bolton, Ryan MacLean, Rob Wilson, Melissa Moos, Brian Ginn
  - Data Management - Sara Rawski
- MOE staff
  - Autosampler set-up - Mike Mueller
  - Data Management - Hamdi Jarjanazi

Questions?

Suggestions?

Comments?

Concerns?

Collection of samples

- Mondays and Thursdays plus events
- Composite samples for events
  - 2 samples per bottle, every 2 or 4 hours
  - 14 or 24 bottle rack
- Samples must go to lab before they expire
  - Submission and transportation
- Holland Landing site close to office
- Staff lived close to Beaver River site
- Incorporated into routine monitoring programs

Tributary Phosphorus Loads

- **Loads:** a function of flow and concentration
- **Flow:** measured continuously at a reasonable cost
- **Concentrations:** discrete samples

- Complete the load calculation for the periods between samples – calculations/models
- Loads are inherently difficult to quantify!