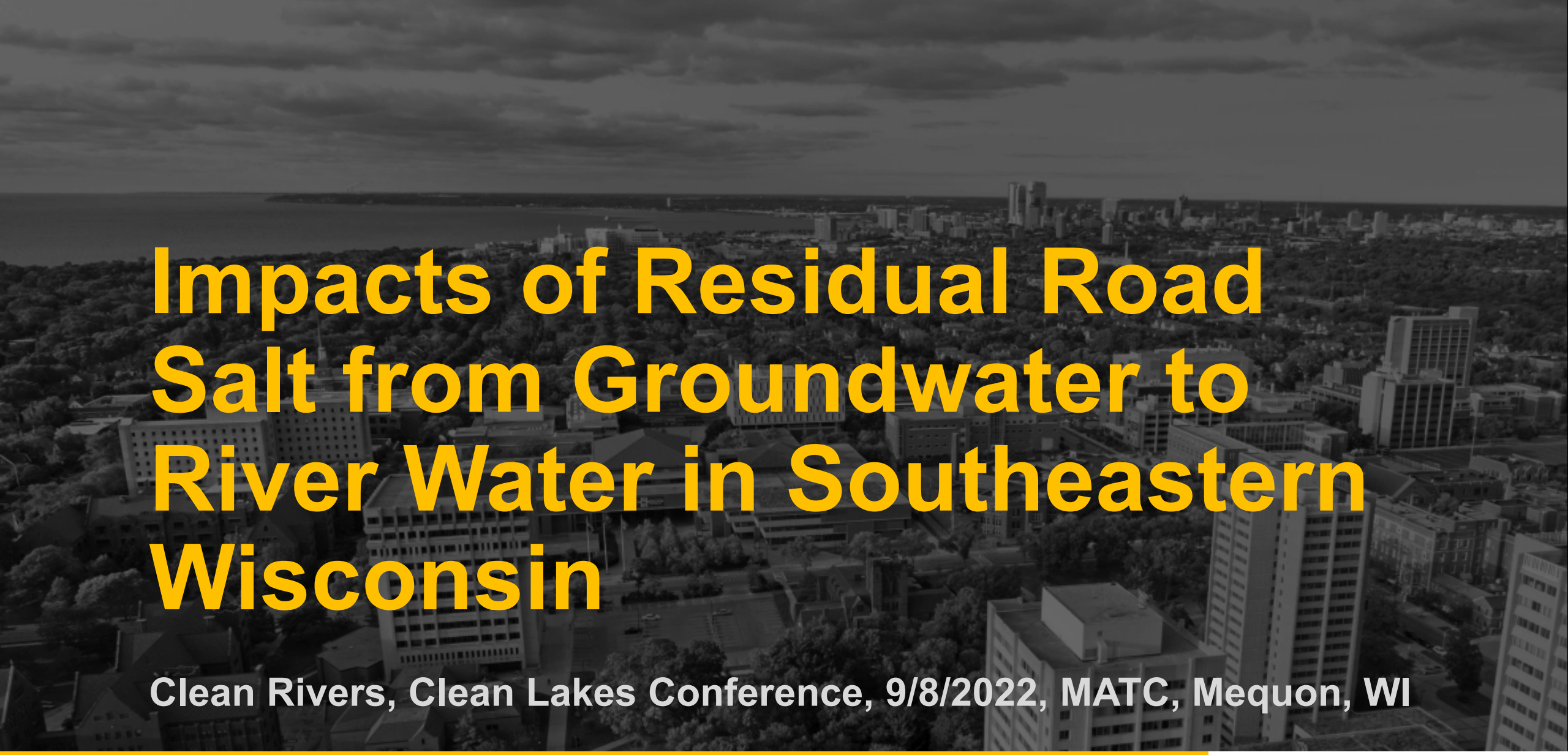

Impacts of Residual Road Salt from Groundwater to River Water in Southeastern Wisconsin

Clean Rivers, Clean Lakes Conference, 9/8/2022, MATC, Mequon, WI

Charles Paradis[1], Leah Dechant[1], and Tim Wahl[2]

[1]Department of Geosciences, UW-Milwaukee

[2]School of Freshwater Sciences, UW-Milwaukee

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Road Salt Application Data

- US: 1941-1942 applied 5,000 tons
- US: 2010 applied 10-20 million tons each winter
- WisDOT: 2020-2021 applied 324,265 tons in WI
- WisDOT: 2020-2021 applied 70,415 tons in SE WI
- 2020-2021 applied ≈33,000 tons in Root River Watershed
- Where is all this road salt going?
  - Lake Michigan: chloride ≈1.5 mg/L (1800's) to 15 mg/L (2020)

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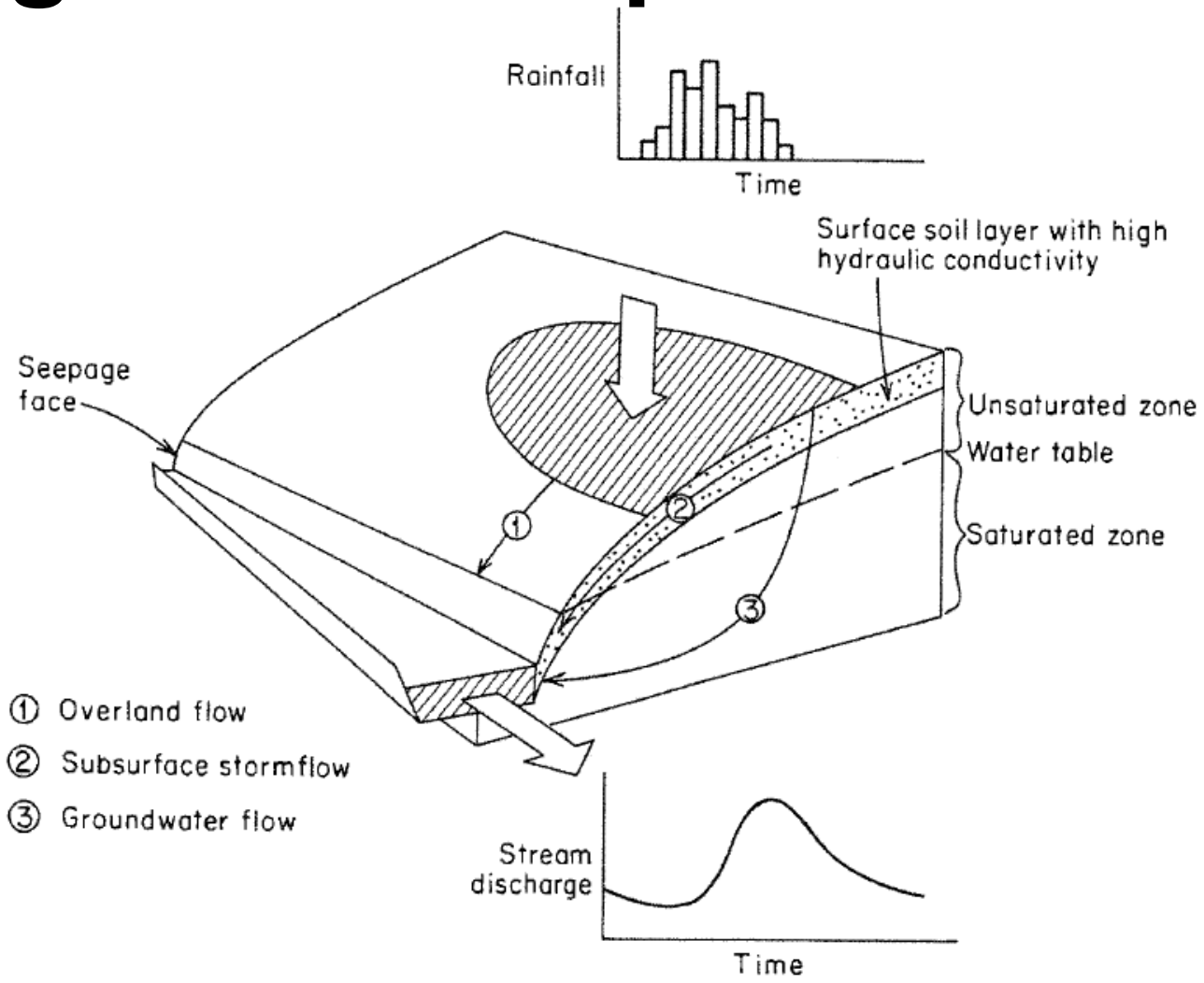
Hydrological Conceptual Model



Freeze and Cherry (1979)

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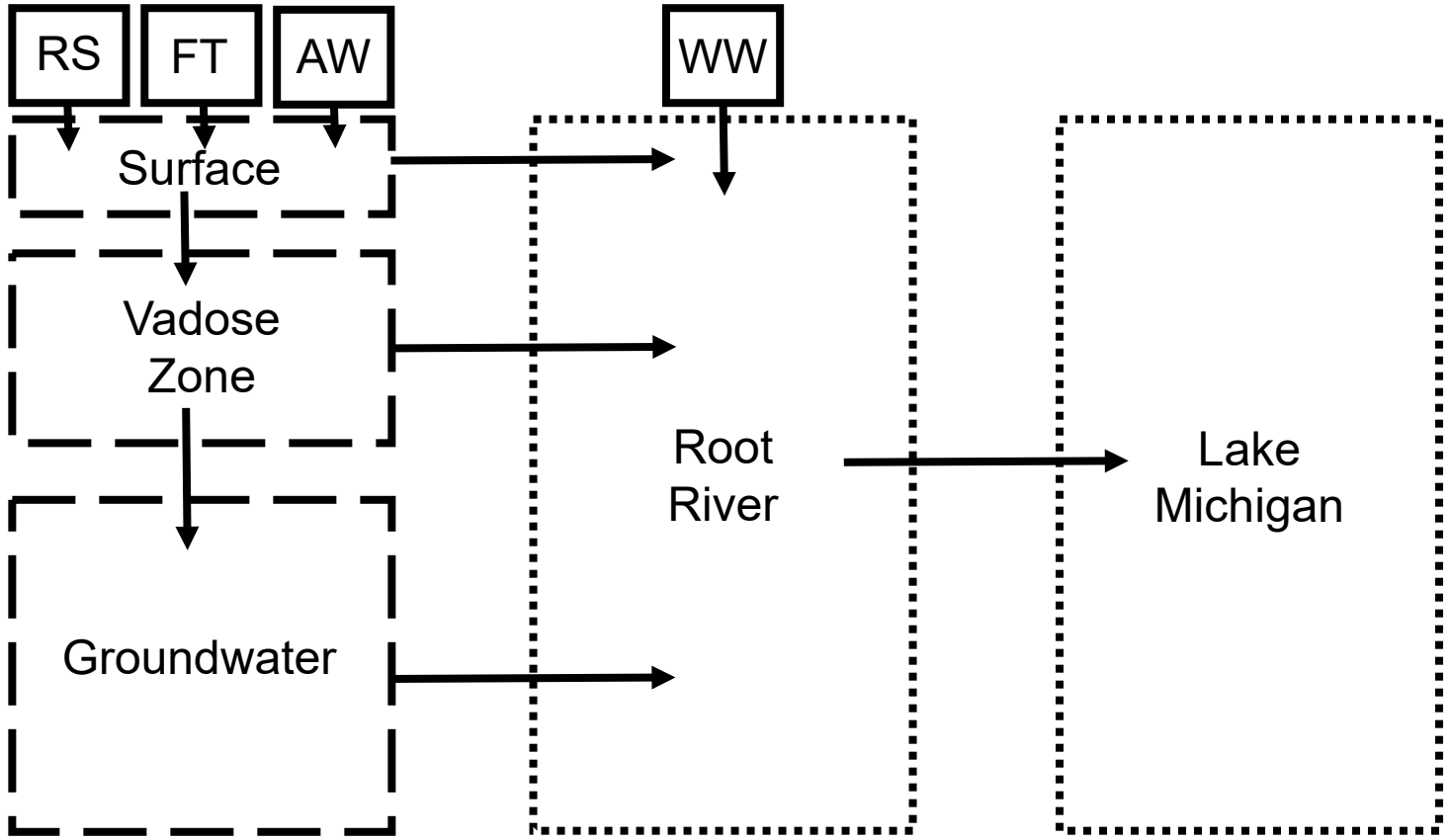
Hydro-Chloride Conceptual Model



Legend

Primary Source

Secondary Source

Sink

Transport

RS = Road Salt
FT = Fertilizer
AW = Animal Waste
WW = Wastewater

3 Scientific Questions

1. How much mass of chloride is being discharged from groundwater to the Root River during summer months?
   - Assumes chloride is predominantly from road salt
2. How much mass of old water is being discharged to the Root River during the summer months?
   - Old: water that existed in the watershed prior to the rain event
3. What hydrogeologic compartment is storing the most mass of chloride during the summer months?

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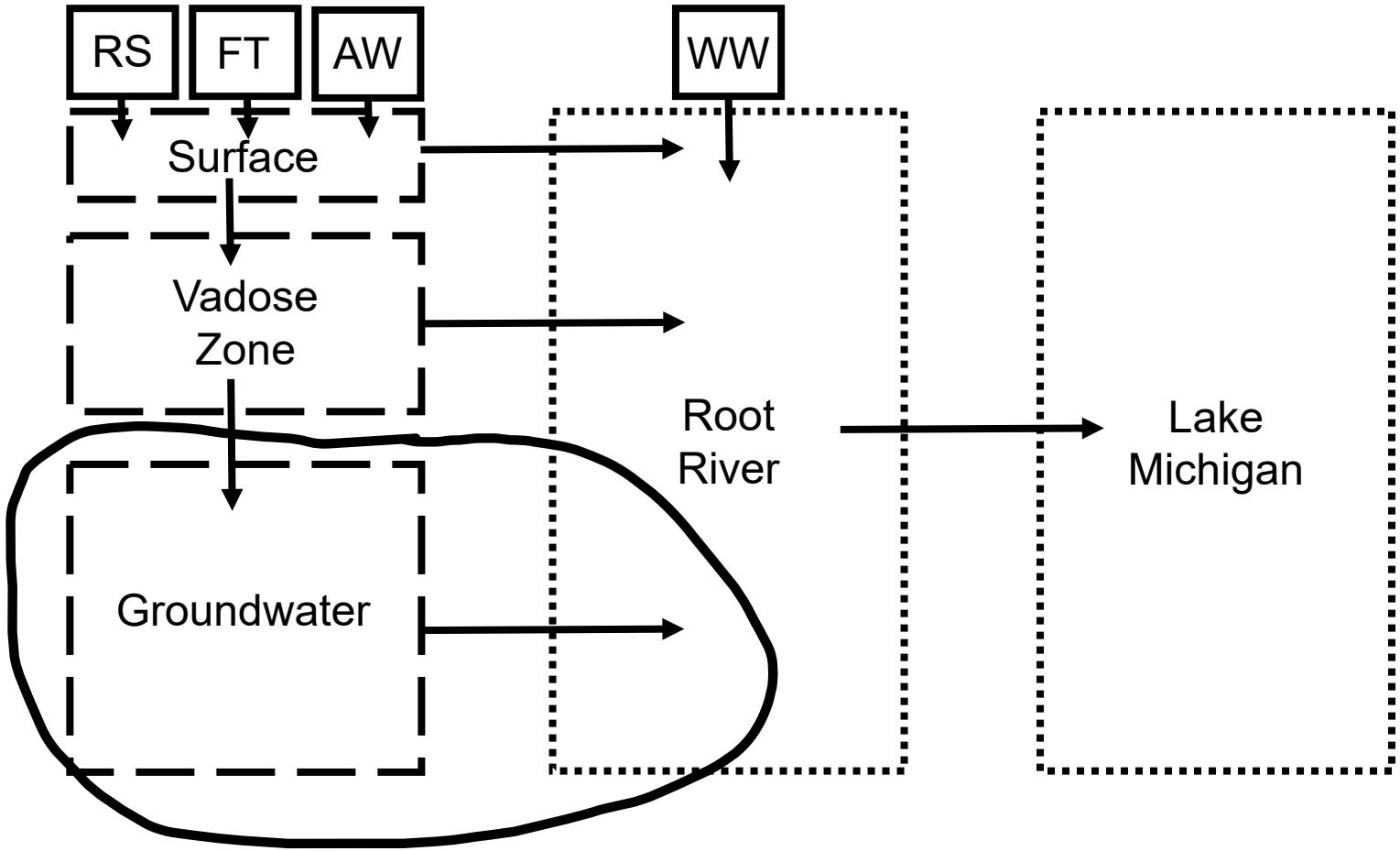
Hydro-Chloride Conceptual Model



Legend

Primary Source

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RS = Road Salt
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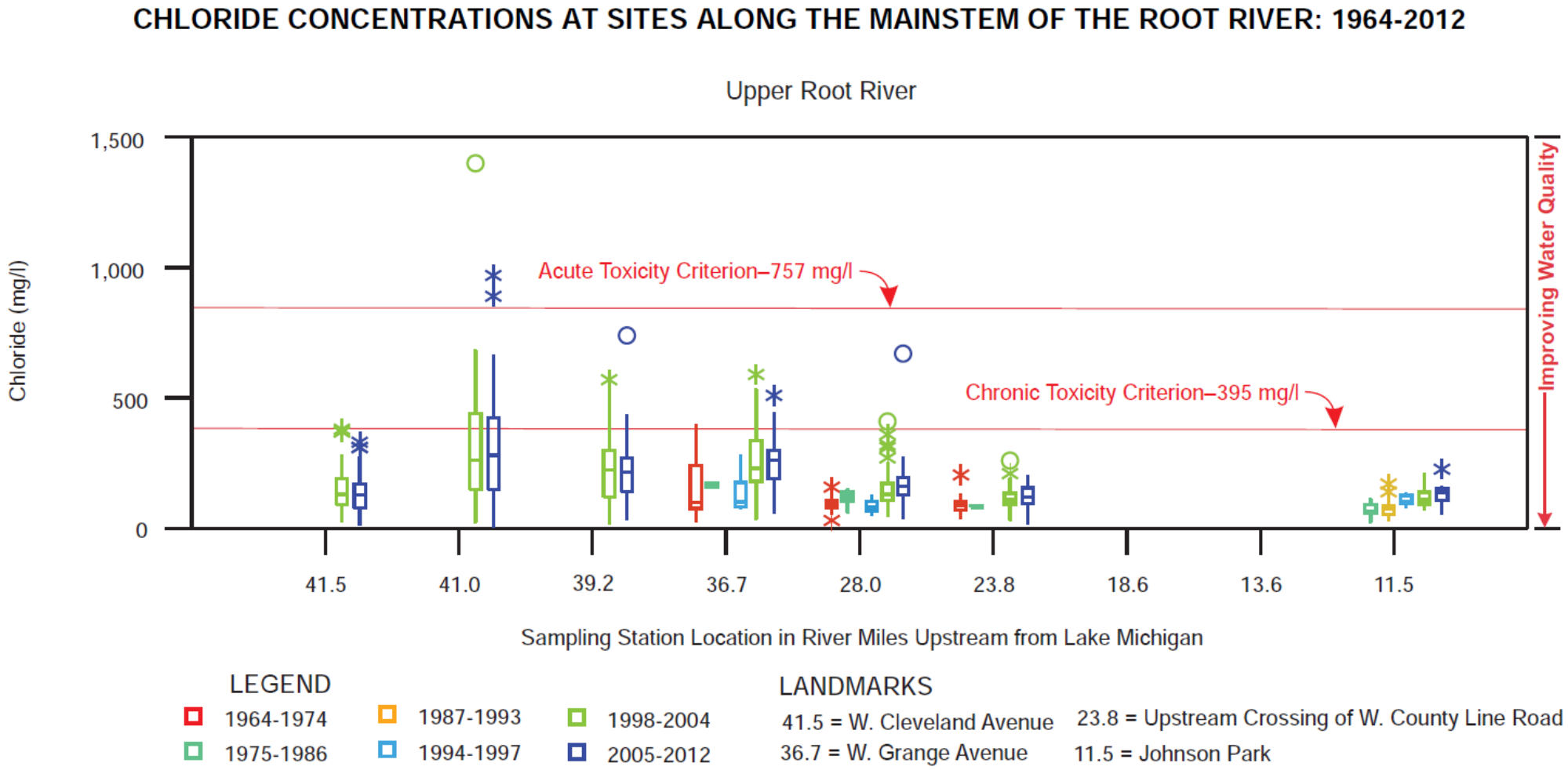
Research Motivation



SEWRPC (2016)

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3 Scientific Questions

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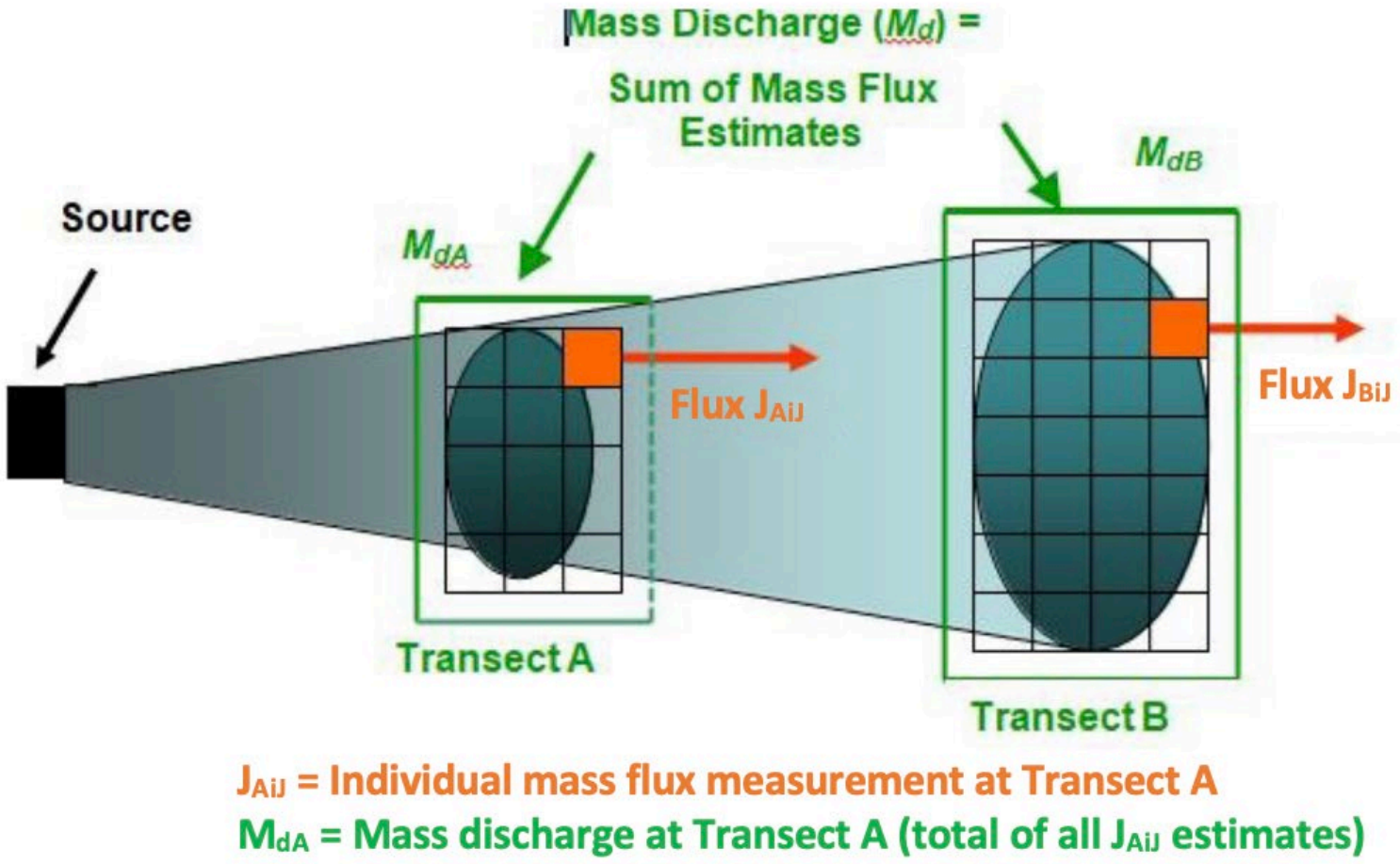
Mass Flux & Mass Discharge

- Mass flux is a rate measurement specific to a defined area
  - mass/time/area
  - lbs/day/square feet
- Mass discharge is an integrated mass flux
  - mass/time
  - lbs/day



ITRC (2010)

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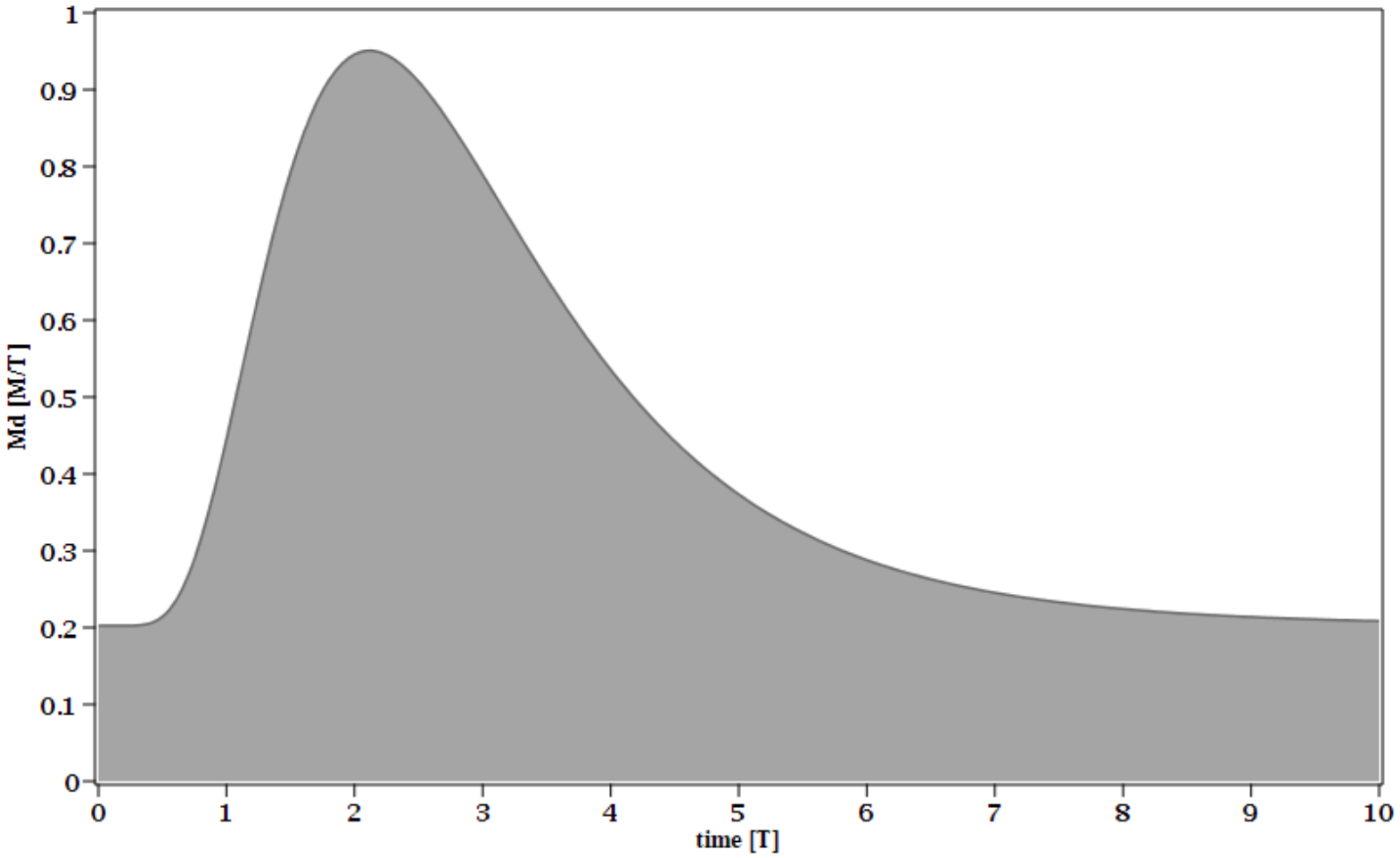
Mass Discharge (M_d) & Mass (M)

- $M_d = \sum_{n=1}^{N} Q_n C_n$
- $M = \int_{t_o}^{t} M_d dt$
- Mass is area under Md vs t data
- How to get Md data?
- Need Q from USGS
- Need C from students
  - A's & B's preferred ☺



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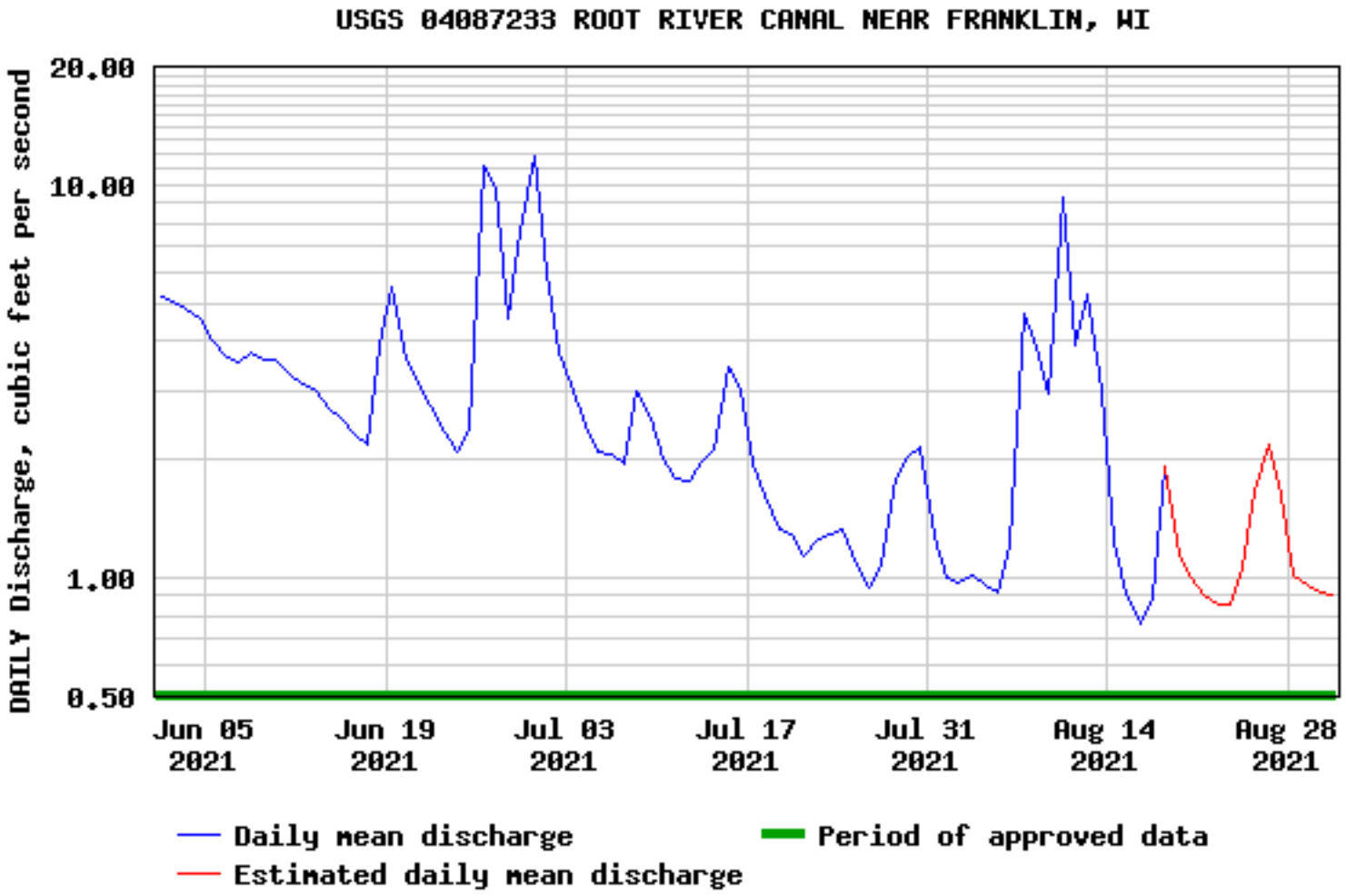
Stream Discharge (Q) From USGS



USGS (2022)

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Concentration (C) From Students

Dylan Childs (left), Autumn Routson (right)

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3 Scientific Questions

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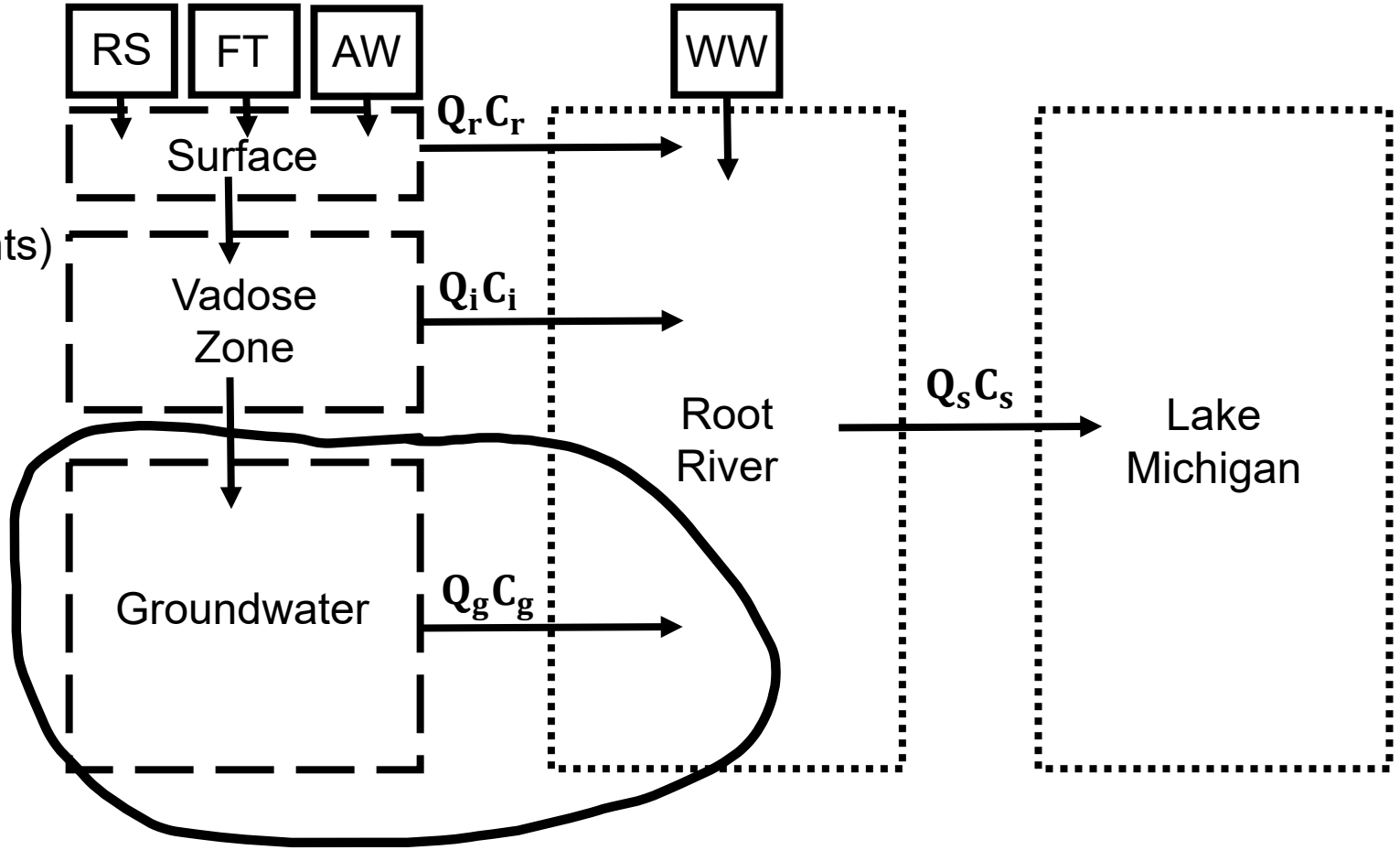
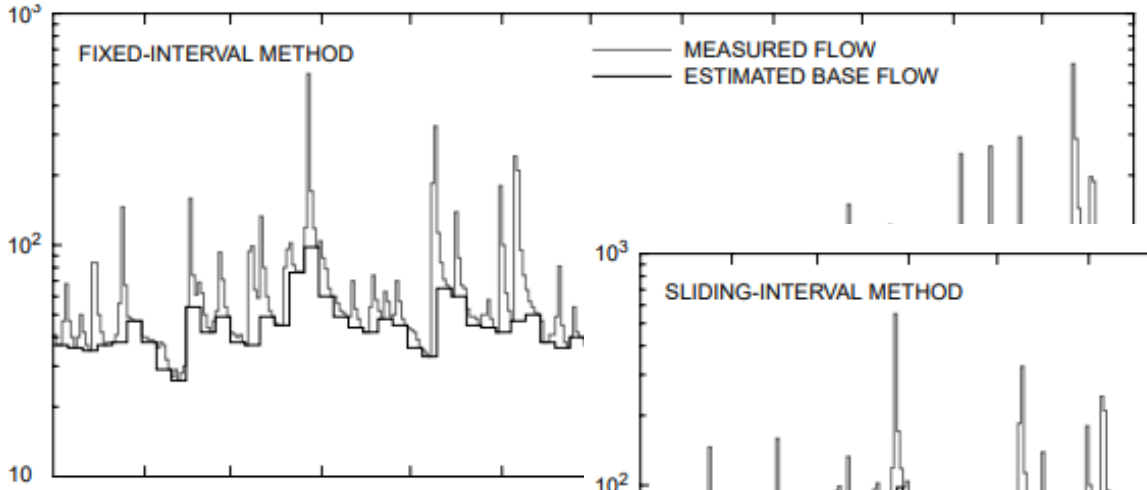
Hydrological Mass Balance Model

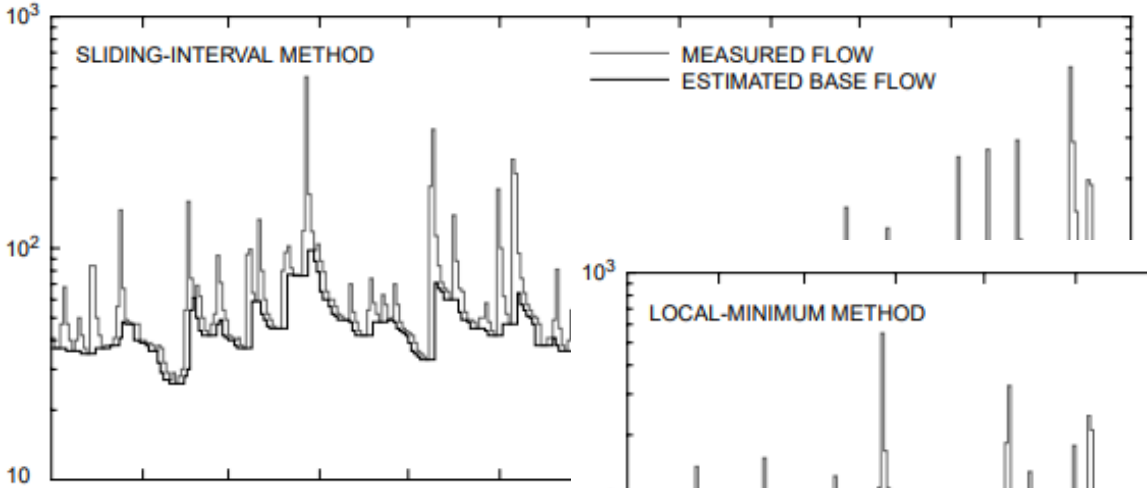
- $\check{Q}_s\check{C}_s = \overset{**}{\check{Q}}_{r,i}C_{r,i} + \overset{**}{\check{Q}}_g\overset{*}{\check{C}}_g$

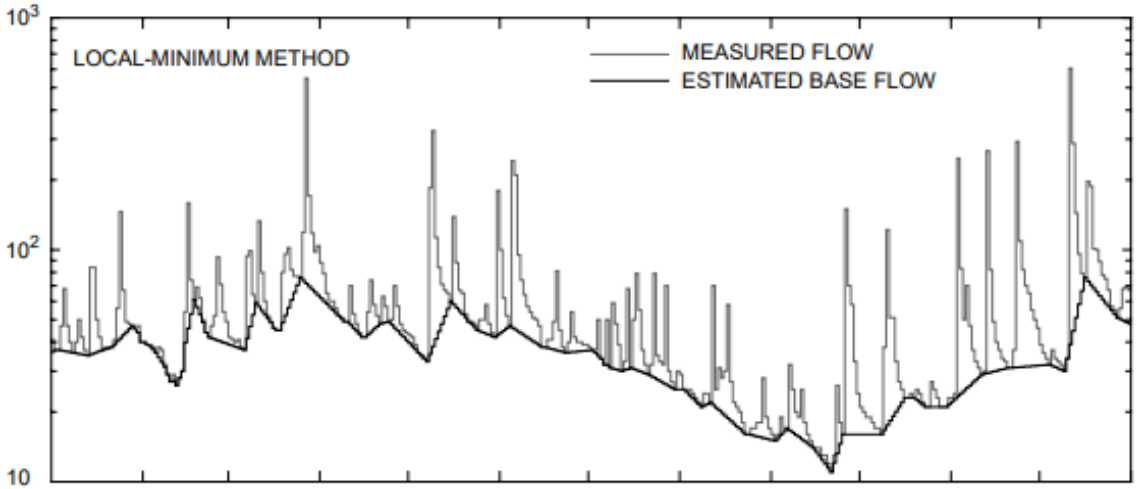
✓ Measure directly (USGS, students)
✓* Measure indirectly (baseflow-students)
✓** Estimate (hydrograph separation)



Hydrograph Separation (HYSEP)







$$N = A^{0.2}$$

A= area (mi^2)
N = time (days)

USGS (1996)

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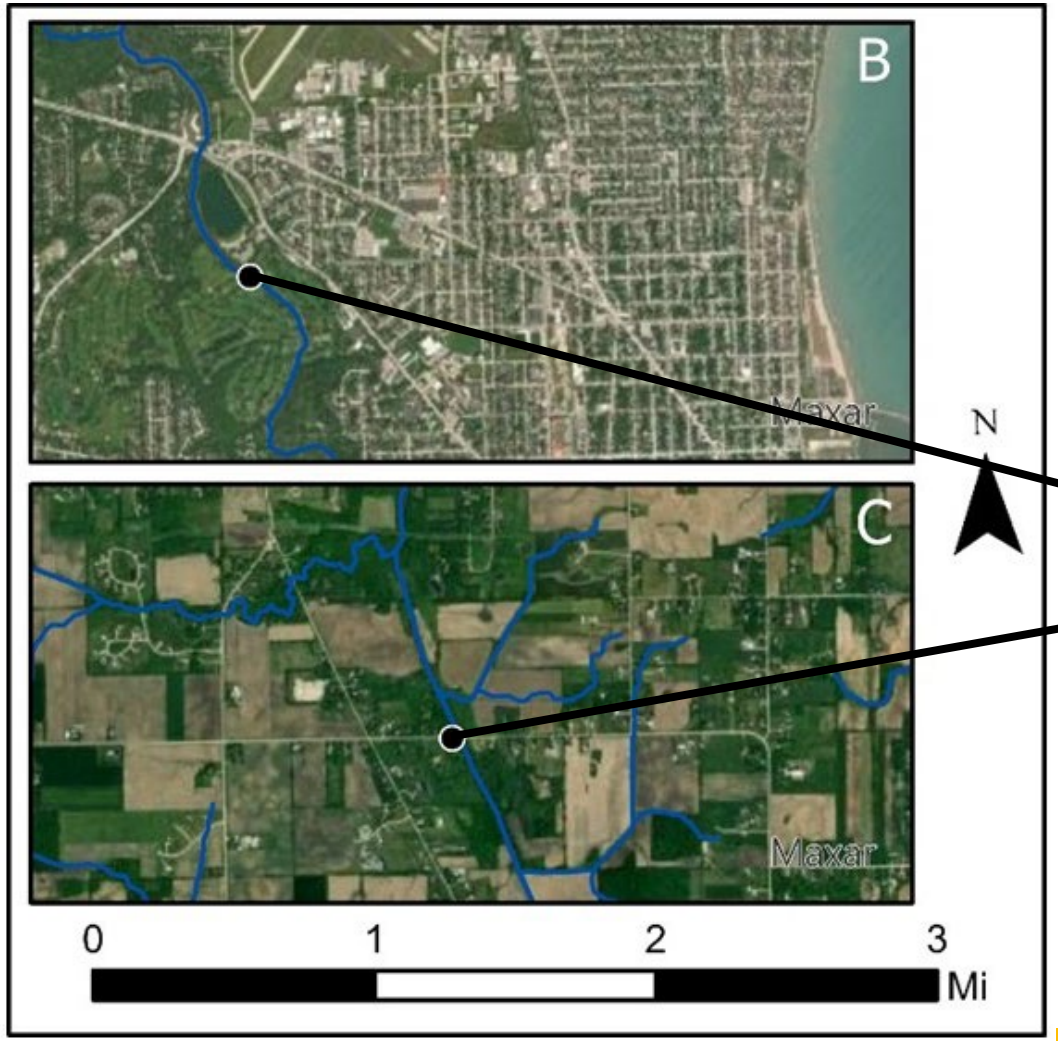
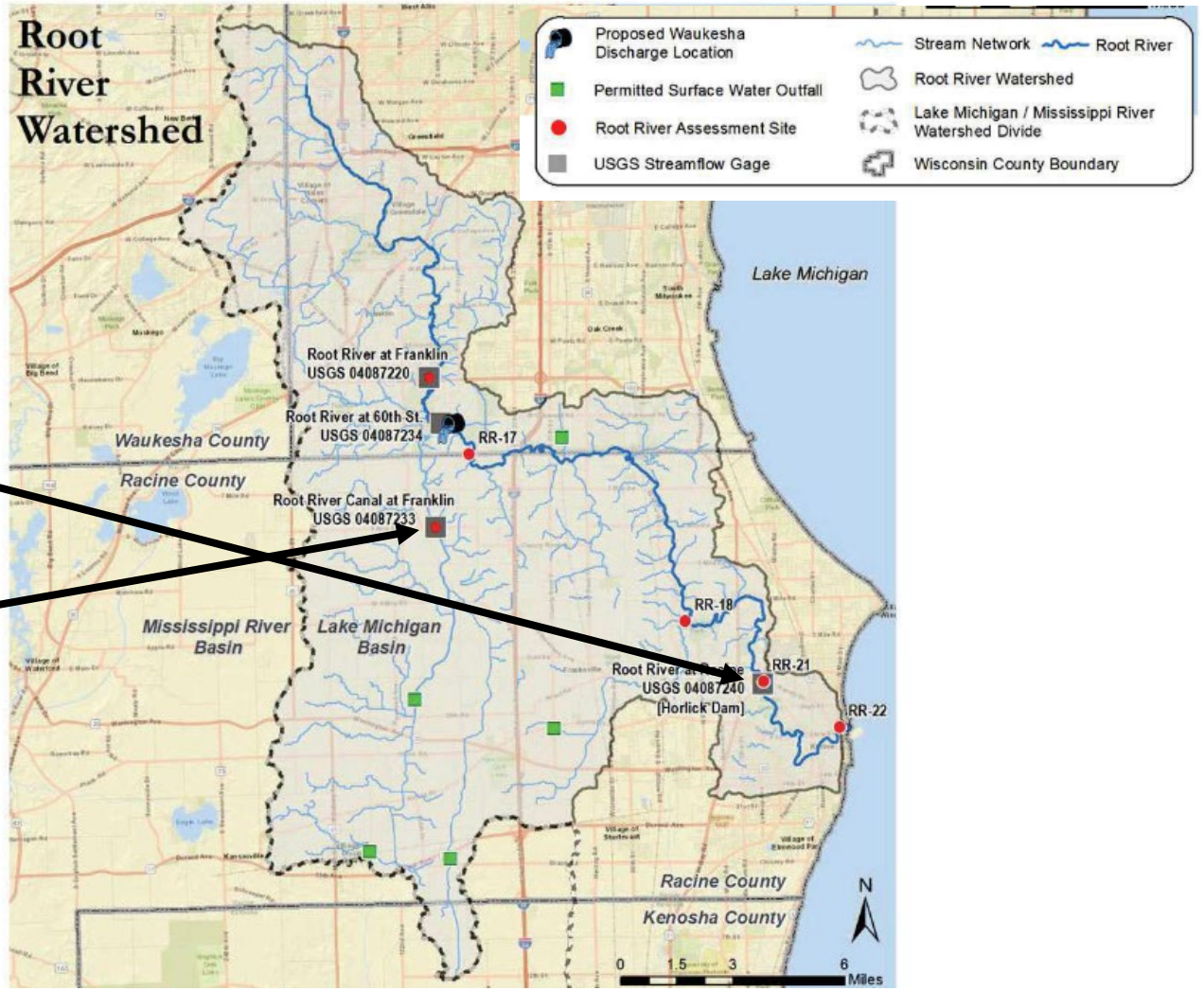
Field Sites: Root River (Rural & Urban)





Map on right: WIDNR (2019)

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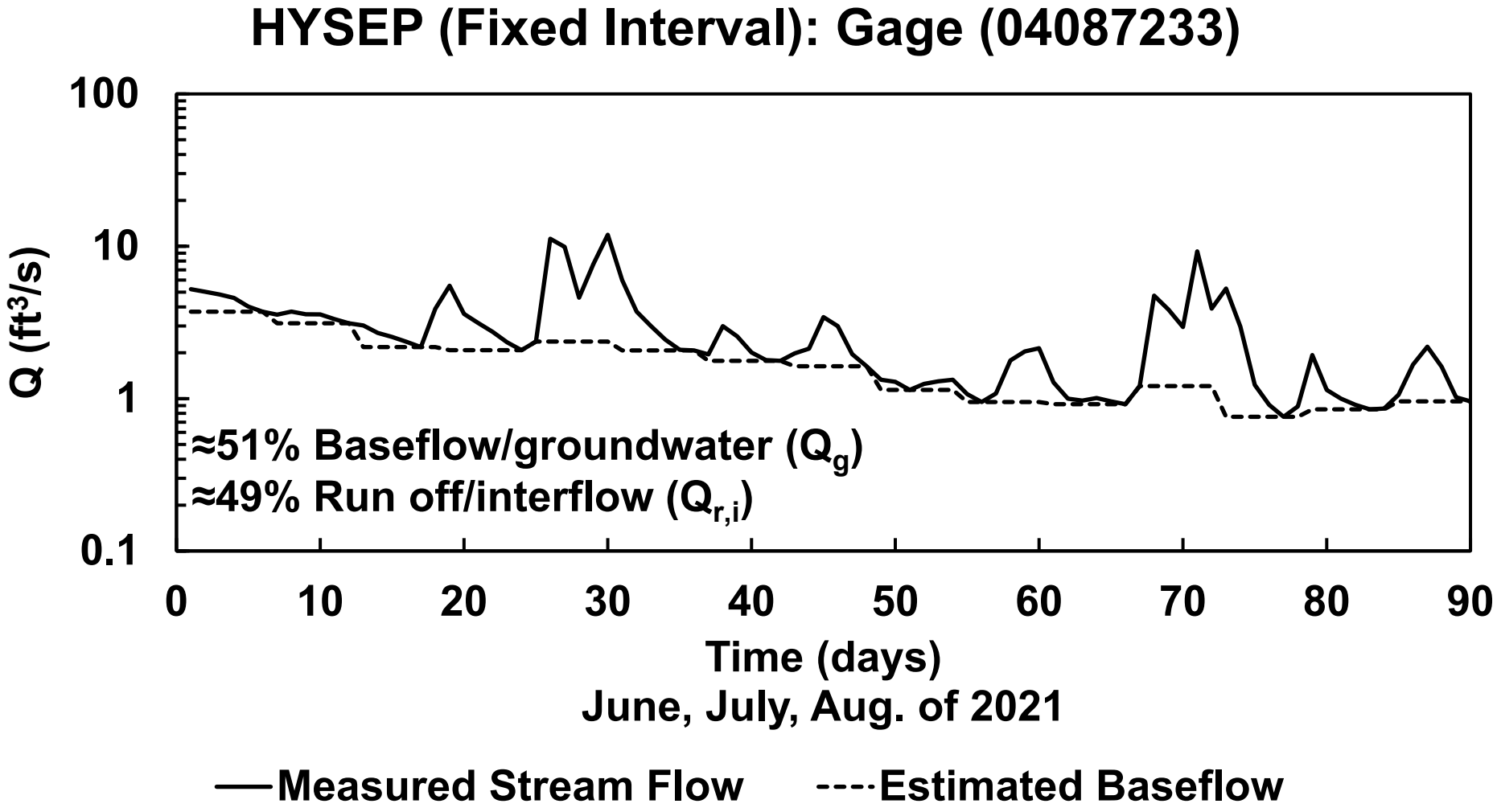
Data Analysis: HYSEP Assumptions

Site Number and Type	Streamflow conditions		Hydrologic units		Size of Watershed in square miles		Time Scale of analysis period		Basin slope, in percent		Groundwater or surface-water development*		Streamflow record		Total of points for determining whether the methods are appropriate for use**
	Gaining	3	Single	3	≤1	1	<Monthly	1	<1	2	None	3	Complete and <1 year in length	2	
	Losing	1			>1 to ≤500	3	Monthly or Seasonal	2			Minor	2			
	Perennial	3	Multiple	2	>500	2	Annual or longer	3	≥1	3	Substantial	1	Complete and ≥ year in length	3	
	Intermittent	2													
Site 1 – Urban	3		3		3		2		3		1		3		***18 out of 21***
Site 2 – Rural	3		3		3		2		3		2		3		***19 out of 21***

*Includes groundwater pumping, surface-water discharges, or diversions, and so forth.

**Numeric scale adapted from the USGS; higher totals represent appropriate methods while lower totals do not represent appropriate methods.

Hydrograph: Rural Site



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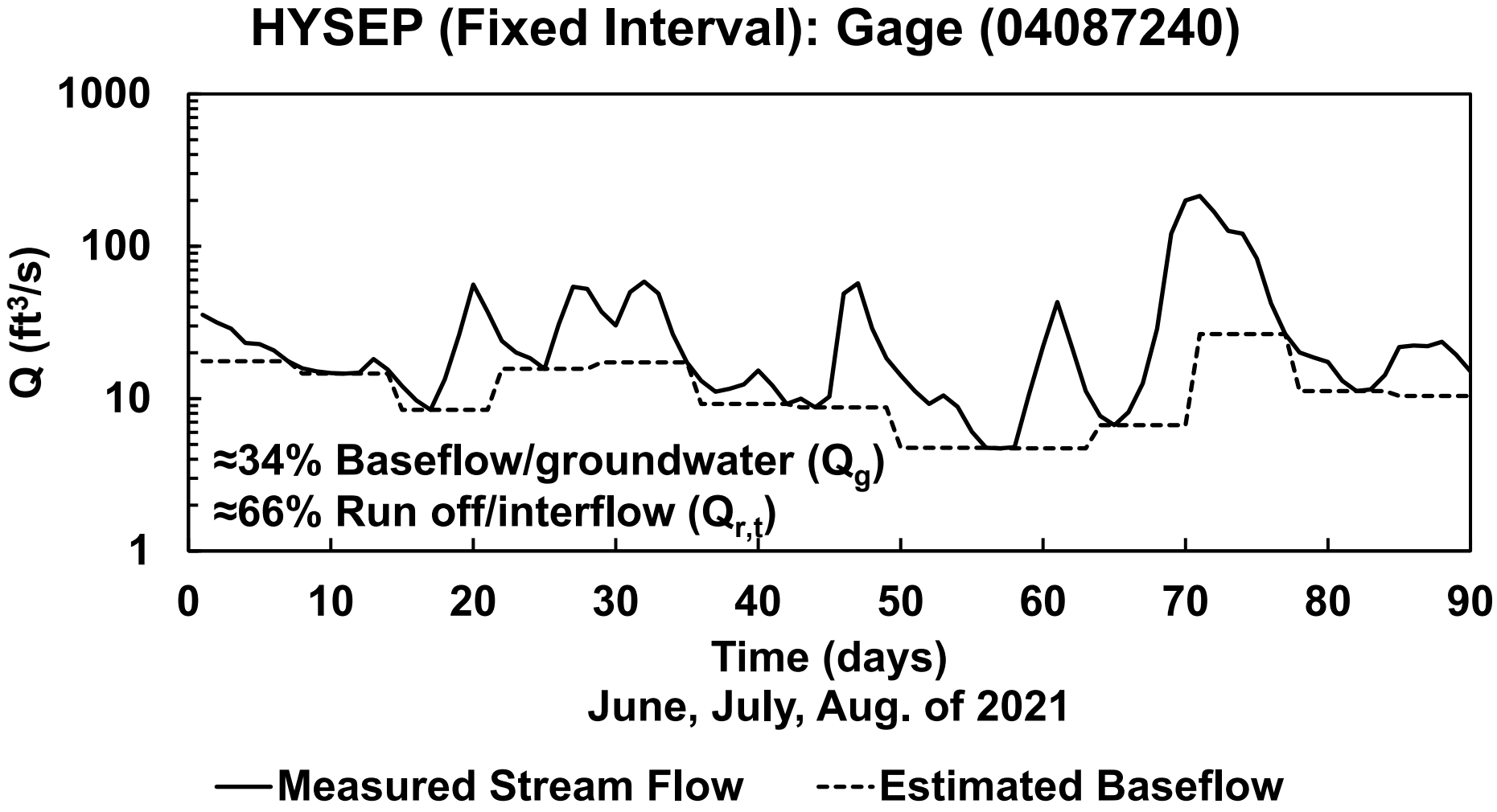
Hydrograph: Urban Site



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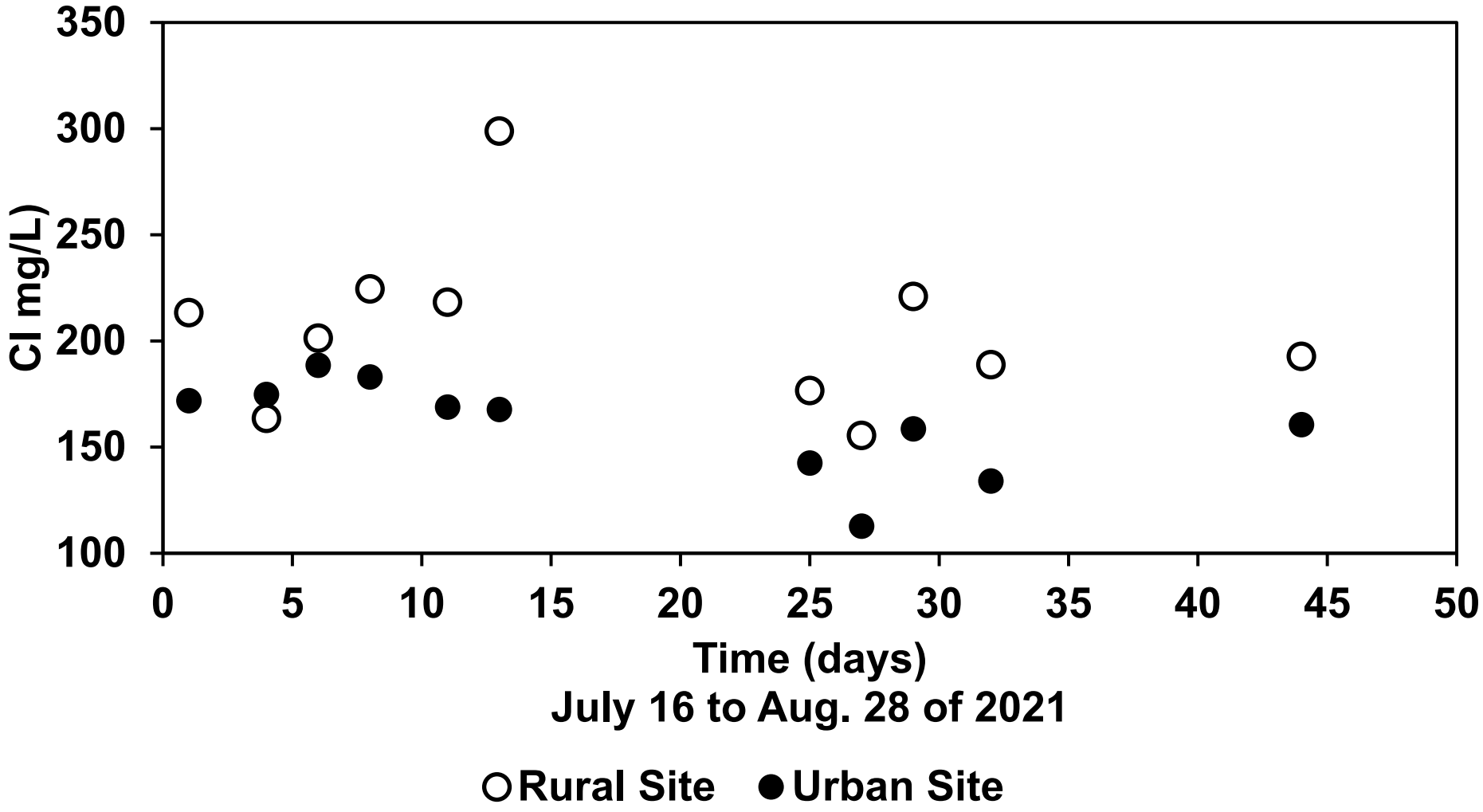
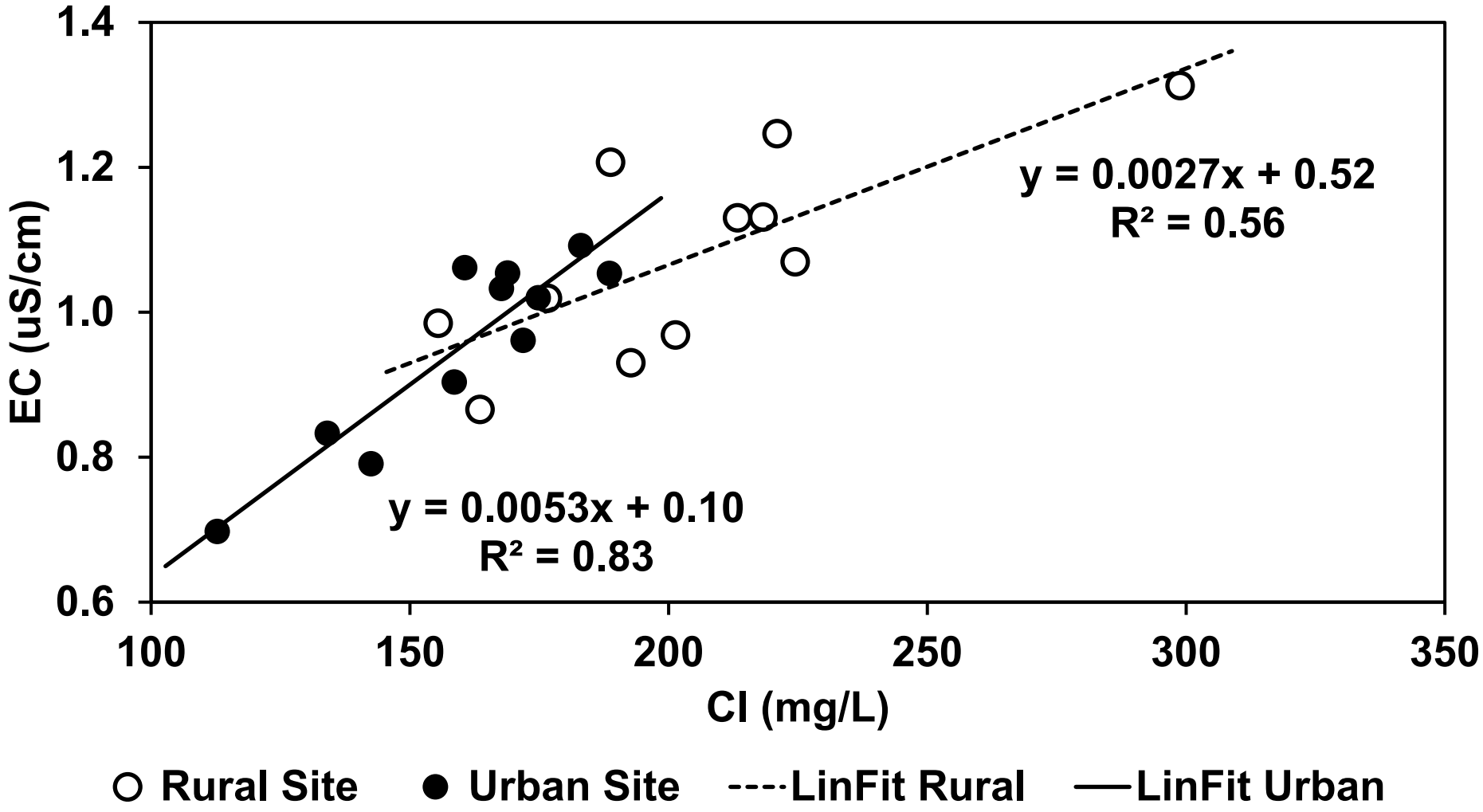
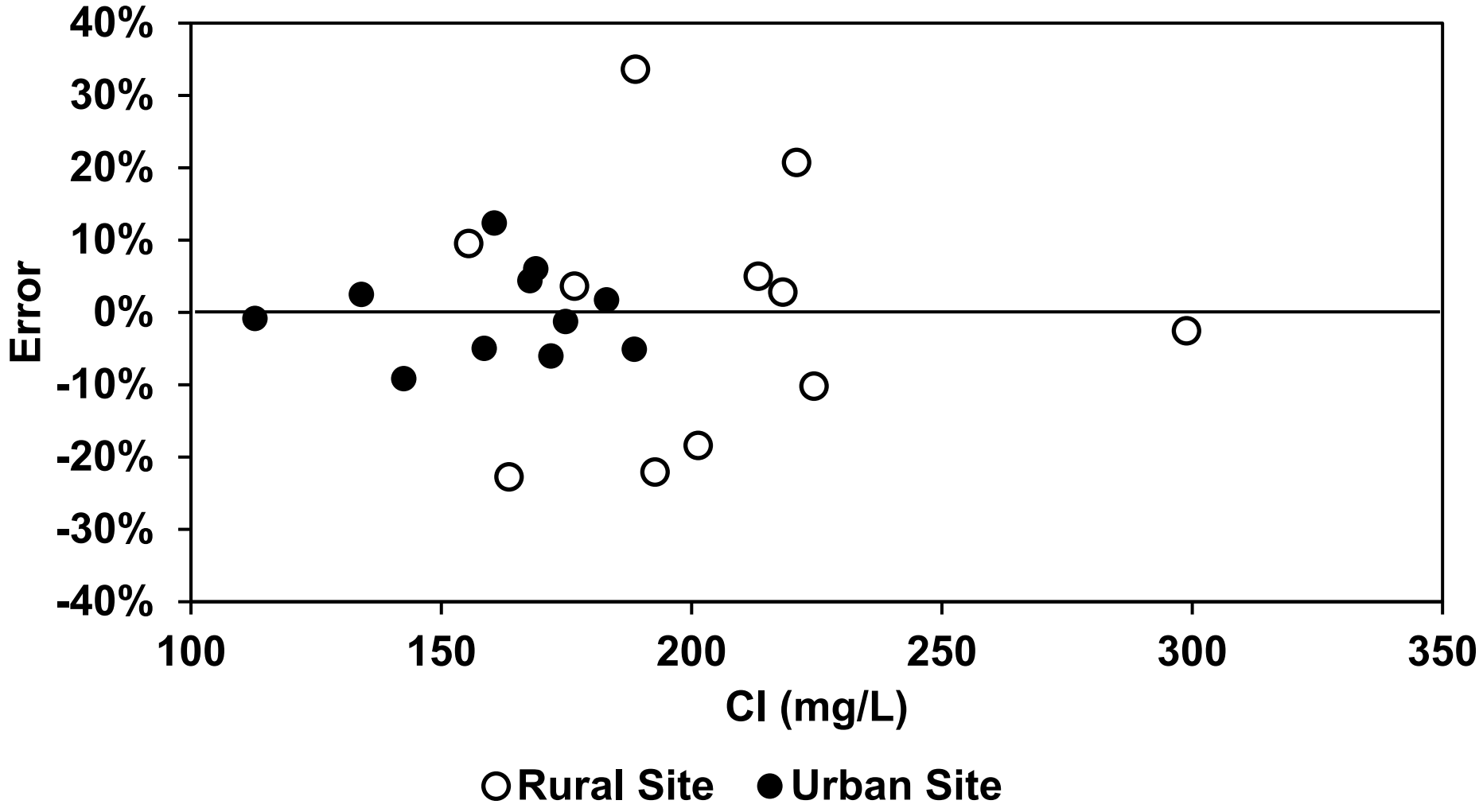
Chloride (Discrete): Rural & Urban



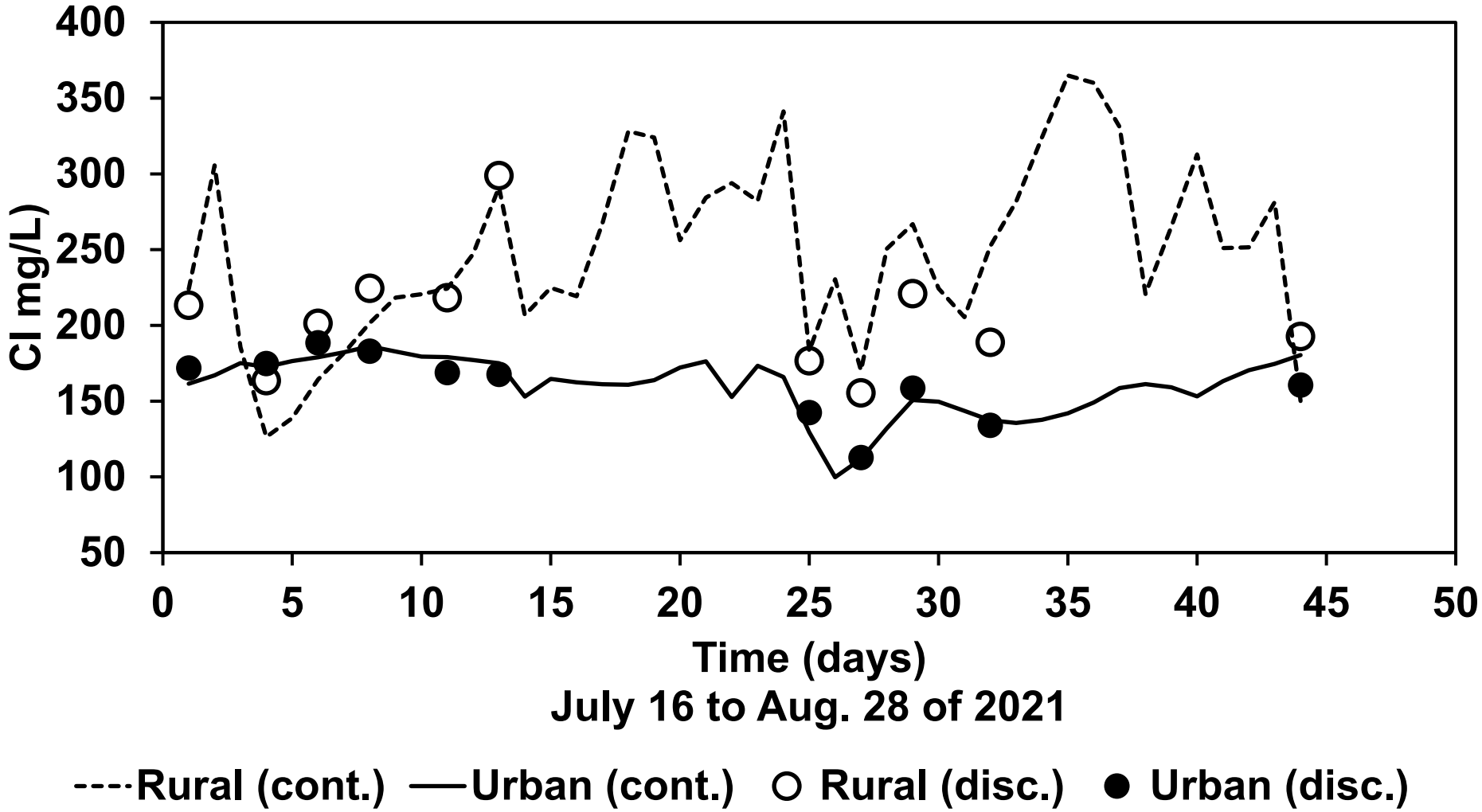
EC (cont.) vs Cl (disc.): Rural & Urban



Error of Cl (cont.): Rural & Urban



Cl (cont.) vs Time: Rural & Urban



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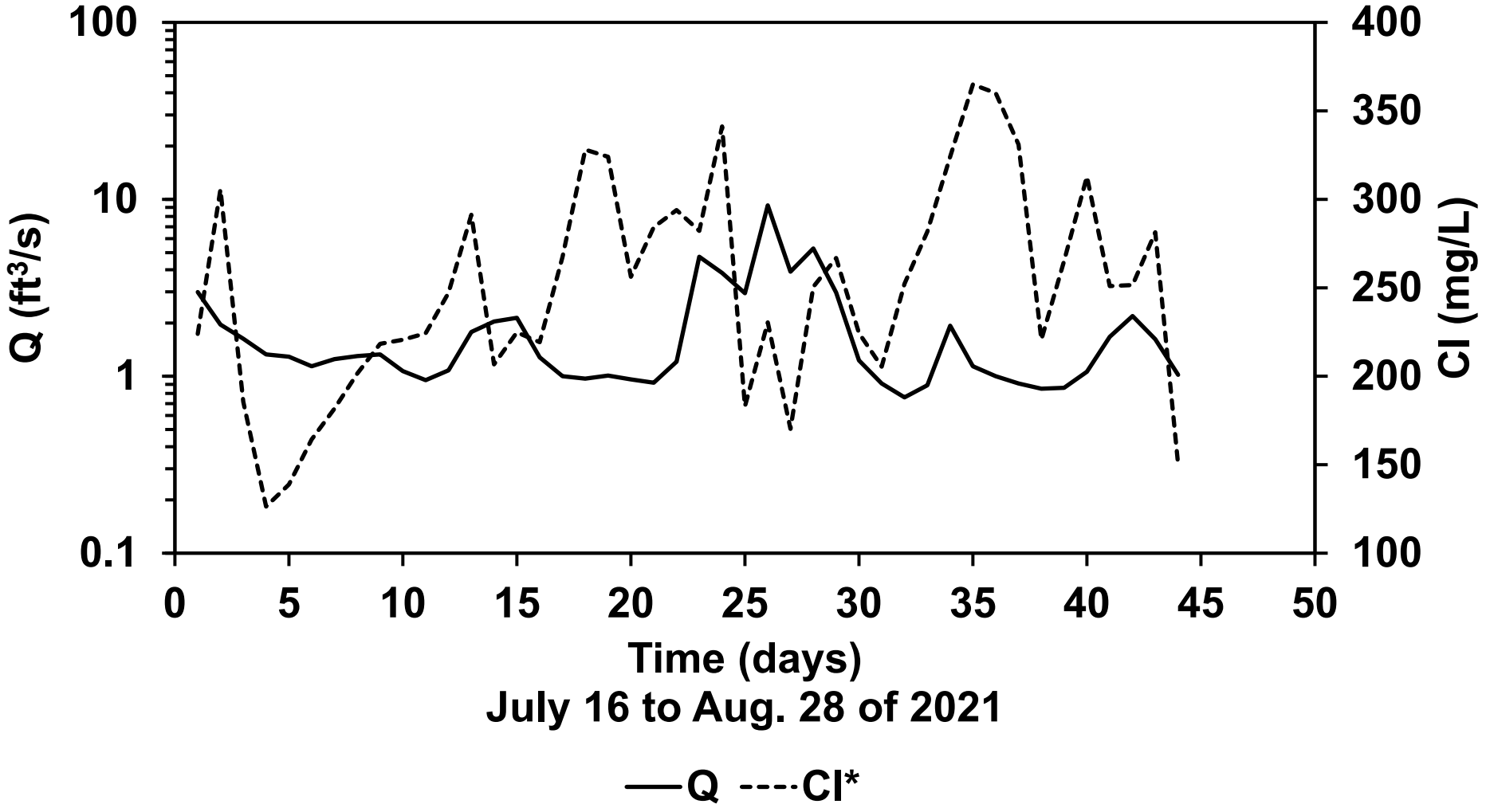
Flow (Q) vs Conc. (C): Rural Site



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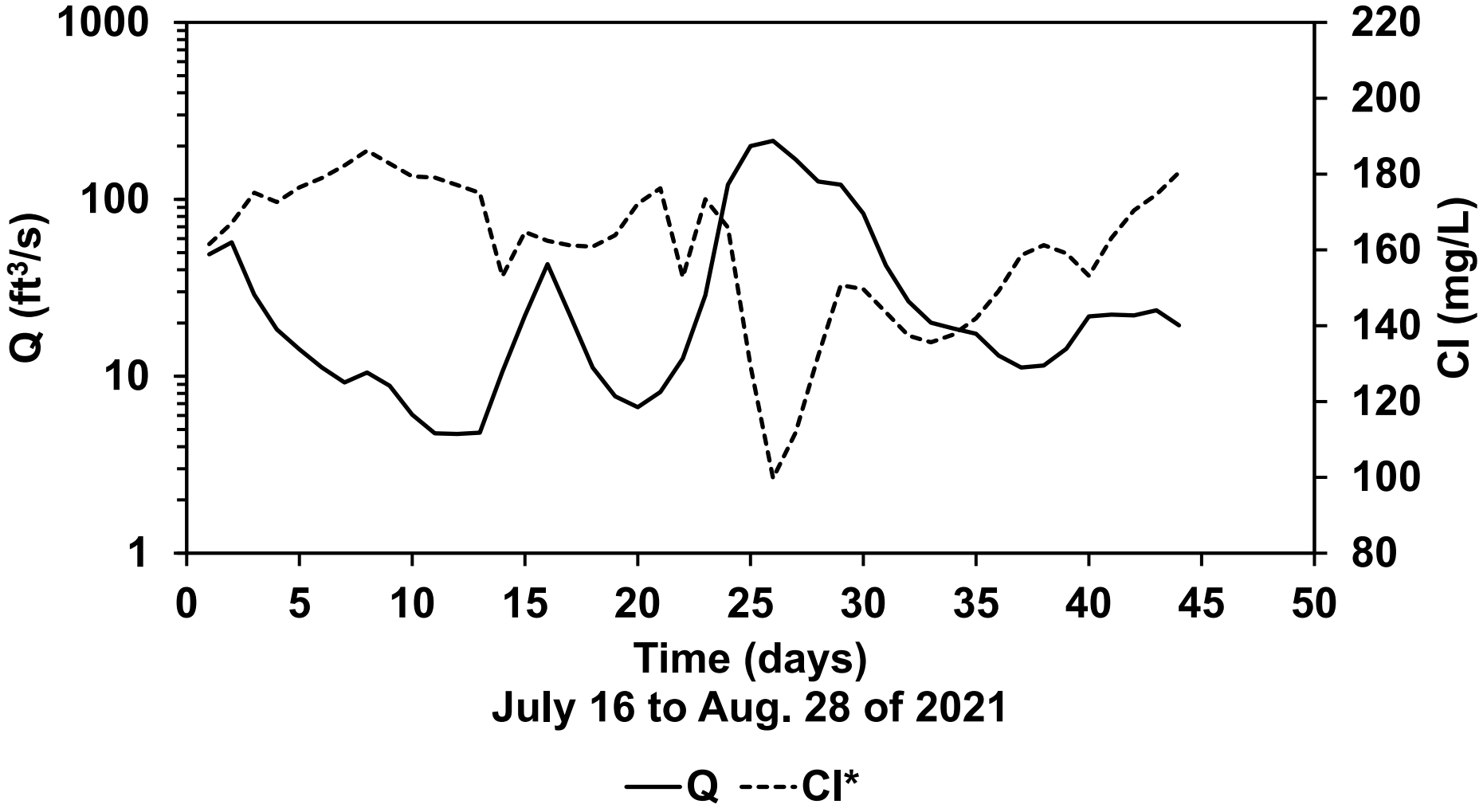
Flow (Q) vs Conc. (C): Urban Site



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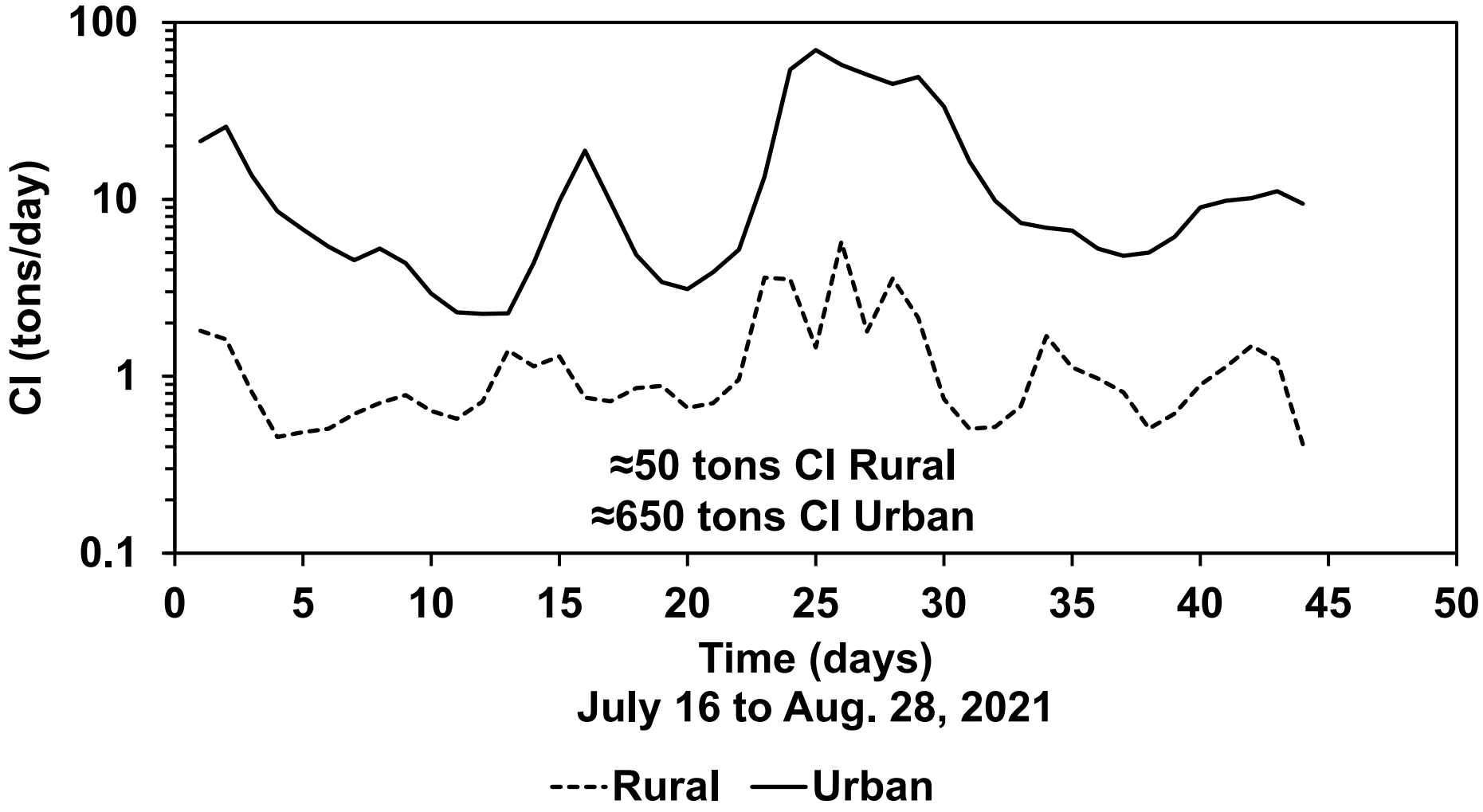
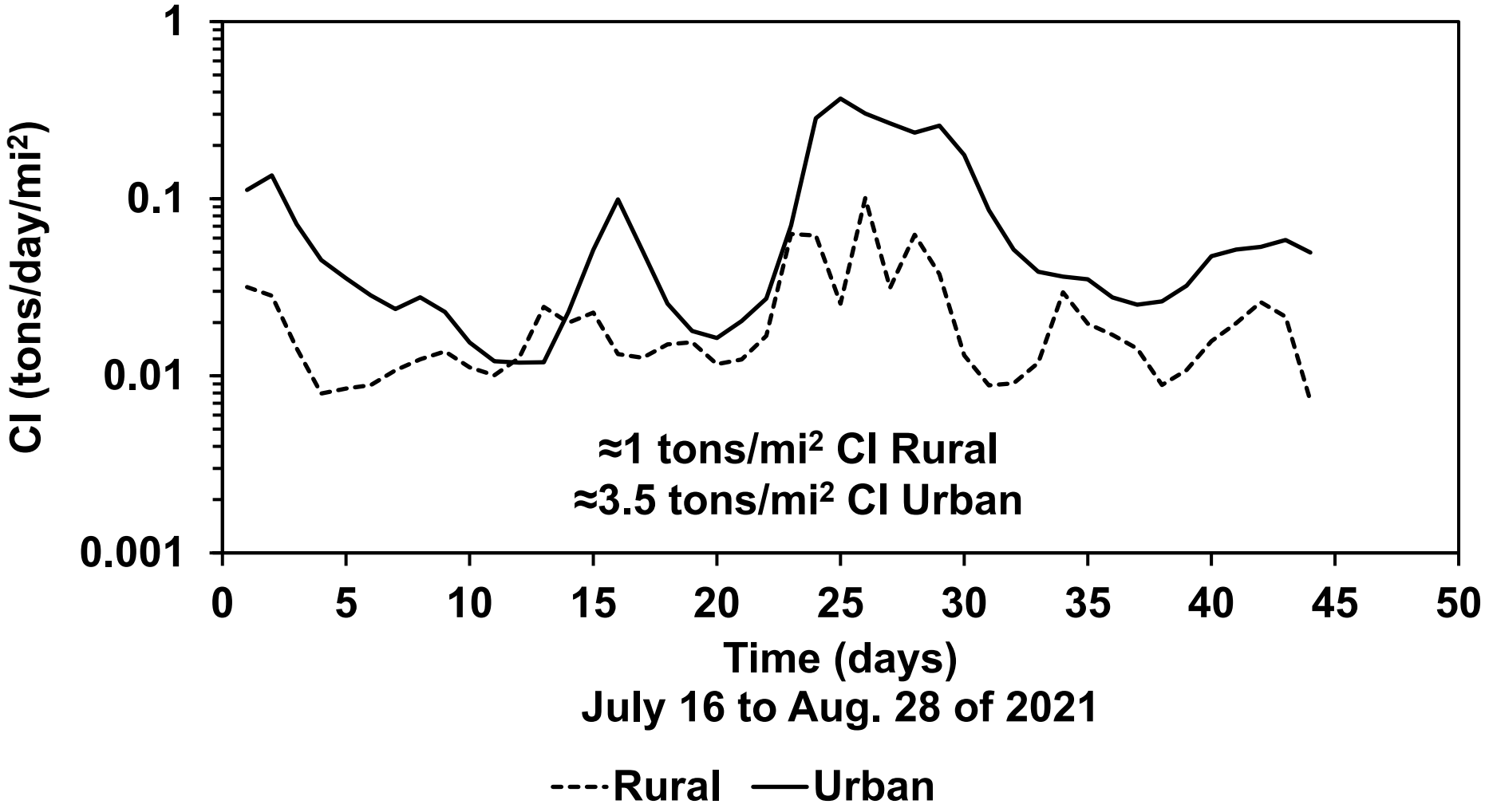
Cl Mass Discharge: Rural & Urban



Cl Mass Dis/Area: Rural & Urban



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Hydrological Mass Balance Model

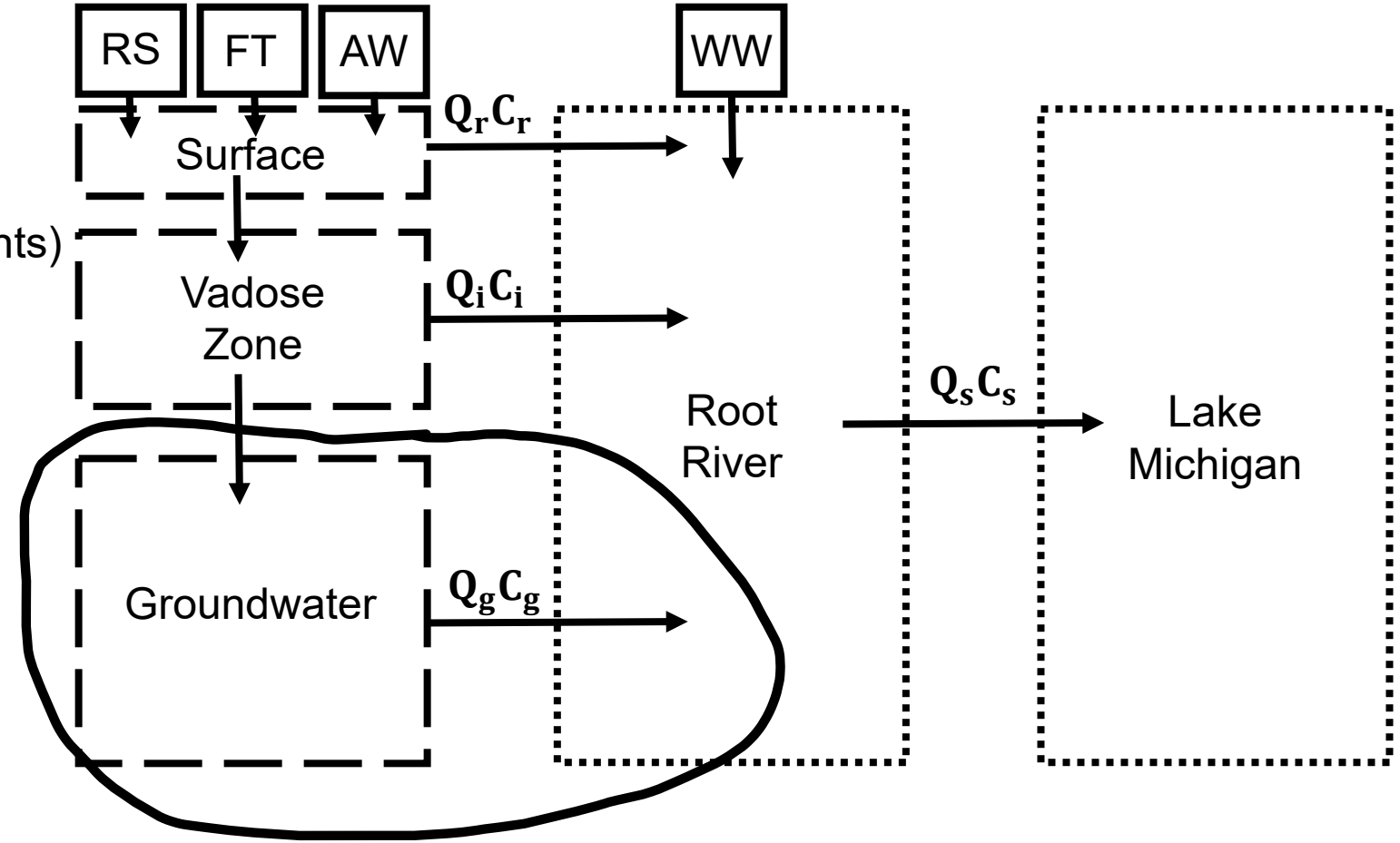
$$\checkmark Q_s \checkmark C_s = \overset{**}{\checkmark} Q_{r,i} C_{r,i} + \overset{**}{\checkmark} Q_g \overset{*}{\checkmark} C_g$$

- ✓ Measure directly (USGS, students)
- ✓* Measure indirectly (baseflow-students)
- ✓** Estimate (hydrograph separation)

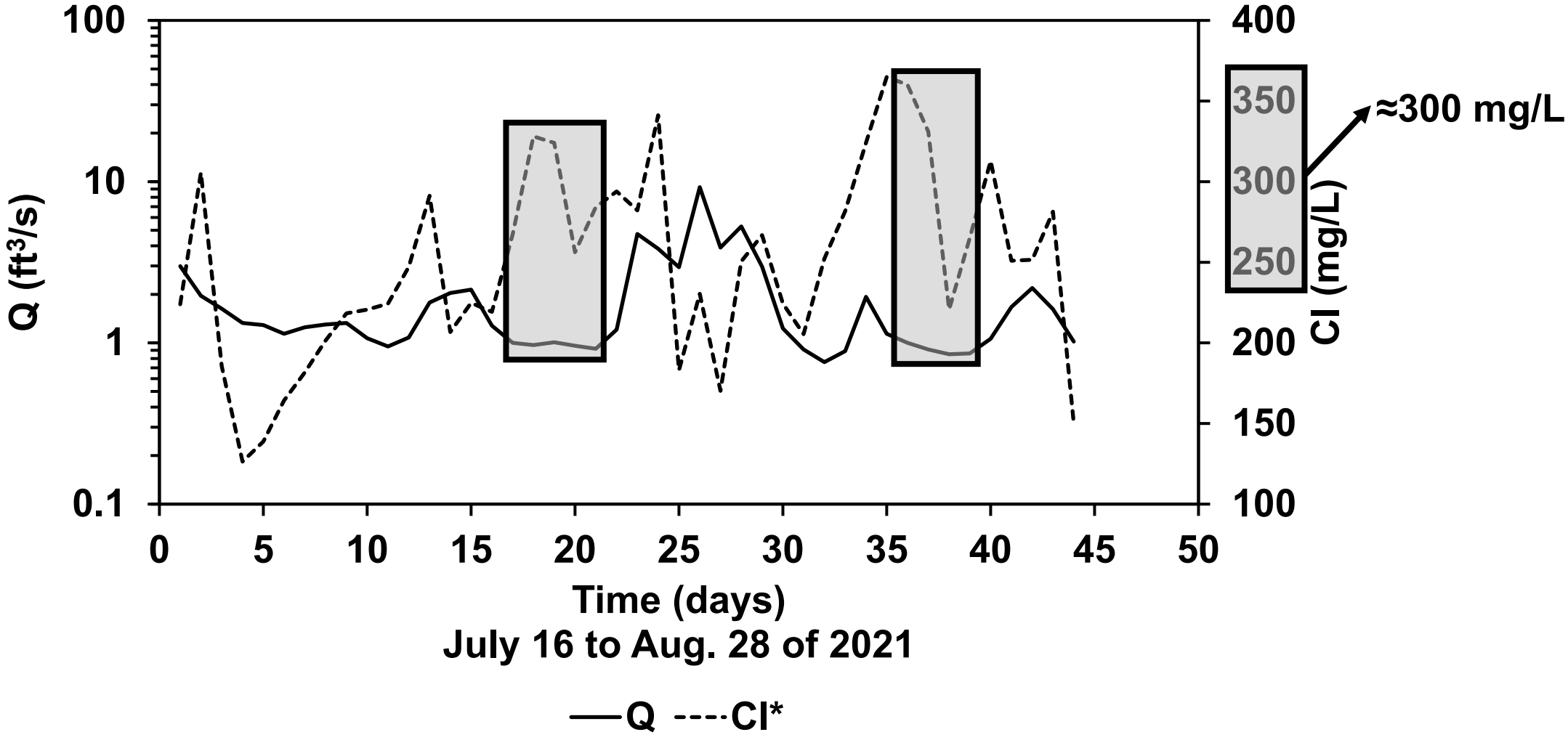
≈50 tons Cl Rural
≈650 tons Cl Urban
≈1 tons/mi² Cl Rural
≈3.5 tons/mi² Cl Urban

≈? Rural
≈? Urban

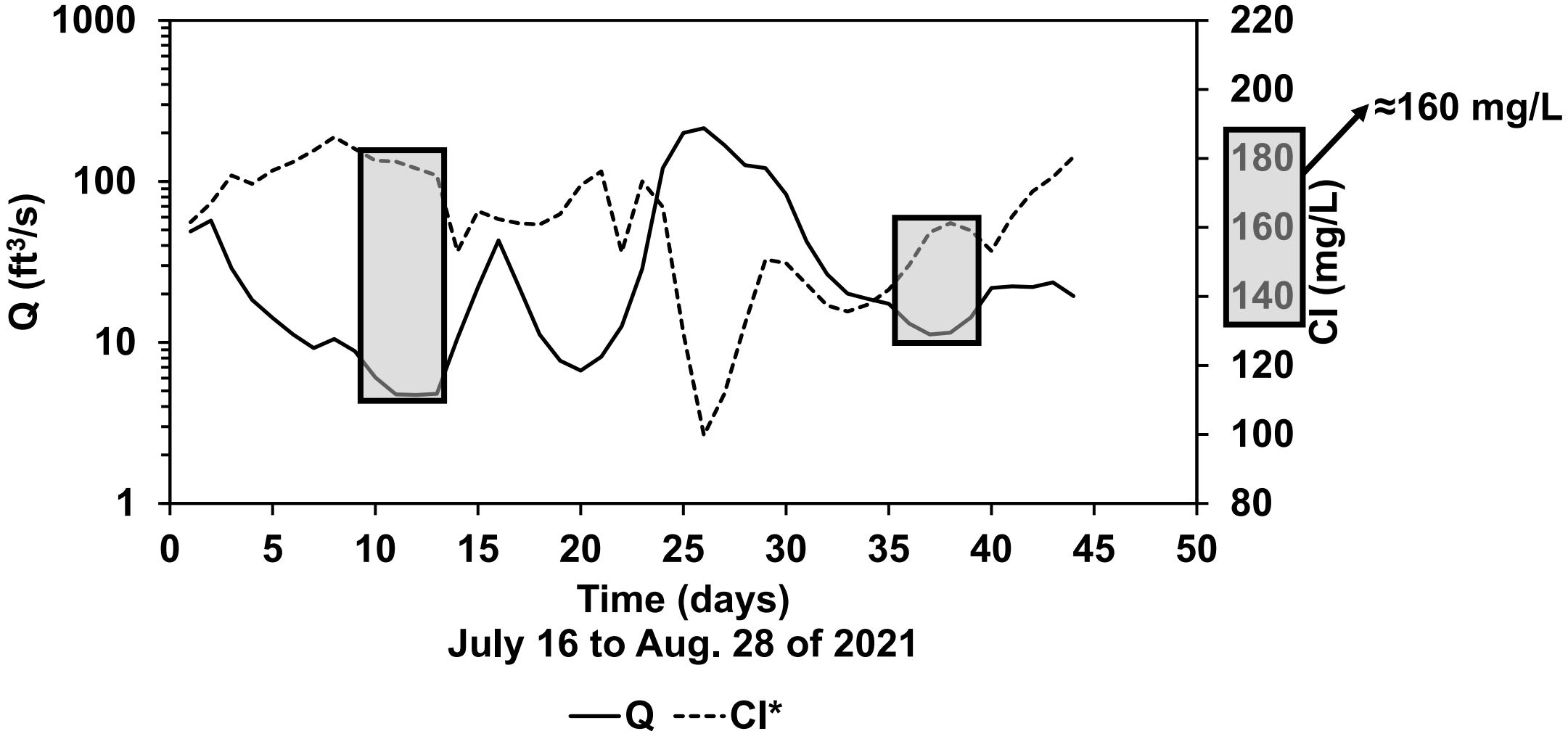
≈51% Rural
≈34% Urban



Baseflow Cl (Cg): Rural Site



Baseflow Cl (Cg): Urban Site



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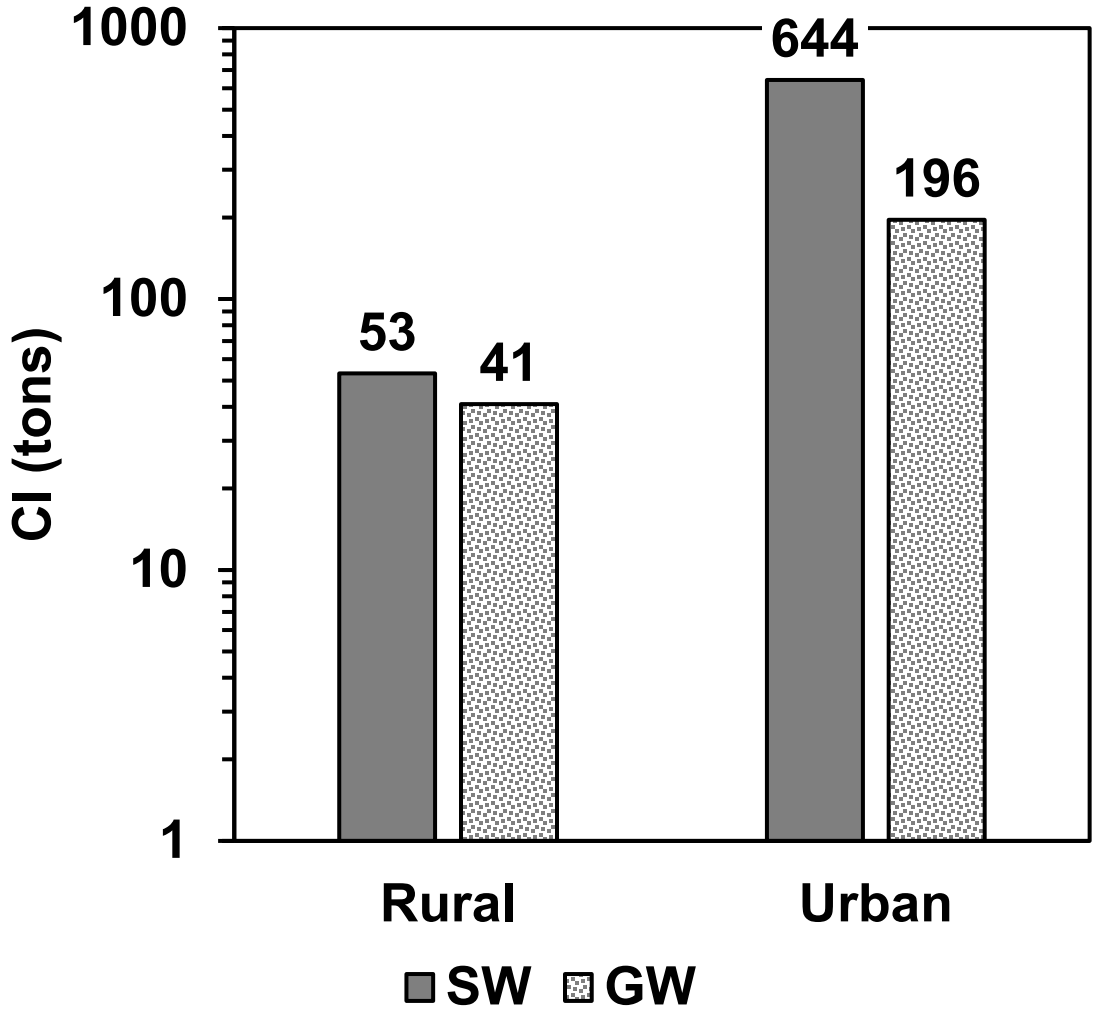
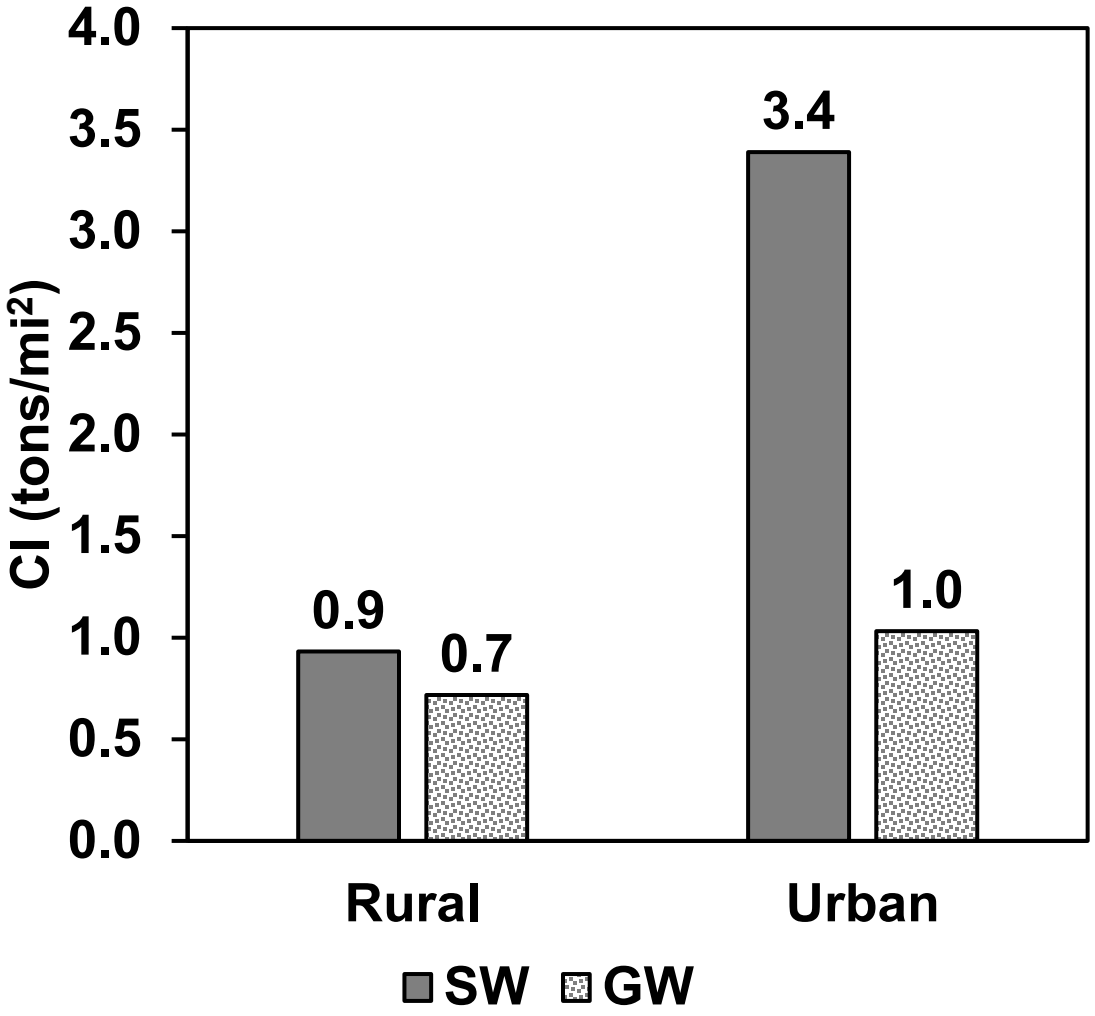
Cl Mass Groundwater to Root River





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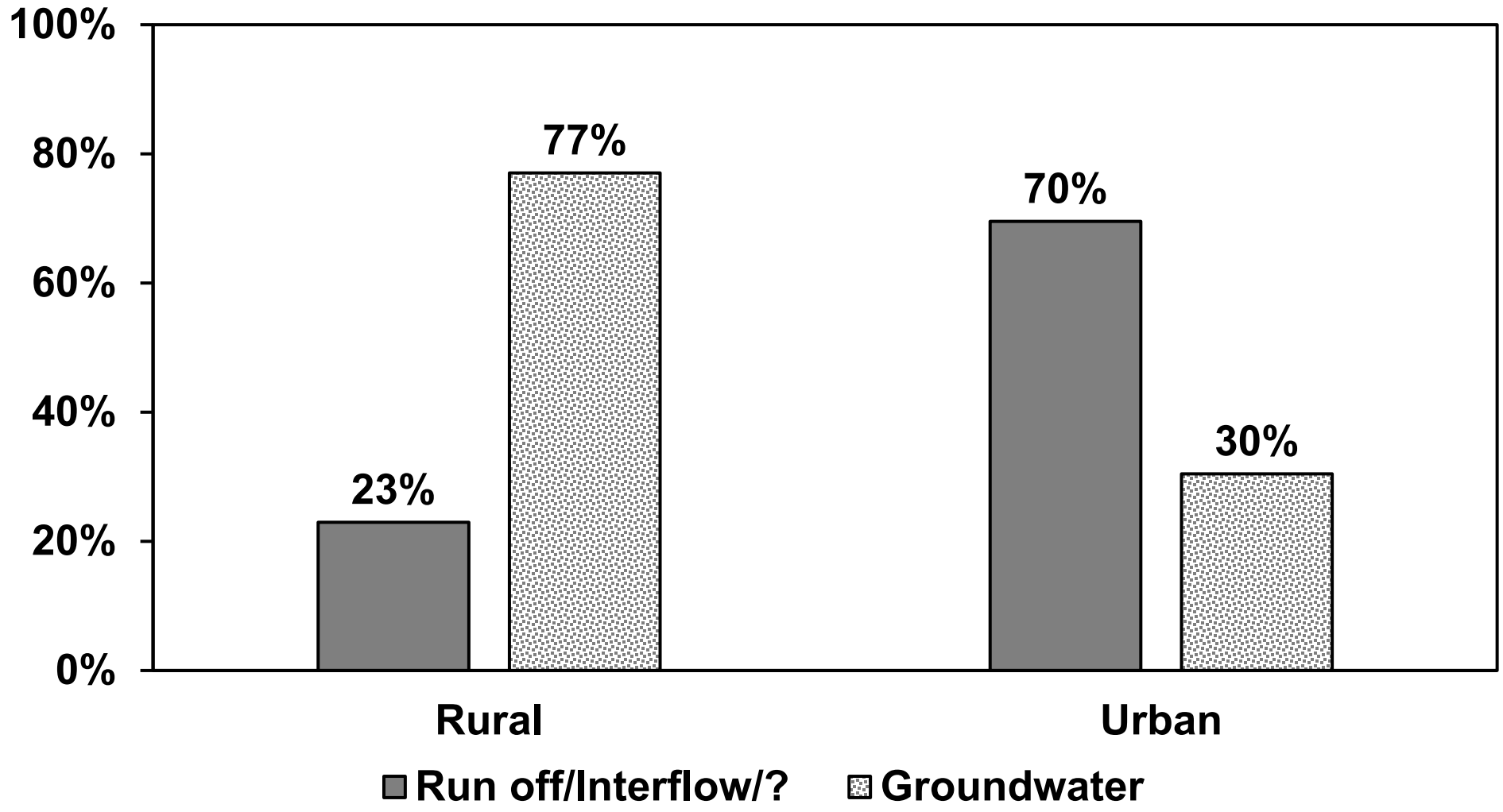
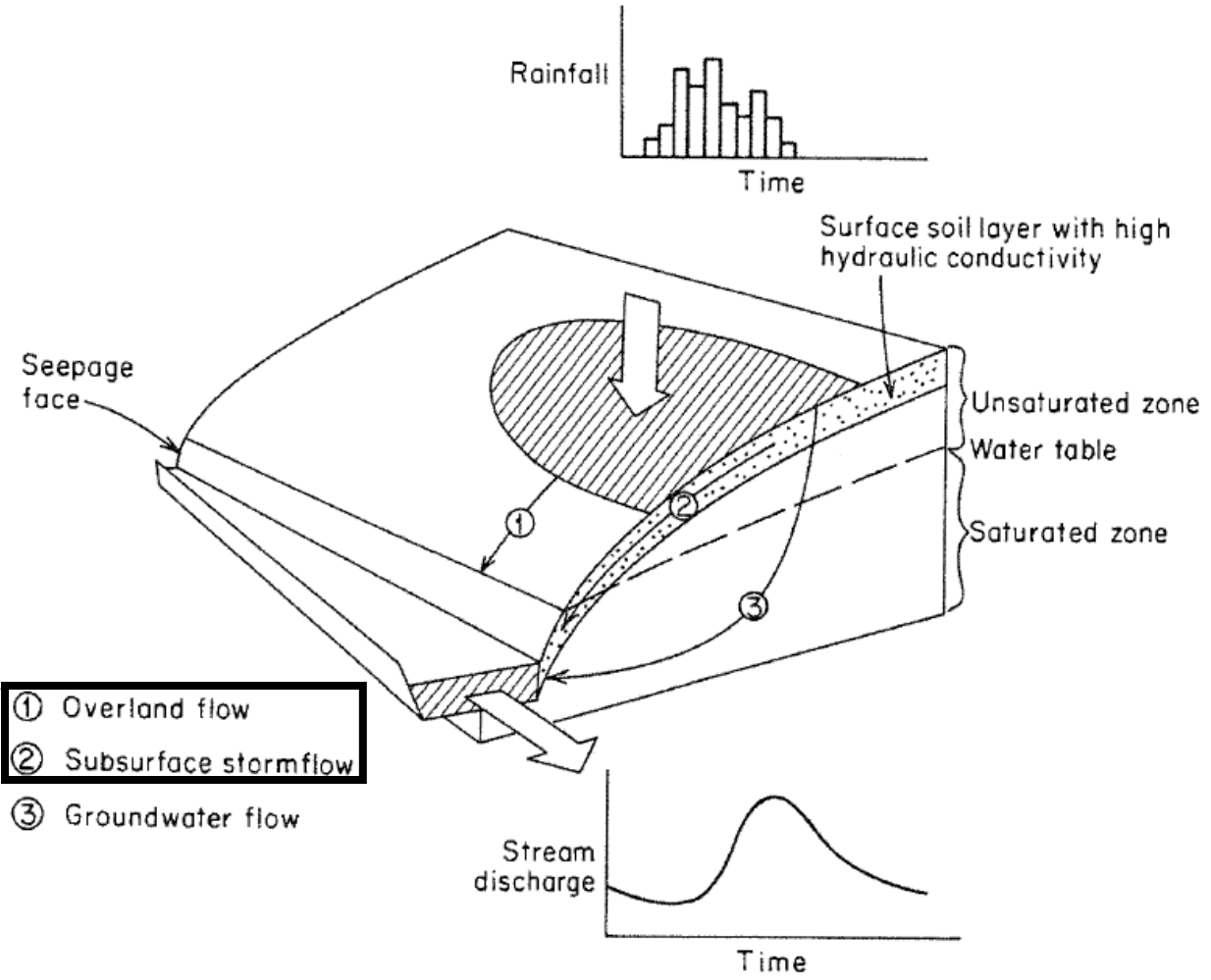
Residual Sources of Chloride



Chloride Mass Data Summary

- 2020-2021 applied ≈33,000 tons Root River Watershed
- Summer 2021 (July 16 to Aug. 28)
  - Rural site
    - ≈50 tons Cl
    - ≈1 ton/mi^2
    - ≈77% GW
    - ≈23% other???
  - Urban site
    - ≈650 tons Cl
    - ≈3.5 tons/mi^2
    - ≈30% GW
    - ≈70% other???



Freeze and Cherry (1979)

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Future Data Analyses

- Full summer 2022 (June 1 to Aug. 31) data set
- Many more analyses in addition to Q and C
  - pH, Alk: help separate water sources, e.g., rain, groundwater, run off, interflow, etc.
  - Br, I, Na, K, TN: help identify primary source of Cl
  - Stable isotopes of water: help separate water sources
  - TDS: help characterize dominant dissolved-phase species
  - Total leachable solids from soil: help characterize non-groundwater secondary sources/compartment
- Dechant MS Defense: late spring 2023 (in person & virtual)

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   - Old: water that existed in the watershed prior to the rain event
3. What hydrogeologic compartment is storing the most mass of chloride during the summer months?
   - Rural: likely groundwater
   - Urban: not sure…surface run off and/or vadose zone/interflow

New Publication: Halophilic Bacteria

ELSEVIER

Science of The Total Environment

Volume 846, 10 November 2022, 157458

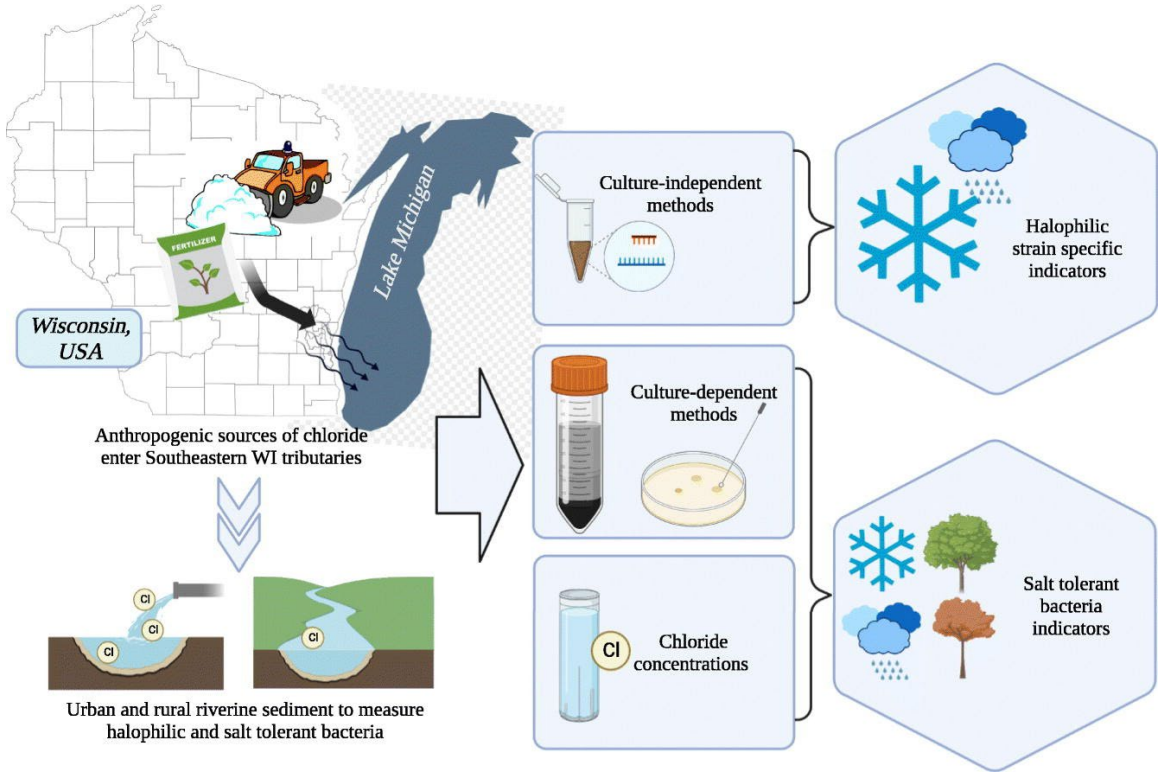
Halophilic bacteria in a Lake Michigan drainage basin as potential biological indicators of chloride-impacted freshwaters

Elexius K. Passante [a], Leah E. Dechant [b], Charles J. Paradis [b], Sandra L. McLellan [a]

[a] School of Freshwater Sciences, University of Wisconsin Milwaukee, Milwaukee, WI, USA

[b] Department of Geosciences, University of Wisconsin Milwaukee, Milwaukee, WI, USA

Received 13 May 2022, Revised 27 June 2022, Accepted 13 July 2022, Available online 18 July 2022, Version of Record 23 July 2022.



Passante et al., (2022)

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References

- Freeze, R. A. & J. A. Cherry, 1979. Groundwater. Prentice-Hall, Inc., Englewood Cliffs, New Jersey 07632.
- ITRC, 2010. Use and Measuremnt of Mass Flux and Mass Discharge. Interstate Technology and Regulatory Council, Washington, District of Columbia.
- Passante, E. K., L. E. Dechant, C. J. Paradis & S. L. McLellan, 2022. Halophilic bacteria in a Lake Michigan drainage basin as potential biological indicators of chloride-impacted freshwaters. Science of The Total Environment 846 doi:https://doi.org/10.1016/j.scitotenv.2022.157458.
- SEWRPC, 2016. Prospectus for a Chloride Impact Study for the Southeastern Wisconsin Region. Southeastern Wisconsin Regional Planning Commission, Waukesha, Wisconsin.
- USGS, 1996. HYSEP: A COMPUTER PROGRAM FOR STREAMFLOW HYDROGRAPH SEPARATION AND ANALYSIS. In: Sloto, R. A. & M. Y. Crouse (eds). United States Geologial Survery, Lemoyne, Pennsylvania.
- USGS, 2022. National Water Information System: Web Interface. United States Geological Survey, Reston, Virgina.
- WIDNR, 2019. Final Environmental Impact Statement: City of Waukesha, Proposed Great Lakes Diversion Wisconsin Department of Natural Resources, Madison, Wisconsin.

Acknowledgments

University of Wisconsin Water Resources Institute

SEWRPC
Serving the counties of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha

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THE GEOLOGICAL SOCIETY OF AMERICA®

Clockwise from top right: **Leah Dechant**, Maxwell Morgan, Dylan Childs, Samuel Sellars, Autumn Routson, Anna Sniadach

Extra Slides

Road Breakdown for the Root River Watershed

- Road Breakdown for the Root River Watershed

- GIS Map Analysis – Map Layers from Wisconsin DNR GIS portal or the WisDOT (Department of transportation)
- Major Roads (HWY) = 225,609.7 meters or 140.187 miles
- • Attribute table, select desired shape/polygon features, right click, statistics (chart icon) and GIS will produce statistics for the selected shapes.
- County and Local Roads = 1,784,852.8 meters or 1109.05562 miles
- • Attribute table, select desired shape/polygon features, right click, statistics (chart icon) and GIS will produce statistics for the selected shapes.

- Total Roads (not including private or personal driveways/lots/parking features) = 2,010,462.5 meters or 1,249.24 miles.

- Miles vs Lane Miles
- Mile = unit of length/distance.
- Lane Mile = distance of driving on a road. So, a common road as two-lanes (traffic in each direction) so on average a road would have two-lane miles per mile of road (distance).
- So, applying this to a GIS measurement of a shape a more realistic measurement of “road length” or “road milage” would be double the above values 4,020,925 meters or 2,498.48 miles.

- Road Salt Application Data/History from WisDOT (Wisconsin department of transportation)
- 2020 - 2021 in Racine there was a total of 73.5 inches of snow fall and the rate of salt application for the same year was 13.20 tons per lane mile. This was only calculated for Racine County and only account for state lane miles.
- It is recommended and assumed that the state, county, and local entities apply at the same rate per lane mile each season (however salt application is dependent on weather – year to year changes).
- So, using salt application rates from 2020-2021 and lane miles based on GIS analysis. The amount of salt applied on roads alone in the Root River Watershed is estimated at around 32,979.93 tons!

Field Sites: Root River (rural & urban)

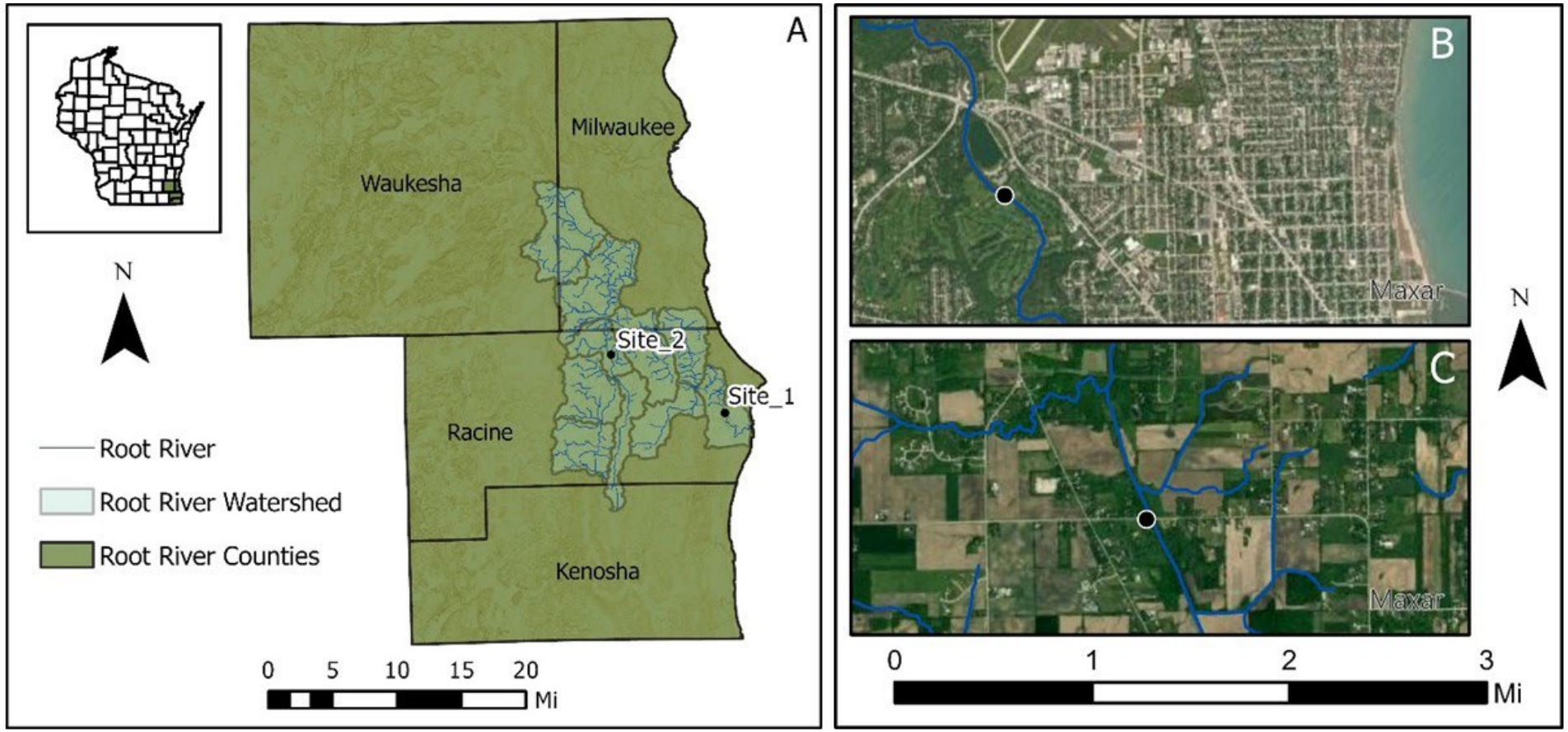

Figure 1 Root River field sites A) displays the regional area, watershed, sub watersheds, and the river channel with sites 1 and 2 labeled B) displays site 1, urban, with river channel C) displays site 2, rural, with river channel.

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