Cayuga Lake Modeling Project *Update*

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November 12, 2015

Presentation Outline

- Description of the Cayuga Lake Modeling Project
  - Relation to Lake Source Cooling permit renewal
  - Project team
- Findings to Date: November 2015
  - Sources of phosphorus and bioavailability
  - Lake hydrodynamics
- Model Development Status
- Implications and Next Steps

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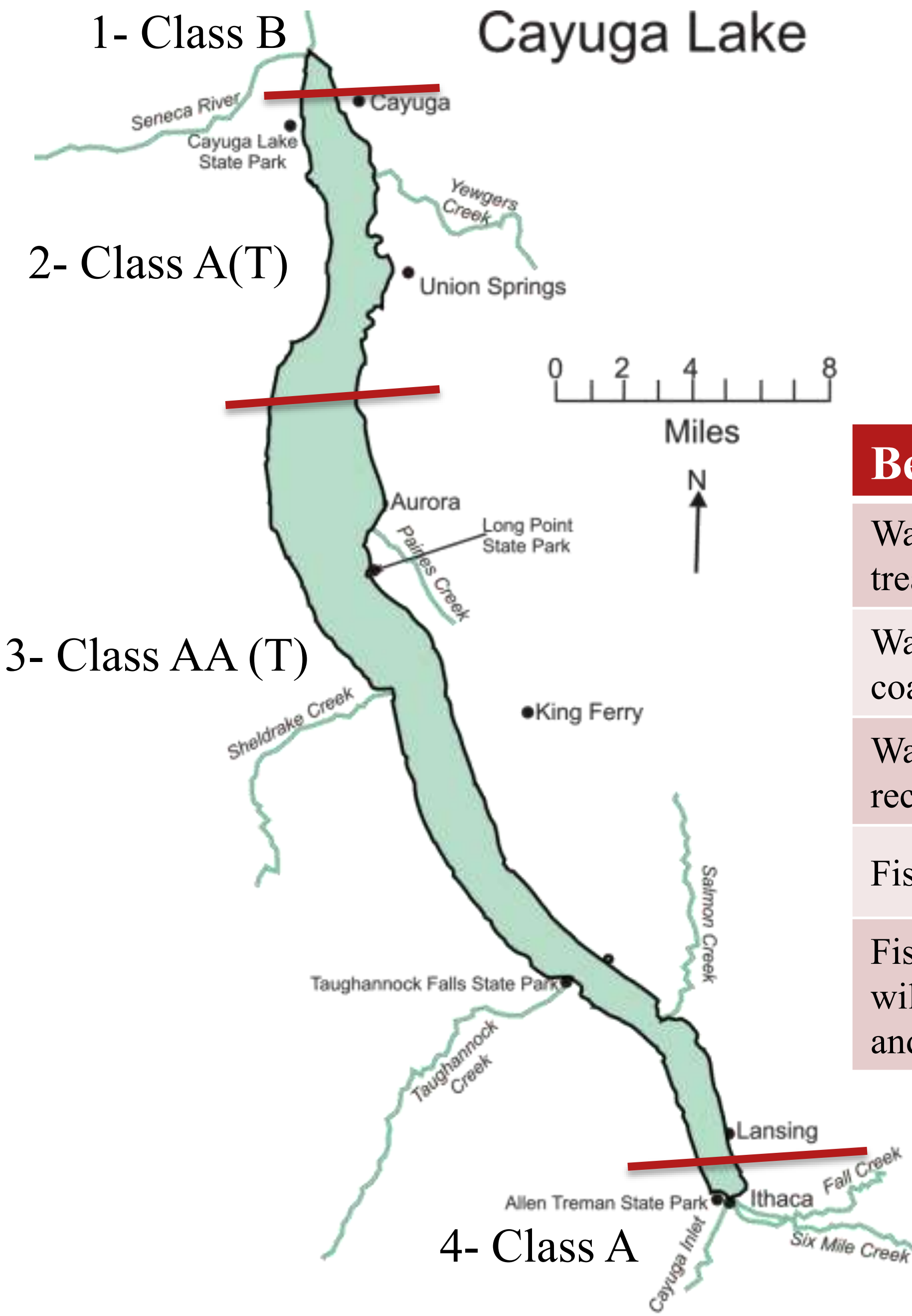
Cayuga Lake Modeling Project (CLMP)

- Scientific investigation of sources of phosphorus to Cayuga Lake and the consequences for algal growth
- Included as a permit requirement for operation of Cornell's Lake Source Cooling (LSC) facility

Why investigate the sources and impacts of phosphorus in Cayuga Lake?

- Phosphorus is the limiting nutrient for algal growth
- In 2002, DEC listed southern Cayuga Lake as *impaired* by excessive phosphorus and silt/sediment
  - Impaired relative to a designated "best use"
  - In 2008, listed for pathogens, delisted in 2014 based on City and CSI data
- Once southern lake was listed as impaired, DEC was required to act
  - Identify and quantify the source(s) of impairment
  - Identify strategy for improvement- TMDL or other



NYSDEC classifies Cayuga Lake in four distinct segments, depending on "best use", and habitat suitability for salmonids, designated by (T)

Best Use:	AA	A	B
Water supply- minimal treatment	✓		
Water supply- coagulation & filtration		✓	
Water contact recreation	✓	✓	✓
Fishing	✓	✓	✓
Fish, shellfish & wildlife propagation and survival	✓	✓	✓

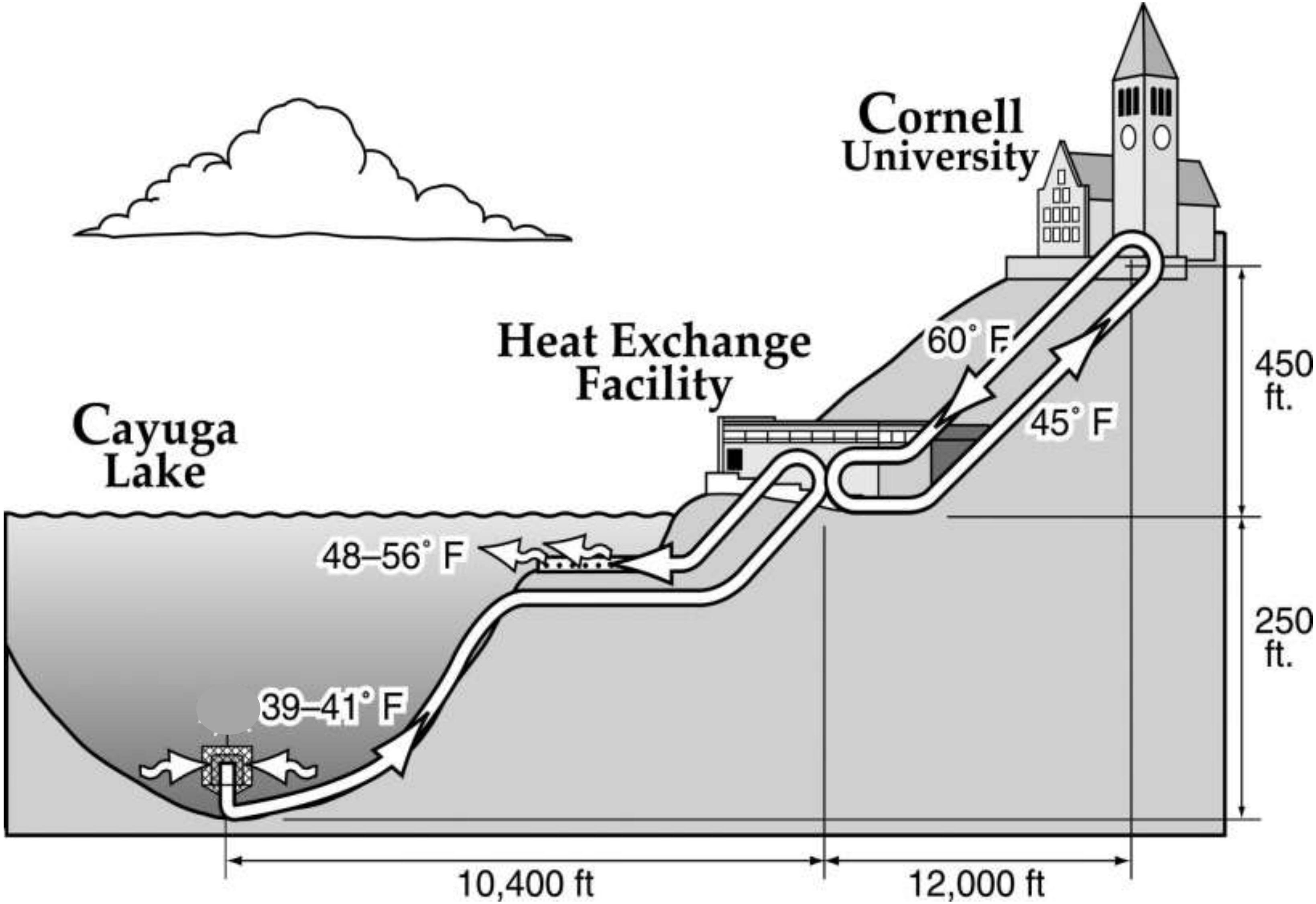
CLMP focuses on phosphorus (P) and algae

- Southern shelf listed as impaired due to occasional exceedances of Total P guidance value – 20 µg/L summer average
- Guidance value designed to protect recreational uses in Class AA, A, and B lakes from excessive algae (phytoplankton)
- Sediment not a direct focus of CLMP, only as it contributes to biologically-available P and affects water clarity

Why is the CLMP included as a permit condition for operation of the LSC facility?

- LSC draws cold water from deep in the lake—segment 3, circulates it through a shoreline heat exchange facility, and returns water (slightly warmed) to segment 4
- No phosphorus is added
- Assuming that deep & shallow lake waters do not naturally mix during summer, DEC considered LSC a point source of phosphorus to segment 4 (the shelf)

The Lake Source Cooling Process



Environmental Benefits of the LSC Facility

- Renewable resource
- Energy efficiency
  - 86% reduction in energy used for cooling of campus and Ithaca High School
  - Overall reduction of campus energy use by 10%
  - Decreased reliance on fossil fuels & reduced adverse impacts, including greenhouse gases
- Cornerstone of University's commitment to sustainability: multiple awards

Cornell Perspective on CLMP Requirement

- Willing to invest in research and modeling to support rational management approach
  - Integrate science into policy decisions: CU mission
  - Draw on local knowledge
  - Collaborate with DEC to apply an emerging approach that considers impacts on water, air, and lands
- Committed to continued operation of the LSC facility

Elements of the CLMP

- Phase 1: Monitoring (April 2013 – Oct 2013)
  - Project plan reviewed and approved
  - Testing streams, lake, point sources
  - Lake biological community- mussels and plankton
  - Bioavailability of phosphorus fractions
- Phase 2: Modeling (Jan 2014 – Dec 2016)
  - Watershed model: effects of land use, land cover, and hydrology on phosphorus flux
  - Lake model: water circulation (hydrodynamics) and water quality, focus on phosphorus and algae

Project Partners

- DEC and EPA: Oversight & Approvals
  - DEC: Technical Advisory Committee
  - EPA: Model Evaluation Group
- Cornell: Project Execution
  - Provide funding
  - Develop and manage technical team
- Community stakeholders: Review & Advisory
  - Led by County Water Resources Council's Lake Monitoring Partnership
- Data sharing partners
  - Community Science Institute, City of Ithaca, Watershed Network, Researchers

40 years of Phosphorus Data from Cayuga Lake Watershed

- Professor David Bouldin- track lake and stream conditions over major changes in land use, population, wastewater treatment, invasive species, and cooling water discharges
  - PowerPoint "Watersheds and Cayuga Lake 1972 to 2011" available on Cornell Ecommons http://hdl.handl.net/1813/39912

CLMP Technical Team

- Upstate Freshwater Institute
  - Lake and stream monitoring, lake water quality model
- Dr. Todd Cowen- Cornell Hydraulics Lab
  - Hydrodynamic model
- Dr. Todd Walter- NY Water Resources Institute
  - Watershed model- phosphorus & sediment loss from landscape to lake
- Drs. Nelson Hairston, Lars Rudstam & Jim Watkins
  - Phytoplankton and zooplankton
  - Zebra and quagga mussels
- EcoLogic
  - Communication among DEC, Cornell project team, & community

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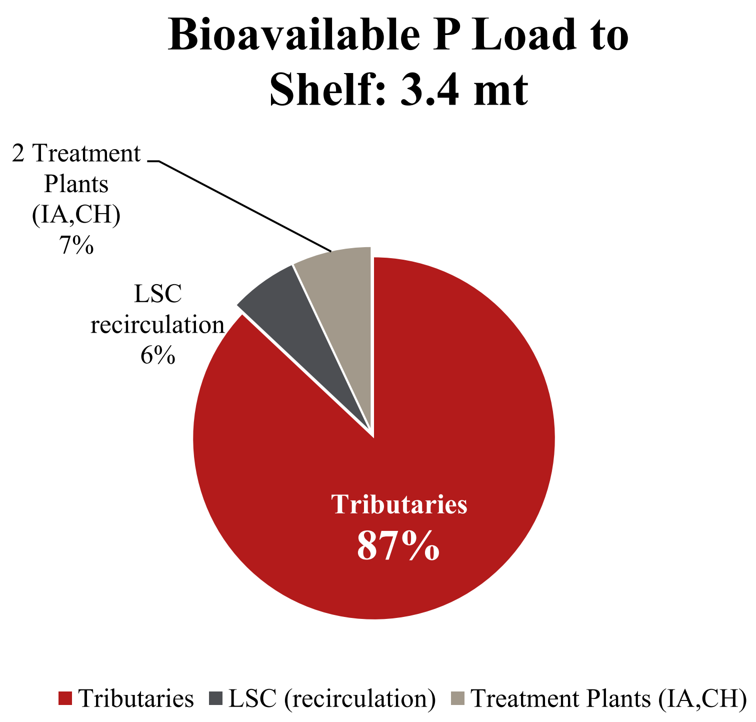
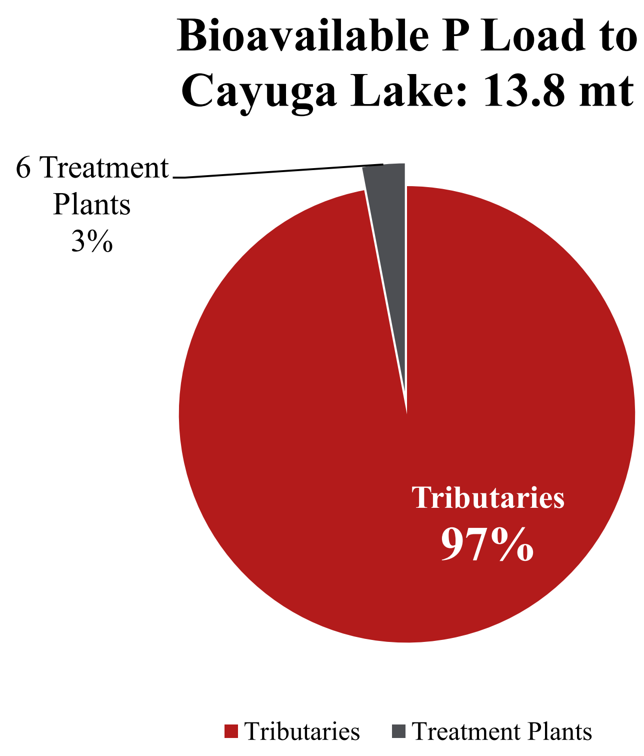
Findings to Date (November 2015)

- Phosphorus fractions (dissolved, particulate, etc.) differ in bioavailability, *i.e., the ability to support algal growth*
- Detailed monitoring and analysis in 2013 reveal that nearly all bioavailable phosphorus to Cayuga Lake came from watershed nonpoint sources (97%), not point sources (3%)
- Elevated total phosphorus concentrations are associated with sediment particles (mud) that enter the lake during runoff events, and the mud has low bioavailability
- Lake circulation is complex and dynamic, with significant mixing between the southern shelf and the main lake

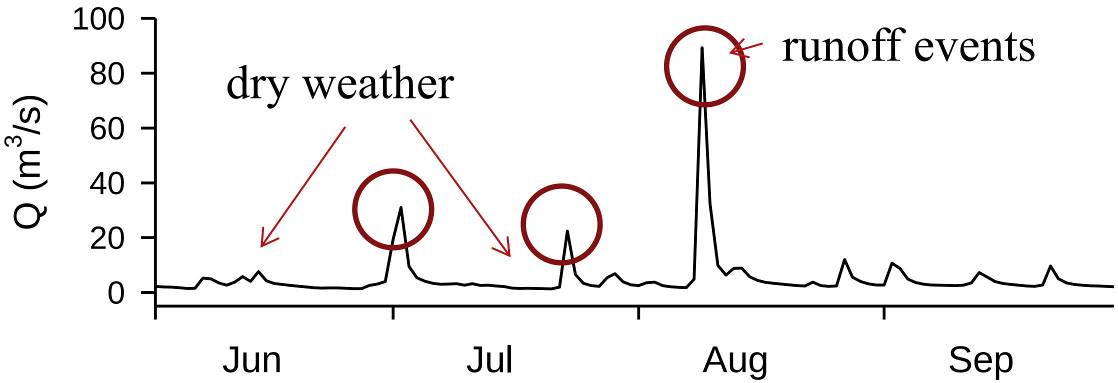
April – October 2013
Bioavailable P Inputs, Shelf and Lake-wide

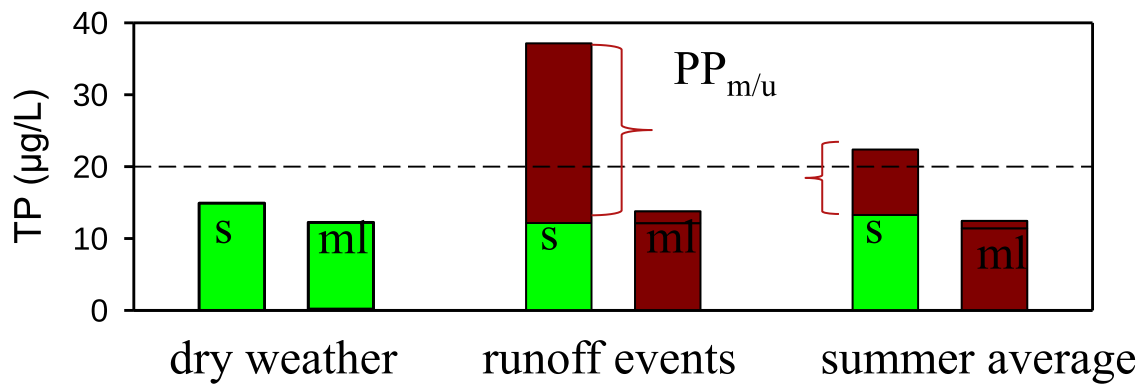




Runoff delivers sediment “mud” to the shelf, but phosphorus (PP m/u) in mud is very low in bioavailability

hydrology cases of interest





wet summer case

Green- total dissolved P+ particulate organic P
Red- particulate inorganic P (mud)
All fractions contribute to Total P (TP)

s – shelf
ml- main lake

Sediment Plume from Taughannock Creek

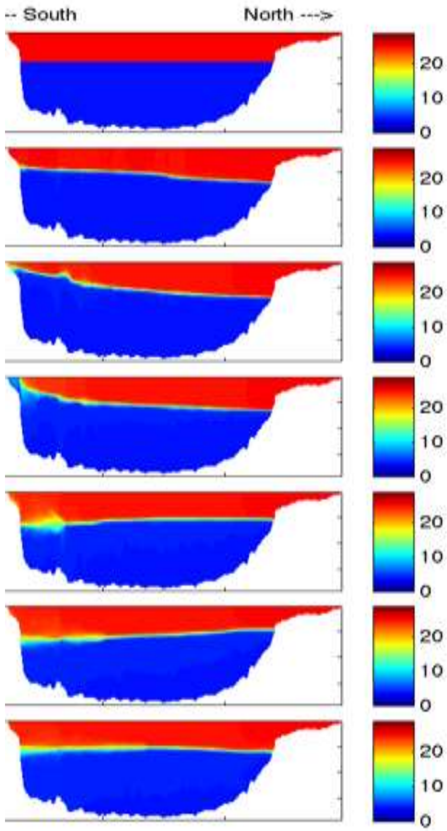
Photo: Bill Hecht

Complex Lake Circulation Patterns

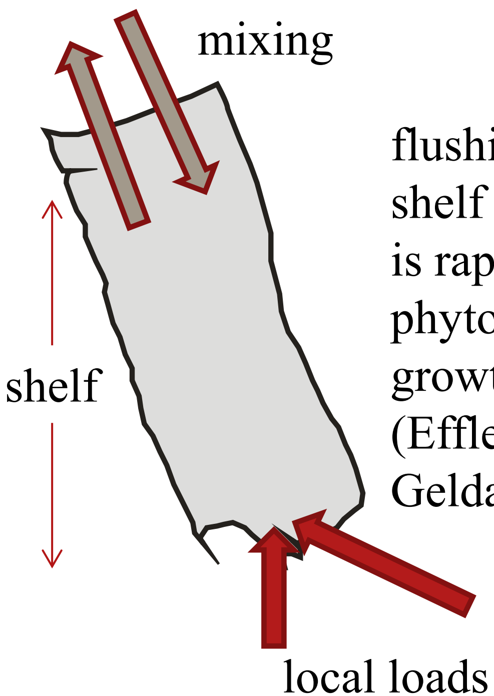
April 5, 2005 CAYUGA LAKE view south from Townline Road, photo by Bill Hecht

Photo: Bill Hecht

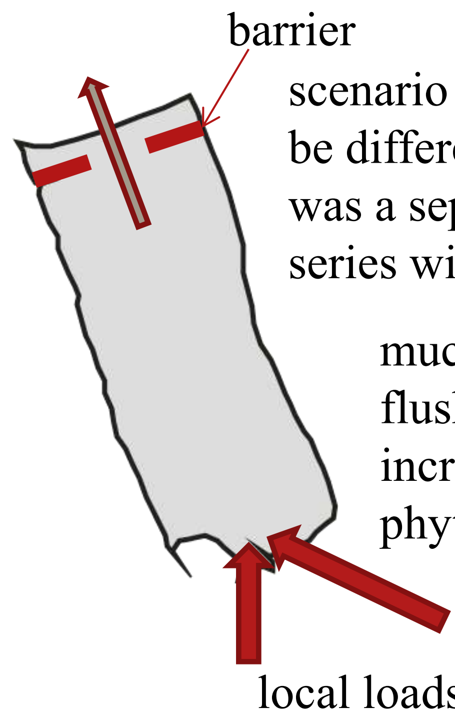
Wind-driven circulation brings deep water onto the shelf



Natural mixing processes prevent development of higher phytoplankton biomass on the shelf



flushing rate of shelf from mixing is rapid relative to phytoplankton growth rates (Effler et al. 2010, Gelda et al. 2015a)



scenario response would be different if the shelf was a separate lake in series with Cayuga Lake

much slower flushing rate; could increase local phytoplankton

Recent upgrades to the Cayuga Heights and Ithaca WWTPs reduced bioavailable P load by ~80% with <u>no response</u> in chlorophyll-*a*. This is attributed to the rapid flushing of the shelf from natural mixing processes

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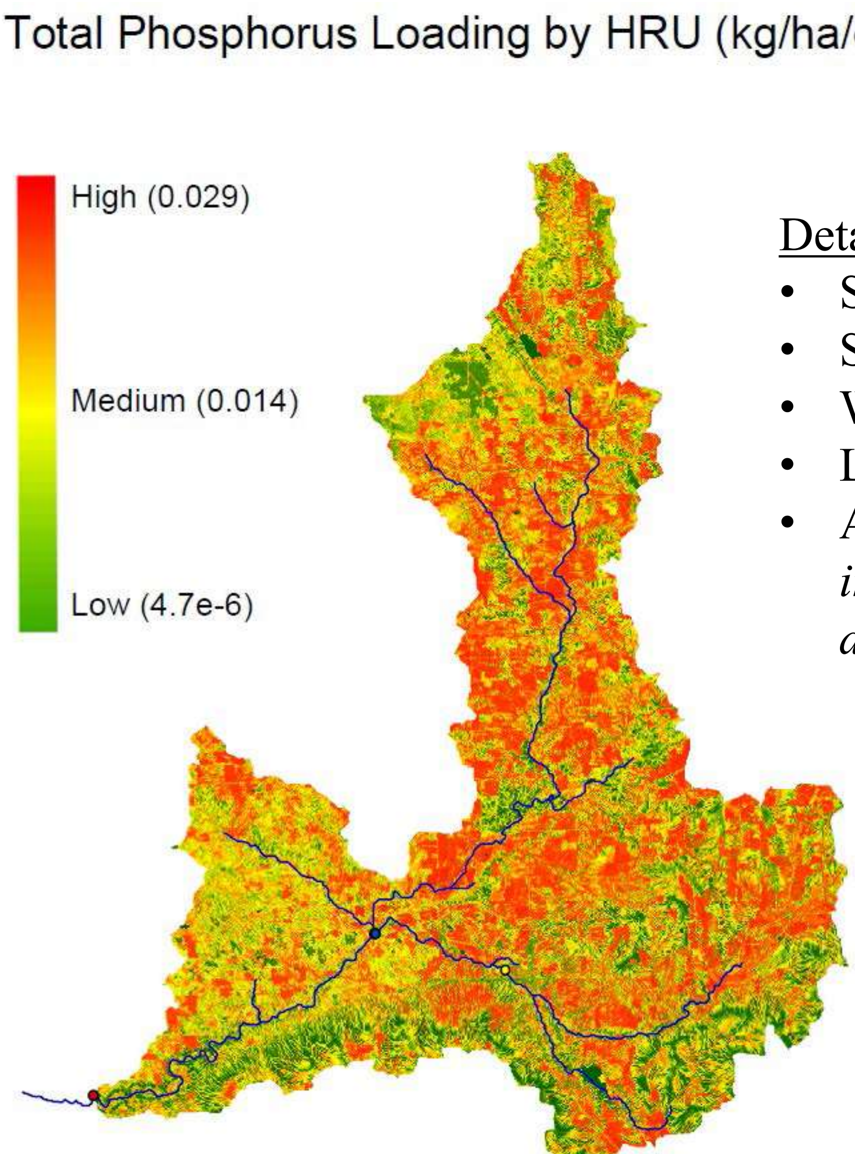
Status of Watershed Model

- Model of phosphorus transport from the watershed to the lake
  - Multiple fractions of P, to interface with lake model
  - Adapted SWAT-VSA to track storm runoff
  - Informed by detailed assessment of agricultural practices in Fall Creek subwatershed
- Working closely with local experts- County SWCDs
- Planning to meet with farmers to discuss realistic management scenarios

Fall Creek Phosphorus Export



Detailed analysis:

- Soils
- Slopes
- Wetness factor
- Land cover
- Agricultural practices *including manure disposal*

Building the Overall Phosphorus: Water Quality Model

No.	Component Description	2015 ●				2016 ●			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	individual constituent modeling analysis NO_X, DOC, TP, SUP, POC	→	→	→					
2	inlet channel adjustment to loads	→	→	→					
3	minerogenic particle submodel	→	→	→					
4	optics submodel			→	→				
5	nutrient-phytoplankton submodel development			→	→	→	→		
6	overall water quality model			→	→	→	→	→	
7	land use - lake models linkages					→	→		
8	long-term model simulations						→	→	
9	Phase 2 report							→	→

To date, UFI and their collaborators have submitted 11 scientific papers to peer-reviewed journals based on their Cayuga Lake investigations (9 accepted, 2 in review)

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Implications

- Reconsider whether southern Cayuga Lake is impaired by phosphorus:
  - Total P is a flawed indicator of algal growth potential, dominated by muds with low bioavailability
  - Extensive water exchange between shelf and main lake
  - Massive (80%) reduction in point source bioavailable P has not reduced chlorophyll-*a*
- What other management methods are appropriate, given these findings?

Next Steps

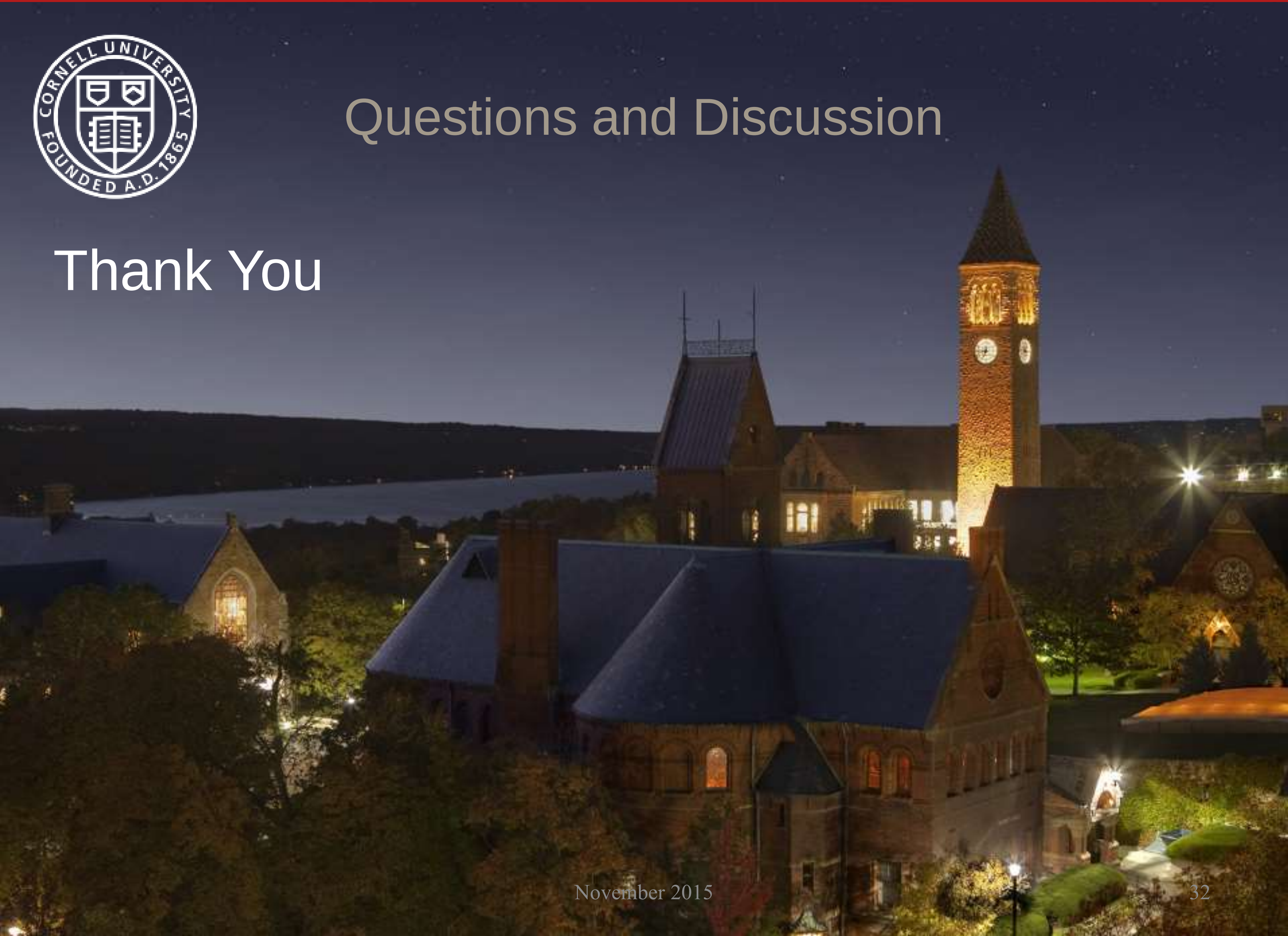
- Review regulatory status of southern Cayuga Lake
  - Filed 11 peer-reviewed papers with DEC as new information related to listing shelf as impaired by excessive phosphorus
  - Plan to comment on draft 303(d) list in January 2016
- Advocate for a robust watershed management approach to protect Cayuga Lake that reflects the detailed scientific investigations

All Reports, Presentations, Technical Papers and Data are on the Cayuga Lake Modeling Project Webpage

www.cayugalakemodelingproject.cornell.edu

Questions and Discussion

Thank You



Estimating the Load of Bioavailable P to Cayuga Lake

- Monitor various P fractions of the major inflows (point and nonpoint), range of flow conditions
- Develop empirical relationship between concentration and streamflow
- Conduct bioassays to assess the bioavailability of particulate and dissolved P from multiple sources
- Estimate the input of biologically-available P to Cayuga Lake
- Estimate the variation in annual loads associated with changing stream flows

Monitoring for Multiple Fractions of Phosphorus

- Phosphorus fractions are defined by how they are analyzed in the lab (3) or calculated (2)
  - TP unfiltered, digested
  - TDP filtered, digested
  - TPP *calculated* as TP-TDP
- TDP (filtered sample) includes:
  - SRP filtered, undigested
  - SUP *calculated* as TDP-SRP

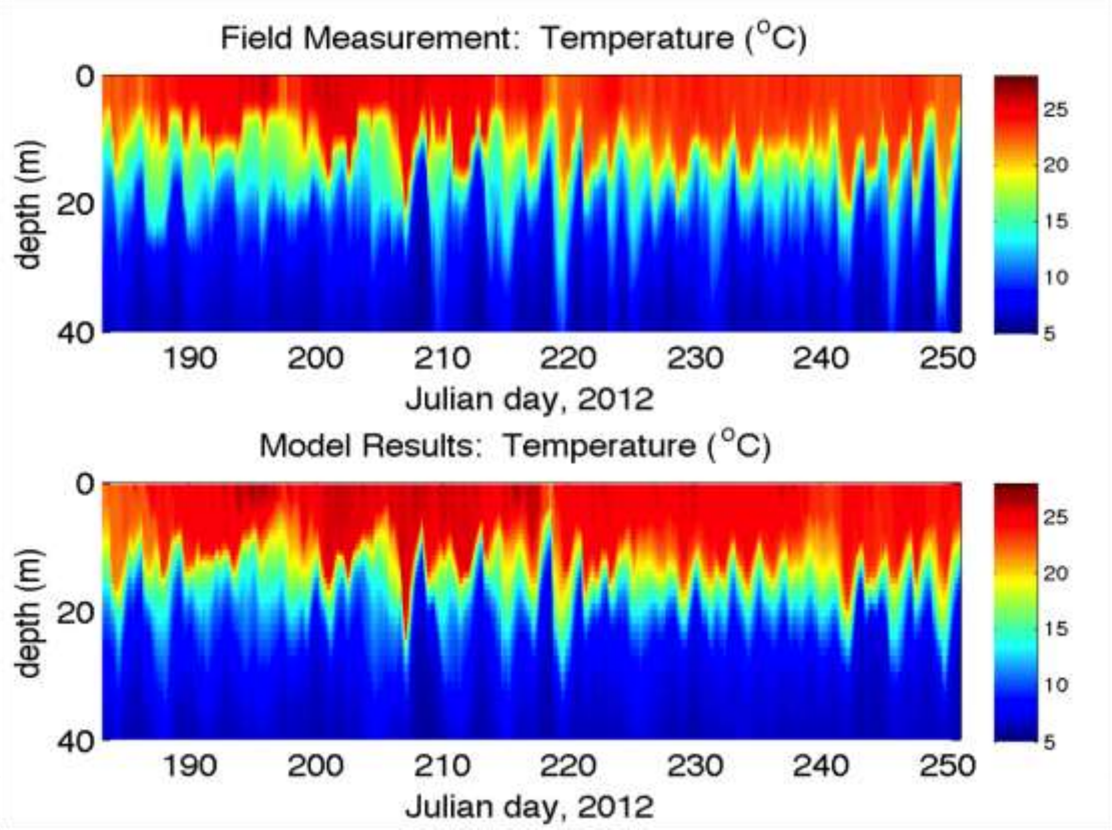
Bioavailability of P Fractions

- Bioassays used to determine fraction of P actually usable by algae
- Particulate and dissolved fractions
- Algal P uptake measured over 30 days
- Fraction of P used by algae determined (f_{BAP})

Apportionment of Bioavailable Phosphorus Load (BAP_L), Cayuga Lake, April- Oct. 2013

	Inflow (% of Watershed Area)	BAP_L (mt)	Percent Contribution to total external BAP_L
non-point sources	Fall Creek (18%)	2.10	15.2%
	Cayuga Inlet Creek (13%)	0.79	5.7%
	Salmon Creek (12.5%)	2.18	15.8%
	Sixmile Creek (7.2%)	0.47	3.4%
	Taughannock Creek (9.3%)	1.10	8.0%
	Unmonitored Tributaries (40%)	6.75	48.9%
	Sum (watershed load)	13.4	97%
point sources	Ithaca Area WWTP	0.21	1.5%
	Cayuga Heights WWTP	0.08	0.6%
	Minor WWTPs (4)	0.14	1.0%
	Sum (point source load)	0.43	3%
	Total External Load BAP_L	13.8	100%
	LSC (recirculation)	0.22	Not applicable

Hydrodynamic Modeling in Progress



Part 1 - Individual Waterbody Segments with Impairment Requiring TMDL Development (con't)

Water Index Number	Waterbody Name (WI/PWL ID)	County	Type	Class	Cause/Pollutant	Source	Year
	<u>Chemung River Drainage Basin</u>						
Pa 3-58-31- 7-P66	Smith Pond (0502-0012)	Steuben	Lake	B	Phosphorus	Onsite WTS	2008
	<u>Susquehanna River Drainage Basin</u>						
SR- 44-14-27-P35a	* Whitney Point Lake/Reservoir (0602-0004)	Broome	Lake	C	Phosphorus	Agriculture	2002
SR-146- 69	North Winfield Creek and tribs (0601-0035)	Herkimer	River	C(T)	Pathogens	Onsite WTS,	2010
	<u>Oswego River (Finger Lakes) Drainage Basin</u>						
Ont 66- 3-P9	Lake Neatahwanta (0701-0018)	Oswego	Lake	B	Nutrients (phosphorus)	Urban/Storm Runoff	1998
Ont 66-11-14a-P19	Pleasant Lake (0703-0047)	Oswego	Lake	B	Phosphorus	Unknown	2012
Ont 66-11-P26-33- 5	Canastota Creek, Lower, and tribs (0703-0002)	Madison	River	C	Oxygen Demand [1]	Municipal, CSOs	2008
Ont 66-11-P26-33- 5	Canastota Creek, Lower, and tribs (0703-0002)	Madison	River	C	Pathogens	Municipal, CSOs	2008
Ont 66-12-43-P212	Owasco Lake (0706-0009)	Cayuga	Lake	AA(T)	Pathogens	Wildlife/Other Sources	1998
Ont 66-12-43-P212-28	* Owasco Inlet, Upper, and tribs (0706-0014)	Cayuga	River	C(T)	Nutrients	Municipal/Agric	2008
Ont 66-12-46-P222	Duck Lake (0704-0025)	Cayuga	Lake	C	Phosphorus	Unknown	2012
Ont 66-12-P296 (portion 4)	* Cayuga Lake, Southern End (0705-0040)	Tompkins	Lake	A	Phosphorus	Municipal, NPS	2002
Ont 66-12-P296 (portion 4)	Cayuga Lake, Southern End (0705-0040)	Tompkins	Lake	A	Silt/Sediment	Municipal, NPS	2002
	<u>Black River Drainage Basin</u>						
Ont 19- 51	Mill Creek/South Branch, and tribs (0801-0200)	Lewis	River	C	Nutrients	Agriculture	2008
Ont 19- 51	Mill Creek/South Branch, and tribs (0801-0200)	Lewis	River	C	Pathogens	Agriculture	2008
	<u>Saint Lawrence River Drainage Basin</u>						
SL- 1 (portion 1)	Raquette River, Lower, and minor tribs (0903-0059)	St.Lawrence	River	B	Pathogens	Onsite WTS	2010
SL-25- 7- P1	* Black Lake Outlet, Black Lake (0906-0001)	St.Lawrence	Lake	B	Nutrients (phos)	Agriculture	1998
SL-25- 7/P1- 2	Fish Creek and minor tribs (0906-0026)	St.Lawrence	River	C	Nutrients (phos)	OWTS/San Discharge	2010
SL-25-101	Little River and tribs (0905-0090)	St.Lawrence	River	C(T)	Priority Organics	Indust/Landfill	2010