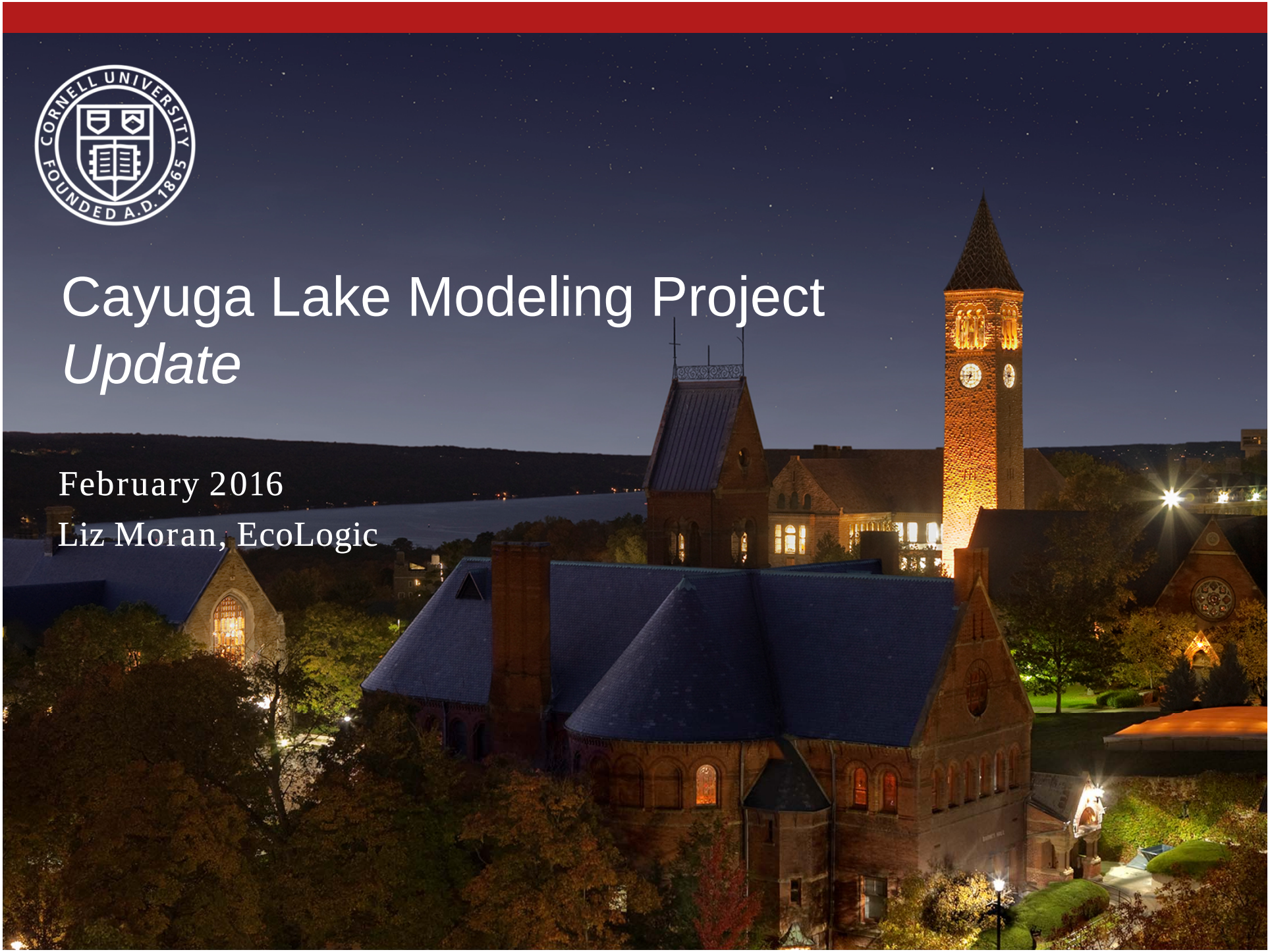


Cayuga Lake Modeling Project
Update

February 2016

Liz Moran, EcoLogic

Presentation Outline

- Description of the Cayuga Lake Modeling Project
  - Relation to Lake Source Cooling permit renewal
  - Project team
- Findings to Date: February 2016
  - Sources of phosphorus and bioavailability
  - Lake hydrodynamics
- Model Development Status
- Implications and Next Steps

Presentation Outline

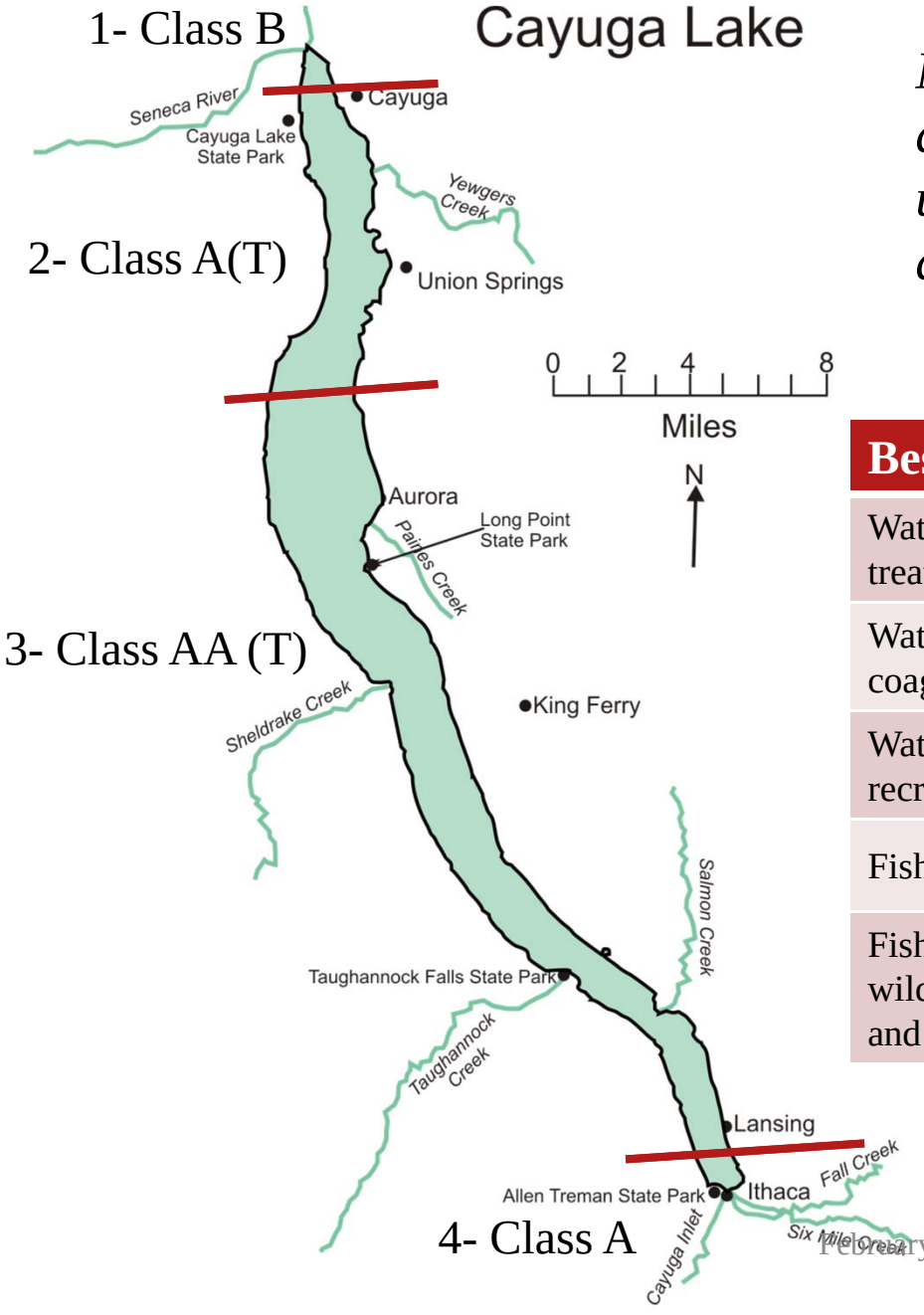
- Description of the Cayuga Lake Modeling Project
  - Relation to Lake Source Cooling permit renewal
  - Project team
- Findings to Date
  - Sources of phosphorus and bioavailability
  - Lake hydrodynamics
- Model Development Status
- Implications and Next Steps

Cayuga Lake Modeling Project (CLMP)

- Scientific investigation of sources of phosphorus to Cayuga Lake and the consequences for phytoplankton growth
- Does not model aquatic plants (macrophytes)
- 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 phytoplankton 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, southern lake listed for pathogens, delisted in 2014 based on City and CSI data
- Once southern Cayuga 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	✓	✓	✓

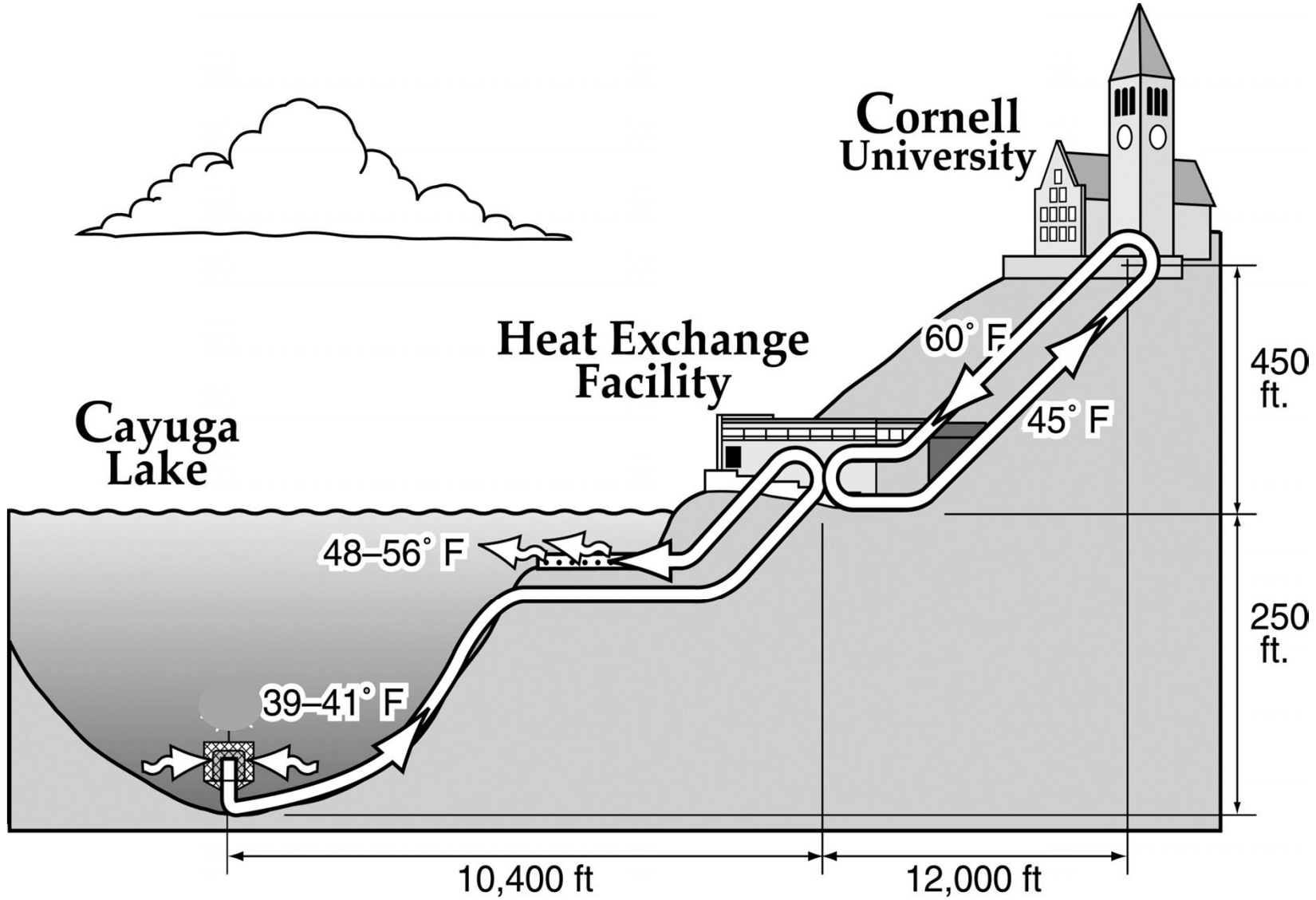
CLMP focuses on phosphorus (P) and algae

- Southern shelf listed as impaired due to occasional exceedances of Total P guidance value – 20 µg/L summer average
- Guidance value selected 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 a 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

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

Presentation Outline

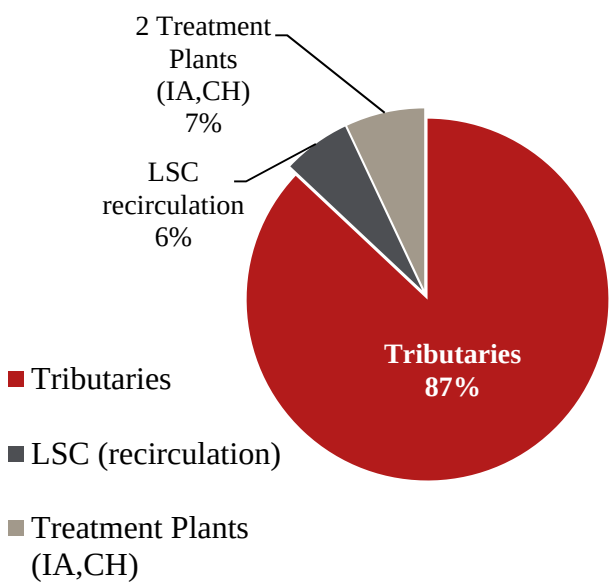
- Description of the Cayuga Lake Modeling Project
  - Relation to Lake Source Cooling permit renewal
  - Project team
- Findings to Date
  - Sources of phosphorus and bioavailability
  - Lake hydrodynamics
- Model Development Status
- Implications and Next Steps

Findings to Date (February 2016)

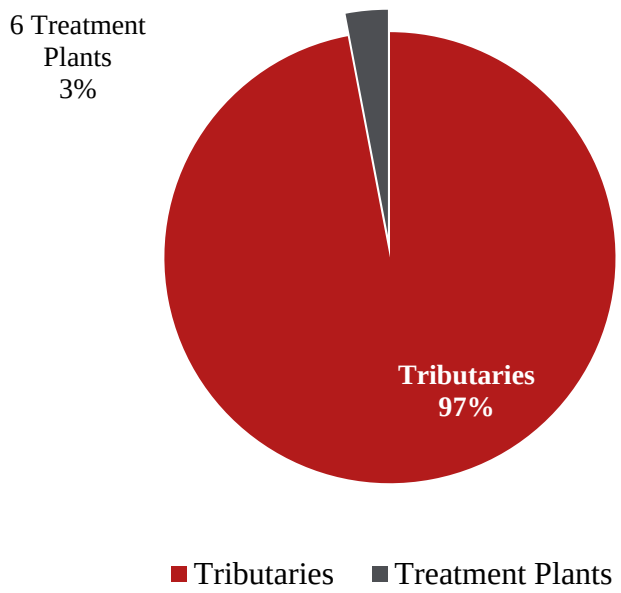
- Phosphorus fractions (dissolved, particulate, etc.) differ in bioavailability, *i.e., the ability to support algal growth*
- Detailed monitoring and analysis in 2013 reveal that nearly all bioavailable phosphorus to Cayuga Lake came from watershed nonpoint sources (97%), not point sources (3%)
- Elevated 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

Bioavailable P Load to Shelf: 3.4 mt

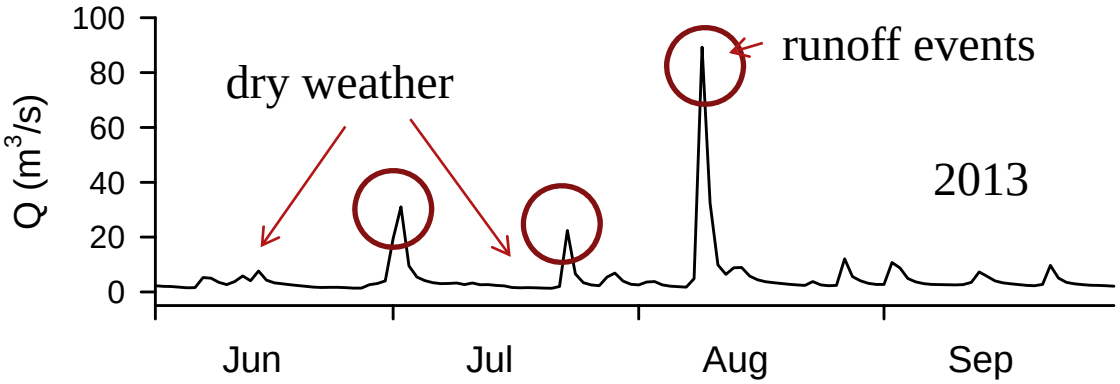


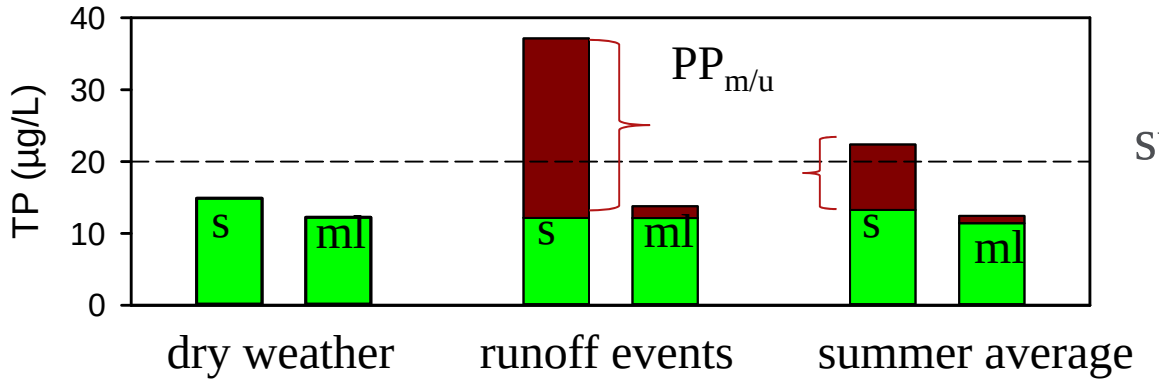
Bioavailable P Load to Cayuga Lake: 13.8 mt



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

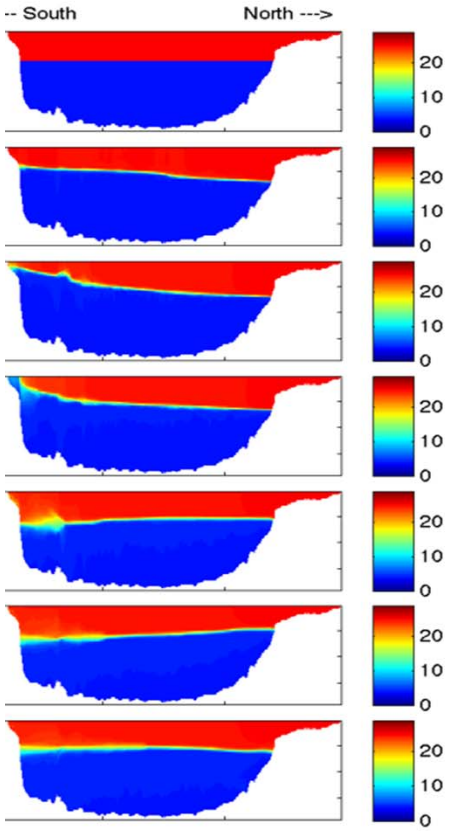
Sediment Plume from Taughannock Creek

Photo: Bill Hecht

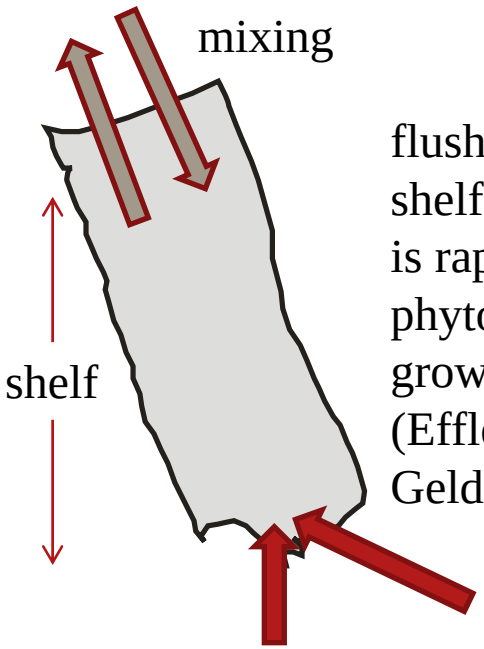
Complex Lake Circulation Patterns

Photo: Bill Hecht

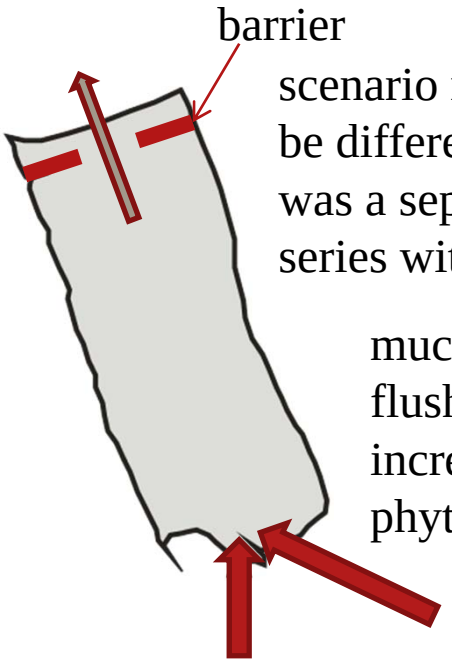
Wind-driven circulation brings deep water onto the shelf



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)

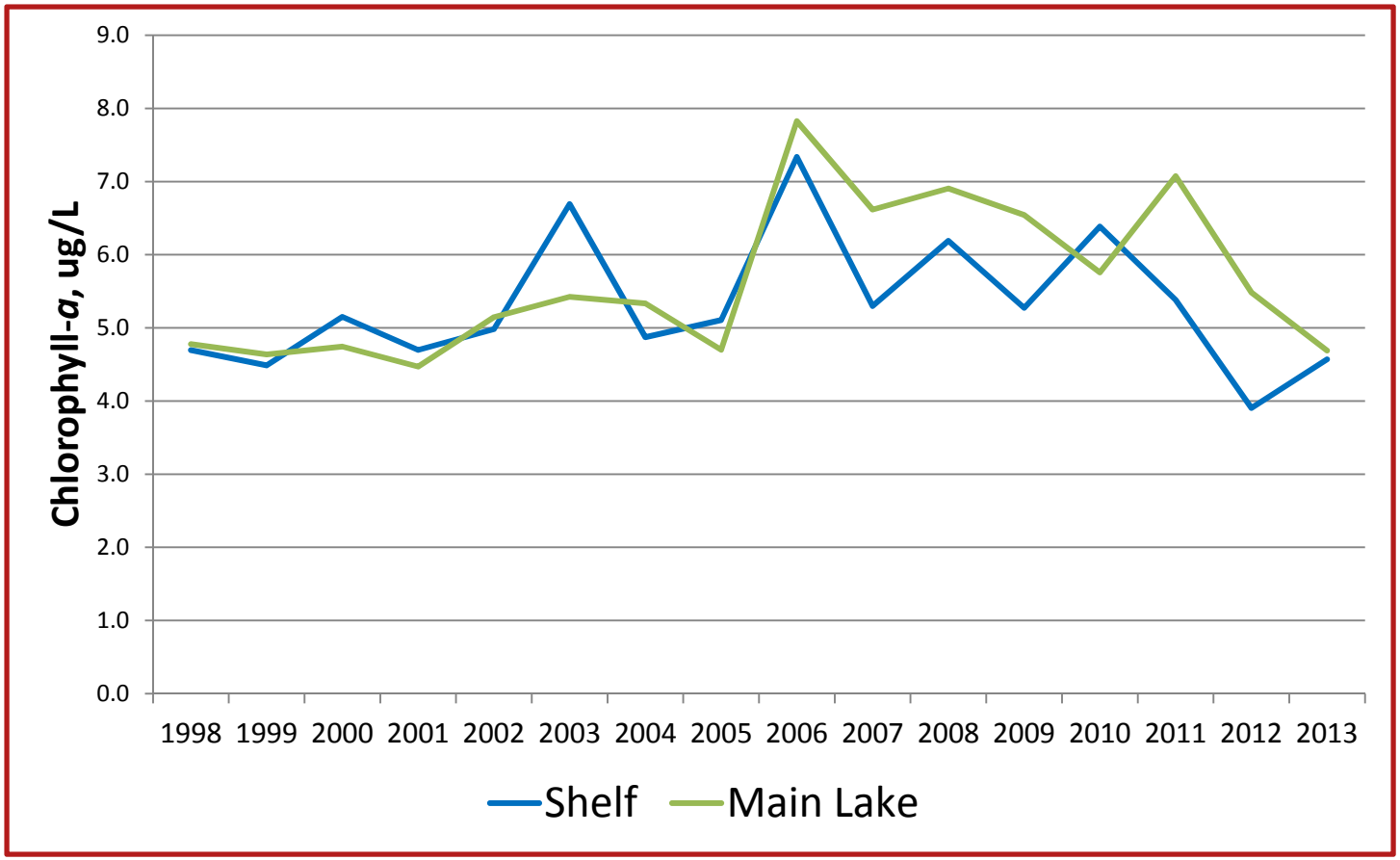


scenario response would be different if the shelf was a separate lake in series with Cayuga Lake

much slower flushing rate; could increase local phytoplankton

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

Chlorophyll-*a* Concentrations Shelf & Main Lake



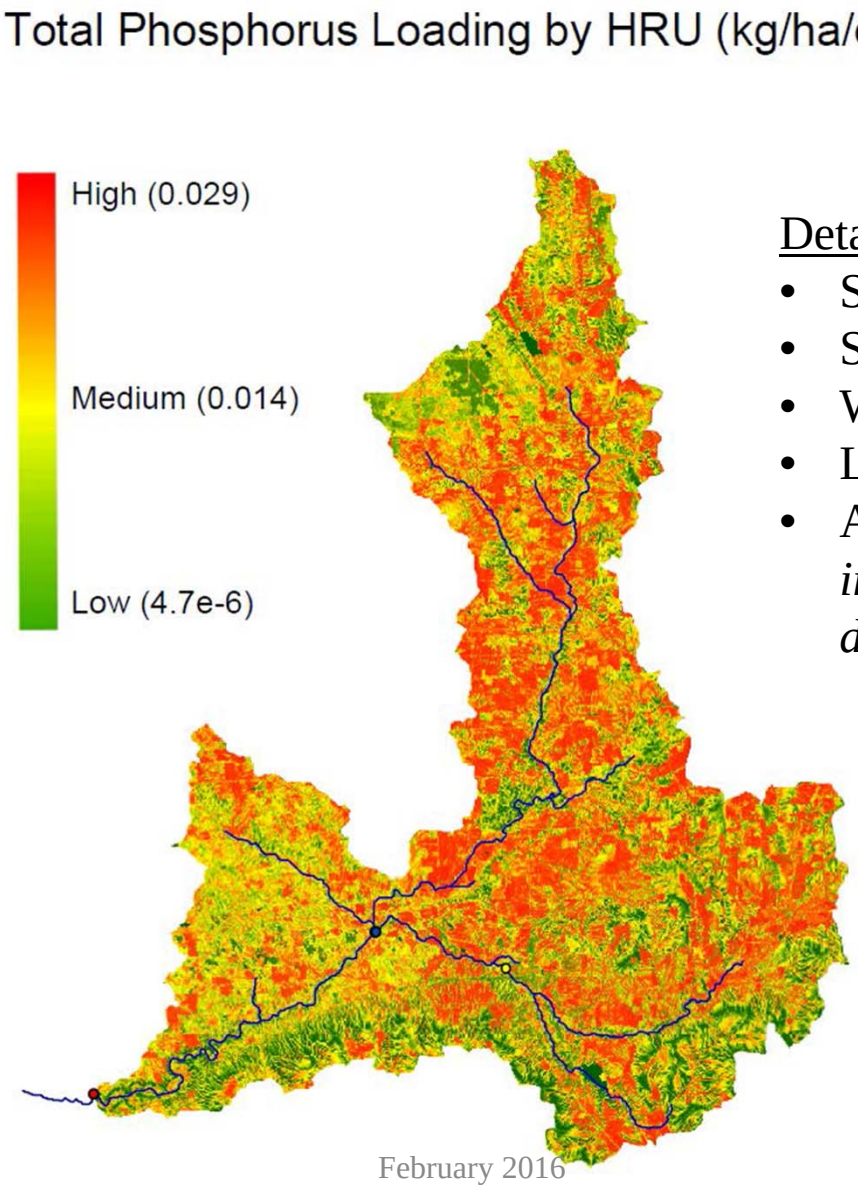
Presentation Outline

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

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 County Soil & Water Conservation Districts and others to define 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)

Presentation Outline

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

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

- Continue to work with NYSDEC to advance the scientific basis for lake management
  - Sharing data and publications with DEC and EPA
- 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