Cayuga Lake Modeling Project
Major Findings and Management Implications

February 2017

Photo: Bill Hecht

Presentation Outline

- Cayuga Lake Modeling Project Overview
- Major Findings and Management Implications
- Looking Ahead

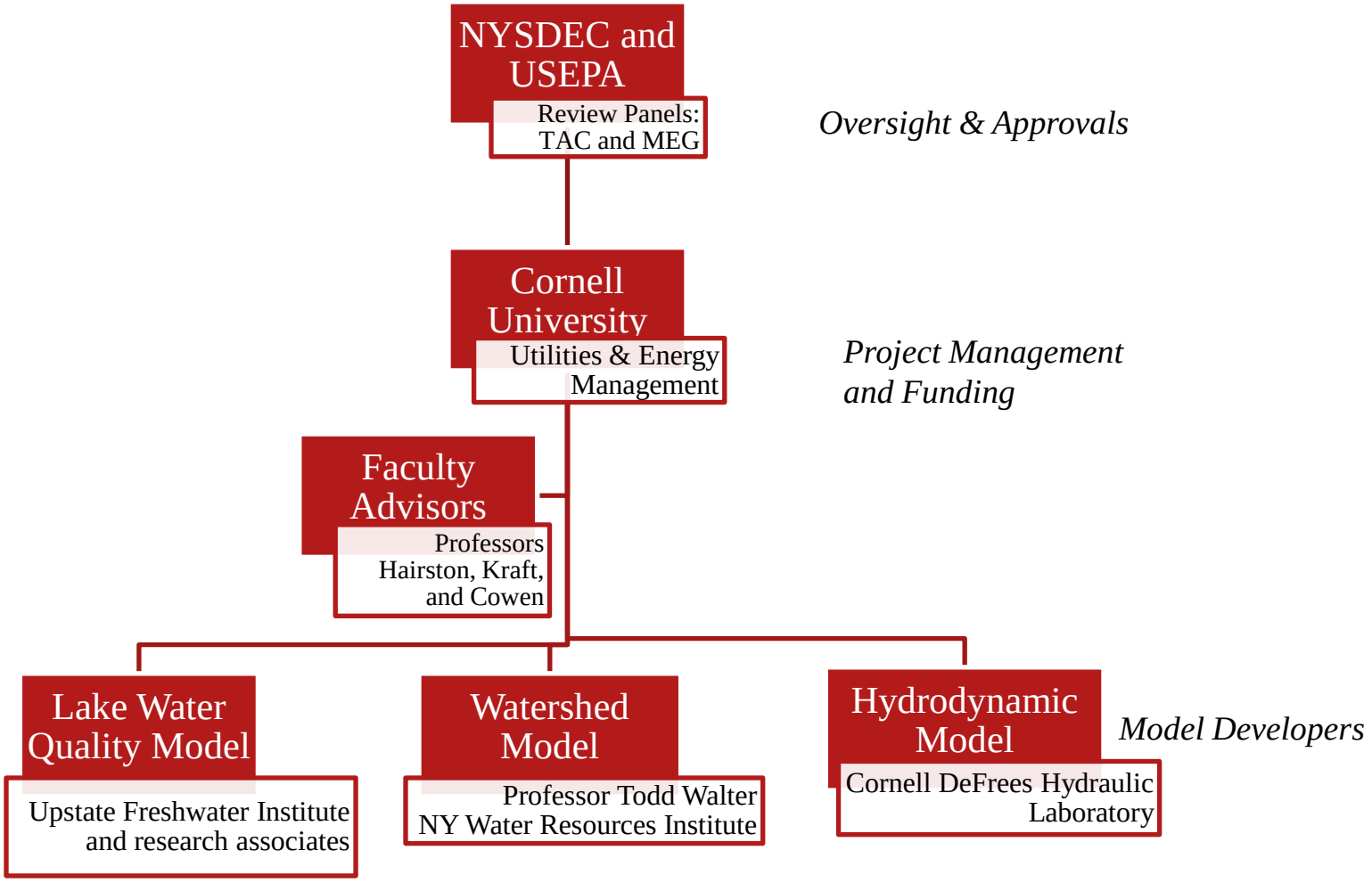
Cayuga Lake Modeling Project (CLMP) Overview

- Investigated the sources of phosphorus (P) to Cayuga Lake and consequences for phytoplankton growth
- Developed mathematical models of the lake and watershed
- Provided NYSDEC with tools to support a science-based approach to lake management

Opportunity to Advance Science and Policy

- CLMP was a significant investment in research and modeling
- Integrate science into policy decisions for managing Cayuga Lake and other lakes
- Apply an ecosystem-based management approach to examine human impacts on natural systems, including water, air, and lands

Project Team



Elements of the CLMP: Investigation Phase

- **Compile and review existing data** (CSI, City of Ithaca, NYSDEC, Cornell, etc.)
  - Lake and stream water quality
  - Land use/land cover and agricultural practices
- **Monitor lake, streams, and point sources**
- **Focus on phosphorus and food web**
  - Test P bioavailability (potency for algal growth)
  - Characterize plankton and mussel communities
- **Record water temperature and velocity** to support hydrodynamic modeling

Elements of the CLMP: Modeling Phase

- **Hydrodynamic model** to simulate lake circulation
- **Watershed model** to quantify relationship of land use, soils, slopes, and management practices on nutrient & sediment export

  ~ Watershed model output informs lake water quality model

- **Lake water quality model** to project the impact of point and nonpoint sources on lake nutrients, algae, clarity, and other metrics

  ~ NYSDEC will use the lake and watershed models to develop a phosphorus Total Maximum Daily Load (TMDL) allocation for all of Cayuga Lake

What is a TMDL?

- **Regulatory Process:** Used when traditional measures will not bring water body into compliance
- **Calculation**: Amount of a substance that can be added to a water body from all sources without causing environmental harm
- **Allocation:** Apportion total allowable load to multiple sources, accounting for margin of error and future growth

Joint NYSDEC/Cornell Outreach Program

- Technical meetings and workshops
- Public meetings
- Presentations to watershed stakeholder groups
- Regular updates to the WRC Monitoring Partnership
- Project web sites
- 20+ technical peer-reviewed publications

Major Findings

- **Hydrodynamics**: Extensive mixing and circulation
- **Phosphorus Sources**: Tributary streams are the overwhelming source (>95%) of bioavailable phosphorus
- **Phosphorus Impacts:** Lake water quality & habitat are stable and healthy, support designated uses
- **Outlook for Long-term Protection:** Focus on nonpoint sources and use CLMP tools and findings to set priorities for best management practices and locations

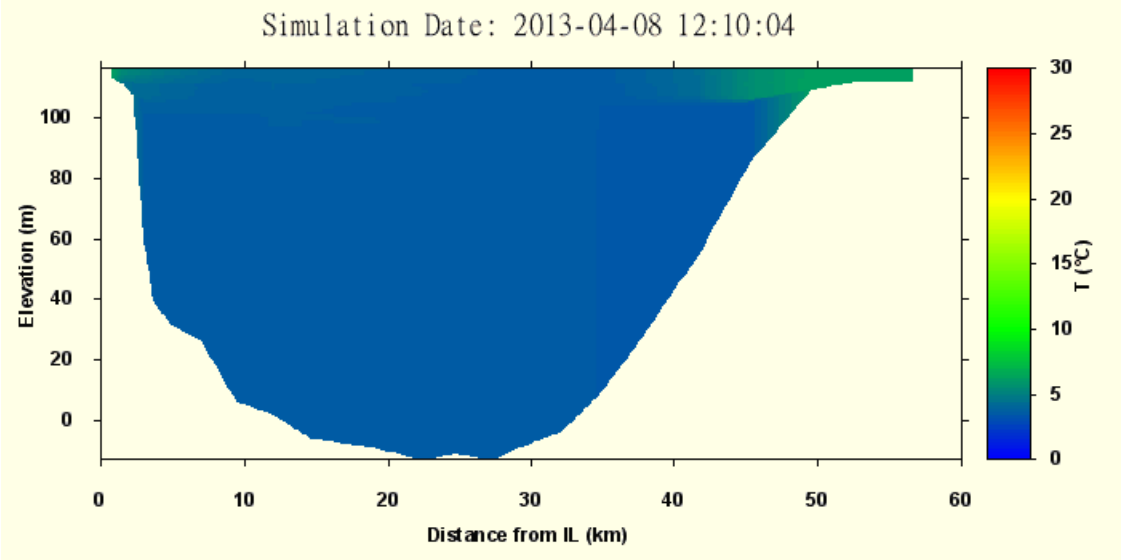
Major Findings and Management Implications

Hydrodynamics

Hydrodynamics: Complex Circulation Patterns

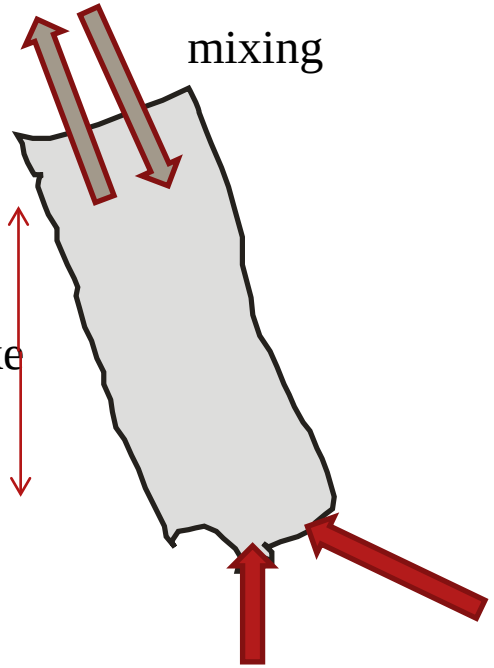
Photo: Bill Hecht

Wind-driven circulation brings deep water onto the southern shelf



South North

Natural mixing processes prevent development of higher phytoplankton (algae) biomass on the "shelf"



Shelf:
Cayuga Lake
Segment 4
1.8 miles

"Flushing rate of the shelf from mixing is rapid relative to phytoplankton growth rates"

(Effler et al. 2010; Gelda et al. 2015a)

Large southern tributaries Fall Creek, Cayuga Inlet
2 wastewater treatment plants
Lake Source Cooling return flow

Hydrodynamics of the Southern Shelf

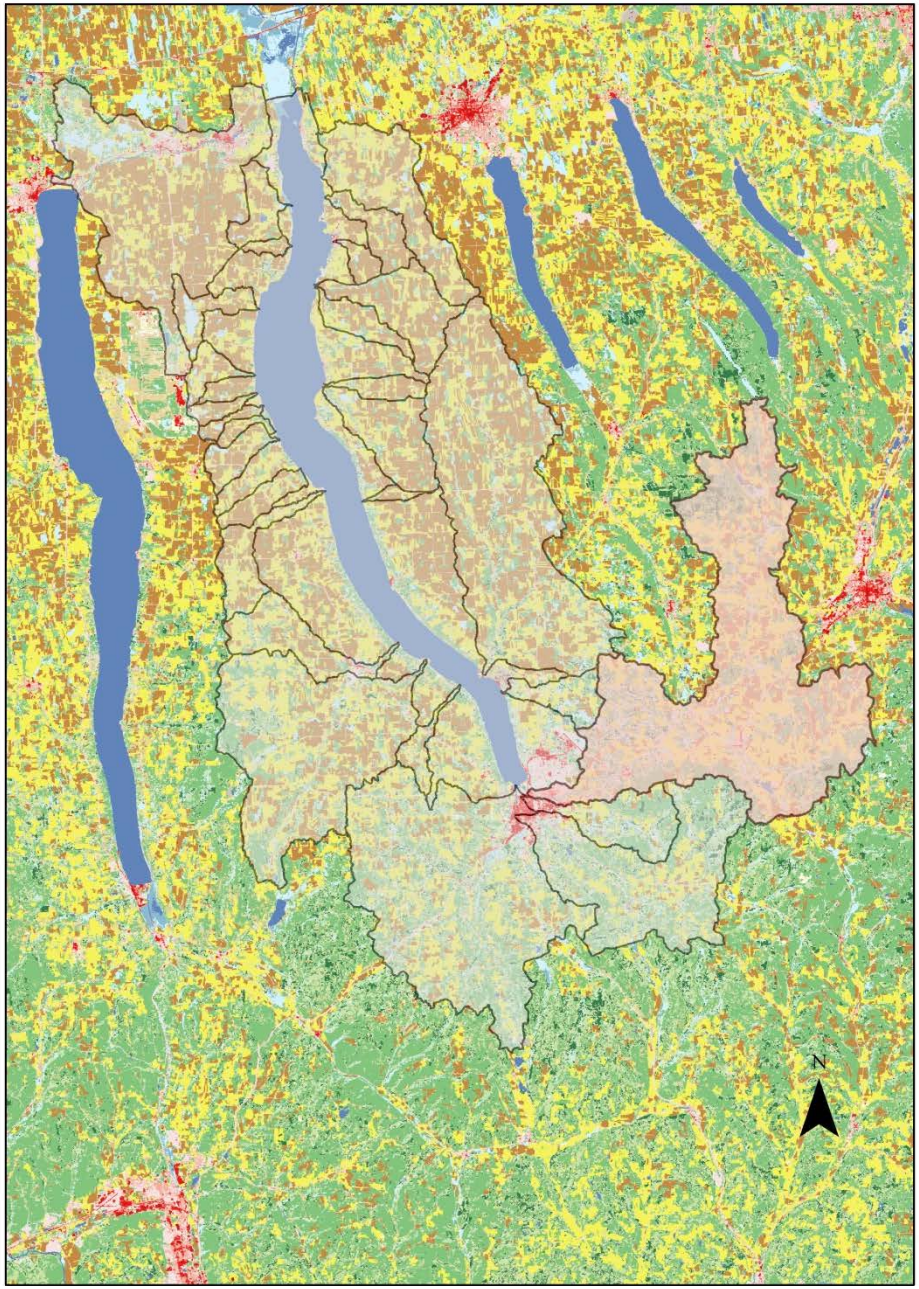
- Three-dimensional hydrodynamic model applied to define LSC mixing zone and shelf water residence time
  - LSC induced flow (primarily back entrainment) is 10X larger than the LSC discharge flow
  - Maximum shelf residence time during summer low flow, low wind conditions is 1.8 days
  - Moving the outfall would increase shelf water residence time by 67%

Management Implications

- LSC return flow enhances circulation and reduces residence time of southern shelf
- Replaces sediment laden- storm water flows with clear lake water
- Moving the outfall is projected to increase ambient levels of total P, sediment, and chlorophyll-*a* on shelf

Major Findings and Management Implications

Phosphorus Sources and Impacts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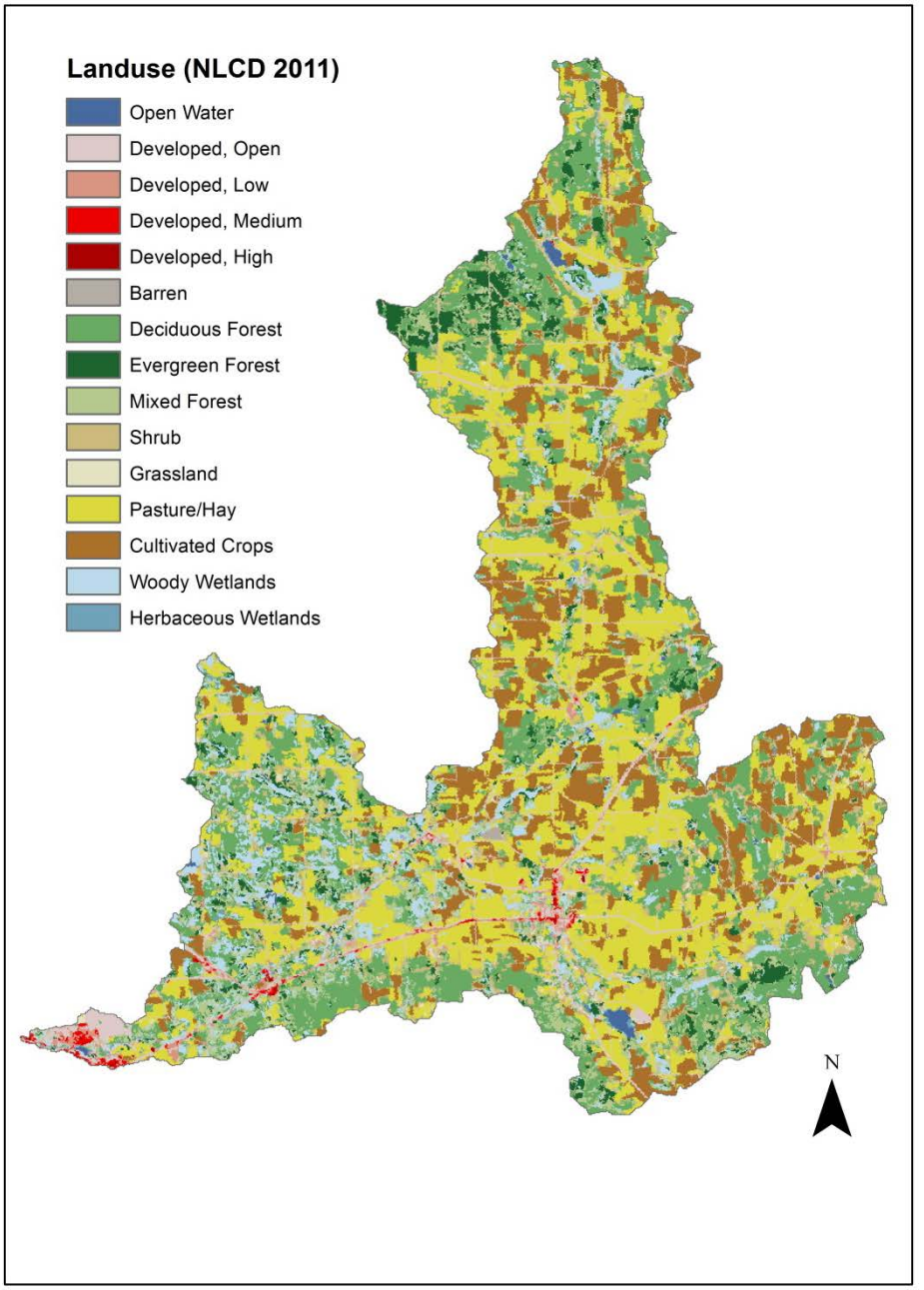

Landuse (NLCD 2011)
Open Water
Developed, Open
Developed, Low
Developed, Medium
Developed, High
Barren
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub
Grassland
Pasture/Hay
Cultivated Crops
Woody Wetlands
Herbaceous Wetlands
N

Bioavailable Phosphorus is Key

- Phosphorus fractions (measured as total, dissolved, organic, inorganic) differ in their potential to support algal growth
- Detailed CLMP monitoring in 2013 documented that 97% of bioavailable P originated from watershed nonpoint sources, 3% from point sources
- Elevated total P concentrations on the shelf are associated with sediment from runoff events (muds)
- P associated with muds is minimally available to support algal growth

Management Implications

Efforts to maintain Cayuga Lake's water quality should focus on minimizing the risk of bioavailable P reaching streams

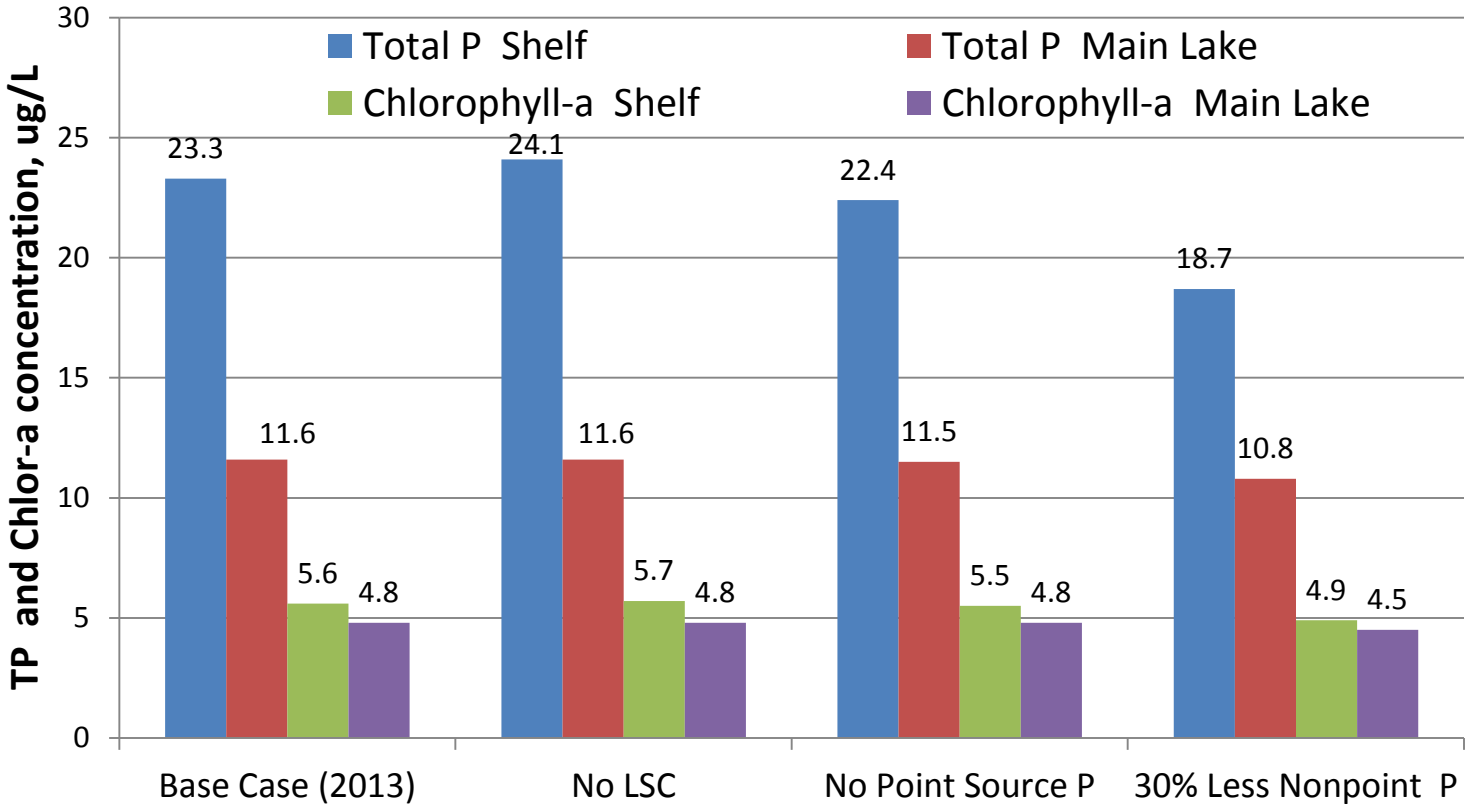
Major Findings and Management Implications

Outlook for Long-term Protection of Cayuga Lake

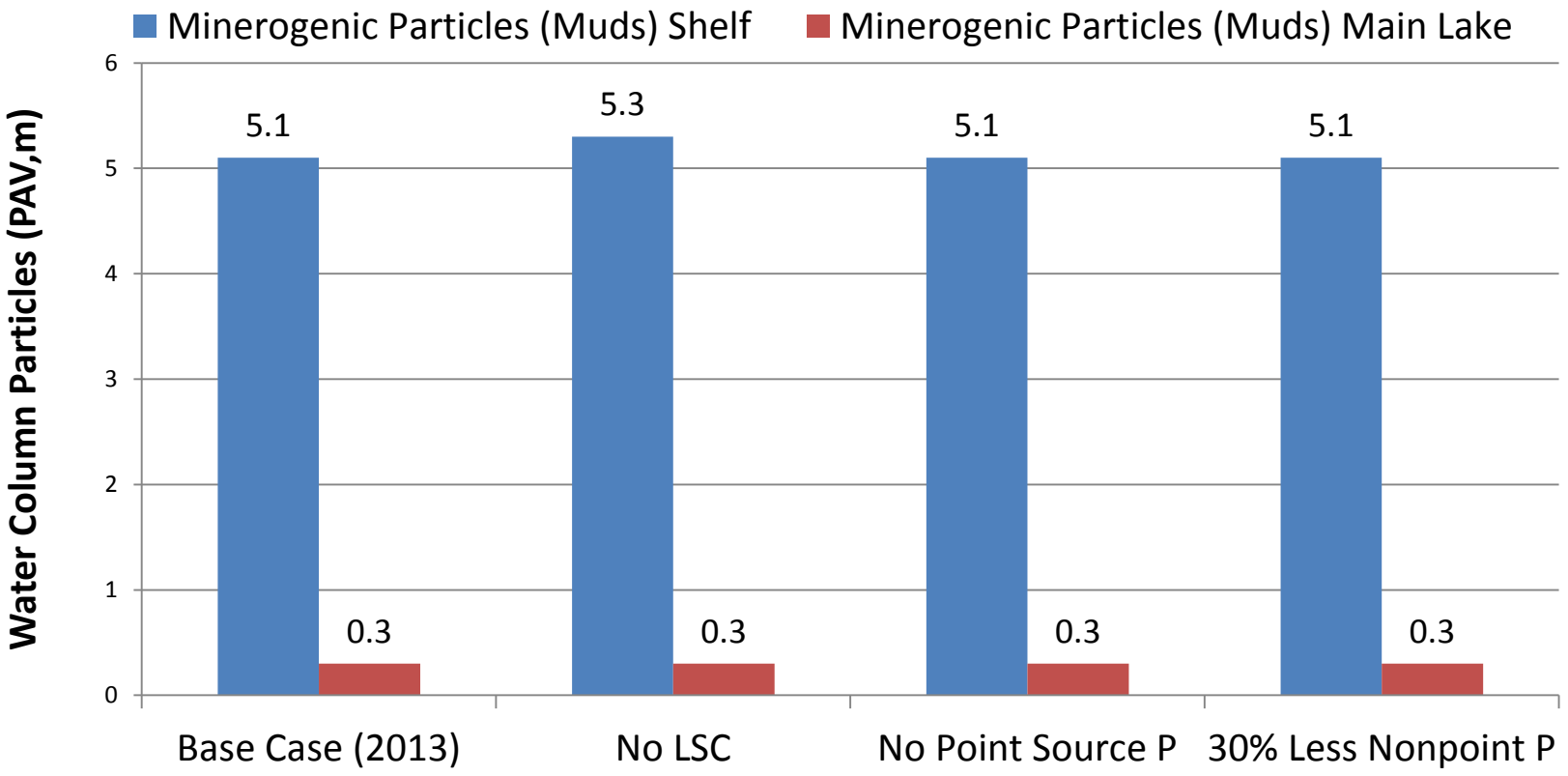
Water Quality Model Test Runs

- UFI tested three scenarios to verify model stability
  - Eliminate Lake Source Cooling
  - Remove P from all six WWTP discharges
  - Reduce all nonpoint source P by 30%
- NYSDEC is responsible for using the watershed and lake models to simulate effectiveness of their selected management alternatives

Projected Impacts on TP and Chlorophyll-*a*



Projected Impacts on Water Clarity



Management Implications

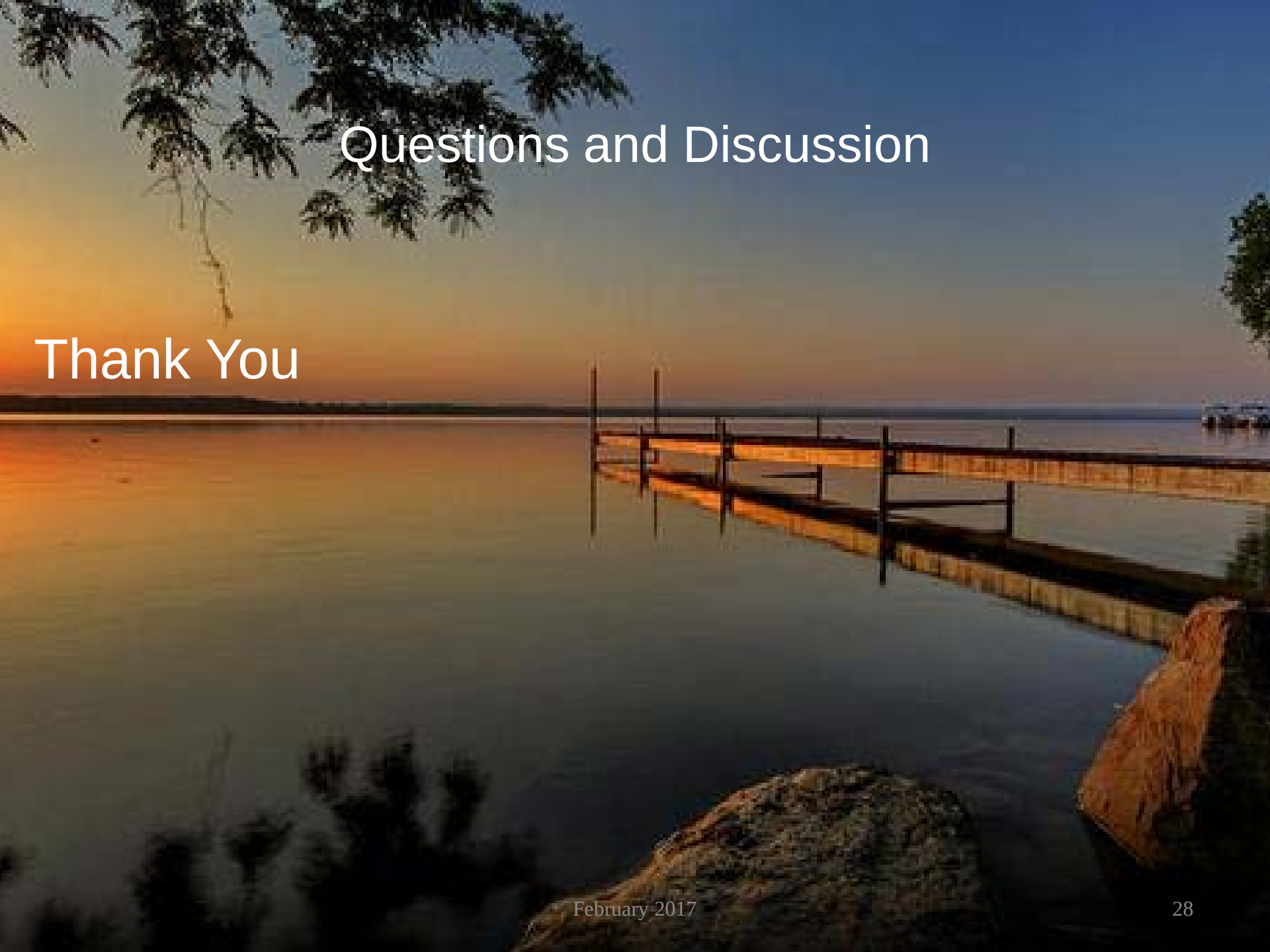
- Additional controls on phosphorus from point sources are not projected to affect lake trophic state
- The LSC return flow provides a modest benefit to the shelf: lower TP, sediment particles, and chlorophyll-*a*
- Nonpoint source management focused on bioavailable P indicated for long-term water quality protection
- NYSDEC will apply these models to develop the phosphorus TMDL for Cayuga Lake

Looking Ahead

- Opportunity to incorporate CLMP knowledge into the Cayuga Lake Restoration and Protection Plan update, and construct a Nine Elements Plan
- The CLMP illustrates the emerging Ecosystem-based Management approach for water resources
  - Develop “place-based” information and alternatives
  - Recognize that humans are part of the ecosystem; manage for multiple uses; and consider impacts on land, air, and climate as well as water

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

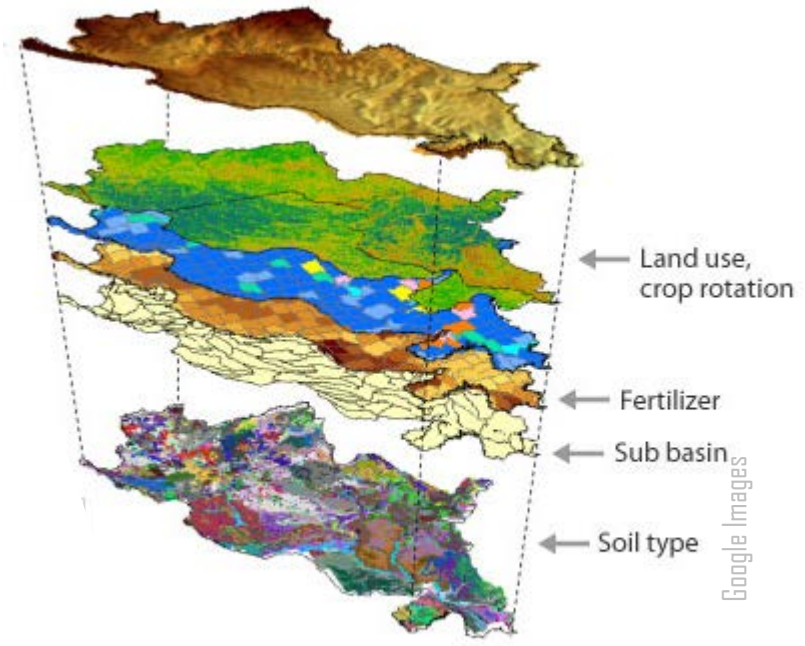
www.cayugalakemodelingproject.cornell.edu


Questions and Discussion
Thank You

Watershed Model

Soil Water Assessment Tool (SWAT)

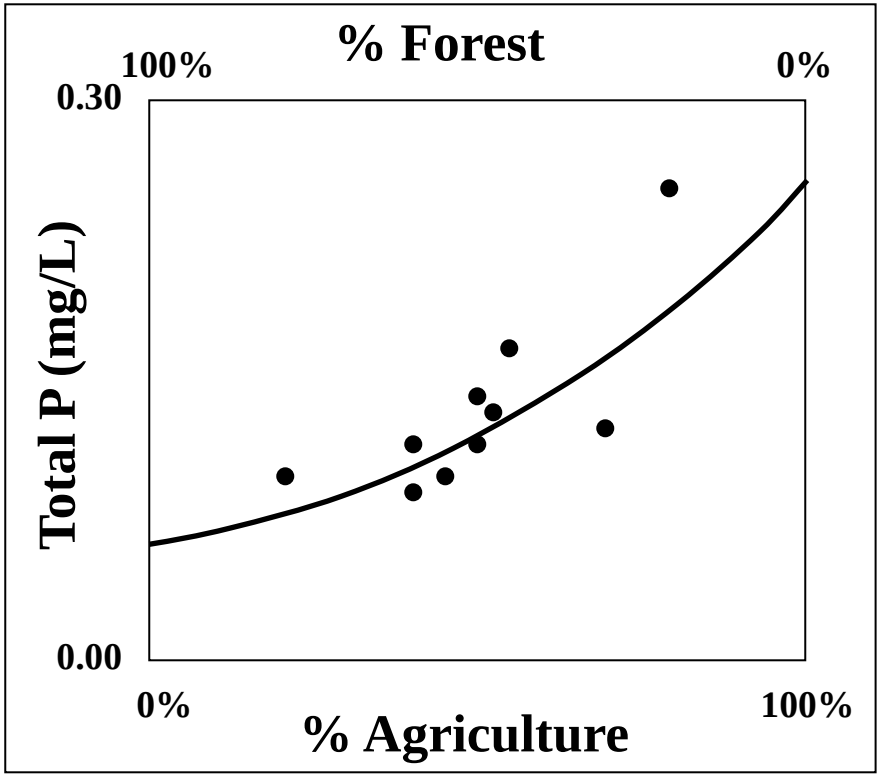
- Developed by USDA-ARS, Texas A&M
- Widely used in TMDL-type projects
- Simulates dissolved & particulate P
- Adaptable to local conditions
- Flexible management input



Land Use/Land Cover Affect Phosphorus Export

- Streams draining agricultural areas have higher phosphorus concentrations

Lyon, Walter, et al. 2006. *JAWRA.* 42(3): 793-804



Objectives of the Watershed Model

- Estimate phosphorus loads from the watershed
  - Inform lake model inputs
- Provide a tool to test management ("what-if") scenarios

Watershed Modeling Tool

- Current conditions
- Hindcast: *What were sediment and phosphorus loads pre-settlement (1700s)?*
- Management:
  - *Turn off individual sources*
  - *Implement agricultural Best Management Practices*
    - Change the timing of manure applications ~ avoid forecasted rain
    - Change the placement of manure ~ buffers around concentrated flow paths
    - Other recommended practices ~ cover crops, swales
- Forecast: *Potential changes in a future climate*