ECOSYSTEM-BASED APPROACH TO LAKE AND WATERSHED MANAGEMENT

Liz Moran
EcoLogic LLC

October 2017

Photo: Bill Hecht

ECOSYSTEM-BASED MANAGEMENT

Ecosystem-based management is an approach that considers the entire ecosystem, including humans. Impacts of our actions on the landscape, air quality, and water quality are assessed in an integrated approach focused on a sustainable future.

Challenges: NYS Finger Lakes

- Protect multiple uses, including as a source of potable water
- Find acceptable ways to reduce nutrient and sediment loss while maintaining agricultural viability
- Prepare for climate change and invasive species

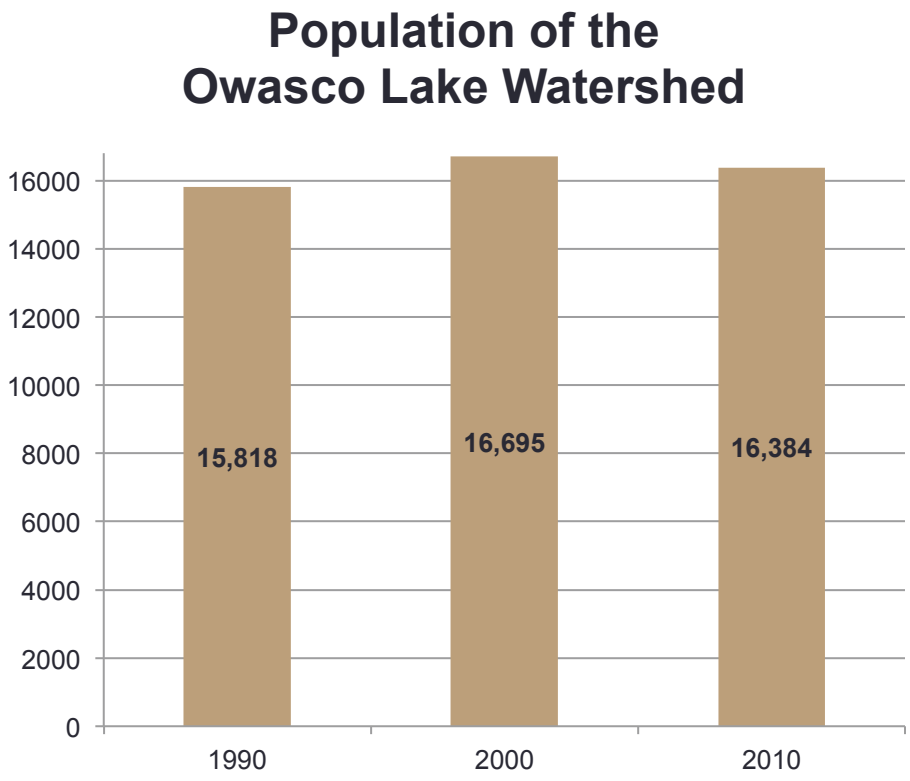
Emerging Threat from Harmful Algal Blooms (HAB)

- Cyanobacteria, some species exude toxins
- Can bloom in nutrient-rich environment, warm water, quiescent condition
- Phosphorus key, evidence of interplay with Nitrogen
- Multiple HABs across NY including all 11 Finger Lakes in 2017

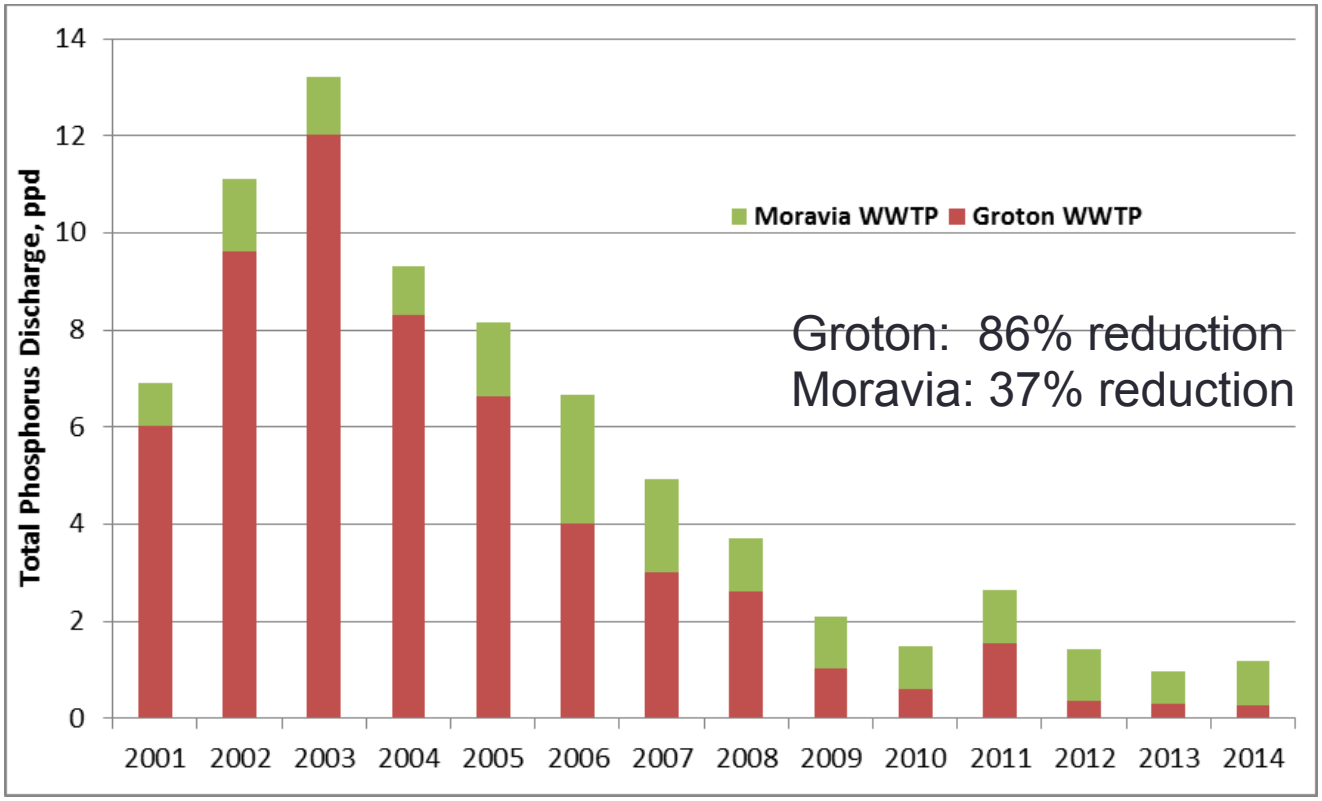
Development

Residential Development

- Population relatively stable
- Growth pressure tends to be outside of areas served by public water and sewer



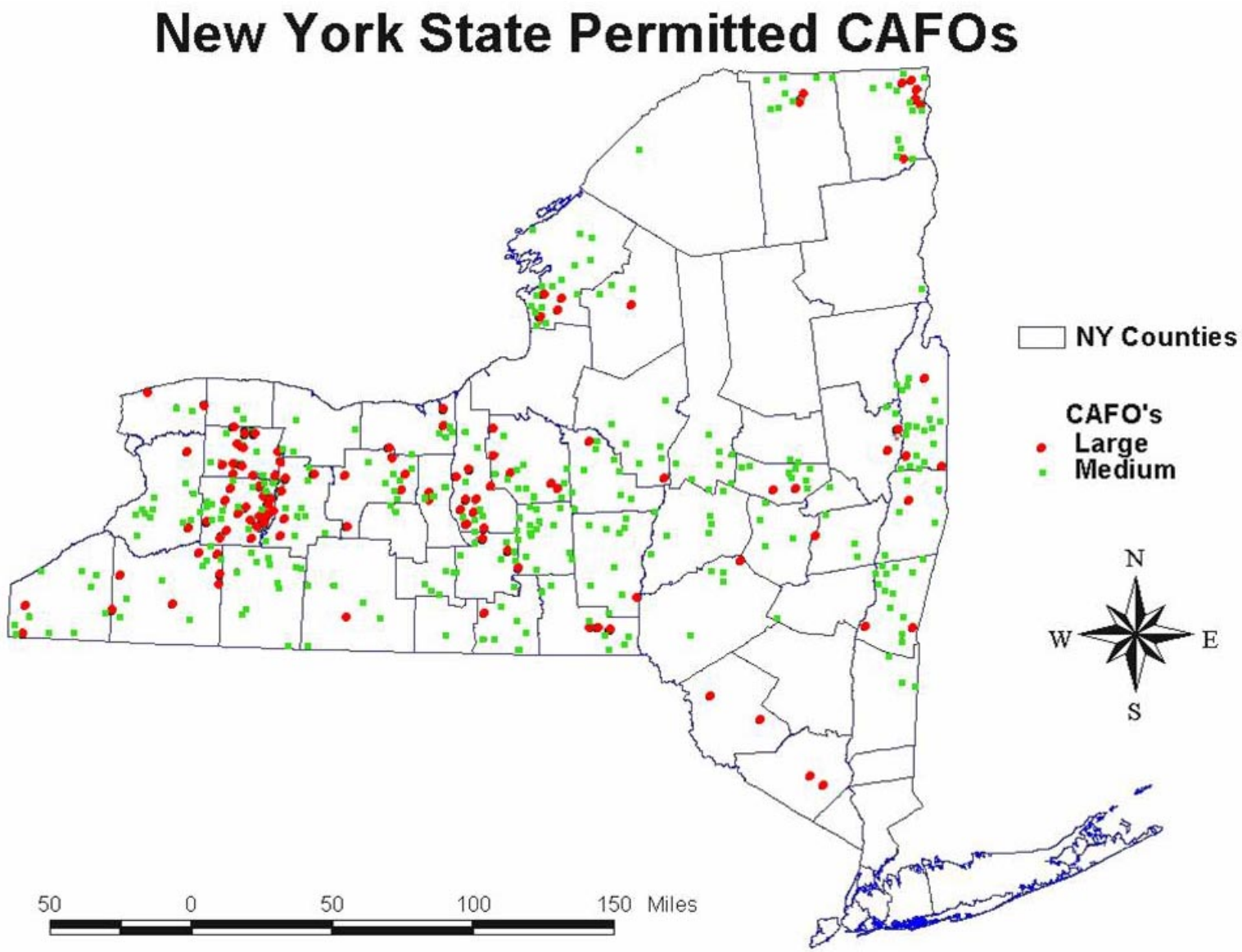
Progress in Wastewater Management



Agriculture and Livestock

- Finger Lakes watersheds support active agriculture
- Major land use and economic impact
- Multiple livestock and dairy operations
  - Concentrated Animal Feeding Operations

New York State Permitted CAFOs



Climate Change Affects Sediment and Nutrient Losses from Landscape

- Between 1958 and 2012, the Northeast experienced a 70% increase in the amount of rainfall measured during heavy precipitation events

EBM Guiding Principles

People are part of the ecosystem

- Land use and development affect water quality and habitat
- Waters support multiple uses- potable supply, wastewater assimilation, fishery, recreation, cooling water
- Working landscapes are essential for sustainable development, food production
- Change is inevitable

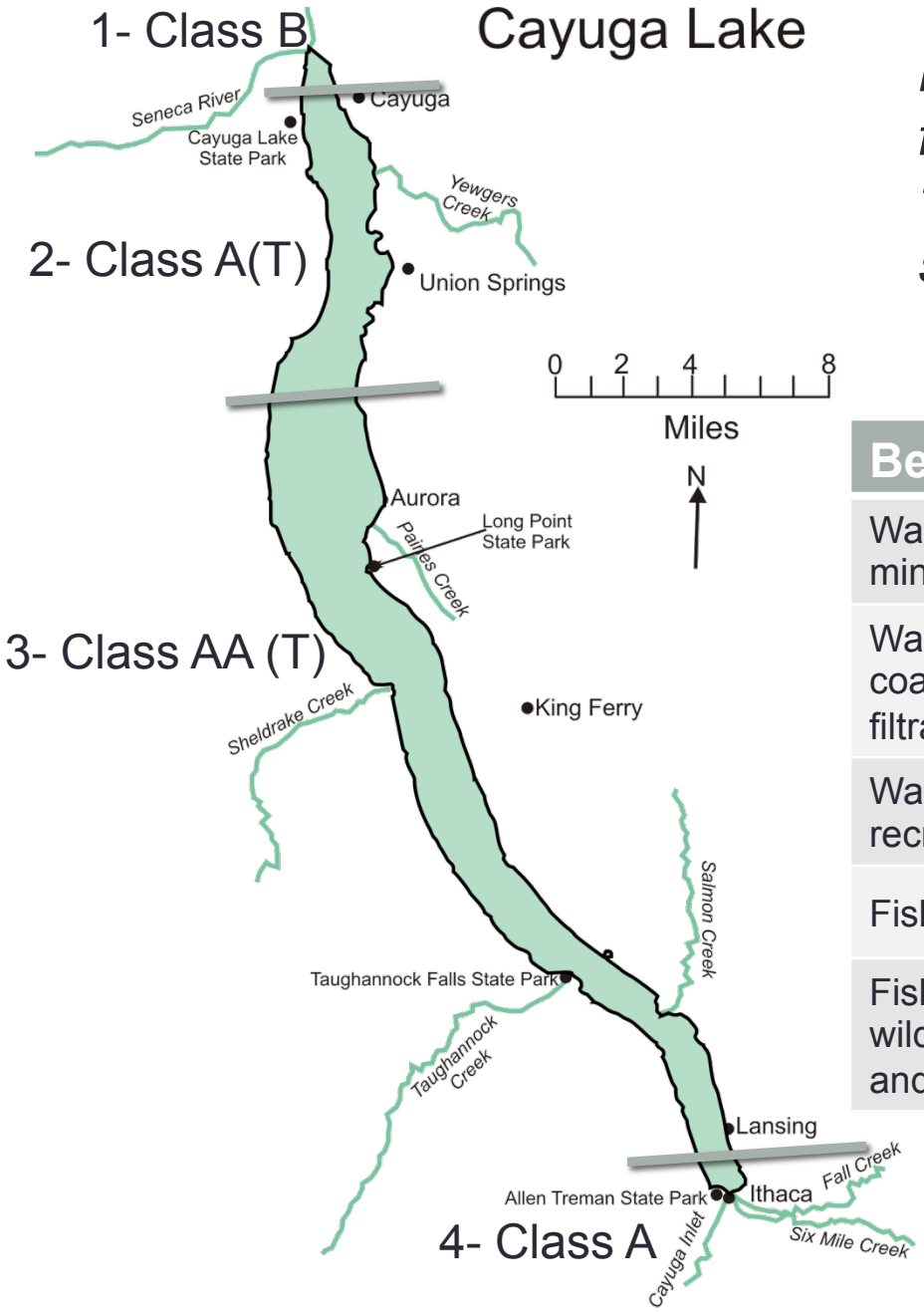
Apply scientific and engineering tools to support decisions

Cayuga Lake Modeling Project (CLMP)

- Permit requirement for continued operation of Cornell's Lake Source Cooling facility
  - Investigated phosphorus (P) inputs and phytoplankton growth
  - Developed mathematical models of the lake and watershed
- Provided NYSDEC with tools for a science-based approach to lake management

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”
- 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



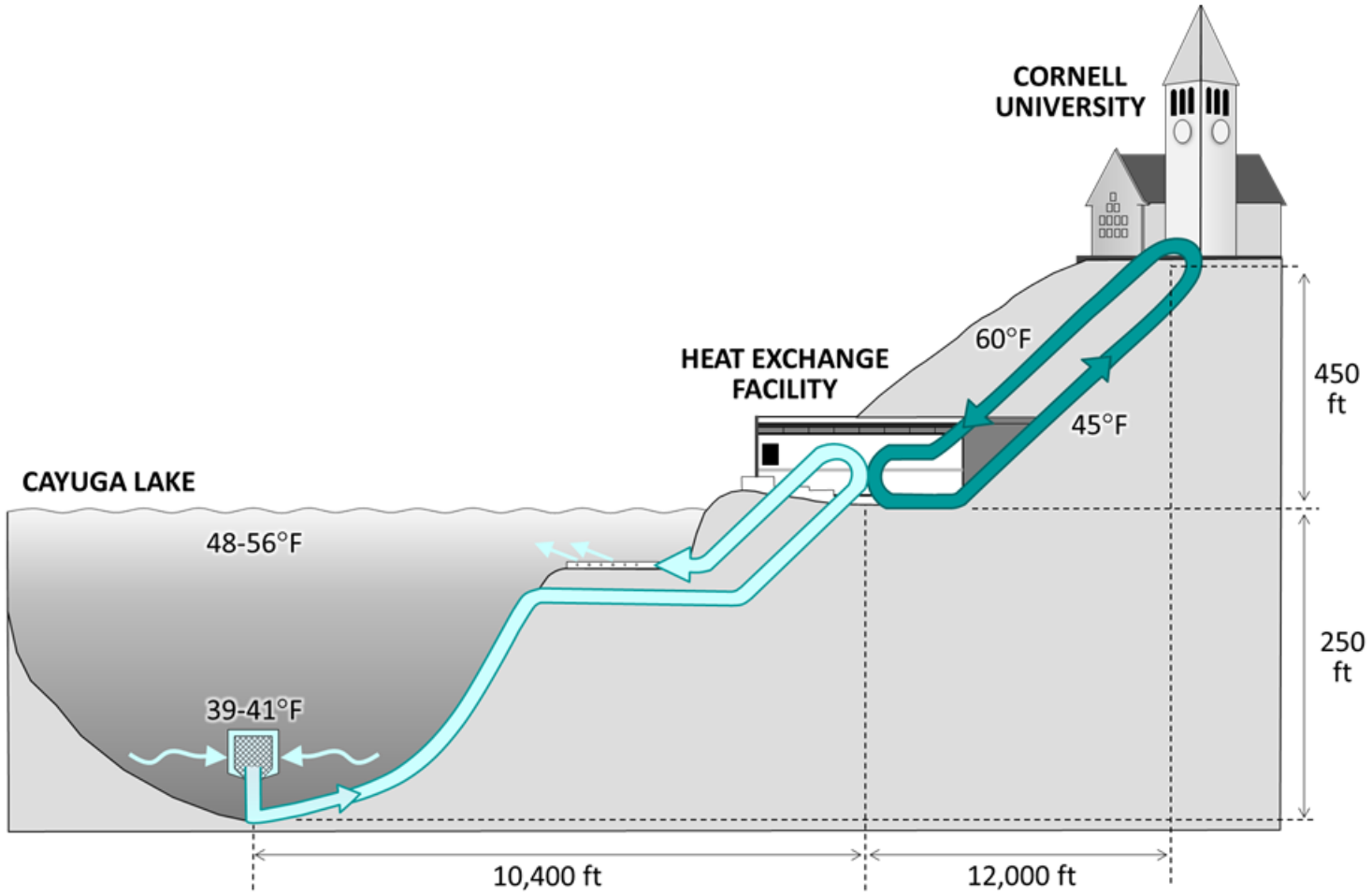
NYSDEC classifies Cayuga Lake in four distinct segments, depending on "best use", and habitat suitability for salmonids, designated by (T)

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

Why was CLMP included as a permit condition for 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, NYSDEC considered LSC a new (point) source of phosphorus to segment 4

Lake Source Cooling Facility



Opportunity to Advance Science and Policy

- Engage world-class researchers to improve understanding of Cayuga Lake
- Integrate science into policy decisions
- Apply an ecosystem-based management approach to examine human impacts on natural systems, including water, air, and lands

Why Cornell Built the Lake Source Cooling Facility

- University commitment to sustainability- carbon neutral
- Reduced fossil fuel consumption for cooling by 86%
- Lowers peak demand on NYS energy grid
- Cost-effective for University over the long term
- Detailed EIS concluded no adverse impact on Cayuga Lake

Elements of the Cayuga Lake Modelling Project

- Monitoring (April – Oct 2013)
  - Inflows from major streams and point sources
  - Lake water quality conditions, 9 sites north to south
  - Biota- plankton and mussels
  - Detailed bioavailability testing
- Modeling (2014-2016)
  - Effects of land use, land cover and hydrology on watershed flux of phosphorus and sediment
  - Cayuga Lake water circulation (hydrodynamics)
  - Cayuga Lake water quality, focus on eutrophication (phosphorus and algae)

Key Questions

- Q1: What are the point and nonpoint sources of TP? Why is TP elevated in Segment 4?
- Q2: How much of measured TP supports phytoplankton growth?
- Q3: How does water movement affect distribution of TP and phytoplankton?

How do the answers to these three key questions inform our understanding of impacts of Cornell's Lake Source Cooling facility?

3 Integrated Models to Answer the Questions

- Watershed Model (SWAT)

  Quantifies relationship of land use, soils, slopes, and management practices on nutrient & sediment export

- Lake Water Quality Model (CL-W2)

  Projects the impact of point and nonpoint sources on lake nutrients, algae, clarity, and other metrics

- Hydrodynamic Model (Si3D)

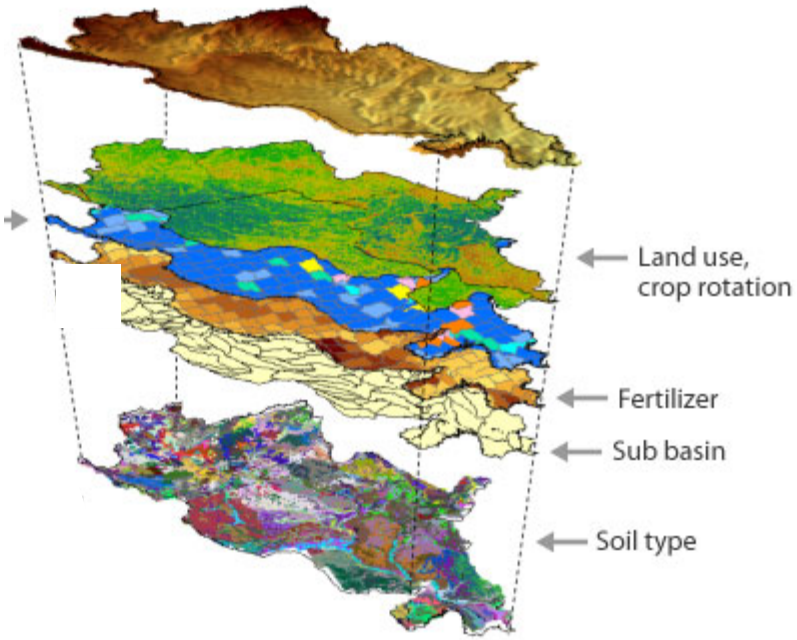
  Simulates water movement in the lake (three dimensional)

Watershed Model

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

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

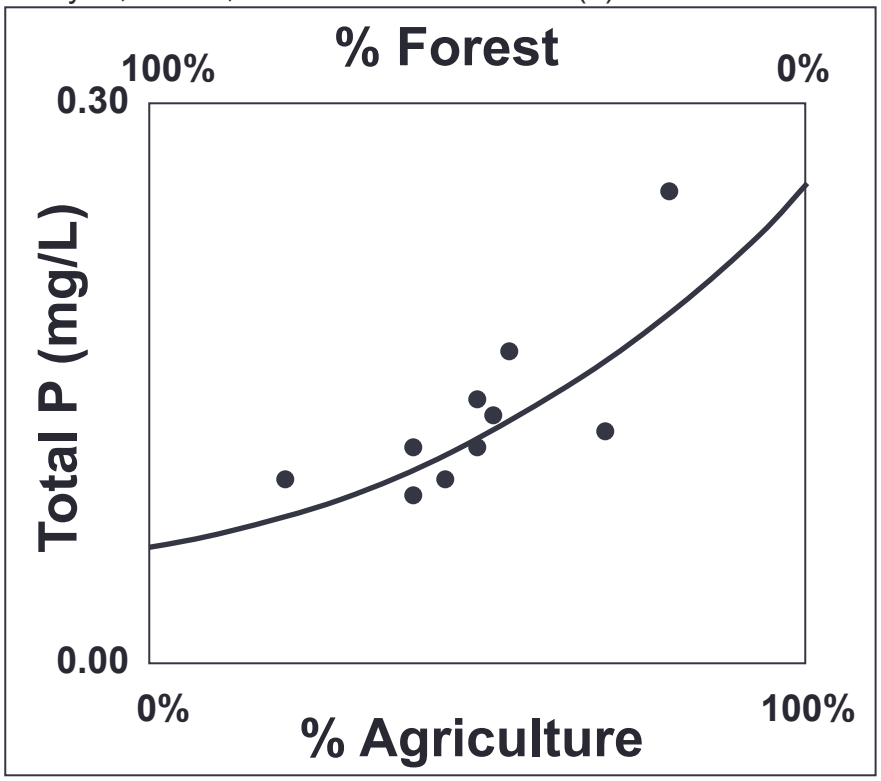


Google Images

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



Watershed Model Approach

- Calibrate to current conditions
- Run management scenarios
  - *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*

Q1: Point and nonpoint sources of TP, and why TP is elevated in Segment 4

Site-specific investigations

- Lake, tributary streams, and point sources were monitored (capturing storm events)

Model Integration

- Watershed model identifies P contributing areas and practices
- Lake water quality model tracks P fractions and predicts phytoplankton growth

Findings

- Tributaries contribute > 97% TP to lake
- Elevated TP on the shelf is associated with sediment from runoff during storm events

Cayuga Lake Water Quality Model

- Informed by watershed model: tributary inflows, plus point sources
- Projects water quality impacts of changing inputs
- Supports quantitative analysis of impacts of future management actions

Q2: How much of measured TP supports phytoplankton growth

Site-specific Investigations

- P bioavailability testing of streams, point sources, LSC return flow, Cayuga Lake

Model Integration

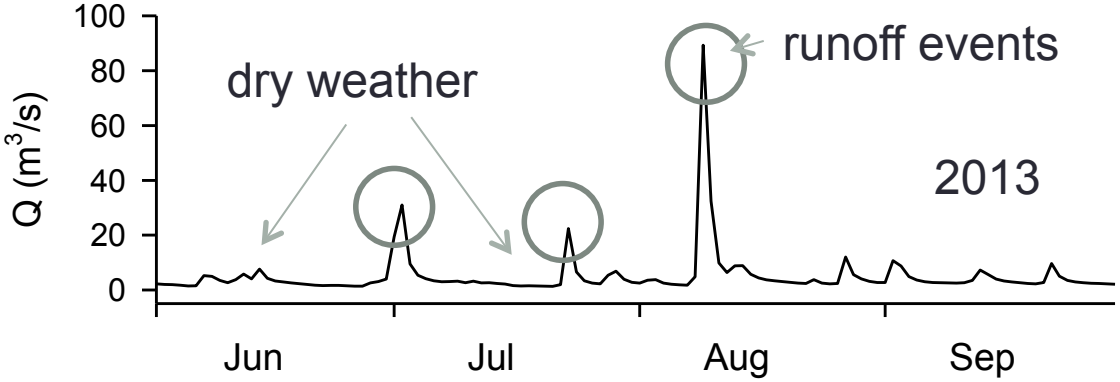
- Lake water quality model explicitly tracks P fractions with respect to their algal growth potential
- Watershed model tracks dissolved and particulate P

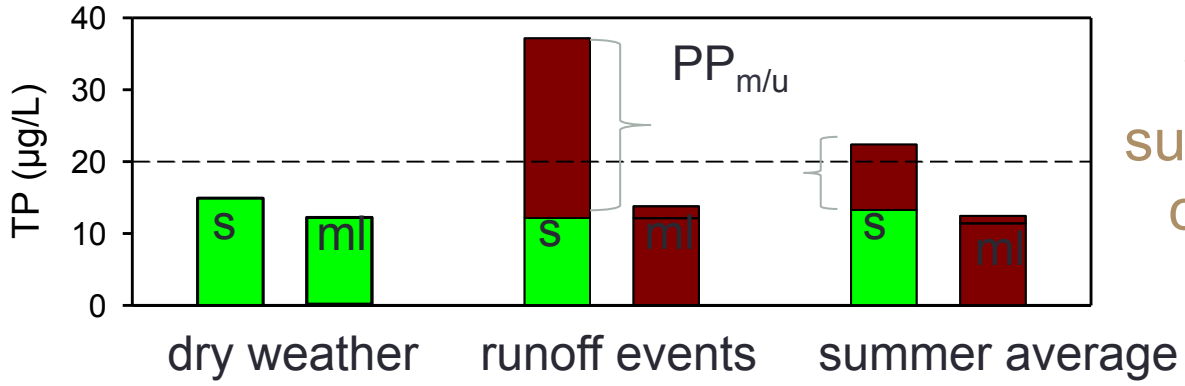
Findings

- Occasional elevated TP on shelf after storm events, low bioavailability (~3%) of P sorbed to these clay particles
- Tributaries contribute ~95% of Bioavailable P

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

Hydrodynamic Model

- Detailed 3D model of Cayuga Lake
- Tracks annual cycle of stratification and mixing
- Responds to meteorological conditions

Photo: Bill Hecht

Q3: How water movement affects distribution of TP and phytoplankton

Site-specific Investigations

- Instrumentation to record lake current velocity & temperature
- Collaboration with US Naval Research Observatory for fly-over during intensive grid study (August 2014)

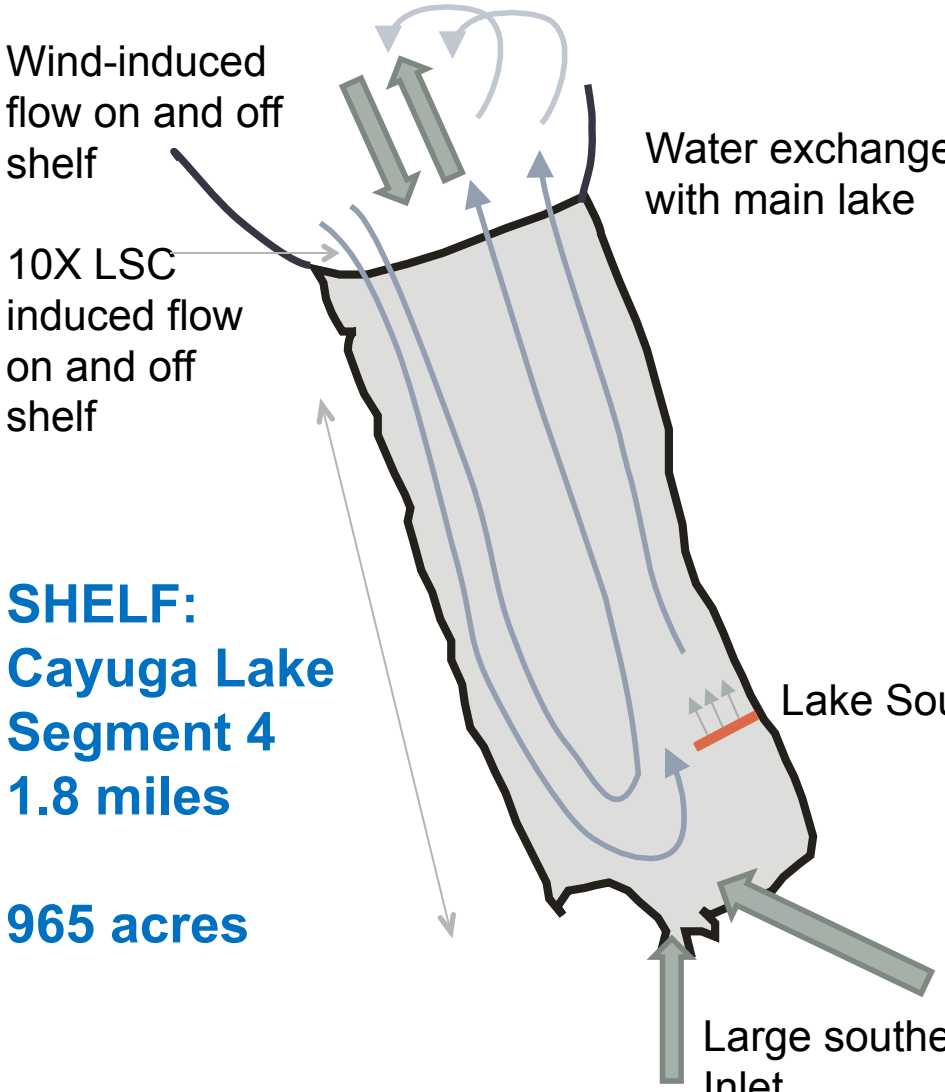
Model Integration

- Si3D model applied to define LSC mixing zone and shelf dynamics
- Lake water quality model applied to examine impact of shelf water residence time on phytoplankton

Findings

- LSC induced flow is 10X larger than LSC discharge
- Outfall relocation increases shelf residence time by 67%, with associated increase in TP, chlorophyll, & turbidity

Mixing processes prevent development of higher phytoplankton biomass on the shelf



SHELF:
Cayuga Lake Segment 4
1.8 miles

965 acres

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

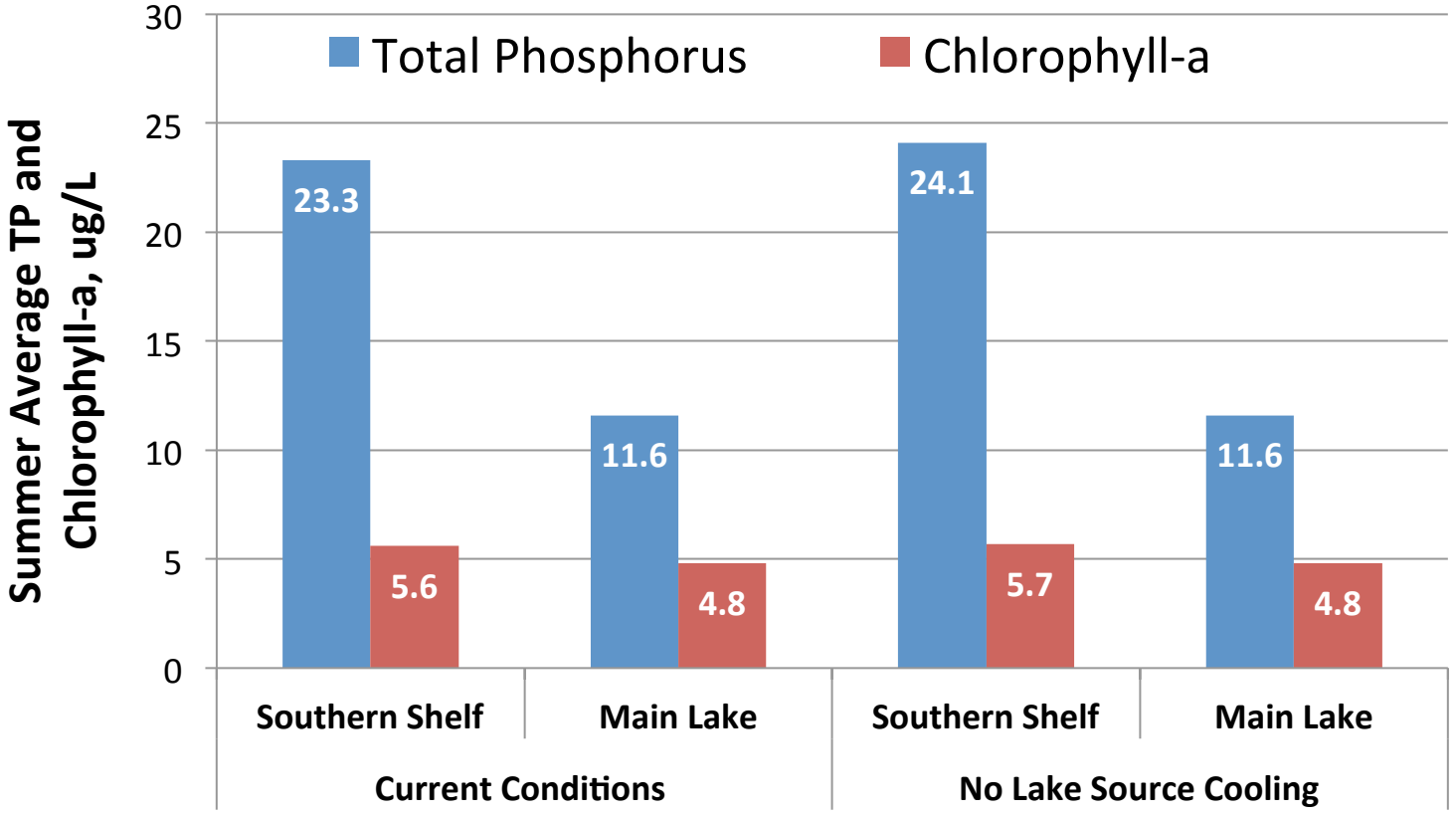
(Effler et al. 2010; Gelda et al. 2015a)

Implications for the LSC facility

Permitting Challenges

- Currently, need to restrict LSC during high demand periods to meet interim TP limit of 6.4 ppd
- Final TP limit 4.8 ppd would severely impact facility operations
- Outfall extension is costly and poses adverse impacts on air quality, no benefit to water quality
- Construction of new chillers to replace LSC capacity would be even more costly and environmentally damaging

Projected TP and Chlorophyll-a, With and Without LSC Discharge to Segment 4



Source: UFI, Dec. 2016. Phase 2 Final Report. Table 7-17, page 7-88.

Looking Ahead

- The CLMP illustrates Ecosystem-based Management approach to water resources
  - State-of-the-art modeling
  - Develop “place-based” information
  - Active stakeholder engagement
  - Recognition that humans are part of the ecosystem; manage for multiple uses; and consider impacts on land, air, and climate as well as water
- Opportunity for NYS to continue leadership on climate actions

Questions and Discussion

Thank You