Model Correlations and Forecasting Using Virtual Beach

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Agenda

- Modeling
- Virtual Beach
- Case study – Ottawa WTP

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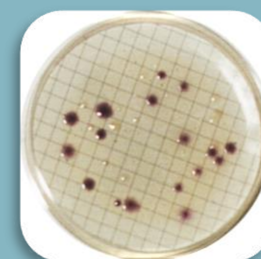
Problem: Delayed notification

- Today's concentrations of *E. coli* are not available until tomorrow

Sample collection

18-24 hour incubation



Concentrations are not available until the next day

- Notify the public based on the previous day's concentrations
- Sanitary conditions can change overnight

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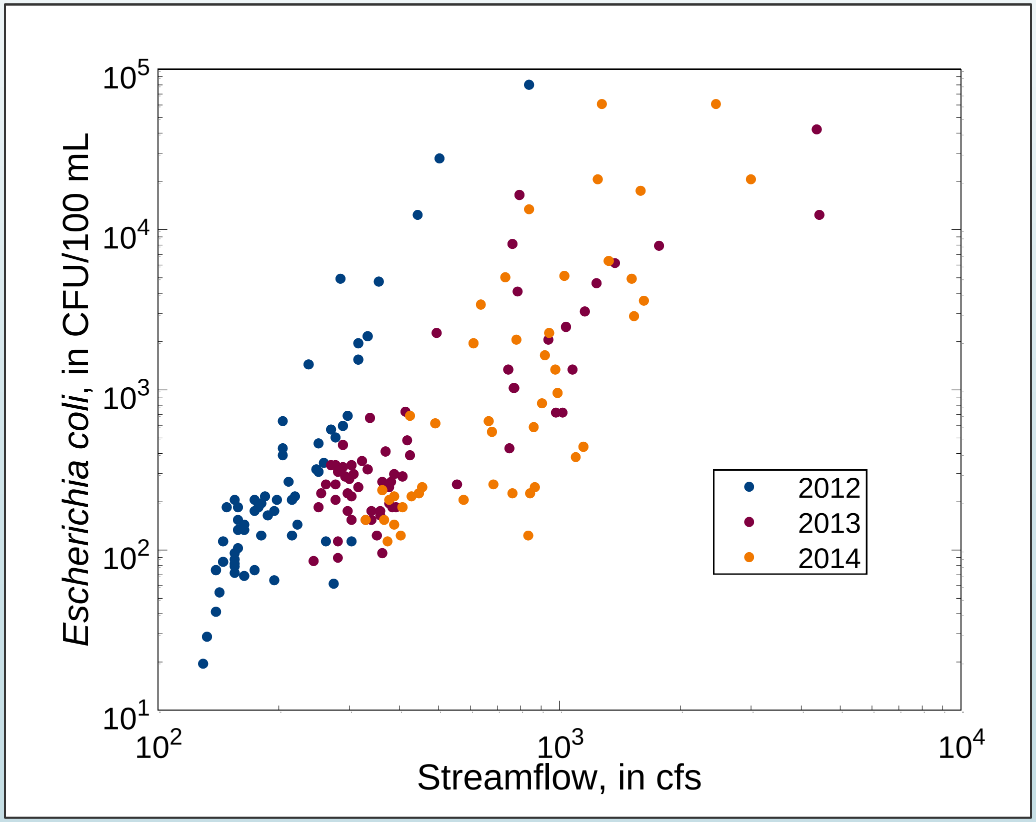
Site-specific multiple linear regression models

- Contain two or more variables related to target concentrations
- Results available within an hour to make timely management decisions
- Multiple linear regression models have been shown to work well to predict recreational water quality at Great Lakes beaches
  - Francy and others 2013

Model development

Multiple years of data are necessary prior to model development to try to capture the annual variability

Relations between *E. coli* and environmental and(or) water-quality variables can vary from year to year based on weather patterns



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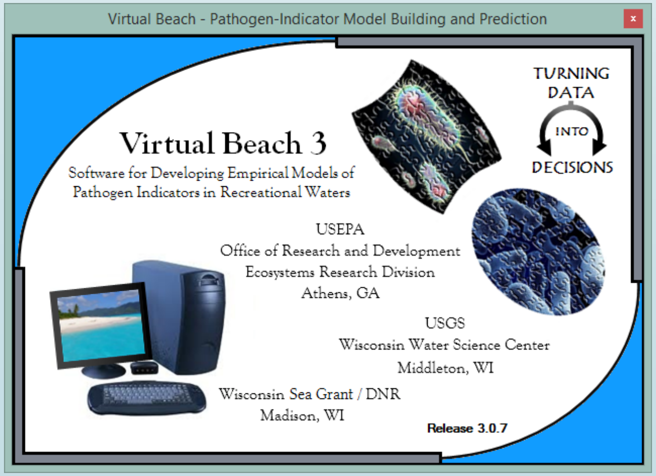
Virtual Beach

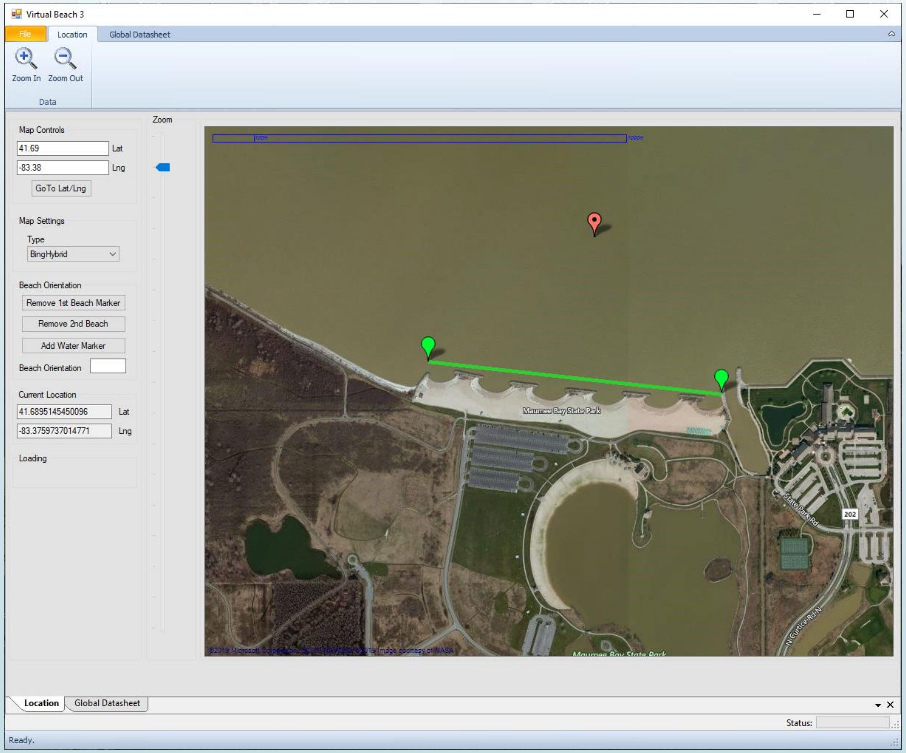
- Free software developed by the USEPA
- Used for studying relations between water-quality indicators or threats and ambient environmental conditions
- Has typically been used to estimate *E. coli* and enterococci concentrations

https://www.epa.gov/ceam/virtual-beach-vb



Virtual Beach components

- Map to define site orientation and calculate wind, wave, and current variables
- Spreadsheet processing and analysis of imported data
  - Key ability to optimally transform the response and independent variables

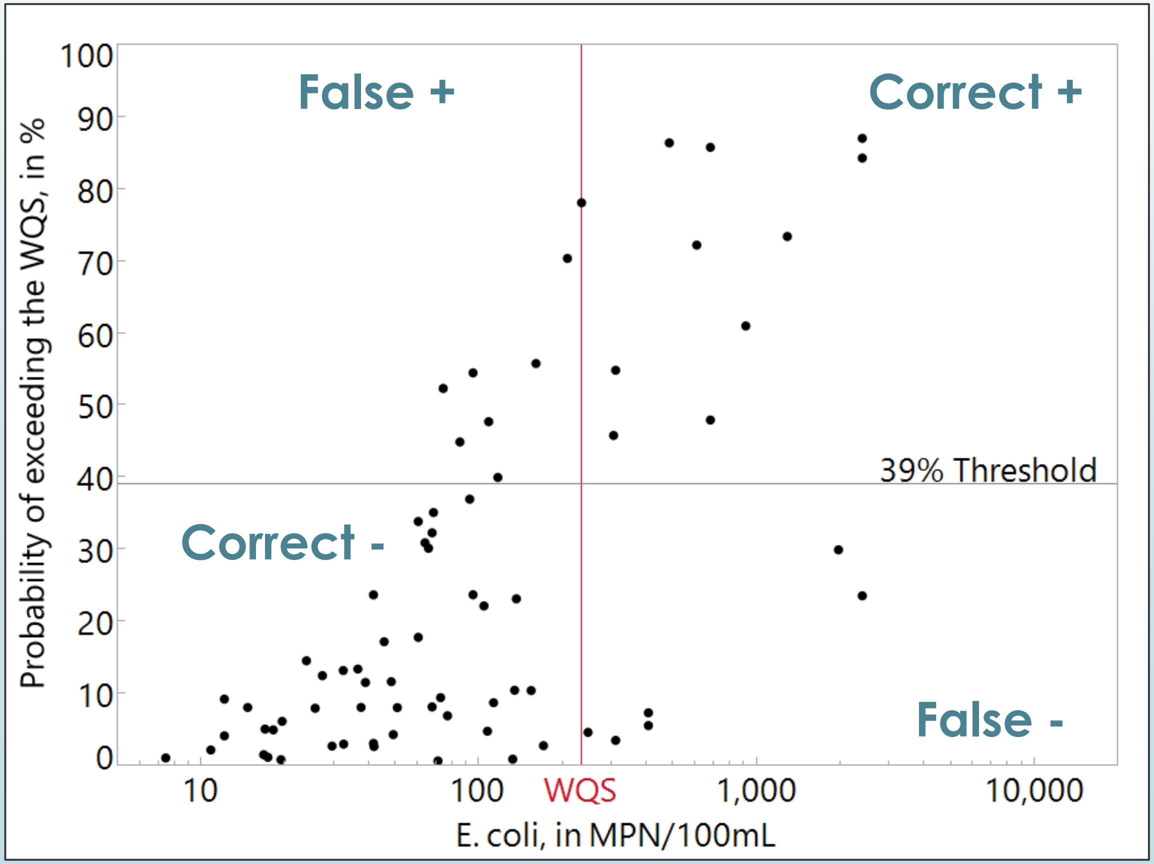


Virtual Beach components

- Linear regression analysis with model selection tools
- Use of chosen models for prediction

Two types of output:

1. Predicted concentration
2. Probability of exceeding a concentration



Two types of cyanoHAB toxin models

- Real-time models include factors that are easily or continuous measured
- Comprehensive models use factors from samples collected and analyzed in a laboratory

Real-time variables

- Phycocyanin
- pH
- Temperature
- Daily mean streamflow
- Satellite data

Comprehensive variables

- Cyanobacterial genes
- Nutrient concentrations

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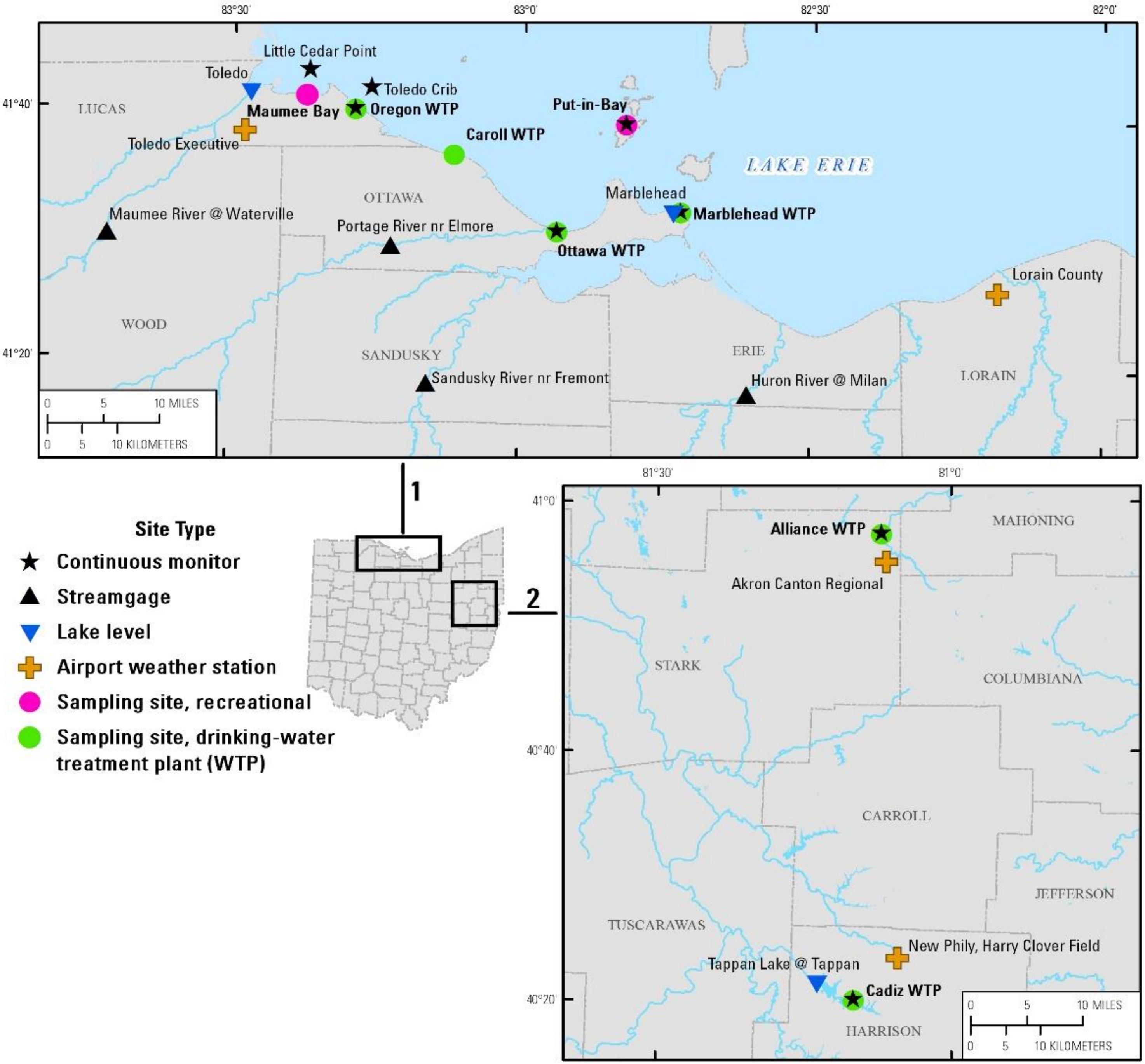
Case Study Model Development – Ottawa WTP

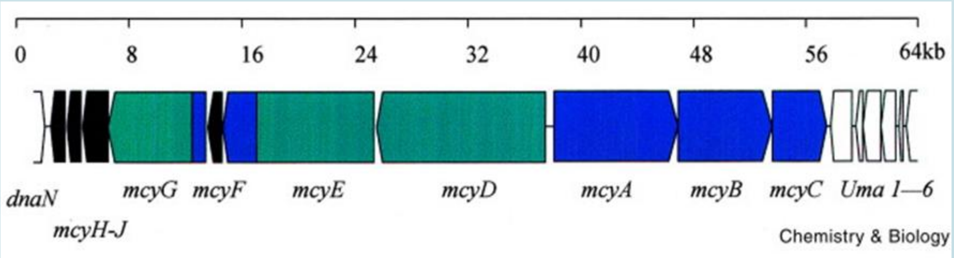
- Lake Erie intake, influenced by Portage River
- Collect samples from their wet well before addition of permanganate
- Data 2016 – 2018
- Samples collected semi-weekly (n = 105)



83°30'
83°0'
82°30'
82°0'
41°40'
41°20'
Little Cedar Point
Toledo
Toledo Crib
LUCAS
Maumee Bay
Oregon WTP
Put-in-Bay
Toledo Executive
Caroll WTP
LAKE ERIE
OTTAWA
Marblehead
Maumee River @ Waterville
Marblehead WTP
Portage River nr Elmore
Ottawa WTP
Lorain County
WOOD
SANDUSKY
ERIE
Sandusky River nr Fremont
Huron River @ Milan
LORAIN
0 5 10 MILES
0 5 10 KILOMETERS
1
2
81°30'
81°0'
41°0'
40°40'
40°20'
Alliance WTP
MAHONING
Akron Canton Regional
STARK
COLUMBIANA
CARROLL
JEFFERSON
TUSCARAWAS
New Phily, Harry Clover Field
Tappan Lake @ Tappan
Cadiz WTP
HARRISON
0 5 10 MILES
0 5 10 KILOMETERS
Site Type
Continuous monitor
Streamgage
Lake level
Airport weather station
Sampling site, recreational
Sampling site, drinking-water treatment plant (WTP)

Data collection and compilation

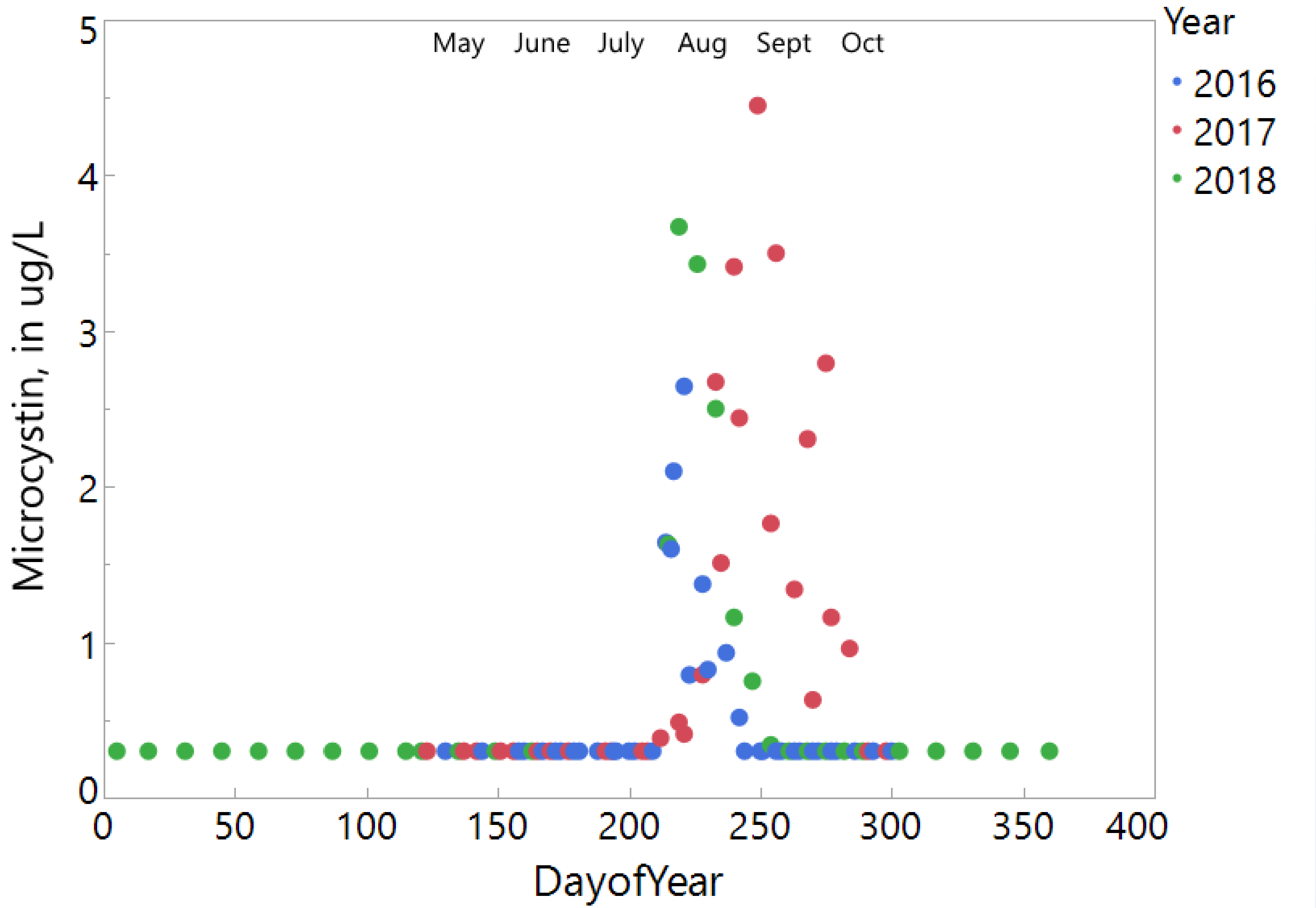
- Microcystin and nutrients
  - Ohio State University, Stone Laboratory, 2016-2017
  - USGS National Water Quality Laboratory, nutrients 2018
  - Oregon WTP, microcystin 2018
- Cyanbacterial genes – Ohio EPA
  - General cyanobacteria
  - Microcystin gene
  - Saxitoxin gene
  - Cylindrospermopsin gene



Data collection and compilation

- Physical parameters measured at the plant
  - Turbidity
  - Water temperature
- Environmental data
  - NOAA weather data
  - NOAA water levels
  - USGS streamflow
  - Continuous monitor data
    - Ottawa WTP
    - Oregon WTP
- Satellite data
  - NASA data

Microcystin at Ottawa intake



Correlations

- Strength of the association: -1 to 1
- Spearman's rho (monotonic) and Pearson's r (linear)
- Significance: p value (<0.05)
- Does not imply cause and effect
  - Helsel and Hirsch, Statistical Methods in Water Resources, 2002

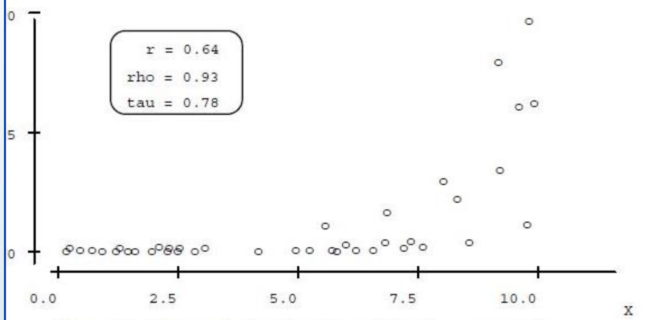


Figure 8.1 Monotonic (nonlinear) correlation between x and y.

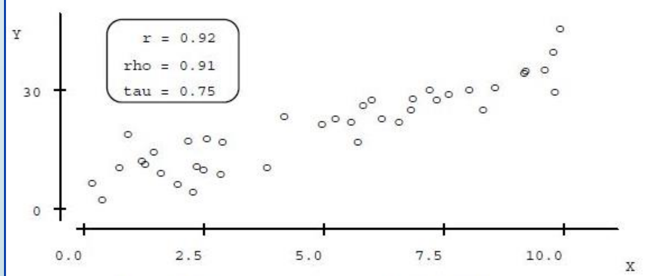


Figure 8.2 Linear correlation between X and Y.

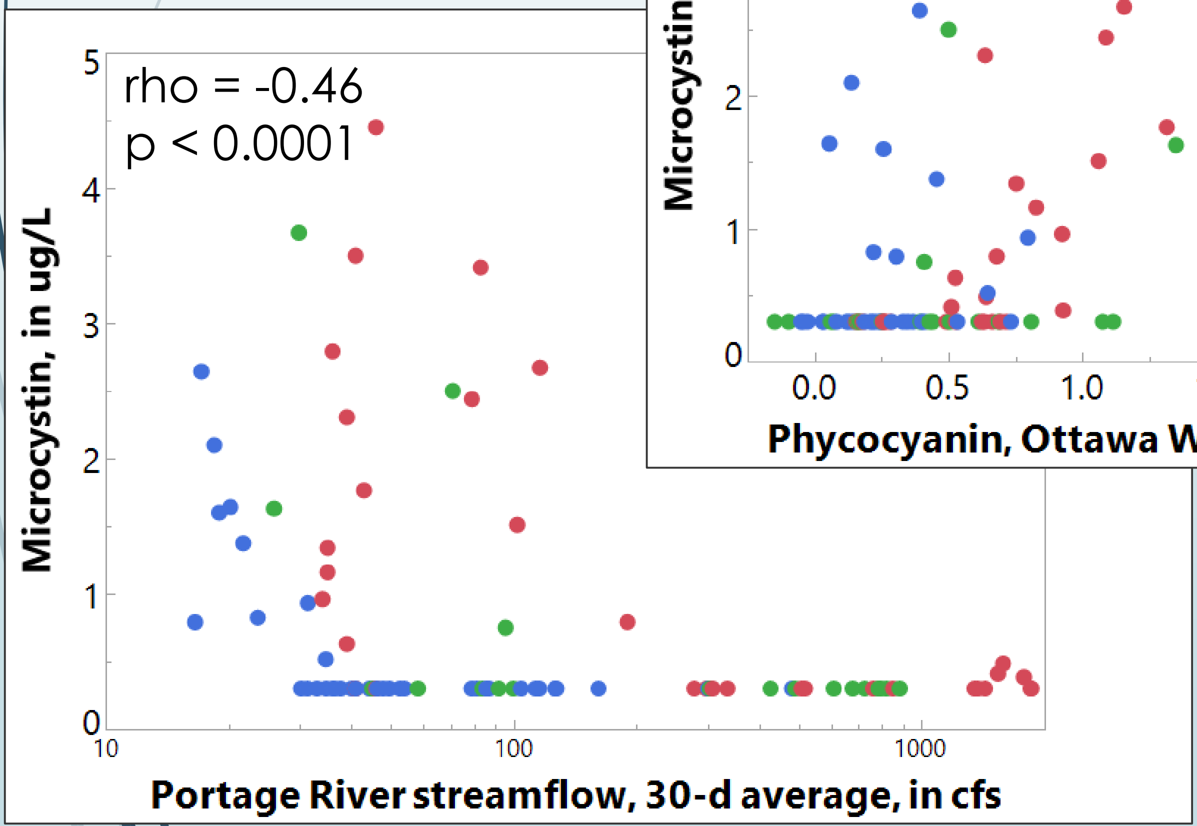
Spearman's correlations (rho)

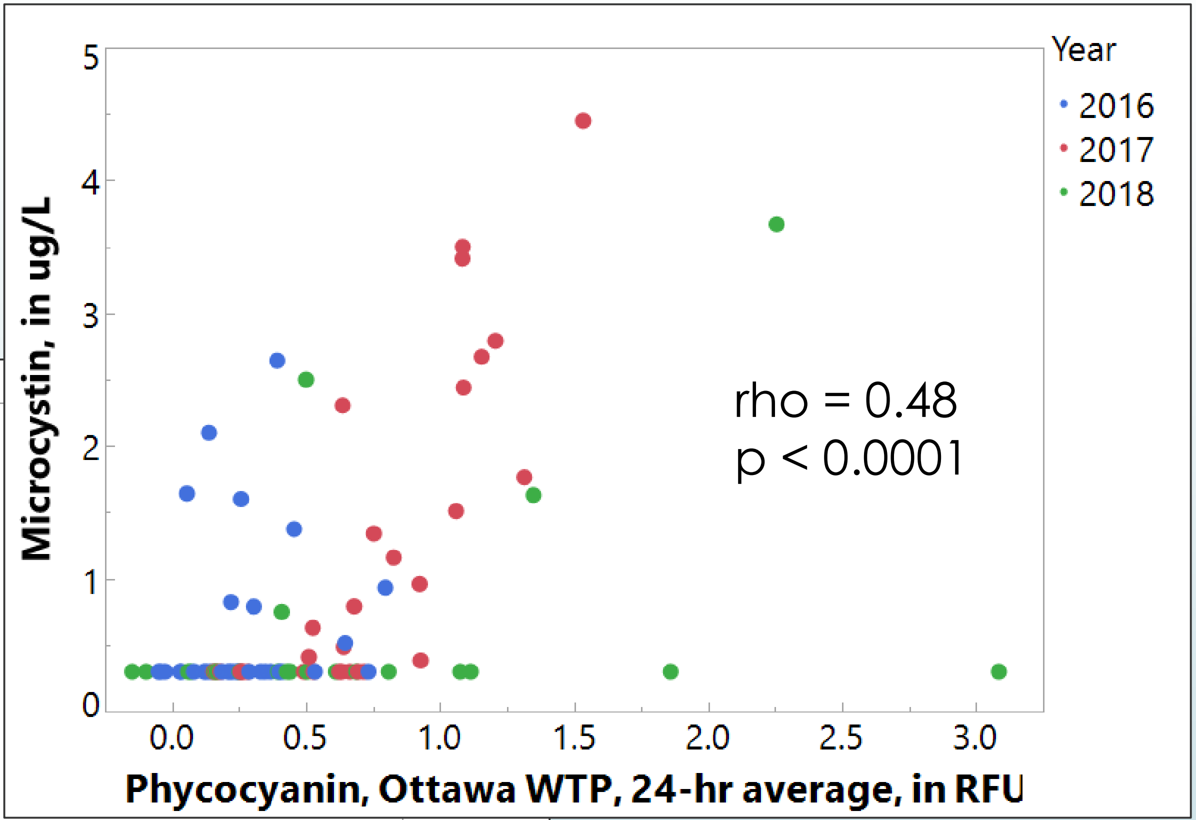
Independent Variables	Ottawa WTP
Nutrients	
Nitrite plus nitrate, lagged	**-0.34**
Dissolved reactive phosphorus, lagged	**-0.66**
N to P ratio; lagged	-0.24
Ammonia, lagged	-0.32
Cyanobacterial genes	
General cyanobacteria, lagged	**0.67**
Microcystin gene, lagged	**0.77**

Spearman's correlations (rho)

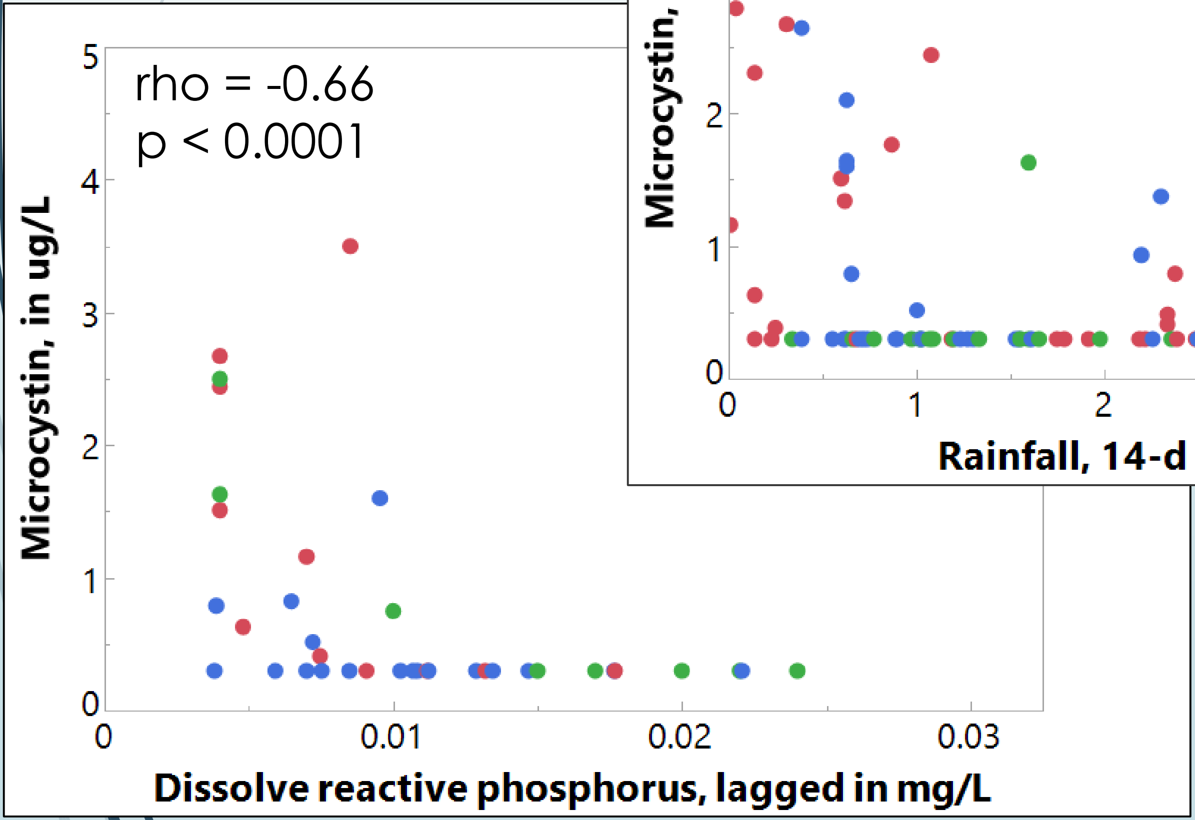
Independent Variables	Ottawa WTP
NOAA and USGS derived data	
Rainfall, 14d sum	**-0.22**
Wind speed, instantaneous	**-0.45**
Lake level, 7d ave	0.19
Portage Rv discharge, 30d ave	**-0.46**
Continuous monitor data	
Phycocyanin, 24hr ave, Ottawa	**0.48**
Phycocyanin, 14d ave, Oregon	**0.70**
Turbidity, 14d ave, Oregon	-0.13
Specific conductance, 14d ave, Ottawa	**-0.56**
pH, 14d ave, Oregon	**0.72**

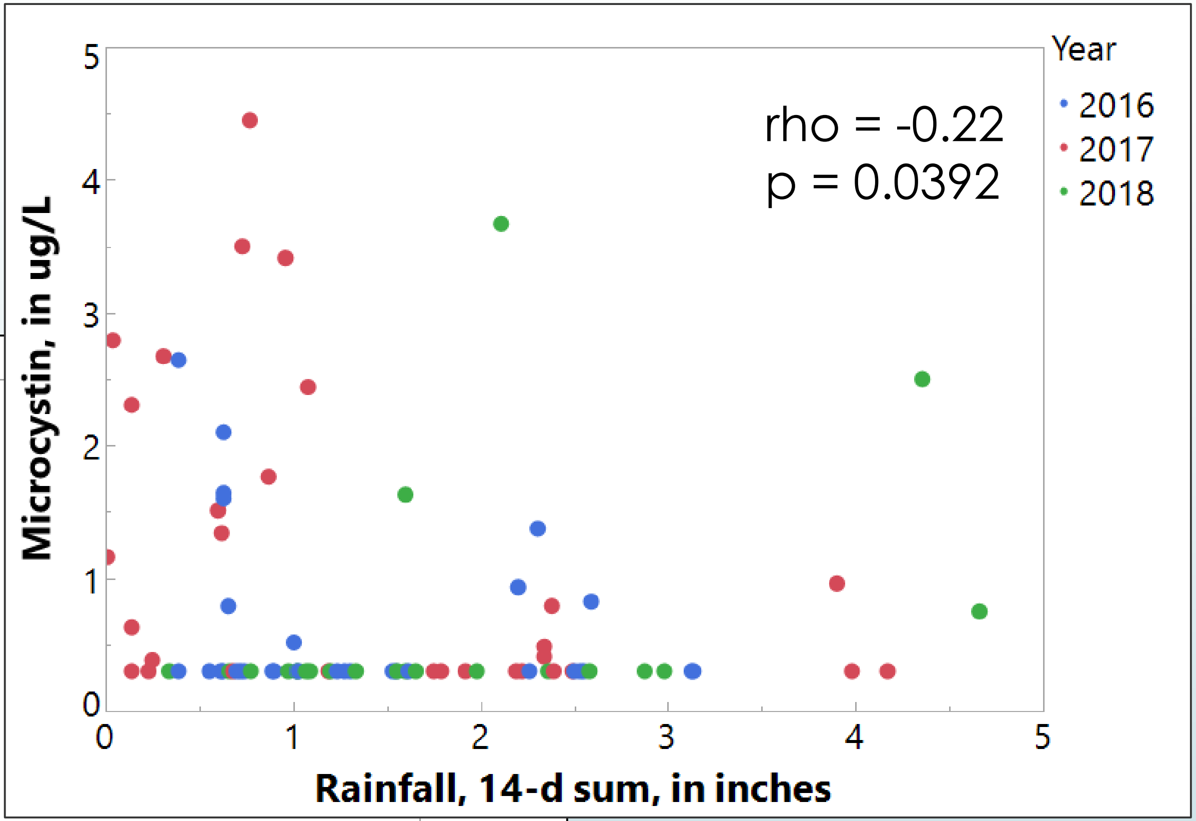
Ottawa WTP: Real-time variables





Ottawa WTP: Comprehensive variables





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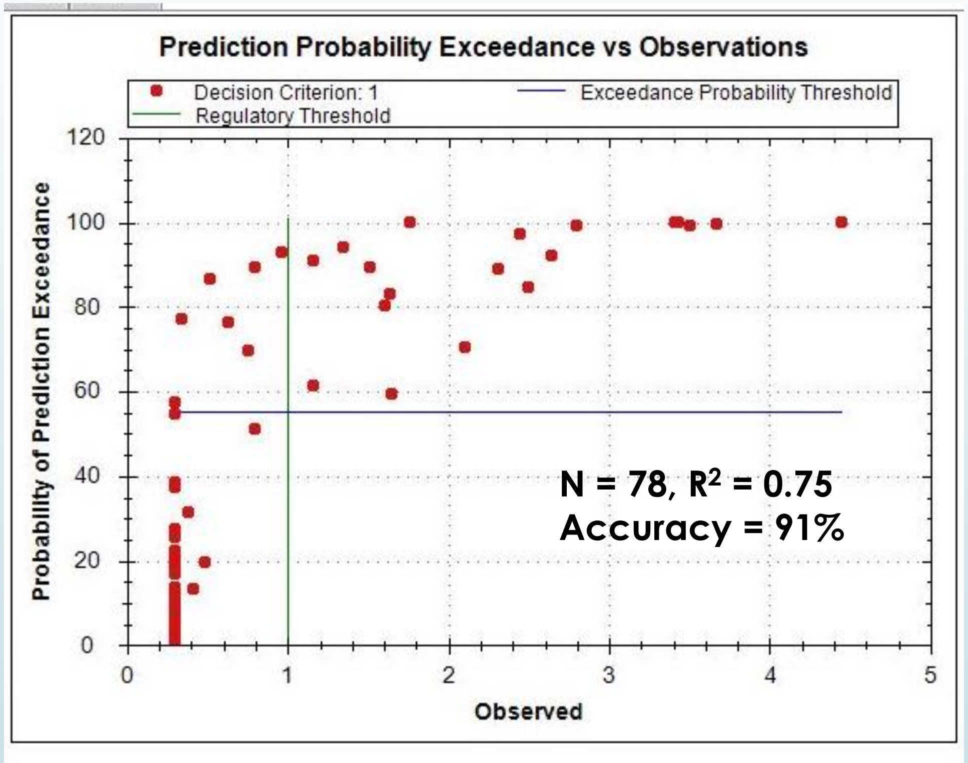
Ottawa WTP real-time model: 2016–18

- **Cosine, day of year**
- **Phycocyanin, 24 h, Ottawa sonde**
- **pH, 14d, Oregon sonde**
- **Discharge, Portage River, 30d average**

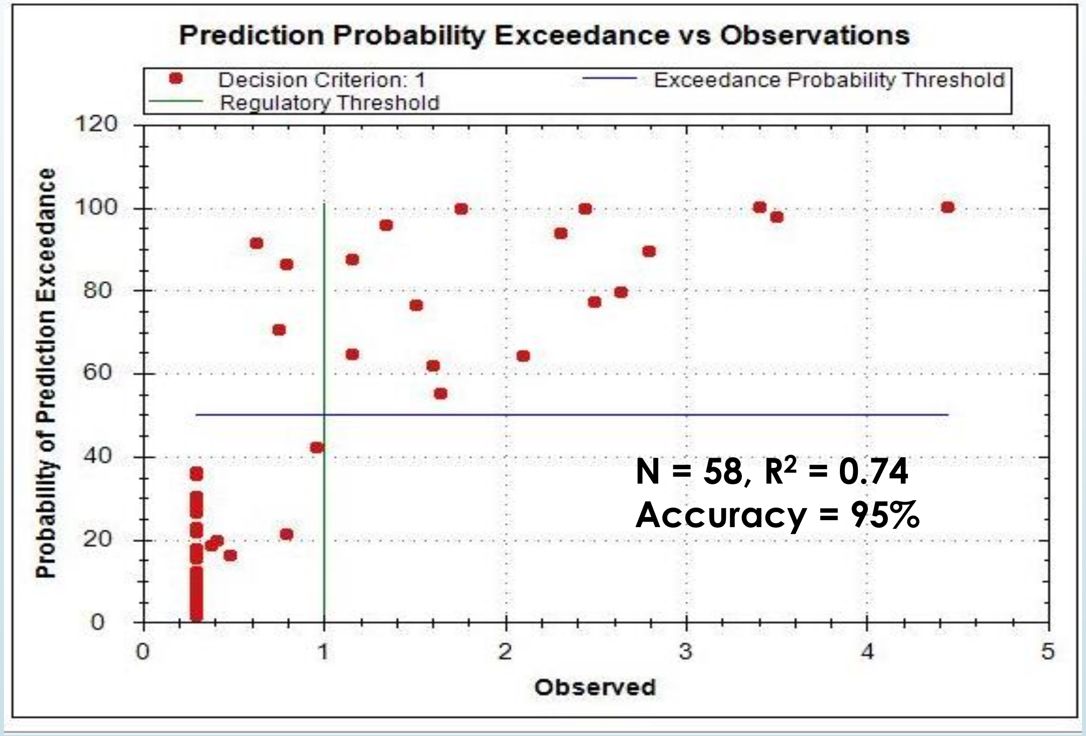


Microcystin = -11.32 - 1.019*(SQUARE(cos_DOY)) + 1.456*(Leoc_BGA_RFU_Ave24hr) + 1.446*(Leorgn_PH_Ave14d) - 0.5159*(LOG10(Portage_Dis_30dAve))

Preliminary information-subject to revision. Not for citation or distribution.

Ottawa WTP comprehensive model: 2016–18

- pH, 14d, Oregon sonde
- Orthophosphate, lagged
- Phycocyanin, 14d, Oregon sonde
- Rain, 14d sum, LPR



Microcystin = -9.896 + 1.313*(Leorgn_PH_Ave14d) - 20.81*(OrthoP_mgL_LAG_PLUS) + 0.2508*(Leorgn_BGA_RFU_Ave14d) - 0.1887*(LPR_Rain_sum14d)

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Benefits of modeling

Real-time predictions

- Provide information to trigger sample collection
- Provide data to optimize water treatment and intake options for current conditions

Comprehensive predictions

- Provide advanced warning of the potential for a toxic cyanoHAB
- Provide an understanding of what factors are related to toxin production

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