Nutrients, Ecosystem Services, and Human Health in Northeastern Lakes and Ponds

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Talk Outline

- Background
- Northeast Lakes Project
- Modeling Lake Appeal
- Lake Volume and Depth
- Beneficiaries
- Decision Support
- Cyanobacteria Project

Background

- Ecosystem Services Research Program (ESRP)
  - 2007-2011
- Safe and Sustainable Water Resources (SSWR)
  - 2012-??
- Common Denominator
  - Lakes
  - Nutrients

Northeast Lakes Ecosystem Services Project

Project on Lakes Ecosystem Services

- Research Questions:
  - How do changes in nutrients change delivery of ecosystem services?
  - How do spatial arrangement of services impact delivery of those services?
- Project Goals:
  - Data Sharing
  - Reproducible Research
  - Decision Support

Ecosystem Services in Lakes

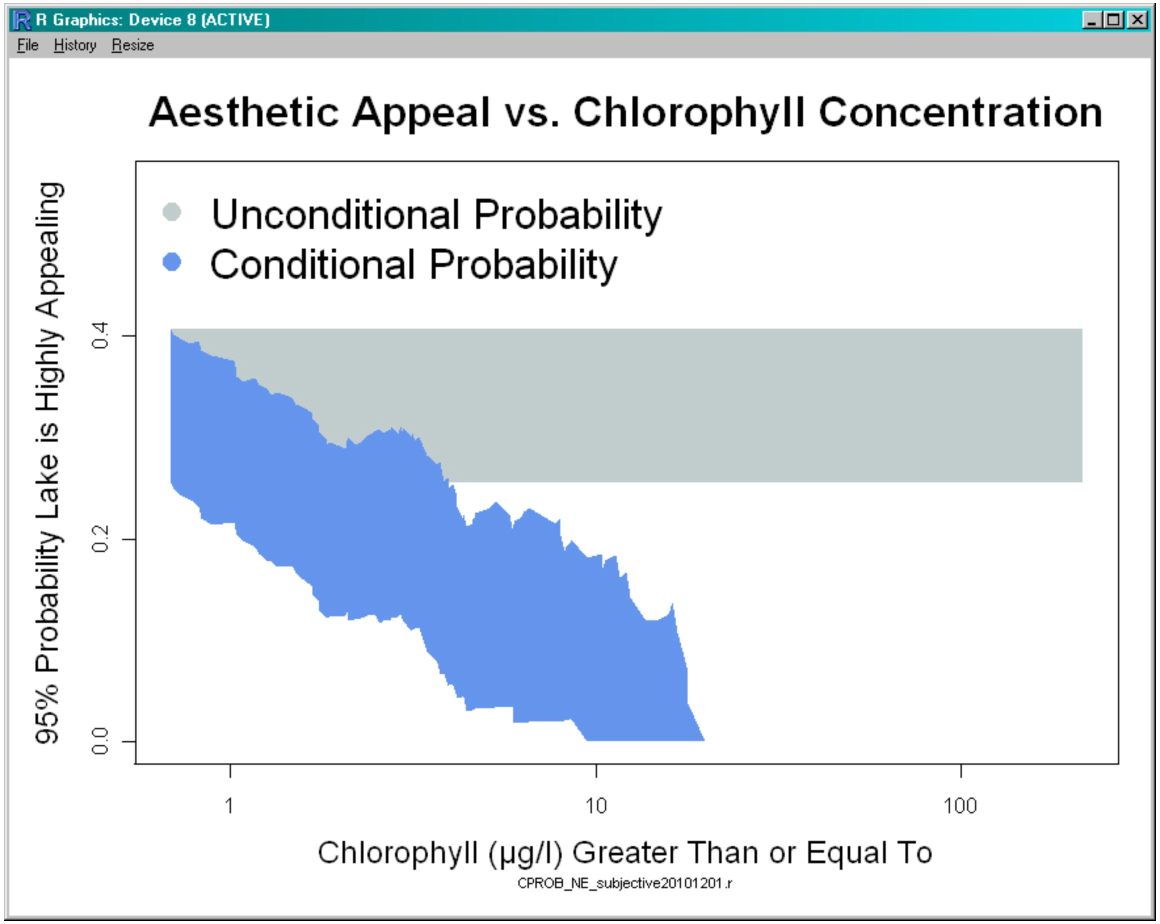
- Swimming
- Fishing
- Drinking Water
- Property Values
- Existence Value
- Aesthetics

How are lakes perceived in the National Lakes Assessment?

- Aesthetic Appeal
- Disturbance
- Biotic Integrity
- Recreational Value
- Swimmability

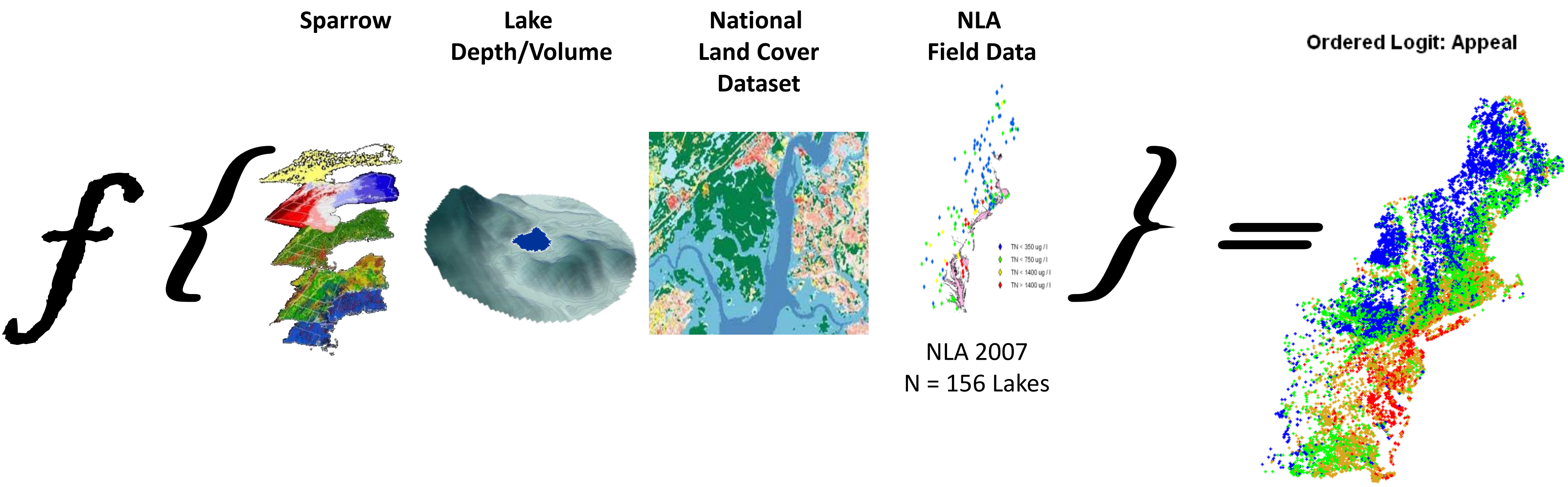
Written Comments from Lakes in Highest Appeal Categories

Nutrients and Ecosystem Services



Modeling Lake Aesthetics/Appeal

Modeling Lakes Aesthetics



Ordered Logit Model

Predictor Variables

- **Chlorophyll *a*** **(µg/l)**
- Elevation (m)
- Shoreline (m)
- Flow
- Shoreline Development
- Area (m^2)
- Max Depth (m)
- Volume (m^3)
- Hydraulic Residence Time (years)
- Proximity to People

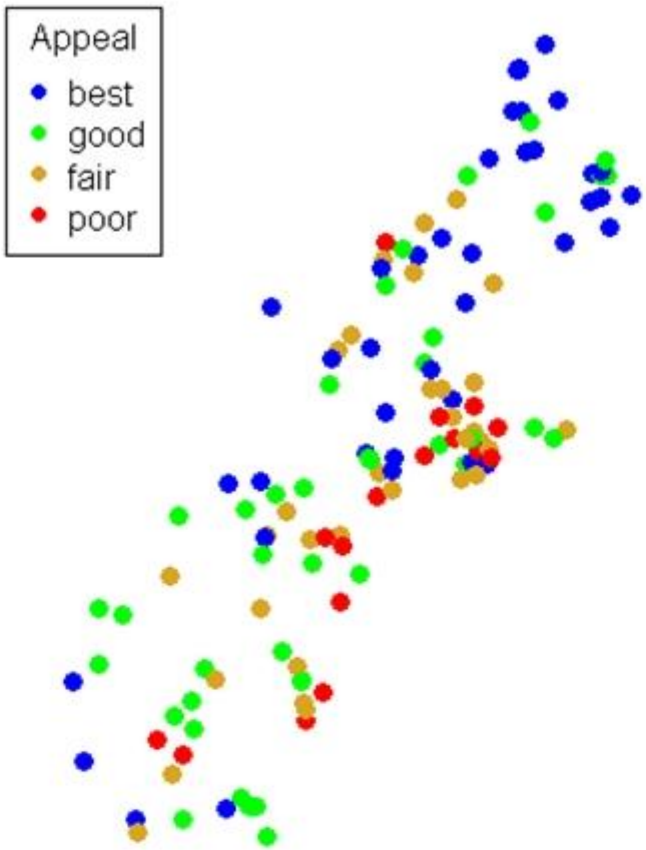
Response Variables

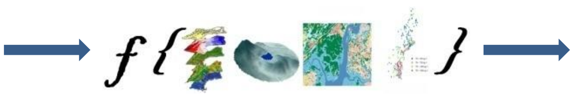
- **Appeal Score**
- Pristine Score
- Recreation Score
- Swimming Score
- Biotic Integrity Score
- Secchi Depth Class
- Microcystin Detected
- Cyanobacteria Count Class

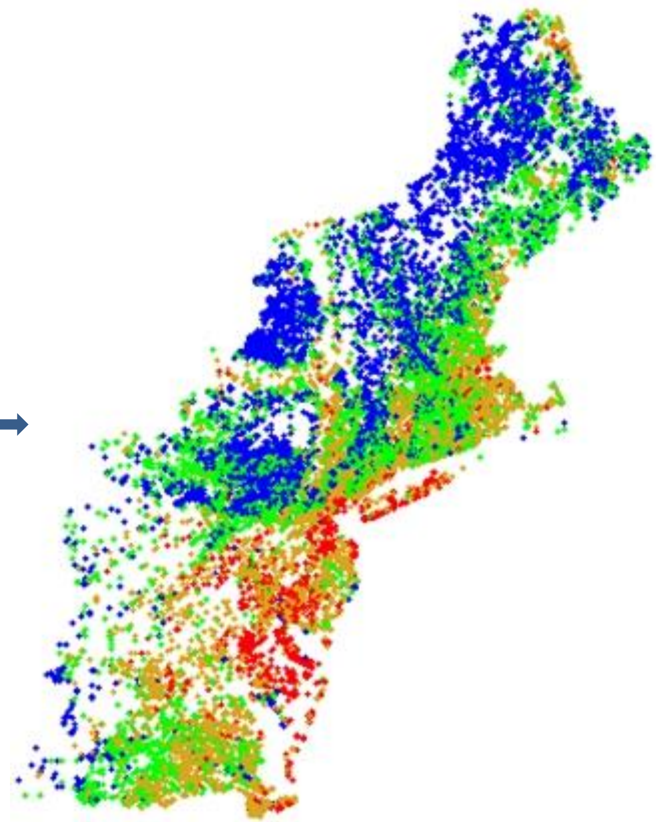
1.) Start with field data

2.) Combine with landscape data in function

3.) Predict Appeal for ~18,000 Lakes







Estimating Maximum Lake Depth and Lake Volume

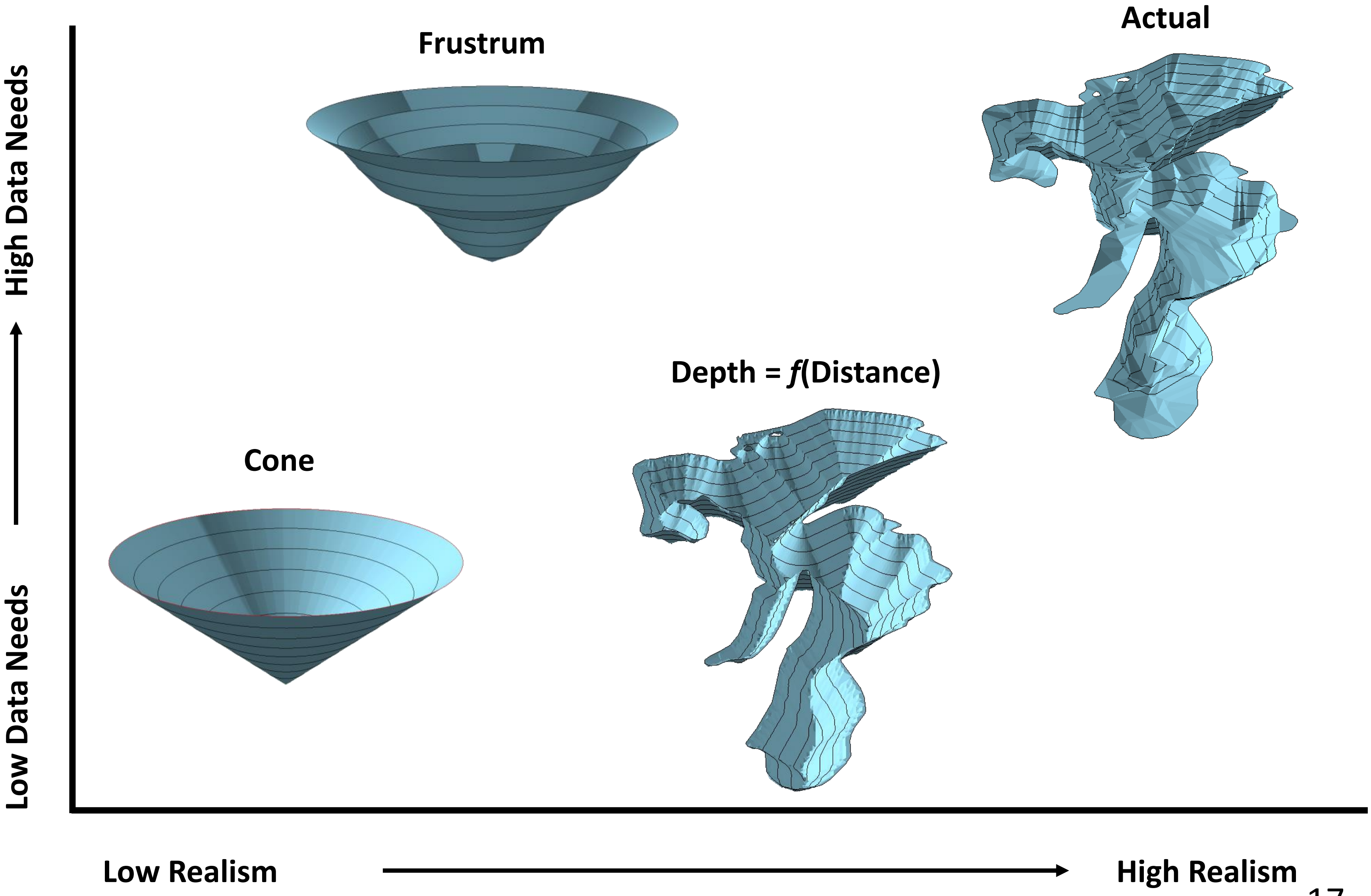
Background

- Ordered Logit Models
  - Need Residence time
- Existing data
  - Limited resources
  - ~18,000 Lakes

Problem #1

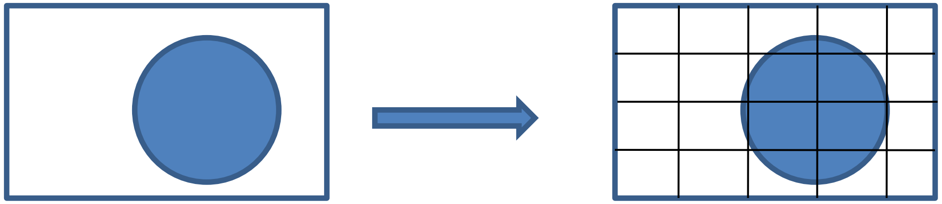
What is the best way to estimate lake volume given, lake shoreline and maximum depth?

Citation: Hollister, J. W., W.B. Milstead (2010). Using GIS to Estimate Lake Volume from Limited Data. *Lake and Reservoir Management*. 26(3)194-199. Contribution no. AED-10-018.


Frustrum
Actual
Depth = f(Distance)
Cone
High Data Needs
Low Data Needs
Low Realism
High Realism

Methods (aka The GIS Method)

- Assume that depth is function of distance from shore
- Rasterize Lake



- Simple linear transformation based on assumption

$$\mathrm{Depth} = PixelDist * \frac{\mathrm{MaximumDepth}}{\mathrm{MaximumDistance}}$$

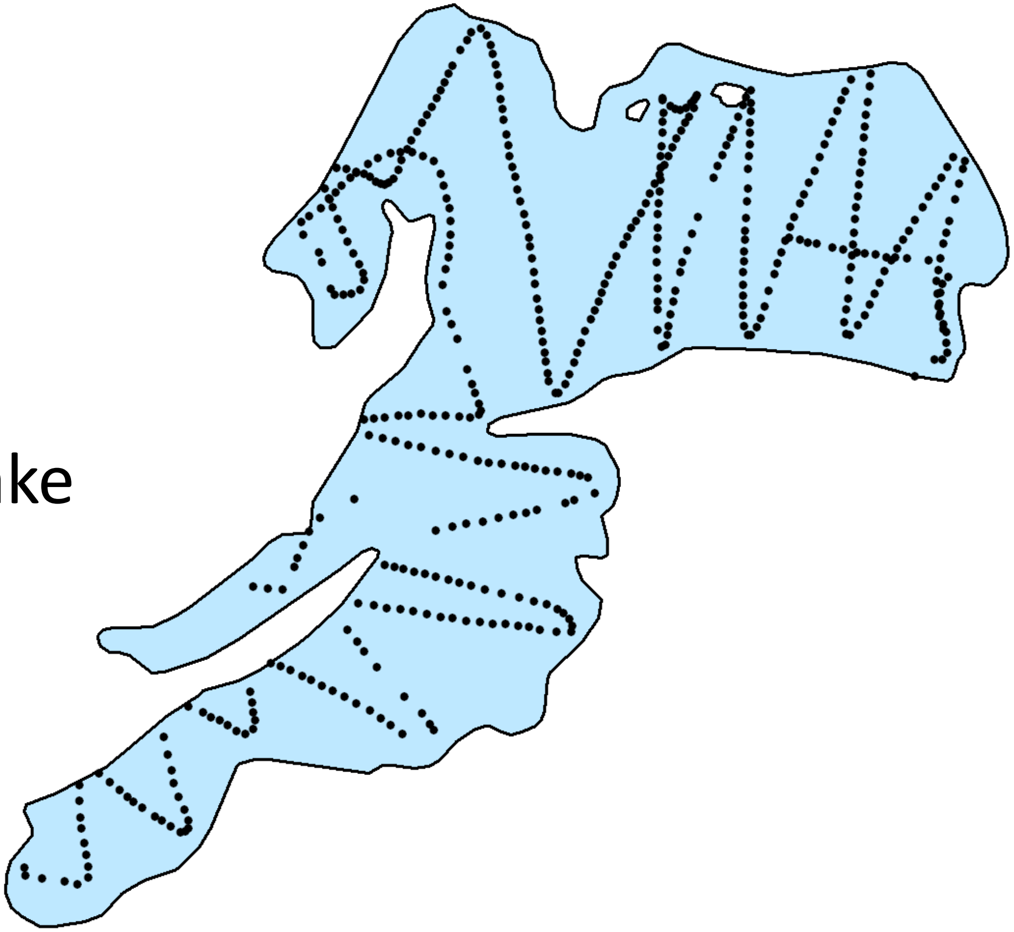
- Calculate volume

$$LakeVolume = \sum CellArea * Depth_{i,j}$$

Methods

- Accuracy Assessment
  - Bathymetry data
    - NH DES for 132 lakes
  - Created TIN for each lake
  - Calculated volumes
    - Cone v TIN
    - GIS Method v TIN

Partridge Lake Bathymetry Data



Results - Volume Error Analysis

Method	RMSD	MD	MAD	P(Better)
GIS – All Lakes	3,287,360	8622	200734	0.59
Cone – All Lakes	6,975,740	608967	225502	0.41

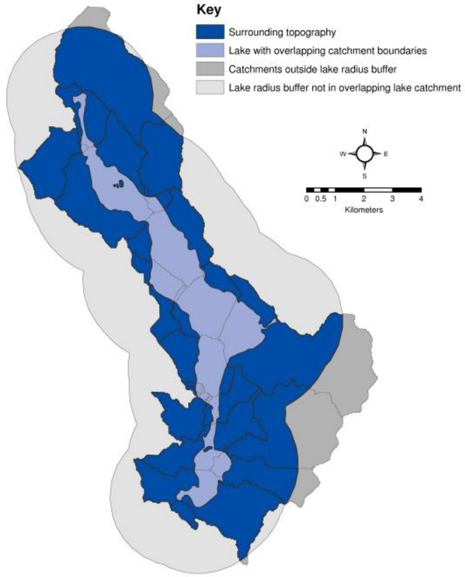
Problem #2

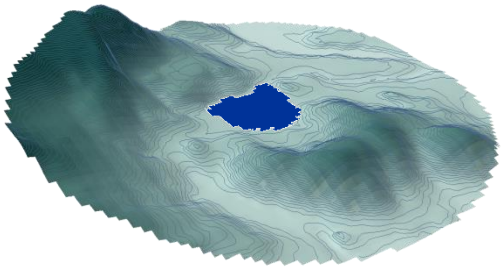
- Method in Problem #1 assumes a measurement of maximum lake depth is available
- Is it possible to create a reasonable estimate of lake depth from the topography surrounding a lake?

Citation: Hollister, J. W., W.B. Milstead, M.A. Urrutia (2011). Predicting Maximum Lake Depth from Surrounding Topography. *PLoS ONE* 6(9): e25764. doi:10.1371/journal.pone.0025764. Contribution no. AED-11-013

Predicting Maximum Lake Depth

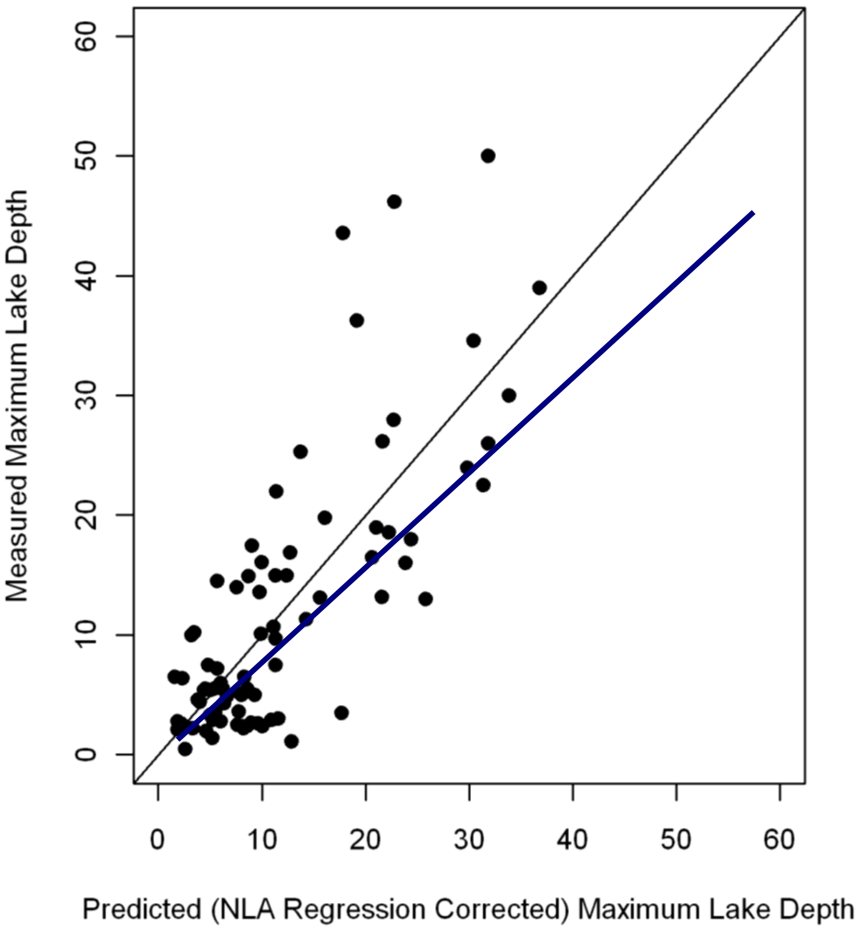
- Select surrounding topography
- Determine median slope
- Determine maximum distance in lake
- Depth
  - Max.Dist * Median.Slope





Assessing the method

- Compare to measured data
  - National Lakes Assessment Data
    - Bootstrapped Cross-validation
  - Web reported depths
- Over predicts
- Fit NLA model
- Use NLA model to correct
- RMSE: ~5-6m
- Correlation: ~0.7

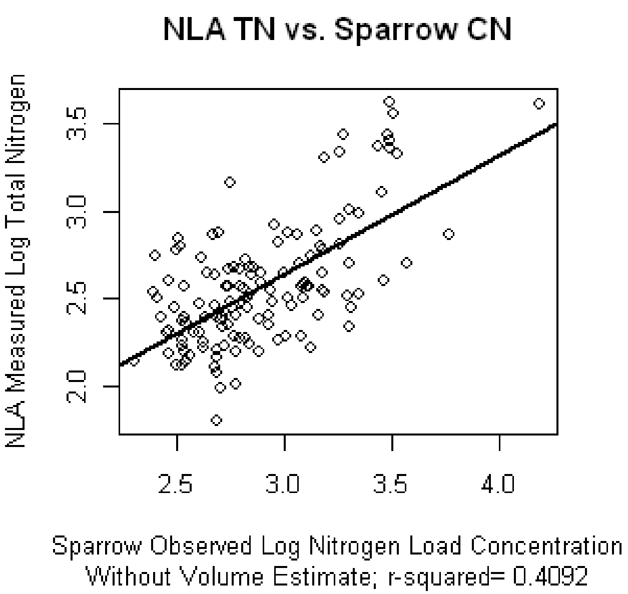


Using Volume Estimates

- Useful if they improve understanding of processes
- Tested
  - USGS SPARROW TN and TP loading estimates
  - Calculate residence time with volume and flow
  - Compare esimates to measured concentrations in lakes.
    - National Lake Assessment

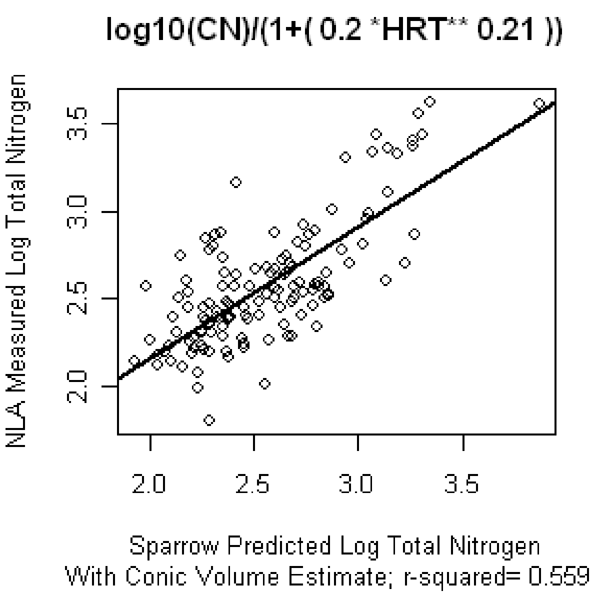
Nitrogen Concentration Comparison

Sparrow Model Estimate



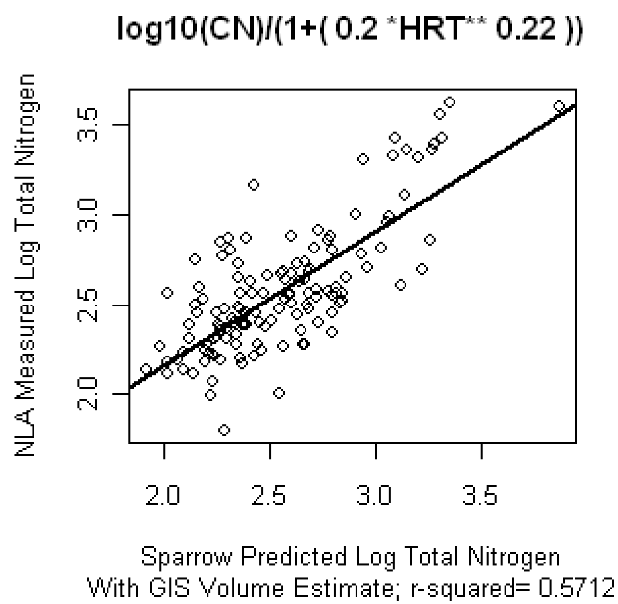
Modified Vollenwieder Estimate

Conic Volume



Modified Vollenwieder Estimate

GIS Volume



Ecosystem Services Beneficiaries

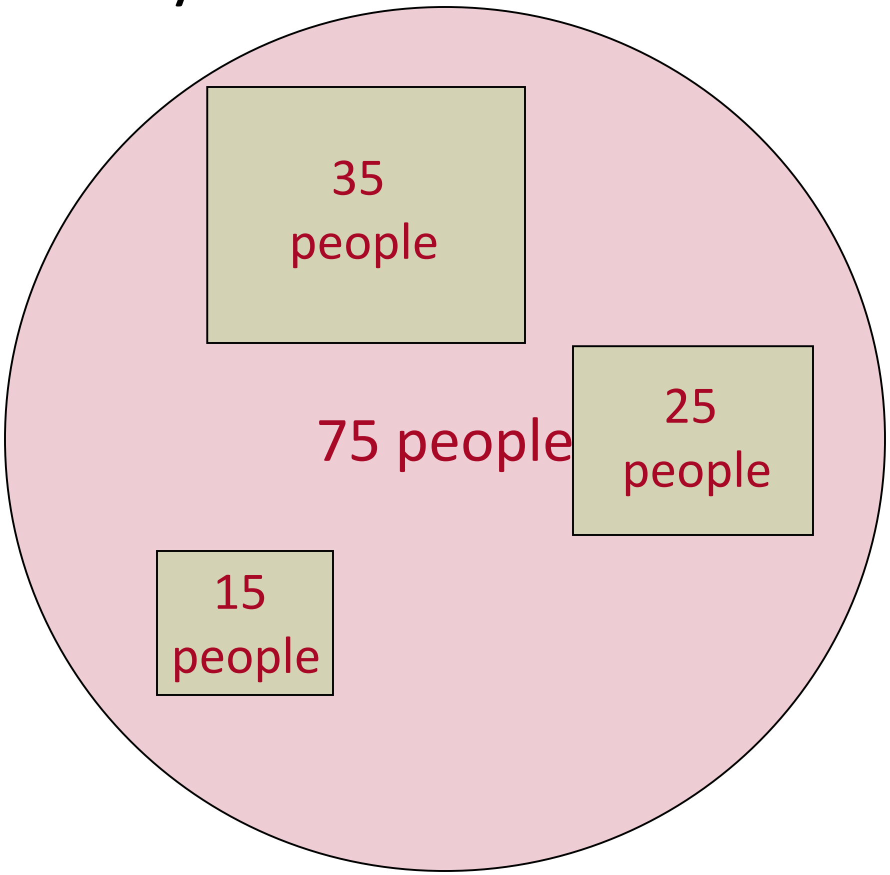
Beneficiaries

- Populations most likely to benefit

How do we connect people with services?

Dasymetric Population Modeling

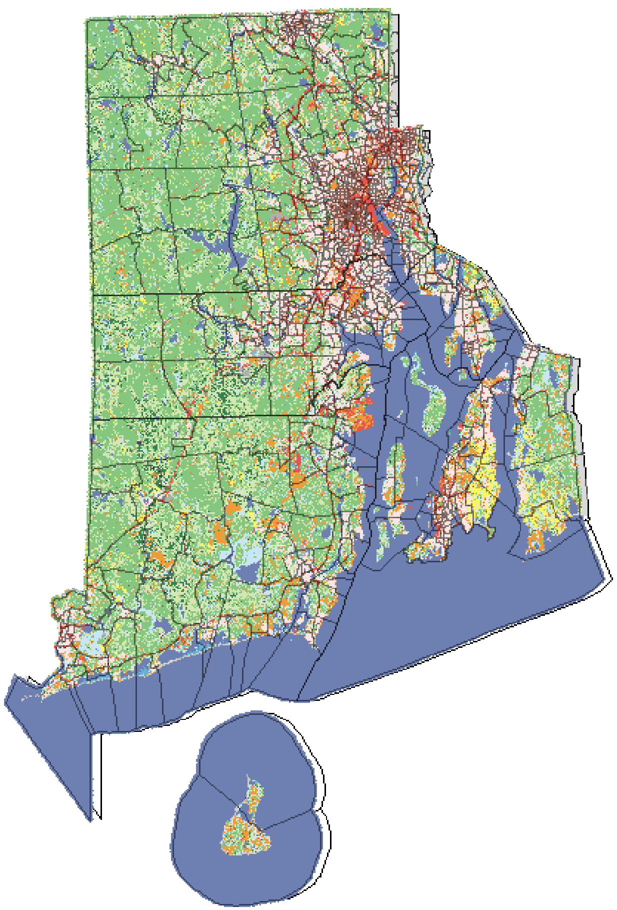
- Redistributing values from one geography to another based on ancillary data



- **Rhode Island Example:**

Census Block Groups

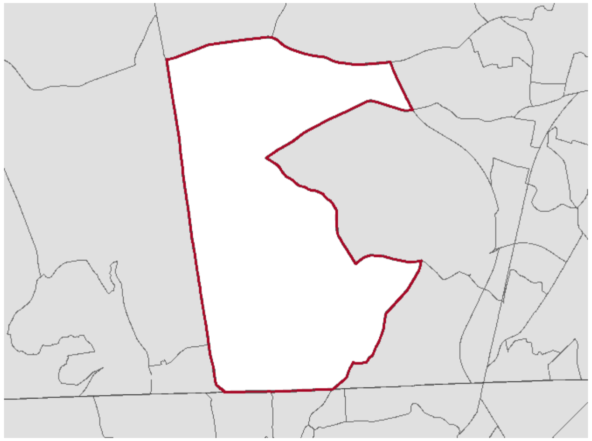
2001 NLCD



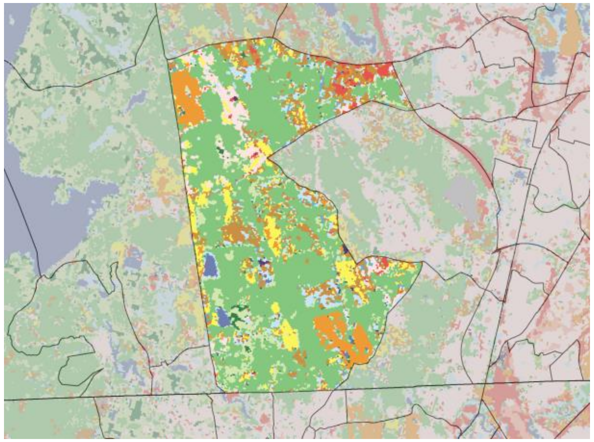
- Open Water
- Low Intensity Residential
- High Intensity Residential
- Commercial/Industrial/Transportation
- Bare Rock/Sand/Clay
- Quarries/Strip Mines/Gravel Pits
- Transitional
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Shrubland
- Orchards/Vineyards/Other
- Grasslands/Herbaceous
- Pasture/Hay
- Row Crops
- Small Grains
- Fallow
- Urban/Recreational Grasses
- Woody Wetlands
- Emergent Herbaceous Wetlands

Dasymetric Mapping

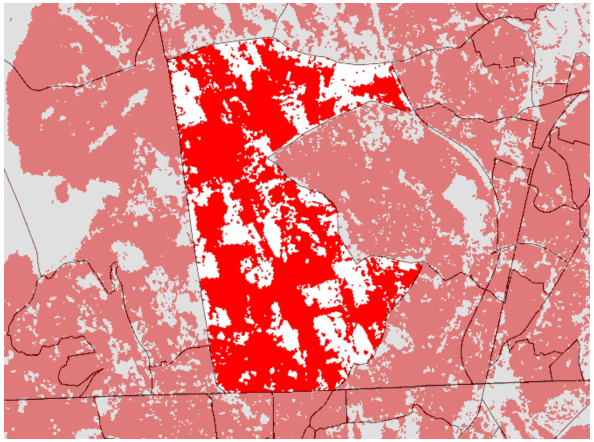
Census Block Group
Population: 2714
Population/pixel: 0.11



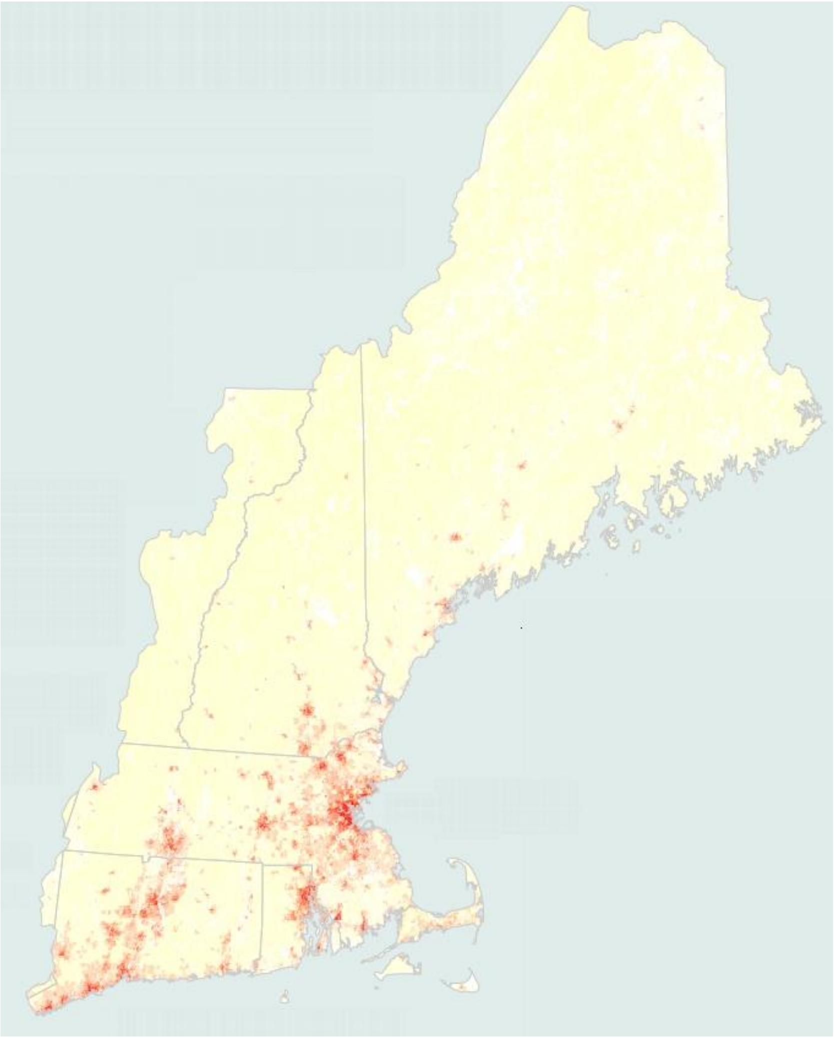
2001 NLCD



Populated Mask
Population: 2714
Population/pixel: 0.17



Dasymetric Mapping



Three Reduction Scenarios

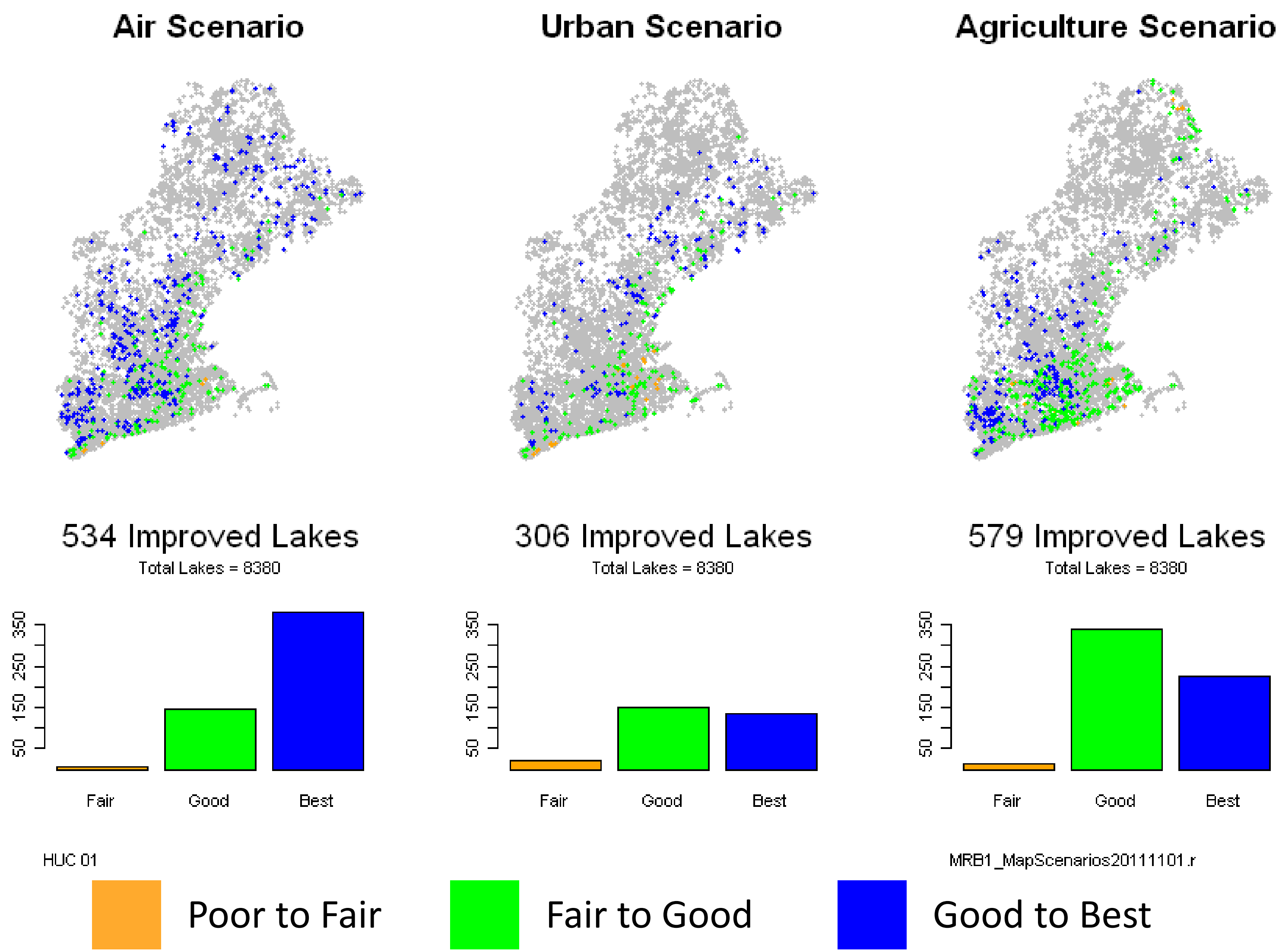
1. Reduce Air Inputs →
2. Reduce Urban Inputs →
3. Reduce Agricultural Inputs →

10% Reduction in Riverine N & P* Inputs to Estuaries

What are the benefits to lakes?

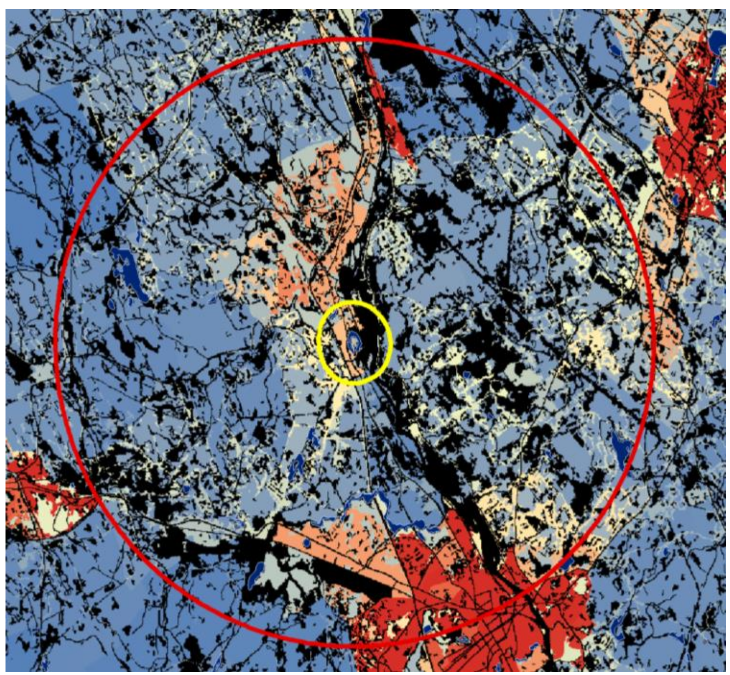
* P reduction for Urban and Agriculture Scenarios Only

New England (HUC 01)



Compare to Population

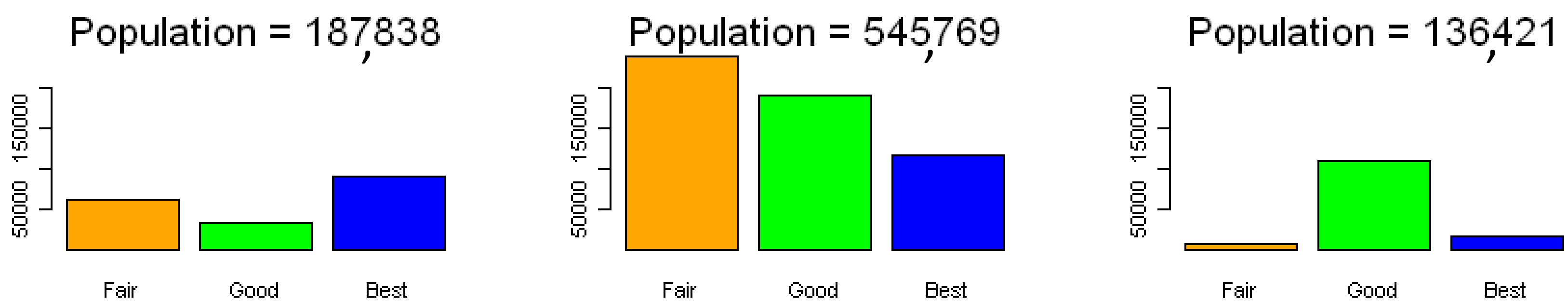
- Calculate total population for each improved lake
- Multiple Scales: 1km, and 10km



1 km Buffer
10 km Buffer
High Population Density
Low Population Density

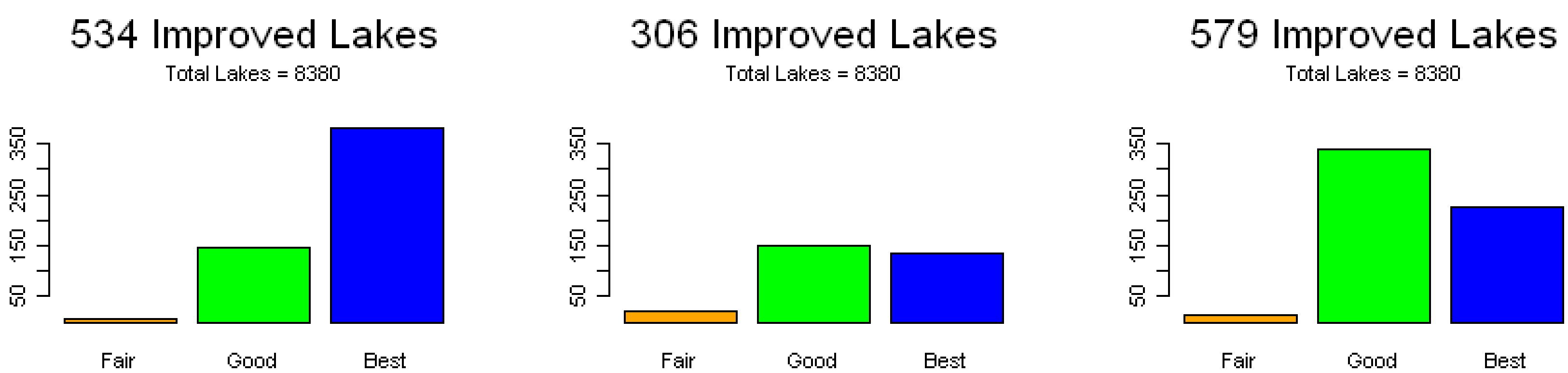
New England (HUC 01)

Population within 1km of Improved Lakes



Air Scenario | **Urban Scenario** | **Agriculture Scenario**

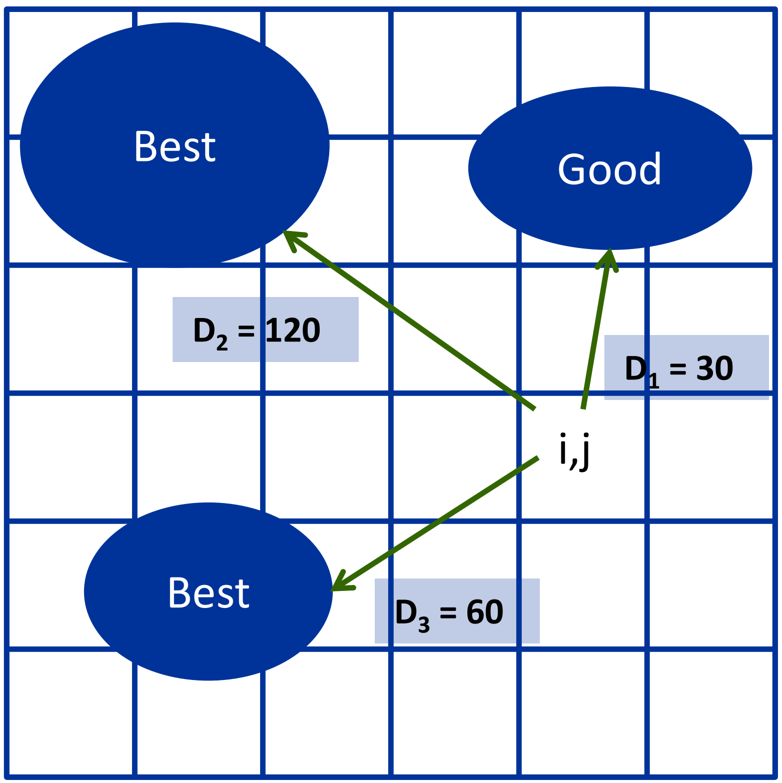
Number of Improved Lakes



Poor to Fair | Fair to Good | Good to Best

Scarcity

- Landscape Lake Aesthetic Index (LLAI)

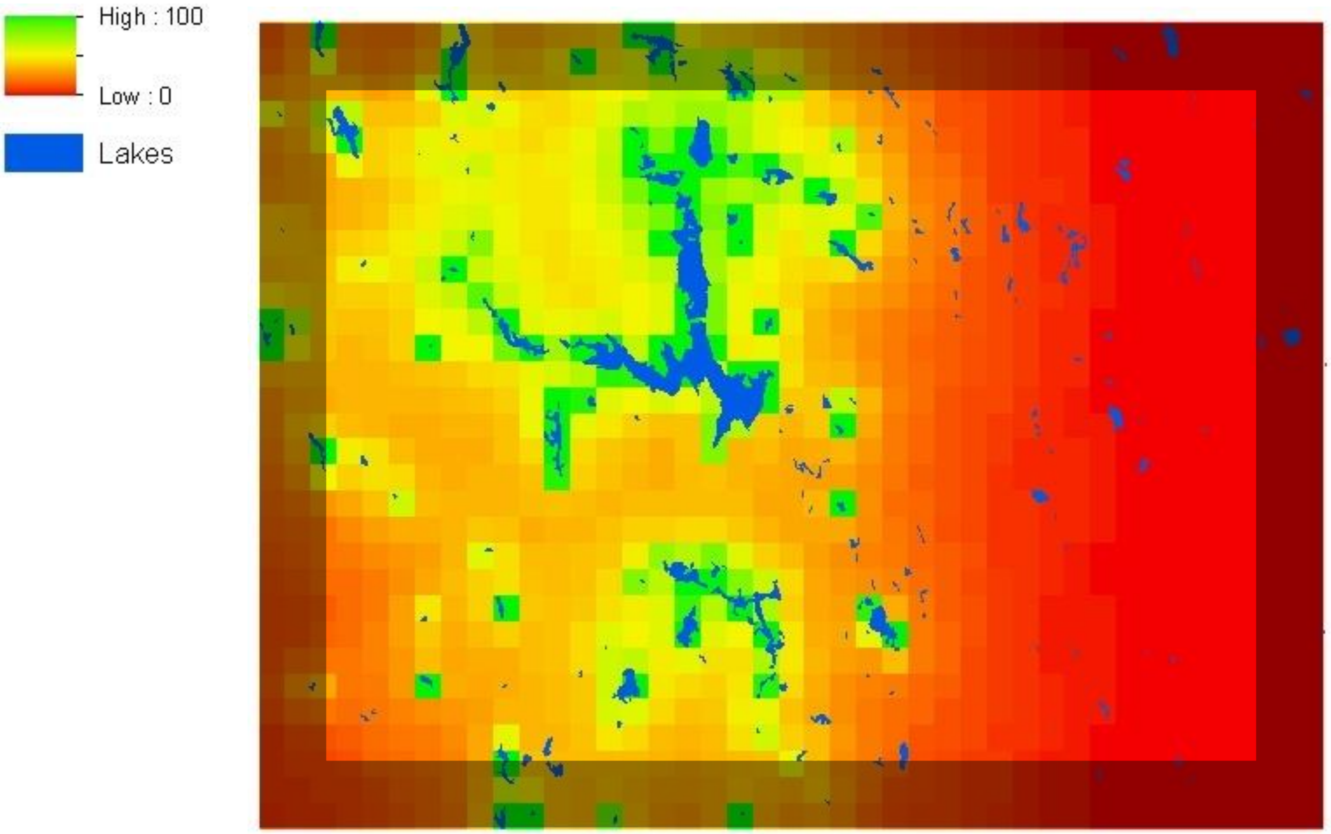


$LLAI_{i,j} = \sum 1/D*Appeal$

$D_1 = 1/30 * 4 = 0.13$
$D_2 = 1/60 * 5 = 0.083$
$D_3 = 1/120 * 5 = 0.041$
$\sum = 0.254$

will provide estimate of each pixels potential to receive aesthetic services from lakes

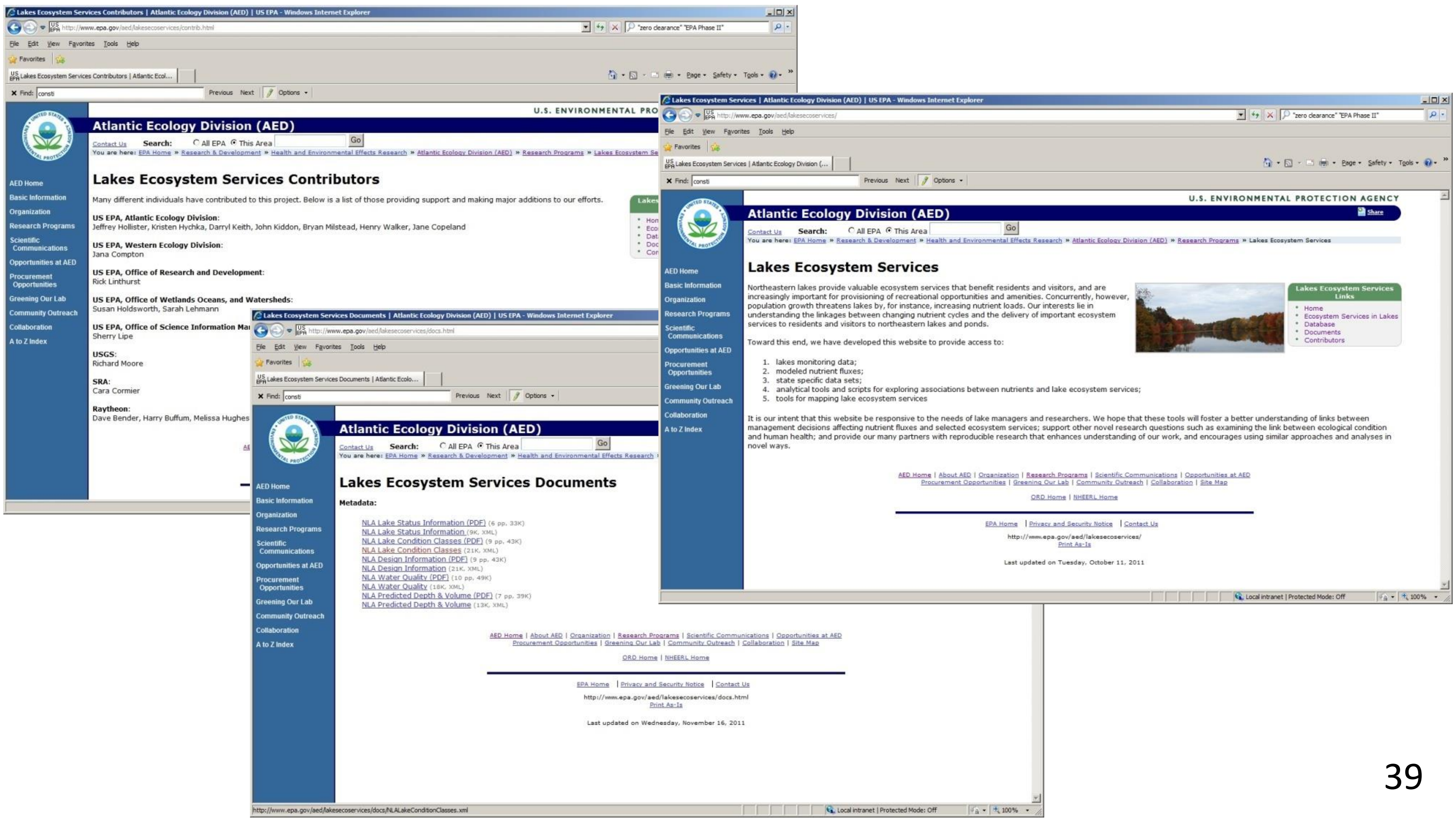
Landscape Lakes Aesthetic Index



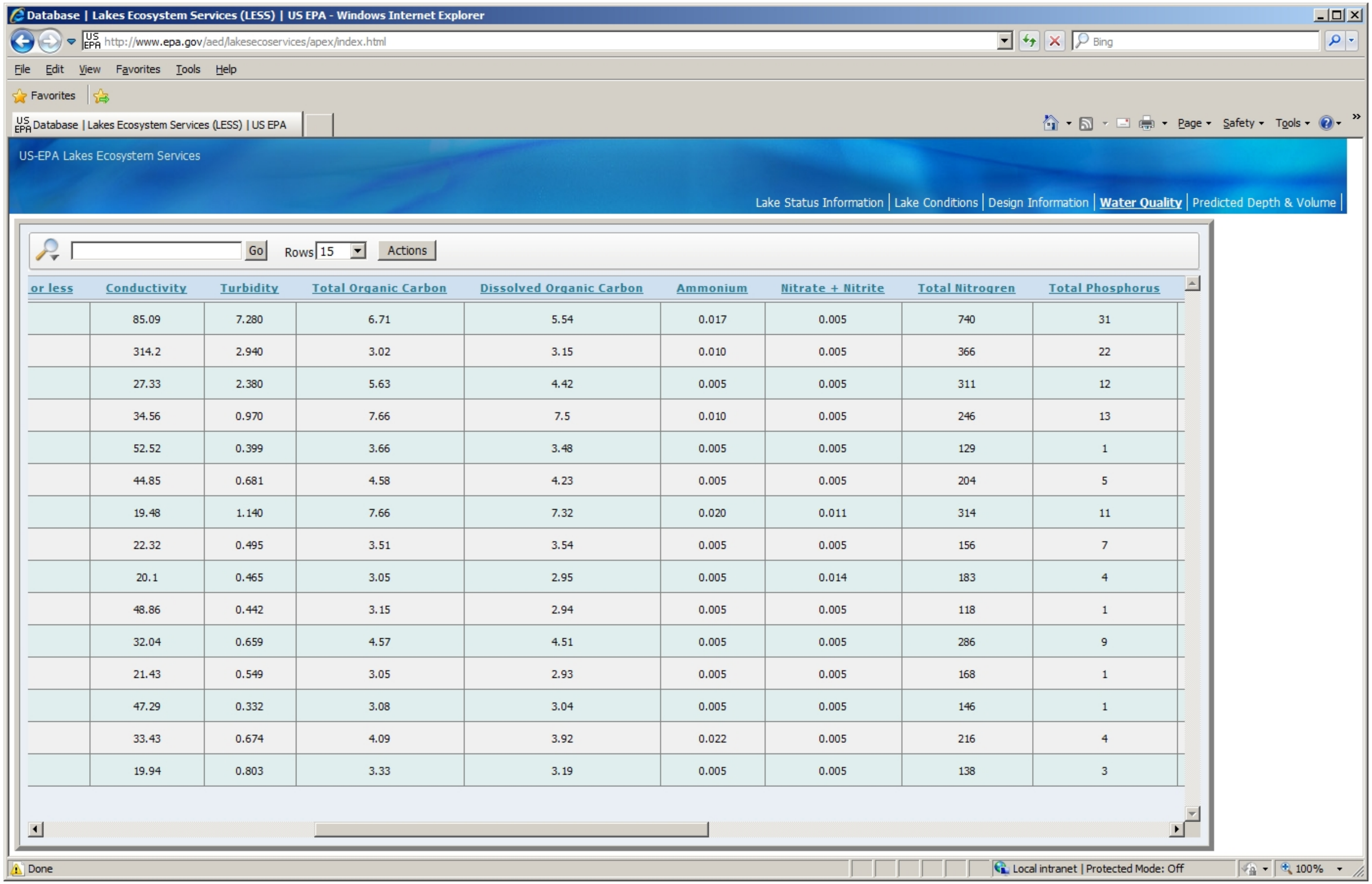
Decision Support

Public Website

(http://www.epa.gov/aed/lakesecoservices)



Database


Database | Lakes Ecosystem Services (LESS) | US EPA - Windows Internet Explorer

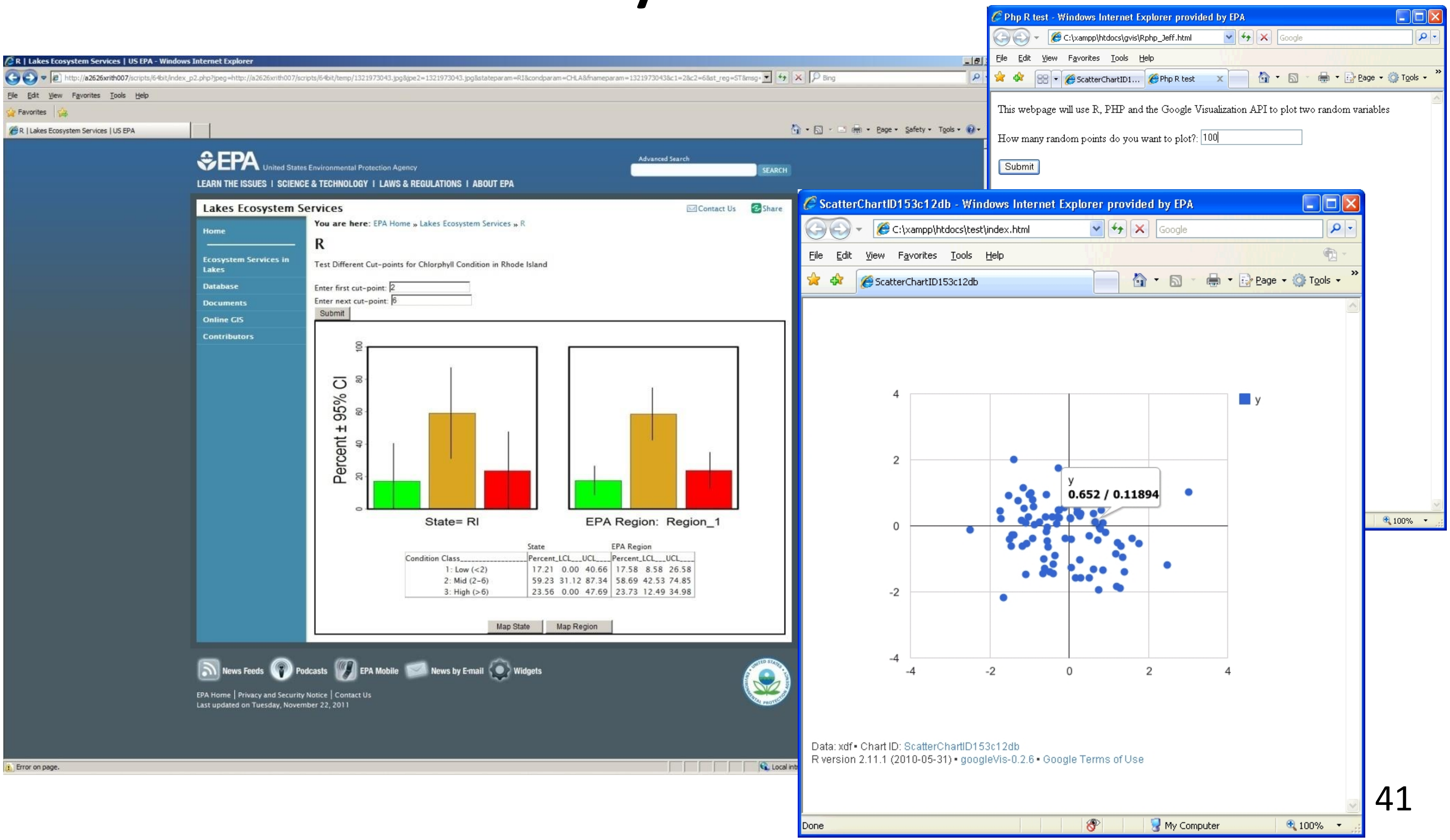
http://www.epa.gov/aed/lakesecoservices/apex/index.html

US-EPA Lakes Ecosystem Services

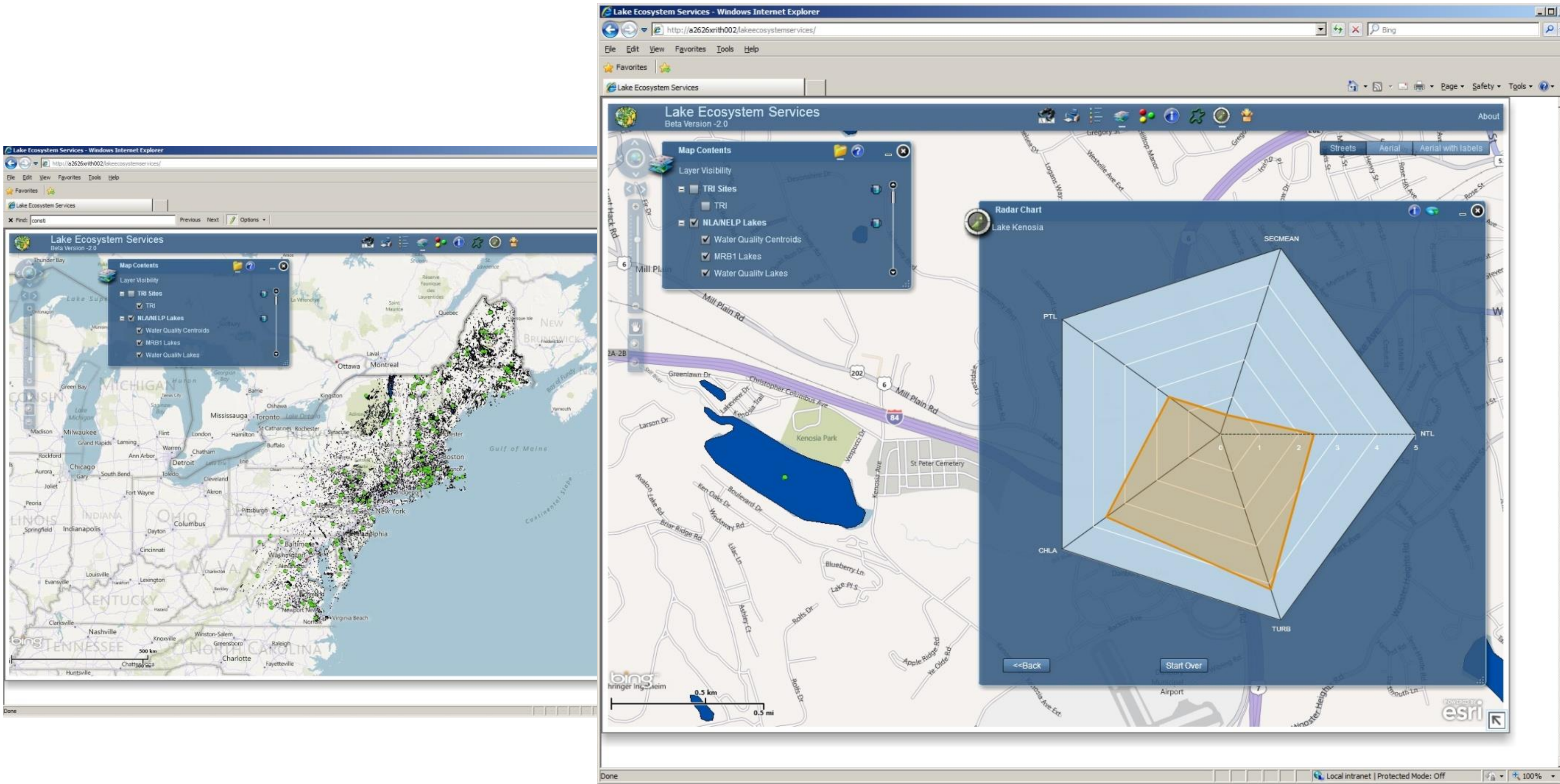
Lake Status Information | Lake Conditions | Design Information | Water Quality | Predicted Depth & Volume

or less	Conductivity	Turbidity	Total Organic Carbon	Dissolved Organic Carbon	Ammonium	Nitrate + Nitrite	Total Nitrogren	Total Phosphorus
	85.09	7.280	6.71	5.54	0.017	0.005	740	31
	314.2	2.940	3.02	3.15	0.010	0.005	366	22
	27.33	2.380	5.63	4.42	0.005	0.005	311	12
	34.56	0.970	7.66	7.5	0.010	0.005	246	13
	52.52	0.399	3.66	3.48	0.005	0.005	129	1
	44.85	0.681	4.58	4.23	0.005	0.005	204	5
	19.48	1.140	7.66	7.32	0.020	0.011	314	11
	22.32	0.495	3.51	3.54	0.005	0.005	156	7
	20.1	0.465	3.05	2.95	0.005	0.014	183	4
	48.86	0.442	3.15	2.94	0.005	0.005	118	1
	32.04	0.659	4.57	4.51	0.005	0.005	286	9
	21.43	0.549	3.05	2.93	0.005	0.005	168	1
	47.29	0.332	3.08	3.04	0.005	0.005	146	1
	33.43	0.674	4.09	3.92	0.022	0.005	216	4
	19.94	0.803	3.33	3.19	0.005	0.005	138	3

Analytical Tools

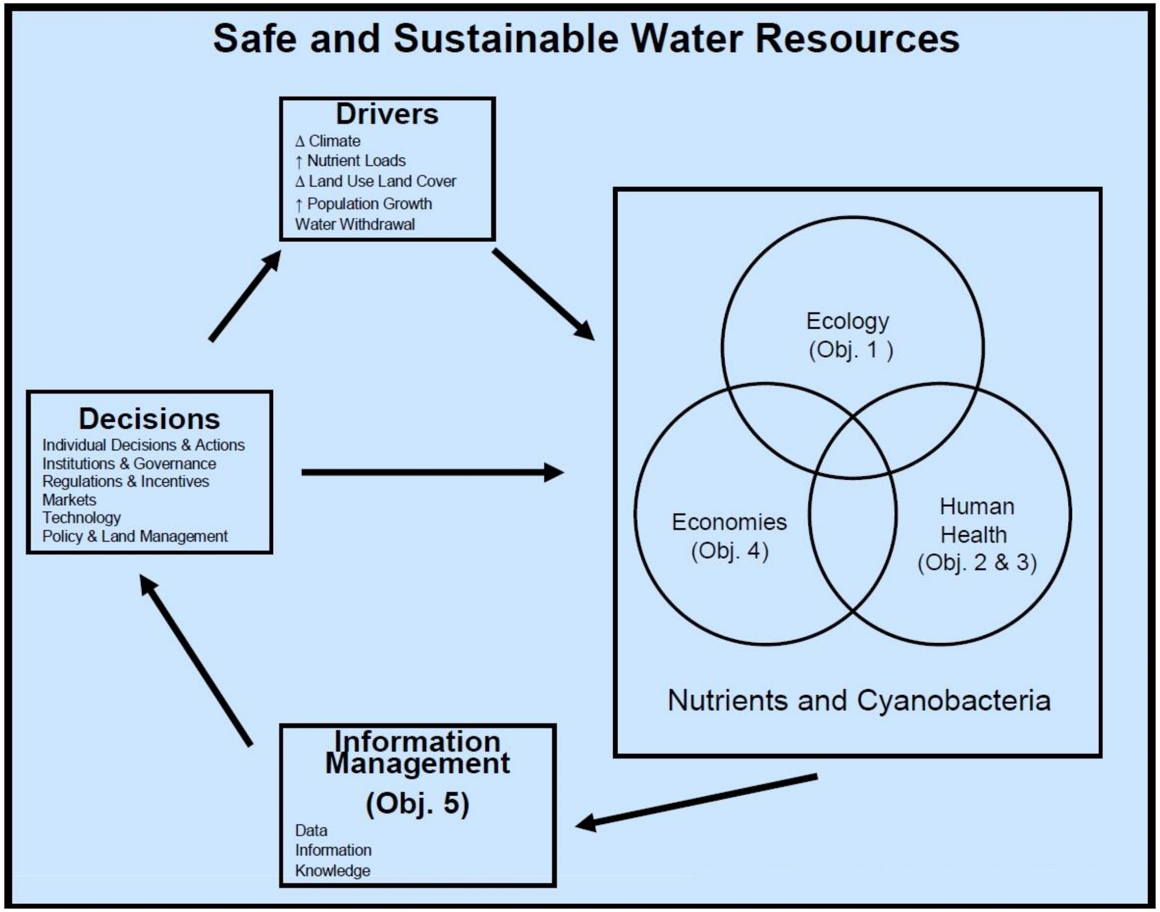


ArcGIS Server



What's Next:
Economics,
Cyanobacteria, and Human Health

Cyanobacetria Integrated Approach



Expected Products

- Models predicting cyanobacteria abundance and probability of human toxicity risk
- Better understanding of cyanotoxin effects on mammalian endpoints
- Decision support system to estimate changes in human health risk and economic impact due to a variety of nutrient reduction scenarios

Economic Analysis

- Combine
  - Policy Relevant Scenario Analysis
  - Beneficiaries
  - Access to Services & Substitutes (Landscape Lake Aesthetic Index)
  - Public Values (Is a change from Good to Best of the same value as a change from Fair to Good?)
  - Environmental Justice

Questions?

Methods

- Is assumption that Depth = *f*(Distance)