SC DEPARTMENT *of*
ENVIRONMENTAL
SERVICES

South Carolina Surface Water Monitoring: Different Designs for Different Objectives

Presented by David Chestnut

Presentation Outline

- Purpose of surface water monitoring
- Ambient Surface Water Quality Monitoring Design
- Indicators
- Assessment
- Other SCDES BOW Water Monitoring Programs
- State-Scale Statistical Surveys, Why?
- What Do The Statewide Survey Results Show?
- Water Quantity and Water Quality: Loading vs. Concentration

Ambient Surface Water Quality Monitoring

- Ambient
  - Relating to the immediate surroundings of something
  - Existing or present on all sides, encompassing
  - Environment
- EPA - Ambient refers to open waters such as rivers, lakes, and streams, as opposed to closed water systems that distribute treated drinking water or wastewater
- So, in our context Ambient refers to surrounding natural environment

Ambient Surface Water Quality Monitoring

- Monitoring data is the foundation for informing the Department's water quality decision-making responsibilities
- Monitoring is a tool, not an end in itself
  - Monitoring data are the basis for decisions regarding achievable and desirable resource use
- Monitoring alone does not achieve protection and restoration of water quality
  - Just because something is monitored does not mean conditions will automatically improve
  - Somebody must act on what the monitoring data tells us
  - Frequently the necessary corrective actions are beyond the authority of SCDES

Purpose of the Ambient Surface Water Quality Monitoring Program

- The collection and analysis of data to make water quality management decisions and meet federal reporting requirements:
  - State-scale summary of condition of aquatic resources (§305(b) report)
  - Assess water quality status & identify specific waters not meeting standards (§303(d) list)
  - Determine long-term trends in specific constituents at individual sites (§303(d) list)

Purpose of the Ambient Surface Water Quality Monitoring Program (Cont.)

- The collection and analysis of data to make water quality management decisions and meet federal reporting requirements:
  - Collect data used for:
    - Wasteload Allocation Modeling
    - TMDL (Total Maximum Daily Load) development
    - Water quality standards development
  - Support specific NPDES permit limits
  - Evaluate effectiveness of SCDES programs

Federal Reporting Requirements

- **§303(d) List**
  - Listing of known impaired waters (in SC case = monitoring sites)
  - Including pollutants (stressors) responsible for impairment
- **§305(b) Report**
  - Comprehensive statewide summary of overall water resource condition
  - Reported as **size** and **percentage** of each aquatic resource type meeting and not meeting water quality standards
  - Size and percentage of water resources impacted by specific stressors
  - Based entirely on the **State-Scale Statistical Survey** component

Other Data Needs

- **Capability for targeted monitoring for specific needs:**
  - Special studies
  - Tracking the implementation of control strategies
  - Respond to emerging issues

Ambient Surface Water Quality Monitoring Design

SC DES

Basic Designs of Ambient Surface Water Chemistry Monitoring are:

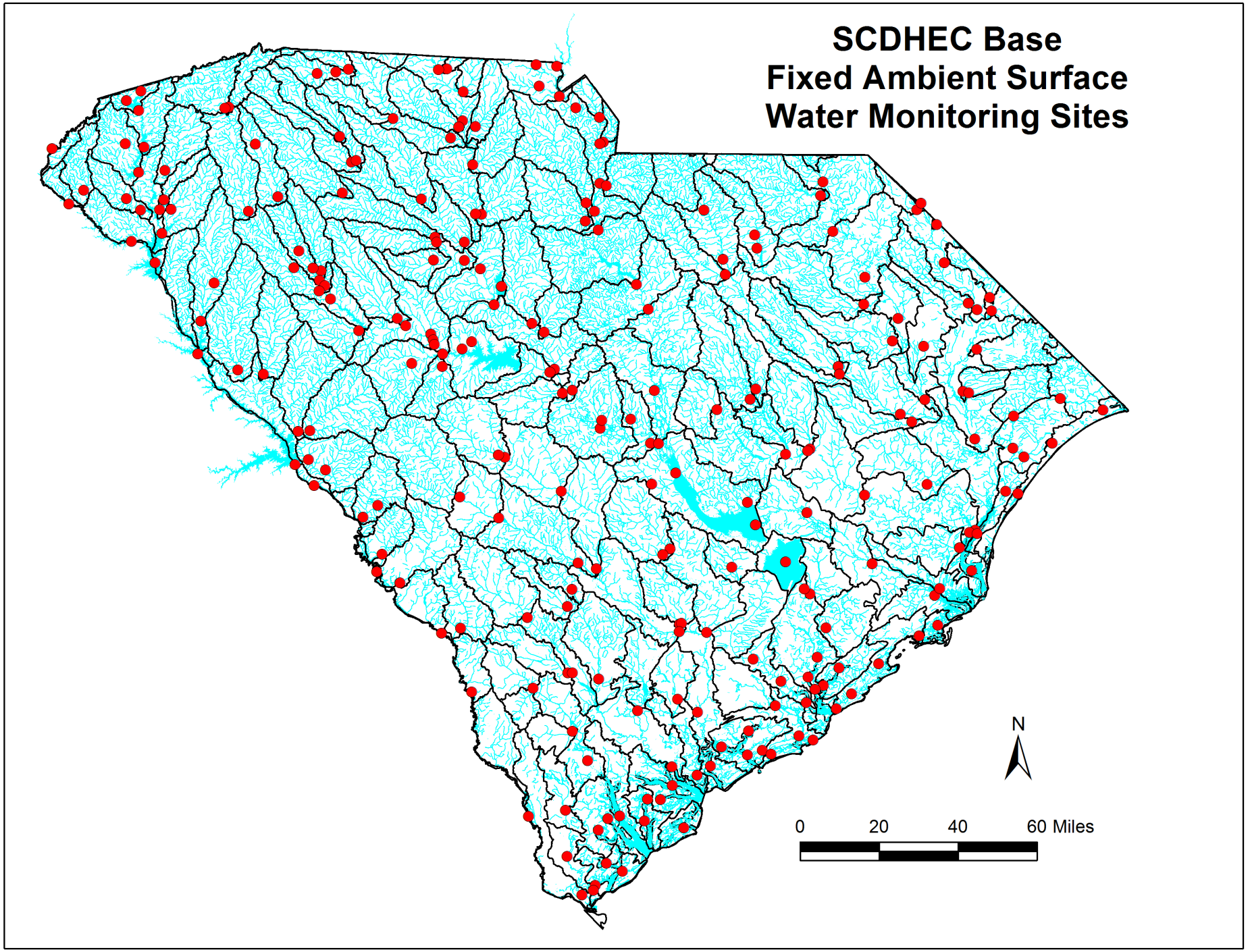
- **Site Specific Information**
  - Fixed sites
  - Examine long-term trends in concentration of specific WQ parameters [§303(d)]
  - Identify waterbodies not meeting classified uses [§303(d)]
  - Track specific targeted activities
- **Big Picture Summary:**
  - Make state-scale statements about representative WQ condition [§305(b)]

Components of the current Ambient Monitoring Network design

- **Fixed Monitoring Network**
  - Long-term trends at individual site level
  - **Consistent** statewide coverage year after year
- **Statistical Survey Monitoring**
  - State-Scale Statistical Survey of resource condition
  - Long-term trends at state-scale
  - New sites selected every year
  - Sample new locations

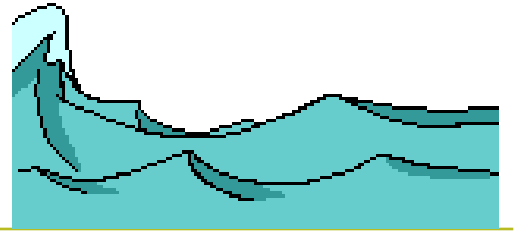
Types of Fixed Statewide Surface Water Chemistry Monitoring Sites

- **Base Sites**
  - Sampled **monthly** year-round, every year
  - Target outflow of 10-digit WSU or specific data needs
- **Special Request Sites**
  - Target specific data needs
  - Limited duration
  - Sampled **monthly** year-round every year


SCDHEC Base
Fixed Ambient Surface
Water Monitoring Sites
N
0
20
40
60 Miles

Statistical Survey Component

- **Statistical Survey Sites**
  - Sampled monthly for 1 year
- **Make comprehensive statements about statewide WQ conditions (§305(b) use support)**
  - Unbiased random sample of water resources (statistical survey, like a phone survey or exit poll)
  - Represents entire resource **("All Waters")**
  - Known confidence of condition estimates
- **Sample previously unsampled locations**
  - Identify new §303(d) candidates



Indicators

Main Ambient Surface Water Quality Monitoring Activities

- **Physical, Chemical, & Microbiological Monitoring**
  - Water Column
- **Biological Community Monitoring**
  - Macroinvertebrates
- **Fish Tissue Monitoring**

Core Parameters - All Physical & Chemical Sites

Monthly - Every Site Visit

Water Temp

Dissolved Oxygen

pH

Specific Conductivity

BOD_5

Enterococci - SW

Escherichia coli - FW

Turbidity

Total Phosphorus

Kjeldahl Nitrogen

Nitrate/Nitrite

Ammonia

Alkalinity

Core Parameters - All Physical & Chemical Sites

Quarterly

Cadmium

Chromium

Copper

Iron

Lead

TSS*

Manganese

Mercury

Nickel

Zinc

Hardness**

*Streams Only

**Freshwater sites only

Core Parameters - Waterbody-Type Specific

Monthly

Salinity - Saltwater sites only

Chlorophyll a

May-Oct. all lakes sites

Microcystin

May-Oct. all lakes sites

Transparency

Secchi depth, all lakes

Ambient Surface Water Chemistry Monitoring Numbers

243 Base Sites, Monthly

41 Special Request Sites, Monthly

30 River & Stream Survey Sites, Monthly

30 Lake & Reservoir Survey Sites, Monthly

30 Tide Creek & Open Water Survey Sites, Monthly

Assessment

Aquatic Life Use Support

- Degree to which water quality supports a balanced indigenous aquatic community
- ~Clean Water Act “Fishable” goal

Dissolved Oxygen
Metals
Macroinvertebrate Community (wadeable streams)
Nutrients (lakes)
pH
Ammonia
Turbidity
Chlorophyll-a (lakes)
Microcystin (lakes)

Recreational Use Support

- Degree to which water quality supports recreational activities in and on the water
- ~Clean Water Act “Swimmable” goal

Saltwater - Enterococci

Freshwater - *Escherichia coli*

Other SCDES Monitoring Programs

Ocean Water Monitoring

- 122 fixed sites coast wide sampled May 1 thru October 1
  - 48 Sampled weekly
  - 74 Sampled twice per month

- Used to issue swimming advisories at coastal beaches

Shellfish Sanitation Monitoring

- Statewide fixed sites
  - 465 sites sampled monthly

- Used to determine shellfish harvesting status

Chlorophyll a and Microcystin Monitoring

- **Chlorophyll *a*** – May-October all lake/reservoir sites
- **Microcystin** – May-October all lake/reservoir sites
  - Used to issue swimming watches and advisories
- Other sites as needed based on:
  - Bloom conditions
  - Drinking water taste & odor issues

Macroinvertebrate Monitoring

- The macroinvertebrate community integrates all environmental influences: water chemistry, sedimentation, scouring, habitat loss, land runoff, streambank modification, etc.
- **Approximately 80 sites per year**
  - Includes reference sites within major river basins
- **Statistical survey stream sites**
  - Wadeable stream sites, around 10 per year
- **Habitat & community assessment at all sites**

Fish Tissue Monitoring

- Used to issue fish consumption advisories
- ~60 sites visited annually statewide
- The goal is at least 2 species per site
- 5 Individuals per species, each fish treated as a separate sample
- Mercury on each individual fish
- 2 fish from each site for other metals, pesticides, and PCBs

State-Scale Statistical Surveys

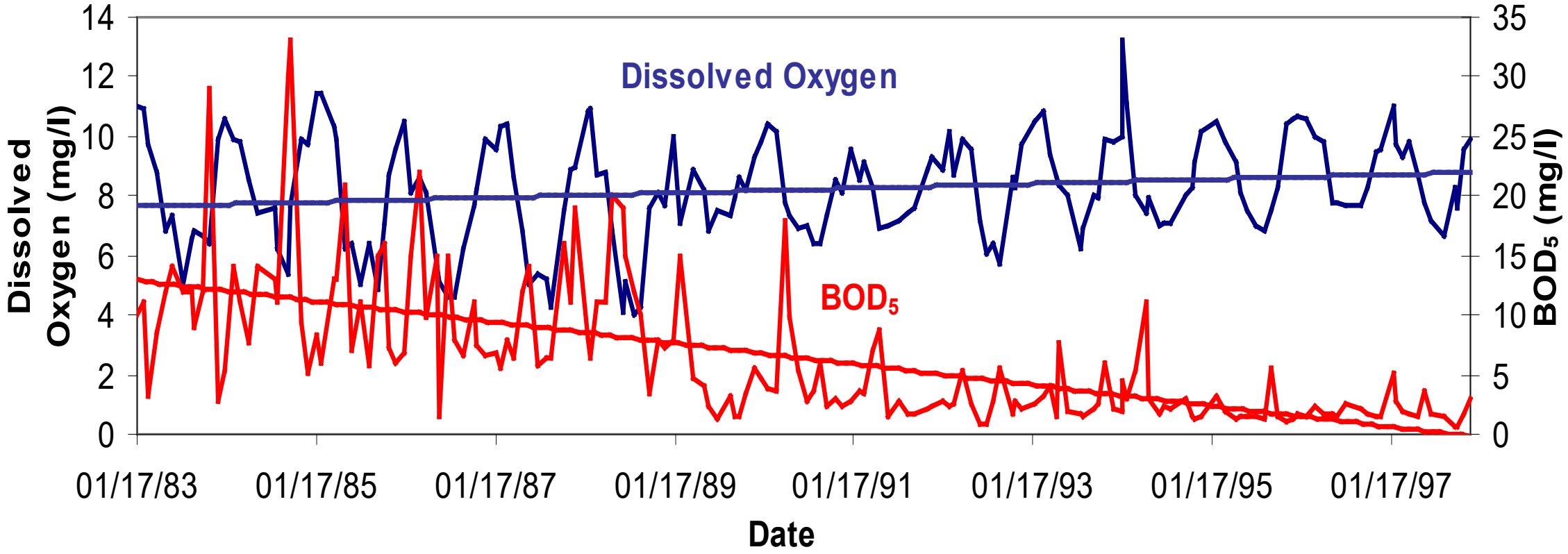
Why?

SC DES

What Do Fixed-Sites Represent?

- Sites are located based on a system of pre-defined watershed boundaries
- “Trends” are for individual parameters at specific sampling locations
- Under the fixed-site monitoring design, larger streams dominate the conditions sampled
- The smaller order streams are not proportionally represented
- Fixed sites could at best only represent a small portion of the total resource

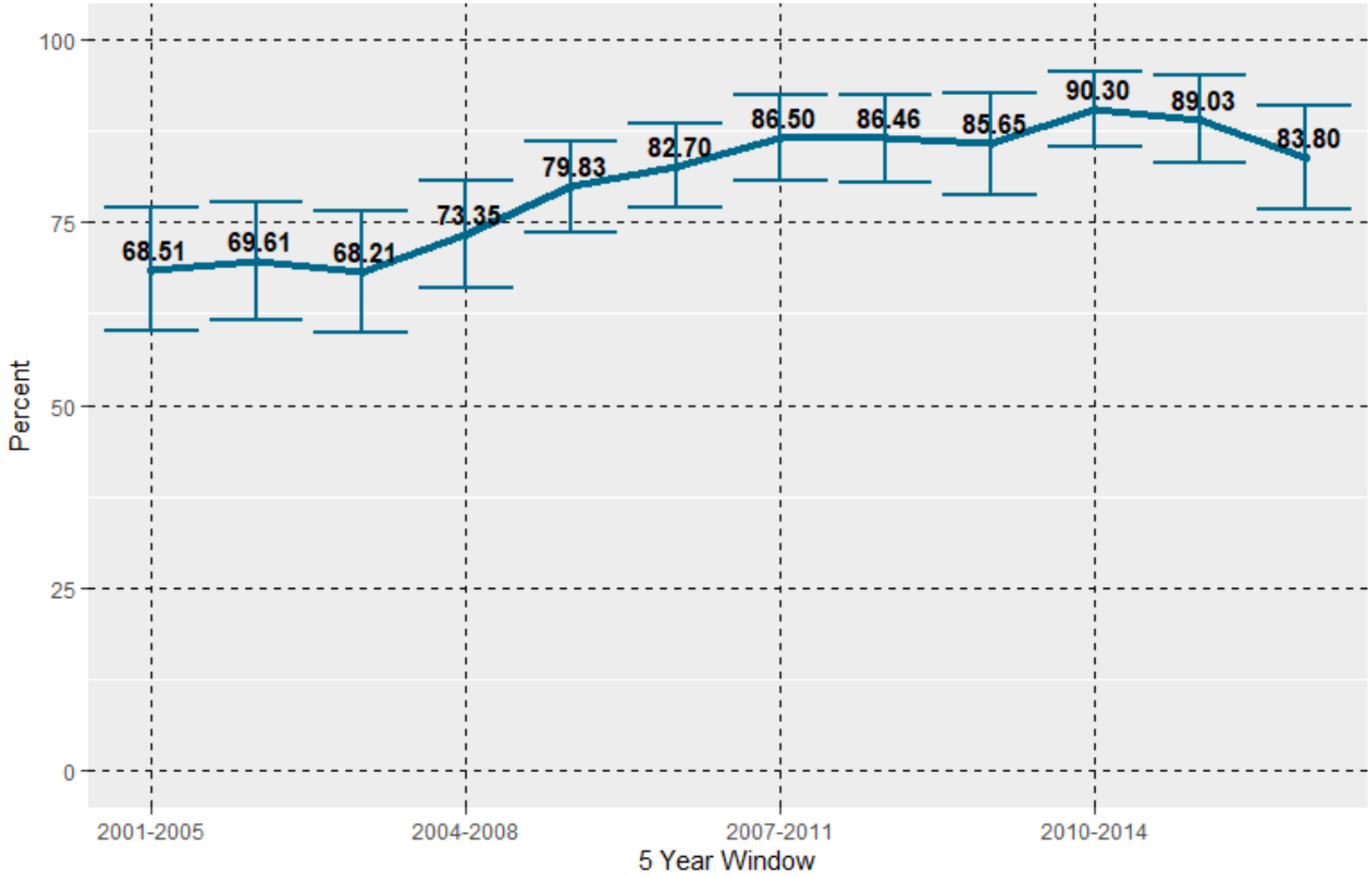
S-018 Dissolved Oxygen vs. Five-Day Biochemical Oxygen Demand



Difference in What is Represented

- The statistical survey component is like an election poll or phone survey, and represents an estimate of the condition of an entire resource (population)
- A statement can be made about the population of interest by extrapolation from a relatively small subsample
- Under the statistical survey design all stream sizes are included and proportionally represented in the results

Streams – Statewide Percent of Stream Miles Fully Supporting Aquatic Life Use Rolling 5 Years



HOW?

SC DES

Generalized Random Tessellation Stratified (GRTS) Survey Design

EPA Aquatic Resources Monitoring – General Overview of Statistical Surveys

- Statistical sample producing design-based estimators and variance estimators
- Gives another option to simple random sample and systematic random sample designs
- Emphasize spatial-balance
  - Every replication of the sample exhibits a spatial density pattern that closely mimics that of the resource

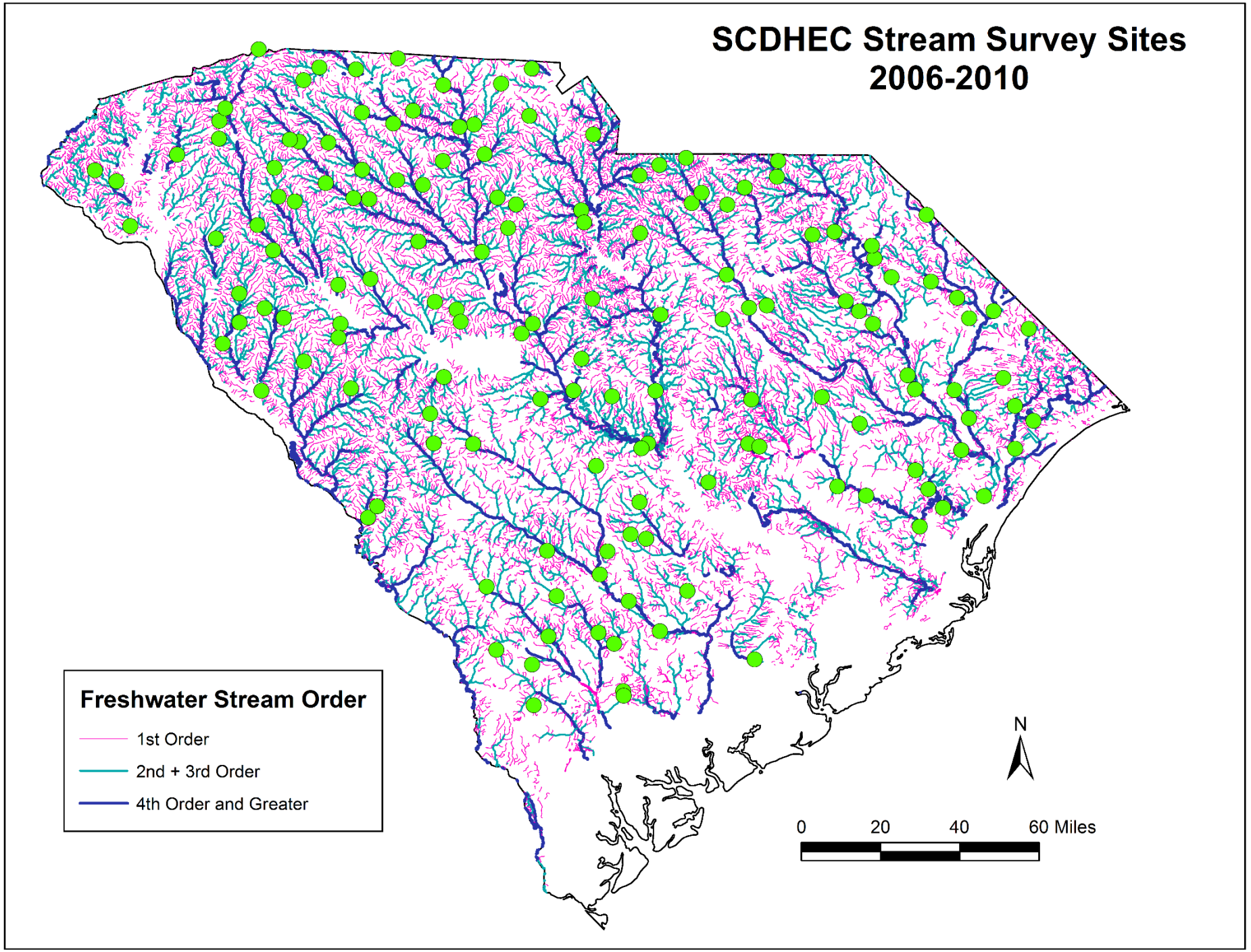
Statistical Magic

- It requires around 50 to 60 sites to make a population statement around ± 10% accuracy with 90% confidence
- We sample 30 sites per year in each waterbody type
- Currently we compile 5 years of data for each waterbody type to make a statewide statement around ± 6% accuracy with 95% confidence

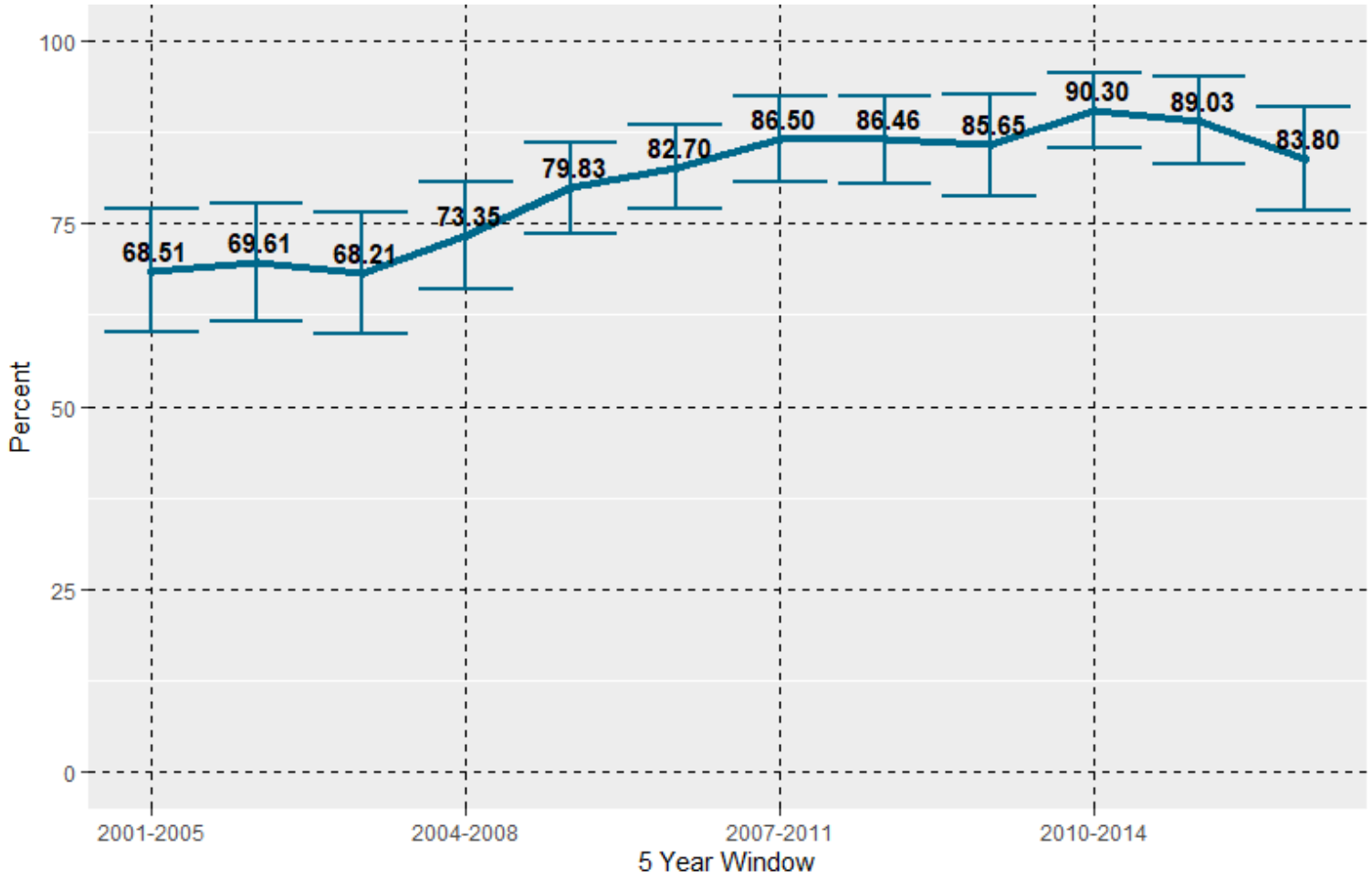
What Do The Statewide Survey Results Show?

Targeted Categories for Statistical Survey Sites

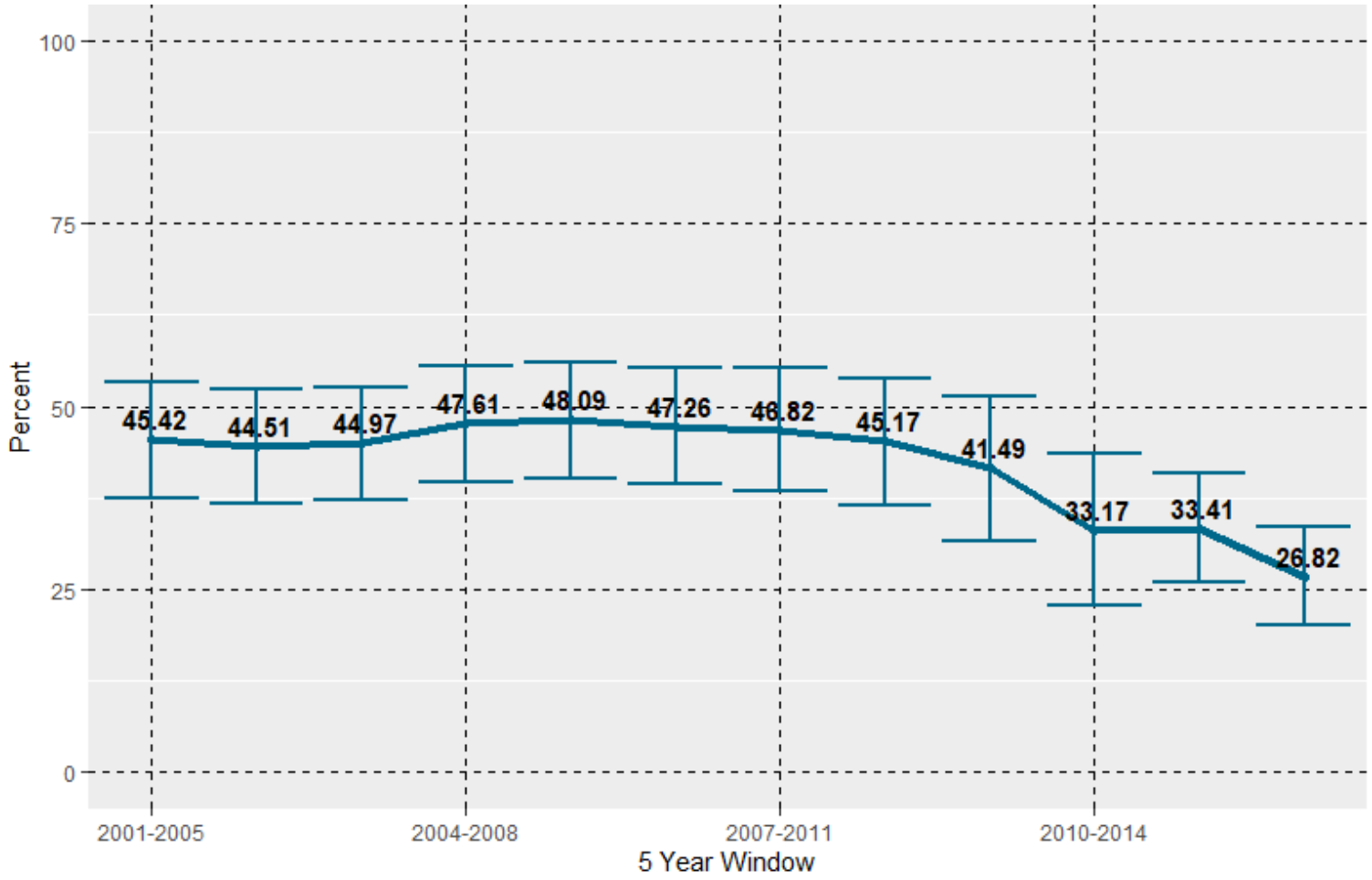
- **Streams**
- 30 sites sampled monthly
  - 8 first order streams
  - 10 second & third order streams
  - 12 fourth order & greater streams
- Unequal weights


SCDHEC Stream Survey Sites
2006-2010
Freshwater Stream Order
1st Order
2nd + 3rd Order
4th Order and Greater
N
0
20
40
60 Miles

Streams – Statewide Percent of Stream Miles Fully Supporting Aquatic Life Use Rolling 5 Years



Streams – Statewide Percent of Stream Miles Fully Supporting Recreational Use Rolling 5 Years



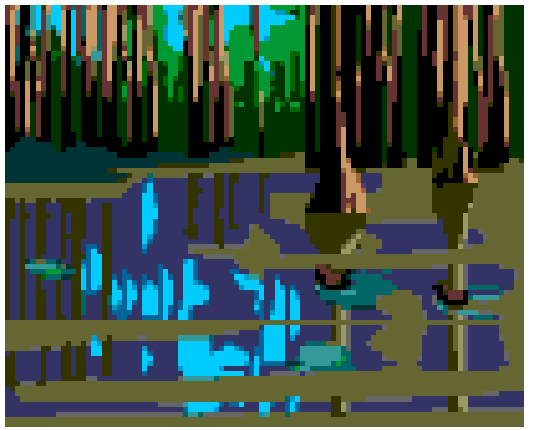
Streams - Top Causes of Aquatic Life Use Impairment

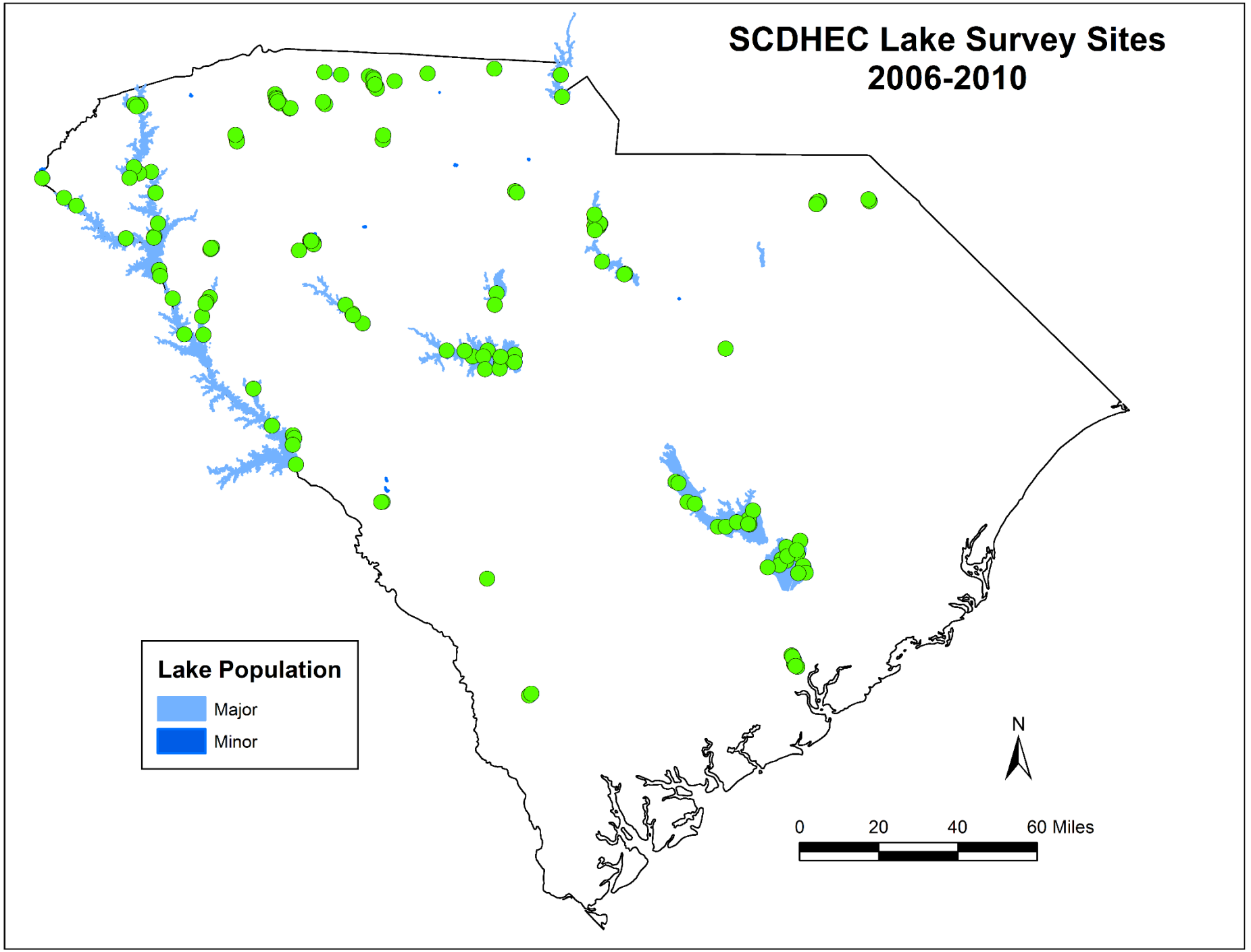
1. Macroinvertebrates
2. Dissolved Oxygen
3. - 5. pH, Zinc, Turbidity jockey for position

Sometimes the top 1. and 2. shift position

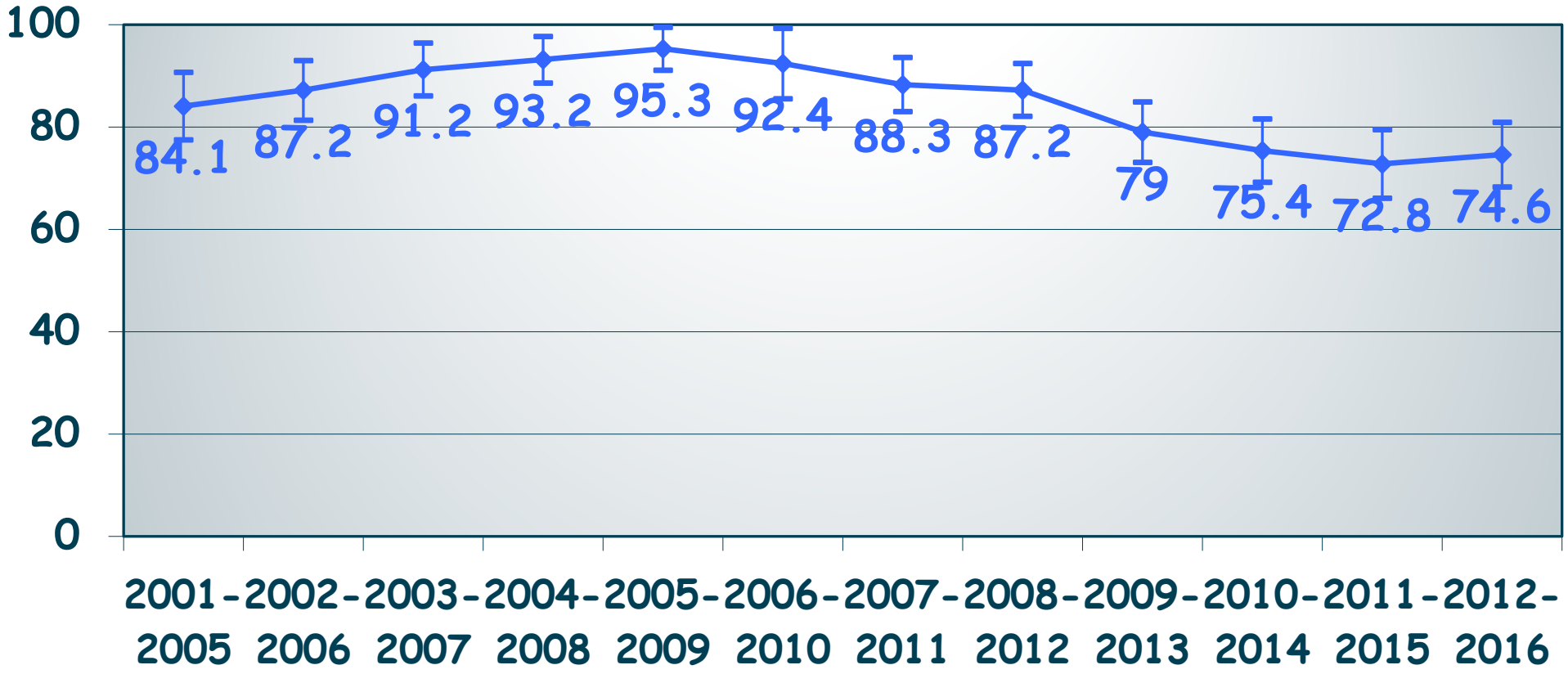
Targeted Categories for Statistical Survey Sites

- **Significant Lakes with Public Access:**
  - 17 Major Lakes (≥ 850 acres)
  - 15 Minor Lakes (40 to 850 acres)
- 30 sites sampled monthly
  - 20 in Major lakes
  - 10 in Minor lakes
- Unequal weights

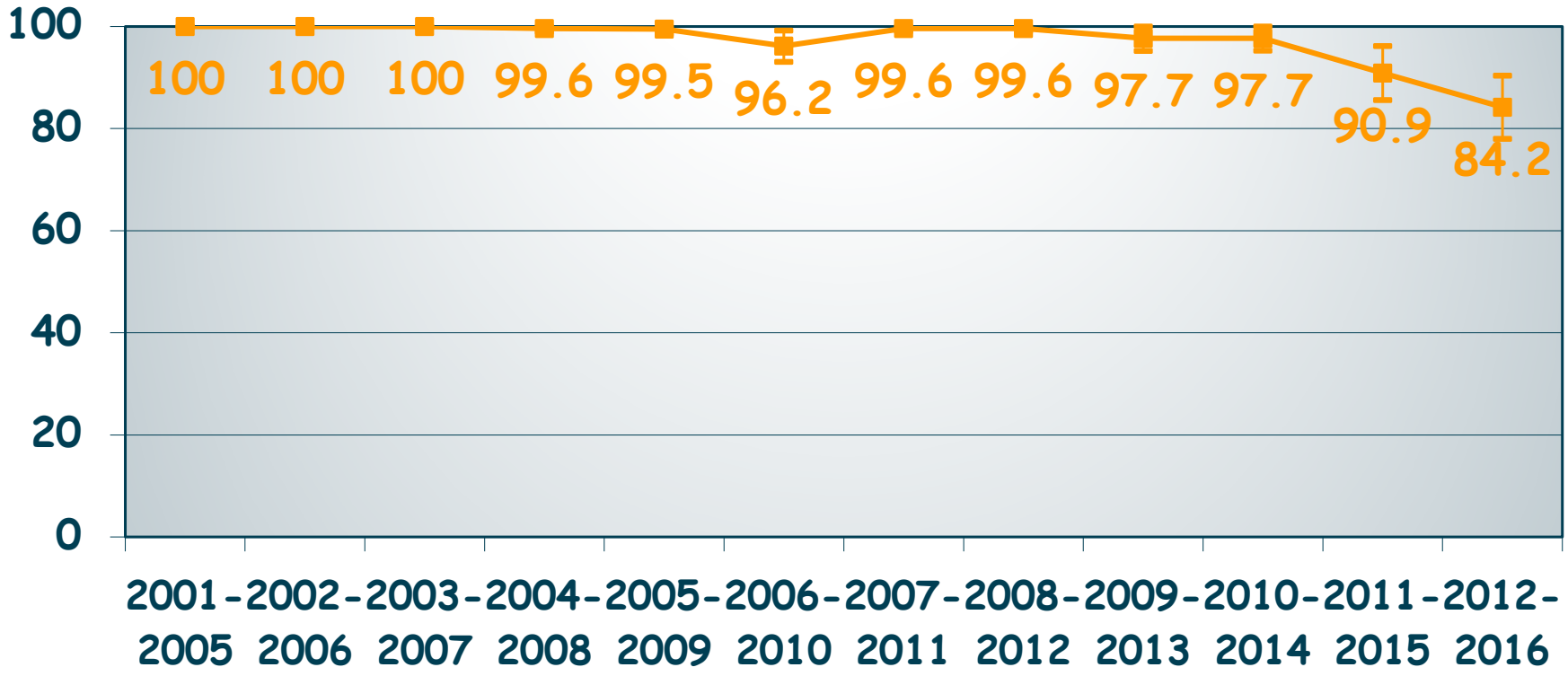



SCDHEC Lake Survey Sites
2006-2010
Lake Population
Major
Minor
N
0
20
40
60 Miles

Lakes – Aquatic Life Use
Fully Supporting - Rolling 5 Years



Lakes – Recreational Use
Fully Supporting - Rolling 5 Years



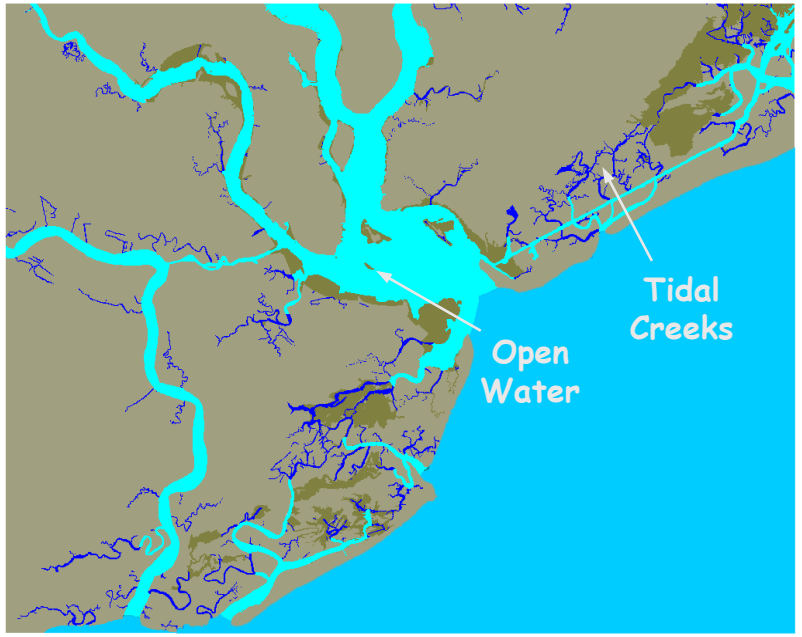
Note: No fecal coliform data were collected at 1 site in 2008 and 4 sites in 2010. This represents area Not Assessed, not Impaired.

Lakes - Top Causes of Aquatic Life Use Impairment

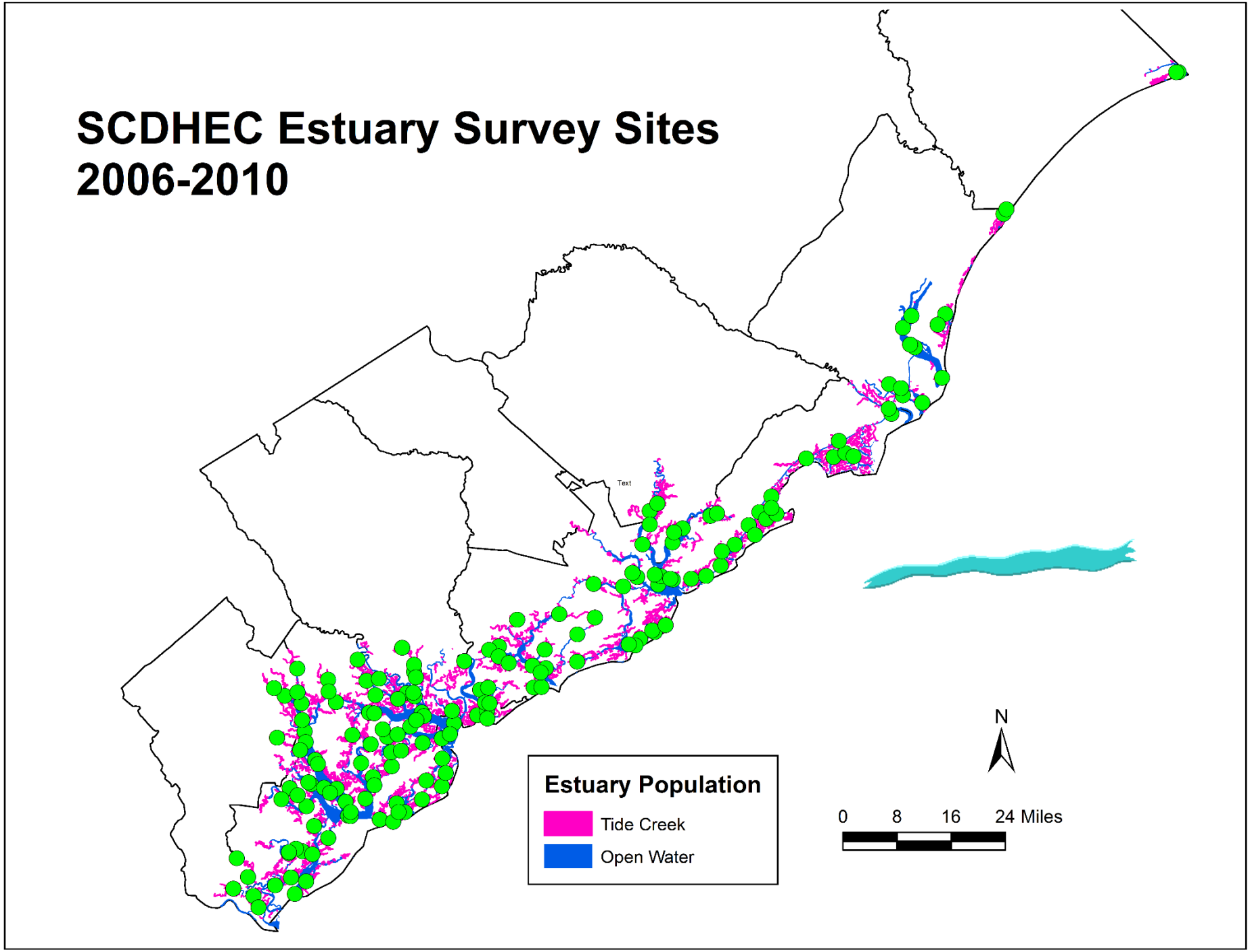
- Positions 1 and 2 varied between pH and Total Phosphorus for all assessment periods
- Positions 3, 4, and 5 varied between Dissolved Oxygen, Turbidity, Total Nitrogen, Chlorophyll-*a*
- Copper and Ammonia each made the top 5 at least once

Targeted Categories for Statistical Survey Sites

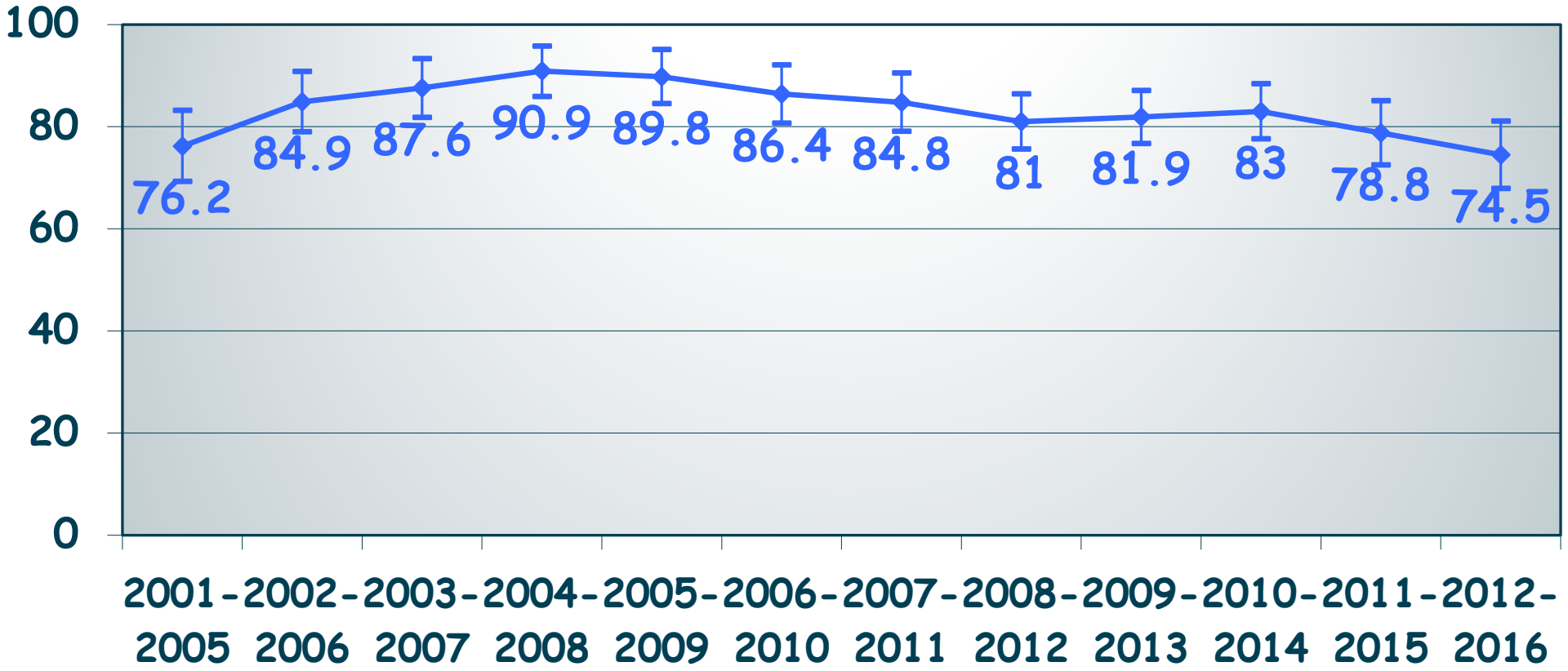
- **Estuaries**
- 30 sites sampled monthly
  - Two distinct strata:
    - 15 Open water (> 100 m wide)
    - 15 Tide Creeks (< 100 m wide)



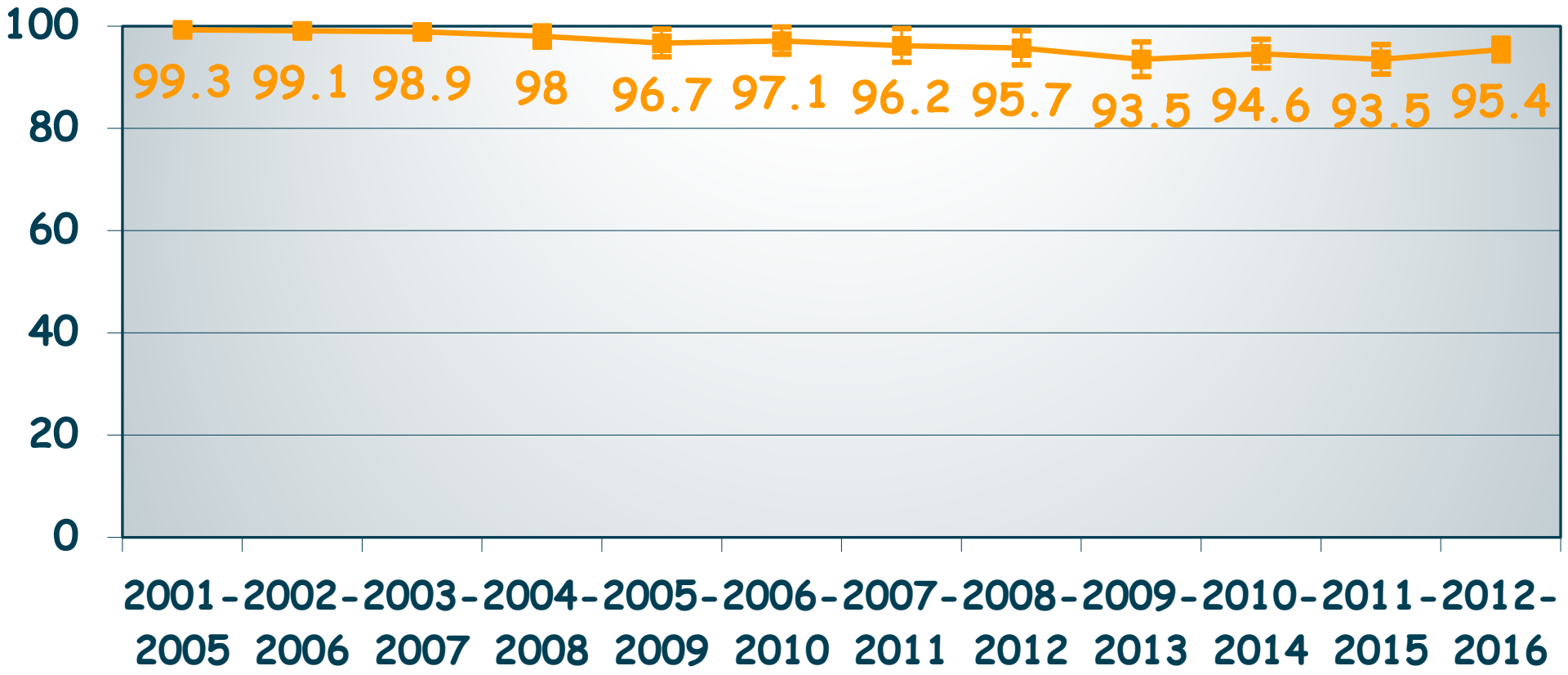
Also part of the joint SCDES/SCDNR SCECAP program
https://www.dnr.sc.gov/marine/scecap


SCDHEC Estuary Survey Sites
2006-2010
Text
Estuary Population
Tide Creek
Open Water
N
0 8 16 24 Miles

Estuaries – Aquatic Life Use
Fully Supporting - Rolling 5 Years



Estuaries – Recreational Use
Fully Supporting - Rolling 5 Years



Estuaries - Top Causes of Aquatic Life Use Impairment

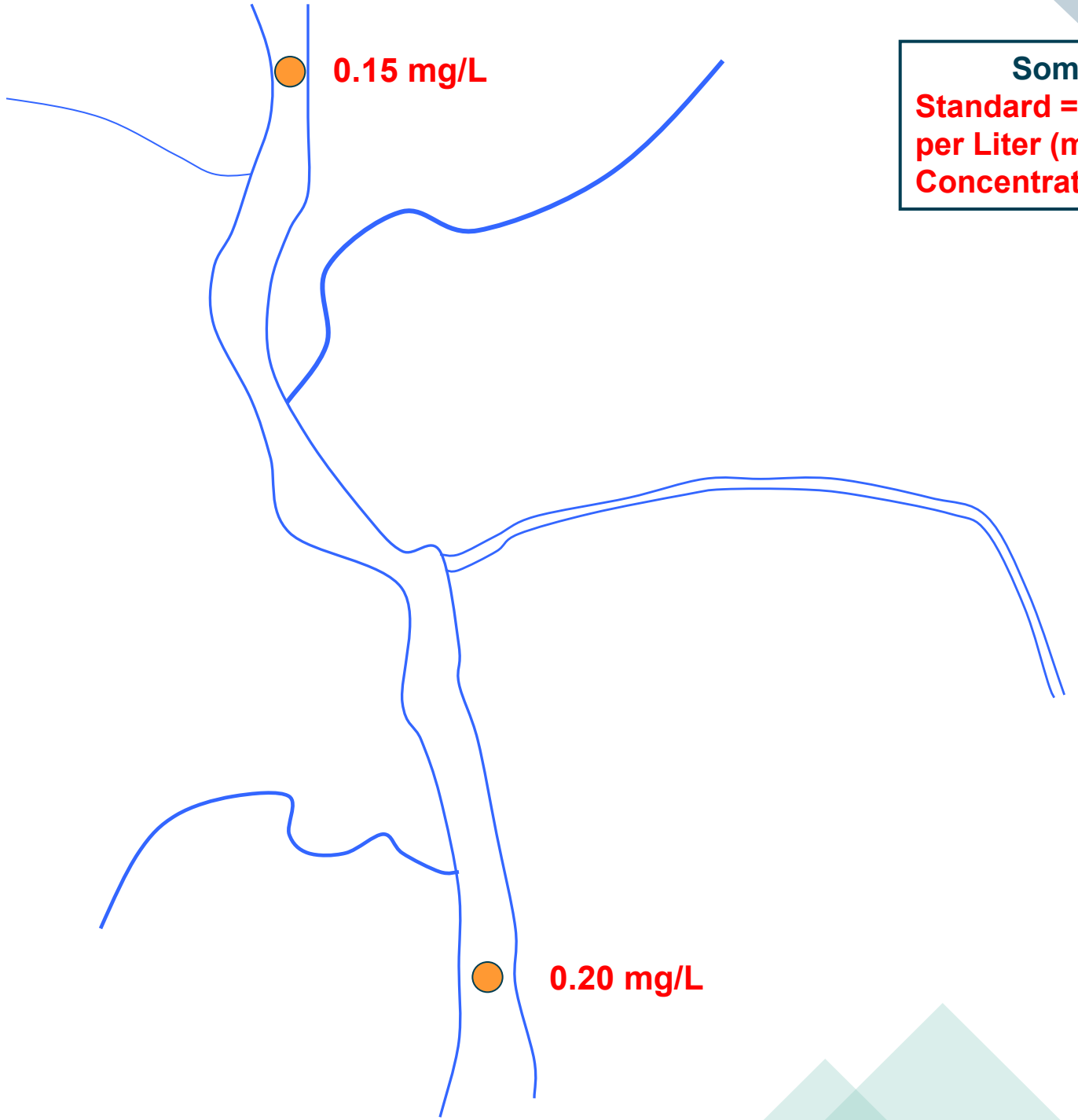
- Dissolved Oxygen and Turbidity are among the top 3 in all assessment periods
- Copper and Zinc were among the top 4 in the earlier periods, but no longer seem to be dominant
- For more recent periods Dissolved Oxygen and Turbidity were the only causes of impairment

Water Quantity and Water Quality: Loading vs. Concentration

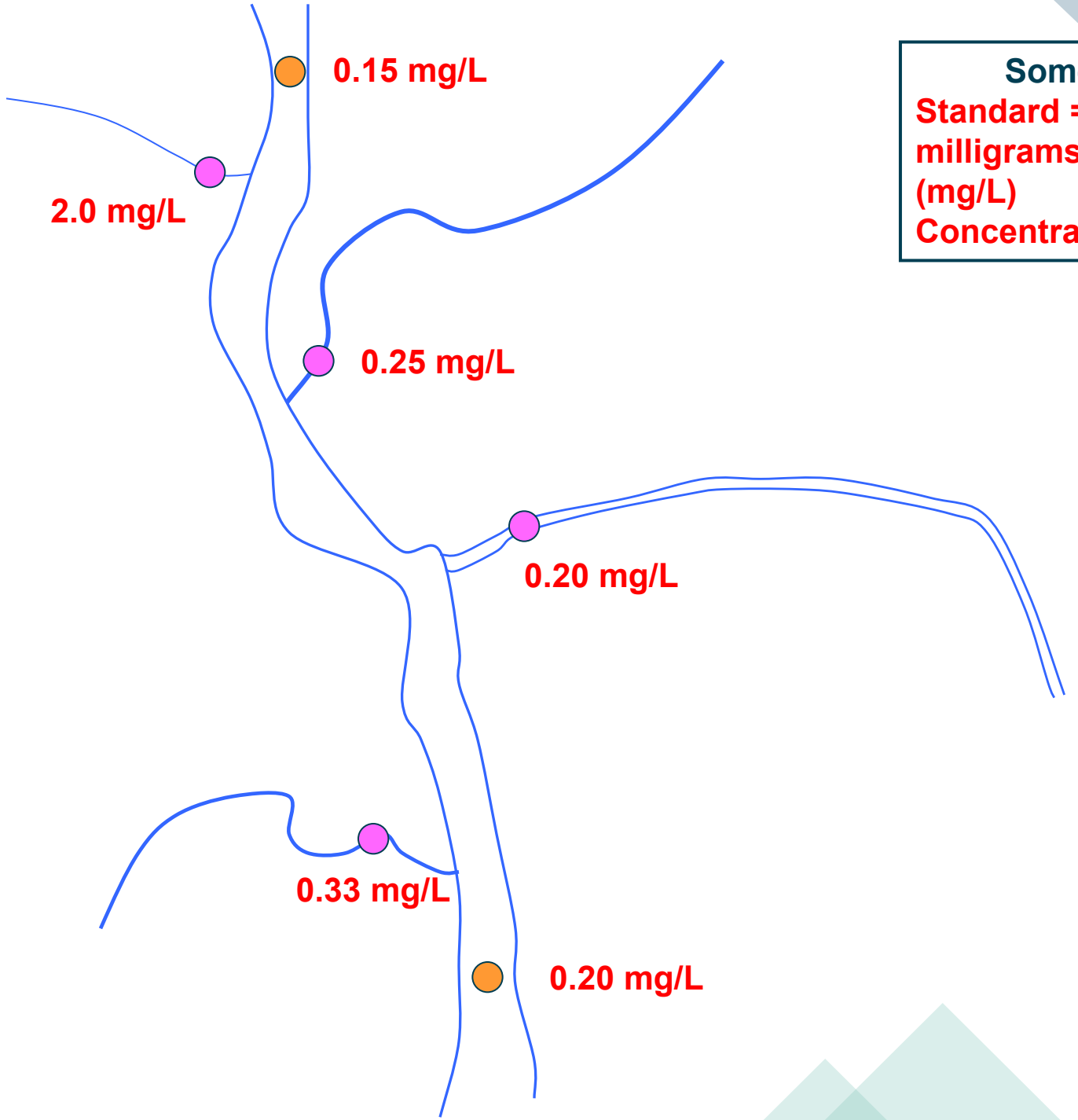
SC DES

Water Quality Standards

- **Based on constituent concentrations below which no adverse impacts are observed**
- **Human Health**
  - Primarily drinking water related, SDWA
  - Fish & Shellfish consumption advisories
- **Aquatic Life Use**
  - Acute – short term exposure causes death
  - Chronic - long term exposure causes damage
- **Recreational Use**
  - Derived from epidemiological studies of the occurrence of gastroenteritis following swimming at high use public swimming beaches

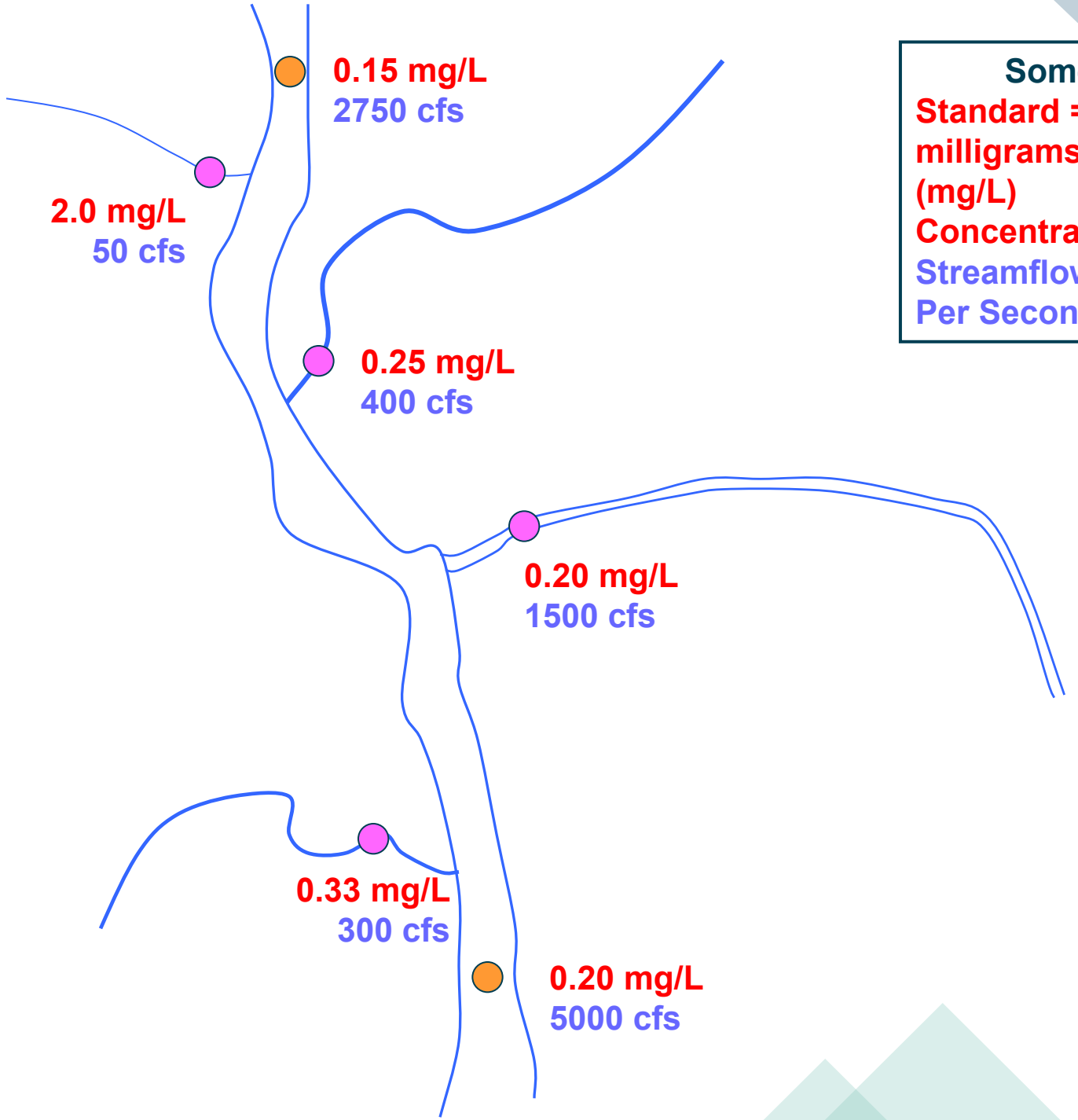


Some Pollutant
Standard = 0.16 milligrams per Liter (mg/L) Concentration



Some Pollutant

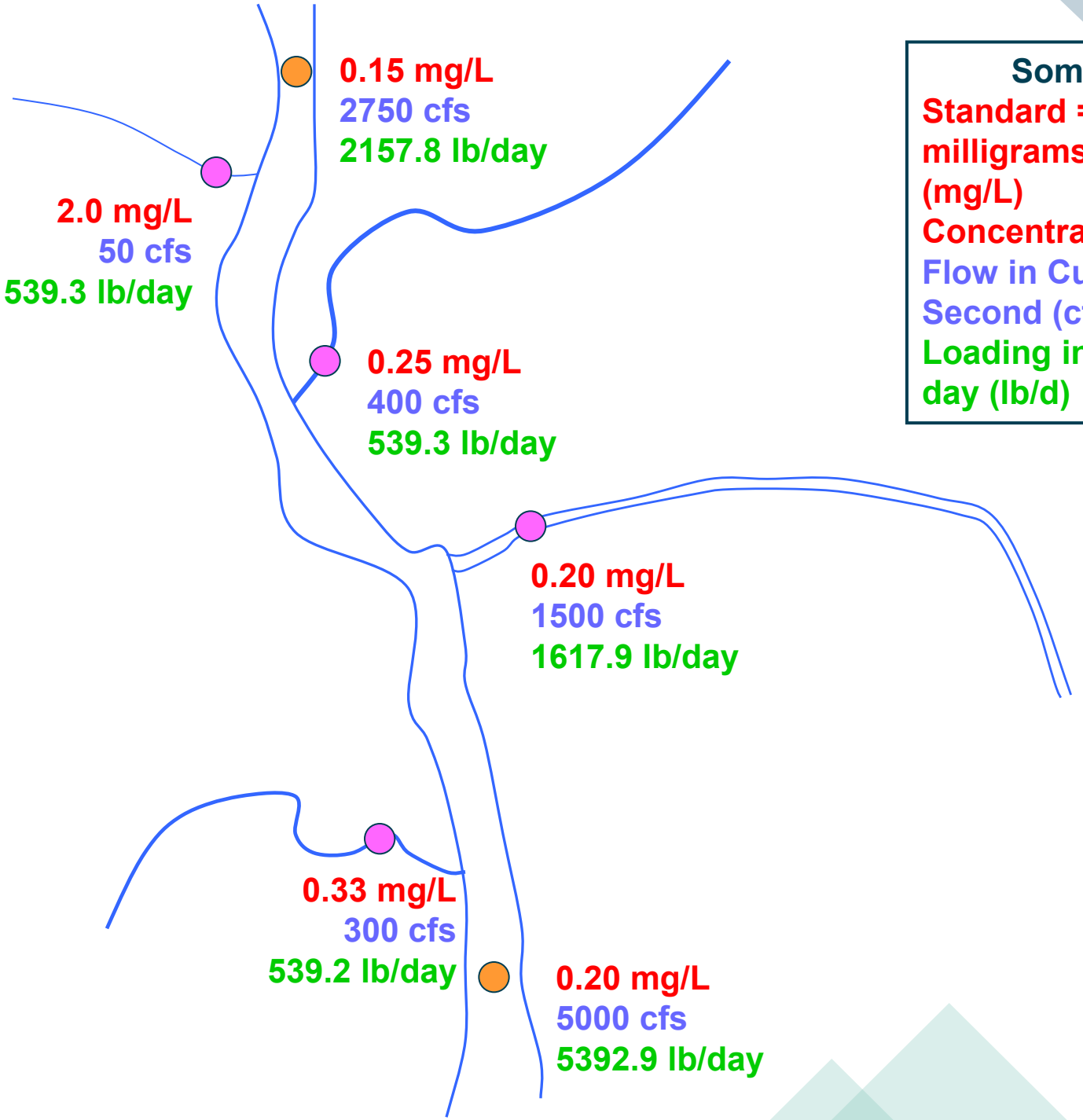
Standard = 0.16 milligrams per Liter (mg/L) Concentration



Some Pollutant

Standard = 0.16 milligrams per Liter (mg/L) Concentration

Streamflow in Cubic Feet Per Second (cfs)



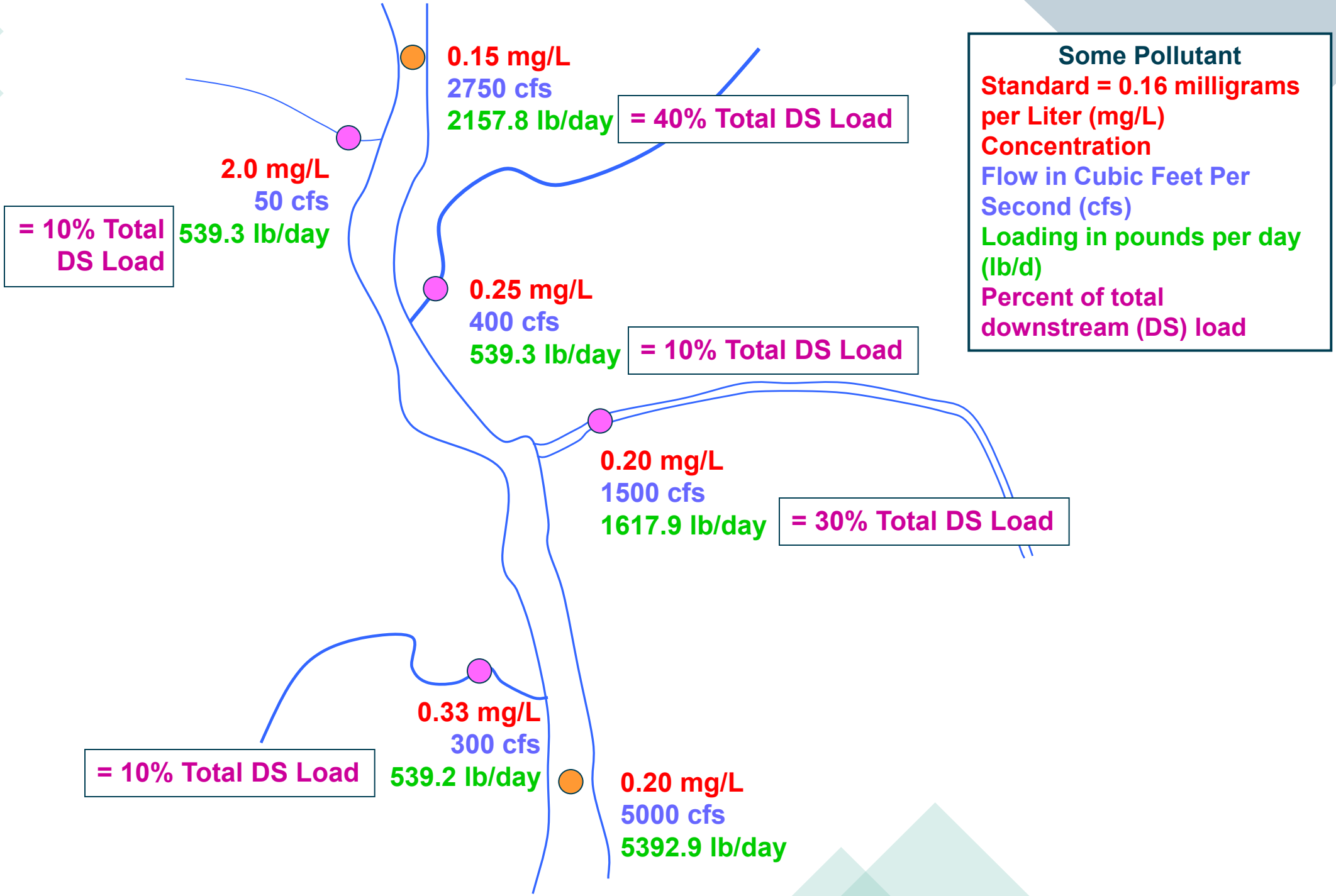
Some Pollutant

Standard = 0.16 milligrams per Liter (mg/L)

Concentration

Flow in Cubic Feet Per Second (cfs)

Loading in pounds per day (lb/d)


0.15 mg/L
2750 cfs
2157.8 lb/day
= 40% Total DS Load
2.0 mg/L
50 cfs
539.3 lb/day
= 10% Total DS Load
0.25 mg/L
400 cfs
539.3 lb/day
= 10% Total DS Load
0.20 mg/L
1500 cfs
1617.9 lb/day
= 30% Total DS Load
0.33 mg/L
300 cfs
539.2 lb/day
= 10% Total DS Load
0.20 mg/L
5000 cfs
5392.9 lb/day
Some Pollutant
Standard = 0.16 milligrams per Liter (mg/L) Concentration
Flow in Cubic Feet Per Second (cfs)
Loading in pounds per day (lb/d)
Percent of total downstream (DS) load

Dilution is the Solution to Pollution

- All four of the tributaries exceed the water quality standard
- Each of the three smaller tributaries only provide 10% of the total downstream load
- It would require addressing all three of those tributary's watersheds to equal the improvement gained from bringing the tributary that provides 30% of the total downstream load into standards compliance

Dilution is the Solution to Pollution

- It is only “dilution” if it is polluted water being discharged into clean water
- Otherwise, it is polluted water being added to dirty water, making a bad situation worse
- You can have all the water you need, but if it is too polluted for your use, it is useless
- Or it requires expensive treatment to clean it to the level you need for your use

Dilution is the Solution to Pollution

- Adding 1 mg of arsenic in an Olympic size swimming pool results in a concentration **25,000 times less** than the DW standard
  - If someone swallows 8 ounces of water, they probably wouldn't feel a thing
- Adding 1 mg of arsenic to an 8-ounce glass of drinking water results in a concentration **~400 times greater** than the DW standard
  - That's most likely fatal
  - It means your spouse is ready to collect the life insurance and move on with their life

Dilution is the Solution to Pollution

- If flow volume is reduced without a commensurate reduction in pollutant loading it results in higher concentration exceedances of the standard (i.e. more toxic), and more frequent exceedances of the standard
- This is what happens with decreased flow (evaporation, water withdrawal, reduction in dam releases, meteorological changes, impacts from wastewater discharges, etc.) without pollutant reduction

Monitoring for Different Purposes: We Need to Have a Little of Everything

- Multi-media, multi-purpose, & program specific capabilities
- Inform public health advisories
  - Swimming advisories
  - Fish consumption advisories
  - Shellfish harvesting
- Statistical survey design for big picture statements
- Fixed sites to examine standards compliance and long-term trends in individual parameters at individual sites
- Capability for targeted monitoring for specific needs:
  - Emerging issues/special studies
  - Tracking of implementation of control strategies

That’s All Folks!

- Any Questions?
- Discussion?

Water Quality Standards

- **Human Health**
  - Primarily drinking water related, SDWA
    - MCLs – Maximum Contaminant Level, level not expected to cause adverse health effects in a lifetime
    - Laboratory studies on human surrogates, e.g. rats, pigs, etc.
    - Extrapolation/exposure modeling
  - Fish & Shellfish consumption advisories
- **Aquatic Life Use**
  - Laboratory studies on sensitive aquatic organisms
  - Acute and chronic standards
- **Recreational Use**

Aquatic Life Use Standards

Aquatic Life standards based on:

- **Acute Toxicity** – short term exposure causes death
  - Poison
  - Water Toxemia
- **Chronic Toxicity** – long term exposure causes damage
  - Reproductive success
    - Sterile offspring
    - Birth defects
  - Tumors, carcinogens

Bacteriological Recreational Standards

- Derived from epidemiological studies of swimmers at high use public swimming beaches
- Protective for full body immersion exposure, i.e., primary contact recreation
- Based on minor human health responses, like the occurrence of gastroenteritis, ear infections, eye infections, open wound infections, etc.
- **Not** acute events (deaths) or long-term chronic effects (tumors, reproductive failure) like aquatic life criteria
- Not based on evidence of widespread historic natural conditions
- Risk communication concerns

Pollutants

- The American Chemical Society's Chemical Abstracts Service division, identifies more than 204 million unique organic and inorganic substances and 69 million protein and DNA sequences
  - The vast majority have no human health or aquatic life criteria
- Historically if a substance had a desirable effect there was no requirement to demonstrate safety or long-term effects before it went to market
- There usually wasn't much consideration about the potential long-term impacts or short-term changes to humans or other ecosystem impacts
- Now we have the Toxic Substances Control Act (TSCA)?

Toxic Substances Control Act (TSCA)

- Frank R. Lautenberg Chemical Safety for the 21st Century Act, June 2016
- Mandated by section 5 of the Toxic Substances Control Act (TSCA), EPA's New Chemicals program helps manage the potential risk to human health and the environment from chemicals new to the marketplace. The program functions as a "gatekeeper" that can identify conditions, up to and including a ban on production, to be placed on the use of a new chemical before it is entered into commerce.
- Only applies to “new chemicals” not already on the TSCA inventory.
- TSCA Chemical Substance Inventory contains all existing chemical substances manufactured, processed, or imported in the United States that do not qualify for an exemption or exclusion under TSCA, currently 86,847 chemicals, 42,495 active (manufactured or imported in last 10 years).
- https://www.epa.gov/reviewing-new-chemicals-under-toxic-substances-control-act-tsca/basic-information-review-new

Pollutants – Risk Communication

- Man-made pollutants du jour panics
- DDT
- PCBs
- PAHs
- Dioxin
- Organotins
- Endocrine disruptors
- PFAS

- Natural origin panics
- Mercury
- Lead
- Copper
- Arsenic
- Bacterial indicator organisms
- *Pfiesteria piscicida*

- Attention and concern (panic) is generally set off by media attention which fails to provide any context, e.g., PFAS vs. over 204 million unique organic and inorganic substances, most without human health or aquatic life criteria or standards
- The public becomes single-mindedly focused on doing something about the pollutant du jour without ever realizing and considering all of the other compounds they are exposed to every day that aren't yet newsworthy

Pollutants - Ignorance is bliss

- Out of sight, out of mind
- No one cares
- Today's human population and genetics is the expression of generations of exposure to these substances and compounds and today's children are the expression of a lifetime of exposure to compounds their parents may not have ever been exposed to, e.g., PFAS