Dissolved Oxygen Modeling for WLAs

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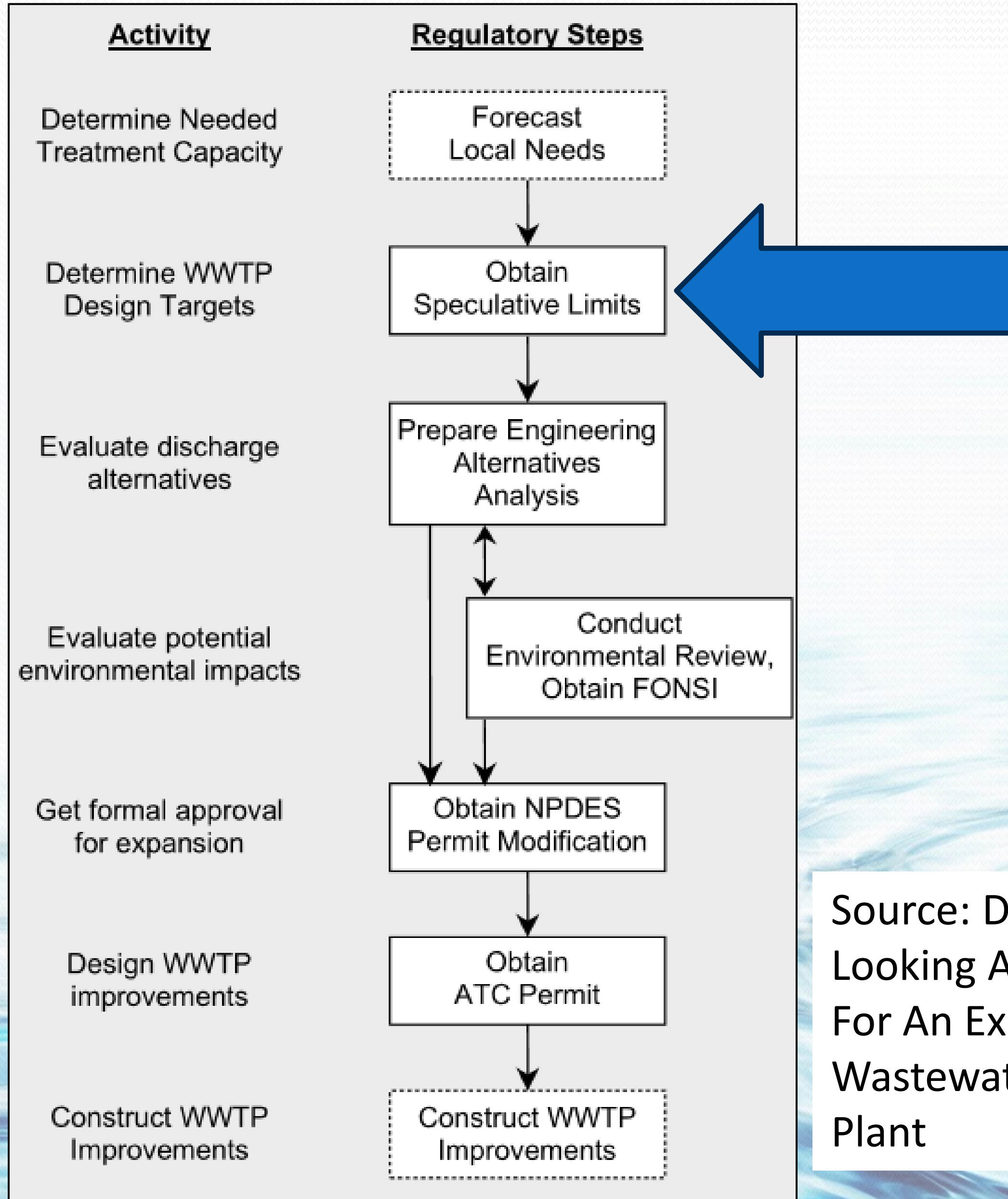
Outline

- Need for dissolved oxygen (DO) modeling of receiving waters to support permits
- DO modeling process
- Recommendations

Key Steps for WWTP Expansion



Source: DWR 2014. Looking Ahead: Planning For An Expansion At Your Wastewater Treatment Plant

Permit Limits

- Three main categories of pollutants regulated:
  - Oxygen-consuming and conventional parameters
  - Toxicants and non-conventional parameters
  - Nutrients and parameters related to eutrophication

Two of these can affect DO concentrations

Need a DO model to calculate what the limits should be

Dissolved Oxygen

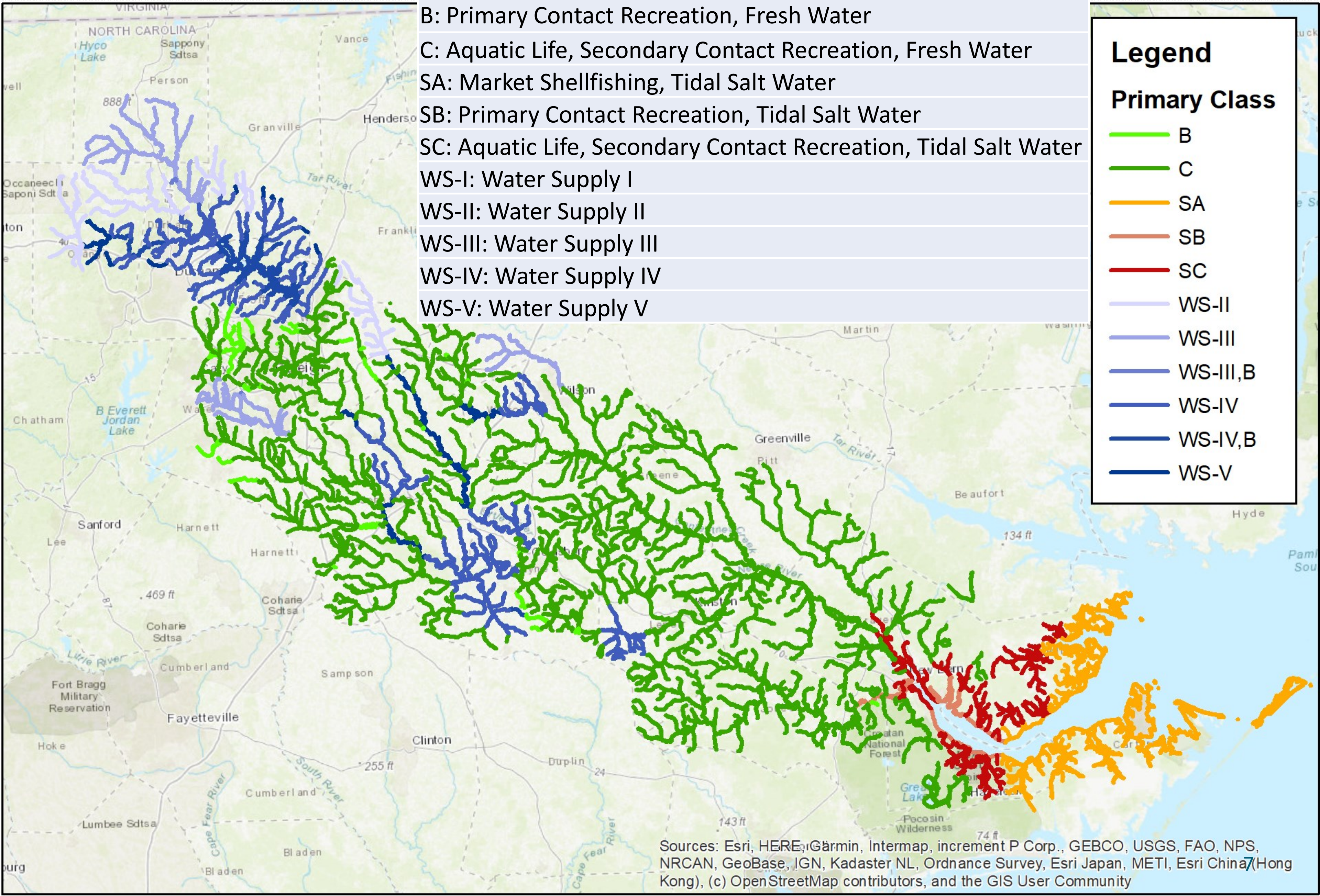
- Aquatic life needs DO to survive
- State water quality standards (WQS) define the minimum DO needed to protect aquatic life.
- WQS varies depending on how each waterbody is classified by the state for its use
- Discharge permits have limits to make sure that the WQS is met for the water body

Water Classifications in Neuse Basin

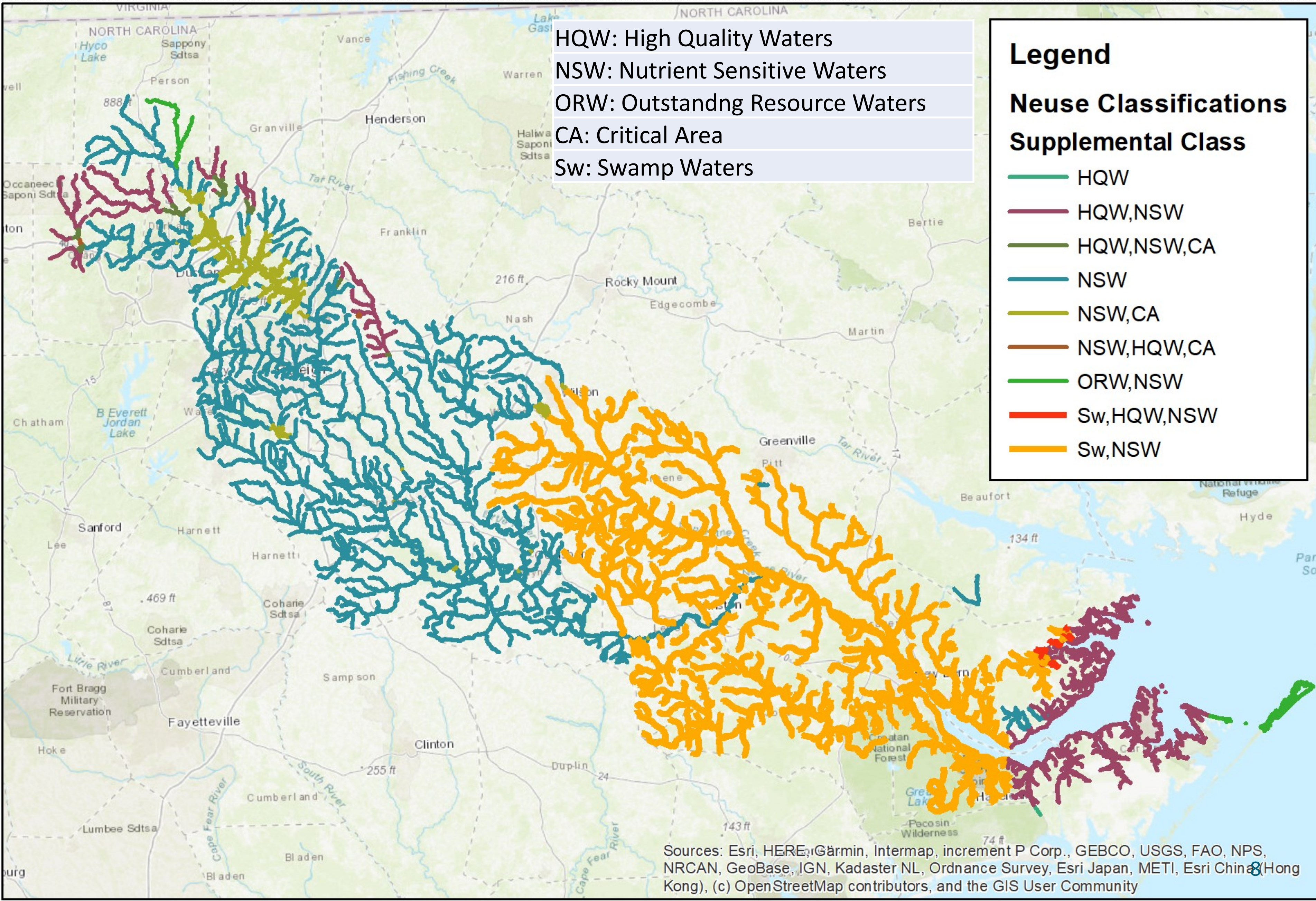
- Classifications are designations that define the best uses to be protected within each water body
- For example: swimming, fishing, drinking water supply
- Classes carry with them an associated set of WQS to protect those uses.

Primary Classifications in the Neuse Basin

B: Primary Contact Recreation, Fresh Water
C: Aquatic Life, Secondary Contact Recreation, Fresh Water
SA: Market Shellfishing, Tidal Salt Water
SB: Primary Contact Recreation, Tidal Salt Water
SC: Aquatic Life, Secondary Contact Recreation, Tidal Salt Water
WS-I: Water Supply I
WS-II: Water Supply II
WS-III: Water Supply III
WS-IV: Water Supply IV
WS-V: Water Supply V



Supplemental Classifications



NC DO Standards

Fresh Water DO Standards

- Classes B, C and WS
- Not less than 6.0 mg/l for trout waters;
- For non-trout waters, not less than a daily average of 5.0 mg/l with an instantaneous value of not less than 4.0;
- Swamp waters, lake coves, or backwaters, and lake bottom waters may have lower values if caused by natural conditions

Salt Water DO Standards

- Classes SA, SB and SC
- Not less than 5.0 mg/l, except that swamp waters, poorly flushed tidally influenced streams or embayments, or estuarine bottom waters may have lower values if caused by natural conditions.

HQW – Additional Standards

- Specific effluent limitations for oxygen consuming wastes: BOD5= 5 mg/l, NH3-N = 2 mg/l, and DO = 6 mg/l.
- Cumulative Effects <= 0.5 mg/l DO:
  More stringent limitations will be set, if necessary, to ensure that the cumulative pollutant discharge of oxygen-consuming wastes does not cause the DO of the receiving water to drop more than 0.5 mg/l below background levels, and in no case below the standard.

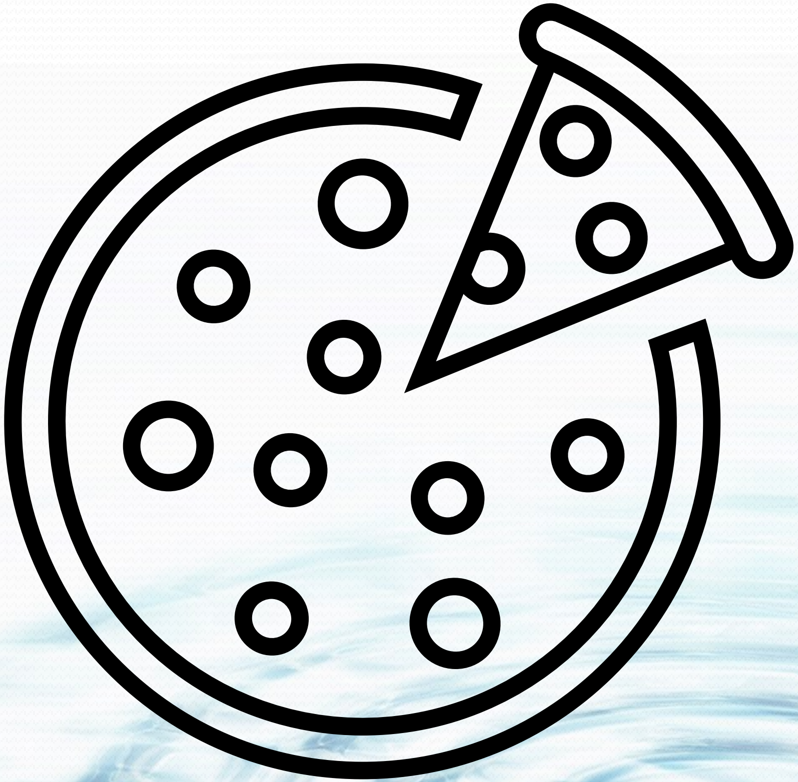
Swamp Waters DO Standards

- Session Law 2022-43, House Bill 219, effective 6/30/2022.
- "For surface waters of the State that have naturally occurring low dissolved oxygen levels, as determined by the Department, permitted wastewater discharges to such surface waters shall not cause a reduction in the dissolved oxygen levels of such surface waters of more than 0.10 mg/l below the approved modeled in-stream dissolved oxygen level for the surface waters at total permitted capacity for all discharges to such surface waters."
- GA and SC use 0.1 mg/l

Wasteload Allocation (WLA)

- **Loading Capacity**: the total amount of pollutant load that can be assimilated in the stream while maintaining the DO standard

- **Wasteload Allocation**: the portion of the loading capacity that is allocated a point source discharge.



Calculating WLAs

Water Uses/ Classifications

DO Standards

Waterbody Characteristics

Impairments

→

Water Quality Model Analysis

→

Loading Capacity & WLA

Who Does the Analysis?

- Publicly owned facilities can request speculative limits from DWR
  - NDPES Unit: Simple modeling analyses
  - Modeling and Assessment Branch (MAB): More complex modeling analyses
  - Permittee should review!
- Permittees can submit their own modeling (need DWR approval)

Modeling Process for Permittees

1. Preliminary modeling analysis [optional]
2. Scoping meeting with MAB
3. Study plan
4. Field data collection
5. Model analysis
6. Submit modeling report to DWR for review

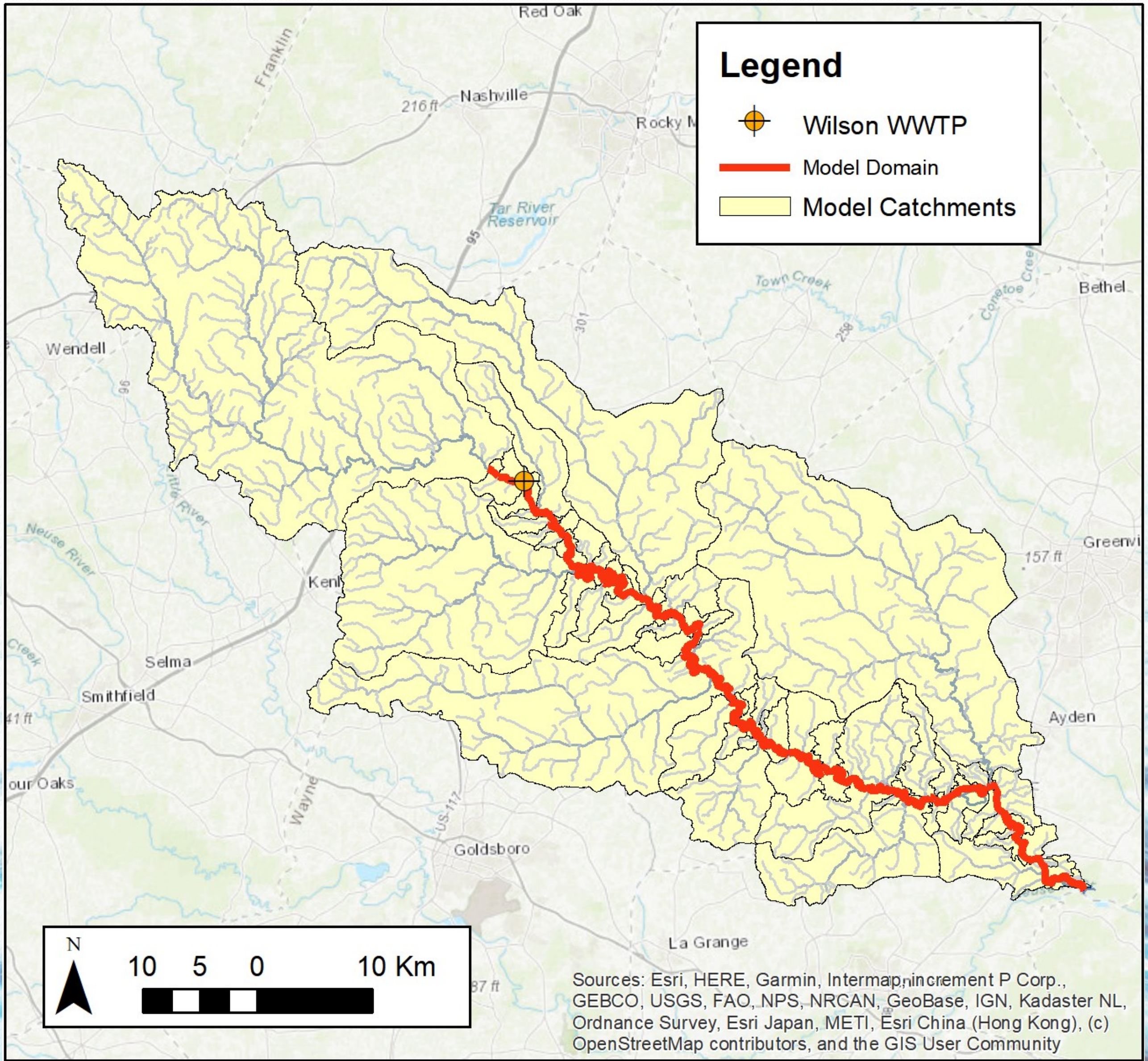
Study Plan

1. Project Team Organization / Responsibilities
2. **Modeling Analysis Plan**
3. Data Management
4. Quality Assurance
5. Schedule

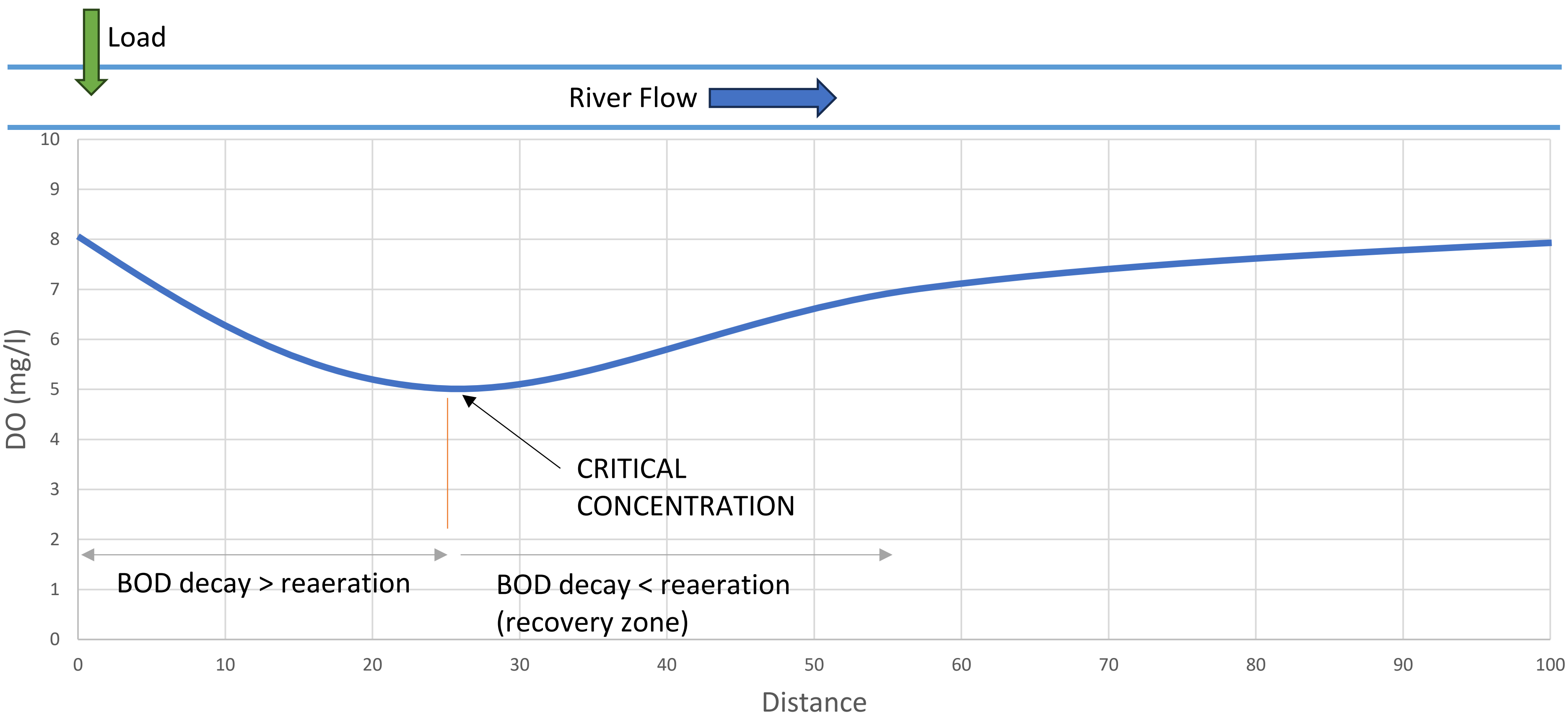
Modeling Plan Section

- Model geographic scope
- Model endpoints
- Temporal scope
- Model selection
- Model configuration
- Model data needs
- Field data collection
- Model kinetics
- Model calibration/validation
- Model performance targets
- Model application
- Model sensitivity analysis

Geographic Scope



DO Impact Downstream from Point Source



Temporal scope

- Should consider both the observed WQ (i.e., when is DO lowest?) and the DO standard
- Most common critical period is the low-flow, high temperature summer period
- Floods that pick up large amounts of organic debris from adjacent floodplains may result in severe DO depletion

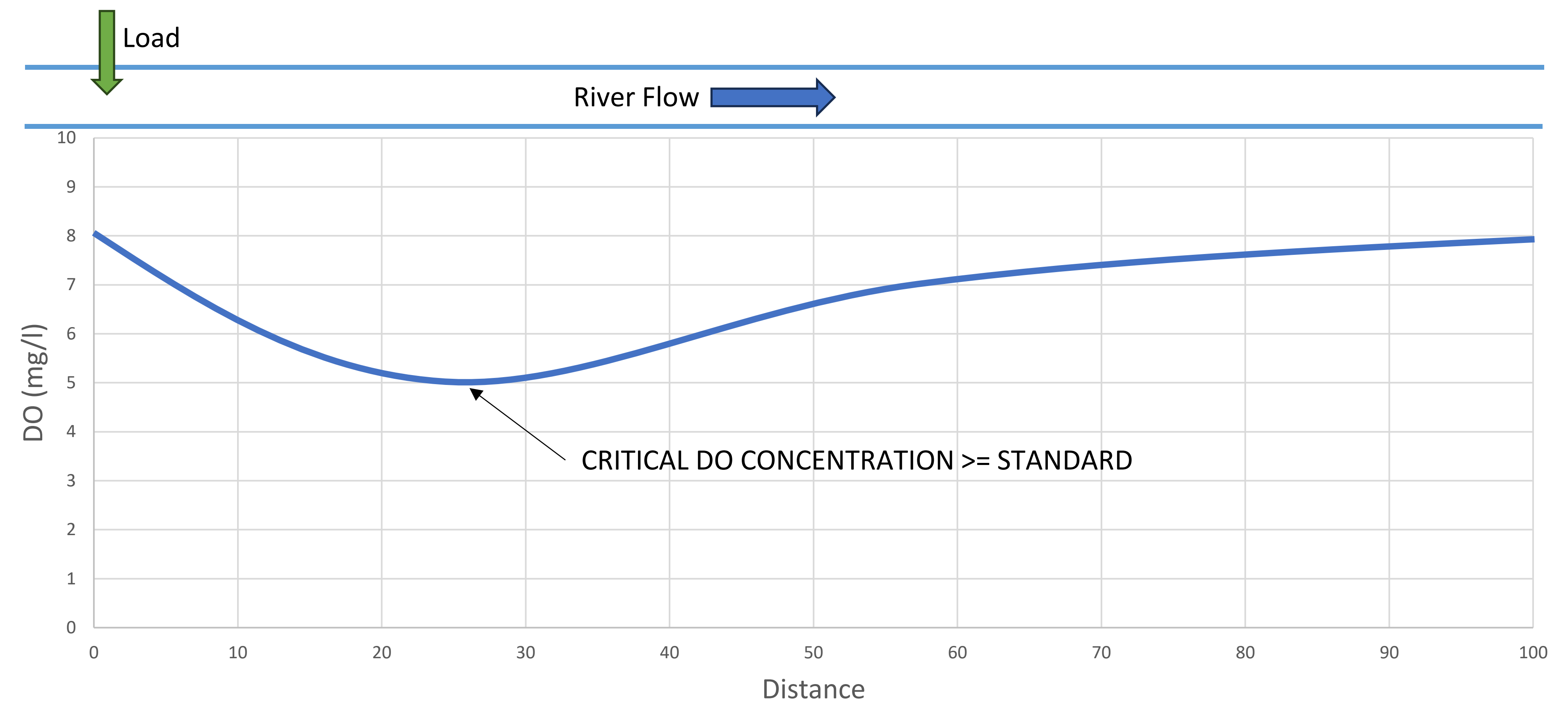
Technical Guidance Manual for Performing Waste Load Allocations, Book II, Streams and Rivers, Chapter 1, BOD/DO. Environmental Protection Agency. Report EPA-440/4-84-020. September 1983.

DO Standard Considerations

Modeling Absolute DO Standards

(e.g., not less than 4.0 mg/l, 5.0 mg/l daily average)

1. Model steady-state critical conditions (worst case):
   - Low river flow, warm temperature, low ambient river DO



Modeling Absolute DO Standards

1. Steady-state
   - Constant worst case
2. Quasi-steady state
   - Constant worst case flows, plus daily variations (heat, algae/plants and water quality kinetics)

Modeling Absolute DO Standards

1. Steady-state
2. Quasi-steady state
3. Dynamic: time variable
   - Variable of flow and water quality conditions
   - Estuaries
   - Episodic events (e.g., stormwater runoff, algae blooms, etc.)
   - Need for standards that allow % time exceeded

Modeling Swamp Water DO Standards

- Relative standard: <= 0.10 mg/l reduction
  Compare discharge scenario to baseline condition (no discharge).

Modeling Sw DO Standards

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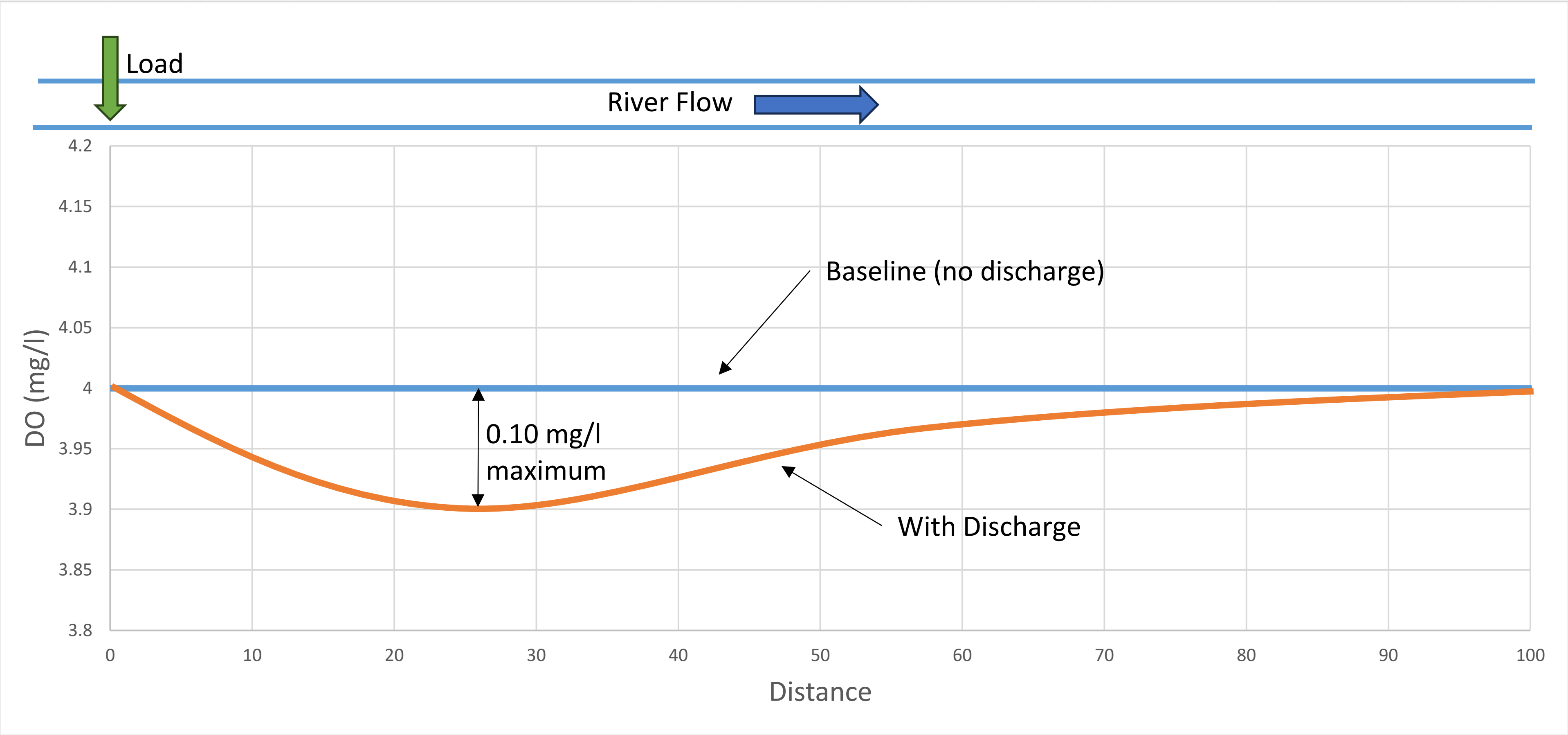
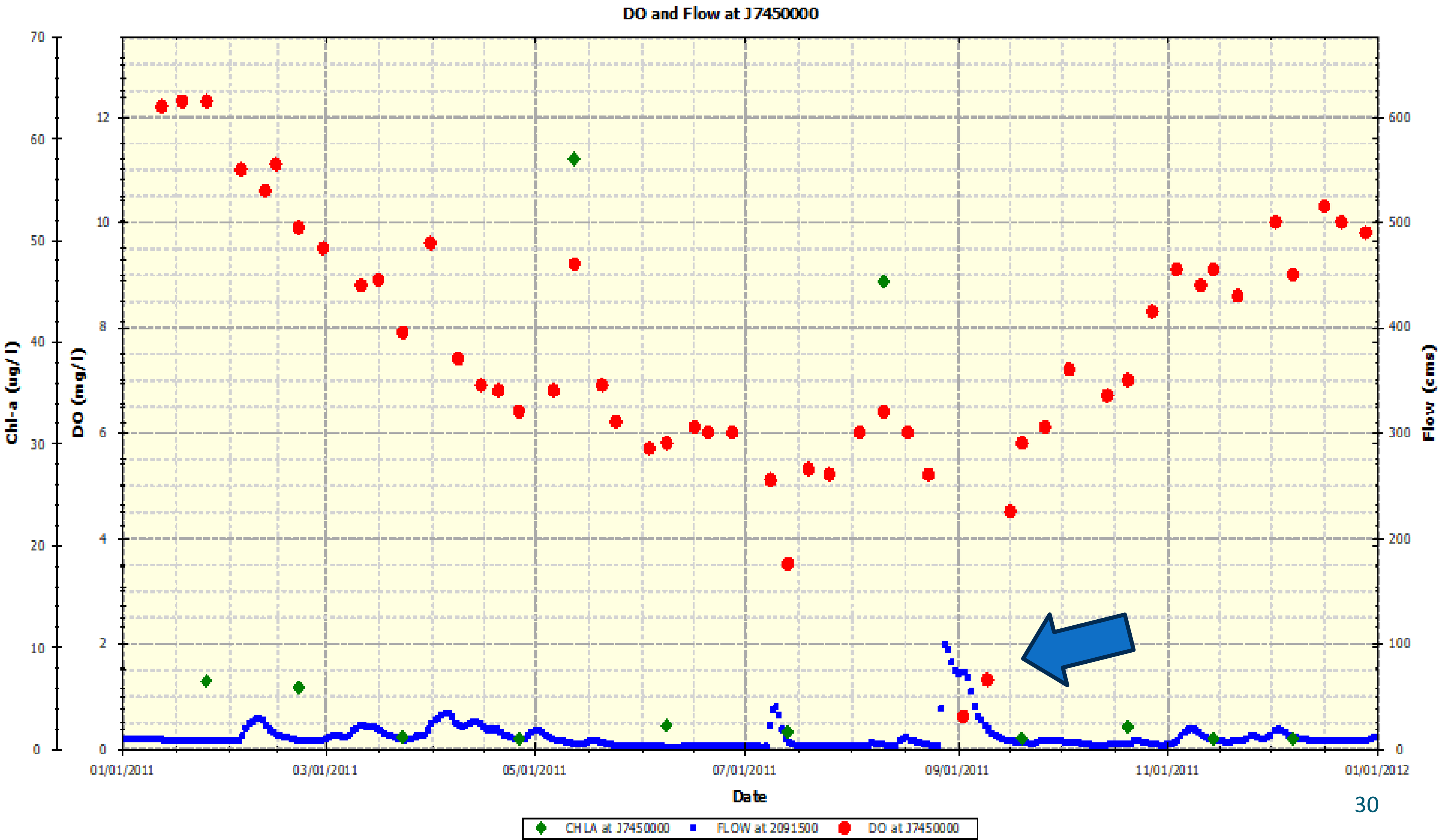


Modeling Sw DO Standards

1. Steady-state critical conditions*
2. Quasi-steady state: Steady-state critical flow conditions + diel (daily) variations
3. Dynamic: Time variable

*Critical conditions may not be when ambient DO is lowest. Instead, critical conditions are when discharges cause greatest reduction in DO while ambient DO is low.

Example: Contentnea Creek



Example: Contentnea Creek

- When will point source discharges have greatest adverse effect on DO (largest reduction)?
- Low flow
  - Less dilution and longer residence time $\rightarrow$ greater DO reduction from discharge
  - Point source discharge will have a greater impact
- High flow
  - More dilution and shorter residence time $\rightarrow$ less impact on DO
- $\therefore$ Modeling high flow event not needed for Sw WQS, even though that is associated with lowest absolute DO

Model Selection and Configuration

Focus on Important Features

1. What are important features of water body system?
   - Analyze available WQ monitoring data
   - What affects DO in the system?
   - What affects transport and fate of the discharged effluent?
2. Select the simplest model that retains all important features of the system.
   - Overly complex model will not usually result in an improved simulation and may increase uncertainty in the analysis. (and can add cost!)
3. Select model based on ease of application, cost and problem significance

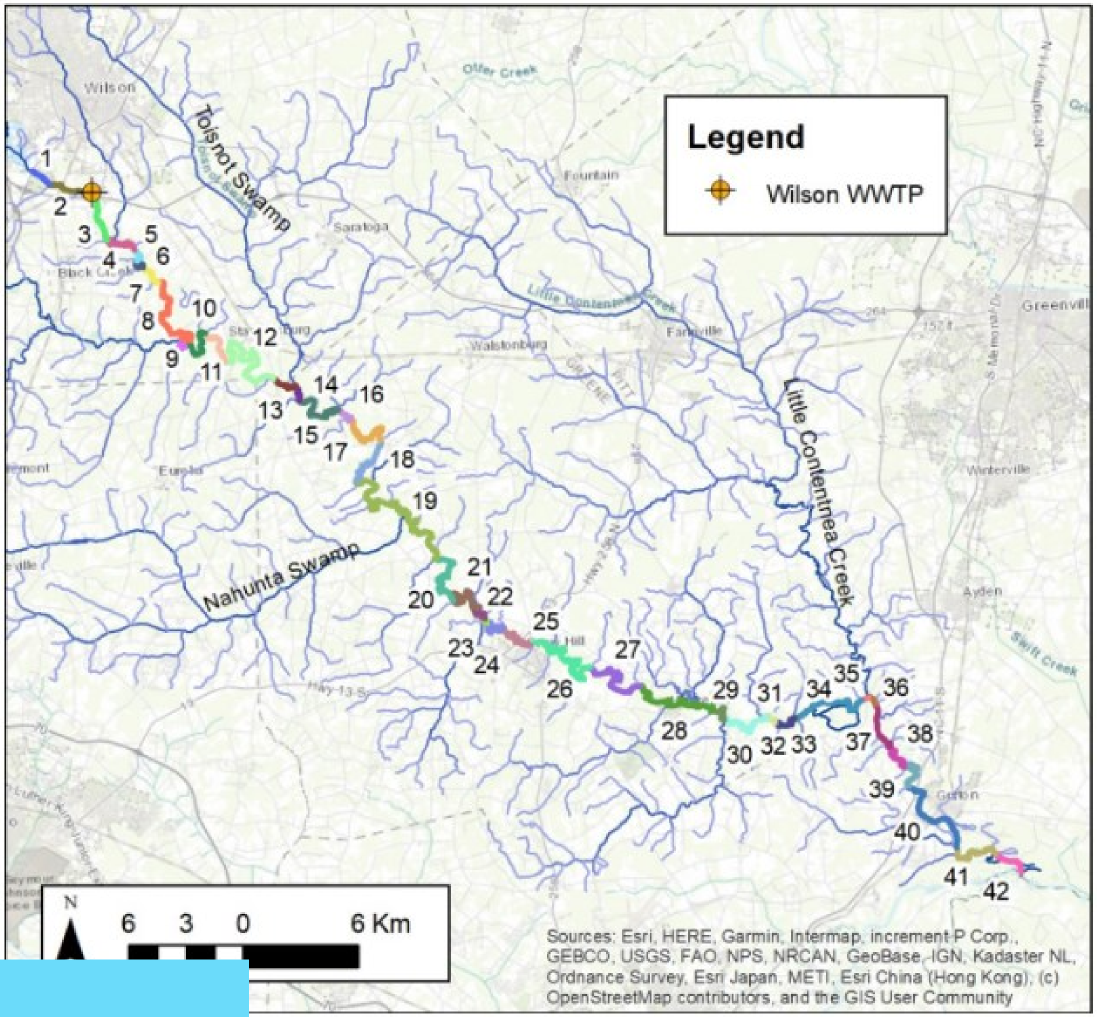
Technical Guidance Manual for Performing Waste Load Allocations, Book II, Streams and Rivers, Chapter 1, BOD/DO. Environmental Protection Agency. Report EPA-440/4-84-020. September 1983.

Model Dimensions

- Most streams & rivers: 1D
- Lakes and reservoirs:
  - 1D if shallow
  - 2D if deep and vertical stratification (multiple vertical layers),
  - 2D if need to resolve lake arms (2D horizontal grid)
  - 3D if vertically stratified and need to resolve lake arms
- Estuaries
  - 1D, 2D or 3D

Example: Contentnea Creek

- DO gradients along longitudinal axis of the stream
- Minor variations in vertical dimension
  - Contentnea Creek is shallow during low flow conditions
- Minor horizontal variations
  - Narrow receiving stream with no wide impoundments



One-Dimensional model appropriate

Loads, DO Sources, and DO Sinks

Source	**Options**
Point source discharges	• Constant • Dynamic (good for multiple discharges)
Nonpoint sources (watershed)	• Steady-state (dry weather, low flow) • Dynamic (wet weather)
Sediment oxygen demand (SOD)	• Steady-state • Dynamic (model-calculated in response to loads)
Algal productivity and respiration	• None • Diurnal effects (quasi-steady state) • Dynamic

Model Software

- Common 1D models in EPA Region IV:
  - QUAL2E
  - QUAL2K
  - WASP
- 2D models
  - WASP
  - EFDC
  - CE-QUAL-W2
- 3D models
  - WASP
  - EFDC

Data Needs

- Inputs for model geometry
  - Stream cross-sections
- Velocities and water levels
  - Velocities and water levels for calibration, or
  - Stage-flow-velocity relationships
- Inputs for model boundaries
  - Upstream, tributaries, atmosphere
  - Water chemistry, physical (flow, temperature)
- Water chemistry for calibration at locations in model domain
- Rates (SOD, CBOD decay, ammonia decay)

Field Data Collection

- What data is not already available?
- Focus model calibration data collection on periods as similar as possible to critical conditions (e.g., low flow warm weather)

Modeling Process for Permittees

1. Preliminary modeling analysis
2. Scoping meeting with MAB
3. Study plan
   - Get approved by DWR
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Notes and Recommendations

1. If DWR completes analysis, complete a review
   - Will more data or model refinement help?
2. If you complete the analysis:
   - Conduct preliminary analysis
   - Plan ahead: Allow for a long schedule
3. Swamp Waters:
   - Rule change to 0.1 mg/l DO?

Questions?

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