APPROACHES TO NUTRIENT CRITERIA DEVELOPMENT: PRINCIPAL APPROACHES

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Outline

- Guidance
- Classification
- Analytical Approaches
  - Reference estimation
  - Stressor-response
  - Mechanistic models
  - Scientific literature

Nutrient Criteria Development: Guidance

Nutrient Criteria Guidance

- Nutrient
  - P
  - N
- Biological
  - TOC
  - Chl a/Biomass
  - Clarity
  - DO
  - macrophyte coverage/biomass
  - biological indicators
- Could add:
  - User perception endpoints
  - Nuisance algal abundances
  - Toxin/other chemical levels (e.g., MIB)

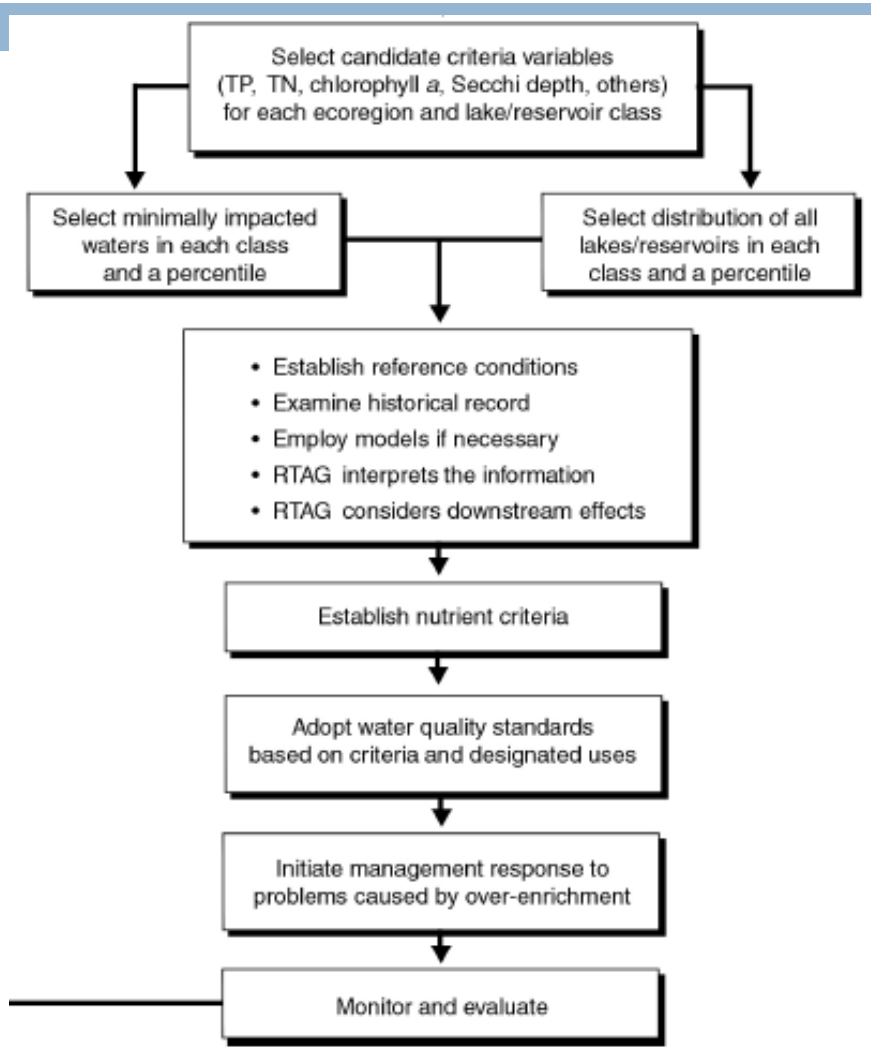
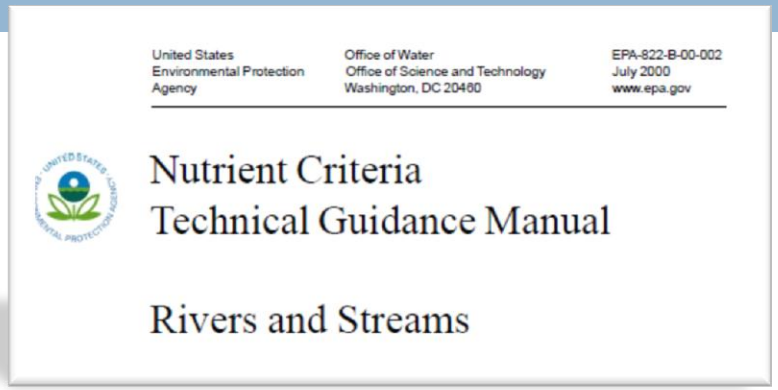


Figure 1.2. Flowchart of the nutrient criteria development process.

General Approaches: Setting Targets


United States Environmental Protection Agency
Office of Water
Office of Science and Technology
Washington, DC 20460
EPA-822-B-00-002
July 2000
www.epa.gov

Nutrient Criteria
Technical Guidance Manual

Rivers and Streams

- Nutrient Criteria Guidance
  1. Classification
  2. Reference Condition Approaches
  3. Stressor-Response Approaches*
  4. Scientific Literature and Expert Judgment
  5. Mechanistic Models
  6. Multiple Lines of Evidence

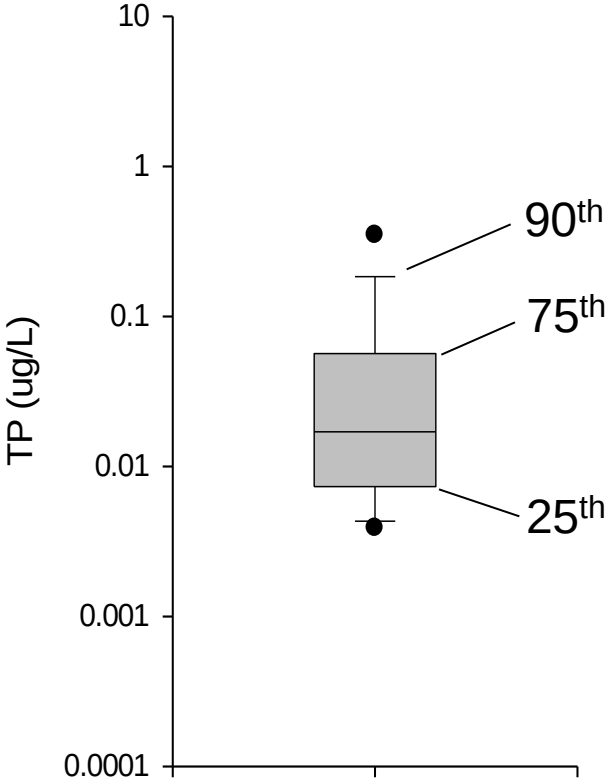
- TMDL Guidance for Nutrients involves a very similar set of steps
- *Specific guidance for stressor-response approaches now exists

General Approach: Classification

- Classification
  - Apples and Oranges
  - Separate waterbodies into ones expected to exhibit similar nutrient dynamics and biological responses in the absence of human impacts
    - *A priori*
      - Flow, climate, geology, hydrology
      - Ecoregions, physiographic provinces
    - *A posteriori*
      - Analyze nutrient/response dynamics in reference sites across landscape
  - Can also be refined during analysis

General Approach: Reference

- Reference
  - Ideally natural or near-natural
    - Integrity
  - Often "least disturbed"
  - May need to use all sites
  - Select a percentile
    - Management decision that involves risk/acceptability of reference
    - Will depend on quality of reference, sampling, and risk acceptability
  - Linkage to use?



General Approach: Reference

- Continued refinement

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Developing nutrient criteria and classification schemes for wadeable streams in the conterminous US

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wadeable streams across the 48
streams in the Pacific Northwest

Policy Analysis

Natural Background Concentrations of Nutrients in Streams and Rivers of the Conterminous United States

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Determining natural background concentrations of nutrients in watersheds in the developed world has been

a matter of conjecture. Data from reference sites, however, provide a potential baseline for estimating the extent of change in nutrient levels in developed watersheds that has occurred since the time that cultural sources of nitrogen and phosphorus first began to affect aquatic ecosystems.

Federal, state, and tribal officials in the United States are currently attempting to develop preliminary criteria and standards for total nitrogen (TN) and total phosphorus (TP) in the nation's surface waters to reduce the risk of eutrophication (*5–7*). To allow for regional variation in nutrient criteria, the U.S. Environmental Protection Agency (EPA) has divided the nation into 14 "nutrient ecoregions" (*5*) based on climate, physiography, and vegetation cover (Figure 1). Although the goal of criteria development is not to set nutrient standards at natural background levels, knowledge of the

General Approach: Reference

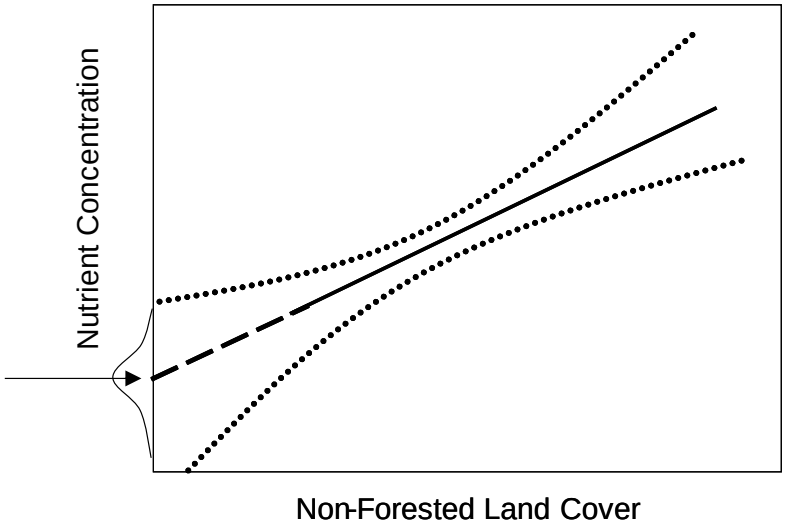
- Example: South Carolina lake TN, TP, and Chl a criteria
- Used 75th percentile of SC specific lake nutrient data to generate criteria
  - Based on EPA recommended approach

b. Numeric nutrient criteria for lakes are based on an ecoregional approach which takes into account the geographic location of the lakes within the State and are listed below. These numeric criteria are applicable to lakes of 40 acres or more. Lakes of less than 40 acres will continue to be protected by the narrative criteria.

(1) For the Blue Ridge Mountains ecoregion of the State, total phosphorus shall not exceed 0.02 mg/l, chlorophyll *a* shall not exceed 10 ug/l, and total nitrogen shall not exceed 0.35 mg/l.

General Approach: Reference

- Modeling Reference
  - Model the reference condition based on disturbance
  - Also can incorporate classification into this
    - Add factors for ecological setting, size, date, etc.



PIEDMONT TN MODEL
LogTN = 0.1 + 0.49*Agriculture + 0.14*Urban
TN = $10^{0.1}$ = 1.0 mg/L

General Approach: Reference

- Example: Kansas

Lake and Reservoir Management 22(2):151-159, 2006
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Determining Ecoregional Reference Conditions for Nutrients, Secchi Depth and Chlorophyll *a* in Kansas Lakes and Reservoirs

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Abstract

Determining ecoregional reference conditions for nutrients, Secchi depth and
and Reserv. Manage. 22(2):151-159.

consideration in the development of scientifically defensible aquatic nutrient
stratified data to determine reference conditions in Kansas lakes and reservoirs
ecchi depth, and planktonic chlorophyll *a* (chl *a*). First, minimally developed
ating geographical databases and visual basin surveys. Lakes and reservoirs in
ast impacted "reference" waters. Second, median nutrient, Secchi depth, and chl
akes and reservoirs and applied as indicators of reference condition (trisection).
is applied to estimate water quality conditions in the absence of anthropogenic
onal effect on the trophic status of minimally impacted reference water bodies,
nificant ecoregional differences. Lack of ecoregional effect in reference bodies
ropogenic influences rather than natural regional characteristics. Reference con-
adly agreed for all parameters and were generally at or less than literature values
and reservoirs worldwide. Reference values for total phosphorus were primarily
acterial blooms. Overall, the data suggest that multiple methods can be used to
lakes and reservoirs reference condition corresponds to mesotrophic state.

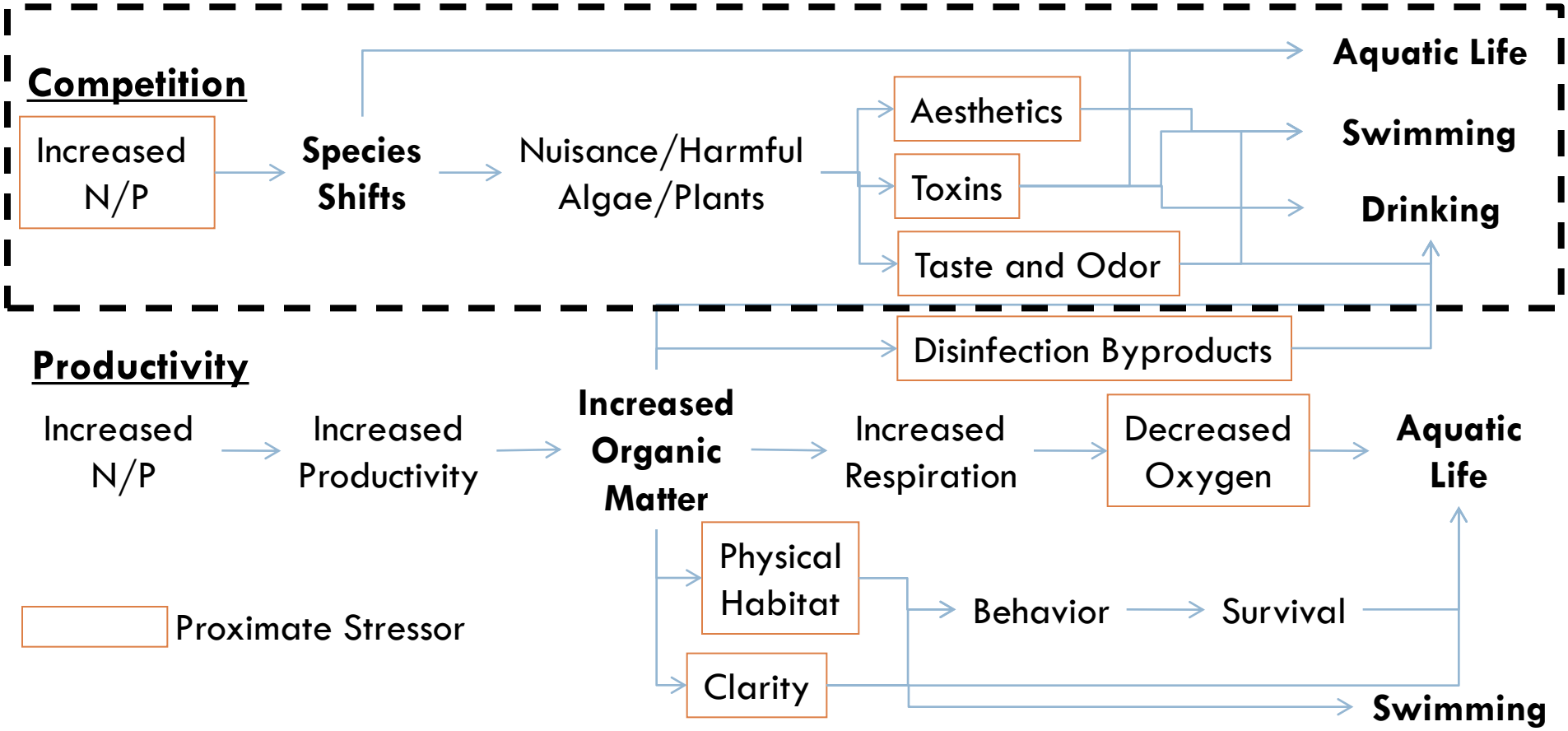
, ecoregion, eutrophication

Table 4.-Reference values for total phosphorus and total nitrogen for reservoirs, rivers and streams in selected U.S. Environmental Protection Agency level III Ecoregions in Kansas. Dodds and Oakes (2004) and Smith *et al.* (2003) values are for rivers and streams in aggregated nutrient ecoregions corresponding to the Level III Ecoregion. Values for Smith *et al.* (2003) are corrected for atmospheric deposition. All values in µg · L^{-1}. "NA" = not analyzed because method did not provide a statistically significant model. Note aggregated ecoregions were used in the two literature sources.

Parameter	Ecoregion	Trisection (Lakes)	n	Extrapolation (Lakes)	n	Dodds and Oakes (Streams)	Smith *et al.* (Streams)
Total Phosphorus	Central Great Plains	44	16	62	40	23	58
	Central Irregular Plains	20	33	27	97	31	48
	Flint Hills	19	9	23	25	59	60
	Western Corn Belt	25	6	27	17	23	54
Total Nitrogen	Central Great Plains	695	8	NA		566	258
	Central Irregular Plains	362	17	NA		370	150
	Flint Hills	301	13	NA		659	95
	Western Corn Belt	201	4	658	10	215	355

Stressor-Response: General Model

- Competition and productivity lead to impacts
- Many endpoints possible depending on uses



General Approach: Stressor-response

- Identify that concentration associated with an adverse response condition
  - Is this just kicking the can? What is an "adverse condition"?
    - Can be an existing criterion (DO, pH)
    - Could be an existing translator (biocriteria)
    - Can be BPJ (seagrass coverage)
    - Can be estimated from reference
    - Can be identified from S-R relationship
    - Can use a series of S-R models to get from something with an existing value to nutrient criteria?
- Original guidance was vague on stressor-response

Stressor-response is an improving field

United States Environmental Protection Agency

Office of Water
Mail code 4304T

EPA-820-S-10-001
November 2010

Using Stressor-response Relationships to Derive Numeric Nutrient Criteria

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Original Articles

To threshold or not to threshold? That's the question

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DOI: 10.1007/s00267-002-0036-4

Integrating Bioassessment and Ecological Risk Assessment: An Approach to Developing Numerical Water-Quality Criteria

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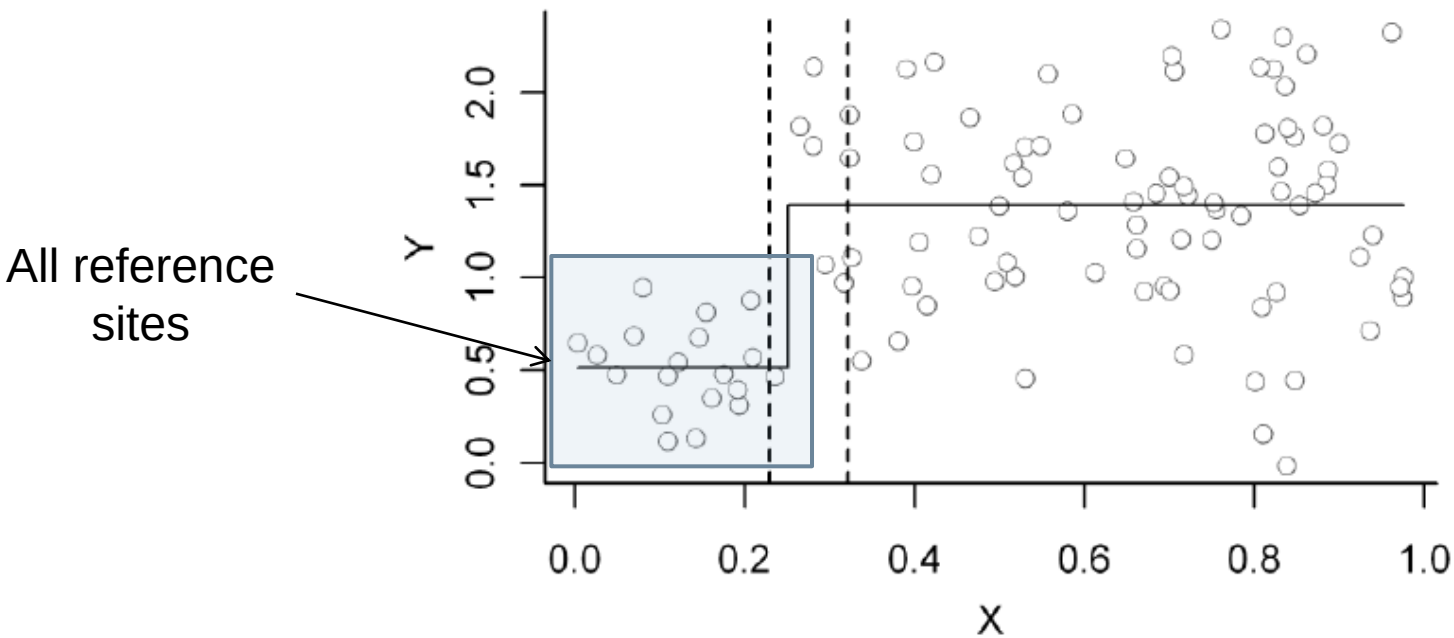
ABSTRACT / Ioassessment is used worldwide to monitor aquatic health but is infrequently used with risk-assessment

five were validated in the experiment. These five core metrics were subjected individually and as an aggregated Nutrient–IBI to nonparametric changepoint analysis (nCPA) to estimate cumulative probabilities of a threshold response to TP. Threshold responses were evident for all metrics and the IBI, and were repeatable through time. Results from the observed gradient indicated that a threshold was ≥50% probable between 12.6 and 19.4 μg/L TP for individual metrics and 14.8 μg/L TP for the IBI. Results from the P-dosing experiment revealed ≥50% probability of a response between 11.2 and

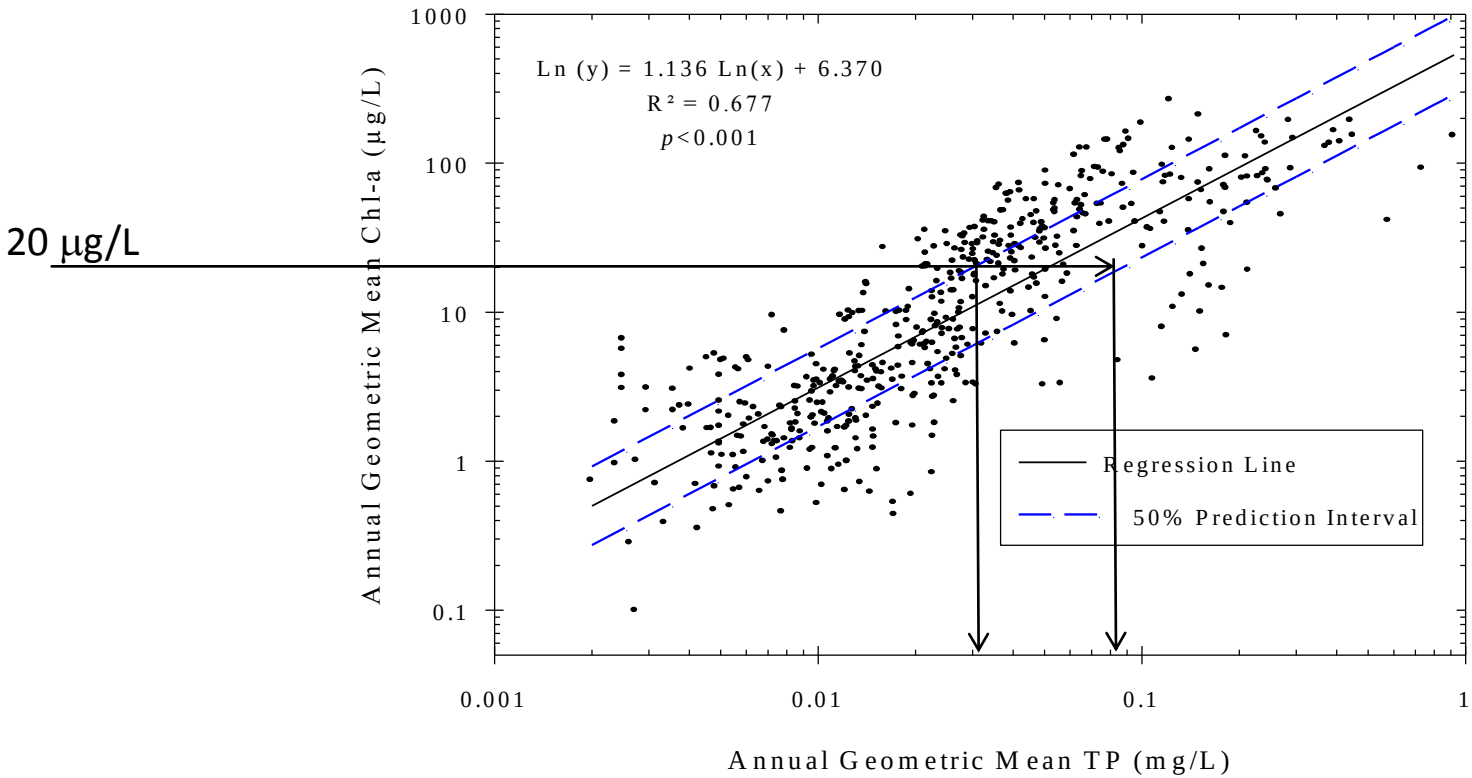
General Approach: Stressor-response

- Empirical Modeling
  - Change points may be informative, but take care…



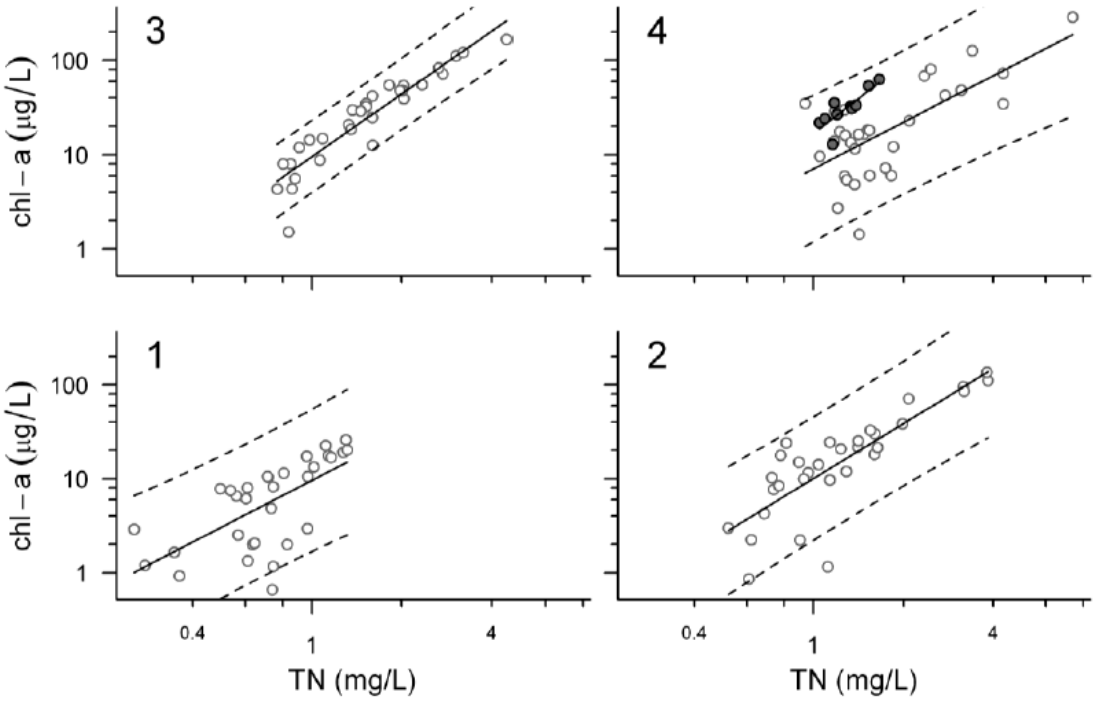
General Approach: Stressor-response

- Empirical modeling – linear models with interpolation



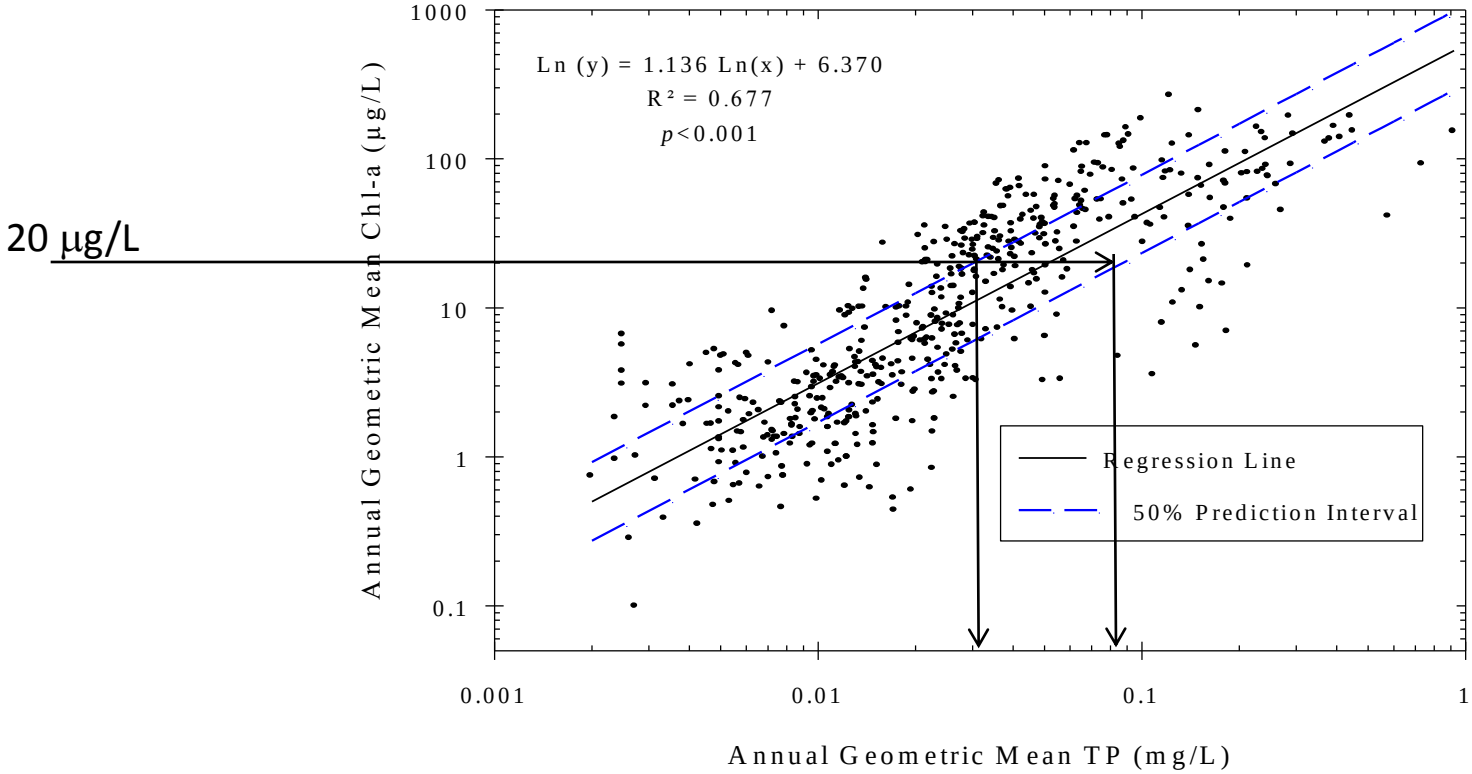
General Approach: Stressor-response

- Controlling for covariation/other variables
  - Classification (e.g., splitting, clustering, propensity classes)



General Approach: Stressor-response

- Example: Florida lake criteria by EPA <u>and</u> FDEP



- Incorporates site specific elements into criteria setting

General Approach: Scientific Literature/Expert Judgment

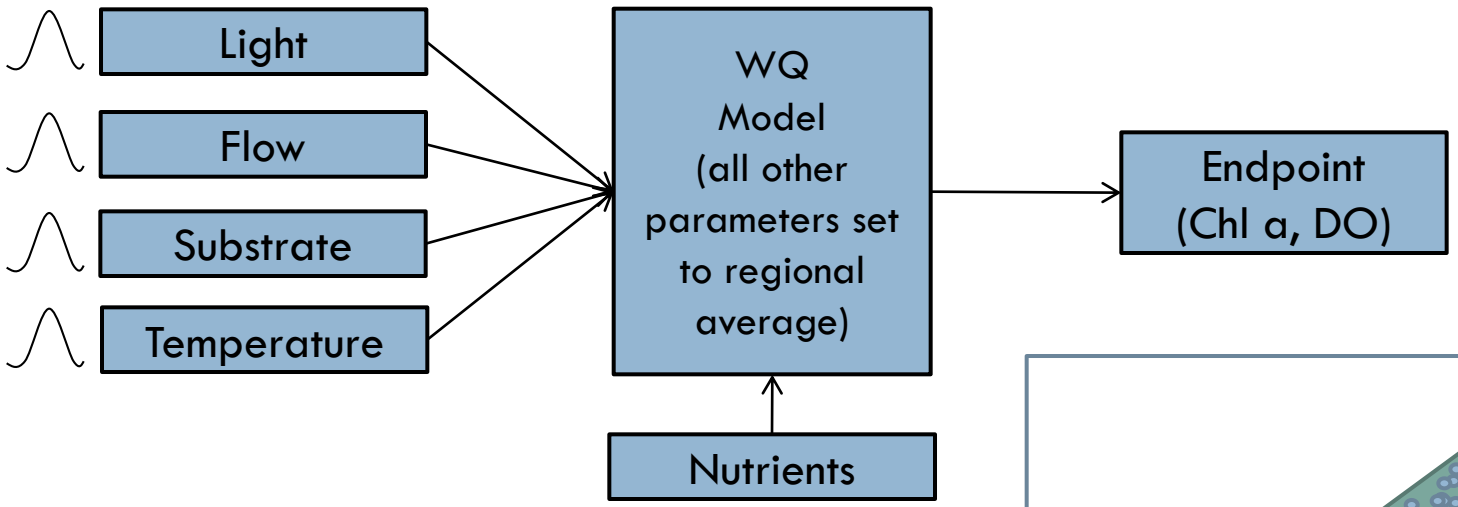
- Voluminous literature on nutrient effects on aquatic systems
  - For example, 9,300 citations in EPA/NSTEPS bibliography alone
- Scientific expertise
  - Criteria development guidance encourages development of technical advisory groups
  - Accumulated knowledge is useful
- No state has relied solely on scientific literature, but all of them use it in support

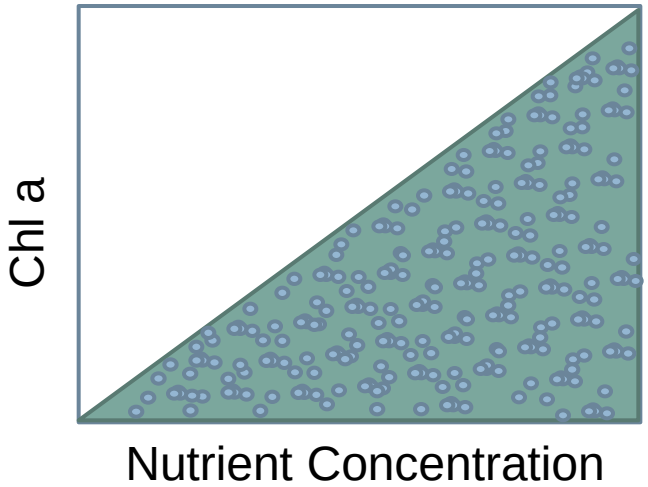
General Approach: Mechanistic Models

- Mechanistic and/or Process Models
  - E.g., WASP, QUAL-2k, EFDC, CE-QUAL, HSPF, MIKE…
  - Model specific endpoints to generate nutrient goals
  - Still need a desired endpoint for something…kicking the can, again
    - Primarily chemical endpoints (DO, clarity, pH), some biological endpoints (Chl a, some species)
    - AQUATOX can do ecological endpoints
    - Run these to back out nutrient concentrations/loads to meet response endpoint
  - Site specific application has limited the utility for regional criteria

General Approach: Mechanistic Models

- Mike's Ideal – Generic Waterbody Models





- Making process models "regional"
- Complement empirical models

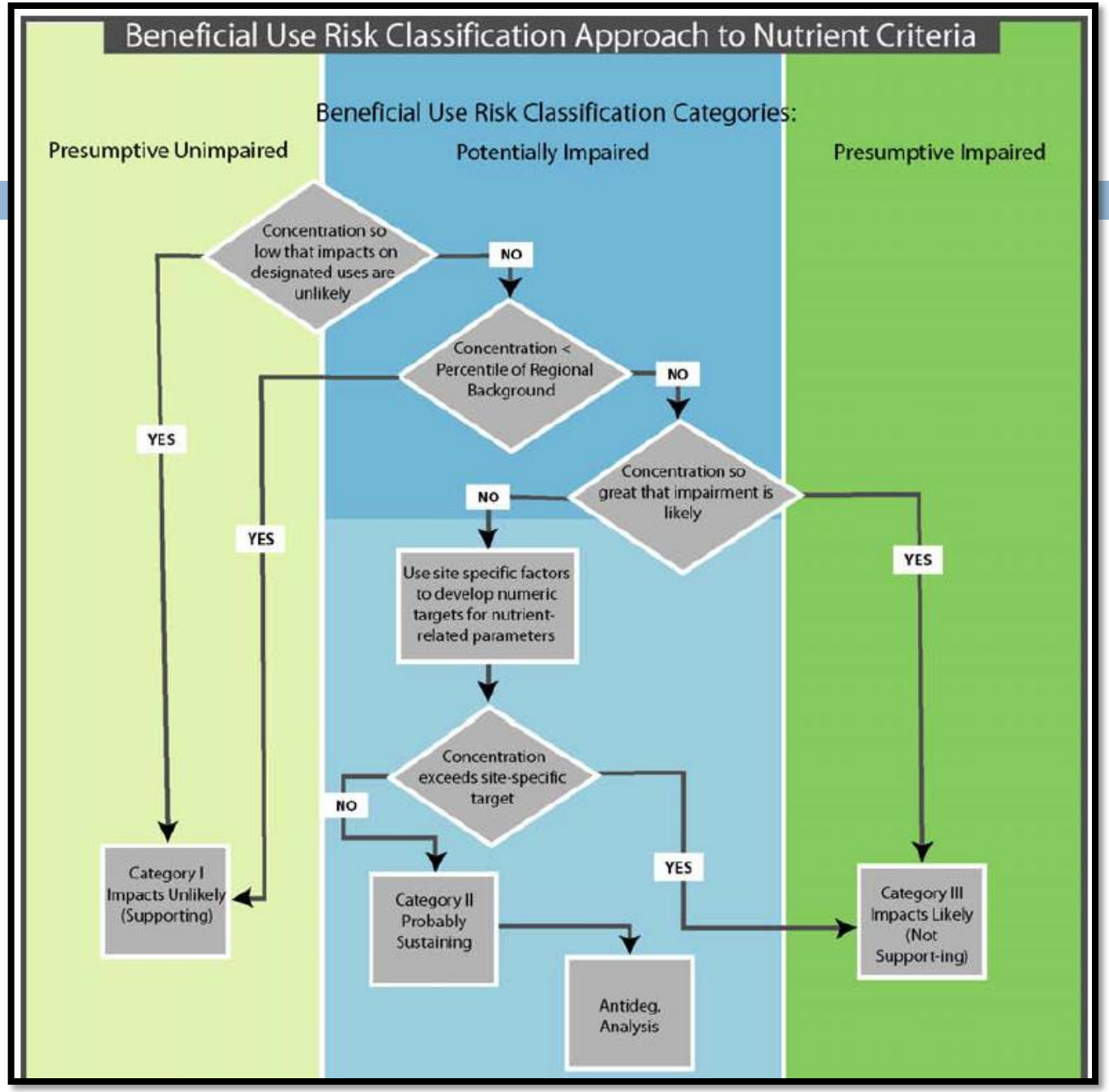
General Approach: Mechanistic Models

- Example: Several states have used mechanistic models to set site-specific nutrient criteria

- Georgia uses water quality models for TMDLs and will use the output of those models to "help refine the lakes' nutrient standards and develop the nutrient standards for the watersheds" (GA EPD, 2008)

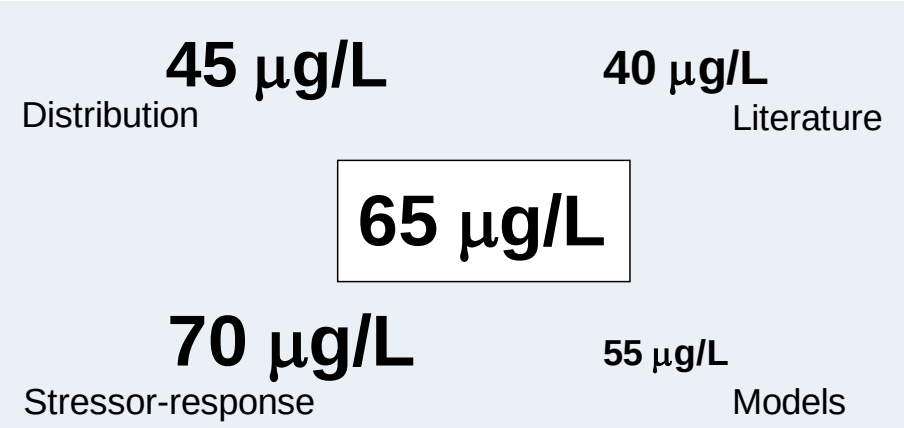
Models

- CA NNE



Multiple Lines of Evidence

- Generally what states use is multiple lines of evidence
- May or may not be weighted



- "A weight of evidence approach that combines one or more of the three approaches described below will produce criteria of greater scientific validity." – USEPA Streams and Rivers Guidance

Outline

- Guidance
- Classification
- Analytical Approaches
  - Reference estimation
  - Stressor-response
  - Mechanistic models
  - Scientific literature

- Now that you have a number, how do you implement it?
  - Traditionally, straight up magnitude, duration, frequency
  - But nutrients have presented challenges