Using Numeric Nutrient Criteria for Nutrient Permitting

Michael Suplee, Ph.D.
Water Quality Standards & Modeling Section
Montana Dept. of Environmental Quality

2017 ACWA Nutrient Permitting Workshop
Boise, ID
December 5, 2017

DEQ
Montana Department of Environmental Quality

Montana

Presentation Outline

1. Overview of numeric nutrient standards development

2. Derivation of the low-flow design flow (14Q5) for permitting nutrients

3. The permitting process

PART 1. Deriving the Nutrient Criteria

Wadeable Streams

Three Components:

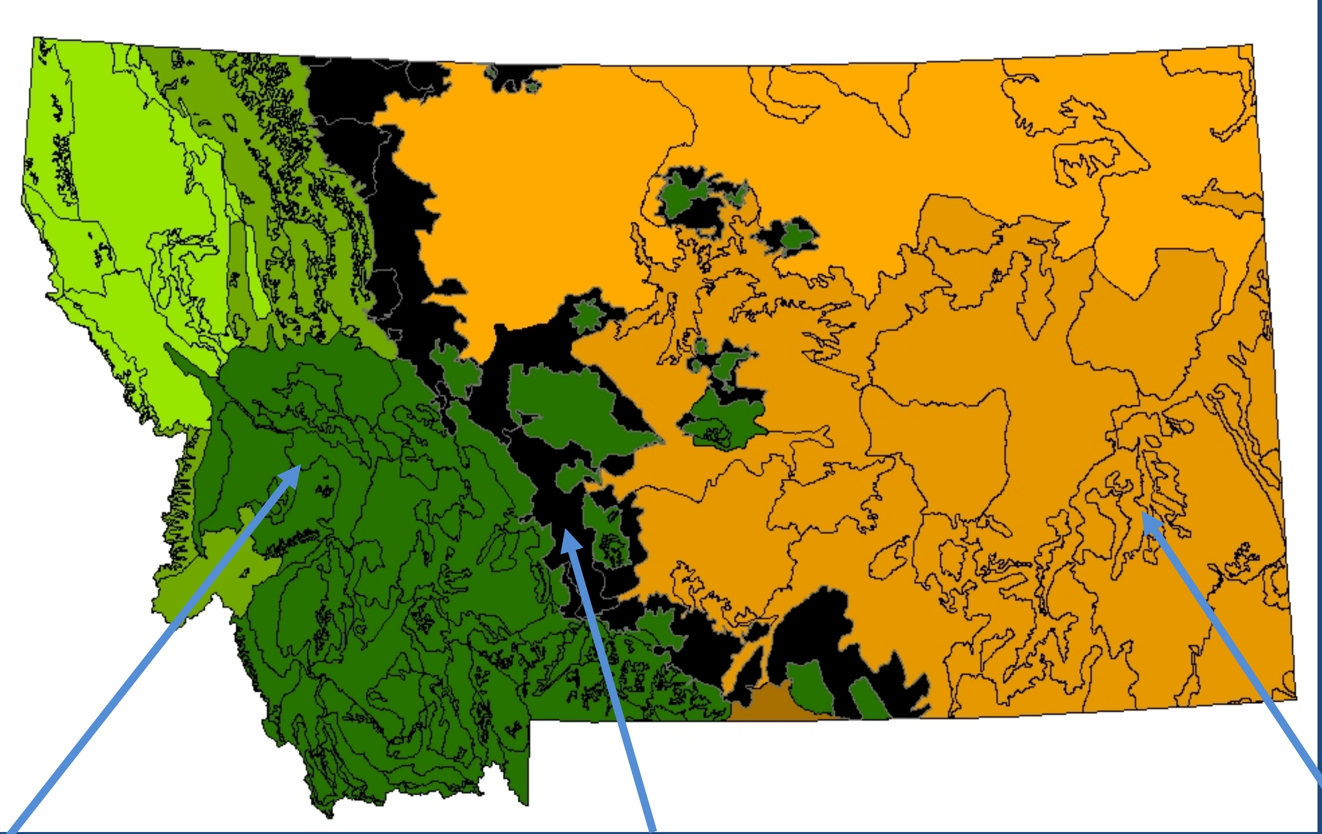
1) Identify geographic zones for specific criteria

2) Understand cause-effect relationships between nutrients and beneficial uses
   - Requires determining “harm to use” endpoints
   - Different expectations for different regions

3) Characterize water quality of reference sites

Nutrient Criteria for Wadeable Streams: the Geospatial Frame

- Nutrient concentrations vary naturally — geology, soils, climate, vegetation
- DEQ tested these frames:
  - Ecoregions (Omernik 1987)
  - Lithology (Montana surface geology)
  - Strahler Stream Order (~watershed area)
- Best frame maximizes variance between zones, minimizes variance within zones
- Focused on reference stream data from the zones

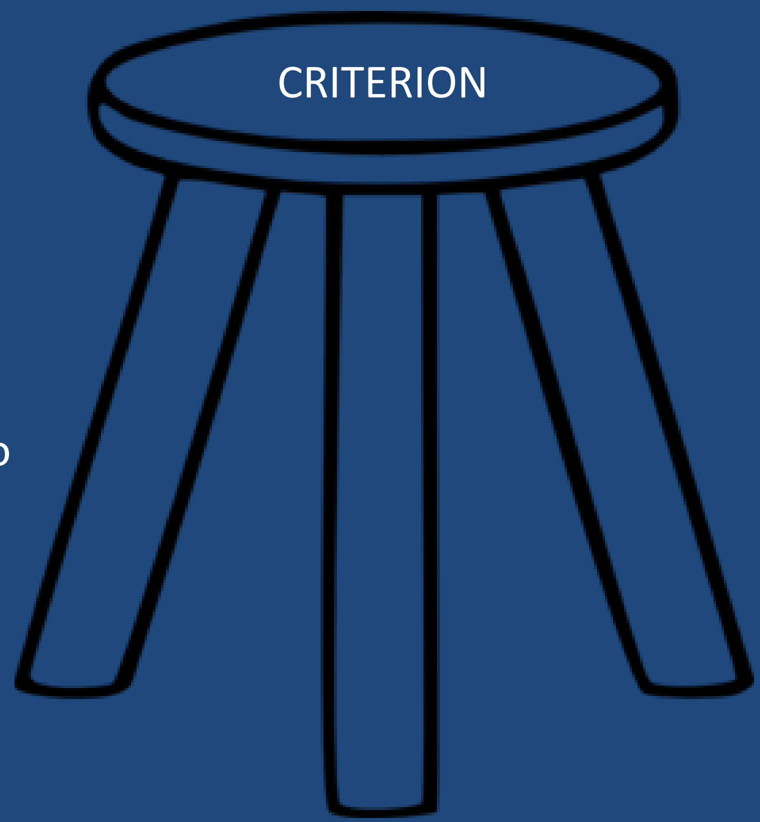


Mountainous

Transitional

Prairie

Montana's Wadeable Stream Nutrient Criteria



N:P Resource Ratio (Redfield Ratio)

Comparison to Regional Reference-site Data

Regional Dose-response studies

Attached algae growth commonly quantified as chlorophyll *a* per square meter of stream bottom

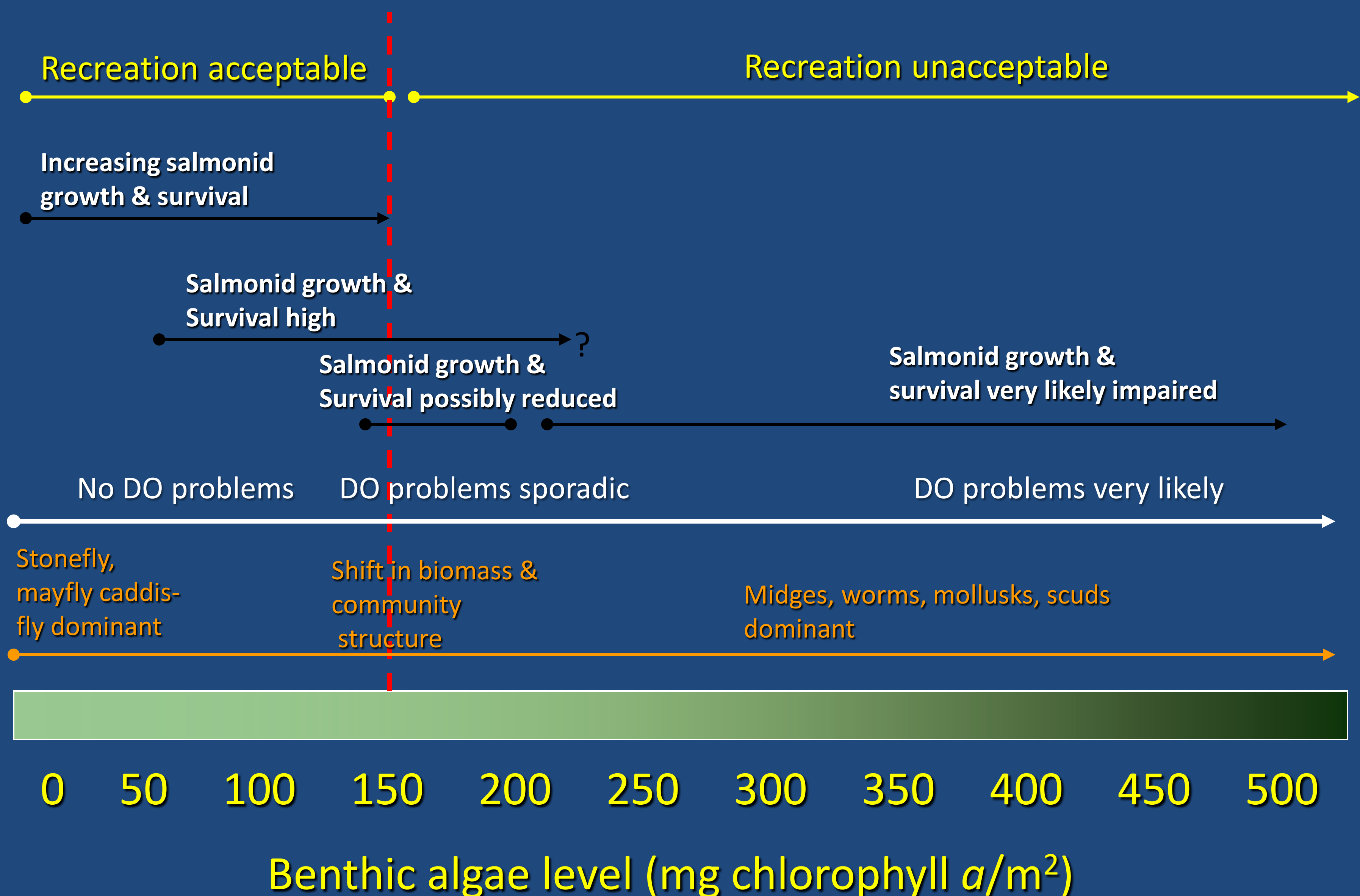
40 mg Chl*a*/m²

120 mg Chl*a*/m²

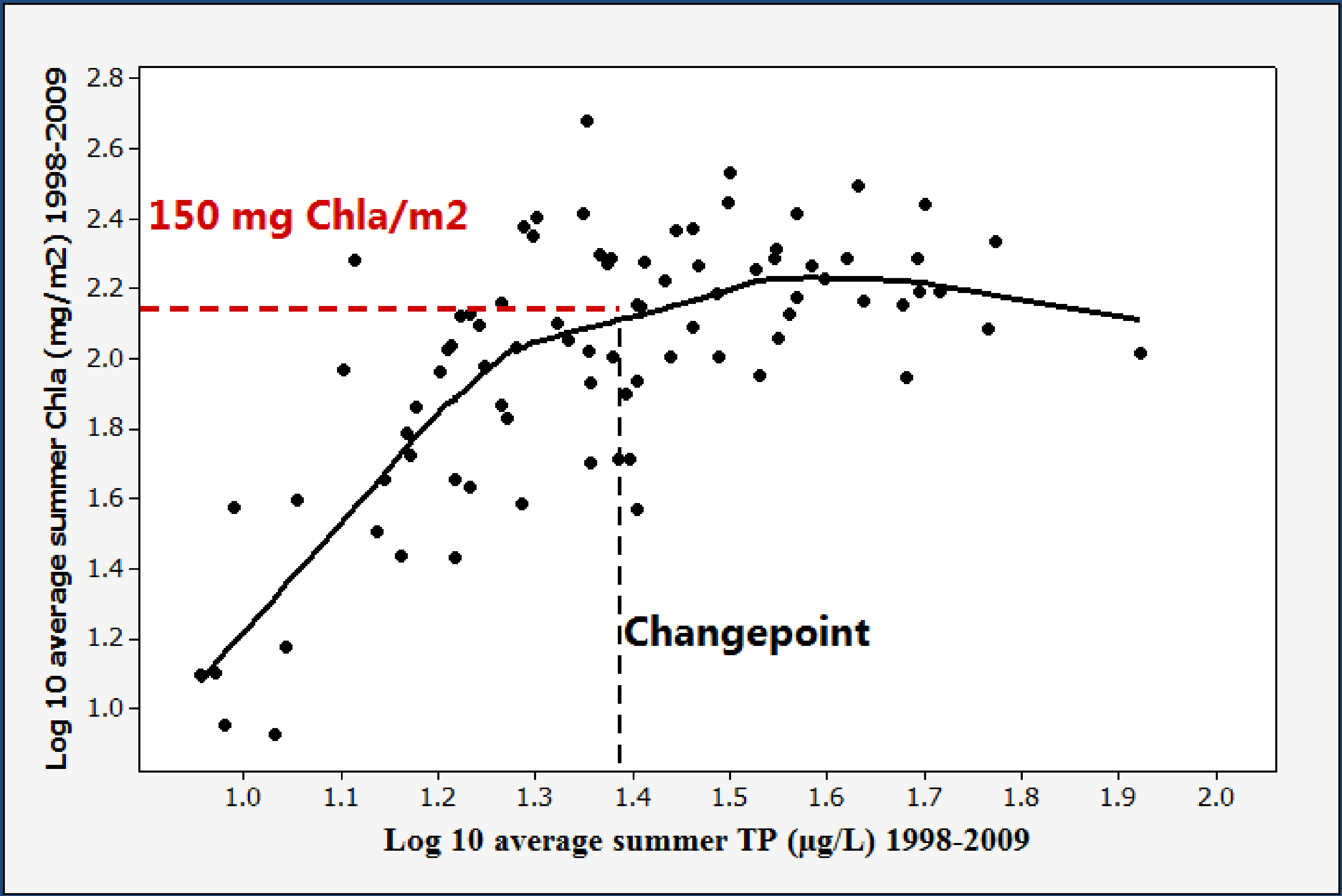
≤ 150 mg Chla/m² nuisance limit per MT public recreation survey
-Suplee et al. (2009)

300 mg Chl*a*/m²

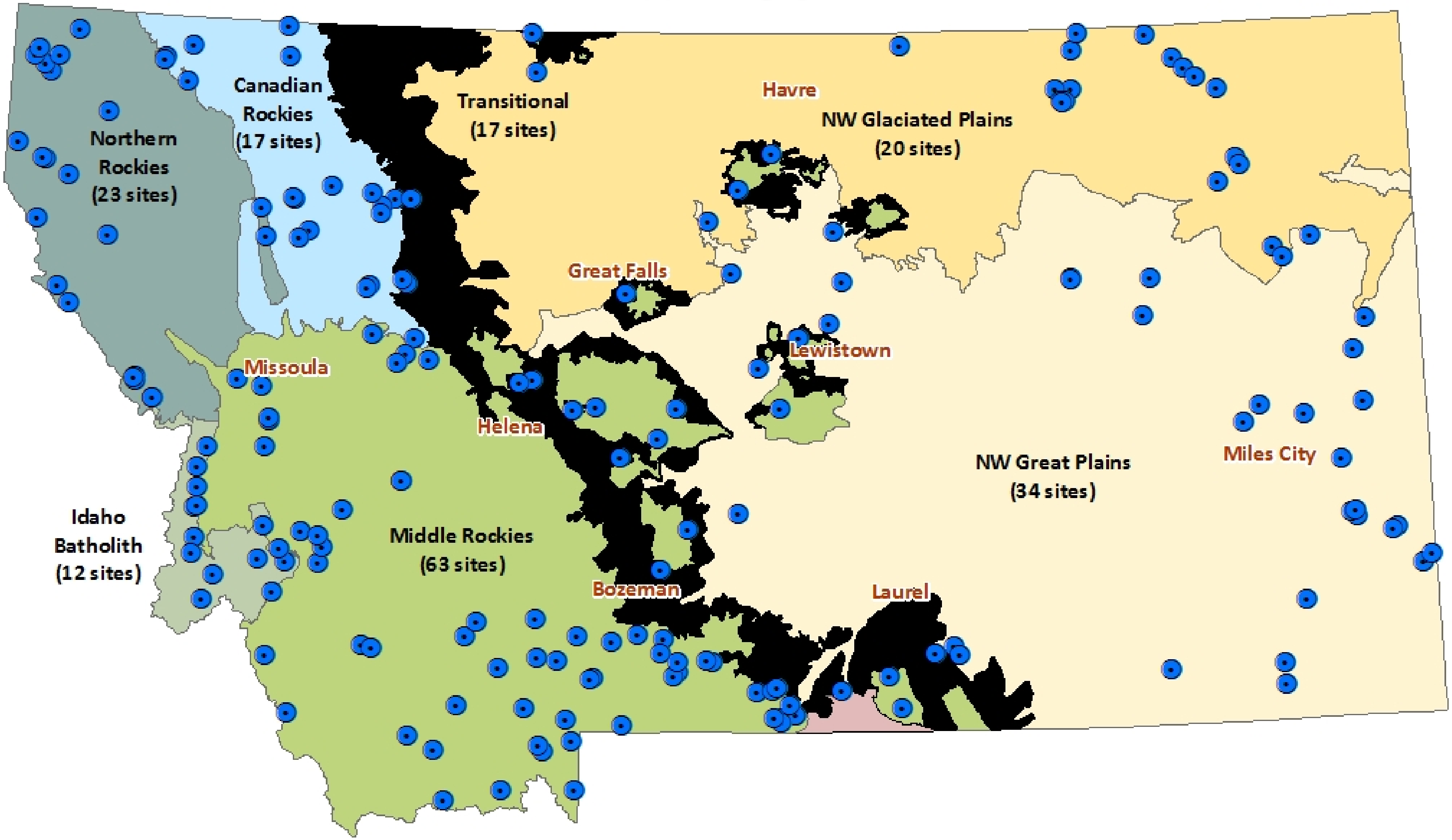
Known/likely effects on wadeable-streams at different algae levels (western MT)



Example Dose-Response Relationship: Clark Fork River, 1998-2009



Stream Reference Sites
n=186



Nutrient Criteria for Large Rivers

Why Mechanistic Models in Large Rivers?

- Traverse multiple coarse-scale ecoregions
- No comparable reference sites available
- Wadeable-stream empirical relationships likely poorly transferable
- Predictive benefits of models:
  - Define endpoints upfront based on other water-quality standards (DO, pH, benthic algae biomass, TDG, TOC)
  - Forecast <u>or</u> hind-cast water quality conditions

Adopted
July 2014

Montana Department of
Environmental Quality

DEPARTMENT CIRCULAR

DEQ-12A

Montana Base Numeric Nutrient Standards

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Selected MT Numeric Nutrient Standards: wadeable streams, large rivers

			Numeric Nutrient Standard	
Ecoregion (level III or IV) and Number	**Ecoregion Level**	**Period When Criteria Apply**	**Total Phosphorus (µg/L)**	**Total Nitrogen (µg/L)**
Northern Rockies (15)	III	July 1 to September 30	25	275
Canadian Rockies (41)	III	July 1 to September 30	25	325
Idaho Batholith (16)	III	July 1 to September 30	25	275
Middle Rockies (17)	III	July 1 to September 30	30	300
Absaroka-Gallatin Volcanic Mountains (17i)	IV	July 1 to September 30	105	250
Northwestern Glaciated Plains (42)	III	June 16 to September 30	110	1300
Sweetgrass Upland (42l), Milk River Pothole Upland (42n), Rocky Mountain Front Foothill Potholes (42q), and Foothill Grassland (42r)	IV	July 1 to September 30	80	560
Northwestern Great Plains (43) and Wyoming Basin (18)	III	July 1 to September 30	150	1300
River Breaks (43c)	IV	Narrative only	Narrative only	Narrative only
*Non-calcareous Foothill Grassland (43s), Shields-Smith Valleys (43t), Limy Foothill Grassland (43u), Pryor-Bighorn Foothills (43v), and Unglaciated Montana High Plains (43o)**	IV	July 1 to September 30	33	440
Large Rivers:				
Yellowstone River (Bighorn River confluence to Powder River confluence)	n/a	August 1 -October 31	55	655
Yellowstone River (Powder River confluence to stateline)	n/a	August 1 -October 31	95	815

Most Montana Streams already Meet Standards

Based on probabilistic stream survey:

- About 70-80% of stream miles statewide currently meet the TP standards

- About 85-90% of stream miles statewide currently meet the TN standards

PART 2. A Low-flow Design Flow for Nutrients

- EPA generally does not expect aquatic life WQ standards to be "no exceedence of any sample ever"

"Most aquatic ecosystems can probably recover from most exceedences in about three years. Therefore…it does not seem reasonable to require that these kind of stresses only occur once in every five or ten years on the average.*"

- EPA recommends dynamic models to simulate if a chronic standard (over 4 days, averaged) is exceeded more than once every 3 years

*EPA, 1985. *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and their Uses (Stephan et al.)*

The Other Way: Hydrologic Design Flow

- Montana (and others) uses the hydrologically-based <u>7Q10</u> to permit toxic pollutants
  - "7" —averaging <u>duration</u> (in days) for measured flows
  - "10" —<u>frequency</u> of excursions (the flow occurs 1 of every 10 years)
  - Calculated by USGS (log-Pearson type III)
  - Independent of biological considerations

- EPA (1991) compares the 7Q10 flows to EPA's biologically-based 4 day, once-in-three years model method
  - 7Q10 is only a rough surrogate for the biological approach
  - EPA prefers dynamic modeling, but it's rarely used by states

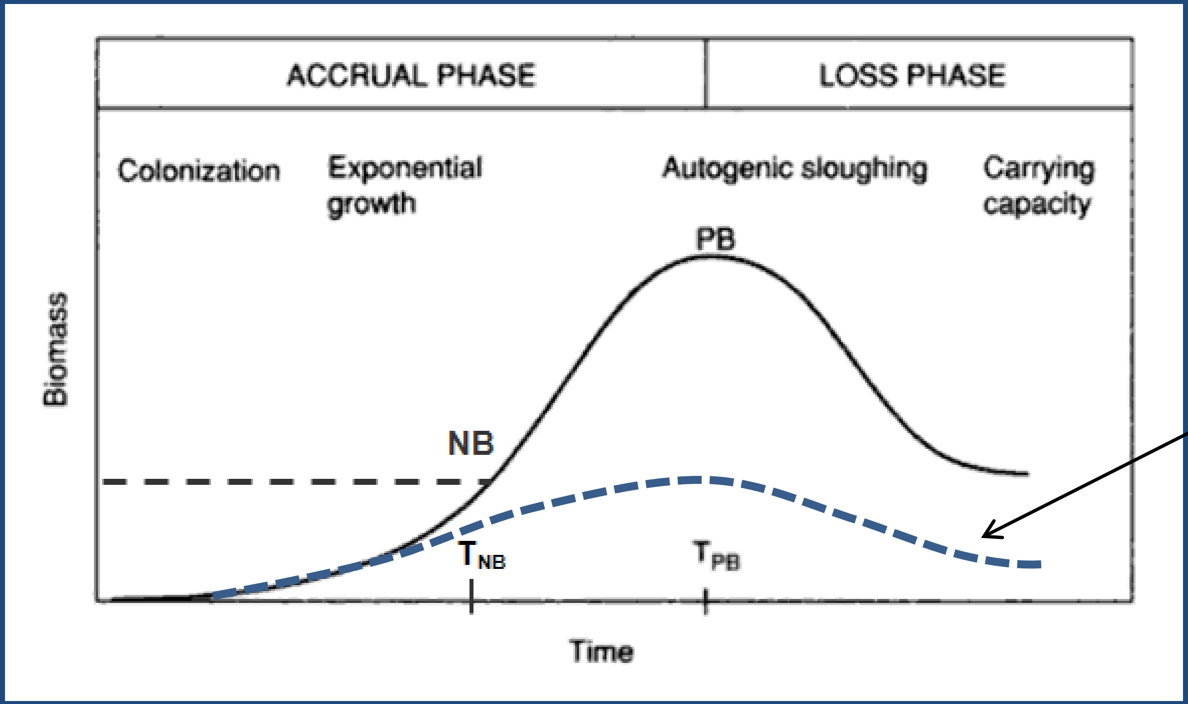
Frequency of Excursions for Nutrient Standards

"Most aquatic ecosystems can probably recover from most exceedences in about three years." -EPA 1985

- MT DEQ selected a recurrence frequency of 5 years:
  - Slightly more protective than EPA's 1 in 3
    - But not as restrictive as every 5 to 10 years
  - 5 year recurrence for seasonal flows (July-Oct) routinely reported by USGS

Identifying averaging duration

- Minimize impacts on recreation and aquatic-life uses caused by excess benthic algae



The nutrient criteria themselves should keep algae below nuisance for duration of summer

Estimating Time to Nuisance Algae

$$a_b(t) = \frac{a_{b,\max} \exp^{kt}}{\dfrac{a_{b,\max}}{a_{b,init}} + \exp^{kt} - 1}$$

$a_b(t)$ = benthic algal biomass (mg Chl*a*/m^2) at a defined point in time after growth initiation

$a_{b,init}$ = initial biomass condition (mg Chl*a*/m^2)

$a_{b,\max}$ = max biomass carrying capacity (mg Chl*a*/m^2)

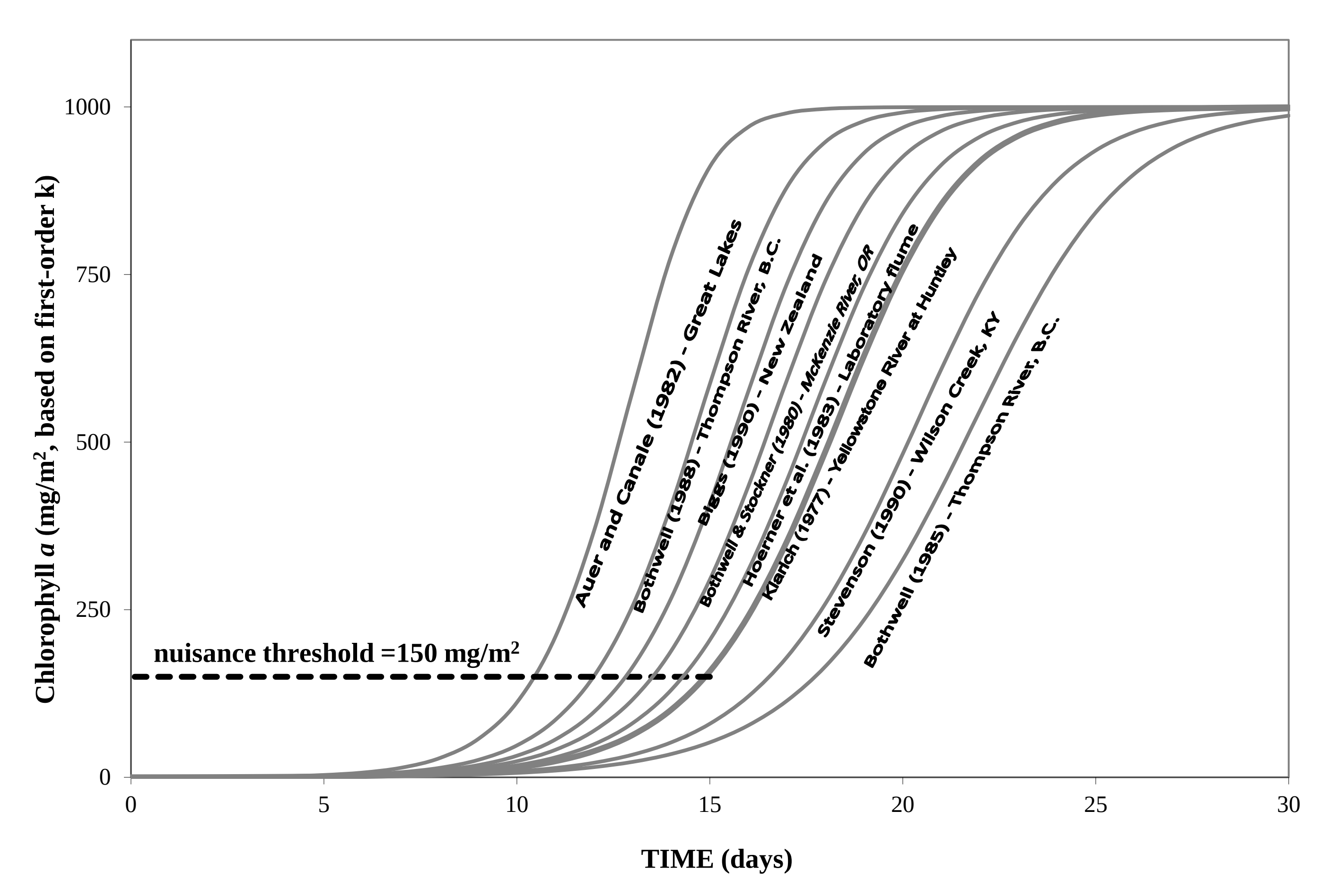
k = temperature dependent 1st order net-specific growth rate (day^{-1})

t = time (days)

Duration

150 mg Chl$a$/m^2: threshold for recreation and aquatic-life impacts

Literature benthic algae growth rates (k, day^{-1}) normalized to 20° C, modeled



0.5 day^{-1} most appropriate for duration, <u>equal to about 14 days to nuisance</u>

Confirming the 14-Day Duration

Whole-stream Dosing Study

- Quantitative stressor-response study to better understand impacts to beneficial stream uses
  - Provided a way to test "time to peak" benthic algal growth rate
  - Nutrients were added at moderately-enriched levels

Box Elder Creek, Carter County, MT

07/28/2010: 21 days prior to dosing

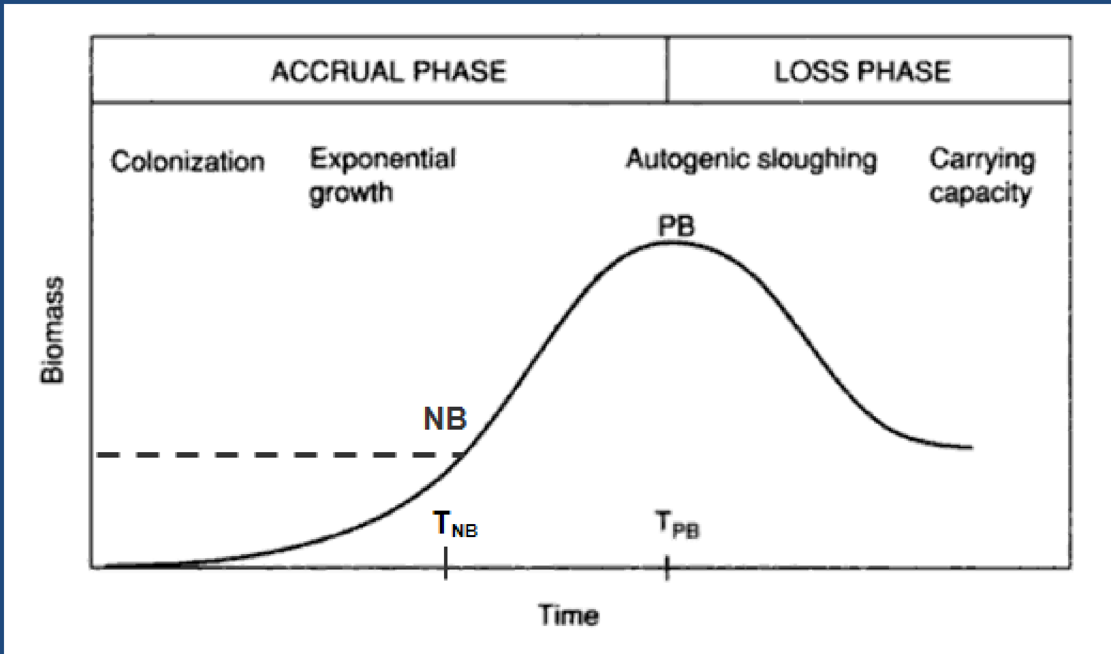

08/24/2010: +15 days


08/29/2010: +20 days
Peak Algae Density

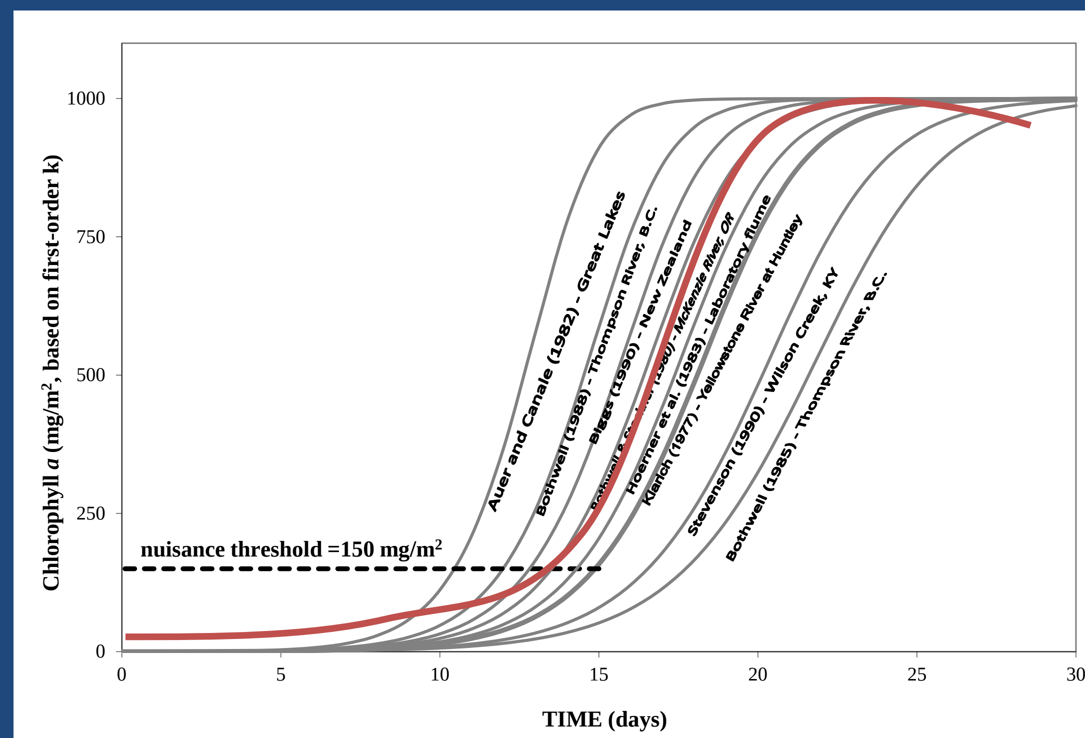

09/7/2010: +29 days


09/22/2010: +44 days

Dosing study net-specific growth rate at 20°C: 0.42 day^{-1}



Net Specific Growth Rate at 20˚C (k, day^{-1})	Reference
0.50	Klarich (1977)
0.55	Bothwell and Stockner (1980)
0.71	Auer and Canale (1982)
0.52	Horner et al. (1983)
0.42	Bothwell (1985)
0.62	Bothwell (1988)
0.58	Biggs (1990)
0.45	Stevenson (1990)



The Low-flow Design Flow

- Averaging duration of 14 days of flow is appropriate to prevent stream algae from reaching 150 mg Chl*a*/m^2
  - A longer averaging duration (say, 90 days) might lead to nuisance algae, because there could be >14 continuous days when flows are well below the 90-day average flow on which the permit would be based
- Once in 5 year recurrence interval (policy)

14Q5

Part 3. Developing Permit Limits for Numeric Nutrient Standards

- Based on *Technical Support Document for Water Quality-based Toxics Control* (EPA 1991)

- Techniques specific to nutrient standards:
  - Treated as chronics, only develop average monthly limit (no max daily)
  - Use 95th percentile probability distribution of the effluent
  - Apply limits only during growing season (~July-~Oct)
  - 100% of the 14Q5 is used for mixing—if dilution is available

As MPDES permits are renewed, MT DEQ:

- Determines applicable TN and/or TP standards from Circular DEQ-12A

- Conducts Reasonable Potential (RP) analysis per methods in the TSD (EPA, 1991)
  - If RP, will calculate effluent limit(s)

Example RP Analysis – Total Nitrogen

Will the stream concentration after mixing (C_r) be greater than the standard?

$$\boldsymbol{C_r = [(Q_s\ x\ Cs) + (Q_d\ x\ Cd)]\ /\ Q_r}$$

Q_s = 18.4 mgd seasonal 14Q5

Q_d = 1.8 mgd average daily design flow

C_s = 0.1 mg/L = 75th percentile background data (i.e., upstream concentration)

C_d= 54.6 mg/L = 39 mg/L TN max observed x 1.4 Table 3-2 multiplier in TSD

$$\boldsymbol{C_r} = [(18.4\ x\ 0.1\ ) + (1.8\ x\ 54.6)]\ /\ (18.4\ \ +1.8)$$

$$\boldsymbol{C_r} = (1.84 + 98.3)\ /\ 20.2$$

$\boldsymbol{C_r}$ = 5.0 mg/L TN > 0.275 mg/L Circular DEQ-12A standard

→ RP exists, so TN effluent limit needs to be developed

Develop Effluent Limits

Montana's modified TSD-approach:

1. Calculate Wasteload Allocation (WLA): use TMDL-WLA or calculate with mass-balance
2. Calculate chronic Long-term Average (LTA)
3. Calculate Average Monthly Limit (AML) as concentration
4. Calculate AML as load

The calculated effluent limits are expressed on a monthly average basis, as both:

- Concentration (mg/L), and Load (lb/day)

This may be implemented immediately (or by compliance schedule) UNLESS the facility is eligible to request a variance from the numeric nutrient standards…

Recap

- The N and P criteria are scientifically defensible, appropriate for different regions and lotic waterbody types
  - Provide clarity as to what the true water-quality endpoints are
  - Ongoing work will lead to other large-river nutrient standards, additional site-specific wadeable stream standards

- A low-flow design flow was developed for permitting nutrient standards
  - 14Q5 (14-day low flow occurring, on average, every 5 years)

- Permitting follows standard TSD (EPA 1991) methods, however:
  - Nutrients are treated as chronic criteria, AML only (no max daily)
  - 95^{th} percentile probability distribution of the effluent is used
  - Limits apply only during growing season (~July-~Oct)
  - 100% of the 14Q5 is available for mixing if dilution can occur

Acknowledgments

- Rosie Sada, Dr. Kyle Flynn, many other MT Dept. of Environmental Quality staff
- Dr. Vicki Watson– University of Montana
  - and her students
- George Mathieus– Deputy Director, MT Dept. of Environmental Quality
- Members of the Nutrient Work Group

Thank You

Contact Information for Michael Suplee:

(406) 444-0831, or msuplee@mt.gov

Rock Creek, in eastern Montana

Montana Department of Environmental Quality