# Narrative Nutrient Standards: Summary Technical Support Document

## December 4, 2023

**Prepared by:**
Michael Suplee, PhD
Montana Department of Environmental Quality
Water Quality Standards & Modeling Section
1520 E. Sixth Avenue
P.O. Box 200901
Helena, MT 59620-0901

**Suggested citation**: Suplee, M.W. 2023. Narrative Nutrient Standards: Summary Technical Support Document. Helena, MT: Montana Dept. of Environmental Quality.

# Executive Summary

This document provides brief summary overviews of causal and response variables found in Part I of **Circular DEQ-15** (December 2023 edition), and the rationale for their use**.** In most cases, technical documents referenced herein contain the important details about the causal and response variables. However, in some cases, important details are provided here if they were not sufficiently covered in the reference materials. This document addresses magnitude, duration, and frequency of the causal and response variables (aka criteria) in **Circular DEQ-15**.

# TABLE OF CONTENTS

# ACRONYMS

| | |
|---|---|
| **ARM** | Administrative Rules of Montana |
| **DEQ** | Montana Department of Environmental Quality |
| **DO** | Dissolved oxygen |
| **DO Δ** | Dissolved oxygen delta (daily maximum minus daily minimum concentration) |
| **EPA** | United States Environmental Protection Agency |
| **MCA** | Montana Code Annotated |

# 1.0 INTRODUCTION AND BACKGROUND INFORMATION

Changes in Montana law[1] necessitated the development of a structured translation process to interpret the state's narrative water quality standards applicable to total nitrogen (TN) and total phosphorus (TP) concentrations (ARM 17.30.637(1)(e)). DEQ proposed that this translation process include (a) for aquatic life beneficial uses, macroinvertebrate metrics and the daily change in dissolved oxygen (DO Δ) as response variables; and (b) for recreational beneficial uses, benthic algae chlorophyll *a*, benthic algal ash free dry weight, and percent bottom cover by filamentous algae as response variables. The translators for these parameters are found in Part I of **Circular DEQ-15** (December 2023 edition).

This document provides a summary overview of response and causal variables from Part I of **Circular DEQ-15**, and the rationale for their use. In most cases, referenced technical documents contain the important details about the response and causal variables and the reader should refer to them as needed. However, in some cases, important details are provided here if they were not sufficiently covered in the reference materials. This document addresses **magnitude**, **duration**, and **frequency** aspects of the response and causal variables (aka criteria) in **Circular DEQ-15**; these three terms are provided in bold throughout the document to ease identification of the subject.

# 2.0 TECHNICAL SUMMARIES

Technical summaries regarding causal and response variables and the rationale for their selection are provided below for both the aquatic life and recreation beneficial uses.

## 2.1 AQUATIC LIFE BENEFICIAL USES

### 2.1.1 MACROINVERTEBRATE METRICS

- Beck's Biotic Index (version 3)
    - Mountains threshold (**magnitude**): 35.1
    - Low Valleys and Transitional threshold (**magnitude**): 18.7

Rationale: See details in Schulte and Craine (2023) and Suplee (2023). Beck's Biotic Index (v3)—which is based on macroinvertebrate population structure—was the most consistent biological metric across Montana's western and transitional region in terms of correlation with TN and TP concentration gradients. DEQ also considered the multimeric indices that were developed in Schulte and Craine (2023), but concluded that the large increase in complexity, difficulty in interpreting their biological meaning, and modest increase in explanatory power was far outweighed by the simpler and nationally recognized Beck's Biotic Index (v3).

In terms of time, macroinvertebrates generally represent conditions of weeks to months due to the nature of macroinvertebrate life histories (Hering et al., 2006), but even up to years for some taxa.

[1] 75-5-321, MCA

Thus, macroinvertebrates generally represent time periods of intermediate **duration**. Because a macroinvertebrate sample represents an intermediate **duration** of time at a stream site, one might expect a fair degree of across-time stability (all things being equal) in metric scores and this was shown to be the case in Montana streams (Suplee, 2023). Nevertheless, even duplicate field samples will disagree, in terms of indicating stream impairment or non-impairment, about 18% of the time (Stribling et al., 2008). Therefore, averaging results from two or more macroinvertebrate samples from a site will provide a more accurate site assessment. Thus, DEQ recommends that average macroinvertebrate scores be compared to the Beck's Biotic Index (v3) which can then be assessed as "meets" or "exceeds" per section 3.0 in **Circular DEQ-15**.

## 2.1.2 Dissolved Oxygen Delta (DO Δ)

- Western Montana (streams and medium rivers with water surface slope ≤1%)
  - Threshold (**magnitude**) = 3.0 mg/L
- Eastern Montana (all streams and medium rivers; non-drought periods)
  - Threshold (**magnitude**) = 6.0 mg/L

Rationale**:** See Suplee (2023). The western Montana DO Δ threshold is based on relationships between macroinvertebrate metrics (including Beck's Biotic Index v3) and DO Δ; the eastern Montana threshold is based on the relationship between weekly DO Δ and DO minimum standards (during non-drought periods). DO Δ **duration** (i.e., averaging period) for both western and eastern Montana is recommended to be expressed as the 7-day average (rolling or calendar). This corresponds to the expression of DO minima in adopted water quality standards (**Circular DEQ-7**; DEQ, 2019). Further, GLEC (2021)—after analyzing the DO Δ dataset from DEQ's 5-year study of eastern Montana plains streams—recommends that weekly summary measures are intuitively more stable and find that weekly summaries based on only a day or two's data should be avoided as most outliers (high residuals) in their analysis were likely caused by weekly averages comprising too few days. Thus, weekly averages provide a better, more consistent **duration** for this response variable.

Per the translator in **Circular DEQ-15** (see Table 2-1 of that document), there is a 10% allowable exceedance **frequency** for weekly average DO Δ in western Montana. This is based on the minimum allowable exceedance rate commonly used by states for conventional pollutants such as biochemical oxygen demand (BOD) and pH (California, 2004). DO Δ is generally analogous to these conventional pollutants in terms of its harmful biological effects. For eastern Montana DO Δ, the allowable 15% exceedance **frequency** was derived from an analysis of Montana plains reference sites during non-drought periods (Suplee, 2023).

## 2.1.3 Consideration of Conditions Downstream of Dams

Rationale: **Circular DEQ-15** allows for adjustments to the DO Δ threshold downstream of dams (note: these must be reviewed and approved by DEQ case-by-case). Scientific research shows that macrophyte abundance is strongly associated with current velocity and flood disturbance (French, 1995; Riis and Biggs, 2003). Velocity and flood disturbance are greatly altered (and usually moderated) below dams. DEQ has observed dense macrophyte mats in the tailrace areas of some Montana rivers (e.g., the Missouri River below Holter dam) whereas dense macrophyte beds are absent in free-flowing rivers like the Yellowstone River. As shown in GLEC (2021) and discussed in Suplee (2023), dense macrophytes beds generally increase DO Δ and for this reason DEQ is providing the option for adjustment to DO Δ.

Beck's Biotic Index (v3) is likely to be affected as well, thus the allowance for potential adjustments to the threshold in areas below dams (again, case-by-case after DEQ review).

## 2.1.4 SPRING CREEKS

Rationale: Spring creeks were excluded from the narrative nutrient standards translator in **Circular DEQ-15**, although stand-alone causal criteria for them are included in the circular (see the circular's section 2.3.2). Continuous DO and macroinvertebrate data collected by DEQ in Elk Springs Creek (a low-gradient reference stream in southwestern Montana) showed that neither the DO Δ nor the Beck's Biotic Index (v3) thresholds presented above could be met. Elk Springs Creek is a tier I (nearly pristine; Suplee et al., 2005) reference stream site located in the Red Rock Lakes National Wildlife Refuge with zero percent agriculture in the watershed and no grazing allowed in the refuge (however moose are common). It is extremely sinuous, very low gradient (0.08%), has extensive stands of native macrophytes (61% bottom cover on average), is essentially devoid of filamentous algae (1.5% cover), and has a very fine (mud and fine sand) bottom substrate. These natural conditions lend themselves to quite high DO Δ due to the macrophytes (5.9 mg/L on average, summer/fall 2023) and a low Beck's scores (score = 1). Spring creeks typically have extensive macrophyte stands and very limited (or no) hydrologic flushing events, and DEQ assumes that other spring creeks would similarly not be able to meet DO Δ nor the Beck's Biotic Index (v3) threshold.

Fortunately, Montana spring creeks are inventoried (Decker-Hess, 1989), making it clear which waterbodies the different criteria in **Circular DEQ-15** should be applied to. The ecoregional total phosphorus (TP) criteria recommendations from Suplee and Watson (2013) are applied to the spring creeks and to the best of DEQ's knowledge are of the appropriate **magnitude**. **Duration** should be considered as a monthly average. In **Circular DEQ-15**, DEQ provides an allowable TP exceedance **frequency** of 20%; this is based on long-term analysis of numeric nutrient standards on the Clark Fork River (see appendix A.4.2.3 in Suplee and Sada, 2016).

Nitrogen concentrations in spring creeks, on the other hand, are elevated when compared to streams and medium rivers subject to annual spring runoff. This is especially true for nitrate ($NO_3$), which has an interquartile range of about 185 to 915 µg/L and an average around 690 µg/L in spring creeks (n>30 spring creeks; see Appendix 2 in Decker-Hess, 1989). Therefore, for nitrogen, DEQ assigned a range of total nitrogen (TN) concentrations within which spring creek nitrogen concentrations will normally fall. The range was based on current scientific understanding of protective TN criteria for Montana (Suplee and Watston, 2013) and the interquartile range of spring creek nitrate concentrations in Decker-Hess (1989). Like TP, **duration** should be considered as a monthly average. The allowable exceedance **frequency** for an identified, site-specific TN concentration is 20%, based on the same rationale provided above for TP in spring creeks.

## 2.1.5 LARGE RIVERS: LOWER YELLOWSTONE RIVER

- Yellowstone River mainstem, Bighorn River confluence to the Power River confluence
    - Causal variables **magnitude**: 55 µg TP/L, 655 µg TN/L
    - DO Δ threshold (**magnitude**): 4.1 mg/L

Rationale: Site-specific analysis undertaken via mechanistic water quality modeling identified the causal variable concentrations for the Yellowstone River reach listed above (Suplee et al., 2015). Regarding the DO Δ threshold of 4.1 mg/L, note in Suplee et al. (2015) that DO Δ increases with each incremental

nitrogen or phosphorus dose added to the river in the model (see tables 6 and 7, first half in each, Suplee et al., 2015). DEQ took the average DO Δ of the two modeled dosing scenarios (4.3 mg DO/L and 3.87 mg DO/L) at the point where the model showed impacts to the pH standard—which is what the causal variables are also based on.

For the causal variables (TP, TN), **duration** should be considered as a monthly average with an allowable exceedance **frequency** of 20% based on analyses from the Clark Fork River (see appendix A.4.2.3 in Suplee and Sada, 2016). The **duration** for the response variable DO Δ is a weekly average (rolling or calendar) and the allowable exceedance **frequency** is once in three years, on average, consistent with Stephan et al. (1985).

### 2.1.6 Large Rivers: Other Large Rivers and Large River Reaches

Rationale: For aquatic life use in other large rivers or river reaches, the causal variable **magnitudes** are provided as ranges in **Circular DEQ-15** (see section 4.0 there) based on DEQ's best scientific understanding from Yellowstone River modeling work (Flynn et al., 2015; Suplee et al., 2015) and other large river criteria work (Smith and Tran, 2010). **Circular DEQ-15** provides that the DO Δ threshold should be determined case-by-case (see footnote in the circular's table 4-1).

DEQ is requiring that the combined criterion method be applied to all large rivers and large river segments, however additional work will be required to derive appropriate causal criteria concentrations and an appropriate DO Δ threshold for other large rivers or large river segments. The work should follow methods DEQ will provide in the guidance document for large river assessment.

## 2.2 Recreation Beneficial Uses

### 2.2.1 Western Montana Recreational Use Thresholds (All Streams and Medium Rivers)

- Benthic Chlorophyll a (**magnitude**): 150 mg/$m^2$
- Ash Free Dry Weight (**magnitude**): 35 g/$m^2$
- Percent Cover by Filamentous Algae (**magnitude**): 30% cover

Rationale: The benthic (bottom-attached) chlorophyll *a* and ash free dry weight thresholds are based on acceptable levels from public opinion surveys in both Montana and Utah (Suplee et al., 2009; Jakus et al., 2017). Percent filamentous cover is based on public opinion work in Utah (Ostermiller et al., 2019) and is consistent with cover percentages and preferences documented in Montana's public opinion survey in Suplee et al. (2009). **Duration** of these algae-based parameters is typically several weeks, at most, which is why DEQ requires two sampling events per index period (**Circular DEQ-15**). The allowable exceedance **frequency** is once every three years, on average, based on EPA recommendations (Stephan et al., 1985).

No recreation-based criteria are being proposed for eastern Montana plains streams or medium rivers. DEQ has documented that these streams may naturally exceed the 150 mg chlorophyll *a*/$m^2$ threshold (Suplee et al., 2007). DEQ has no other information regarding appropriate recreation-based thresholds linked to nitrogen and phosphorus for plains streams and medium rivers.

## 2.2.2 Large Rivers: Lower Yellowstone River

- Yellowstone River mainstem, Power River confluence to State Line (causal variables **magnitude**): 95 µg TN/L, 815 µg TN/L
- Benthic Chlorophyll a (**magnitude**): 150 mg/$m^2$
- Ash Free Dry Weight (**magnitude**): 35 g/$m^2$
- Percent Cover by Filamentous Algae (**magnitude**): 30% cover

The causal criteria for the lowest reach of the Yellowstone River (Power River confluence to State Line) were based on impacts to the recreational use by excess benthic algae growth in near-shore areas (Suplee et al., 2015). For the causal variables (TP, TN), **duration** should be considered as a monthly average with an allowable exceedance **frequency** of 20% based on analyses from the Clark Fork River (see appendix A.4.2.3 in Suplee and Sada, 2016).

The recreational thresholds for chlorophyll *a*, ash free dry weight, and percent cover are the same as for wadeable streams and medium rivers except that they apply only to the wadeable region of this lower Yellowstone River reach. The **duration** for these algae-based response variables is typically several weeks at most. The allowable exceedance **frequency** for the response variables is once every three years, on average, based on EPA recommendations (Stephan et al., 1985).

## 2.2.3 Large Rivers: Other Large Rivers and Large River Reaches

Rationale: For recreation uses in other large rivers or river reaches, the causal variable **magnitudes** are provided as ranges in **Circular DEQ-15** (see the circular's table 4-1) based on DEQ's best scientific understanding from Yellowstone River modeling work (Flynn et al., 2015; Suplee et al., 2015) and other large river criteria work (Smith and Tran, 2010). Additional work will be required to derive appropriate causal criteria concentrations for other large rivers or large river segments and the work should follow methods DEQ will provide in the guidance document for large river assessment. Once identified, **duration** for the causal variables should be considered as monthly averages. The allowable exceedance **frequency** for an identified, site-specific TP or TN concentration should be 20%, based on the same rationale provided in **Section 2.2.2**.

The recreational thresholds for chlorophyll *a*, ash free dry weight, and percent cover are the same as for the lower Yellowstone River in **Section 2.2.2**. The **duration** for these algae-based response variables is typically several weeks at most. The allowable exceedance **frequency** is once every three years, on average, based on EPA recommendations (Stephan et al., 1985).

# 3.0 REFERENCES

California (CA Environmental Protection Agency State Water Resources Control Board). 2004. *Functional Equivalent Document, Water Quality Control Policy for Developing California's Clean Water Act Section 303(d) List - Final*. Division of Water Quality, State Water Resources Control Board.

Decker-Hess, J. 1989. *An Inventory of the Spring Creeks in Montana*. Kalispell, MT; Montana Dept. of Fish, Wildlife, and Parks.

DEQ. 2019. Circular DEQ-7, *Montana Numeric Water Quality Standards*. *June 2019 Edition*. Helena, MT: Montana Dept. of Environmental Quality.

Flynn, K.F., M.W. Suplee, S.C. Chapra, and H. Tao. 2015. Model-based nitrogen and phosphorus (nutrient) criteria for large temperate rivers: 1. Model development and application. *Journal of the American Water Resources Association* 51: 421-446.

French, T.D. 1995. *Environmental Factors Regulating the Biomass and Diversity of Aquatic Macrophyte Communities in Rivers*. Master of Science thesis, Department of Biological Sciences, University of Alberta.

GLEC (Great Lakes Environmental Center, Inc.). 2021. *Dissolved Oxygen Spatial Analysis, Technical Progress Report —Phase II*. Prepared by Dale White, Principal Research Scientist.

Hering, D., R.K Johnson, and A. Buffagni. 2006. Linking organism groups—major results and conclusions from the STAR project. *Hydrobiologia* 566: 109-113.

Jakus, P.M., N. Nelson, and J. Ostermiller. 2017. Using survey data to determine a numeric criterion for nutrient pollution. *Water Resources Research* 53: 1–13.

Ostermiller, J.D., M. Shupryt, M.A. Baker, B. Neilson, E.B. Gaddis, A. J. Hobson, B. Marshall, T. Miller, D. Richards, and N. von Stackelberg. 2019. *Technical Support Document: Utah's Nutrient Strategy.* Utah Department of Environmental Quality, Water Quality Division.

Riis, T., and B.J.F. Biggs. 2003. Hydrologic and hydraulic control of macrophyte establishment and performance in streams. *Limnology and Oceanography* 48: 1488-1497.

Schulte, N.O., and J.M. Craine. 2023. *Eutrophication Thresholds Associated with Benthic Macroinvertebrate Conditions in Montana Streams*. Prepared for the MT Dept. of Environmental Quality by Jonah Ventures. October 5, 2023.

Smith, A.J., and C.P. Tran. 2010. A weight-of-evidence approach to define nutrient criteria protective of aquatic life in large rivers. *Journal of the North American Benthological Society* 29: 875-891.

Stephan, C.E., D.I. Mount, D.J. Hansen, J.H. Gentile, G.A. Chapman, and W.A. Brungs. 1985. *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and*

*Their Uses.* PB85-227049. U.S. Environmental Protection Agency, Environmental Research Laboratories, Corvallis, Oregon.

Stribling, J.B., B.K. Jessup, and D.L. Feldman. 2008. Precision of benthic macroinvertebrate indicators of stream condition in Montana. *Journal of the North American Benthological Society* 27: 58-67.

Suplee, M.W. 2023. *An Analysis of Daily Patterns of Dissolved Oxygen Change in Flowing Waters of Montana*. Document No. WQDWQSMTECH-05. Helena, MT: Montana Dept. of Environmental Quality.

Suplee, M.W., Sada de Suplee, R., Feldman, D., and T. Laidlaw. 2005. *Identification and Assessment of Montana Reference Streams: A Follow-up and Expansion of the 1992 Benchmark Biology Study.* Helena, MT: Montana Dept. of Environmental Quality.

Suplee, M.W., A. Varghese, and J. Cleland, 2007. Developing nutrient criteria for streams: An evaluation of the frequency distribution method. *Journal of the American Water Resources Association* 43: 456-472.

Suplee, M.W., V. Watson, M. Teply, and H. McKee. 2009. How green is too green? Public opinion of what constitutes undesirable algae levels in streams. *Journal of the American Water Resources Association* 45: 123-140.

Suplee, M.W., and V. Watson. 2013. *Scientific and Technical Basis of the Numeric Nutrient Criteria for Montana's Wadeable Streams and Rivers—Update 1*. Helena, MT: Montana Dept. of Environmental Quality.

Suplee, M.W., K.F. Flynn, and S.C. Chapra. 2015. Model-based nitrogen and phosphorus (nutrient) criteria for large temperate rivers: 2. Criteria derivation. *Journal of the American Water Resources Association* 51: 447-470.

Suplee, M.W. and R. Sada. 2016. *Assessment Methodology for Determining Wadeable Stream Impairment Due to Excess Nitrogen and Phosphorus Levels*. Helena, MT: Montana Dept. of Environmental Quality. https://deq.mt.gov/files/Water/SurfaceWater/UseAssessment/Documents/NtrntAssessMethod_May2016_FINAL.pdf