NUMERIC NITROGEN AND PHOSPHORUS CRITERIA: UTAH HEADWATER STREAMS

3/11/2015

Application of Stressor-Response Models and Multiple Lines of Evidence

This document summarizes UDWQ's rationale for establishing numeric nutrient criteria for headwater streams, which is one component of Utah's Nutrient Reduction Strategy.

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UTAH NUTRIENT STRATGEY

Proposed Numeric Nutrient Criteria for Utah's Headwater Streams

EXECUTIVE SUMMARY

Utah's Division of Water Quality (UDWQ) proposes a two-tiered numeric nutrient criteria (NNC) to protect aquatic life uses in headwater streams (Table 1). Under this proposal, the lower criteria for Total Nitrogen (TN) and Total Phosphorus (TP), of 0.4 and 0.035 mg/L, respectively, are to be used in concert with ecological responses, while higher respective concentrations of 0.81 and 0.080 mg/L can stand alone without the concomitant ecological responses. While there are a myriad of mechanisms whereby nutrients can degrade aquatic life uses, they all branch from increased growth of plant/algae (autotrophs) and/or microbes/fungi (heterotrophs). UDWQ selected bioconfirmation criteria (ecological responses) to cover both pathways. In the case of plant/algae growth two indicators are not to be exceeded at any headwater stream: a daily Gross Primary Production (GPP) rate higher than 10 g O_2/m^2/day or any incident where aerial percent filamentous algae cover exceeds 1/3 of the stream bed. Linkages among microbes/fungi to the nutrients and aquatic life uses are less well understood, in part because these processes are more difficult to observe or measure. However, it is possible to measure ecosystem respiration (ER), which captures the net metabolic activities of all stream biota. UDWQ proposes a not to be exceeded rate for ER of 9 g O_2/m^2/day. The second, higher nutrient concentration criteria are still protective of aquatic life uses because they fall below the upper thresholds (those that differentiated groups of streams in relatively fair as opposed to poor conditions) for all ecological responses that were evaluated. These upper thresholds will allow UDWQ to identify headwater streams with nutrient related problems in circumstances where response data are unavailable.

Nutrients can also degrade recreation uses. To protect these uses UDWQ proposes an additional benthic algae concentration of 125 mg/chl-a/m^2, or the equivalent 49 g Ash Free Dry Mass (AFDM)/m^2, again not to be exceeded. These criteria were selected from a survey of Utah citizens who were asked whether streams with varying amounts of benthic algae cover represented "desirable" or "undesirable" conditions. These recommended criteria fall just below the point where the proportion of undesirable responses start to increase and should therefore be protective of recreation from the perspective of degraded aesthetics.

Table 1. Numeric nutrient criteria and associated ecological responses (bioconfirmation criteria) proposed to protect aquatic life uses in Antidegradation Category 1 and 2 (UAC R317-2-12) headwater perennial streams[1].

Low Nutrient Headwater Streams: Ecological Responses not Proposed

Summertime Average Nutrients		Assessment Notes
TN <0.40[2,5]	TP <0.035[2,5]	Fully supporting biological uses if ≥4 summertime samples fall within the range; sites with fewer samples will not be assessed for nutrients. If available response data suggest that more protective criteria are needed, site-specific standards will be developed.

Intermediate Nutrient Concentrations with Proposed Ecological Responses

Summertime Average Nutrients		Ecological Response	Assessment Notes
TN 0.41-0.80[2]	TP 0.036-0.079[2]	**Plant/Algal Growth[3]** 1/3 or more filamentous algae cover[4,6] OR GPP[3] of >10 g O_2/m^2/day OR **Plant and Microbial Growth** ER[3] >9 g O_2/m^2/day	Headwater streams within this range of nutrient concentrations will be considered impaired if <u>any</u> response exceeds defined thresholds. Streams <u>without response data</u> will be listed as having <u>insufficient data</u> and prioritized for additional monitoring if either TN or TP falls within the specified range.

Upper Threshold Nutrient Concentration: No Proposed Ecological Responses[6]

Summertime Average Nutrients		Assessment Notes
TN > 0.81[2,5]	TP > 0.080[2,5]	Streams over these thresholds will initially be placed on Utah's 303(d) list as threatened. Threatened streams will be reclassified as impaired the following assessment cycle unless additional data such as nutrient responses, biological assessments and nutrient-related water quality criteria (e.g., pH and DO) demonstrate that aquatic life uses are fully supporting; in which case, site-specific standards will be developed unless downstream resources are threatened.

FOOTNOTES:

1. *Applicable unless more restrictive Total Maximum Daily Load (TMDL) endpoints have been established to protect downstream waters.*
2. *Seasonal average of ≥4 samples collected during the summertime growing season (June 1 – September 30). Not be exceeded. TP means Total Phosphorus and TN means Total Nitrogen in mg/L.*
3. *Daily whole stream metabolism obtained using open channel methods. GPP means Gross Primary Production. ER means Ecosystem Respiration. Daily values are not to be exceeded on any collection event.*
4. *Filamentous algae cover means patches of filamentous algae >1 cm in length or mats >1 mm thick. Daily values are not to be exceeded at any time during the growing season (June-September).*
5. Response data, when available, will be used to confirm impairments or support the need for site-specific criteria.
6. *Quantitative estimates based on reach-scale averages with at least 3 measures from different habitat units (i.e., riffle, run) made with quantitative visual estimation methods.*

This proposal provides the background, rationale and application of these proposed criteria. The first introductory section describes why nutrients are a water quality concern and why UDWQ decided to prioritize headwater streams for the development of NNC. The second section of the document summarizes how the thresholds for TP, TN and ecological responses were calculated. In essence, this section of the document explains, as briefly as possible, the investigations that underpin the proposed criteria. A second companion document entitled Technical Basis for Utah's Nutrient Strategy (Ostermiller et al. 2014) provides much more detail and a more thorough review of related scientific literature. Readers interested in the science that underpins these proposed criteria should refer to this companion document.

The third section called *Proposed NNC: A Rationale* outlines UDWQ's proposed criteria. This section provides details with respect to the rationale behind the magnitude, duration and frequency of the proposed criteria. This section includes benchmarking with criteria proposed by others and thresholds from the scientific literature to help provide context to UDWQ's proposal. The last two sections provide regulatory context, attempting to briefly explain how the proposed criteria interface with other UDWQ programs. The first of these sections, *Regulatory Context*, explains how these criteria would be implemented through UDWQ's monitoring and assessment programs. UDWQ conducted a preliminary analysis of existing headwater criteria and these results are summarized at the end of this section. Finally, the last section called *Next Steps* explains a process for modifying the proposed criteria, if needed, on a site-specific basis. This final section also discusses UDWQ's proposal for ongoing collaborative management for implementation of the criteria and a brief description of UDWQ's plans for development of nutrient criteria in streams lower in Utah's watersheds.

LIST OF FIGURES AND TABLES

List of tables in the proposal.

ABBREVIATIONS AND ACRONYMS

Abbreviations and acronyms used in this proposal, separated into those associated with nutrients then all others.

	Nutrients
P	Phosphorus, expressed as mg/L unless otherwise noted.
TP	Total Phosphorus, expressed as mg/L unless otherwise noted.
N	Nitrogen, expressed as mg/L unless otherwise noted.
TN	Total Nitrogen, expressed as mg/L unless otherwise noted.
TIN	Dissolved Inorganic Nitrogen, expressed as mg/L unless otherwise noted.
	Others (in alphabetic order)
AFDM	Ash Free Dry Mass: a measure of the amount of organic material in a sample. In this proposal it is an alternative measure to chl-a for purposes of quantifying benthic algae density. Expressed as grams of carbon/m^2.
Chl-a	Chlorophyll-a: a measure of the amount of chlorophyll in a sample. In this case, it is used as a quantitative estimate of the amount of living algal material in a sample. Expressed as grams of chl-a/m^2.
DO	Dissolved Oxygen: typically expressed as mg/L
ER	Ecosystem Respiration: the heterotrophic component of whole stream metabolism measures (see Table 2); in this report expressed as g O_2/m^2/day consumed by stream organisms.
GPP	Gross Primary Production: the autotrophic component of whole stream metabolism measures (see Table 2); in this report expressed as g O_2/m^2/day produced by plants and algae within the stream.
MMI	Multi-Metric Index: a term for a combination of biological characteristics that are mathematically combined to create a single estimate of biological integrity (ecological condition).
NNC	Numeric Nutrient Criteria: in this case this includes N and P concentration in addition to coupled responses.
POTW	Publically Owned Treatment Works
SAP	Sample and Analysis Plan: in this case detailed plans that describe the monitoring and assessment methods that will be followed for purposes of developing site-specific numeric criteria.
S-R	Stressor-Response: empirical models that relate stressors—in this case nutrients, to various ecological responses.
TMDL	Total Maximum Daily Load: studies conducted under the Clean Water Act that determine pollutant reductions that are necessary to meet water quality standards.
UDWQ	Utah's Division of Water Quality
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency

INTRODUCTION

Why are excess nutrients a concern?

Nutrients provide critical support for both stream and lake food webs. However, excess accumulation of nutrients, particularly nitrogen (N) and phosphorous (P), causes numerous water quality problems that have been demonstrated to degrade aquatic life, drinking water, and recreation uses. Resulting economic losses from these degraded conditions are considerable—in the United States estimated costs from reactive N exceed $210 billion annually or $254/ha/yr. (Sobata et al. 2015). More importantly, these problems threaten the sustainability of our water resources and diminish our quality of life (CH2MHill 2012). Problems associated with excess nutrients in water bodies (collectively called cultural eutrophication) have been documented for almost two centuries (Smith et al. 1999, Bricker at al. 2008). However, cultural eutrophication problems have been rapidly increasing nationally in extent and magnitude over the past 50 years due to the combination of widely available commercial fertilizers and exponential population growth. Many water resource professionals and regulatory agencies—including the United States Environmental Protection Agency (USEPA) and Utah's Division of Water Quality (UDWQ)—now consider cultural eutrophication to be among the greatest threats to our lakes, rivers and estuaries (USEPA 2009).

Nutrient pollution is among the most widespread and challenging of water quality problems. Nutrient pollution can degrade aquatic life, drinking water and recreational uses through a variety of complex mechanisms.

There are many ways that excess nutrients can degrade surface water quality. Many of these processes are associated, directly or indirectly, with excess plant and algae growth and/or rates of microbial decomposition of organic matter. For most people, problems associated with plant and algae growth are most obvious because the growth is unsightly and degrades the aesthetics of our lakes and streams (Suplee et al. 2009, CH2MHill 2012). Less obvious are very low levels of dissolved oxygen (DO) that occur when plants and algae consume oxygen at night and decompose when they die. Sometimes, low DO problems are sufficiently bad that they cause extensive fish kills (Smale and Rabeni 1985, Dodds 2007). Another subtle consequence of cultural eutrophication is the loss of biodiversity in lakes and streams (Jeppasen et al. 2000). These losses of resident species typically start with changes in water chemistry (e.g., lowered DO) and habitat degradation (e.g., increased sedimentation, reduced water clarity), resulting in a competitive advantage for species adapted to high nutrient conditions at the expense of more sensitive species (Davies et al. 2006). Such losses are important because they diminish the ecological resilience of water bodies to extreme events such as droughts and floods (Folke et al. 2004). Recent evidence also suggests that reductions in algal biodiversity causes negative feedbacks that reduces nutrient uptake rates, which has the potential to further degrade water quality at downstream waterbodies (Cardinale 2011). In lakes, excessive primary production sometimes manifests as growth of cyanobacteria (or blue-green algae), which can produce toxins that are harmful to people and animals (Hudnell 2000). These toxins directly threaten the security of culinary water supplies because they cannot be easily removed with standard treatment processes. Sometimes, the toxicity of "blooms" can even be deadly, particularly for animals like dogs and cattle (Briand et al. 2003).

Groundwater culinary sources are also threatened by excess nutrients because they can become contaminated with nitrate, a form of nitrogen that can be toxic especially to infants (Dubrovsky and Hamilton 2010). In addition, nitrate and phosphate in groundwater can become a source of these nutrients to streams and lakes, with the potential to contribute to negative nutrient responses (Rueben et al. 2014, Rueben and Stevens 2014 a, b).Enrichment of groundwater sometimes takes years to manifest and once contamination occurs remediation is often exceedingly difficult. In Utah, groundwater nitrate contamination has resulted in several municipal and private drinking water sources exceeding federal human health criteria.

All of these harmful responses to excess nutrients have been observed in Utah and UDWQ is committed to solving nutrient-related water quality problems. To accomplish this goal, UDWQ and stakeholders have been developing a comprehensive nutrient reduction strategy. The strategy consists of several elements which broadly attempt to identify water bodies with nutrient-related problems and then seek out appropriate nutrient reductions with programs directed at various nutrient sources. Until now, nutrient related water quality issues have been handled through the development of Total Maximum Daily Loads (TMDLs) and watershed-scale planning. Adoption of numeric nutrient criteria (NNC) for headwaters provides additional tools for UDWQ to manage the use of the most pristine and protected waters in Utah and assess the maintenance or improvement of their quality.

Why headwater streams?

Headwater streams are critically important ecosystems—both ecologically and economically. Ecologically, headwater streams contribute to the biological integrity of all streams by providing critical hydrologic connectivity among streams across large landscapes (Freeman et al. 2007). At regional scales headwater streams are critically important for the maintenance of aquatic biodiversity ("β-diversity"; Clarke at al. 2008), in part because they are physically diverse with a corresponding rich diversity of potential habitats (Lowe and Likens 2005). Native fish, like Utah's cutthroat trout (*Oncorhynchus clarkii*), inhabit these streams year round or migrate to them in early spring to spawn (Schrank and Rahek 2004). In an economic context, headwater streams provide many important ecosystem services. These streams protect downstream waters through nutrient retention (Bernhardt et al. 2005), maintenance of sediment transport (Lowe and Likens 2005) and organic matter storage and processing. Moreover, protecting headwaters from cultural eutrophication will have the added benefit of protecting downstream waters because a large percent of nutrients that enter these waters are ultimately transported downstream (Newbold et al. 1981).

In Utah, the majority of our water falls as mountain snow, so these catchments are a critical part of our water future. For over three decades, UDWQ has acknowledged the importance of headwater streams and afforded them antidegradation Category 1 or 2 protections (UAC R-317-2). These are among the most pristine waters in the state and generally no permitted discharges are permitted in Category 1 waters and discharges only at background concentrations are permitted in Category 2 waters. All told, Utah has ~8,000 miles of perennial headwater streams (as defined here), which is about 47% of the total perennial stream miles in Utah.

> **"It is difficult to see how any conservation action with the goal of protecting the long-term ecological integrity and ecosystem services of natural systems, whether aquatic or terrestrial, can succeed without a foundation of intact and functional headwaters." Lowe and Likens 2005**

UDWQ also has practical reasons for starting NNC development with headwater streams. Simply put, it is easier to estimate undegraded conditions, with respect to both nutrient concentrations and ecological responses for headwater streams than for streams lower in the watershed that often are affected by multiple stressors. Determining appropriately protective water quality goals in headwaters is more straightforward, in part, because reference streams can be used to estimate undegraded conditions. Importantly, water quality goals that are defined by reference conditions are generally appropriate in headwaters because they are achievable; whereas, some conditions in downstream reaches are irreversible due to permanent changes in hydrology or habitat.

While regional NNC are appropriate for headwaters, UDWQ has determined that site-specific approaches are more appropriate in downstream waters due to several factors. The first relates to the influence of covariates. Stream ecologists have known for decades that many ecological attributes change naturally and predictably from headwaters to downstream reaches (i.e., see Vanote et al, 1980). Water quality goals, particularly for naturally occurring pollutants like nitrogen and phosphorus, need to be adjusted to account for these natural changes. Another complication in developing defensible water quality goals for downstream waters relates to patterns of human land use. Most of Utah's population resides in valleys. As a result, both the number of stressors on steam ecosystems and their magnitude of influence on stream organisms increase from headwaters to downstream reaches. Many of these stressors cause patterns of degradation that are similar to nutrients, which makes it difficult to separate the effects of many different causes of ecological degradation (Allan 2004). Together, these factors make the development of NNC for headwaters a logical first step in Utah's overall nutrient strategy.

Numeric nutrient criteria (NNC) define concentrations of nitrogen and phosphorus that need to be maintained to avoid the impairment of the designated uses—typically aquatic life or recreation—of lakes or streams.

What are numeric nutrient criteria (NNC)?

NNC define the magnitude (maximum concentration), duration (averaging periods), and frequency (acceptable number of violations) of nitrogen (N) or phosphorous (P) levels that must be maintained to prevent the degradation of existing beneficial uses. In addition, NNC can also include ecological indicators that demark water quality goals based on potentially deleterious responses to nutrients. NNC, such as those proposed here, that include both nutrients and responses are sometimes called "combined criteria". Regional NNC, such as those that UDWQ proposes for headwaters, are typically derived from thresholds obtained from two methods: empirical stressor-response (S-R) relationships and regional distributions of N and P concentrations (USEPA 2000). UDWQ used both of these approaches as lines of evidence to determine NNC that are appropriately protective of aquatic life and recreational uses in headwater perennial streams. A third approach for development of NNC, mechanistic modeling, will be used to develop site-specific NNC in the future primarily for downstream waters.

Why are NNC important?

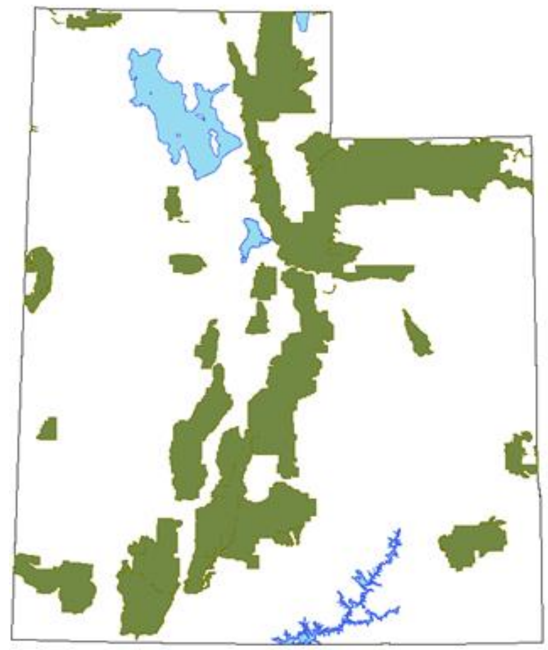

Figure 1. Map of headwater stream watersheds.

While many states, including Utah, conduct water quality assessments based on indicators that can be used to infer nutrient-related ecological responses (e.g., dissolved oxygen, pH), USEPA has determined that these approaches are not resulting in nutrient reduction programs that adequately protect beneficial uses from the degradation of designated uses that sometimes results from nutrient pollution. Instead, USEPA believes that comprehensive nutrient reduction programs must be developed to protect aquatic ecosystems (USEPA 2011). This policy directs each state to develop a nutrient reduction program, a key component of which is defining a clear path toward the development of NNC that sets clear limits on nutrient concentrations so that it is clear when protective action is needed. While these policy considerations are necessary, a more important consideration from the perspective of UDWQ is that NNC are appropriately protective: they should accurately identify streams with nutrient-related problems without diverting resources where nutrient-related problems are not manifest. These pollutants are among the most important threats to water quality that have not yet been explicitly addressed in Utah's water quality standards.

What streams are captured by these criteria?

UDWQ proposes to apply these NNC to perennial headwater streams that are currently protected as Antidegradation Category 1 and 2 waters (UAC R317-2-12, Figure 1). These streams consist of waters that Utah's Water Quality Board has determined are "…of exceptional recreational or ecological significance or have been determined to be a State or National resource requiring protection." In Utah these streams include, among others, all stream segments within USDA Forest Service boundaries, which encompasses approximately 8.2 million acres, over 15% of the acreage in Utah (Gorte et al. 2012).

DEVELOPMENT OF NUMERIC NUTRIENT CRITERIA

An Adaptive Management Framework

There is considerable uncertainty and controversy, both scientific and socioeconomic, surrounding the development of NNC and the associated nutrient reduction programs that aim to address nutrient pollution. As a result, UDWQ and Utah's Nutrient Core Team—a stakeholder group charged with the development of a nutrient reduction program (www.nutrients.utah.gov)—have incorporated an adaptive management framework into several aspects of Utah's nutrient strategy. Generally speaking, the adaptive management process begins with the development of immediate action plans based on current information, followed by phased implementation of potential solutions problems that are identified. As actions are implemented, concurrent monitoring is used to identify success in comparison with the plan's objectives. Finally, the plan is either maintained or modified based on the analysis of the results and the process is continued until management objectives are realized.

> *ADAPTIVE MANAGEMENT IS "…THE PROCESS BY WHICH NEW INFORMATION ABOUT THE HEALTH OF THE WATERSHED IS INCORPORATED INTO THE WATERSHED MANAGEMENT PLAN. ADAPTIVE MANAGEMENT IS A CHALLENGING BLEND OF SCIENTIFIC RESEARCH, MONITORING, AND PRACTICAL MANAGEMENT THAT ALLOWS FOR EXPERIMENTATION AND PROVIDES THE OPPORTUNITY TO 'LEARN BY DOING.' IT IS A NECESSARY AND USEFUL TOOL BECAUSE OF THE UNCERTAINTY ABOUT HOW ECOSYSTEMS FUNCTION AND HOW MANAGEMENT AFFECTS ECOSYSTEMS"* **(USEPA 2003).**

With respect to Utah's approach to NNC Development, UDWQ intends to apply this adaptive approach first for headwaters and then for streams further downstream on a site-specific basis. Within headwater UDWQ proposes regional NNC, with an adaptive and collaborative management framework for addressing problems that are identified. These proposed NNC are adaptive because they call for ongoing modification to these criteria if ongoing data collection efforts suggest that the criteria—both nutrients and responses—are either over- or under-protective.

For streams further downstream UDWQ proposes, at least initially, development of site-specific NNC. Development of iterative site-specific NNC allows UDWQ and collaborators an opportunity to augment the science and better understand the implications of NNC implementation in an iterative manner (Figure 2). This approach will also help prioritize limited resources either to specific sites

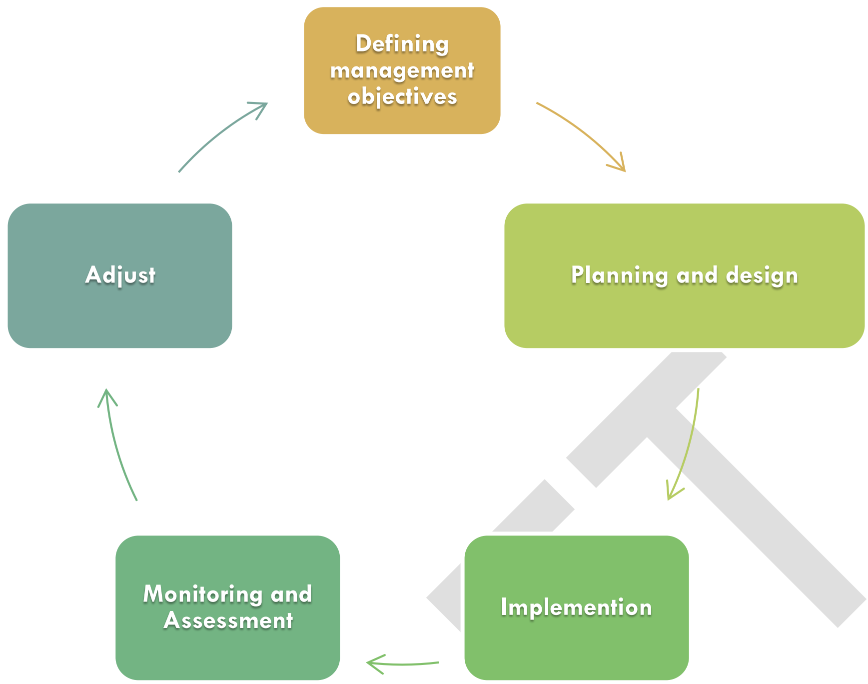

Figure 2. Adaptive management approach for Utah's nutrient strategy.

where remediation efforts are most likely to result in water quality improvements or to sites where definitive numeric criteria are needed to make regulatory decisions. UDWQ has also implemented technology-based limits to reduce phosphorus from point sources, and is developing similar optimization approaches for nitrogen, which allows affordable and immediately achievable point-source nutrient reductions of ~50% to be made while site-specific studies aimed at downstream NNC development are ongoing.

Development of Nutrient Enrichment Indicators

In addition to specifying TN and TP concentrations that must be maintained to meet aquatic life uses, UDWQ also proposes NNC that combine ecological responses to the lower TN and TP criteria (sometimes called combined criteria). Linkages between nutrient pollution and designated uses are complex, with many interrelated processes (Figure 3). NNC, for both nutrient concentrations and responses require thresholds that can be used to identify degraded conditions. These thresholds are generally defined by evaluating the distribution of reference site TN and TP concentrations, or by developing empirical models that relate nutrients to measures of biological condition. For the latter approach, measures of biological condition should be as directly linked to nutrients as possible.

To meet these NNC data requirements UDWQ conducted a state-wide study that evaluated the effects of nutrients on Utah's streams including several ecological responses that can be used as water quality indicators. UDWQ already measures water quality parameters that are potentially related to nutrient-related problems (e.g., pH, DO, biological assessments), however these responses are indirectly linked to nutrient enrichment. To overcome this limitation, DWQ identified and measured several water quality indicators to be as proximate to nutrients as possible. Specifically, this study involved measures of ecosystem functions and existing measures of biological integrity that were measured at streams with varying nutrient conditions. These studies are described in detail in the *Technical Basis for Utah's Nutrient Strategy* (Ostermiller et al. 2014) and summarized here in support of headwater NNC.

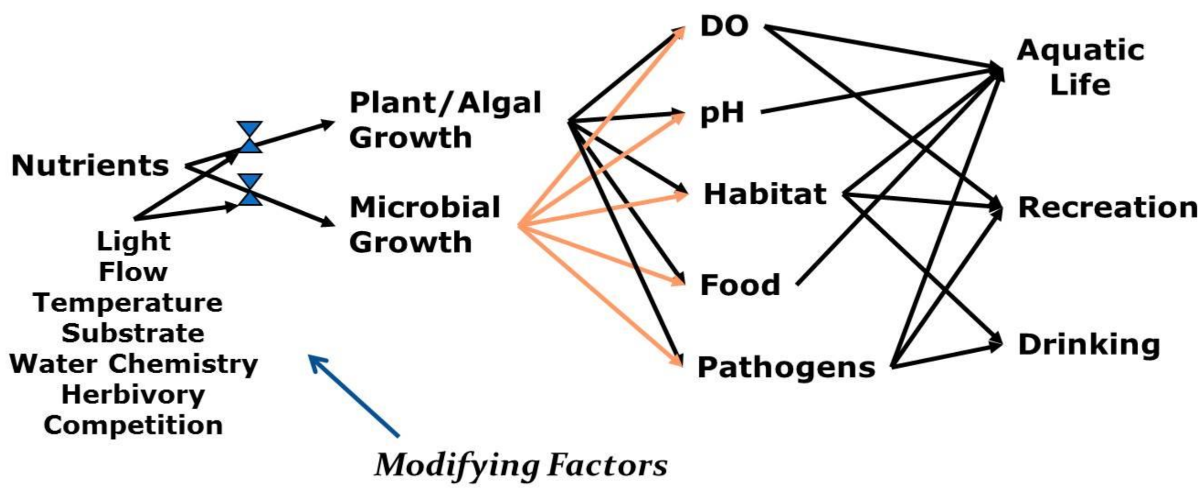

Figure 3. Simplified descriptive model depicting linkages between nutrients and designated uses. (after Paul 2009).

Candidate responses (water quality indicators) were selected in consultation with UDWQ's nutrient technical subcommittee, academic researchers and the ecological literature. Candidate responses were included for evaluation if they met two objectives. First, the nutrient response indicators had to be derived from well-established measures, supported by scientific literature. Second, the indicators had to be able to be routinely incorporated into Utah's monitoring and assessment programs. The indicators that were ultimately selected included five functional measures of condition and biological structure derived from two assemblages (macroinvertebrates and diatoms) (Table 2). Subsequent to Utah's selection of these indicators, USEPA convened a workshop of national experts to discuss potential responses that were most sensitive to nutrient enrichment (USEPA 2014).

Many of the most highly ranked responses that the USEPA Technical Advisory Panel (USEPA 2014) selected were already included in the UDWQ investigation.

UDWQ partnered with Utah State University to expand on the ecological responses evaluated in this investigation to develop and implement a plan that would utilize these measures, among others, to better parameterize mechanistic models (Hobson et al. 2014). Models were developed for all locations downstream of the point sources in this investigation. These models are already being used to develop more accurate waste load analyses to support permit limits. In the future, these models will be used to supplement the empirical responses in follow up site-specific investigations. Utah's Water Quality Board was supportive of these plans and provided the funds to conduct the investigations. Finally, UDWQ also took advantage of a subsequent economic study to evaluate the potential impact of nuisance algal blooms on recreational uses.

Table 2. Summary of indicators used to develop nutrient thresholds that guided the proposed headwater NNC.

	Functional Indicators
Nutrient Saturation	These thresholds, derived from nutrient diffusing substrates, quantify the concentration of total nitrogen and phosphorus where, on average, additional nutrients did not cause an increase in algal growth. At these thresholds other factors, such as light, substrate, or CO_2 cause additional algal growth.
Stream Metabolism: Gross Primary Production (GPP)	GPP measures the total amount of oxygen produced by photosynthesizing plants and algae each day (g O_2/m^2/day). Nutrient thresholds derived from GPP are the concentrations that were associated with streams with relatively low, moderate and high rates of GPP. UDWQ proposed to use this as a water quality criteria paired to nutrient criteria.
Stream Metabolism: Ecosystem Respiration (ER)	ER measures the oxygen consumed either through the processing (oxidation) of organic matter to CO_2 or by plant and algae growth (g O_2/m^2/day). Many stream organisms—including bacteria, protozoa and fungi—rely on organic carbon as an energy source for cellular metabolism and growth, and these processes consume oxygen. UDWQ proposes to use this metric as a water quality criteria paired with nutrient criteria.
Organic Matter Standing Stock	Organic matter standing stocks quantify, as g C/m^2 or AFDM/m^2, the amount of organic matter, excluding larger particle and macrophytes, in stream reaches. This measure provides an estimate of the amount of material available to feed bacterial, protozoan and fungal respiration. Nutrient thresholds were derived as the concentrations that, on average, distinguished among streams with relatively low, moderate, and high organic matter standing stocks.
	Structural Indicators
TITAN (nCPA): Diatoms	TITAN (Threshold Indicator Taxa ANalysis, Baker and King 2010) is a method that calculates indicator scores that capture the occurrence, abundance and directionality of species responses to stressors. The method then uses these indicator scores to determine, in this case, the nutrient concentration (nCPA) that captures the point where those species with statistically significant changes in abundance occurs. In this case, TITAN scores capture biological changes associated with diatom taxa, a diverse assemblage of algae that are known to be sensitive to nutrients.
Macroinvertebrate Biological Assessments: O/E	UDWQ currently uses macroinvertebrate-based RIVPACS models to evaluate biological integrity and to determine whether streams are meeting their designated aquatic life uses. The output of the models, O/E, is a ratio of the macroinvertebrates that were actually observed at a site, compared with those that were predicted to occur in the absence of human-caused stressors. Nutrient thresholds were derived for concentrations that best distinguished between streams in degraded and non-degraded condition.

Study Design

In the summer of 2010, UDWQ collected much of the data necessary to derive headwater NNC. An important aim of the investigation was to ensure that collectively the sites encompassed the range of stream types found statewide. To meet this objective, we collected data upstream and downstream of 8 Publically Owned Treatment Works (POTW) and at an additional 15 physically similar reference sites that could be used to define healthy conditions (Figure 4). This design allowed UDWQ to capture a gradient of nutrient conditions, as well as the influence of both non-point sources (upstream reaches) and point sources of nutrients. Ultimately, the design successfully included streams that were representative of the range of nutrient concentrations that occurs statewide (Figure 5).

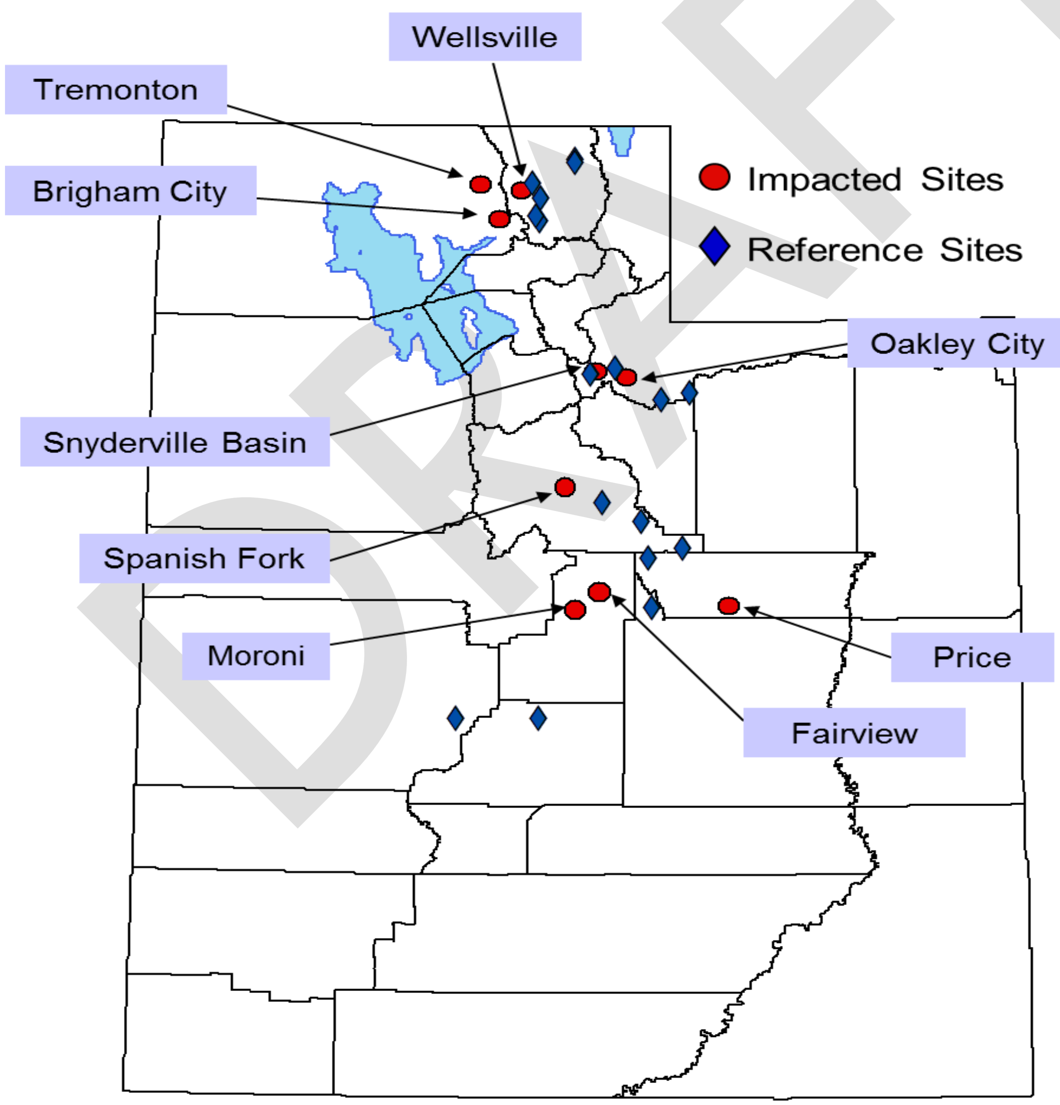

Figure 4. Map depicting locations of sites that were used for the stressor-response analysis.

Note: Enriched sites are a combination of two study reaches above and below a POTW discharge (labeled). Reference sites represent minimally enriched stream locations.

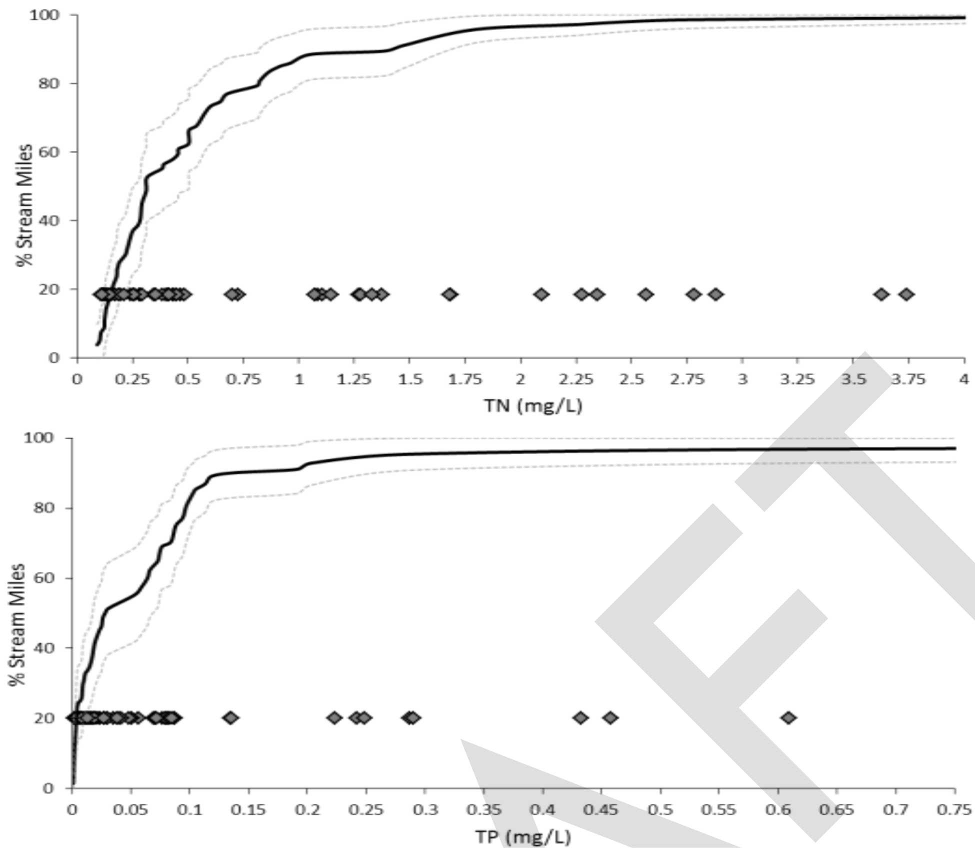

Figure 5. Nutrient concentrations at stressor-response study sites in comparison with statewide estimates.

Note: Solid black lines represent the cumulative frequency distribution of all Utah perennial streams. The CDF data were obtained from 50 randomly selected sites throughout Utah. The dashed lines depict the 95th percent confidence interval of statewide average nutrient concentration (solid black line). Grey diamonds are the average nutrient concentrations obtained from the sites used in this functional response study. These plots do not include three high TN and four high TP sites because they exceeded the plot scale.

Summary of Findings

UDWQ used empirical models to evaluate the relationships among stream nitrogen and phosphorus concentrations and various measures of ecological response. The objective of these evaluations was to establish thresholds of nitrogen and phosphorus concentrations that best separated each indicator into 2–3 groups of streams in varying degrees of condition. The three steps of these analyses were: classification, derivation of stressor-response models, and validation of the empirically derived thresholds (see Ostermiller et al. 2014 for details).

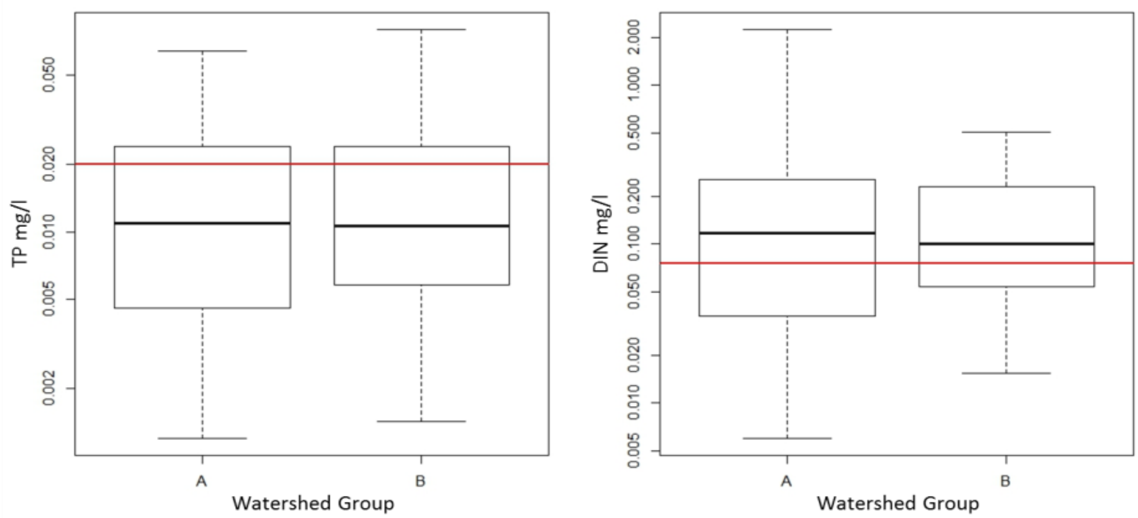

Figure 6. A comparison of nutrient concentrations between the two most distinct groups of headwater streams.

Note: Boxplots showing distributions of total phosphorus (TP) and dissolved inorganic nitrogen (DIN) between two groups of headwater, reference streams (N = 89) that were as physically distinct from each other as possible (from k-means clustering). Important physical characteristics included: air temperature, precipitation,elevation and soil characteristics. Data below red vertical lines are non-detects and were extrapolated using Kaplan-Meier survival

Classification

Addressing natural variation—in both background concentration and ecological responses—remains a challenge for NNC development. Background nutrient concentrations vary as a result of physical and environmental factors such the mineral composition of soils and bedrock, soil erosion rates, organic matter inputs, channel type and gradient (Smith et al. 2003). In fact, ambient stream nutrient concentrations among reference sites nationally can vary considerably (Lewis et al. 1999). In a recent review of national nutrient concentrations among reference streams the 75th percentile of reference site TN varied from 0.13-1.19 mg/L, while TP varied from 0.009-0.170 mg/L (Evans-White et al. 2014). Moreover, differing environmental gradients can buffer or exacerbate ecological responses to nutrient enrichment, which means that failure to account for gradients can result in NNC that are either over- or under-protective of beneficial uses (Dodds and Welch 2000). Classification minimizes natural variation by systematically grouping streams with similar physical and environmental characteristics..

The decision to limit proposed NNC to headwater streams is, in essence, a classification. However, UDWQ wanted to determine whether additional subclasses were needed to further minimize natural variation in nutrient concentrations. To meet this objective, UDWQ compiled numerous measures of landscape-level physical conditions (e.g., stream gradient, stream size, elevation, background lithology) that are known to be directly or indirectly associated with natural gradients in nutrient concentrations or ecological responses. Multivariate statistical techniques were then used to divide headwater streams into two classes of streams—one class with 46 reference sites and another with 43—that were as physically distinct in these physical characteristics as possible (see Chapter 10, Ostermiller et al. 2014 for details). Finally, nutrient concentrations from reference sites were compared between these two populations of streams. In the end, neither nitrogen nor phosphorus was statistically different between these two groups of headwater reference streams, which allowed UDWQ to conclude that additional sub-classes were not needed to establish NNC for headwaters (Figure 6). Finer scale groups of nutrients may still be needed, but existing data are currently insufficient to justify additional classes of streams. UDWQ will continue to evaluate the need to further refine headwater criteria as additional data are collected through the proposed routine monitoring and assessment processes that accompany these proposed NNC.

EVALUATING ECOLOGICAL RESPONSES TO NUTRIENTS

Ultimately, NNC for headwater streams need to be protective of uses, which means that indicators need to be sensitive enough to detect deleterious responses before impairment to uses occurs. As previously mentioned, there are many different and interrelated paths between nutrients and uses and the most important routes can vary spatially and temporally. As a result, UDWQ opted to derive thresholds from several different indicators so that protective nitrogen and phosphorus concentrations could ultimately be selected on a weight of evidence basis. To accomplish this objective S-R statistical models were developed, and thresholds subsequently established for all possible combinations of each stressor (total nitrogen and total phosphorus) and all responses (Figure 7).

Collectively, the nitrogen and phosphorus thresholds established from these models fell within a narrow range of nutrient concentrations. For TN, the vast majority of thresholds were between ~0.30-0.70 mg/L, whereas the majority of thresholds for TP fell between 0.020 and 0.060 mg/L (with one as high as 0.08) (Figure 7). Of course, these are regional generalizations, so each of these thresholds is bounded by upper and lower confidence estimates. Accounting for this variance, the overlap among indicators is even more apparent. Any value within these ranges of protective conditions could potentially be justified as an appropriately protective concentration of TN or TP.

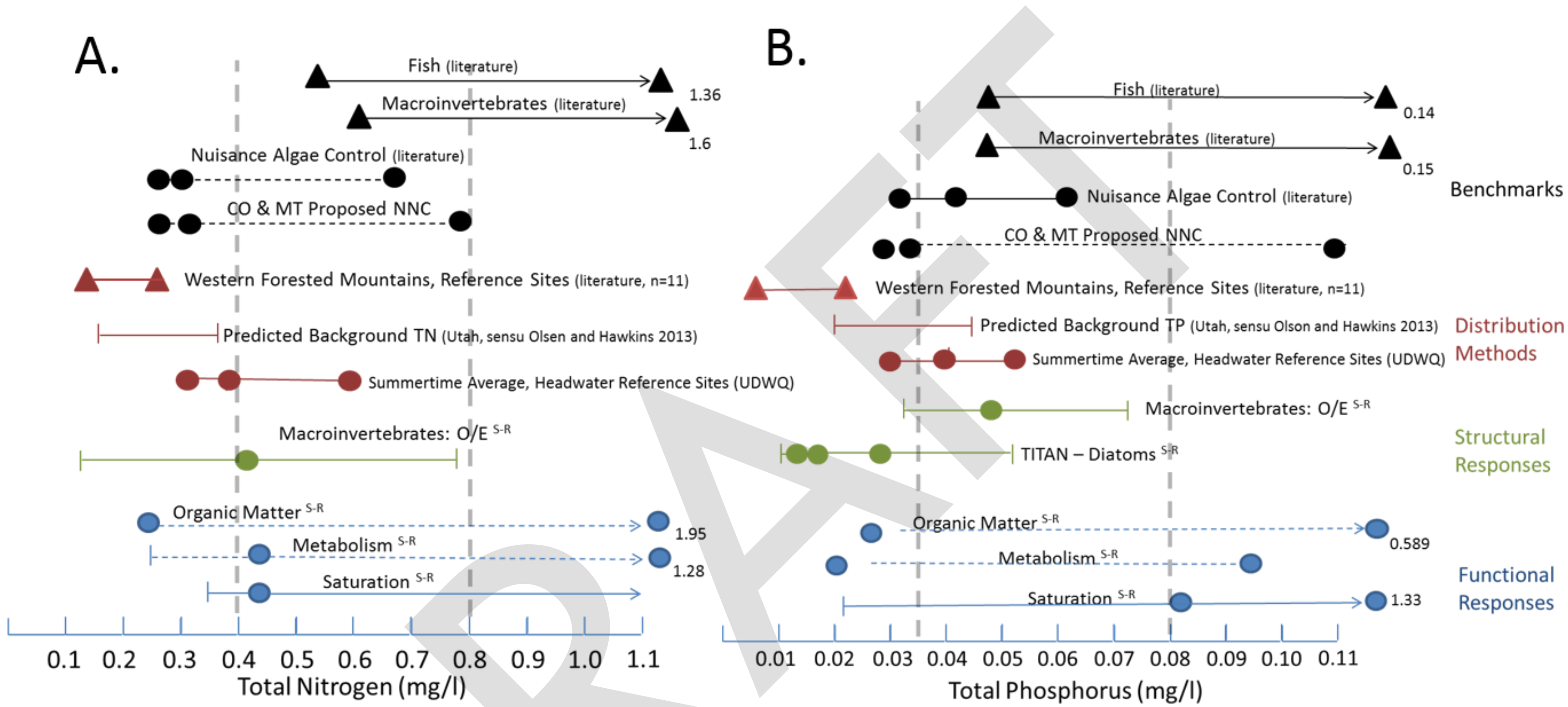

Figure 7. Thresholds for Total Nitrogen (Panel A) and Total Phosphorus (Panel B) along with proposed headwater criteria (dashed vertical lines).

Notes: Lines bracketed by triangles indicate the omission of numerous intermediate thresholds (dots). The graphics are colored to demarcate different categories of thresholds. Starting from the bottom, blue denotes functional responses, whereas structural responses are depicted in green (UDWQ calculations). Red denotes thresholds derived using distribution methods. The bottom red dots indicate the 75th, 90th and 95th percentiles of the summertime average of Utah reference sites. The middle red line are background concentrations obtained from an empirical model that predicts background concentrations from natural environmental gradients, whereas the top red line denotes other distribution methods from reference site distributions in EPA Nutrient Ecoregion II(Evans-White et al. 2014). Finally, black graphics in are broad benchmarks with other proposed numeric criteria from EPA Region 8 on the bottom and whereas the top three black lines are values obtained from the primary literature.

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ECOLOGICAL CONFIRMATION OF EMPIRICAL THRESHOLDS

The thresholds derived from S-R models are based on the statistical distributions of nutrients and responses, which does not necessarily mean that they are ecologically relevant. To some extent, the fact that the thresholds derived from different responses are similar provides some evidence that they are meaningful. However, UDWQ took this analysis a step further wherever possible by evaluating the thresholds against other related, but independently derived measures of water quality. The functional measures of gross primary production, ecosystem respiration and organic matter standing stocks are all related to the production or consumption of oxygen, and instantaneous measures of Dissolved Oxygen (DO) corresponded to violations of the 30-day average DO criterion (Figure 8). Specifically, when ER or organic matter exceeded recommended thresholds we saw appreciably more DO observations that fell below this water quality benchmark. Admittedly, these DO benchmarks are conservative because instantaneous values of DO cannot directly assess a criterion that is expressed as a 30-day average. Nevertheless, these comparisons suggest that the recommended ER threshold (9 g O_2/m^2/day) is associated with conditions that are potentially stressful to stream biota because somewhere around 7-9 g O_2/m^2/day the proportion of observations went from near zero to approximately forty percent. In the case of structural responses, we were able to compare nutrient thresholds against independent measures of biological condition that UDWQ already uses to assess the condition of streams (O/E) and again we found a close match with these independent measures of stream condition. In fact, the corresponding nutrient thresholds that were established using these biological assessments resulted in a fair balance between false positive and negative assessment errors, as determined from previously established impairment thresholds for O/E.

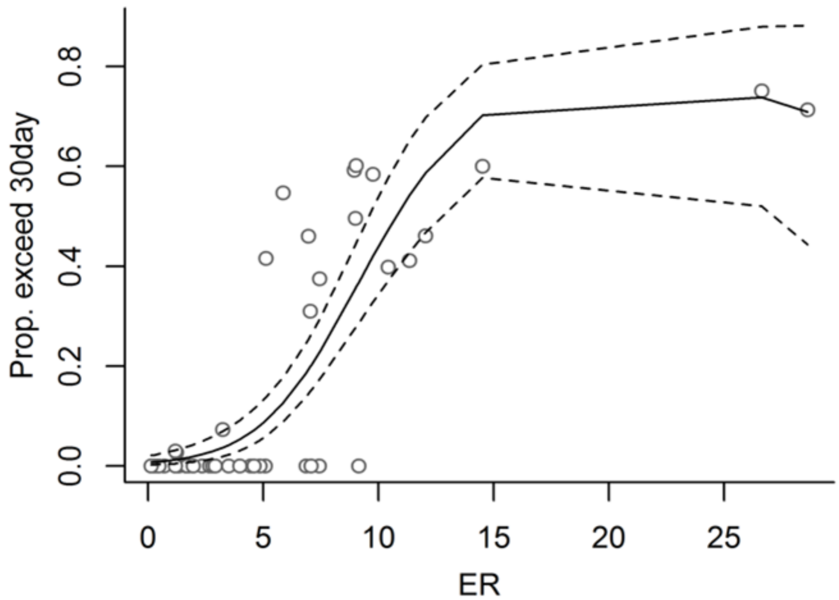

Figure 8. Relationship between Ecosystem Respiration (ER) and the proportion of instantaneous Dissolved Oxygen (DO) measurements that exceed a water quality benchmark (Utah's 30-day average DO criterion for all life uses (6.5 mg/L)).

While it is not possible to determine cause-effect relationships with regional S-R models, the collective results—particularly when coupled with benchmarking from the literature and other proposed criteria—gives UDWQ confidence in the legitimacy of S-R derived thresholds for headwater streams. However, it is equally important to note that there were site-specific exceptions to general patterns for every indicator that we evaluated. We also observed significant influences of important covariates (i.e., stream gradient, channel shading) on several responses. These observations highlight the importance of simultaneous examination of both nutrient and responses to avoid either missing sites with nutrient-related problems or making erroneous impairment conclusions.

DISTRIBUTION METHODS FOR NNC DEVELOPMENT

As previously mentioned, another approach to NNC development involves the derivation of NNC from the distribution of observed TN and TP among reference streams (USEPA 2010). The most common metrics used to establish NNC from these distributions are the 75th, 90th, or 95th percentiles. While UDWQ did not derive criteria directly using these approaches, we calculated these values as conformational evidence in support of the S-R thresholds (Table 2). We identified 45 reference sites with TP summertime data, and 43 reference sites to evaluate TN. However, many of the potential TN reference samples lacked organic nitrogen data, which required calculating predicted total nitrogen (PredTN) from total inorganic nitrogen (linear regression, $r^2 = 0.92$, $p<0.001$). For each of these sites, summertime averages were calculated with all data collected from June through September across the most recent 10-years of available data. Several percentiles were then calculated from these reference site distributions (Table 3). These thresholds align nicely with those derived from stressor-response relationships providing further support for the headwater NNC that UDWQ proposes.

Table 3. Distributions (percentiles) of summertime average total phosphorus and total nitrogen concentrations in headwater streams.

Percentile	Total Phosphorus (TP, mg/L)	Predicted Total Nitrogen (predTN, mg/L)
75th	0.027	0.294
90th	0.037	0.382
95th	0.053	0.605

EFFECTS OF NUISANCE ALGAE ON RECREATION USES

Previous investigations have observed that excessive stream algae create conditions that people find undesirable (Supplee et al. 2009). UDWQ thought that this human dimension warranted exploration. This is especially true given the importance of headwater watersheds to outdoor recreation, which Utah's Office of Outdoor Recreation estimates to contribute $12 Billion/year and over 100,000 jobs to Utah's economy. These streams are also critical culinary water sources to a state that is the second driest in the country with one of the fastest growth rates. UDWQ has long acknowledged the importance of these waters, which has subsequently been codified in Utah Rules (R317-2-6.2; R317-2-7.2). Also, maintenance of stream aesthetics is an important aspect of the general quality of life for Utahns considering that >70% of Utah citizens recreate on or around streams, many of them in headwater watersheds.

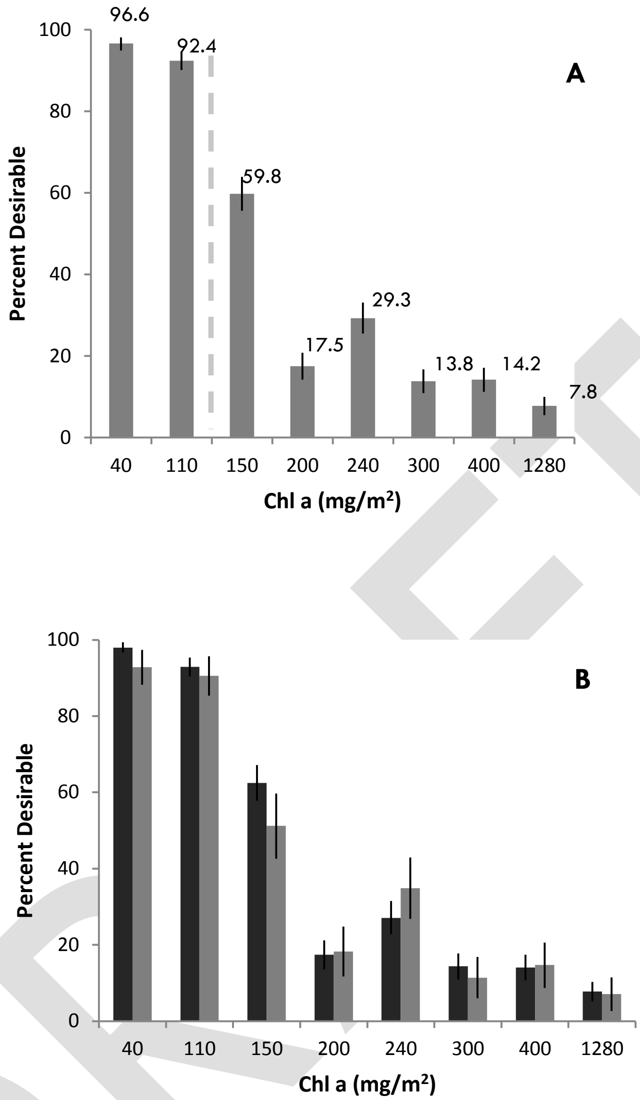

Figure 9. Results of Utah's survey regarding undesirable benthic algae in recreational waters with proposed criterion depicted as a dashed, vertical line.

Note: A) Percent desirable benthic algae response from all Utah survey participants. B) Percent desirable benthic algae responses from users (black) and non user (grey) groups showing similarity in responses. Error bars indicate 95% confidence intervals.

UDWQ, in conjunction with a larger economic study, surveyed randomly selected citizens (1,411 respondents) to evaluate the potential impact of nuisance algae on recreational uses (CH2MHill 2012). Each survey included photographs of streams with varying quantities of algae growth. For each photograph, citizens were asked whether or not the conditions represented "desirable" recreation conditions. With remarkable consistency, citizens reported a drop in desirable conditions as algae increased from 110 to 200 mg chl-a/m^2 (Figure 9). From these results, and literature benchmarking with other independent investigations, UDWQ proposes a benthic algae concentration of 125 mg chl-a/m^2 as a numeric criterion protective of recreational uses in headwater streams. This proposed criterion is protective of degradation to recreational uses because it is above the benthic chlorophyll concentration where nearly all respondents indicated desirable conditions, but below the point where respondents start indicating that the depicted stream conditions are undesirable.

RATIONALE BEHIND PROPOSED HEADWATER NUMERIC NUTRIENT CRITERIA

This section summarizes the rationale behind the proposed NNC for Utah's headwater streams. Criteria are proposed for TN and TP at two different concentrations. The higher concentration is intended to be used in circumstances where response data are unavailable, whereas the middle levelis to be interpreted in combination with ecological responses. Criteria and supporting rationale are also provided for the ecological responses. For all proposed criteria, a rationale is provided for the recommended magnitude (concentration), duration (averaging period) and recurrence interval (acceptable number of violations). Technical details that support this rationale are available in the *Technical Basis for Utah's Nutrient Strategy* (Ostermiller et al. 2014). However, the section ends with a discussion that benchmarks the proposed NNC against criteria proposed elsewhere and investigations from the scientific literature.

Elsewhere, NNC have been proposed that rely exclusively on water column nutrient concentrations. However, over reliance on chemical constituents alone may lead to under protection of streams because biological uptake lowers ambient nutrient concentrations, at least on a temporary (i.e., within-season) basis. When water column nutrients are incorporated into algal or plant cells, the nutrients can be captured with samples that quantify total (both organic and inorganic) nitrogen and phosphorus. However, in small to moderate size streams most primary production occurs on the streambed, which TP or TN water column samples may miss. The end result is that water column concentrations can sometimes be deceptively low in situations where primary production is high. As a result, UDWQ proposes that appropriately protective criteria should include both concentrations of nitrogen and phosphorus and indicators that measure autotrophic and associated heterotrophic responses to nutrients. Another advantage of simultaneous measures of the cause of cultural eutrophication (nutrients) along with ecological responses is that these data can highlight circumstances where regional headwater NNC may need to be modified on a site-specific basis because natural conditions are either protective of or exacerbate deleterious ecological responses. Despite the advantages of combined criteria, UDWQ acknowledges that there are circumstances where nutrient data are available but responses are not. As a result, UDWQ also proposes additional TN and TP criteria—higher, but still protective of uses—for use in circumstances where response data are unavailable and to prioritize the most nutrient impacted headwater streams for further investigation. The combination of these enrichment levels (low nutrient concentrations with coupled ecological response and higher concentrations without) allows UDWQ the flexibility necessary to ensure that nutrient-related water quality problems do not degrade uses in any headwater stream, while helping UDWQ prioritize monitoring and watershed planning resources.

Other considerations in the NNC that UDWQ proposes were pragmatic: the criteria are expressed in a manner that allows them to be evaluated with data that are readily available from routine water quality monitoring programs. At first glance, this consideration may seem self-evident. However, the disconnect between monitoring data and the averaging periods expressed for many existing numeric criteria is an ongoing challenge for Utah and many other states. For example, acute toxicity is expressed as a 5-day average, whereas monitoring is typically conducted across broader temporal scales (e.g., monthly or bi-weekly samples). UDWQ has defined a monitoring and assessment strategy and minimum sample requirements to help ensure that both nutrient and response data are available (see *Programmatic Implications* below).

Numeric Criteria for Nitrogen and Phosphorus

The Importance of both Nitrogen and Phosphorus

An important consideration in the NNC that UDWQ proposes relates to the relative importance of nitrogen (N) and phosphorus (P) in controlling ecological responses. There is considerable evidence from nutrient diffusing substrates (Elsner 2007) and streamside experimental additions (Rier and Stevenson 2006), that streams are often co-limited by nitrogen and phosphorus—the addition of N and P may lead to greater algal responses than either alone. This is particularly true across broad spatial and temporal scales. Using nutrient diffusing substrate methods, UDWQ found co-limitation to be the most common condition in study streams (Ostermiller 2014); although, these results need to be confirmed with alternative experimental methods. In streams there is a range of total N:P—of ~6-10 (algae cell concentration, by mass)—where co-limitation is likely. As N:P drops below 10 nitrogen becomes limiting, whereas phosphorus becomes limiting as N:P exceeds 17 (Smith 1982, Dodds 2003). Different algal assemblages can exhibit vastly different N:P ratios and limitation can be difficult to determine from these estimates alone. One reason for natural variation in N:P relates to physical differences among watersheds. The N:P of underlying soil and lithology varies from place-to-place, as does the extent to which nutrients are mobilized (Olson and Hawkins 2012). UDWQ's proposed criteria need to acknowledge these natural differences among streams, but should also be broadly protective by including both nitrogen and phosphorus.

Differences in N:P among streams can also be biologically driven based on differing nutrient requirements among algal species. Controlling exclusively for phosphorus is complicated by the fact that some species are capable of storing P in excess of their immediate requirements (luxury uptake) which would offset the environmental benefits of P control efforts. For example C*ladophora,* a common nuisance algae in Utah, has been shown to have increasing concentrations of tissue phosphorus as concentrations declined in surrounding waters (Lohman and Priscu 1991). Other species are capable of "fixing" N from the environment, which ultimately moves streams toward P-limitation. The presence and relative dominance of different algal species within a stream varies temporally. Moreover, different algal species favor different microhabitats within streams. Together these factors, coupled with varying nutrient demands among algal species, mean that the relative importance of TN and TP varies both spatially and temporally. While additional research is needed, there is increasing evidence that the expanding nuisance algae *Didymosphenia* is exacerbated by high N:P (mean of 31:1, range = 98 to 3.7:1; N = 5, Whitton et al. 2009), in hydrologically stable streams.

Finally, it is important to note that human sources of nutrient enrichment in headwater streams either result from atmospheric deposition or other non-point sources. In reality, Best Management Practices (BMPs) that address these diffuse sources are equally effective at reducing both nutrients. If it were possible to reduce one nutrient in favor of another it would be more important to determine exactly which nutrient was limiting at site with appropriate autotrophic or heterotrophic bioassays conducted over the course of several seasons.

For these reasons, DWQ believes that headwater NNC are more likely to protect designated uses if they include both N and P, and that the specific N:P of these criteria should not favor limitation of one nutrient over another. UDWQ also proposes that these criteria should be set for <u>total</u> nitrogen and phosphorus. Elsewhere NNC are sometimes proposed for total inorganic nitrogen (TIN) or soluble reactive phosphorus (SRP), because these inorganic forms of nutrients are immediately available to aquatic plants and algae. While this may be true over relatively small spatial and temporal scales, organic forms of nutrients are cycled fairly quickly into inorganic forms (Dodds 1993). As a result, criteria based on total nitrogen and phosphorus better captures the risk to aquatic biota over the spatial and temporal scales of management concern, and are reflected in the duration and frequency proposed by UDWQ. That said, UDWQ strongly recommends that all nutrient constituents are collected whenever possible and will continue to do so because the knowledge of the constituents of TN and TP is critical when interpreting water quality data (see *Monitoring* in *Programmatic Implications* below).

Magnitude of TN and TP

UDWQ recommends that three levels of nutrients are established for TN and TP for Utah's headwater perennial streams.

Level 1: Low Nutrient Enrichment

Streams at these levels for both TN and TP are considered to be supporting aquatic life uses.

Total Phosphorus (as P) < 0.035 mg/L
Total Nitrogen (as N) < 0.40 mg/L

Level 2: Moderately Enriched

Streams in this range of nutrients require documentation of a deleterious ecological response (see below) before making a determination that aquatic life uses have become degraded.

Total Phosphorus (as P): 0.036-0.079 mg/L
Total Nitrogen (as N): 0.41-0.79 mg/L

Level 3: Highly Enriched

Total Phosphorus (as P) >0.080 mg/L
Total Nitrogen (as N) >0.81 mg/L

All of the above concentrations are based on summertime (June through September) averages from ≥4 samples.

Both upper and lower numeric TN and TP criteria are appropriately protective of the 3A and 3B aquatic life uses in headwater streams for the following reasons:

- The lower concentrations are consistent with the 90th percentile of reference sites, which have been used to support criteria elsewhere.
- All proposed concentrations are within the range of values—thresholds and associated confidence intervals—associated with fully supporting conditions as measured with biological assessments (structural indicators).
- The lower threshold is at or near the relatively good to fair conditions that were empirically defined with functional response indicators, whereas the upper threshold falls below the fair to poor condition thresholds.
- While there is no general agreement about what constitutes excess algae, most researchers suggest that appropriate values lie somewhere between 125-200 mg chl-a/m^2. Calculations

derived from regional estimates (Dodds et al. 2006) suggest that the lower values should, on average, prevent growth in excess of the lower end of this range while the upper concentrations should not allow growth in excess of the upper range.

- All proposed concentrations are below levels where production was, on average, saturated with respect to nutrients, which indicates that other factors were limiting algal growth at these sites.

In addition, these values fall within the range of NNC proposed by other states and values that are generally considered indicative of healthy conditions in several published studies from the primary scientific literature (see *Benchmarking* section below for details).

Duration and Frequency

Duration
The proposed NNC are based on a seasonal (June – September) arithmetic average of water column TN and TP.

Frequency
The summertime seasonal average TN and TP criteria shall not be exceeded.

HOW WILL SEASONAL AVERAGES BE CALCULATED?

Water column nutrient samples are variable and seasonal averages should be based on as many samples as possible. However, sample size requirements must be consistent with the capabilities of UDWQ's monitoring program. UDWQ rotates intensive monitoring among six major basins throughout Utah, so increasing the allowable number of excursions could result in nutrient-related problems not being addressed for six or more years. UDWQ believes that allowing potential water quality problems to go unaddressed for over a decade is an unacceptable risk to our most fundamental public trust: ensuring the protection of water quality. Another practical sampling constraint is that wintertime access to headwaters is, in many cases, difficult or impossible. As a result of these practical constraints, UDWQ or cooperators will obtain a sample size of ≥4 samples for calculating summertime average nutrient concentrations. This sample requirement should be feasible for UDWQ and cooperating state and federal agencies (see *Programmatic Implications* for details). Of course, one possible consequence of smaller sample sizes is that outliers associated with climatic events (e.g., extreme droughts) could result in false positive or false negative assessments. However, such circumstances can be addressed on a case-by-case basis and UDWQ rules already provide the flexibility to exclude samples that were collected under unusual circumstances (UAR R317-2-9). In addition to these sample size requirements, UDWQ also recommends averages be based on an arithmetic mean, as opposed to a measure of central tendency that down weights outliers (e.g., geometric mean, median), because in some streams pulses of nutrients from runoff represents a considerable contribution to the total loads of nitrogen and/or phosphorus.

WHY FOCUS ON THE SUMMERTIME GROWING SEASON?

UDWQ proposes that NNC for TN, TP—and filamentous algae (see below)—apply to the summertime growing season (June through September). Most of the deleterious nutrient problems are the consequence of longer-term nutrient inputs. Growth rates of plants, algae and microbes are higher in the summertime due to higher water temperature and longer days. Flows are generally more stable during this season, which is an important factor in determing whether or not algae in higer nutrient streams accrues to nuisance concentrations. This averaging period also aligns with the recreation season as currently applied to assessment of recreation criteria. Finally, the months selected will be bracketed by snowmelt floods in the spring and the end of the water year in the fall. The latter is of practical importance because UDWQ times rotation of monitoring among major watershed management units based to be coincident with the water year.

WHY NOT TO BE EXCEEDED?

One consequence of basing headwater NNC on summertime averages is that this requires the recurrence interval be stated as a “not to be exceeded” value. One reason for this is practicality. Given Utah’s rotating basin monitoring approach (see Monitoring below for details), up to 12-years could transpire before nutrient-related problems would be documented in more than one season. It would be inappropriate and contrary to the intent of Utah’s water quality standards to allow such delays; particularly at sites where nutrients are high enough to threaten designated uses. One concern for “not to exceed” criteria is identical to those raised with respect to smaller sample sizes: that atypical stream conditions may result in either false positive or false negative assessments. There are a couple of reasons why the risk of such false assessments is less likely for the proposed headwater NNC. First, as with all standards, UDWQ may exclude samples collected under extremely high or low water conditions when calculating summertime averages of TN or TP (UAR 317-2-9). Second, the incorporation of biological responses into these proposed NNC and the ongoing independent assessment of other parameters (see below) provides UDWQ the ability to identify water quality problems with multiple lines of evidence.

Bioconfirmation Criteria: Stream Respiration and Benthic Algae Growth

Aquatic Life Uses

The lower NNC will be combined with the following responses, which are not to be exceeded in headwater perennial streams with either 3A or 3B aquatic life use designations (UAR R317-2):

Plant/Algae Growth

1/3 aerial cover of filamentous algae cover[1] OR Gross Primary Production[2] (GPP) 10 g $O_2/m^2/day$[2]

Microbial Growth

Ecosystem Respiration (ER) of 9 g $0^2/m^2/day$

Footnotes:

1. *Filamentous algae cover means patches of filamentous algae >1 cm in length or mats >1 mm thick. Estimates should be reach-scale averages with at least 3 measures from different habitat units (i.e., riffle, run) using quantitative and repeatable visual cover estimates. Applicable to the summertime growing season.*
2. *Daily whole stream metabolism using open channel methods. GPP measures are based on the amount of oxygen produced by autotrophs, whereas ER measures are based on the amount of oxygen consumed by plants and microorganisms. Applicable year-round.*

There are many potential paths between nutrients and potential degradation of aquatic life uses, but these are all initiated by the influence of nutrients on either autotrophic plants or algae, and or on heterotrophic microbial populations (Figure 3). These proposed bioconfirmation criteria capture alterations to these two principal nutrient-related assemblages, which in turn addresses several alternative paths between nutrients and effects on aquatic life uses. The specific responses that UDWQ proposes are consistent with those that were recommended as the most sensitive and directly linked to nutrients by a recently convened USEPA Technical Advisory Panel (USEPA 2014).

Why Gross Primary Production?

Excessive plant or algal growth is among the principle threats of excess nutrients to stream ecosystems (Quinn 1991, Horner et al. 1993). Both GPP and percent filamentous algae are different and complimentary measures of these responses. GPP measures net primary production via reach scale estimates of the amount of oxygen produced by plants and algae on a daily basis. Worldwide, several researchers have suggested that GPP is among the best measures of nutrient response in streams because it quantifies a fundamental ecosystem process at an appropriate spatial scale (Bunn et al. 1999, Young et al. 2006). Fellows et al. (1999) evaluated several direct and indirect measures of stream primary production and concluded that indirect measures of production were less sensitive than GPP in identifying streams with degraded conditions. UDWQ's proposed threshold of 10 g O_2/m^2/day was empirically derived as the GPP that, on average, best distinguished between statistically derived groups of streams in relatively fair as opposed to poor condition (see Ostermiller et al. 2014, Chapter 4 for details). It is also consistent with the point where other investigations have suggested that nuisance algae begin to become a problem for aquatic life uses (Young et al. 2008). To be protective, UDWQ also proposes that this value should not be exceeded—meaning that the threshold cannot be exceeded on any day during deployment—because this proposed criterion lies at the point where UDWQ considers production to be sufficiently high to constitute an impairment to aquatic life uses.

Why filamentous algae cover?

One of the most common ways that excessive production is manifest in Utah's headwater streams is a shift from an algal assemblage dominated by diatoms to one dominated by less desirable filamentous algae, particularly *Cladophora*. Filamentous algae are a less desirable food resource for most stream grazers (Hicks 1997) and when they become the dominant taxa they degrade the habitat of higher organisms by trapping fine sediment, subsequently filling interstitial spaces within the stream benthos. When this occurs, it directly affects fish reproduction by decreasing the survival of juvenile fish (Dodds and Gudder 1992). As previously noted, excessive amount of filamentous algae also degrades stream aesthetics, creating conditions that are undesirable to recreational uses.

Several experimental and field-based studies have shown that filamentous algae cover is positively correlated to increasing nutrient concentrations. Streamside nutrient enrichment experiments have documented that algal biomass increased with increasing nutrient additions (Bothwell 1989, Rier and Stevenson 2006). Stevenson et al. 2006 found that the probability of getting a filamentous algal cover of 20-40% increased when TP was >0.03 mg/L or TN was >1 mg/L in Midwest United States streams considered susceptible to filamentous algae growth. However, this study also noted that filamentous algae was absent at many streams with high nutrients. Others have also noted that whether or not filamentous algae cover reaches levels of potential concern is also dependent on other stream characteristics such as canopy cover, stream temperature, stream size and hydrology (Riseng et al. 2004, Dodds and Oakes 2004, Busse et al. 2006). As a result, the amount of filamentous algae cover within a given stream can vary both seasonally and also from year-to-year (Dodds and Gudder 1992, Francoer et al. 1999). In essence, while the presence of excessive amounts of algae is ecologically meaningful, the absence of high levels of algae during on any single observation is not particularly informative.

Most aquatic ecologists would agree that a headwater stream dominated (i.e., >50% cover) by filamentous algae is generally representative of degraded conditions. However, there is less consensus of an appropriately protective level of filamentous algae cover with respect to protection of aquatic life uses. Welch and others (1988) reviewed data collected at over 100 streams worldwide and suggest that a filamentous algae cover over 20% (equivalent to 100-150 mg chl-a/m^2) constitutes a nuisance. More recently, Biggs and others (2000) suggest that a filamentous algae cover <30% should be protective of aesthetics, benthic biodiversity, trout habitat and sport fisheries. EPA (2015) convened a group of international experts who recommended a range of 20-40% as being protective of aquatic life uses. UDWQ concurs that protective cover should fall somehere within this range.

UDWQ recommends a criterion of maximum filamentous algae cover of 1/3 of the stream bed. While this number is at the upper end of concentrations that others have suggested is protective of stream aquatic life uses, UDWQ believes that this number is protective of stream conditions because it represents the maximum filamentous algae concentration that is observed on any single collection event. This recommendation also acknowledges the paucity of percent filamentous algae cover data that are currently available for Utah streams. This criterion, among others, will be reevaluated as additional data are collected and will be adjusted if it is found to be either over- or under-protective of the aquatic life uses in Utah's perennial, headwater streams.

Why both GPP and filamentous algae cover?

GPP and filamentous algae cover have strengths and weaknesses as indicators of excessive primary production. GPP measures a fundamental ecosystem process that is directly tied to nutrients, but this response also has several disadvantages. For instance, it is sometimes not possible (or practicable) to make whole stream metabolism calculations at streams with an insufficient diel change in DO to calculate physical reaeration. Another limitation of GPP is that this measure requires deployment of specialized equipment, which makes it is logistically impossible to always have GPP coincident TN and TP samples. These same logistical constraints make GPP ill-suited for capturing within season changes in primary production. On the other hand, filamentous algae can be consistently measured during routine water quality sample collections making it an ideal response to capture within season changes in nuisance algal abundance. Filamentous cover measures also do not require the used of specialized equipment because the equipment (i.e., grids, viewing boxes) can be easily and inexpensively manufactured. Of course fiflamentous algae cover measures have disadvantages as well. In some streams, excessive filamentous algae cover is not observed until later in the season. Similarly, spates can scour filamentous algae from streams, which means that excessive algae cover might be missed on any given sampling event.

UDWQ believes that the use of both GPP and filamentous algae responses will allow more accurate identification of headwater streams with nutrient-related problems. GPP provides a daily measure of primary production that is integrative over smaller temporal scales, whereas filamentous algae cover is an ecological response that is more practical to measure across a growing season. The use of both indicators also provides greater flexibility to integrate the collection of nutrient-related problems into ongoing monitoring and assessment programs.

Why Ecosystem Respiration?

Increased plant and algae growth caused by excess nutrients can cause low nighttime DO—and high daytime pH—levels that are harmful to both mature and juvenile fish and invertebrates (Welch 1992). In streams where physical reaeration is naturally low, nighttime oxygen consumption (respiration) can exceed reaeration, which subsequently causes DO to decline, especially at night when plants and algae are not producing oxygen via photosynthesis. DO problems can also occur because the plants and algae associated with elevated primary production ultimately die and become a food source for microbes, which increase in abundance and decrease oxygen via normal metabolic processes. Whole stream ecosystem respiration (ER) captures these important stream functions by quantifying the amount of oxygen consumed by stream organisms on a daily, per area basis. UDWQ's proposed ER of threshold of 9 g O_2/m^2/day because this was the ER that, on average, distinguished between statistically-derived groups of moderate and highly enriched streams (Ostermiller et al. 2014, Chapter 4 for details). This proposed response criterion was also consistent with circumstances where the majority of instantaneous DO readings fell below screening values—Utah's 30-day DO criterion of 6.5 mg/L for all life stages (Figure 8). Interestingly, this value is also consistent with values proposed by other investigators as indicators of stream health (Young et al. 2008, Fellows et al. 2006, Bunn et al. 1999). As with GPP, this threshold is is a "not to be exceeded" value that should not be violated to maintain aquatic life uses. As with GPP, this value was established at the point where, on average, streams shift from fair-to-poor conditions, however, it is the conservative nature of this recurrence interval that makes the standard protective of aquatic life uses.

What about the other nutrient-related responses?

While UDWQ maintains that the use of ambient nutrients coupled with the proposed responses covers (or blocks) all important response pathways between nutrients and aquatic life uses, it is also important to note that UDWQ will continue to independently measure and assess other related water quality criteria. For instance, pH and DO will continue to be assessed against Utah's numeric criteria for these parameters. In fact, the accuracy with which these parameters can be assessed will likely improve with the additional high frequency data measures required for metabolism calculations. Both DO and pH can vary extensively on a diel basis, which complicates interpretation of instantaneous measures that are currently collected with water quality grab samples. UDWQ will also continue to measure several water quality indicators that quantify the condition of stream habitat and the health of stream assemblages (see *Monitoring and Assessment* below for additional details). The simultaneous measures of these independent water quality criteria, coupled with the combined NNC and responses proposed in this document will provide UDWQ with tools to identify and address nutrient-related water quality impairments in headwater streams.

Recreation NNC: Protecting Stream Aesthetics

Recreation Uses

Recreation aesthetics will be protected for all 2A or 2B uses (UAR R317-2) with the following criteria that are not to be exceeded at any time:

Benthic Algae: <125 mg chl-a/m^2 or <49 g AFDM/m^2

The proposed recreation benthic algae concentrations were derived from the previously mentioned survey and the reduction in aesthetics that Utahns reported. UDWQ selected 125 mg chl-a/m^2 to preclude concentrations of 150 mg chl-a/m^2, which was the level where desirable conditions started to decline (Figure 9). Simply put, if people chose to not recreate in a stream due to degraded aesthetics then this constitutes a degradation of recreational uses. Again, given the importance of recreation to Utah's economy, UDWQ believes that guarding against degradation of this nature is appropriate. The data necessary to support these criteria are already collected in conjunction with UDWQ's Tier 1 Monitoring Program (see discussion in *Programmatic Implications*).

In making these recommendations UDWQ acknowledges that there may be circumstances where a particularly productive and important fishery requires higher production than normal to continue support of this important recreational use. If such circumstances arise, UDWQ will collaborate with Utah's Department of Natual Resources to determine an appropriate balance between the needs of the fishery, aesthetics and the long-term support of the ecosystem. If appropriate, these recreational criteria will subsequently be modified, provided that all loca and doenstream uses wil remain protected.

Benchmarking with Other Investigations

An important part of the adaptive management process is revisiting the planning process once preliminary investigations are complete. In the context of these proposed headwater NNC, such a retrospective will continue to be conducted in a couple of ways. First, the proposed NNC were benchmarked against NNC proposed by other states within USEPA Region 8 and thresholds identified in the scientific literature. Second, in the final section of this proposal several "next steps" are discussed that identify several ongoing processes that will continue to expand on or refine the proposed NNC as UDWQ's nutrient reduction program continues to develop.

How do the proposed NNC compare with other water quality benchmarks?

Statistically significant thresholds are not always ecologically significant. Evaluating multiple lines of evidence is one way to increase confidence that statistical thresholds are ecologically meaningful. In this respect, the fact that the thresholds for several independently measured responses are similar is encouraging. In addition, several thresholds were compared with other existing and independently developed water quality benchmarks. For instance, metabolism metrics, especially respiration (Figure 8), correspond with both higher nutrient concentrations and the proportion of instantaneous DO observations that are potentially stressful to stream biota. A similar pattern was observed for organic matter standing stocks (Ostermiller et al. 2014, Chapter 5)). Similarly, the structural indicators revealed a close correspondence between O/E scores—a metric that UDWQ uses to assess stream condition—and nutrient thresholds (Ostermiller et al. 2014, Chapter 6). The correspondence with the proposed NNC and these independent measures of condition provides additional support that the proposed NNC are appropriate and ecologically meaningful.

How do the proposed NNC compare with those proposed by others?

The proposed nutrient criteria overlap with TMDL endpoints established for Utah and NNC proposed for other mountain ecoregions. Montana DEQ recently proposed seasonal NNC for TN at 0.250–0.325 mg/L and—with one exception of an isolated volcanic range—proposed NNC for TP ranging from 0.025–0.030 mg/L (Suplee and Watson 2013). NNC proposals from other western states are also similar. In Colorado, stream nutrient criteria of 0.090 mg/L TP and 0.84 mg/L TN were recommended to protect cold water fish, although these have not yet been approved by EPA. Other western states, like Arizona and California currently only have TN or TP criteria for a limited number of streams, with values that are commensurate with those proposed by UDWQ. Outside of Utah, but within the western US, several studies have used different distribution approaches to propose NNC and values for streams within USEPA Aggregate Nutrient Ecoregion II (western Forested Mountains) range from 0.08–0.21 mg/L for TN and 0.003–0.020 mg/L for TP (see Evans-White et al. 2014 for summary).

How do the proposed NNC compare with thresholds identified in the scientific literature?

The proposed NNC are also consistent with protective concentrations of nitrogen or phosphorus that other scientific investigations have concluded were indicative of healthy stream conditions (Figure 7, black symbols). Biggs (2000) recommended that Dissolved Inorganic Nitrogen (DIN) and Soluble Reactive Phosphorus (SRP) remain below 0.019 and 0.002 respectively to avoid nuisance algae growth (200 mg/m^2 chl-a for a 50-day accrual). *Cladophora*, a filamentous algae that sometimes leads to nuisance algae growth in Utah streams, has a higher likelihood of reaching nuisance levels when TN exceeds 0.6–1 mg/L or TP exceeds 0.02–0.04 mg/L or (Dodds 1992, Stevenson et al. 2006), although the extent to which nuisance levels are attained depends on the frequency and magnitude of flooding events (Freeman 1986). Dodds et al. 2006 evaluated regional nutrient-algae relationships and derived criteria of 0.4–0.6 mg/L TN and 0.027–0.062 for TP.

Higher organisms are also known to be affected by excess nutrients, although relationships are indirect and some caution against overly depending on these responses (EPA 2015). Wang et al. (2007) evaluated macroinvertebrate responses and found TP thresholds of 0.04-0.09 mg/L and TN thresholds of 0.6-1.6 mg/L, depending on the specific metric evaluated. The same authors evaluated effects on fish and found thresholds for salmonid metrics at ~0.6 mg/L TN and ~0.06 mg/L TP.

PROGRAMMATIC IMPLICATIONS

Monitoring

UDWQ will retain the responsibility of monitoring sites to ensure that sites are meeting their NNC for TN and TP and ecological responses (bioconfirmation criteria). However, given that many headwater sites are located on lands under federal ownership, UDWQ also anticipates ongoing cooperative monitoring efforts with appropriate partner agencies such as the USFS. UDWQ has explored how to best integrate the collection of these data into existing and ongoing monitoring programs. Currently, UDWQ conducts three different tiers of monitoring, with each serving different UDWQ program needs. This section describes how nutrients and ecological responses will be integrated into ongoing monitoring efforts.

Monitoring Efforts Directly Related to these Proposed NNC

Tier 1: 50 Randomly Selected Sites, Rotates among 6 Management Units

Water Chemistry Sample

Sites will be prioritized for additional data collection if either TN or TP exceeds the lower threshold.

Benthic Algae Cover

Samples are collected that will allow assessment of proposed recreation use criteria.

Tier 2: Intensive Water Chemistry Collections at Priority Sites

Water Chemistry Samples

Four or more samples will be collected during summertime months for calculation of seasonal averages.

Filamentous Algae Cover

Quantitative visual assessments will be made monthly during water chemistry collections.

Metabolism

Sondes will be deployed for 3-5 weeks, which will permit as many as 35 measures of daily GPP and ER.

The first monitoring tier uses a spatially balanced, stratified, random sampling design (specifically *Generalized Random Tessellation Stratified* (GRTS)). Each year, 50 sites are selected from one of six rotating basins for tier 1 sampling. At each of these sites, one day is spent monitoring of multiple chemical, physical and biological water quality indicators at each of these sites during the summertime growing season (Table 4). This includes collection of water chemistry with dissolved and TP and TN, and individual nitrogen analytes including: Kjeldahl nitrogen, nitrate-nitrite and ammonium. In addition, these collection efforts currently include collection of a reach scale benthic algal sample for chlorophyll-a and AFDM analysis. UDWQ is refining field and laboratory methods to better quantify algae cover in circumstances with high filamentous algae cover. These new methods will allow UDWQ to assess each of these sites against the proposed recreation criteria. Sites where the TP or TN data exceed the lower, summertime average criteria will be prioritized for subsequent Tier 2 intensive monitoring.

While Tier 1 assessments are comprehensive, they have the disadvantage that there is generally a single water chemistry measure collected at these locations. Hence, UDWQ established a second tier of intensive water chemistry collections where sites are sampled at least once per month over a water year. Tier 2 sites also rotate among the six major management basins with sampling conducted two years following the Tier 1 assessments. Sites are selected for inclusion in Tier 2 monitoring based on Tier 1 results. In this case, sites where the Tier 1 sample exceeds the lower threshold of TN or TP will be prioritized for Tier 2 monitoring. At each of these sites, sondes will be deployed for 3-5 weeks for the purpose of obtaining whole stream metabolism (GPP and ER) data (Table 5). DWQ also proposes adding quantitative visual filamentous algae cover measurements, which will be collected at least monthly during water chemistry collection events. Several studies have shown that trained field technicians can obtain repeatable filamentous algae cover measures and UDWQ is developing SOPs that are modeled on these established methods (Stephenson and Bahls 1999, Stevenson et al. 2006)..

The third and final monitoring tier is conducted as needed to inform specific programmatic needs that are not met by data collected in the first two tiers. For Utah's nutrient reduction program this tier will be used to collect the data necessary for site-specific standard development (Table 6, also additional discussion in *Next Steps* below).

Table 4. Current and proposed water quality indicators collected in conjunction with Tier 1 monitoring efforts.

Notes: *Probabilistic (Tier 1) monitoring is conducted at 50 randomly selected streams within each of six different rotating basins. Existing indicators are those that are currently monitored and assessed. Proposed those that will be incorporated into this tier in conjunction with implementation of the nutrient reduction program. Other related indicators are in development, which means that they are currently monitored, but methods are in development.*

Indicator	Intensity	Frequency
	Existing	
Macroinvertebrates Assemblage Condition (O/E)	1 spatially integrated sample	Once in growing season
Fish Assemblage Condition (MMI)	1 spatially integrated sample	Once in growing season
Benthic Algae Cover	1 spatially integrated sample[1]	Once in growing season
Algae Assemblage Condition	1 spatially integrated diatom sample; assessment methods are in development	Once in growing season
Water Column Nutrients	1 grab sample	Once in growing season
Habitat Health	Multiple parameters are currently measured	Once in growing season
pH and DO (Nutrient-related Core Water Quality Indicators)	1 grab sample	Once in growing season
Discharge	1 grab sample	Once in growing season
	Measures to be added in Support of these Proposed Criteria	
Benthic Algae Cover[1]	1 Day	Once in growing season
High Frequency pH and DO	3-7 days	Independently assessed growing season

Notes: 1. Refine current collection methods to better quantify filamentous algae; data will be used to assess recreation uses.

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Table 5. Current and proposed water quality indicators collected in conjunction with Tier 2 monitoring efforts.

Notes: Intensive (Tier 2) monitoring water quality indicators are collected 1-2 times per month in each watershed management unit two years following probabilistic samples. For the nutrient reduction program, these sites will be selected based on information obtained in previous collection events (see also Figure 10).

Indicator	Intensity	Frequency
	Existing	
Water Column Nutrients	1 grab sample	≥ Monthly
pH and DO (Nutrient-related Core Water Quality Indicators)	1 instantaneous measurement	≥ Monthly
Discharge	1 measurement	≥ Monthly
	Measures to be added in Support of these Proposed Criteria	
Percent Filamentous Algae	1 reach-scale estimate	≥ Monthly
Metabolism Data	3-5 weeks	At priority sites[1]

1. Sites where nutrients exceed lower TN and TP threshold, violate O/E assessments or indicate excessive algae growth.

Table 6. Current and proposed water quality indicators collected in conjunction with Tier 3 monitoring efforts.

Notes: Ongoing and proposed programmatic (Tier 3) monitoring efforts consist of intensive investigations aimed at informing specific water quality programs. For the nutrient reduction program, existing data and information would be augmented with supplemental empirical responses to develop site-specific standards. In the case of headwaters, these investigations would be conducted if there is evidence that regional criteria are either over- or under-protective of existing uses.

Investigations	Intensity	Frequency
	Existing	
Wasteload Allocation Synoptic/Qual2K models	2-3 days downstream of major facilities	Once/3-years
TMDL Investigations	Varies depending on the age and complexity of the report	Most recent report is used (if available)
	Measures to be added in Support of these Proposed Criteria	
Supplemental Ecological Responses	As needed	As needed

Assessment

The breadth of nutrient indicators that UDWQ developed and evaluated to generate the proposed NNC provide an opportunity to refine nutrient-related water quality assessments to be more accurate than has historically been possible. Here we present a draft assessment process for headwater streams. Over the next couple of years UDWQ will collaborate with stakeholders to refine these approaches to help identify and prioritize sites with potential nutrient-related problems. UDWQ aligned the assessment methods as closely to USEPA guidance on conformational criteria as possible, however the three levels established by these proposed criteria makes these specific circumstances somewhat unique. Modifications to these rules may be needed in the final version of this proposal.

Decision Rules

One consequence of the three levels of numeric criteria for TN and TP and combined responses is that decision rules can become somewhat complex. Here we discuss broad decision rules that can be used to assess support of aquatic life uses in headwater streams (Figure 10). Additional assessment details, where appropriate, will be developed and submitted for public comment biennially as part of Utah's

Integrated Report methods. With these proposed NNC, there are two ways that a site would be considered to be supporting aquatic life uses with respect to nutrients. First, a headwater stream would be considered to be meeting its uses if the lower (and by default the upper) NNC for average summertime TN <u>and</u> TP, and all measured responses (N≥1, Figure 10) are met. Sites where TN or TP fall within the middle, moderate enrichment, level would also be considered to be meeting their aquatic life uses provided that at least one response has been measured and no response that has been measured exceeds the established thresholds. In contrast, sites that fall within the two impairment thresholds for either TN or TP would be considered to be impaired if <u>any</u> response that

Figure 10. Decision matrix that will be used to assess support of headwater aquatic life uses for nutrient-related water quality problems. Associated *Integrated Report* categories are in parentheses.

Nutrient Data (TN or TP)	Ecological Responses: No Data	Ecological Responses: < All Criteria	Ecological Responses: > Any Criterion
No Data or < 3 Samples	Not Assessed[1]	Not Assessed	Insufficient Data (3A)[2]
< Low Threshold	Not Assessed	Fully Supporting (1 or 2)[3]	Insufficient Data (3A)[2,4]
Between Lower and Upper	Insufficient Data (3A)[2]	Fully Supporting (1 or 2)[3]	Impaired (5)[6]
Above Upper Threshold	Threatened (5)[5,6]	Threatened (5)[4,5,6]	Impaired (5)[6]

FOOTNOTES:

1. There are insufficient <u>nutrient-related</u> data to assess whether or not aquatic life uses are supported; however, aquatic life uses may be assessed with other water quality parameters.
2. Sites where TN or TP fall below the upper threshold, but above the lower threshold, and lack measures for at least one response variable will not be assessed with respect to nutrients. These sites will be <u>prioritized for follow-up monitoring</u>.
3. The integrated report distinguishes between sites where at least one parameters has been evaluated for <u>all</u> uses (Category 1) and sites where some uses are supported, whereas others are either not supported or not assessed (Category 2).
4. Sites where nutrient and ecological response data are in conflict may be <u>candidates for site-specific criteria</u>.
5. Sites designated as threatened will automatically become impaired in the next assessment cycle unless it can be demonstrated that biological uses are fully supported both locally <u>and</u> downstream.
6. TMDL required unless an alternative remediation (TMDL alternative) plan or a site-specific standard has been approved by UDWQ and USEPA.

has been measured exceeds the thresholds established with the NNC. In circumstances where a response is required to make an assessment decision, it is not necessary to have data on all responses. An individual responses should be sufficient to make a conclusion based on existing and readily available data and information. If other indicators are collected in the future that contradicts an assessment decision options for changing the listing will be explored in the next biennial assessment cycle.

Any headwater stream with a summertime average TN or TP concentration above the upper threshold would be considered to be threatened for one assessment cycle, then reclassified as impaired during the next biennial assessment cycle unless it can be demonstrated to be meeting its aquatic life uses. In circumstances where it can be demonstrated that a higly enriched site is supporting aquatic life uses, site-specific standards will be developed.

Assessment decisions in circumstances where nutrients and response data conflict, or where summertime nutrients averages or response data are unavailable are not as straight forward. For instance, there may be circumstances where fewer than four samples are available for both TN and TP , in which case data quality objective are not met and summertime average nutrient calculations are invalid. These sites will not be assessed until additional summertime samples can be collected,. However those samples that were collected can still be used to prioritize sites for additional monitoring. It is also important to consider circumstances where TN and TP data conflict with one another. If either TN or TP is above a NNC then the site would be considered impaired, provided that appropriate responses concur. However, either TN or TP data are sufficient to make a decision of full support, provided that any measured response (if appropriate) concurs.

It is also possible, albeit highly unlikely, that a site may fall below the lower threshold for both TN and TP, but exceed the criteria thresholds for an ecological response. Such unusual circumstances fall outside the conditions encountered when establishing these thresholds. As a result, UDWQ proposes listing such sites as having insufficient data to make as assessment for one assessment cycle to provide two years to better understand the reason for these unusual circumstances. If these follow-up investigations cannot clearly demonstrate that the response was exceeded due to natural conditions or irreversible hydrologic modification, then such sites would be listed as impaired in the following assessment cycle. Otherwise, the NNC would be modified on a site-specific basis to address these atypical circumstances.

Diagnosing Causes and Sources for the Integrated Report

UDWQ will use a weight of evidence approach to determine if nutrients (either TN or TP) contribute to any observed impairments. However, in some circumstances it is possible that deleterious responses are also caused by other stream stressors. For instance, degraded riparian conditions may contribute to excessive GPP. Similarly, steam channel modification could potentially contribute to excessive ER by trapping sources of carbon that would otherwise be transported downstream. If the weight of evidence suggests that other causes are contributing to an impairment the cause may be listed with a more general "eutrophic conditions" cause so that subsequent investigations can establish the relative importance of different stressors and/or the relative extent to which TN or TP is contributing to the impairment. Programmatically, this distinction may be important because it could potentially allow UDWQ to focus remediation efforts on restoring ecological responses as opposed to seeting goals that are exclusively based on nutrient reductions (see *Addressing Nutrient-Related Impairments: TMDL Alternatives* below) Such investigations are critically important because they can inform the specific remediation practices that are most likely to improve stream conditions and ultimately restore support of uses.

UDWQ will list the source of nutrients as unknown, even in circumstances where UDWQ staff conclude that TN or TP causes or contributes to an impairment. An early step in the TMDL—or alternative remediation planning—process will be quantification of both natural and human-caused sources of TN or TP. Once sources have been accurately quantified, UDWQ will subsequently modify the impairment listing to reflect known sources in the next *Integrated Report* cycle. Sites with high background conditions may be candidates for site-specific modifications to the proposed NNC.

Preliminary Assessment Results

Response data are not historically available. Nevertheless, UDWQ was interested in investigating the potential ramifications of these proposed headwater criteria. To do this UDWQ gathered all TN and TP data for the most recent 10-years of available records. Due to a paucity of organic nitrogen data in historic records TN was predicted from TIN ($r^2 = 0.92$, $p<0.001$). Summertime averages were then calculated for all samples collected from June through September. Not surprisingly, nitrogen and phosphorus concentrations at sites within headwater streams were low in comparison with statewide estimates (Table 7).

Table 7. Comparisons, expressed as percentiles, of headwaters and statewide ambient nutrient concentration data.

	Percentiles			
	25th	***50th***	***75th***	***90th***
	Total Nitrogen (mg/L)			
Headwaters	0.10	0.24	0.38	0.56
All Sites	0.18	0.25	0.50	1.1
	Total Phosphorus (mg/L)			
Headwaters	BRL	0.019	0.038	0.058
All Sites	BRL	0.04	0.05	0.15

Notes: Headwater distributions for TP (n = 494 sites) and TN (n = 448 sites) are site averages derived from all samples collected from 2002-2012. Statewide (all sites) percentile estimates were obtained from cumulative distribution functions derived from samples collected at 50 randomly selected perennial streams.

Based on this review of the summertime average nutrient concentrations collected over the most recent 10-years of available data, UDWQ concludes that most headwater streams are generally in good condition with respect to nutrients. For both TN and TP ~70% headwater streams evaluated would be considered fully supporting their uses because the lower nutrient threshold was not exceeded. In contrast, ~6% of sites are threatened for predTN (Figure 11) and ~9% of sites are threatened for TP (Figures 11 and 12) because the summertime average exceeds the upper threshold. However, this conclusion is not definitive for all of these sites because 1/3 of potentially impaired TP sites, or ½ of TN sites, had fewer than 4 samples. For TN and TP, about 20% of sites exceeded the lower criterion but not the upper criterion, but again about 30% of these sites had fewer than 4 samples. This means that, on average, about 10 existing headwater sites per rotating basin would require follow-up investigations.

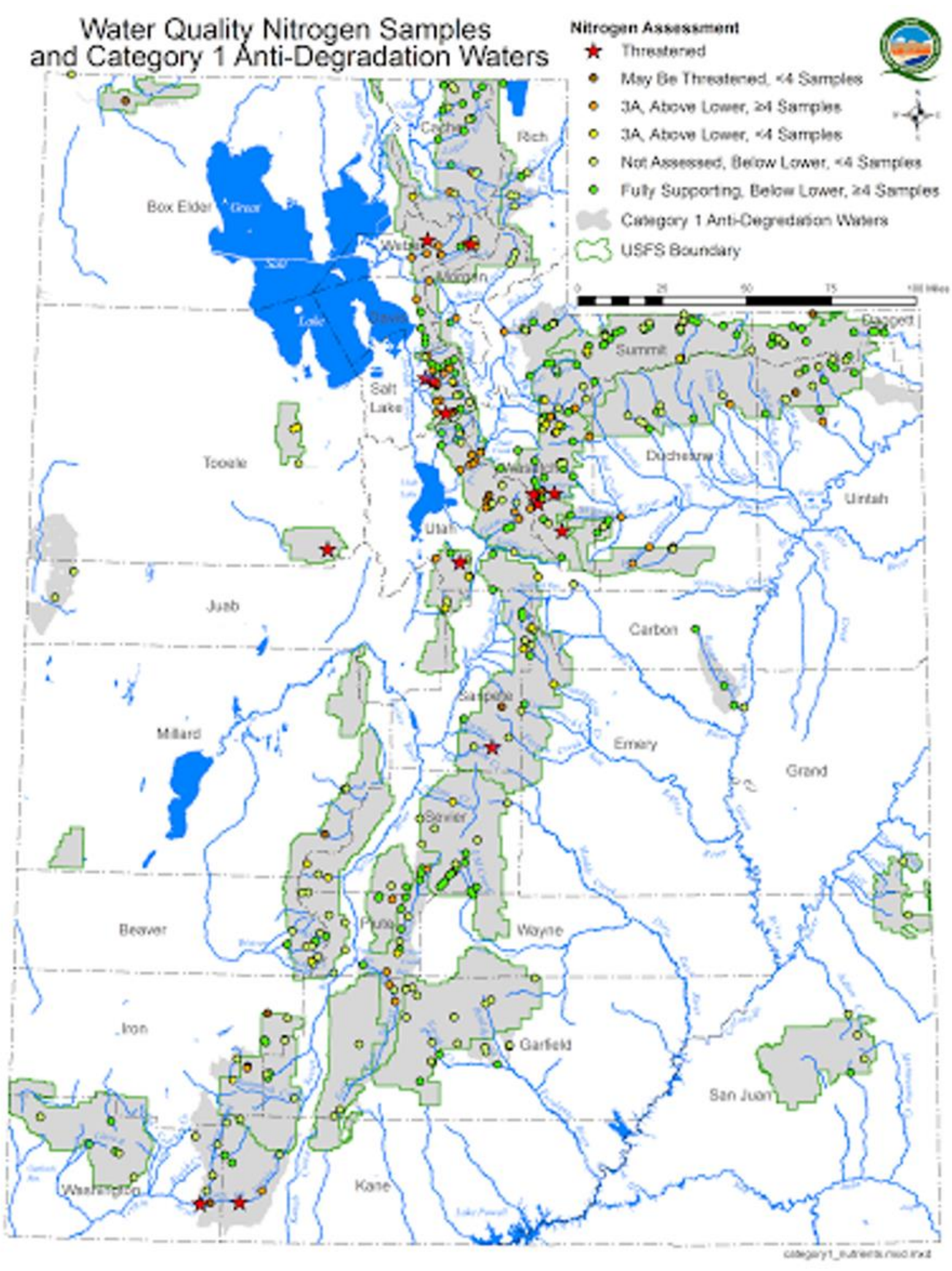

Figure 11. Preliminary assessment results for predTN at headwater streams based on summertime averages calculated from all samples that were collected over the most recent 10-years of available data.

Notes: Follow-up collections will be conducted at threatened sites to confirm the threatened status. Streams that are identified as "may be a problem" fall between the upper and lower thresholds, but do not yet have response data. Follow-up monitoring will be conducted at as many of these sites as possible, but if necessary streams where the summertime average was based on ≥4 samples will be prioritized. Sites blow the lower threshold are not considered to be fully supporting unless ≥4 samples were used to calculate summertime averages.

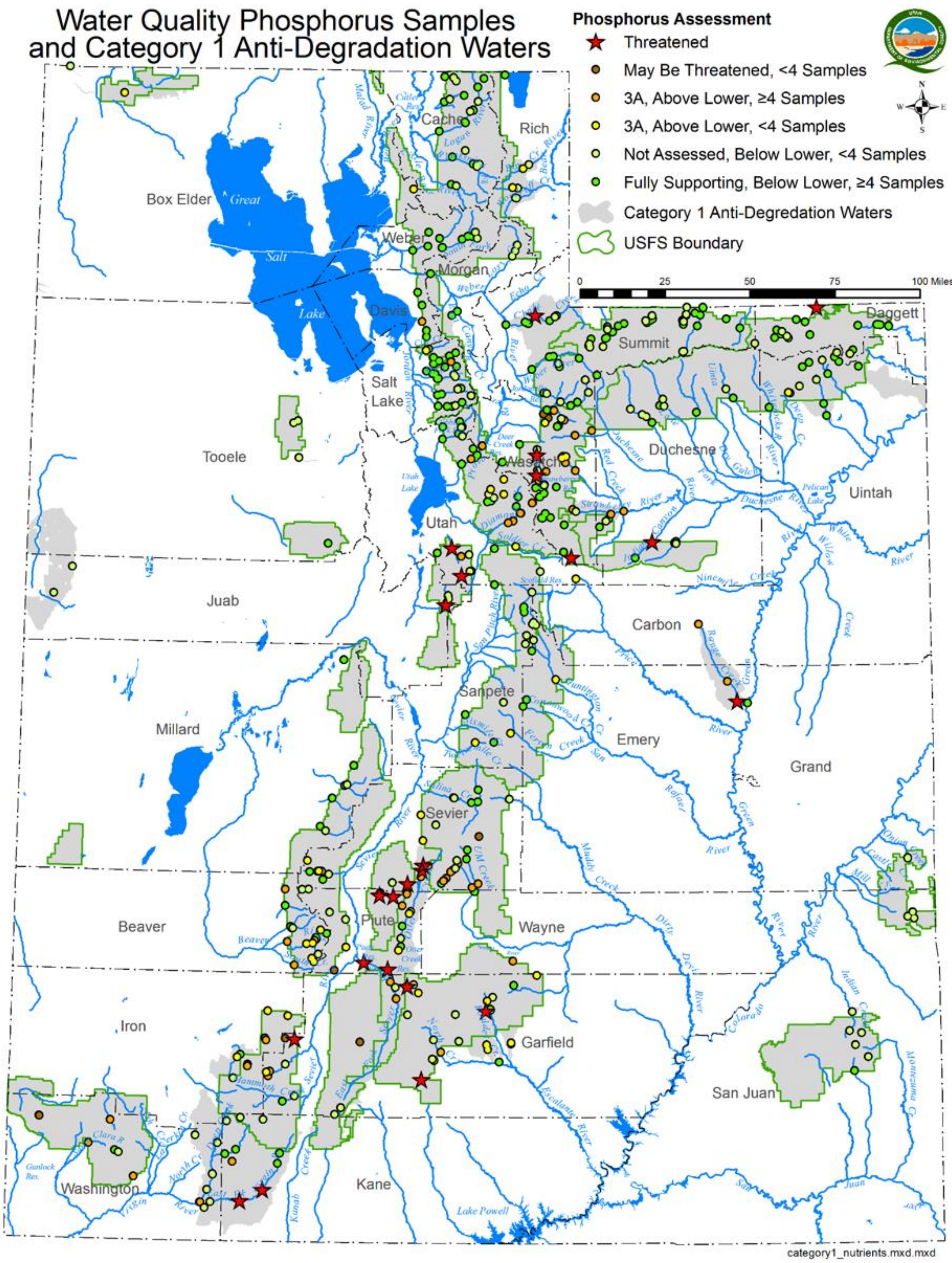

Figure 12. Preliminary assessment results for TP at headwater streams based on summertime averages calculated from all samples that were collected over the most recent 10-years of available data.

<u>Notes</u>: Follow-up collections will be conducted at threatened sites to confirm the threatened status. Streams that are identified as "may be a problem" fall between the upper and lower thresholds, but do not yet have response data. Follow-up monitoring will be conducted at as many of these sites as possible, but if necessary streams where the summertime average was based on ≥4 samples will be prioritized. Sites blow the lower threshold are not considered to be fully supporting unless ≥4 samples were used to calculate summertime averages.

NEXT STEPS

Future Modifications to Regional Headwater Criteria

A critical step in adaptive management is revisiting previous decisions as additional data become available. While UDWQ believes that the proposed NNC are generally applicable to headwaters statewide, there will likely be circumstances where they need to be modified. In fact, one advantage of these NNC and associated monitoring and assessment procedures is that UDWQ will be extending monitoring to include several new responses that are directly related to nutrient enrichment. For instance, these data may reveal the need for additional subclasses of headwater streams with alternate nutrient or ecological response NNC. As such needs are manifest, UDWQ will compile the evidence into a categorical Use Attainability Analysis, which will allow appropriate adjustments to these proposed criteria.

Another possibility is that local conditions will reveal the need to modify these regional NNC on a site-specific basis. For instance, there may be circumstances where either benthic algae or respiration numeric response indicators are exceeded, yet average nitrogen or phosphorous criteria are not. If confirmed, these observations would suggest that either nitrogen or phosphorus criteria were under-protective. Of course, the converse—that regional NNC are over-protective—is also possible. If either TN or TP exceeds the numeric criterion, yet all responses are met and no other evidence exists that existing uses are degraded, then UDWQ may modify the regional criteria on a site-specific basis using background nutrient concentrations to set criteria. Another possibility is that these regional NNC need to be modified to protect downstream uses. Both Clean Water Act regulations (40 CFR 131.10(g)) and Utah's Water Quality Standards (UAR R317-2-7.1) permit site-specific modification of regional NNC to less protective values provided that it can be demonstrated that existing aquatic life uses will remain protected or that existing criteria cannot be met due to irreversible alterations of hydrology or habitat. In the case of headwaters, UDWQ anticipates that the latter circumstance would be particularly rare, with the likely exception of reservoir outlets.

Ongoing Collaborative Management

Most of the headwater streams are contained within watersheds that are managed by the USDA Forest Service. Hence, NNC implementation will require ongoing collaborative management with this and other sister agencies. UDWQ already maintains Memoranda of Understanding (MOUs) with many management agencies in Utah. These MOUs outline, among other things, collaborative monitoring practices. As these proposed NNC are implemented, it will be critical to bolster these collaborative efforts to ensure that both nutrients and responses are measured at streams with potential nutrient-related problems. It will also be important to coordinate on analysis and interpretation of these data, to ensure that any streams that exceed the NNC are logically consistent with one-the-ground management activities.

A New Long-Term Vision for Assessment, Restoration and Protection of Waters

Primary Objectives

Progress Over Pace.
Focus restoration efforts where they are most likely to succeed.
Consider diverse approaches for setting water quality goals
Prioritize effort to protect and restore what is most important.

Addressing Nutrient Impairments

Another important collaborative effort will be working together to determine how best to address nutrient impairments. Traditionally, UDWQ has addressed water quality impairments by creating Total Maximum Daily Loads that mandate load reductions for all pollutant sources. TMDLs remain one option for addressing nutrient-related impairments in headwater streams. However, USEPA and subsequently UDWQ have been undergoing a visioning exercise to rethink restoration practices (USEPA 2013). Among other things, this plan call for flexibility in development of alternatives to TMDLs. Several proposed alternatives focus on the development and implementation of restoration efforts as opposed to stricter TMDL load allocation.

This new restoration vision interfaces well with these proposed NNC and is another opportunity to expand ongoing collaborative management efforts. One opportunity relates to the fact that the primary nutrient-related stressors in Utah's forested streams are livestock grazing, road construction and other development, catastrophic wildfires and mining (Kershner at al. 2004). These activities are not generally thought to cause degradation if Best Management Practices (BMPs) are fully implemented. These NNC have the opportunity to better prioritize where additional BMPs may be needed, by more clearly defining water quality goals. For example, UDWQ has already examined summertime average nutrient concentrations for headwater streams from historic (10-year) data, and the vast majority of streams appear to be in good condition. These proposed NNC allow those streams with higher nutrient concentrations to be prioritized for additional monitoring of both nutrients and responses. In some cases, sources of nutrients may be difficult to quantify because they are diffuse, whereas human activities that are responsible for increased nutrient loads may be easier to identify. Such circumstances are ideal candidates for alternative restoration plans. Successful implementation of these plans will also require collaborative management between UDWQ and other management agencies to ensure that progress continues to be made toward meeting water quality goals. Finally, the incorporation of ecological responses into these NNC offers some flexibility with the specific BMPs that can be incorporated into remediation plans, because water quality goals can be expressed as desirable ecological outcomes. For example, one can envision circumstances where excess GPP could potentially be lowered by restoring riparian ecosystems, which would also likely improve the habitat of the aquatic life that these proposed criteria aim to protect.

As the above examples highlight, once a headwater is listed as impaired, UDWQ and collaborators will need to begin the process of assessing the impairment in more detail to determine the most appropriate path for resolving the impairment (Figure 11). One important consideration in determining the most appropriates path to take with these investigations is the cause of the impairment. If the cause is clearly related to current forest management practices (e.g. grazing, logging, recreation) then UDWQ will work with USFS to update the appropriate plans for the impaired watershed. In some cases, the plans may not need to be updated but implementation and/or enforcement activities may be required to ensure that the plan is followed. If UDWQ determines that the cause of the impairment is natural, then UDWQ will work to develop site-specific standards for the waterbody. If the cause is not pollutant driven (e.g. it relates to habitat modification or hydrologic alteration), then the site will be reclassified to Category 4c during the next assessment cycle. Because Utah is using a bioconfirmation approach to standards and assessment, this scenario is unlikely. If the causes appear to be complex or unknown, UDWQ will engage in additional studies to better understand the impairment. This could result in the development of a TMDL or identification of one of the other paths described above. The USFS will account for the impairment in all decisions under the National Environmental Policy Act, until the waterbody is removed from UDWQ's list of impaired waters (Category 5).

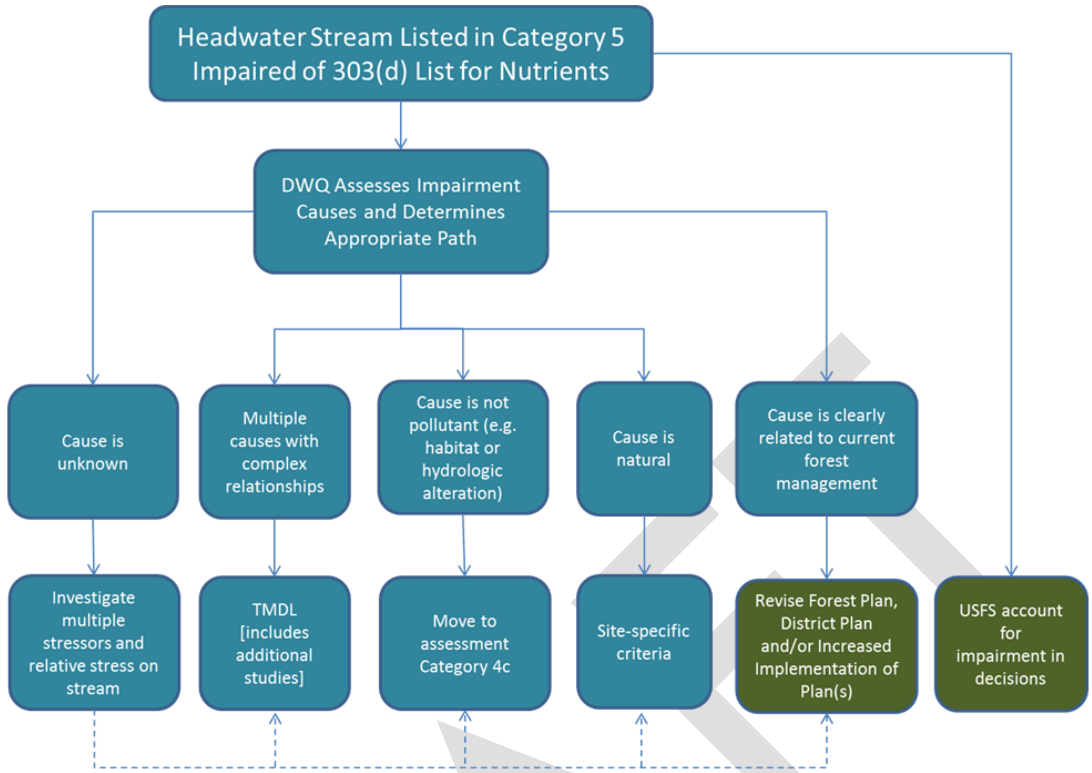

Figure 11. Summary of pathways that DWQ will follow after a headwater stream is listed as impaired for nutrients.

Site-Specific Standards for Streams Lower in Watersheds

In headwaters, NNC will be established and then modified on a case-by-case basis, whereas the converse is true for streams lower in watersheds. The analyses used to develop the proposed headwater NNC encompassed streams with a broad range of ambient nutrient concentrations (Figure 5). The thresholds obtained from these analyses can be immediately used to help prioritize streams for future investigations. However, UDWQ has determined that these responses, and potentially others, need to be evaluated on a site-specific basis before they can be translated to NNC for streams lower in Utah's watersheds. One reason for this decision relates to the influence of natural environmental gradients on nutrients and nutrient-related responses (see Chapter 10, Ostermiller et al. 2014 for detailed review). All of the responses that UDWQ evaluated can be influenced by natural differences in the physical characteristics of streams. Many of these characteristics vary systematically from upstream to downstream sites, whereas others are truly site-specific. A second related complication is that the number and intensity of human-caused stressors increases in an upstream to downstream direction and the responses of some stressors are similar to those related to nutrients. This second consideration complicates the ability to attribute a harmful response to nutrients as opposed to other potential causes, especially if both are contributing to the problem. Together these problems—natural variation in ecological responses and multiple stressor environments—can only be reconciled on a site-specific basis. This challenge is not unique to Utah. Covariation among natural environmental gradients and human-caused stressors is among the central challenges in stream ecology (Allan 2000). The interplay of these potentially confounding factors will need to be thoroughly vetted as site-specific standards are developed for other waterbodies.

Conducting Site-Specific Standard Investigations

Whether UDWQ or others conduct site-specific investigations, a Sample and Analysis Plan (SAP) must be developed and approved by UDWQ prior to data collection. This plan will clearly discuss the type of data to be collected, frequency of data collection, roles and responsibilities (if a collaborative process is proposed), data storage and plans for data analysis. Development of this plan is the best way to ensure that the data can be used as efficiently and effectively as possible to support standard revisions. In addition, the plan can be shared with USEPA to ensure that once proposed numeric criteria are submitted, they will be approved.

Generally, a minimum of 3-years of data will be required to generate sufficient information of year-to-year variation. In addition to the nutrients and responses that were used to create the headwater NNC, it may be necessary to collect other pieces of information to better understand the role of covariates in mitigating or exacerbating nutrient concentrations or ecological responses. While the specific nature of each investigation is likely to be somewhat different, UDWQ envisions that these investigations will generally consist of a combination of process-based models and empirical ecological responses. The data necessary for each site and plans for data analysis shall be clearly outlined in the SAP. Admittedly, such investigations can sometimes be resource intensive. UDWQ will continue to evaluate the need for site-specific modifications to the proposed headwater NNC on an ongoing basis.

Consideration of Site-Specific Data

UDWQ will consider the following when evaluating site-specific investigations:

- The risk of degraded conditions under feasible future scenarios
- Natural conditions that exacerbate or diminish the effects of nutrients and the likelihood of these conditions changing
- The role of natural sources of nutrients
- The risk of increased nutrients to downstream waters

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